EWCE 331
Water Supply Engineering

Lecture 5

Instructor

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Lecture outline

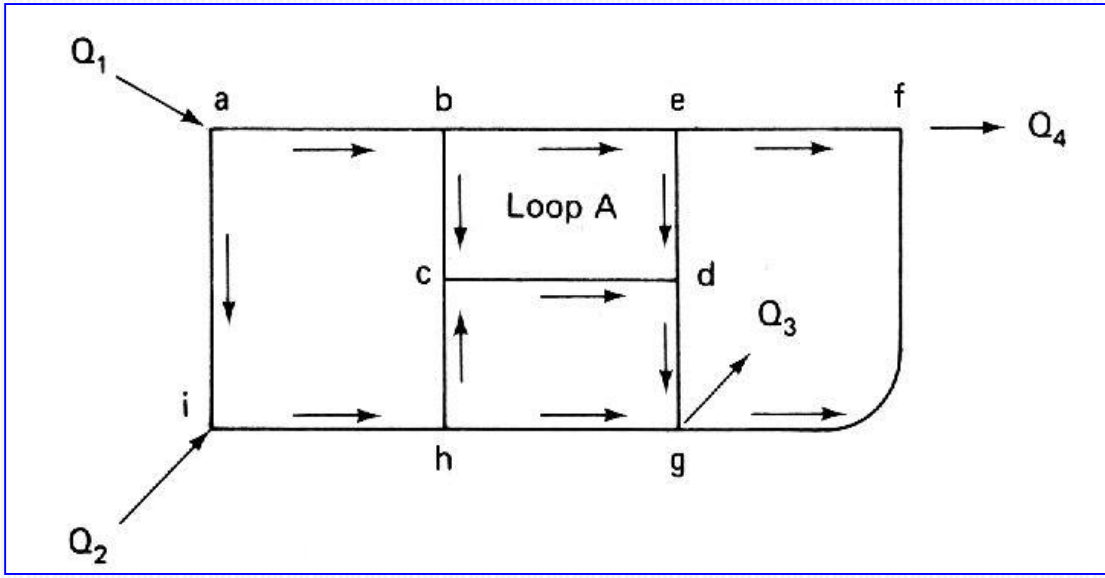
Surface water collection and transmission

Topics	References
• **Water Supply Network Analysis** ✓ **Hardy Cross Method**	**1. Design of Water Supply Pipe Networks** Authors: Prabhata K. Swamee and Ashok K. Sharma Wiley Interscience, A John Wiley & Sons Inc. Publications, New Jersey **2. Water Supply and Sanitation** Authors: M. Feroz Ahmed, Md. Mujibur Rahman 1st ed., ITN-BUET

Hydraulic Analysis of Water Distribution System

Hardy Cross Method

- The earliest systematic method of network analysis (Hardy-Cross Method) is known as the head balance or closed loop method.



- This method is applicable to system in which pipes form closed loops.

Hydraulic Analysis of Water Distribution System

Hardy Cross Method

- The outflows from the system are generally assumed to occur at the nodes junction.

- For a given pipe system with known outflows, the Hardy-Cross method is an iterative procedure based on initially iterated flows in the pipes.

- At each junction, these flows must satisfy the continuity criterion, i.e. the algebraic sum of the flow rates in the pipe meeting at a junction, together with any external flows is zero.

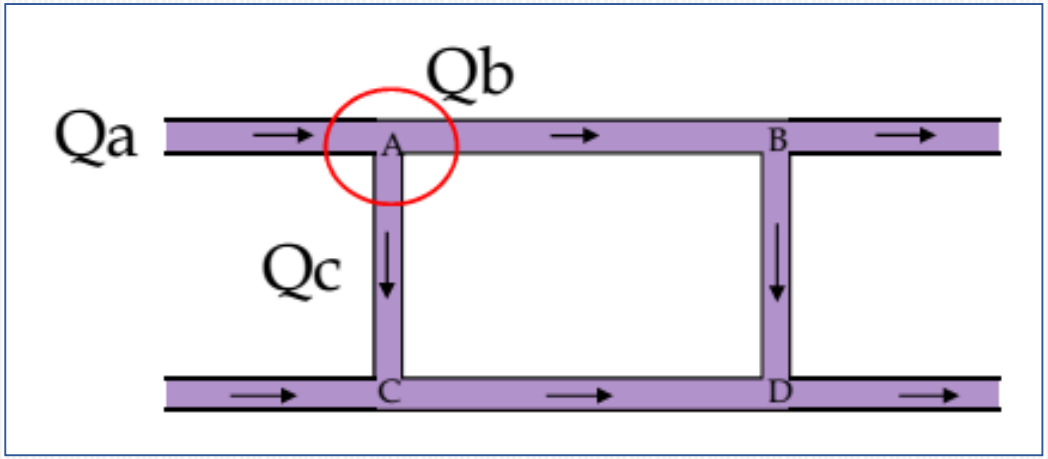
Hydraulic Analysis of Water Distribution System

Hardy Cross Method - is based on

✓***Continuity Equation:***

Inflow = outflow at nodes

$$Q_a = Q_b + Q_c$$



Hydraulic Analysis of Water Distribution System

Hardy Cross Method - is based on

✓***Energy Equation:***

Summation of head loss in closed loop is zero

$$\sum h_l(loop) = 0 \Rightarrow \sum K(Q + \Delta Q)^n = 0$$

Darcy-Weisbach

$$H_L = \frac{8 f L Q^2}{\pi^2 g D^5} = K.Q^2$$

Hazen-Williams

$$H_L = k.Q^{1.85}.L$$

where $$k = \left(\frac{1}{0.278 C D^{2.63}}\right)^{\frac{1}{0.54}}$$

Hydraulic Analysis of Water Distribution System

Assumptions/ Steps in Hardy Cross Method

- Assume that the water is withdrawn from nodes only; not directly from pipes.

- The discharge, Q , entering the system will have (+) value, and the discharge, Q , leaving the system will have (-) value.

- Usually neglect minor losses since these will be small with respect to those in long pipes, i.e.; or could be included as equivalent lengths in each pipe.

Hydraulic Analysis of Water Distribution System

Assumptions/ Steps in Hardy Cross Method

- Assume flows for each individual pipe in the network.

- At any junction (node), as done for pipes in parallel,

$$\sum Q_{in} = \sum Q_{out} \quad \Longrightarrow \quad \sum Q = 0$$

- Around any loop in the grid, the sum of head losses must equal to zero:

$$\sum_{loop} h_f = 0$$

Hydraulic Analysis of Water Distribution System

Assumptions/ Steps in Hardy Cross Method

- Conventionally, clockwise flows in a loop are considered (+ve) and produce positive head losses; counterclockwise flows are then (-ve) and produce negative head losses.

- This fact is called the head balance of each loop, and this can be valid only if the assumed Q for each pipe, within the loop, is correct.

Hydraulic Analysis of Water Distribution System

Assumptions/ Steps in Hardy Cross Method

- The probability of initially guessing all flow rates correctly is virtually null.

- Therefore, to balance the head around each loop, a flow rate correction (Δ) for each loop in the network should be computed, and hence some iteration scheme is needed.

Hydraulic Analysis of Water Distribution System

Assumptions/ Steps in Hardy Cross Method

- After finding the discharge correction, Δ (one for each loop), the assumed discharges Q_0 are adjusted and another iteration is carried out until all corrections (values of Δ) become zero or negligible.

- At this point the condition of :

$$\sum_{loop} h_f \cong 0.0$$ is satisfied.

Hydraulic Analysis of Water Distribution System

Assumptions/ Steps in Hardy Cross Method

Notes:

- The flows in pipes common to two loops are positive in one loop and negative in the other.

- When calculated corrections are applied, with careful attention to sign, pipes common to two loops receive both corrections.

Hydraulic Analysis of Water Distribution System

Steps in Hardy Cross Method

- The relationship between head loss and discharge must be maintained for each pipe.

✓ Darcy-Weisbach Equation

$$h_l(pipe) = KQ^n \quad n = 2 \quad K = \frac{8fL}{g\pi^2 D^5}$$

✓ Exponential friction formula of Hazen-Williams

$$h_l(pipe) = KQ^n \quad n = 1.85 \quad K = \frac{10.67}{C^{1.85} d^{4.87}}$$

Hydraulic Analysis of Water Distribution System

How to find the correction value (Δ)

$$h_f = k\,Q^x$$

$$Q = Q_0 + \Delta$$

$$h_f = k\,Q^x = k\,(Q_0 + \Delta)^x = k\left[Q_0^x + x\,Q_0^{(x-1)}\Delta + \frac{x\,(x-1)}{2}\,Q_0^{(x-2)}\,\Delta^2 + \cdots\right]$$

$$h_f = k\,Q^x = k\left[Q_0^x + x\,Q_0^{(x-1)}\Delta\right]$$ [Neglecting higher degree of Δ]

Hydraulic Analysis of Water Distribution System

How to find the correction value (Δ)

Since for each loop in the grid:

$$\sum_{loop} h_f = \sum_{loop} kQ^x = 0$$

$$\sum k\,Q^x = \sum k\,Q_0^x + \sum x\,k\,Q_0^{(x-1)}\,\Delta = 0$$

Therefore, we have (for each loop in the network)

$$\Delta = \frac{-\sum k\,Q_0^x}{\sum x\,k\,Q_0^{(x-1)}} = \frac{-\sum h_f}{x\sum \frac{h_f}{Q}}$$

$$h_f = KQ^x$$

$$\Rightarrow \frac{h_f}{Q} = \frac{KQ^x}{Q}$$

$$\Rightarrow \frac{h_f}{Q} = KQ^{x-1}$$

Hydraulic Analysis of Water Distribution System

How to find the correction value (Δ)

- If Hazen Williams (which is generally used in this method) is used to find the head losses, then

$$h_f = 10.7 \frac{L}{D^{4.87}} \left(\frac{Q}{C_{HW}} \right)^{1.85} \qquad h_f = k\,Q^{1.85} \qquad \Delta = \frac{-\sum h_f}{1.85 \sum \frac{h_f}{Q}}$$

- If Darcy -Wiesbach is used to find the head losses, then

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2 \sum \frac{h_f}{Q}}$$

Pipe Network Analysis – Hardy Cross Method

Problem 1: Simple Looped Network

A single looped network as shown in the Fig. 1 has to be analyzed by Hardy Cross method for given pipe diameter, length, inflow and outflow discharges.

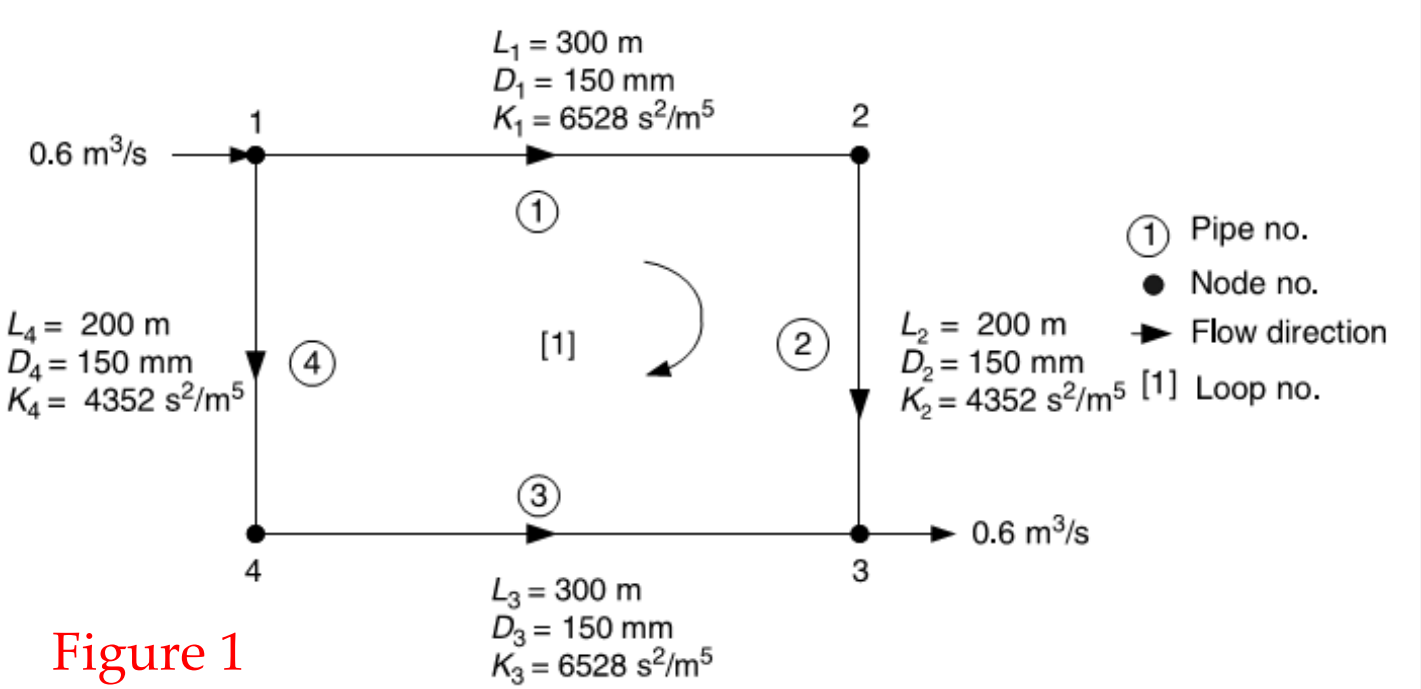


Figure 1

Use Darcy – Weisbach head loss – discharge relationship assuming a constant friction factor, f=0.02.

Pipe Network Analysis – Hardy Cross Method

Solution:

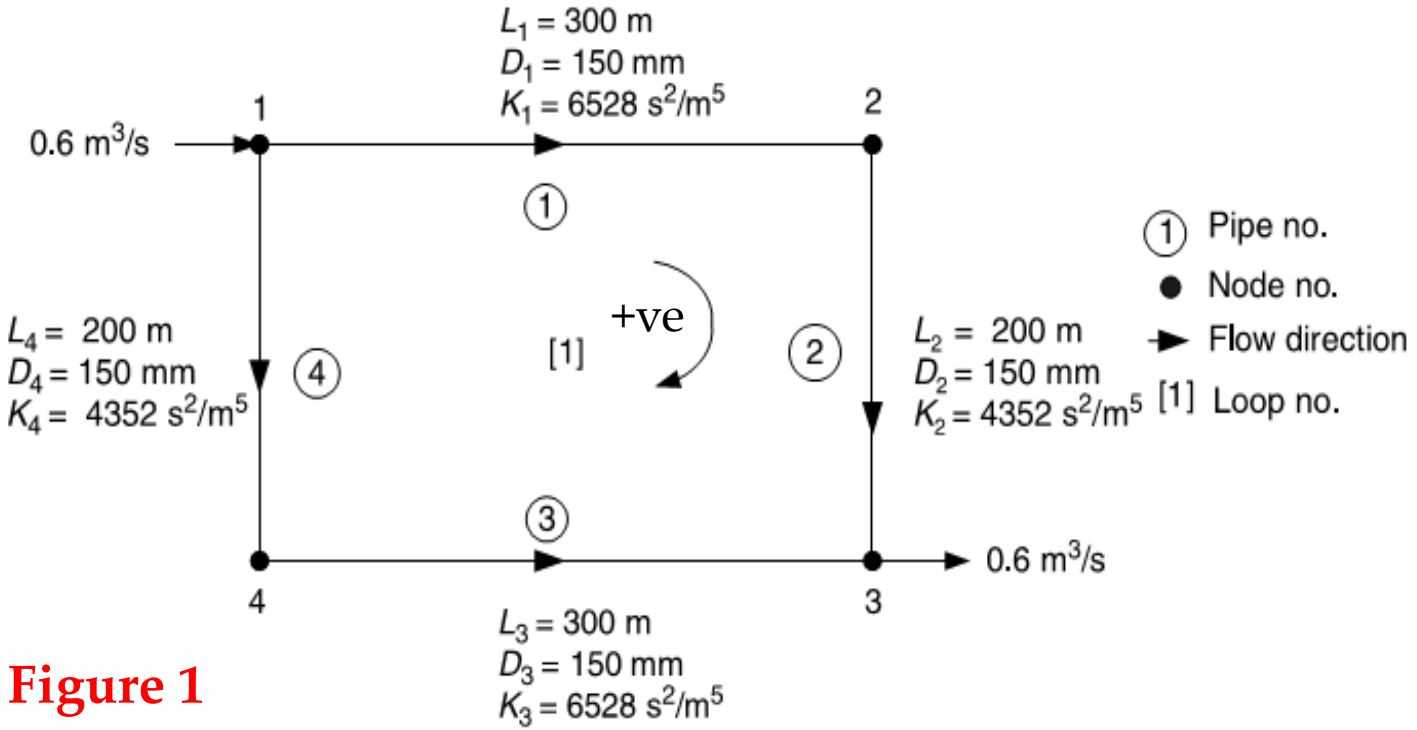


Figure 1

- **Step 1:** The pipes, nodes, and loop are numbered as shown in given Fig (1).

- **Step 2:** Adopt the following sign conventions:

Pipe Network Analysis – Hardy Cross Method

Solution

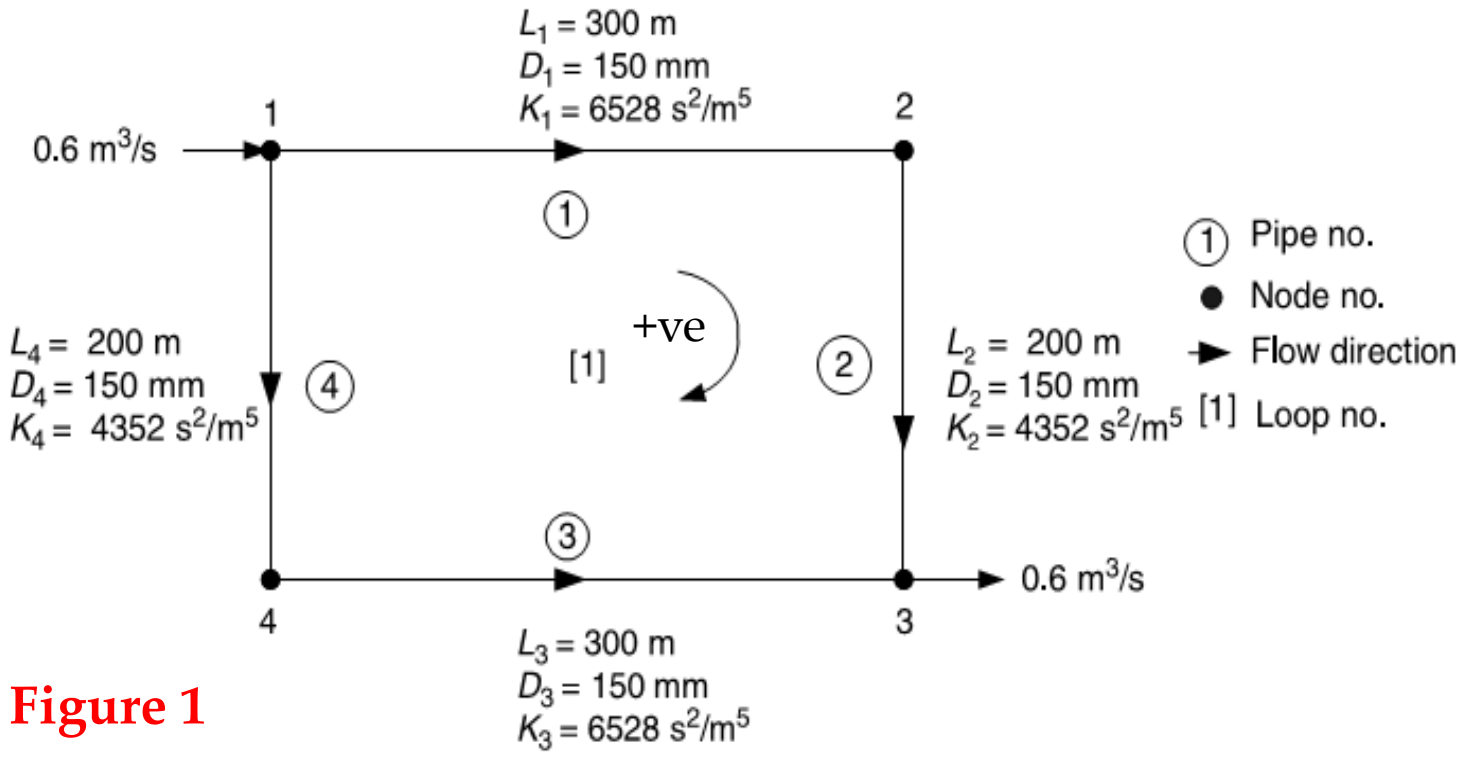


Figure 1

✓ A positive pipe discharge flows from a lower node to a higher node.

✓ Inflow into a node is positive, whereas withdrawal is negative.

Pipe Network Analysis – Hardy Cross Method

Solution:

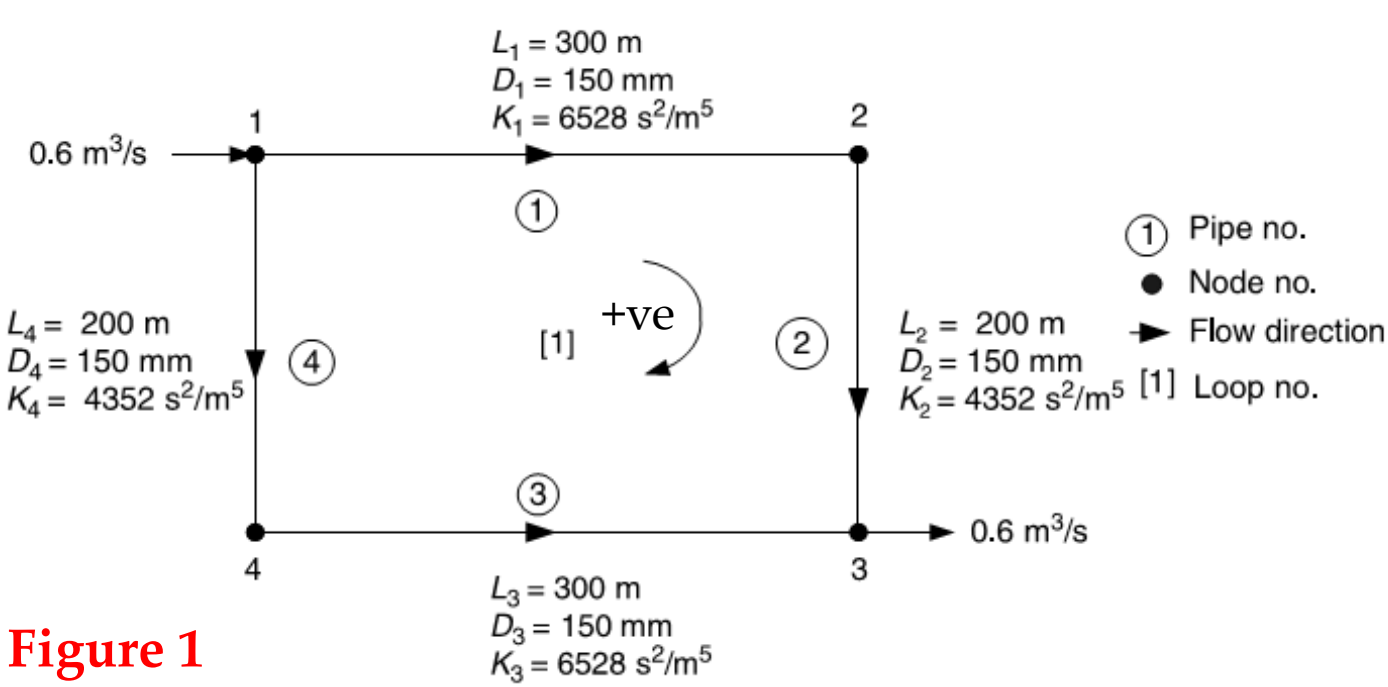


Figure 1

✓ In the summation process of the equation,

$$\sum Q_i = q_j \qquad \text{for all nodes } j = 1, 2, 3, \ldots, j_L, \quad \ldots\ldots (1)$$

a positive sign is used if the discharge in the pipe is out of the node under consideration. Otherwise, a negative sign will be used.

Pipe Network Analysis – Hardy Cross Method

Solution:

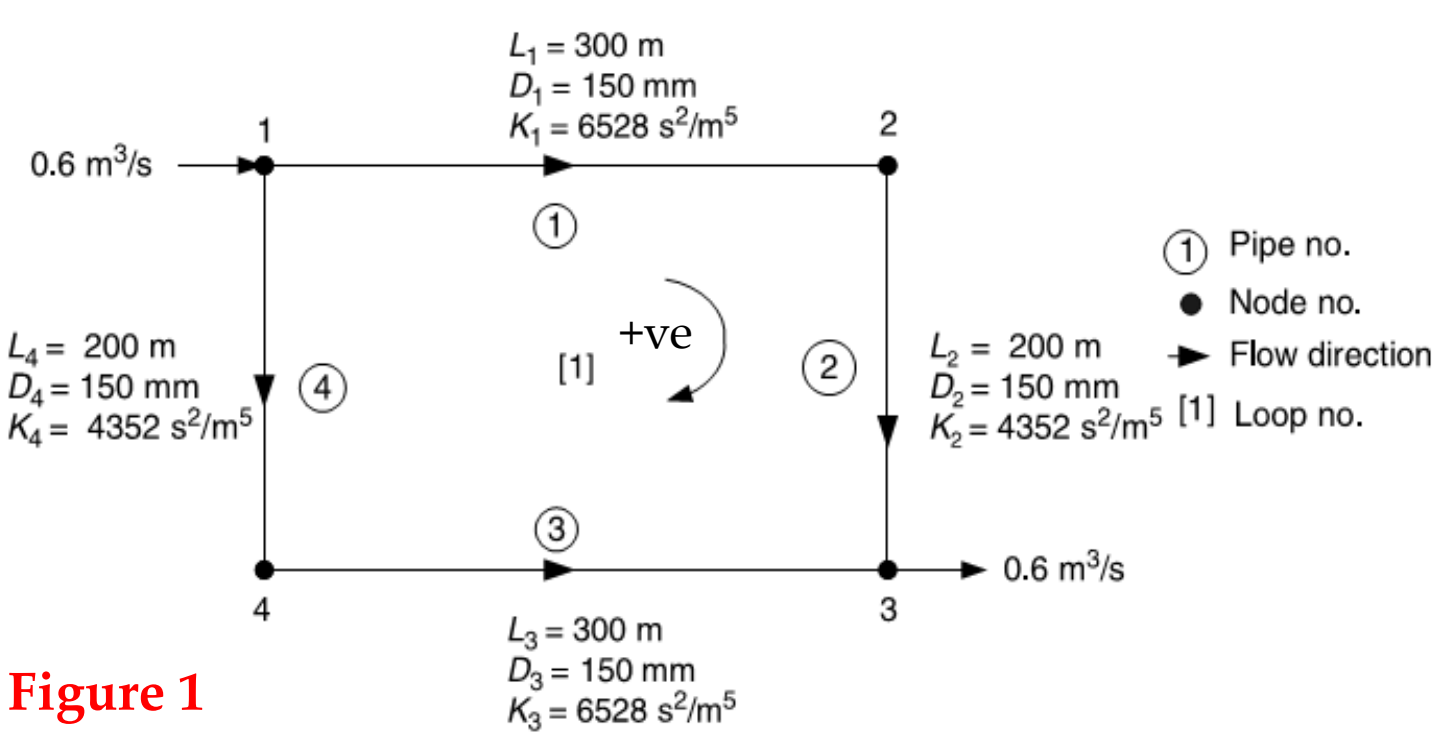


Figure 1

- For example in the given network (Fig 1), at node 2, the flow in pipe 1 is towards node 2, thus the Q_1 at node 2 will be negative while applying Eq. 1.

$$\sum Q_i = q_j \qquad \text{for all nodes } j = 1, 2, 3, \ldots, j_L, \qquad \ldots\ldots (1)$$

Simple Looped Network Analysis – Hardy Cross Method

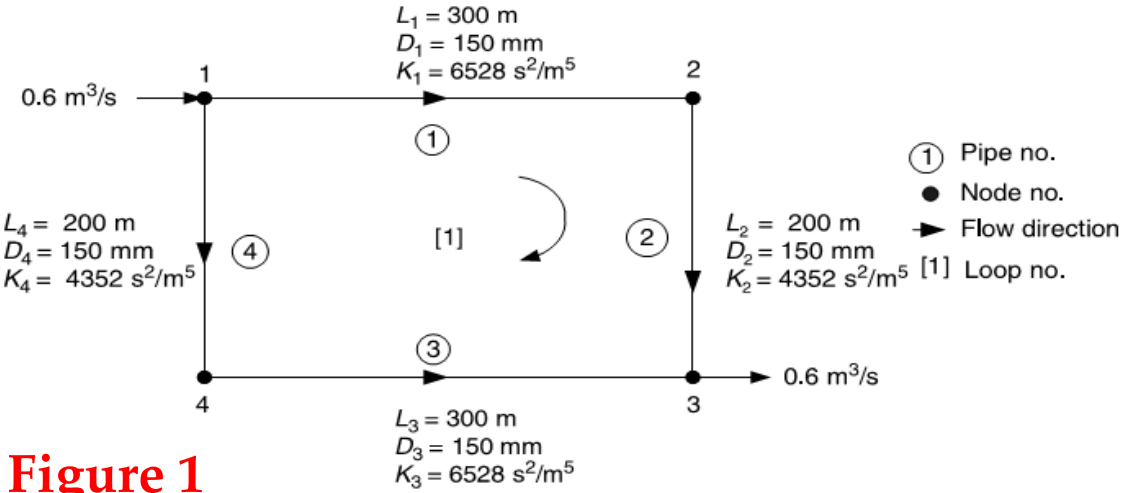


Figure 1

Step 3: Apply continuity equation to obtain pipe discharges.

- The nodal inflow q_1 is 0.6 m^3/s and nodal outflow q_3 is 0.6 m^3/s. The q_2 and q_3 are zero.

- Assume an arbitrary flow of 0.1 m^3/s in pipe 1 (Q_1=0.1 m^3/s), meaning thereby that the flow in pipe 1 is from node 1 to node 2.

Simple Looped Network Analysis – Hardy Cross Method

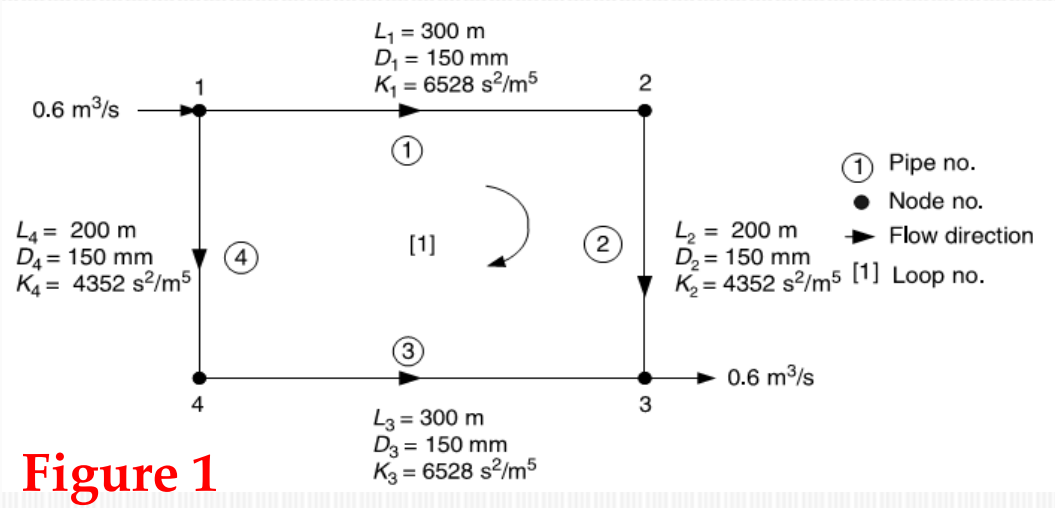


Figure 1

- The discharge in pipe Q_4 can be calculated by applying continuity equation at node 1 as –

$$Q_1 + Q_4 = q_1 \text{ or } Q_4 = q_1 - Q_1$$

$$\text{hence } Q_4 = 0.6 - 0.1 = 0.5\,\text{m}^3/\text{s}$$

- The discharge in pipe 4 is positive, hence the flow will be from node 1 to node 4 (toward higher numbering node).

Simple Looped Network Analysis – Hardy Cross Method

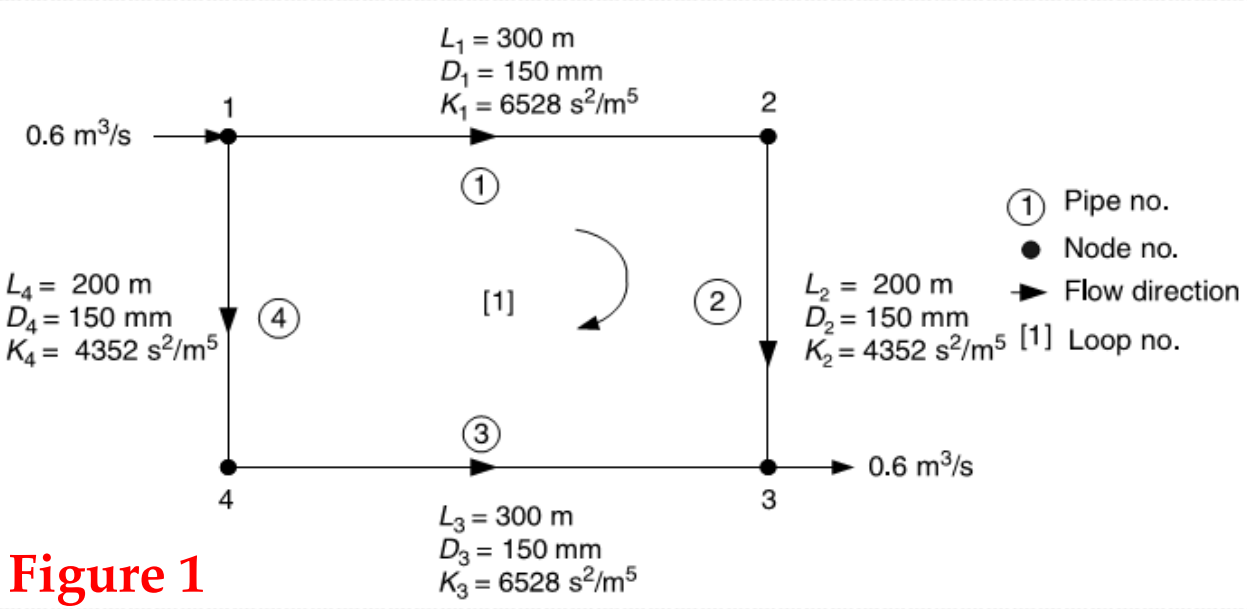


Figure 1

- Also applying continuity equation at node 2:

$$-Q_1 + Q_2 = q_2 \text{ or } Q_2 = q_2 + Q_1$$

$$\text{hence } Q_2 = 0 + 0.1 = 0.1\ \text{m}^3/\text{s}.$$

- Similarly, at node 3, flow in pipe Q_3 = 0.5 m3/s
- The pipe flow directions for the initial flows are shown in the figure.

Simple Looped Network Analysis – Hardy Cross Method

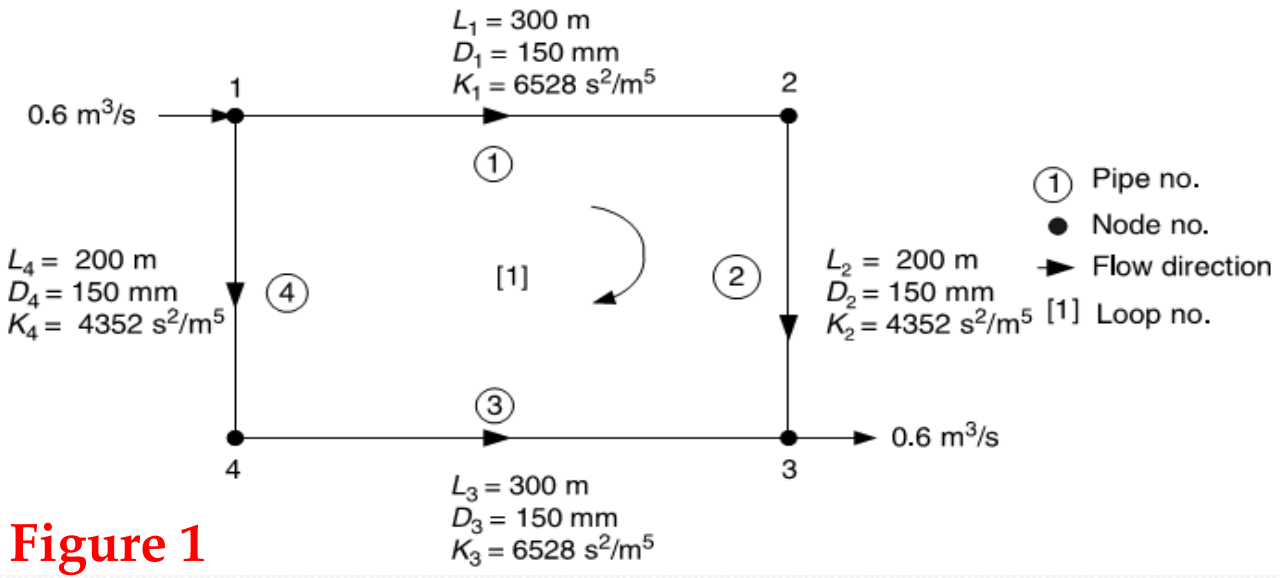


Figure 1

Step 4: For assumed pipe friction factors f_i =0.02, the calculated K values as for all the pipes are given in Fig.1. here, from Darcy – Weisbach head loss equation,

$$K = 8fL/\pi^2 gD^5$$

Step 5: Adopted clockwise flows in pipes positive and counterclockwise flows negative.

Simple Looped Network Analysis – Hardy Cross Method

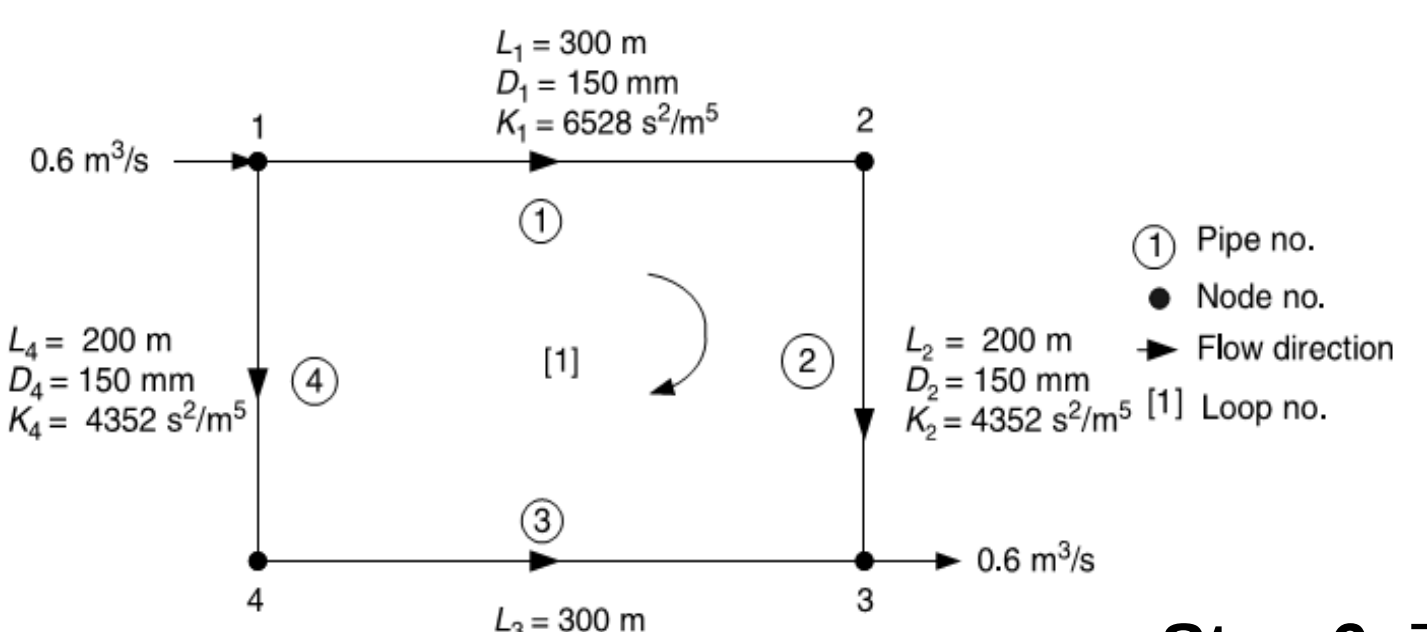


Figure 1

$$K = 8fL/\pi^2 gD^5$$

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

Step 6: The discharge correction for the initially assumed pipe discharges are calculated.

Simple Looped Network Analysis – Hardy Cross Method

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

$$K = 8fL/\pi^2 gD^5$$

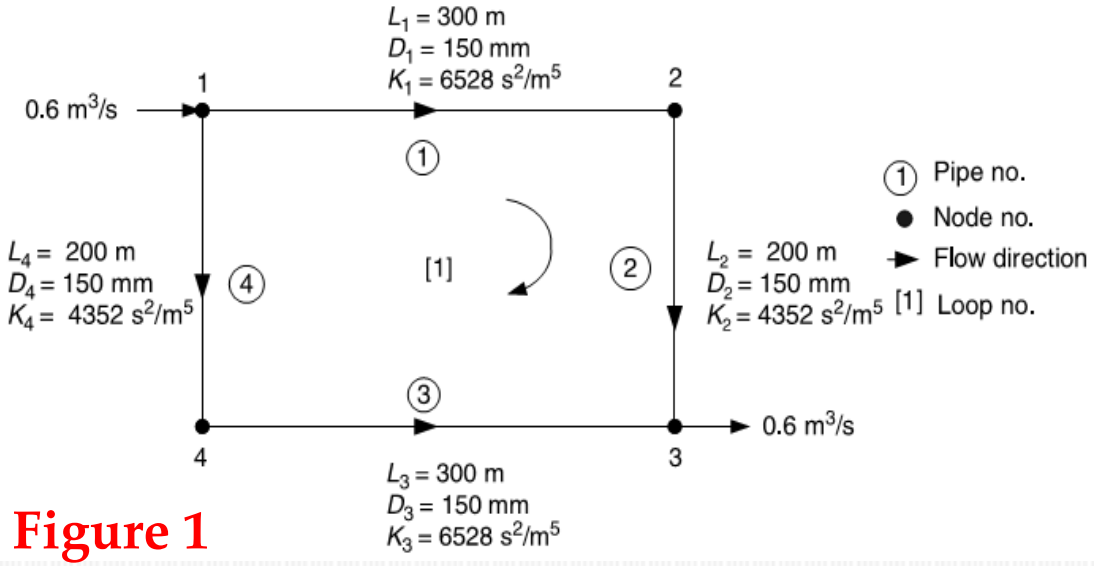


Figure 1

Iteration 1

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
1	0.10	6528.93	65.29	1305.79	0.30
2	0.10	4352.62	43.53	870.52	0.30
3	−0.50	6528.93	−1632.23	6528.93	−0.30
4	−0.50	4352.62	−1088.15	4352.62	−0.30
Total			−2611.57	13,057.85	
ΔQ				$-(-2611.57/13{,}057) = 0.20\ m^3/s$	

Discharge correction, ΔQ is quite large, hence more iteration is required.

Simple Looped Network Analysis – Hardy Cross Method

Step 7: Repeat the process again for the revised pipe discharges.

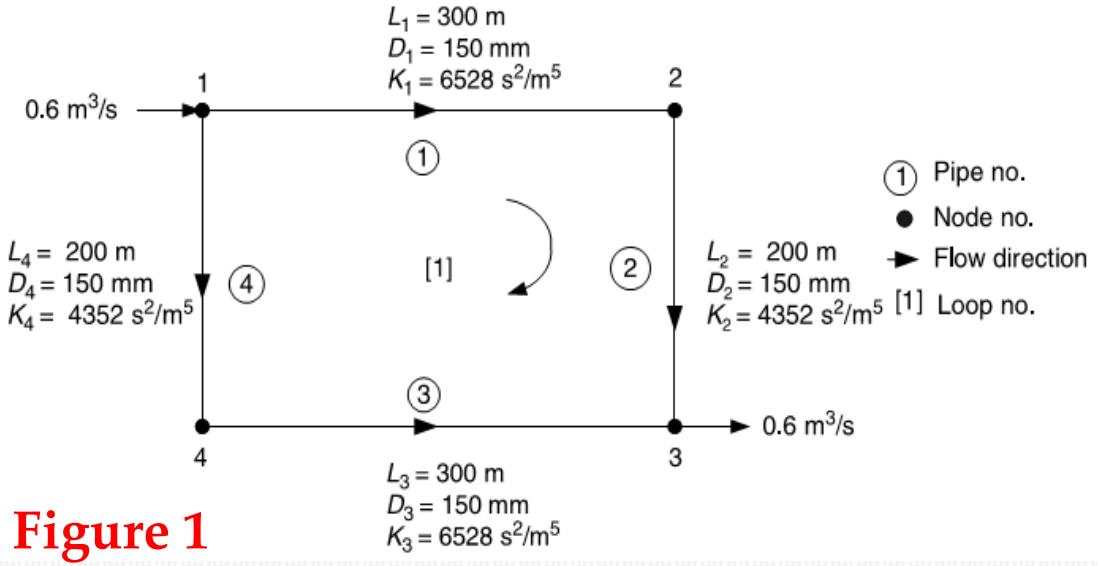


Figure 1

Iteration 2

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
1	0.30	6528.93	587.60	3917.36	0.30
2	0.30	4352.62	391.74	2611.57	0.30
3	−0.30	6528.93	−587.60	3917.36	−0.30
4	−0.30	4352.62	−391.74	2611.57	−0.30
Total			0.00	13,057.85	
ΔQ				$= -(0/13{,}057) = 0.00\ m^3/s$	

Here, discharge correction, ΔQ Is zero.

Simple Looped Network Analysis – Hardy Cross Method

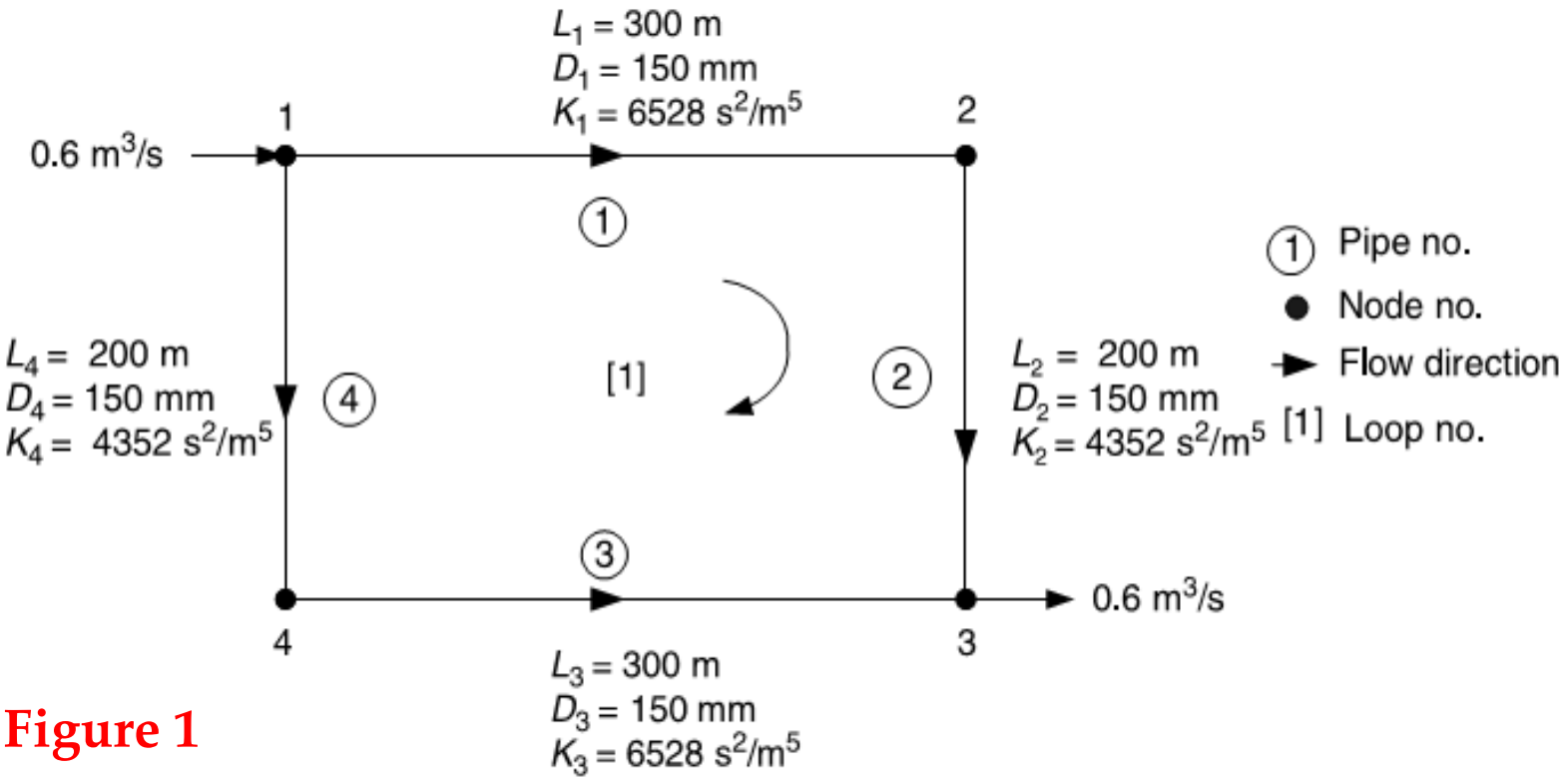


Figure 1

The final discharges are:

$$Q_1 = 0.3 \text{ m}^3/\text{s}$$
$$Q_2 = 0.3 \text{ m}^3/\text{s}$$
$$Q_3 = 0.3 \text{ m}^3/\text{s}$$
$$Q_4 = 0.3 \text{ m}^3/\text{s}.$$

Pipe Network Analysis – Hardy Cross Method

Problem 2: Simple Looped Network

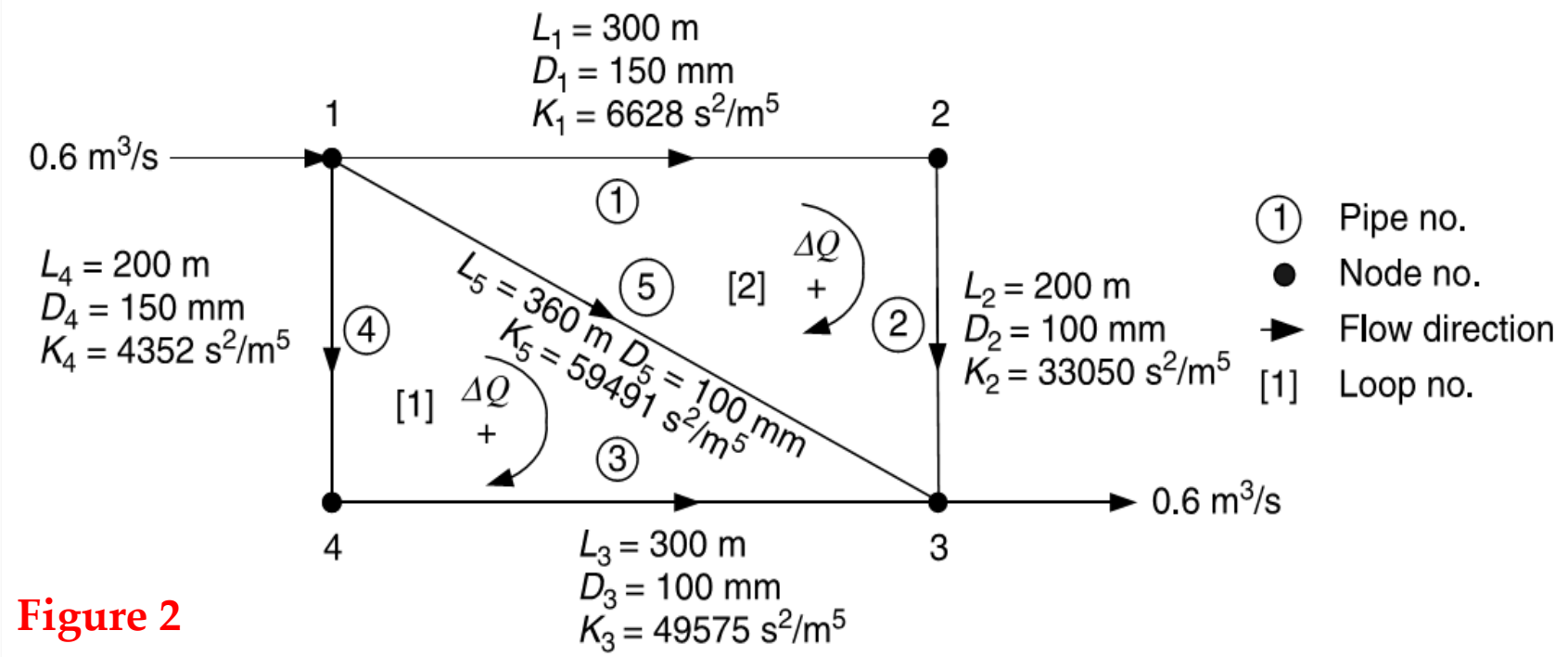


Figure 2

The pipe network of two loops as shown in Fig. 2 has to be analyzed by the Hardy Cross method for pipe flows for given pipe lengths L and pipe diameters D. The nodal inflow at node 1 and nodal outflow at node 3 are shown in the figure. Assume a constant friction factor, f=0.02.

Pipe Network Analysis – Hardy Cross Method

Solution:

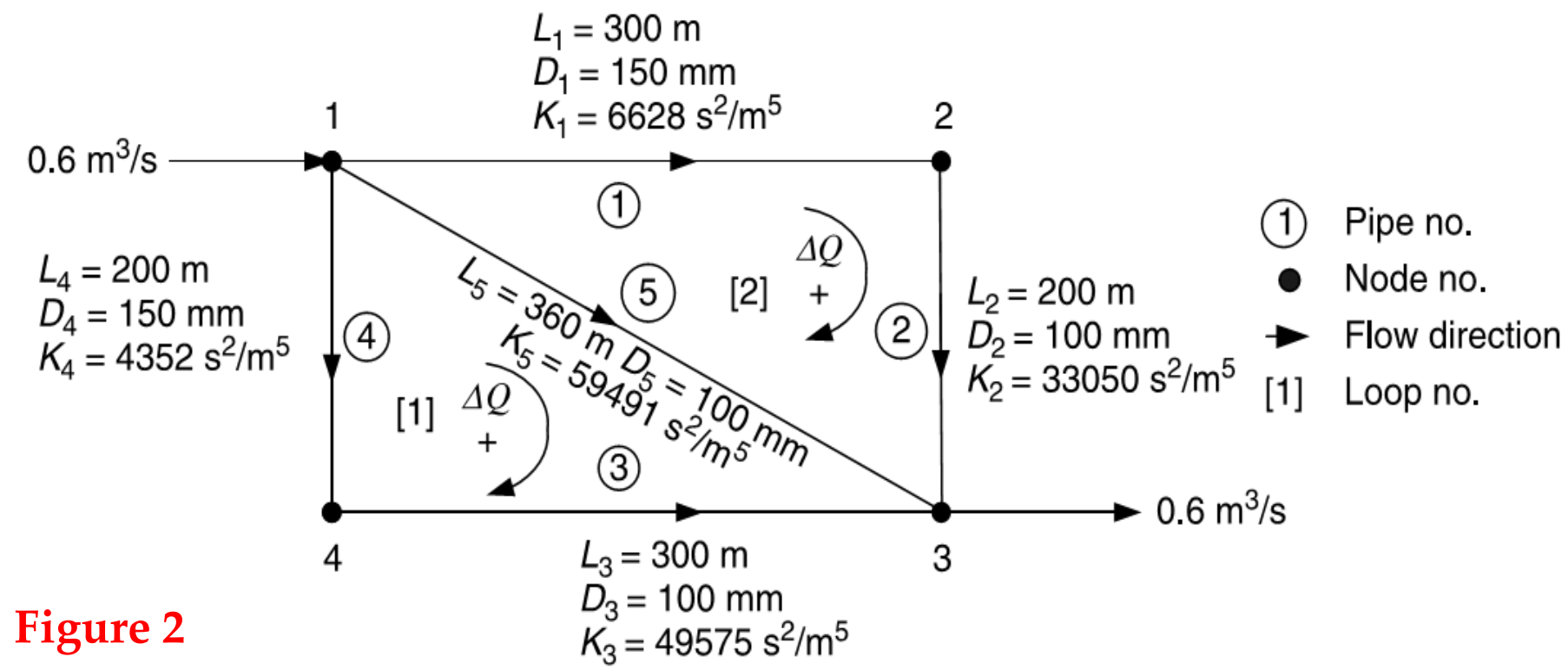


Figure 2

Applying steps 1 – 7 (as mentioned in Problem 1), the looped network analysis can be conducted as illustrated in this example. The K values for Darcy – Weisbach head loss – discharge relationship are also given in Fig. 2 above.

Pipe Network Analysis – Hardy Cross Method

Solution:

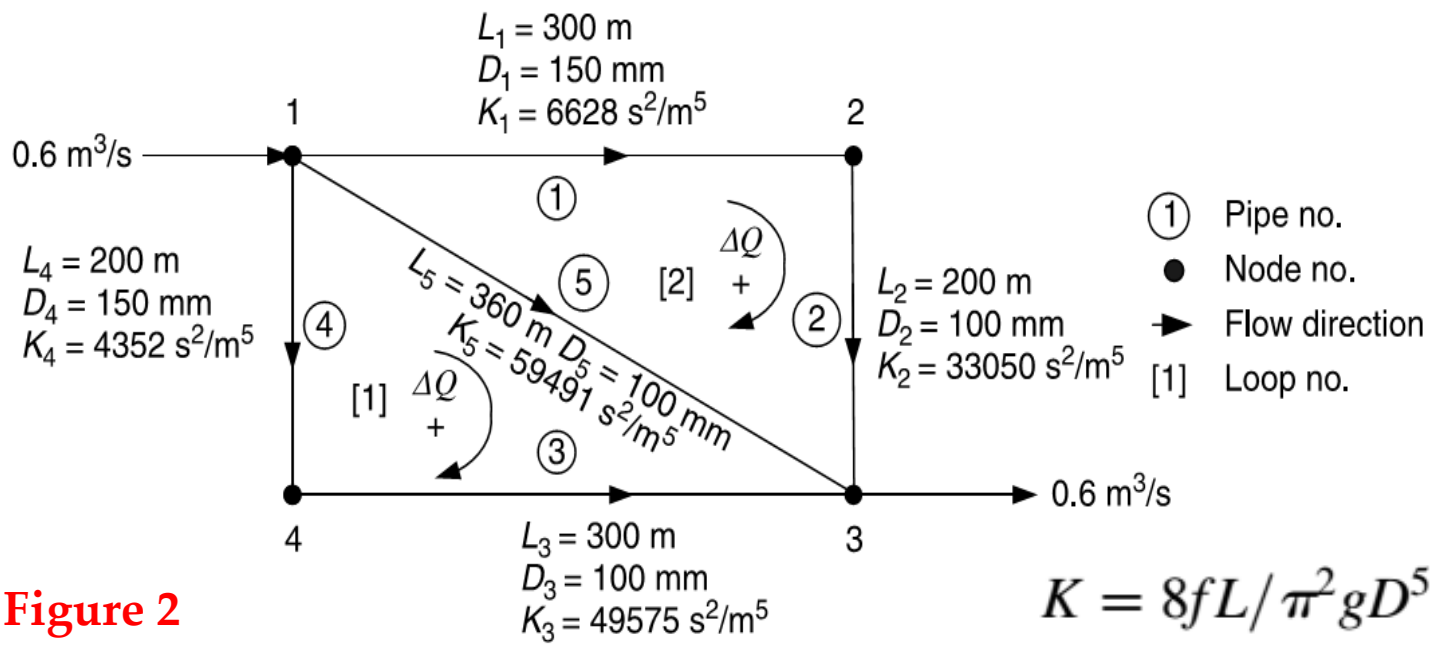


Figure 2

$$K = 8fL/\pi^2 gD^5$$

To apply continuity equation for initial pipe discharges, the discharges in pipes 1and 5 equal to 0.1 m^3/s are assumed.

Now, the obtained discharges are -

$Q_1 = 0.1\ m^3/s$ (flow from node 1 to node 2)

$Q_2 = 0.1\ m^3/s$ (flow from node 2 to node 3)

$Q_3 = 0.4\ m^3/s$ (flow from node 4 to node 3)

$Q_4 = 0.4\ m^3/s$ (flow from node 1 to node 4)

$Q_5 = 0.1\ m^3/s$ (flow from node 1 to node 3)

Pipe Network Analysis – Hardy Cross Method

Solution:

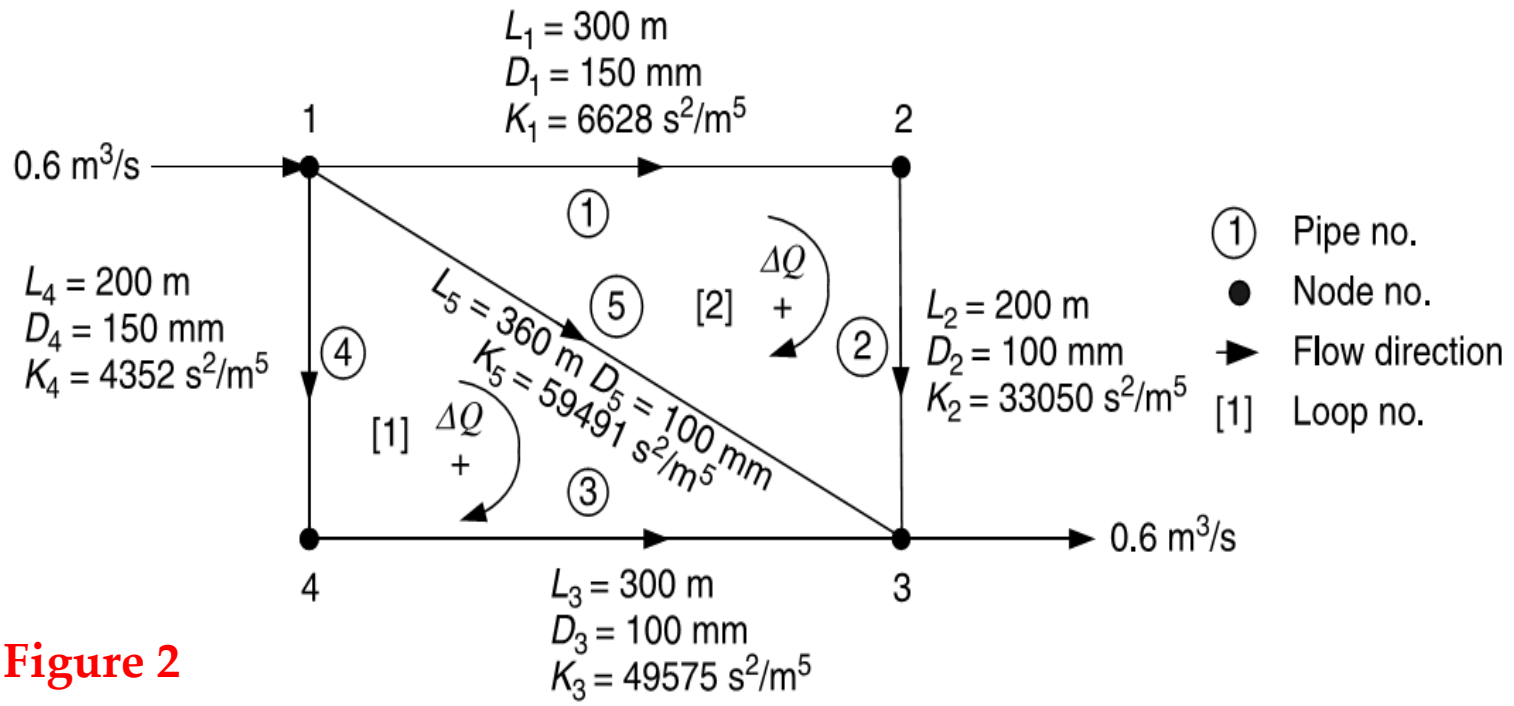


Figure 2

The discharge correction ΔQ is applied in one loop at a time until the ΔQ is very small in all the loops. ΔQ in Loop 1 (loop pipes 3, 4, and 5) and corrected pipe discharges are given in the following table:

Pipe Network Analysis – Hardy Cross Method

Solution:

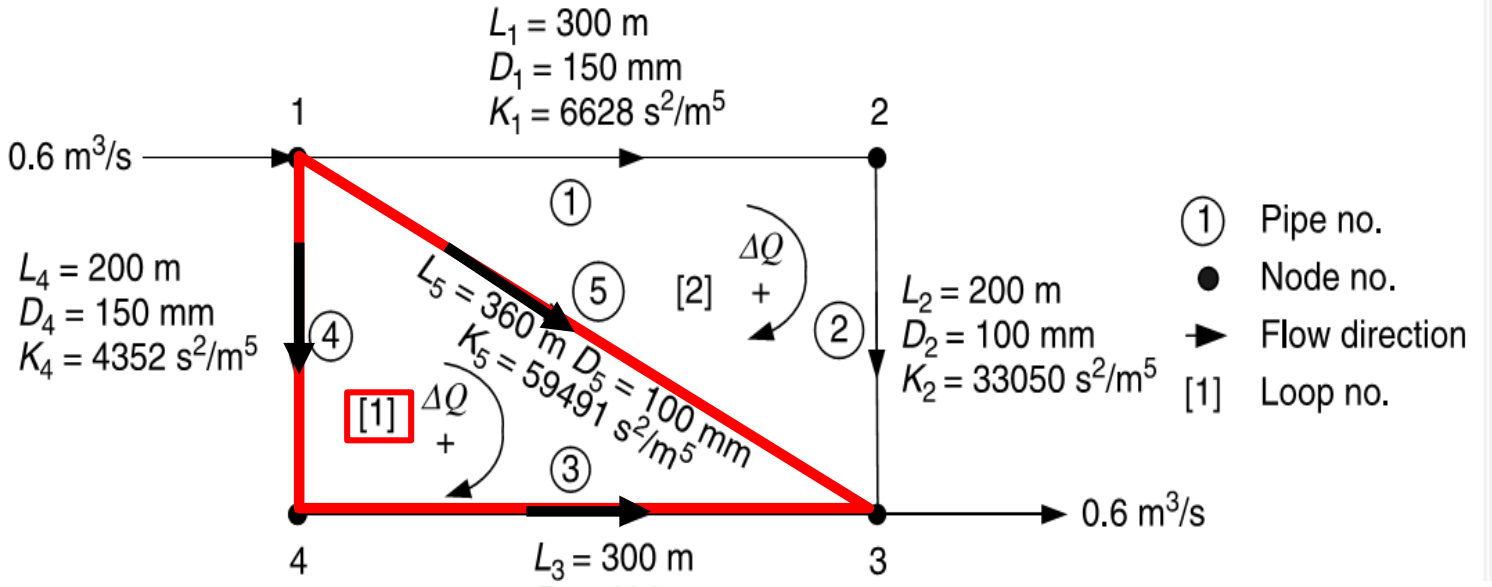


Figure 2

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

Loop 1: Iteration 1

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
3	−0.40	49,576.12	−7932.18	39,660.89	−0.25
4	−0.40	4352.36	−696.38	3481.89	−0.25
5	0.10	59,491.34	594.91	11,898.27	0.25
Total			−8033.64	55,041.05	
ΔQ			0.15 m^3/s		

Pipe Network Analysis – Hardy Cross Method

Solution:

Pipe 5 is common to **Loop 1 and loop 2,** hence it will **take correction from both loops.**

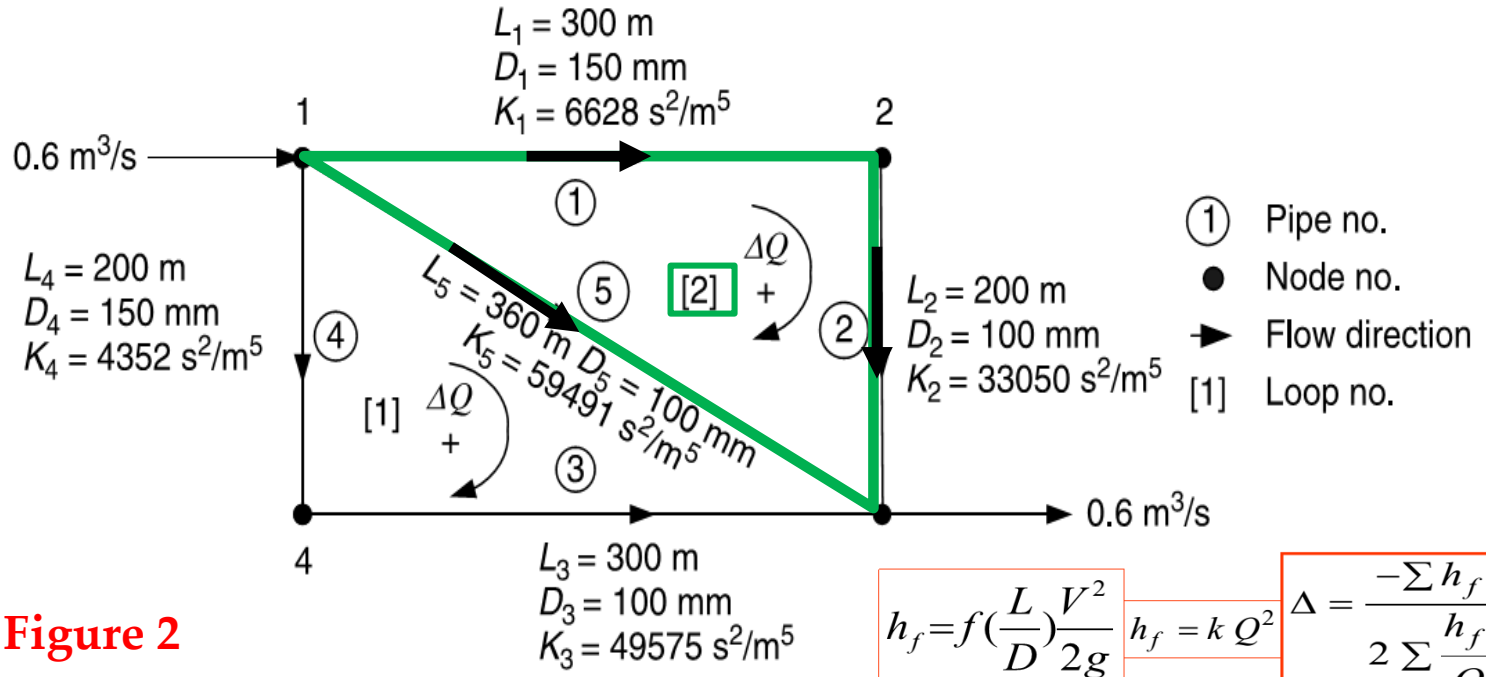


Figure 2

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

Loop 2: Iteration 1

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
1	0.10	6528.54	65.29	1305.71	0.19
2	0.10	33,050.74	330.51	6610.15	0.19
5	−0.25	59,491.34	−3598.93	29,264.66	−0.16
Total			−3203.14	37,180.52	
ΔQ			0.09 m^3/s		

Pipe Network Analysis – Hardy Cross Method

Solution:

Pipe 5 is common to **Loop 1 and loop 2,** hence it will **take correction from both loops.**

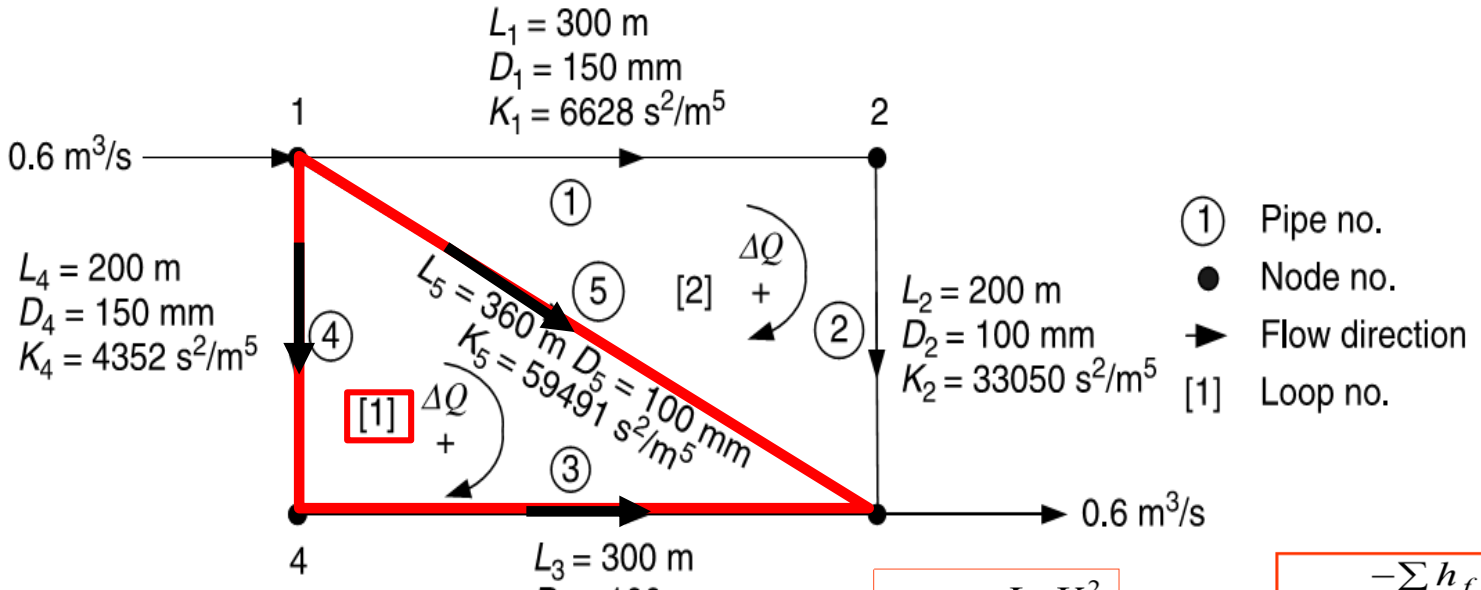


Figure 2

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

Loop 1: Iteration 2

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
3	−0.25	49,576.12	−3098.51	24,788.06	−0.21
4	−0.25	4352.36	−272.02	2176.18	−0.21
5	0.16	59,491.34	1522.98	19,037.23	0.20
Total			−1847.55	46,001.47	
ΔQ			0.04 m^3/s		

Pipe Network Analysis – Hardy Cross Method

Solution:

Pipe 5 is common to **Loop 1 and loop 2,** hence it will **take correction from both loops.**

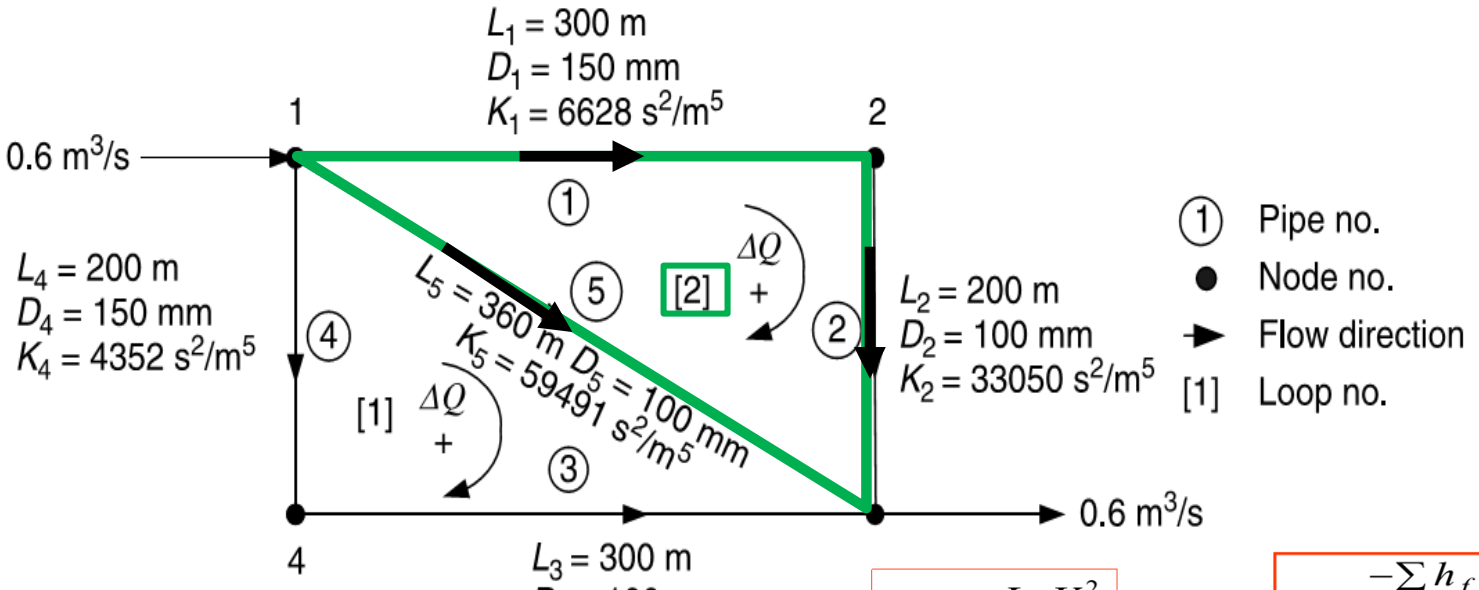


Figure 2

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

Loop 2: Iteration 2

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
1	0.19	6528.54	226.23	2430.59	0.21
2	0.19	33,050.74	1145.28	12,304.85	0.21
5	−0.20	59,491.34	−2383.53	23,815.92	−0.17
Total			−1012.02	38,551.36	
ΔQ			0.03 m^3/s		

Pipe Network Analysis – Hardy Cross Method

Solution:

Pipe 5 is common to **Loop 1 and loop 2,** hence it will **take correction from both loops.**

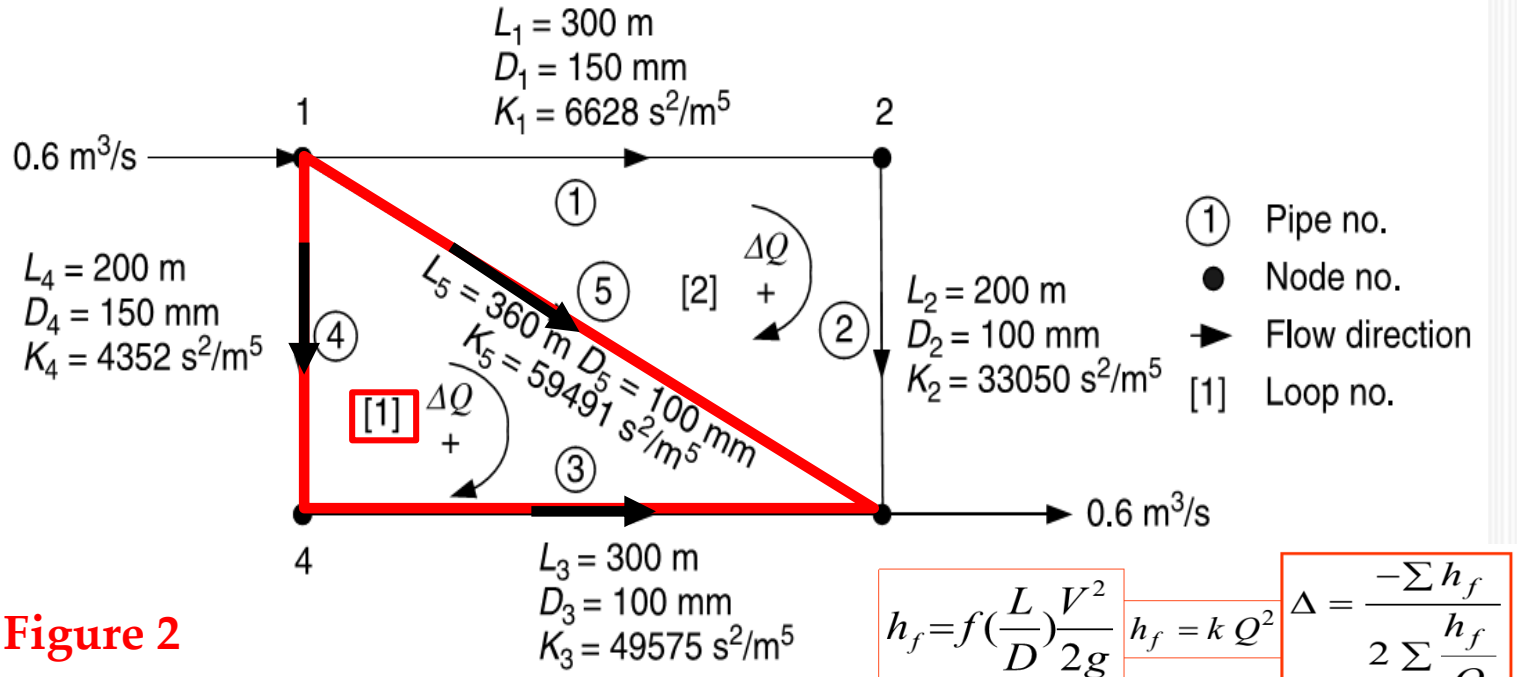


Figure 2

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

Loop 1: Iteration 3

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
3	−0.210	49,576.12	−2182.92	20,805.82	−0.197
4	−0.210	4352.36	−191.64	1826.57	−0.197
5	0.174	59,491.34	1799.33	20,692.47	0.187
Total			−575.23	43,324.86	
ΔQ			0.01 m^3/s		

Pipe Network Analysis – Hardy Cross Method

Solution:

Pipe 5 is common to **Loop 1 and loop 2,** hence it will **take correction from both loops.**

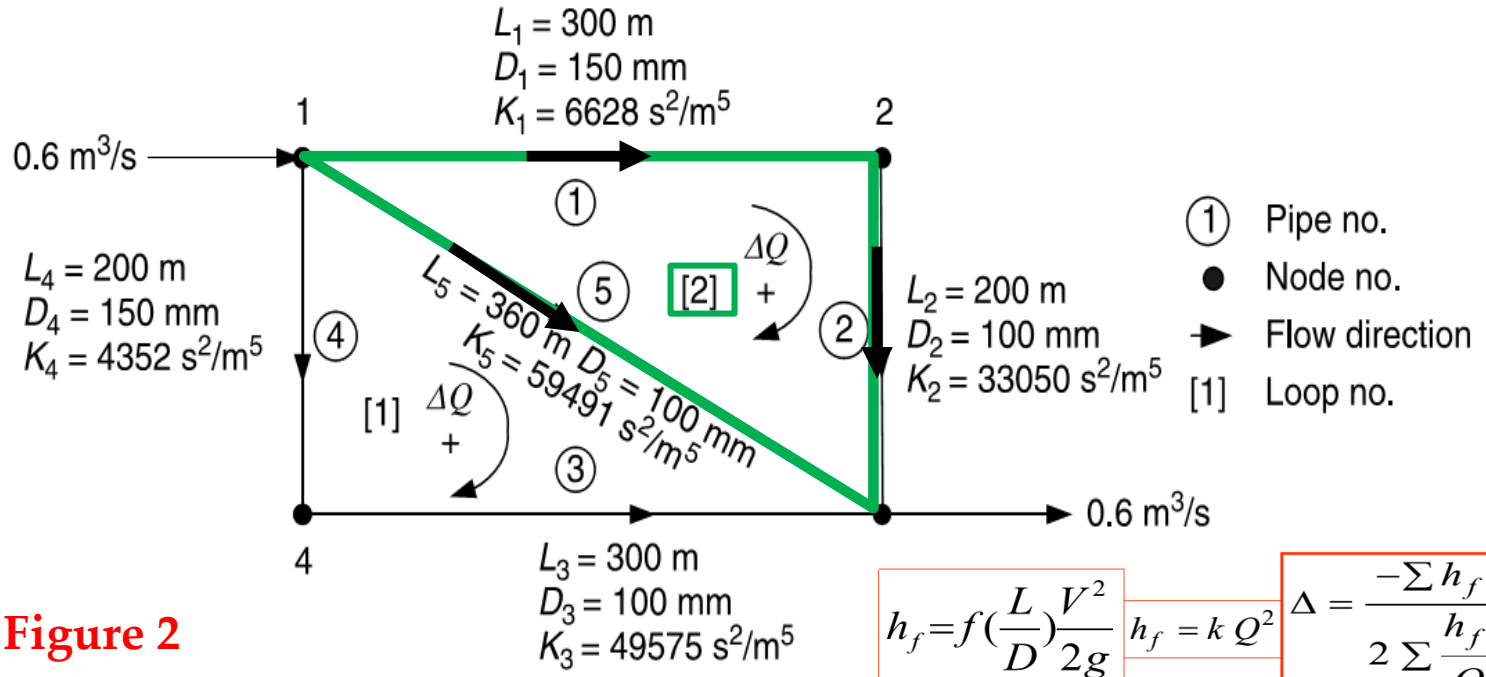


Figure 2

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

Loop 2: Iteration 3

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
1	0.212	6528.54	294.53	2773.35	0.220
2	0.212	33,050.74	1491.07	14,040.10	0.220
5	−0.187	59,491.34	−2084.55	22,272.21	−0.180
Total			−298.95	39,085.67	
ΔQ			0.008 m^3/s		

Pipe Network Analysis – Hardy Cross Method

Solution:

Pipe 5 is common to **Loop 1 and loop 2,** hence it will **take correction from both loops.**

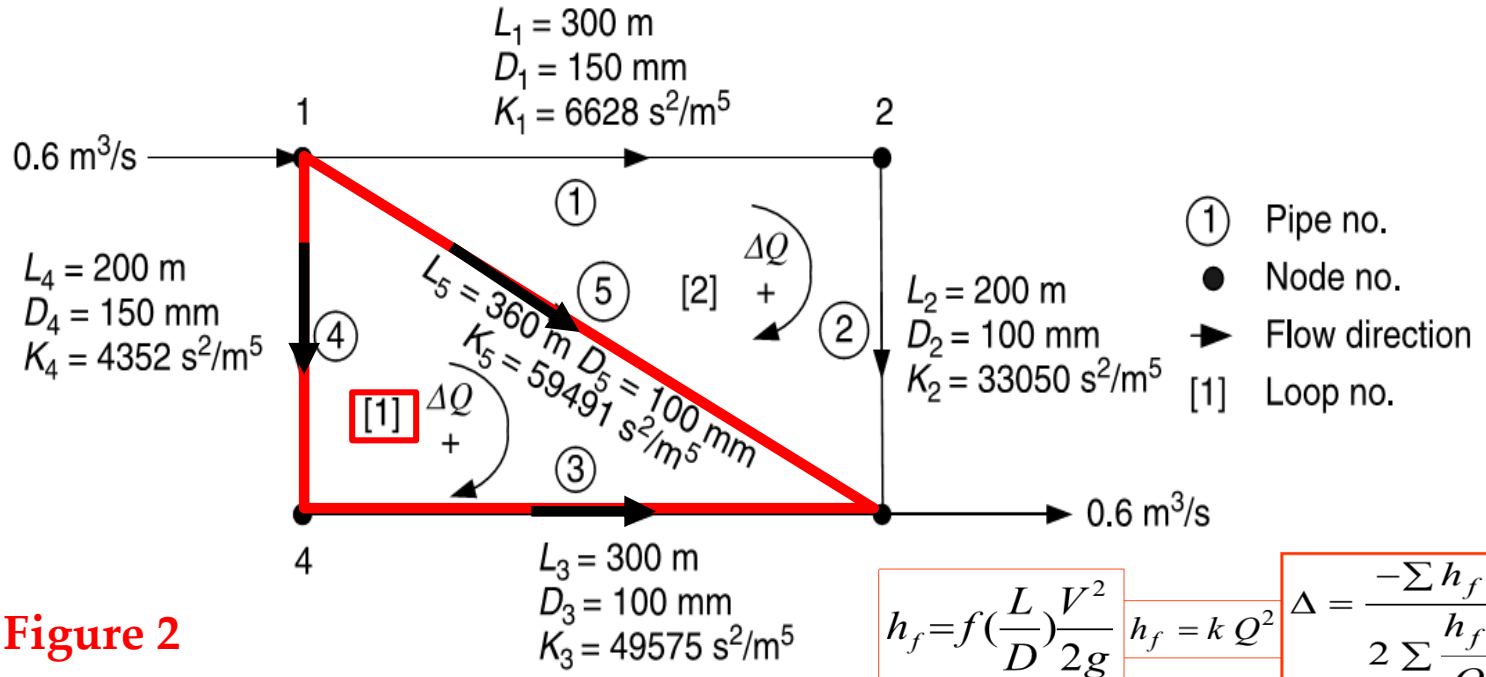


Figure 2

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

Loop 1: Iteration 4

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
3	−0.197	49,576.12	−1915.41	19,489.36	−0.193
4	−0.197	4352.36	−168.16	1711.00	−0.193
5	0.180	59,491.34	1917.68	21,362.18	0.183
Total			−165.89	42,562.54	
ΔQ			0.004 m^3/s		

Pipe Network Analysis – Hardy Cross Method

Solution:

Pipe 5 is common to **Loop 1 and loop 2,** hence it will **take correction from both loops.**

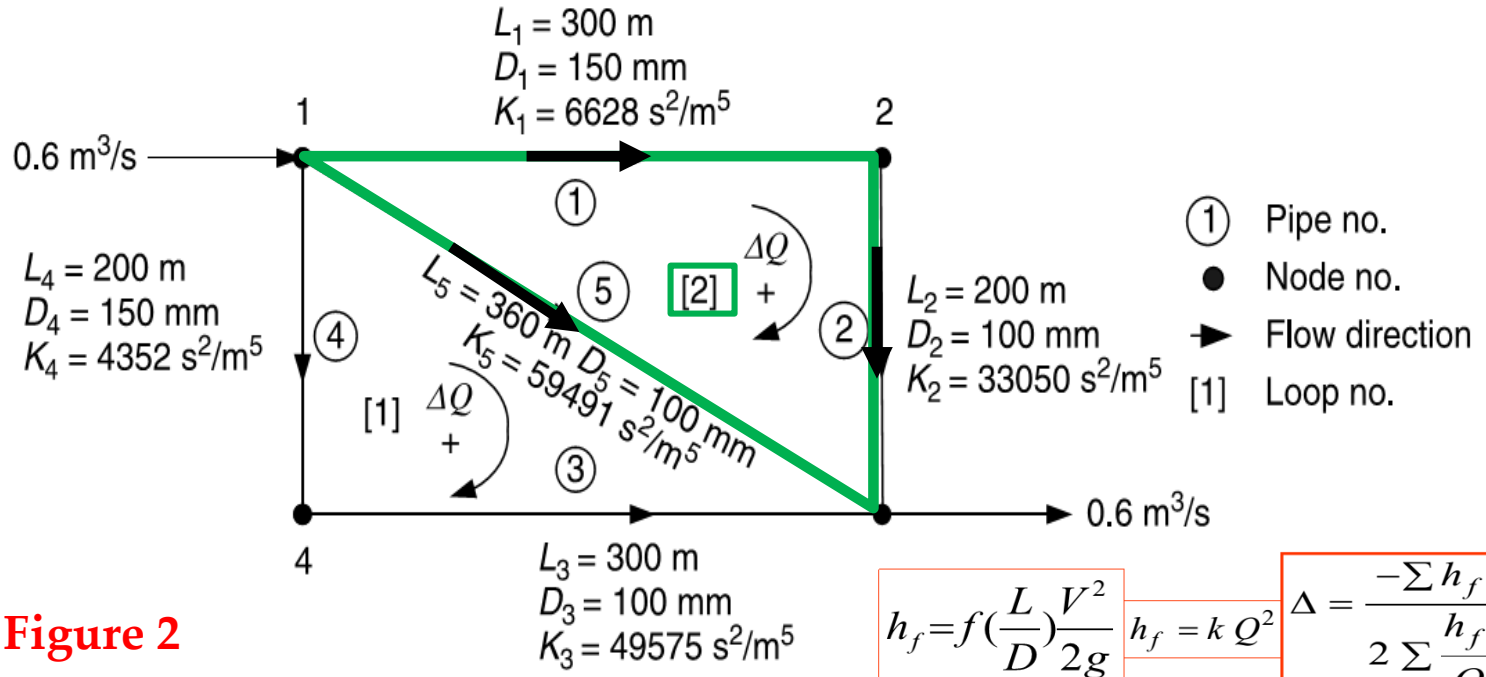


Figure 2

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

Loop 2: Iteration 4

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
1	0.220	6528.54	316.13	2873.22	0.222
2	0.220	33,050.74	1600.39	14,545.68	0.222
5	−0.183	59,491.34	−2001.85	21,825.91	−0.181
Total			−85.33	39,244.81	
ΔQ			0.002 m^3/s		

Pipe Network Analysis – Hardy Cross Method

Solution:

Pipe 5 is common to **Loop 1 and loop 2,** hence it will **take correction from both loops.**

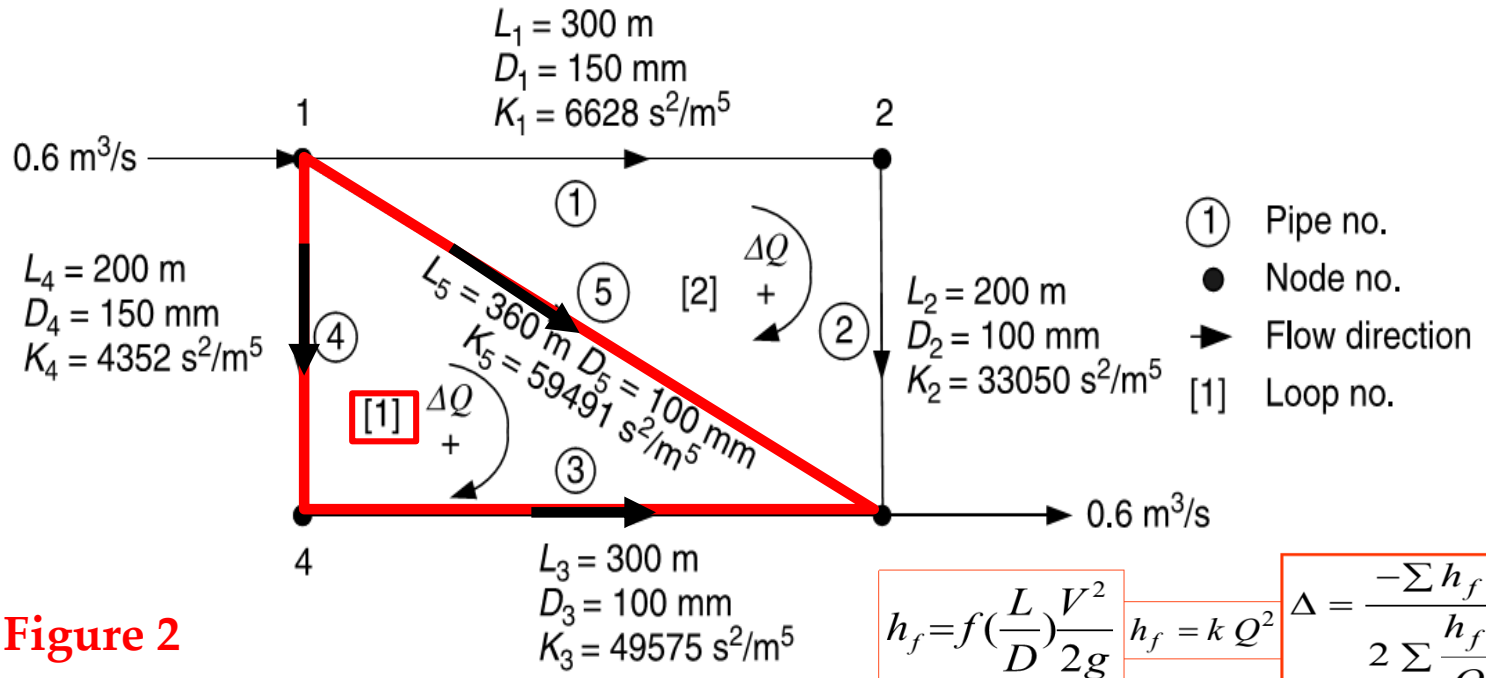


Figure 2

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

Loop 1: Iteration 5

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
3	−0.193	49,576.12	−1840.21	19,102.92	−0.192
4	−0.193	4352.36	−161.55	1677.07	−0.192
5	0.181	59,491.34	1954.67	21,567.21	0.182
Total			−47.09	42,347.21	
ΔQ			0.001 m^3/s		

Pipe Network Analysis – Hardy Cross Method

Solution:

Pipe 5 is common to **Loop 1 and loop 2,** hence it will **take correction from both loops.**

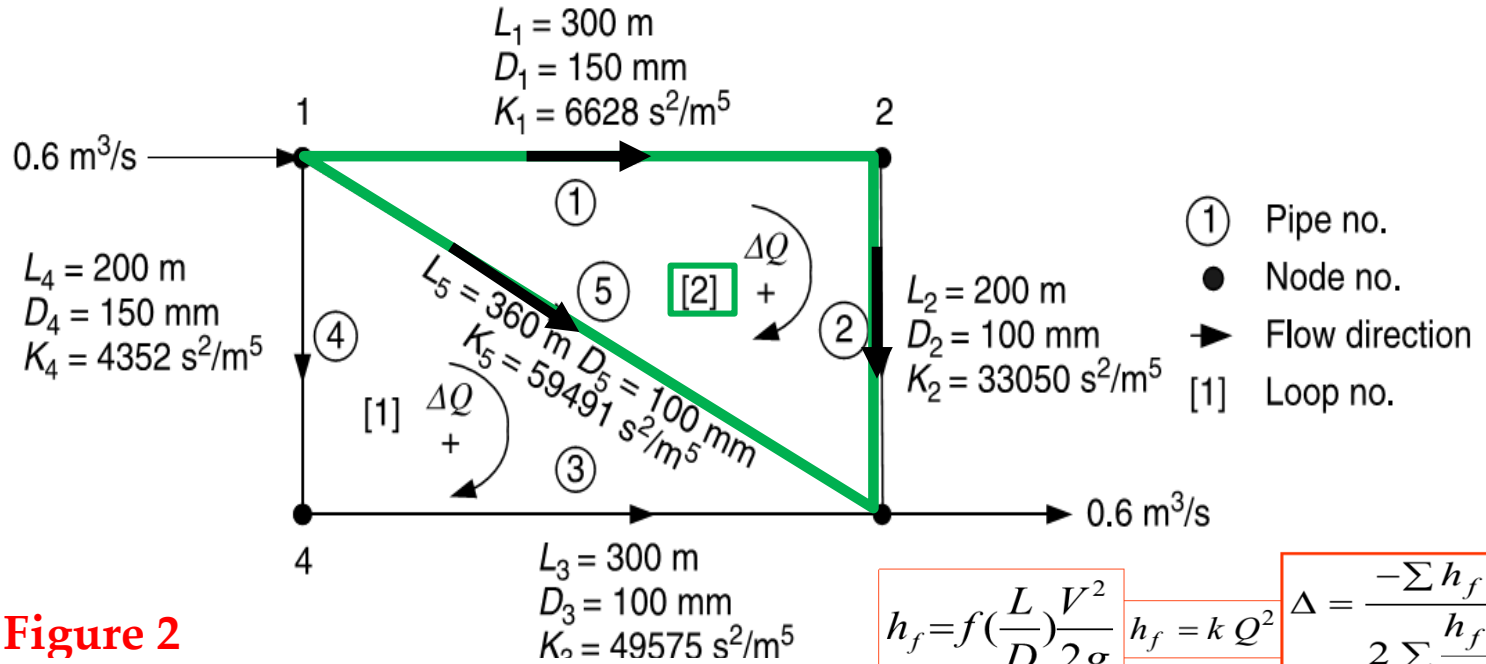


Figure 2

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} \qquad h_f = k\,Q^2 \qquad \Delta = \frac{-\sum h_f}{2\sum \frac{h_f}{Q}}$$

Loop 2: Iteration 5

Pipe	Flow in Pipe Q (m^3/s)	K (s^2/m^5)	h_f (m)	$2h_f/Q$ (s/m^2)	Corrected Flow $Q = Q + \Delta Q$ (m^3/s)
1	0.222	6528.54	322.40	2901.61	0.223
2	0.222	33,050.74	1632.17	14,689.40	0.223
5	-0.182	59,491.34	−1978.73	21,699.52	−0.182
Total			−24.15	39,290.53	
ΔQ			0.001 m^3/s		

Pipe Network Analysis – Hardy Cross Method

Solution:

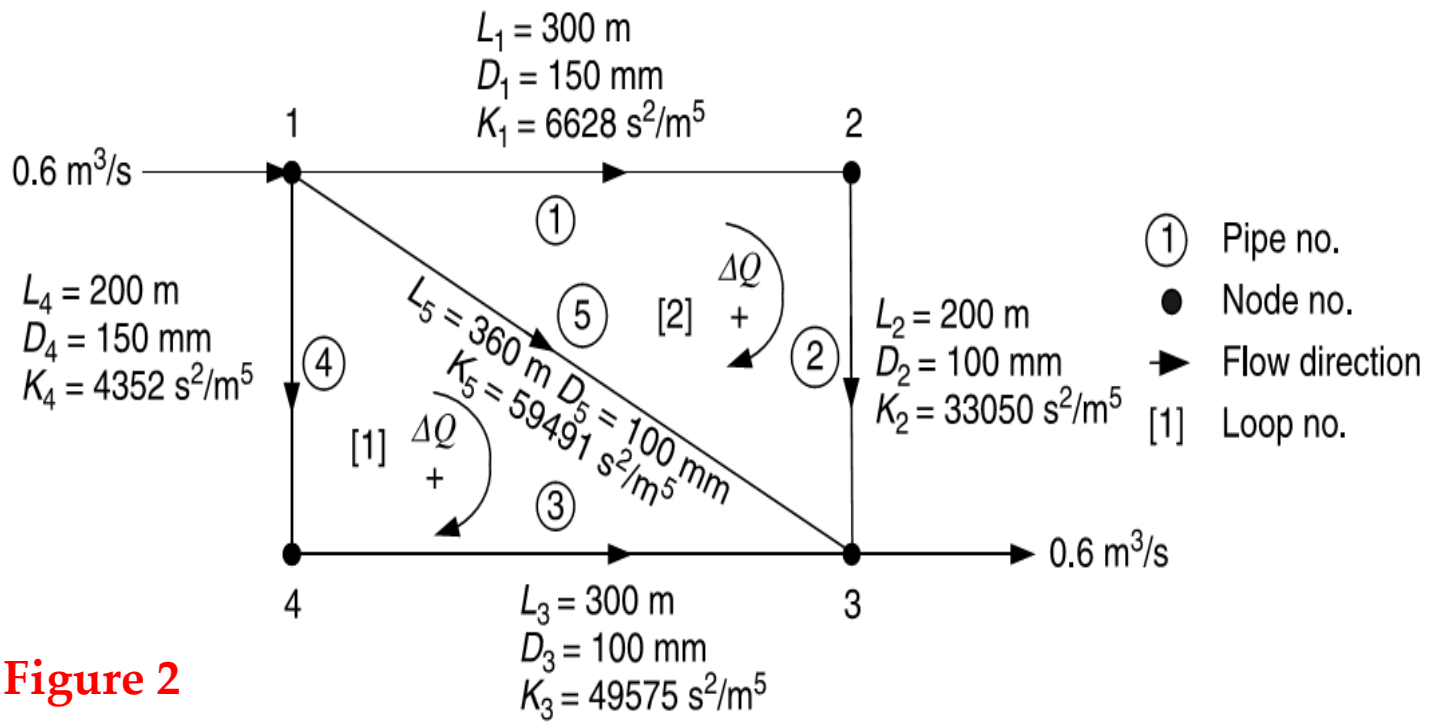


Figure 2

The discharge corrections in the loops are very small after five iterations, thus the final pipe discharges in the looped pipe network in Fig. 2 are -

$$Q_1 = 0.223\ \text{m}^3/\text{s}$$
$$Q_2 = 0.223\ \text{m}^3/\text{s}$$
$$Q_3 = 0.192\ \text{m}^3/\text{s}$$
$$Q_4 = 0.192\ \text{m}^3/\text{s}$$
$$Q_5 = 0.182\ \text{m}^3/\text{s}$$