ENVIRONMENTAL ENGINEERING 1

Lecture 11 – Hydraulics of Water Distribution System

Engr. Gul-E-Hina
Lecturer ,
Institute of Environmental Engineering & Research(IEER)
University of Engineering and Technology, Lahore

gulehina@uet.edu.pk

Design of Water Distribution System

- The design requirements of water distribution system are to satisfied:

☐ The **water need** ,and

☐ The **minimum residual pressure*** at each point of the water distribution system

*Minimum residual pressure is the amount of the water required at the farthest point .It should be between 14-35 m.

Pressure in Water Distribution System

- Pressure in distribution system varies with consumption.
- Min. Pressure at peak flow(not less than 150 kPa to avoid infiltration, proper flow to other buildings)
- Max. pressure during low flows
- Residential areas (3 stories)-150-300kPa(15-30m)
- Residential areas (firefighting)-400kPa(40m)
- Commercial areas-500KPa(50m)

Velocities in Water Supply System

- Velocities in water supply system<1m/s
- 2m/s upper limit may be reached near fire flows
- **Min velocity-0.25m/s (WASA)**

Hazen-Williams equation for pipe flow

- ✓ Headloss in pipes(water supply network)
- ✓ Empirical
- ✓ Named after Allen Hazen and Gardner Stewart Williams.

$$\boxed{H = 10.65\,\frac{Q^{1.85}}{C^{1.85}}\,\frac{L}{d^{4.87}}}$$

Where:

- H= head loss(m)
- Q= flow rate(m^3/sec)
- L= length of pipe(m)
- d= diameter(m)
- C= Hazen William’s coefficient

Hazen-Williams Equation for Pipe Flow

- Hazen William greatly depends upon Roughness of pipe.
- Basic Hazen William Eq is

$$\boxed{V = 0.849C\, R^{0.63} S^{0.54}}$$

Where,

V= velocity ,m/s

C=Hazen William co-efficient

R=Hydraulic radius or hydraulic mean depth

R=A/P(A=Area, P= Wetted Perimeter)

S= Hydraulic gradient=H_L / L

Hazen-Williams Equation for Pipe Flow

$$Q = AV$$

$$Q = \frac{\pi}{4} d^2 \times 0.849 C R^{0.63} S^{0.54}$$

$$Q = \frac{\pi}{4} d^2 \times 0.849 C \left(\frac{d}{4}\right)^{0.63} \left(\frac{H_L}{L}\right)^{0.54}$$

$$Q = 0.278 C (d)^{2.63} \left(\frac{H_L}{L}\right)^{0.54}$$

$$\left(\frac{H_L}{L}\right)^{0.54} = \frac{Q}{0.278 C (d)^{2.63}}$$

$$\left(\frac{H_L}{L}\right) = \left(\frac{Q}{0.278 C (d)^{2.63}}\right)^{\frac{1}{0.54}}$$

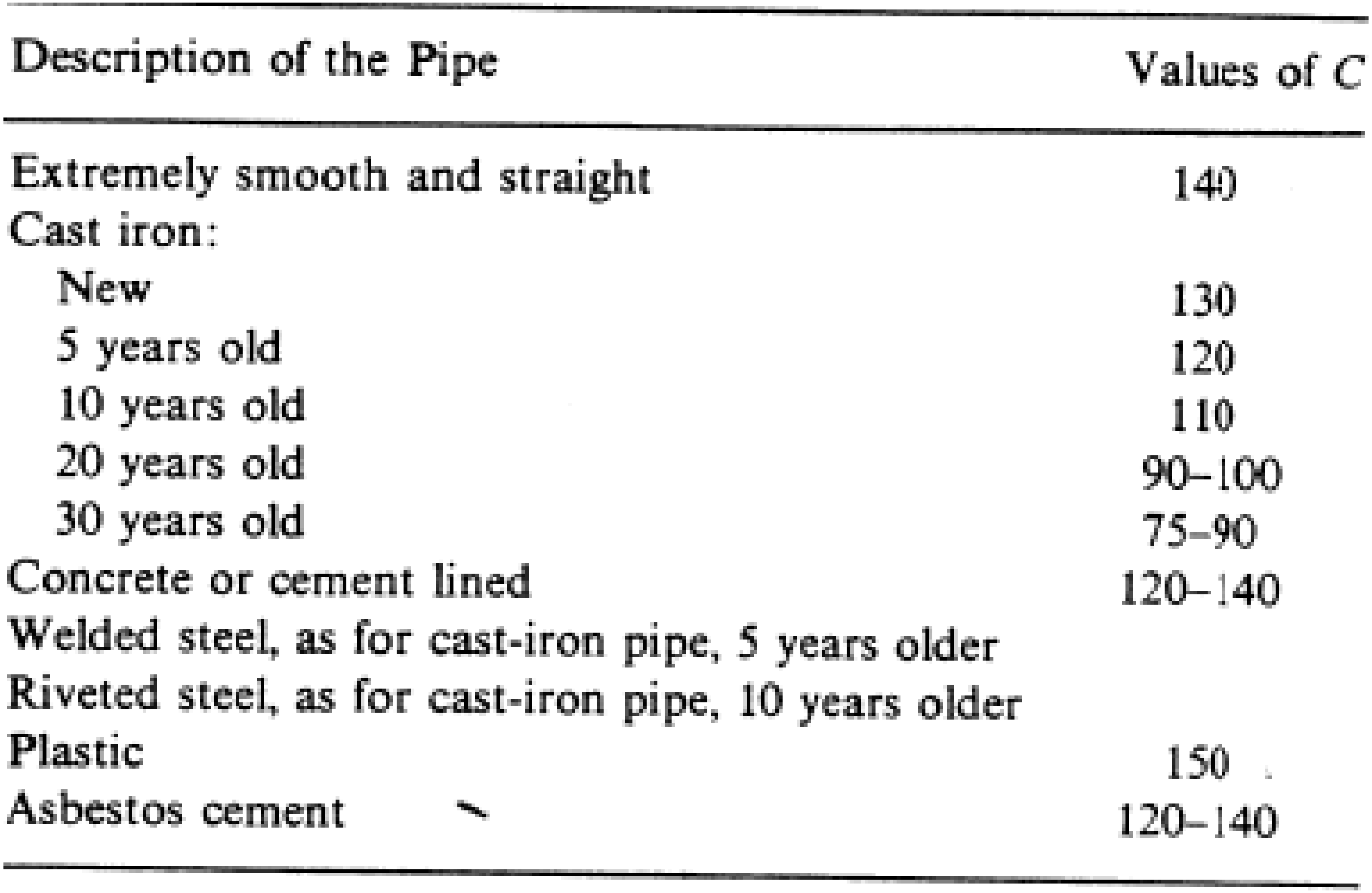
$$\left(\frac{H_L}{L}\right) = \frac{Q^{1.85}}{0.0936 C^{1.85} (d)^{4.87}}$$

$$\boxed{H_L = 10.68 \left(\frac{Q}{C}\right)^{1.85} \frac{L}{d^{4.87}}}$$

H-head loss in meters
Q=flow in cu meter per sec
D= diameter in m
L= length of pipe in meters

For safety factor C=100

Hazen-Williams Coefficients for various Pipe materials



Description of the Pipe	Values of C
Extremely smooth and straight	140
Cast iron:	
New	130
5 years old	120
10 years old	110
20 years old	90–100
30 years old	75–90
Concrete or cement lined	120–140
Welded steel, as for cast-iron pipe, 5 years older	
Riveted steel, as for cast-iron pipe, 10 years older	
Plastic	150
Asbestos cement	120–140

Hazen-Williams equation for pipe flow

Advantages

- Coefficient C is rough measure of relative roughness
- Effect of Reynolds number is included in formula
- Effect of roughness on velocity are given directly

Disadvantages

- Empirical
- Does not differentiate completely between laminar and turbulent flow
- Extremely high and low temp. 20% error in water pipes can not be applied to all fluids in all conditions

Problem-Hazen William

- Problem 1: Calculate the diameter of pipe 1Km laid to discharge a flow of 1000m^3/day under a head loss of 10m(C=100)

- Problem 2: A 6-km-long, new cast-iron pipeline carries 320 l /s of water .The pipe diameter is 30 cm. Find the head loss .

Design Criteria for Distribution System

Design Parameter	Value
Design flow	Peak flow/Max.daily demand
Population	Population per plot
Peaking Factor	2.25/1.5
Minimum Size	75mm
Minimum Residual Head	14m
Input head	20m
Pipe Material	AC or PVC, GI, steel pipe
C	100 or 110

Hardy’s Cross Method

Basic Principle

1. Sum of inflows is equal to the sum of outflows at any junction or any node.

$$\sum \text{inflows} = \sum \text{outflows}$$

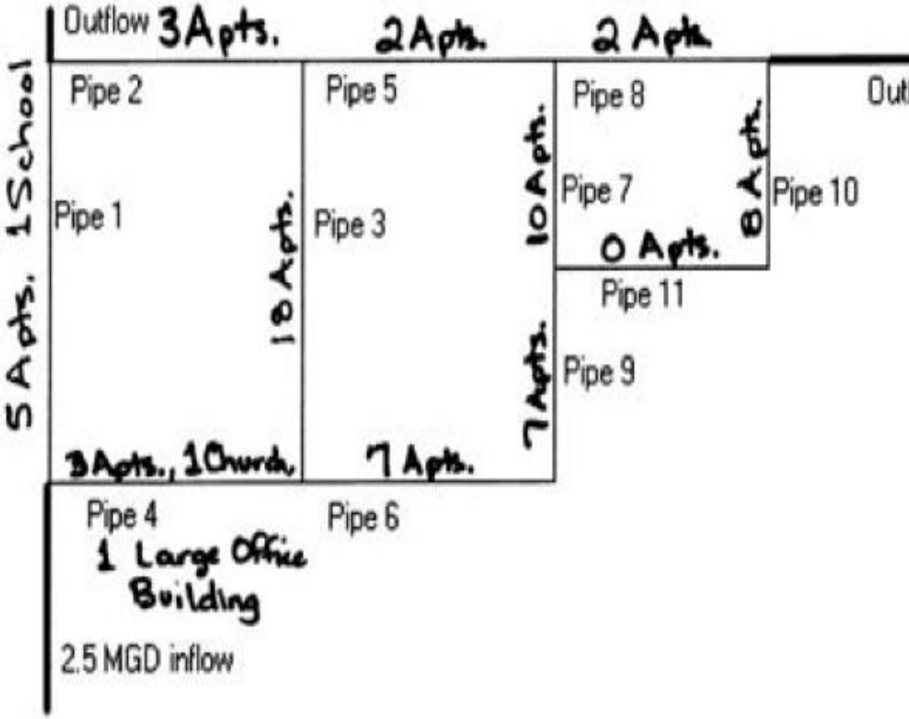
2. Sum of head losses around an elementary loop must be zero.

$$\sum H_L = 0$$

Hardy's Cross Method

Procedure

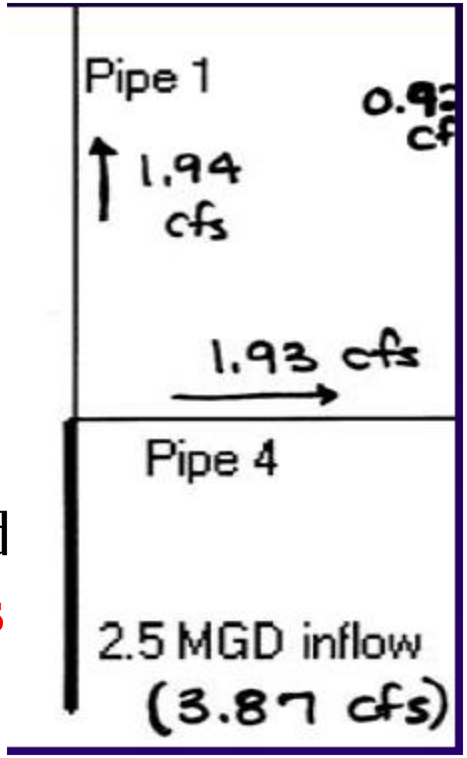
1. Draw the layout of the system.
2. Assign area to each node.
3. Calculate the population for each node
4. Calculate the average consumption at each node.
5. Calculate design flow for each node which should be equal to peak hourly demand.
6. Measure the length of each pipe.



Hardy's Cross Method

Procedure

7. Assume flow in each pipe.
8. Assume the diameter of each pipe.
9. Assume any internally consistent distribution of flow. **The sum of flows entering any junction must equal to sum of leaving flows**
10. Compute the head loss in each pipe by means of equation(Hazen William) or diagram. Conventionally **clockwise flows** are **positive** and produce **positive head loss**. **Anticlockwise flows** are **negative**



Hardy’s Cross Method

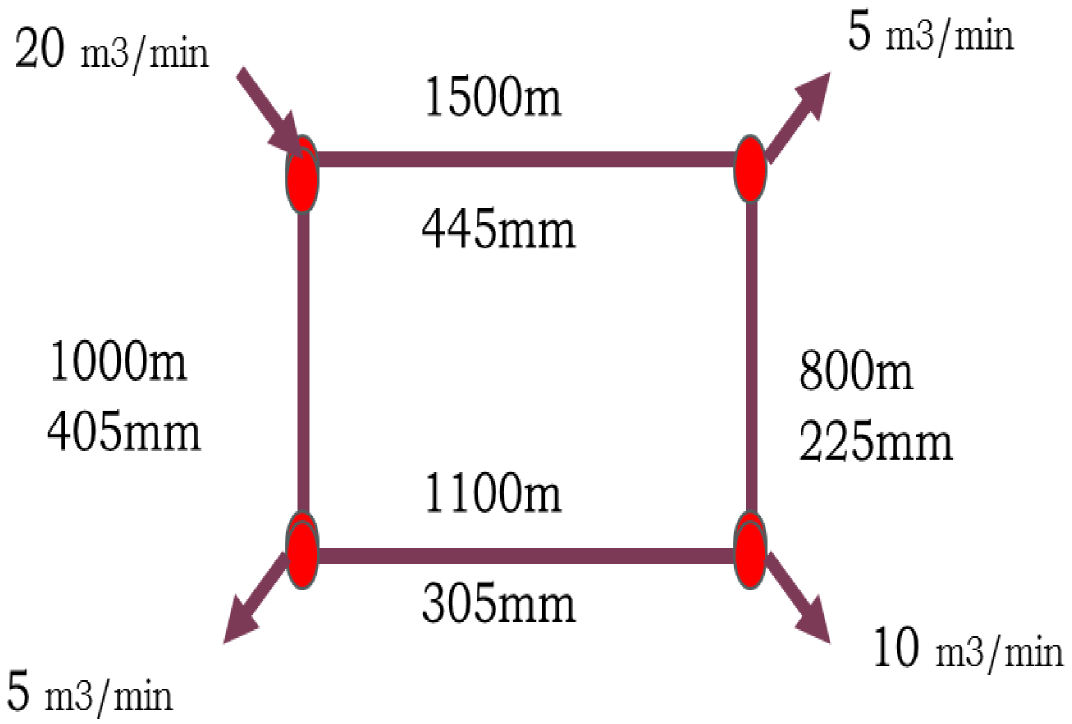
Procedure

11. With due attention to the sign ,compute the total head loss around each loop.
12. Compute without the regard to sign for the same loop for sum of H/Q
13. Apply the correction to the flow in each line

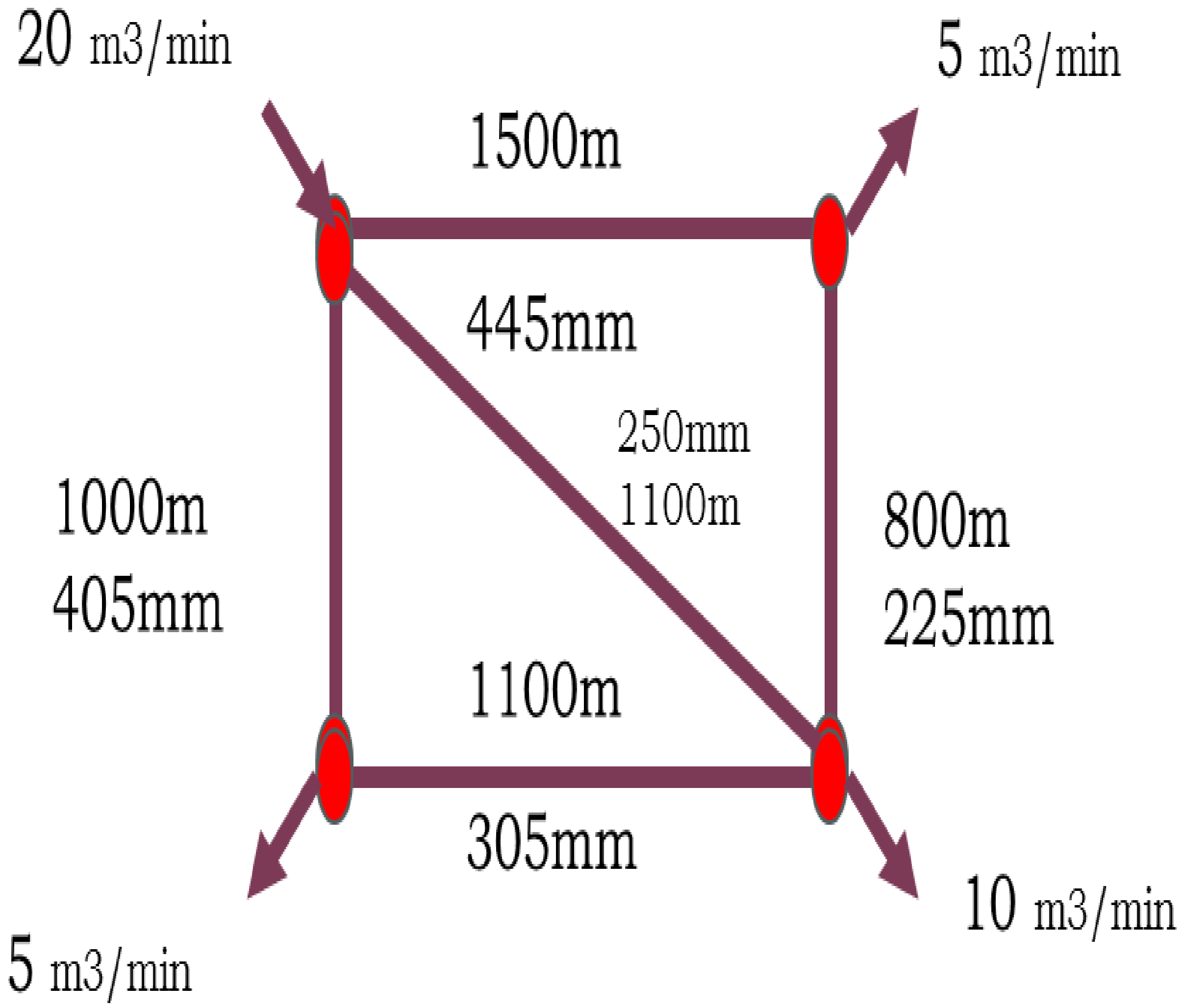
$$\Delta = \frac{-\sum H}{1.85 \sum \frac{H}{Q}}$$

14. Pipe line common to two loops receive both correction with due attention to sign.
15. Balance the flow by Hardy cross method.
16. Calculate the residual pressure at all points of the system and check its adequency.

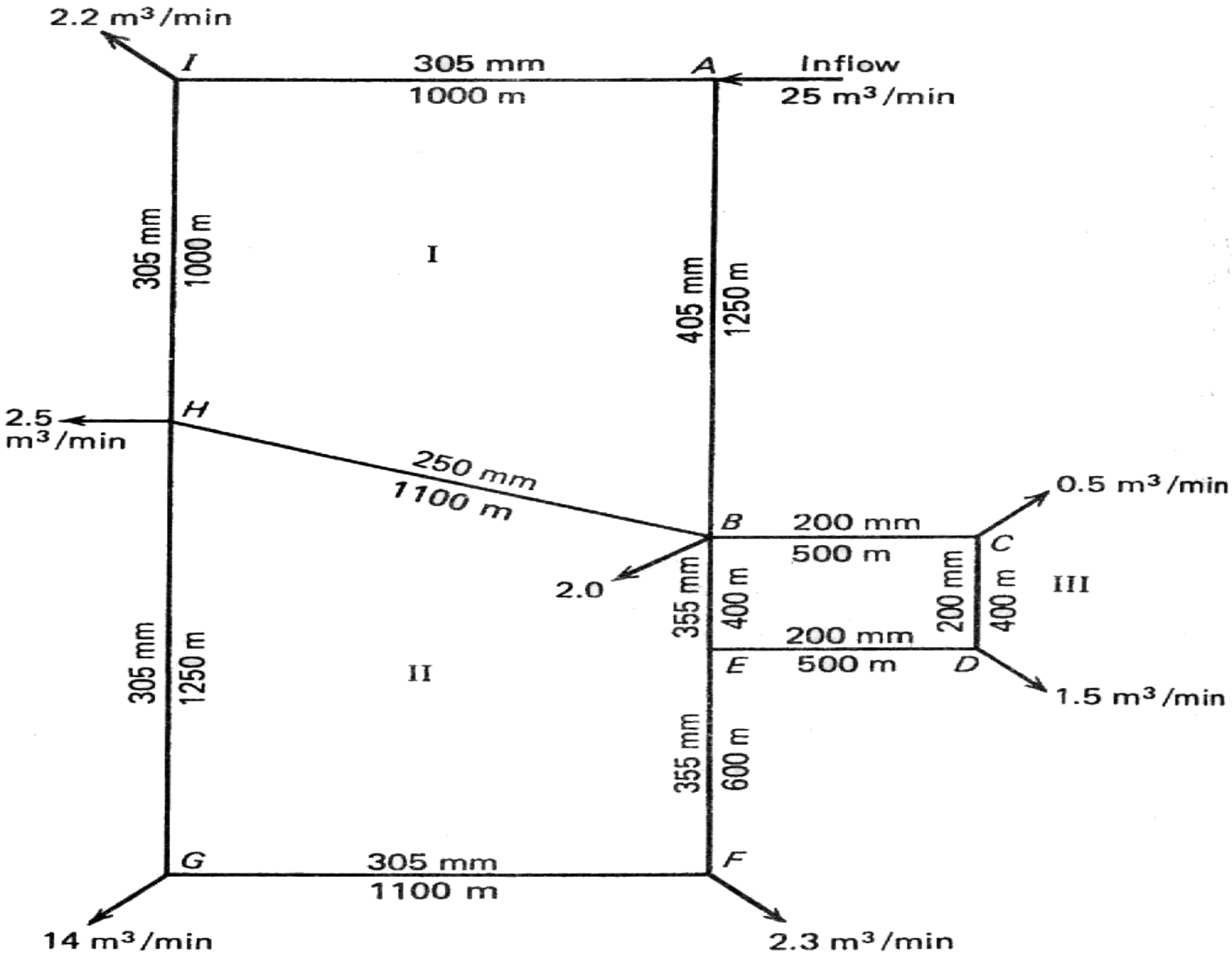
Problem 1-Hardy's Cross Method



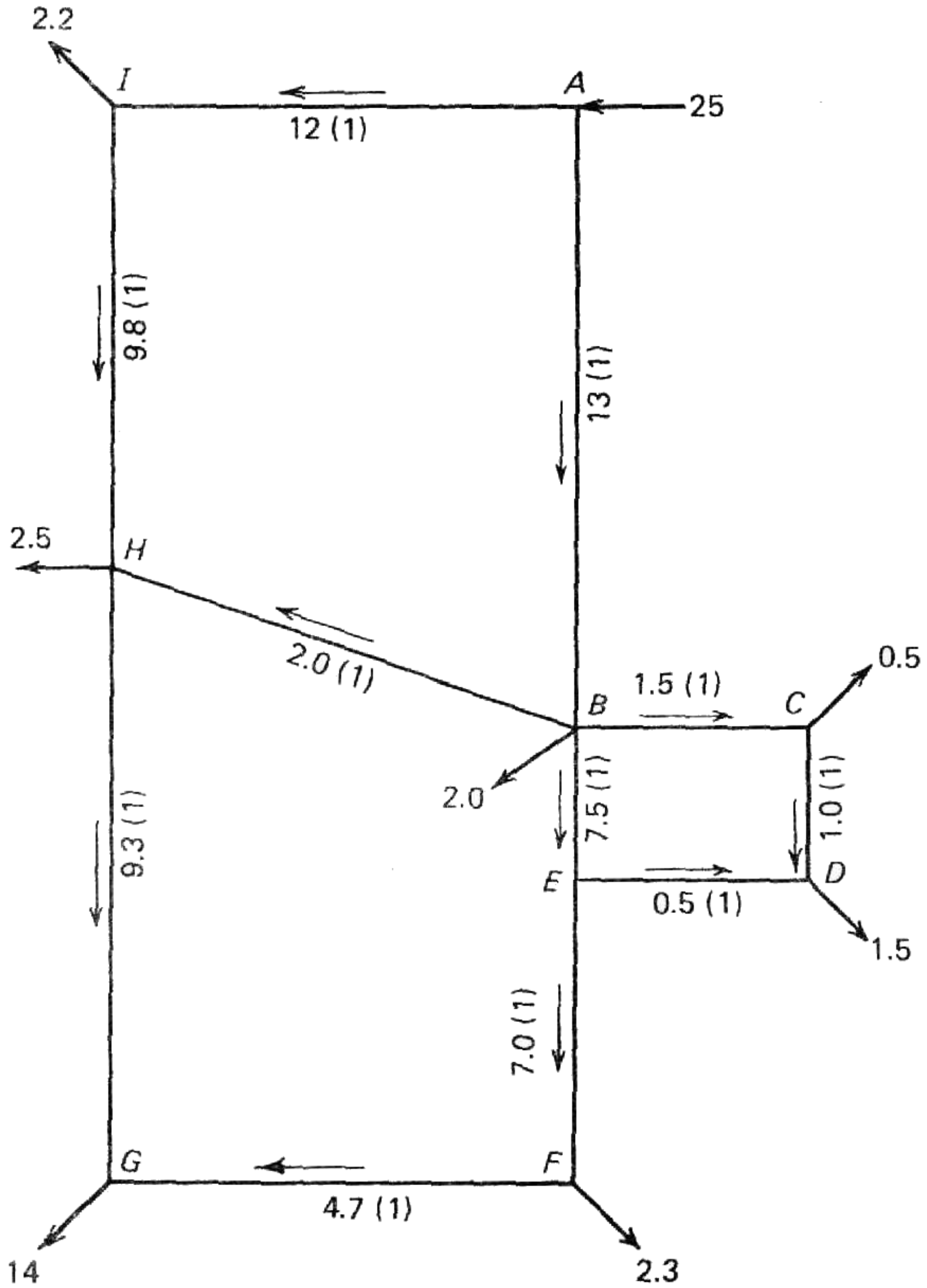
Problem 2-Hardy's Cross Method



Problem 3-Hardy’s Cross Method



Solution


2.2
I
A
25
12 (1)
9.8 (1)
13 (1)
2.5
H
2.0 (1)
1.5 (1)
0.5
B
C
2.0
7.5 (1)
1.0 (1)
9.3 (1)
E
D
0.5 (1)
1.5
7.0 (1)
G
F
4.7 (1)
14
2.3

First Correction

Loop I

Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
AB	13	0.40	1250	0.0110	13.75	1.058
BH	2	0.25	1100	0.0033	3.63	1.815
HI	−9.8	0.30	1000	−0.0260	−26.00	2.653
IA	−12	0.30	1000	−0.0380	−37.80	3.150
					−46.42	8.676

$$\Delta_1 = -\frac{-46.42}{1.85(8.676)} = 2.9$$

Loop II

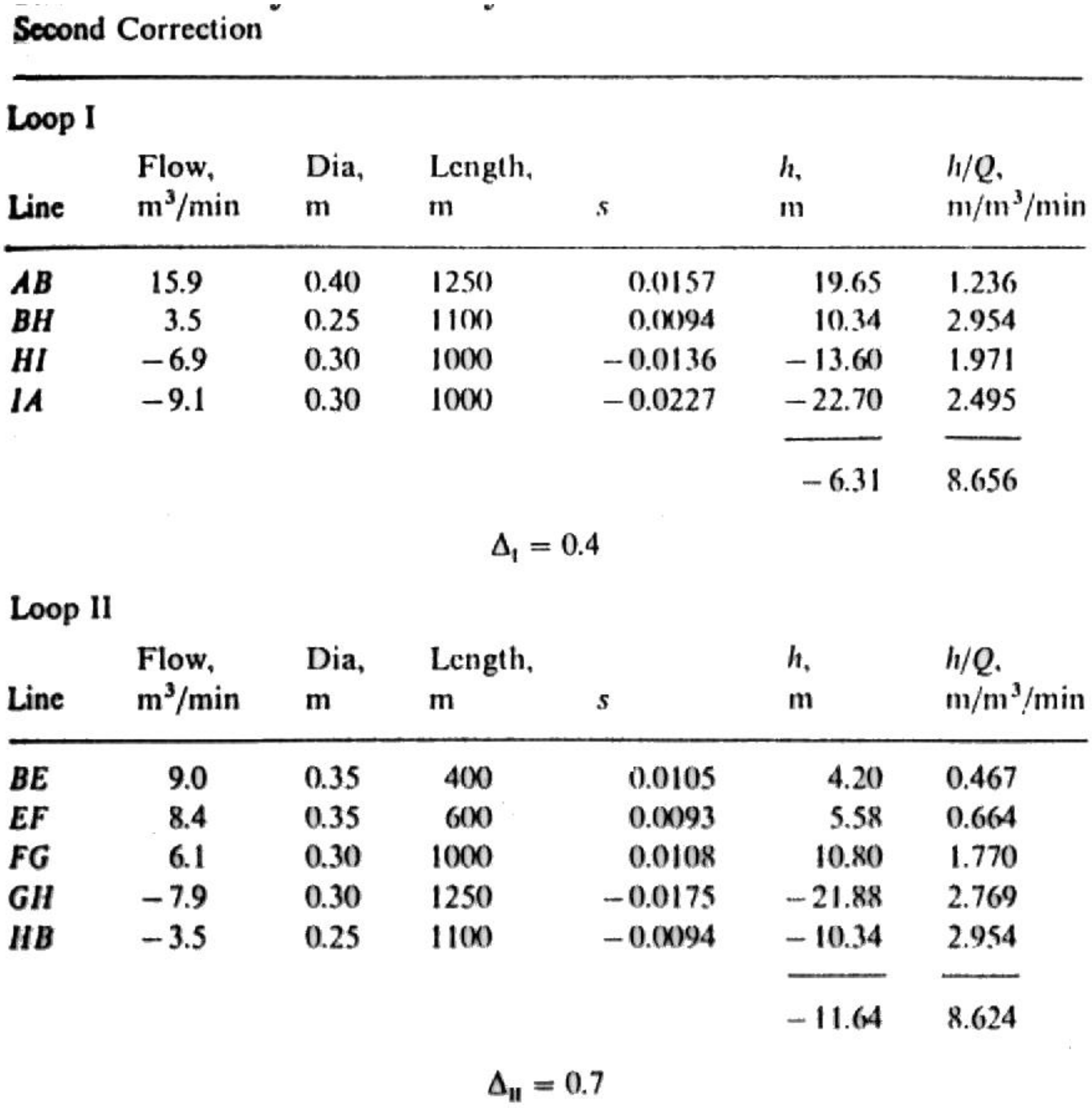
Line	Flow, m³/min	Dia, m	Length, m	s	h, m	h/Q, m/m³/min
BE	7.5	0.35	400	0.0075	3.00	0.400
EF	7.0	0.35	600	0.0066	3.96	0.566
FG	4.7	0.30	1000	0.0067	6.68	1.423
GH	−9.3	0.30	1250	−0.0236	−29.54	3.177
HB	−2.0	0.25	1100	−0.0033	−3.63	1.815
					−19.53	7.381

$$\Delta_{II} = -\frac{-19.53}{1.85(7.381)} = 1.4$$

Loop III

Line	Flow, m³/min	Dia, m	Length, m	s	h, m	h/Q, m/m³/min
BC	1.5	0.20	500	0.0058	2.91	1.937
CD	1.0	0.20	400	0.0028	1.10	1.110
DE	−0.5	0.20	500	−0.0008	−0.38	0.762
EB	−7.5	0.35	400	−0.0075	−3.00	0.400
					0.63	4.209

$$\Delta_{III} = -\frac{0.63}{1.85(4.209)} = -0.1$$



Second Correction

Loop I

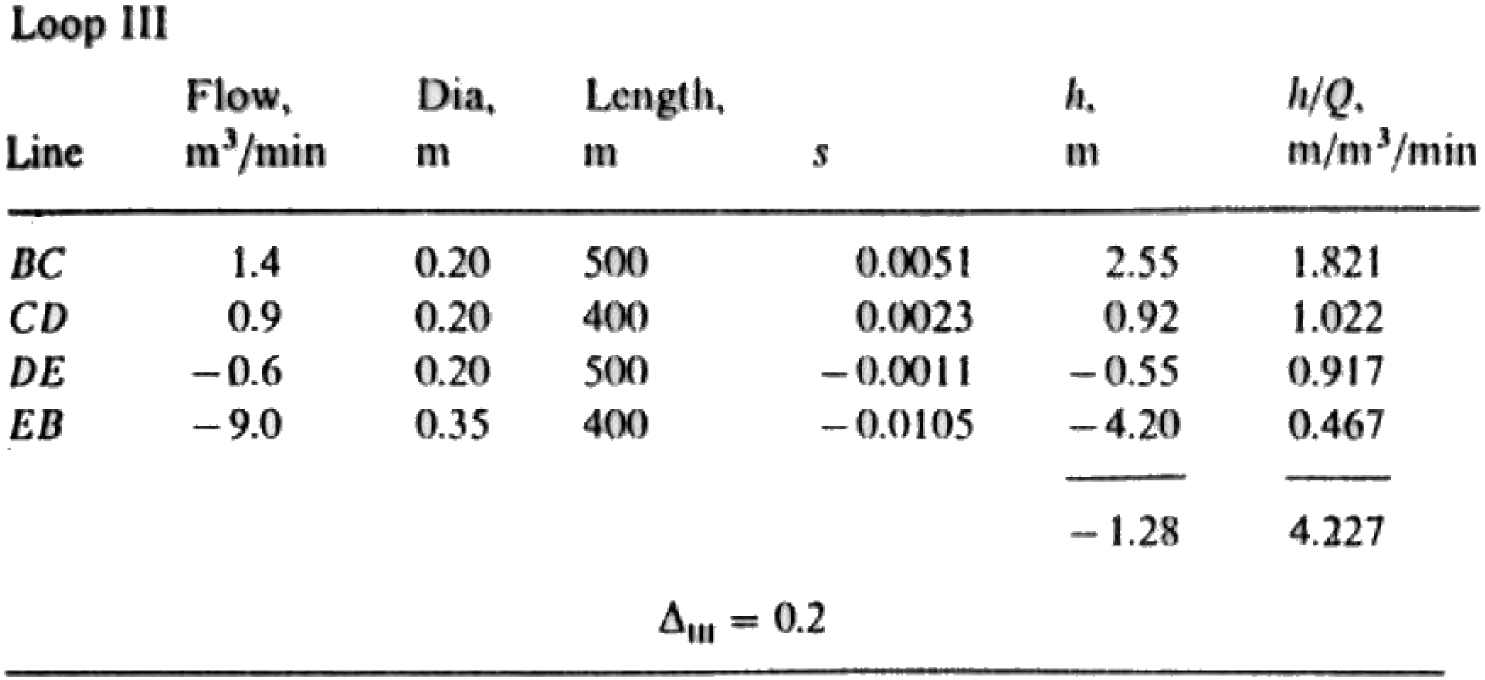
Line	Flow, m³/min	Dia, m	Length, m	s	h, m	h/Q, m/m³/min
AB	15.9	0.40	1250	0.0157	19.65	1.236
BH	3.5	0.25	1100	0.0094	10.34	2.954
HI	−6.9	0.30	1000	−0.0136	−13.60	1.971
IA	−9.1	0.30	1000	−0.0227	−22.70	2.495
					−6.31	8.656

$$\Delta_I = 0.4$$

Loop II

Line	Flow, m³/min	Dia, m	Length, m	s	h, m	h/Q, m/m³/min
BE	9.0	0.35	400	0.0105	4.20	0.467
EF	8.4	0.35	600	0.0093	5.58	0.664
FG	6.1	0.30	1000	0.0108	10.80	1.770
GH	−7.9	0.30	1250	−0.0175	−21.88	2.769
HB	−3.5	0.25	1100	−0.0094	−10.34	2.954
					−11.64	8.624

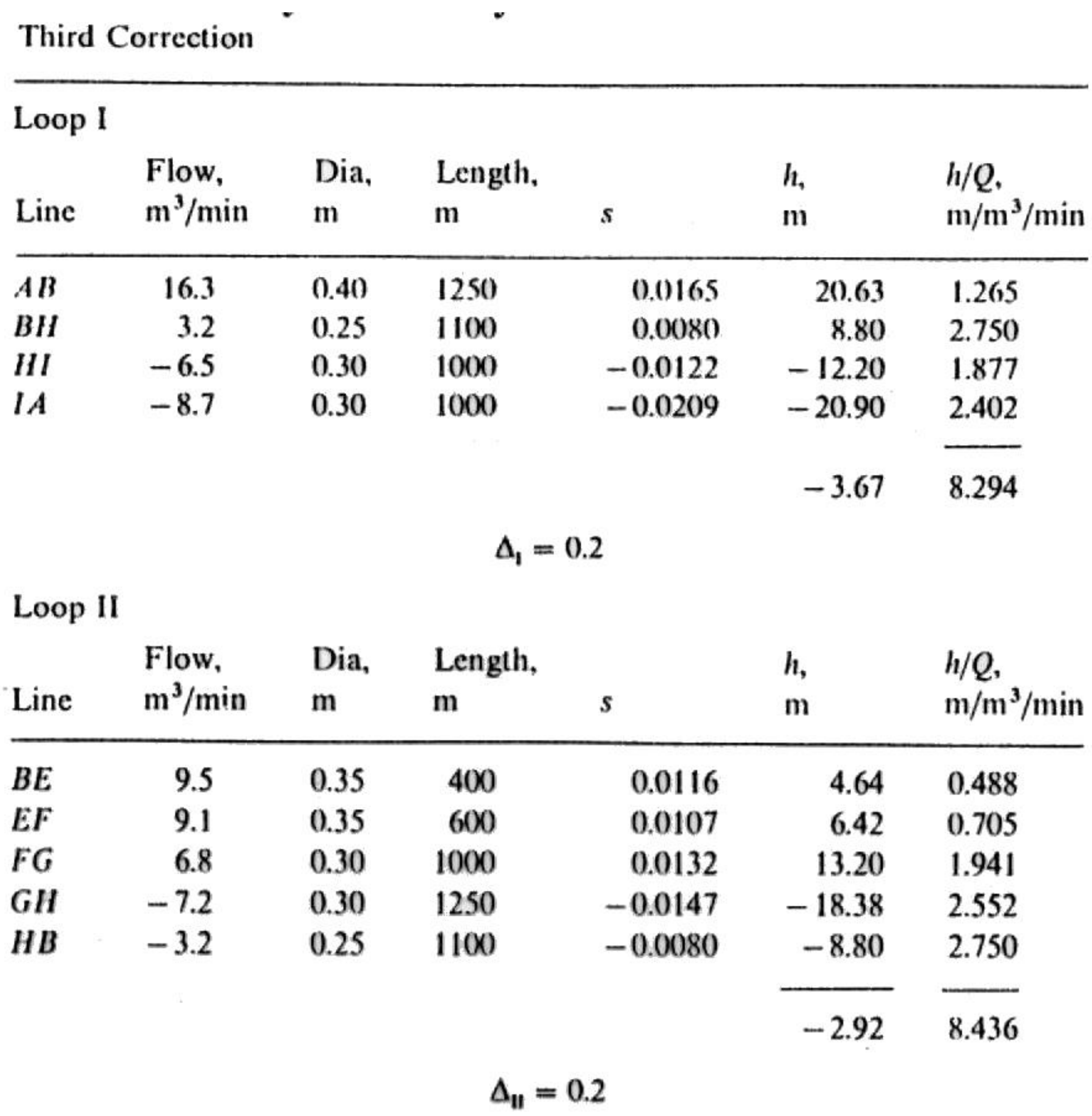
$$\Delta_{II} = 0.7$$



Loop III

Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
BC	1.4	0.20	500	0.0051	2.55	1.821
CD	0.9	0.20	400	0.0023	0.92	1.022
DE	−0.6	0.20	500	−0.0011	−0.55	0.917
EB	−9.0	0.35	400	−0.0105	−4.20	0.467
					−1.28	4.227

$$\Delta_{III} = 0.2$$



Third Correction

Loop I

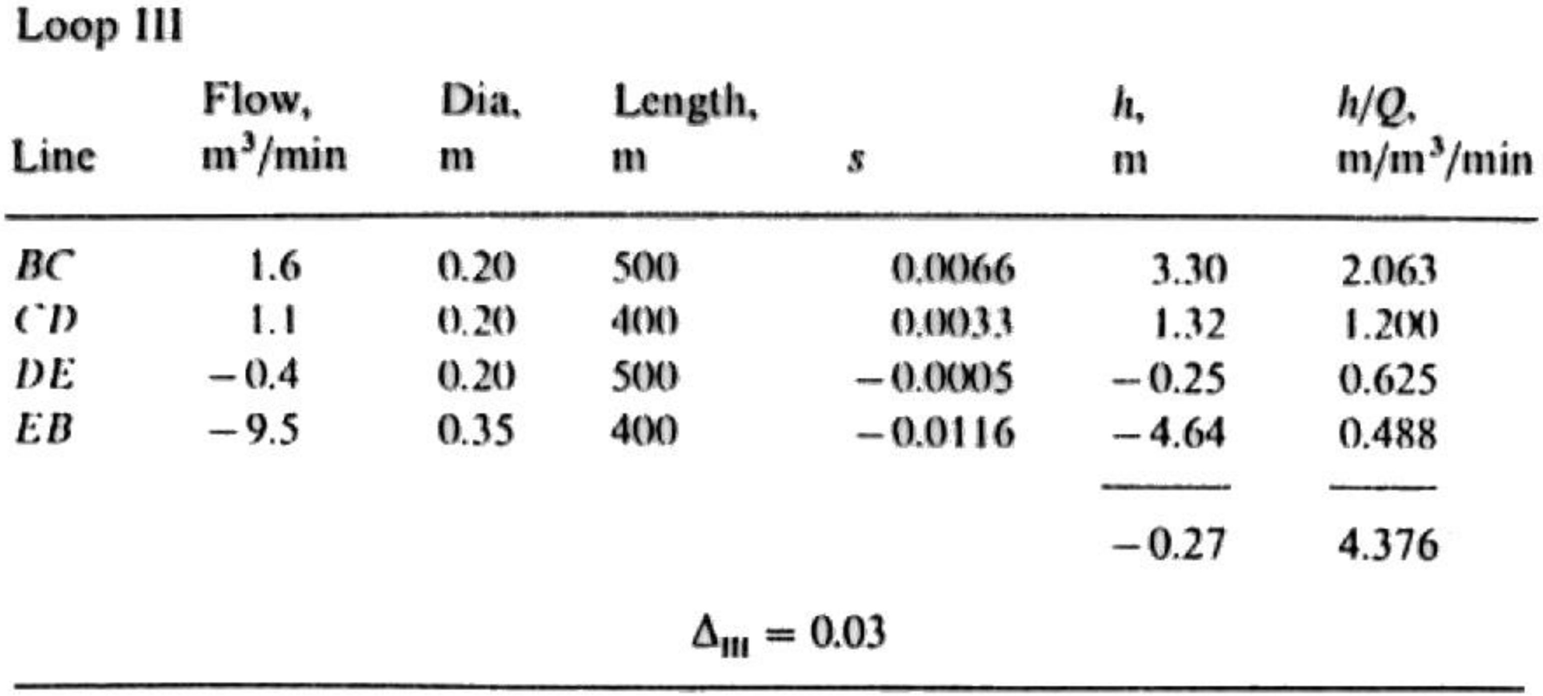
Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
AB	16.3	0.40	1250	0.0165	20.63	1.265
BH	3.2	0.25	1100	0.0080	8.80	2.750
HI	−6.5	0.30	1000	−0.0122	−12.20	1.877
IA	−8.7	0.30	1000	−0.0209	−20.90	2.402
					−3.67	8.294

$\Delta_I = 0.2$

Loop II

Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
BE	9.5	0.35	400	0.0116	4.64	0.488
EF	9.1	0.35	600	0.0107	6.42	0.705
FG	6.8	0.30	1000	0.0132	13.20	1.941
GH	−7.2	0.30	1250	−0.0147	−18.38	2.552
HB	−3.2	0.25	1100	−0.0080	−8.80	2.750
					−2.92	8.436

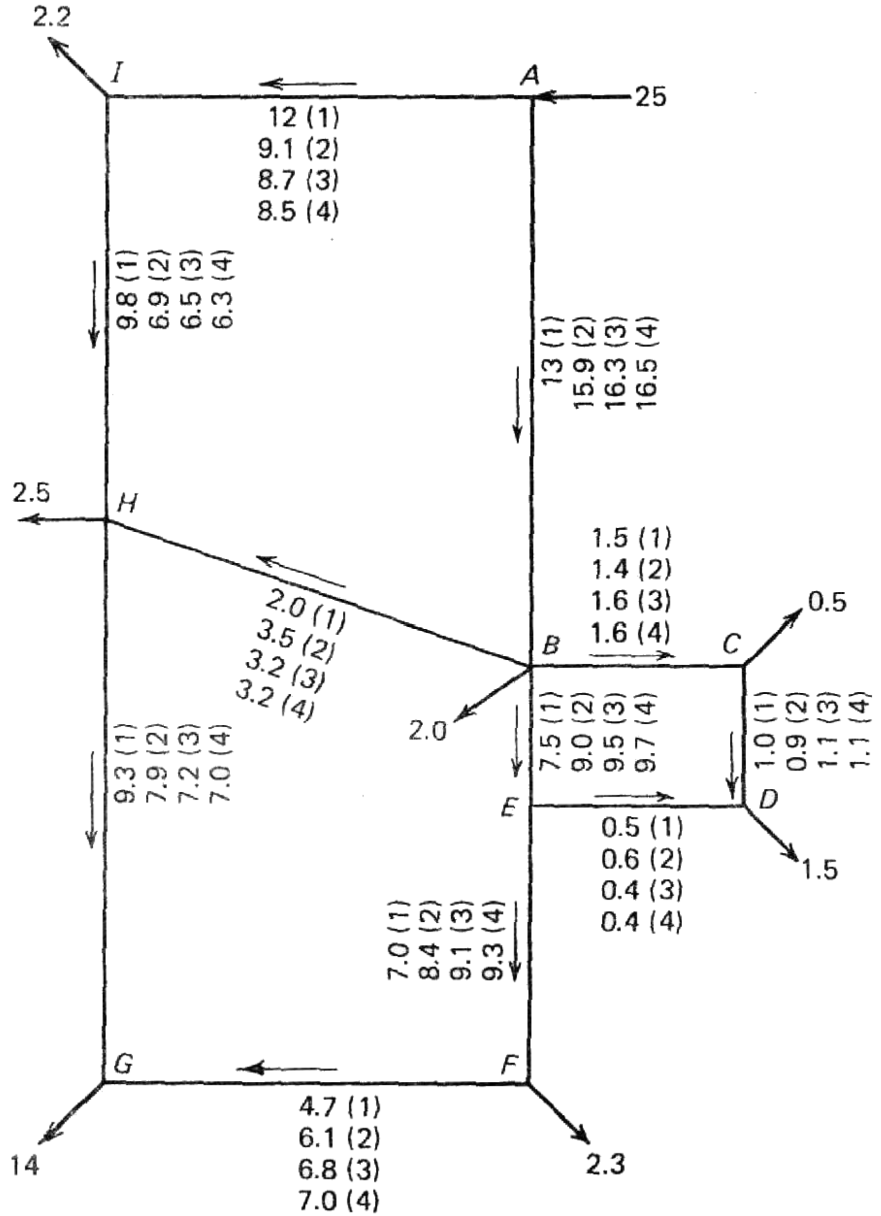
$\Delta_{II} = 0.2$



Loop III

Line	Flow, m³/min	Dia, m	Length, m	s	h, m	h/Q, m/m³/min
BC	1.6	0.20	500	0.0066	3.30	2.063
CD	1.1	0.20	400	0.0033	1.32	1.200
DE	−0.4	0.20	500	−0.0005	−0.25	0.625
EB	−9.5	0.35	400	−0.0116	−4.64	0.488
					−0.27	4.376

$\Delta_{III} = 0.03$

2.2
I
A
25
12 (1)
9.1 (2)
8.7 (3)
8.5 (4)
9.8 (1)
6.9 (2)
6.5 (3)
6.3 (4)
13 (1)
15.9 (2)
16.3 (3)
16.5 (4)
2.5
H
1.5 (1)
1.4 (2)
1.6 (3)
1.6 (4)
0.5
2.0 (1)
3.5 (2)
3.2 (3)
3.2 (4)
B
C
2.0
7.5 (1)
9.0 (2)
9.5 (3)
9.7 (4)
1.0 (1)
0.9 (2)
1.1 (3)
1.1 (4)
9.3 (1)
7.9 (2)
7.2 (3)
7.0 (4)
E
D
0.5 (1)
0.6 (2)
0.4 (3)
0.4 (4)
1.5
7.0 (1)
8.4 (2)
9.1 (3)
9.3 (4)
G
F
4.7 (1)
6.1 (2)
6.8 (3)
7.0 (4)
14
2.3