Unit-05

Environmental engineering

* Distribution of water

→ The Process of supplying water to the consumer at the desired pressure is known as water distribution.

→ The various devices used for this purpose are as follows.

① Sluice valve → The sluice valves are used to regulate the flow of water through the pipe line. these should be located at point of low Pressure.

② Air Relief valve → The air relief valves are used to admit air to the pipe line in order to prevent the formation of vacuum in case of rapid flow negative pressure. This vacuum or negative pressure (known as water hammer) may burst the pipe line at some lower point.

③ Reflux or check valve → A Reflux valve is used to prevent water to flow back in the opposite direction. It is also known as non-return valve. this Valve is installed on the delivery side of the pumping set in order to prevent the back flow when the pump is stopped.

④ Safety valve or pressure relief valve → the safety valve is used to release the excessive pressure which may build up in a closed pipe.

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5) Scour valve or Blow off valve ⇒

⇒ The Scour valve is used to drain off the water from the pipe after closing the supply. these valves are provided at low points.

6) fire hydrant ⇒ A fire hydrant is used for tapping water from main for fire extinguishing street. washing flushing sewer line and many other purposes. the two types of hydrants are flush hydrant and post hydrant.

7) pipe fittings ⇒ in addition to the valve, various types of pipe fittings such as caps, flangers nipples elbows, bends, unions tees etc. are used during laying of water distribution pipe

* Water Distribution Systems

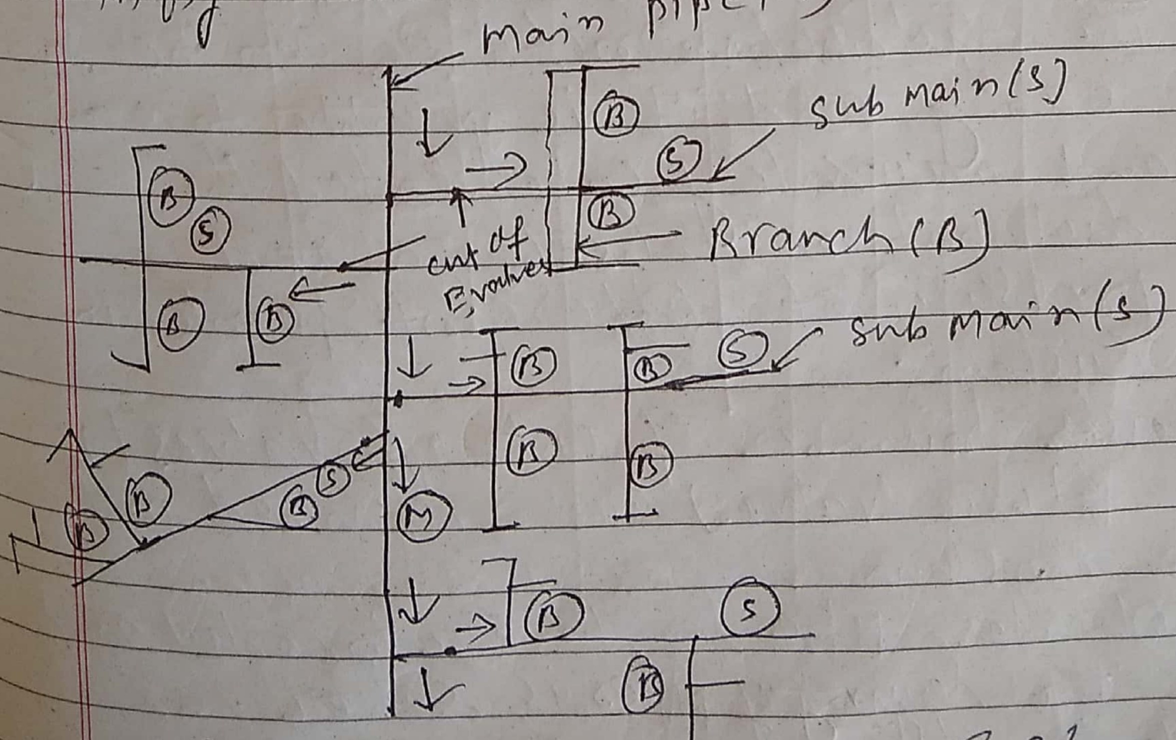
→ The systems of distributing water efficiently to the consumers is known as water distribution systems. The distribution systems are as follows.

(1) Dead end system (2) Grid iron system

(3) Ring system (4) Radial system.

(1) Dead end System → It is also known as tree system. there is only one main supply pipe. A number of sub-main pipes are taken out from it. Each sub-main is divided into many branch pipes called laterals. from laterals the service connections are given to the consumers.

→ A typical plan of such a network is shown in fig



* fig - Dead-end or Tree System

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→ This type of layout may have to be adopted for older towns which have developed in a haphazard manner, without properly planned roads. The water supply main have then to be taken along the main roads, and branches taken off wherever needed thus resulting in the formation of a number of dead ends as shown. This system is ~~have~~ therefore suitable for localities which expand irregularly and where the water pipes have to be laid at random due to the absence of any planned full fledged road network.

→ The advantage of this system are.

(I) The distribution network can be solved easily and it is possible to easily and accurately calculated the ~~distribution~~ discharges and pressure at different points in the system.

(II) Lesser number of cut-off valves (i.e sluice valves) are required in this system.

(III) Shorter pipe lengths are needed and the laying of pipes is easier.

(IV) It is cheap and simple and can be extended

* the disadvantages of this system are

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(I) Since in this method water can reach a particular point only through on route any damage or repair in any pipe line will completely stop the water supply in the area being feed by that pipe. thus if damage occur or repair is taking place in a main pipe or in a submain pipe considerable areas may get affected thereby causing great inconvenience to the consumers.

(II) there are numorous dead ends in this System which prevent the free circulation of water. this stagnation of water may lead to the delegradation in its quality. this stale water should therefore be removed periodically at all the dead ends by providing scour valves at each dead end. this will result in a greater wastage of treated water and will necessitate careful attendance at each valve.

(III) Since in this system the discharge is reaching a point from only one direction the supplies during fire fighting cannot be increased by diverting any other supplies from any other side. Hence it can give only limited supplies and may sometimes prove to be serious handicap.

(2) Grid-Iron System → in this system which is also known as interlaced system, the mains, sub mains and branches are all inter-connected with each other as shown in fig. In fact in a well planned city or a town the roads are generally developed in a grid-iron pattern and the pipe line in such places can follow them easily. Hence this system is more suitable for well planned towns and cities and has been used in chandigarh.

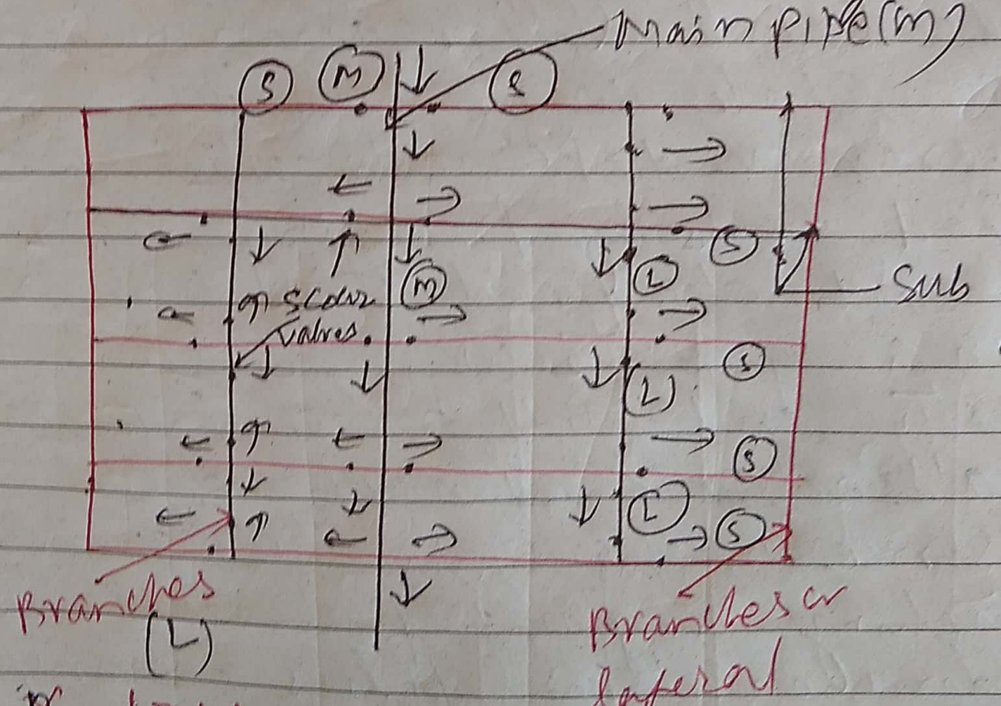

Fig - Grid - Iron System →

* The advantages of this system are
(1) Since the water reaches at different places through more than one route, the discharge to be

carried by each pipe the friction loss and the size of the pipe area would be devoid of complete

(ii) in case of repairs, very small area will be devoid of complete supply as atleast some supply will be reaching at the point from some other route.

(iii) Because of the different inter connections the dead end are completely eliminated and therefore water remains in continuous circulation and hence not liable to pollution due to stagnation.

(iv) During fire more water can be diverted towards the affected point from various directions by closing and manipulating the various cut-off-valves.

* The disadvantages of the system are

(i) this system requires more length of pipe line and a larger number of sluice valves (i.e cut off valves)

(ii) Its construction is costlier

(iii) the design is difficult and costlier the calculations for determining accurately the size of the pipes and

The pressure at various key points is a real tedious job and may require the services of design expected and even computers.

(3) Ring System ⇒ this system is adopted in well planned cities only. in this system each city is divided into square or circular blocks. the water mains are laid around all the four sides of the square or round the circle and the branches sub-mains etc. are laid along the inner roads.

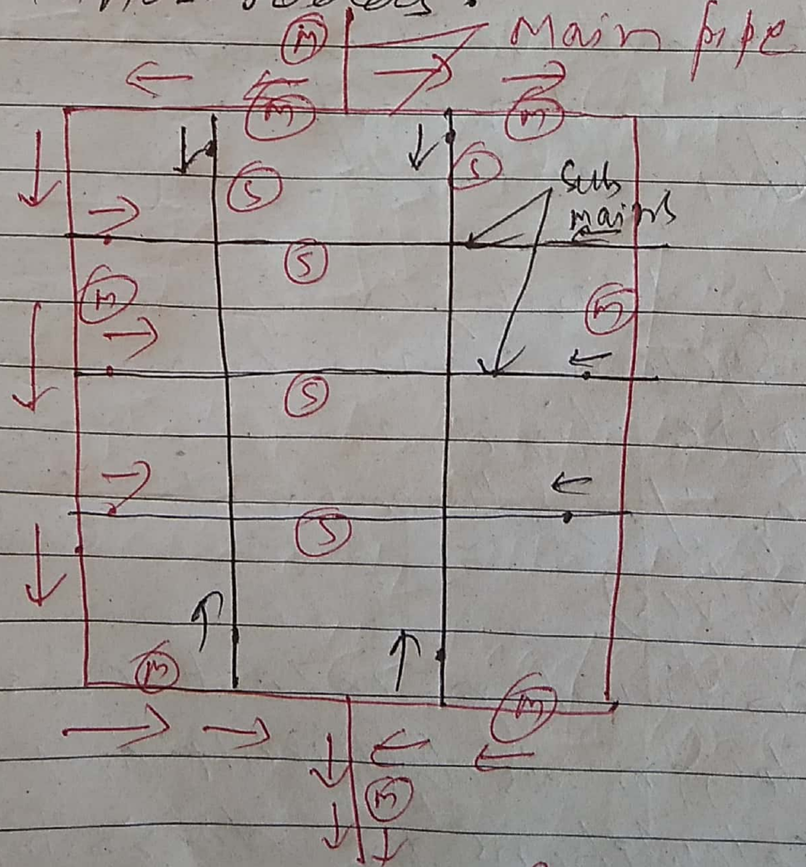

fig - Ring Systems

(4) Radial System → this system is just opposite to the ring system. and water flows towards outer periphery from one point.

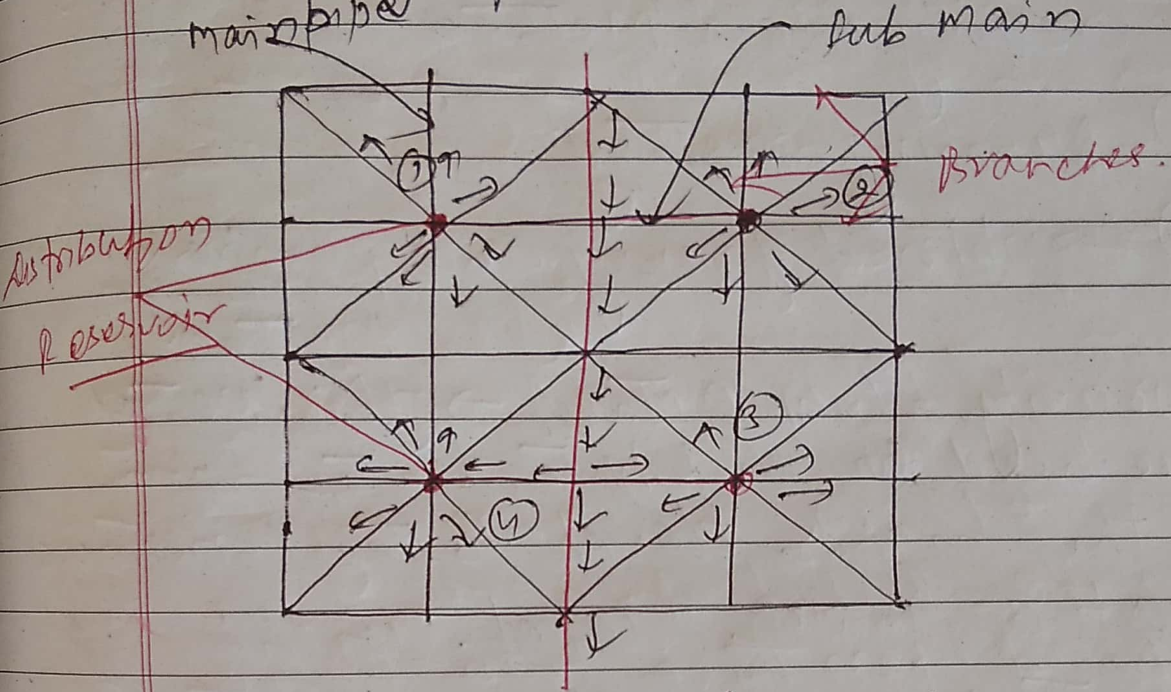

Fig - Radial System

→ This method ensures high pressure and efficient water distribution.

→ the calculation for design of sizes are also simple.

* Methods of Water Distribution System

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→ The following methods are used for distributing water in a distribution system.

1. Gravity flow Method
2. Pumping method
3. Combined gravity and pumping Method.

① Gravity flow Method → This method is used to distribute water from the higher level to the consumers at a lower level. In this method no pumping is involved.

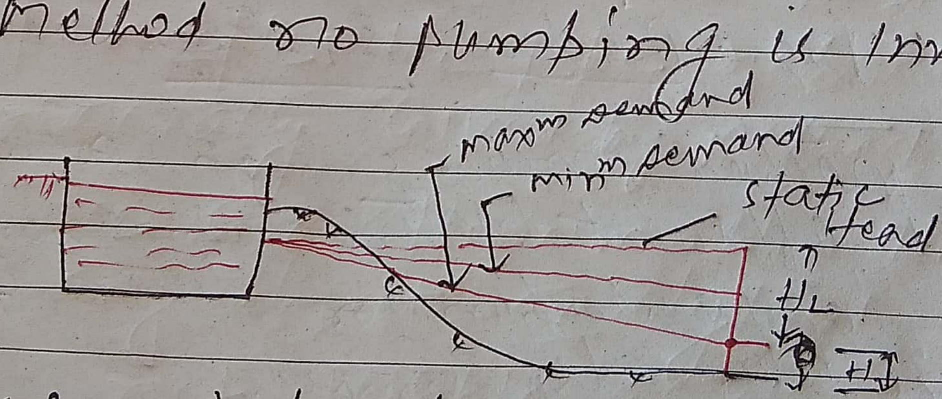

Fig:- Gravitational distribution system

Where H_L = Head loss

H = Head available to consumers.

(2) pumping Method ⇒ in this method treated water is not stored but it is pumping directly into the water main & since the demand of water is not constant, therefore high power pumps are required in this method.

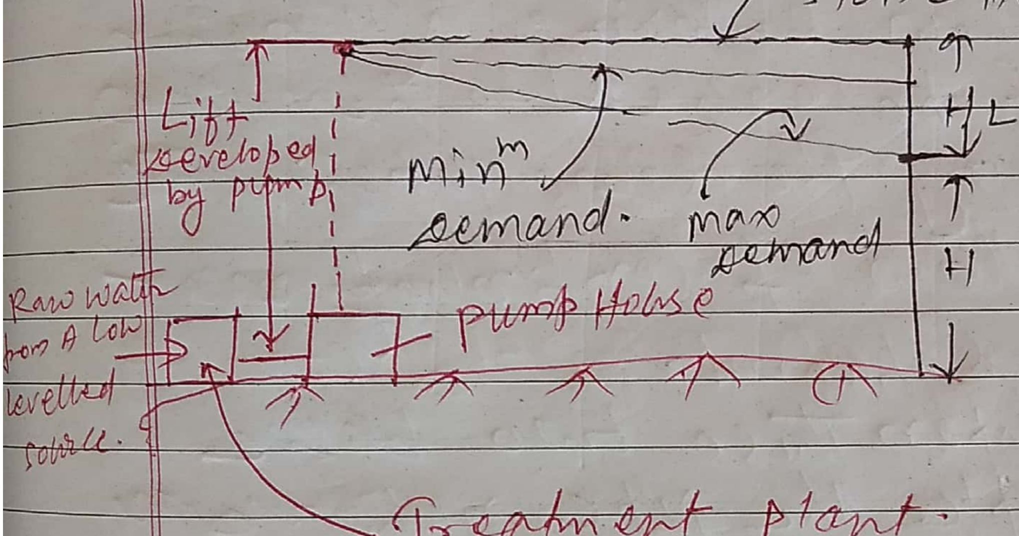

fig - pumping systems for water distribution.

(3) Combined gravity and pumping method →
→ in this method the pump is connected to the main and the elevated reservoir. the water is pumped to the reservoir for storage and then it is supplied to the consumers by gravity flow.

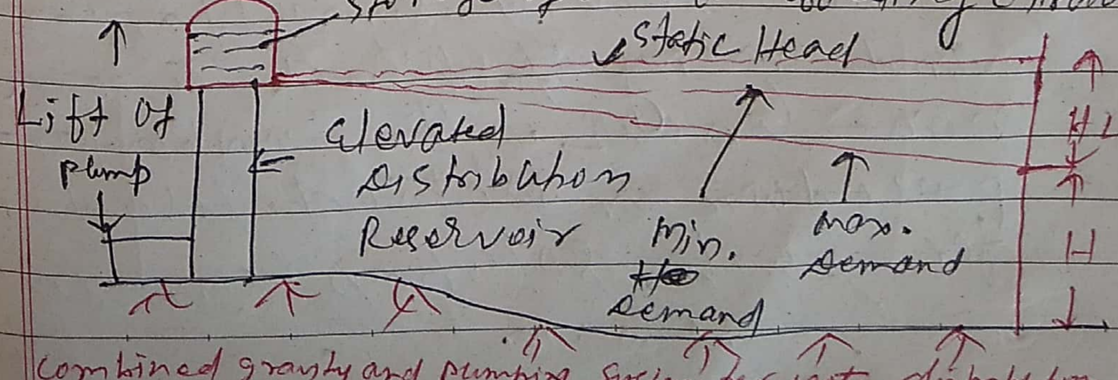

fig - combined gravity and pumping system for water distribution.

* Analysis of Complex pipe Network

→ in any pipe network the following two condition must be satisfied.

(i) the algebric sum of the pressure drops around a closed loop must be zero i.e there can be no discontinuity in pressure.

(ii) The flow entering a junction must be equal to the flow leaving the same junction i.e the law of continuity must be satisfied.

→ Based upon these two basic Principles the pipe network are generally solved by method of Successive approximation because any direct analytical solution is not possible as the same will involve various equation to be solved simultaneously and many of which are non-linear. the important procedure or Method used for such solution are given below.

Hardy-Cross-Method →

→ The procedure suggested by Hardy and Cross require that the flow in each pipe is assumed by the designer (in magnitude as well as direction) in such a way that the principle of continuity is satisfied at each junction (i.e the inflow at any junction becomes equal to the outflow at that junction)

→ A correction to these assumed flow is then computed successively for each pipe loop in the network until the correction is reduced to an acceptable magnitude.

→ If Q_a is the assumed flow and Q is the actual flow in the pipe then the correction Δ is given by

$$\boxed{\Delta = Q - Q_a}$$

$$\boxed{Q = Q_a + \Delta}$$

Now expressing the head loss (H_L) as

$$\boxed{H_L = K \cdot Q^x}$$

→ We have the head loss in a pipe.

$$= K (Q_a + \Delta)^x$$

$$= K \cdot \left[Q_a^x + x \cdot Q_a^{x-1} \Delta + \text{negligible terms containing higher power of } \Delta \right]$$

$$= K \left[Q_a^x + x Q_a^{x-1} \Delta \right]$$

→ Now around a closed loop, the summation of head losses must be zero.

$$\therefore \quad \Sigma K \left[Q_a^x + x Q_a^{x-1} \Delta \right] = 0$$

or $$\Sigma K \cdot Q_a^x = - \Sigma K x Q_a^{x-1} \Delta$$

Since Δ is the same for all the pipe of the considered loop, it can be taken out of the summation. therefore

or $$\Sigma K \cdot Q_a^x = - \Delta \Sigma K x Q_a^{x-1}$$

or $$\boxed{\Delta = - \frac{\Sigma K \cdot Q_a^x}{\Sigma x \cdot K Q_a^{x-1}}}$$

Since Δ is given the same sign (or direction) in all pipes of the loop. the denominator of the above equation is taken as the absolute sum of the individual items in the summation. Hence.

$$\Delta = -\frac{\Sigma K \cdot Q_a^{x}}{\Sigma |x \cdot K Q_a^{x-1}|}$$

or

$$\Delta = \frac{-\Sigma H_L}{x \cdot \Sigma \left| \frac{H_L}{Q_a} \right|}$$

Where H_L = head loss for the assumed flow Q_a.

→ The absolute sum of respective $K \cdot Q_a^{x-1}$ or H_L / Q_a is then calculated. finally the value of Δ is found out for each loop and the assumed flows in each pipe are ~~corresp.~~ corrected by using ~~eq~~ above equation Pipes common to two loops will receive both corresponding with due attention to sign.

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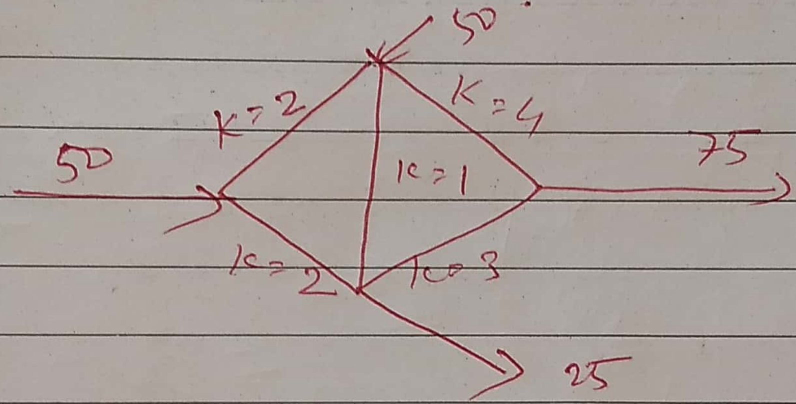
* the entire procedure to be adopted in Hardy cross Method can be summed up as follows.

1. Assume any internally consistent distribution of flow. The sum of the flow entering any junction must be equal the sum of the flow leaves that junction
2. Compute the head loss in each pipe by means of an equation or diagram. conventionally clockwise flows are positive and procedure positive head loss and vice versa.
3. With due attention to sign, compute the total head loss around each circuit i.e $\Sigma K. Q_c^2$.
4. compute without regard to sign for the same circuit, the sum of $\Sigma x. K. Q_c^{x-1}$
5. Apply the correction obtained from above equation to the flow in each pipe. pipes common to two loops will receive both correction with due regard to sign.

Q. Determine the distribution of flow in the pipe network shown in fig. The head loss h_L may be assumed as KQ^n. The flow is turbulent and pipes are rough. The value of K for



each pipe is indicated in the fig.
Use Hardy-cross method.

Soln

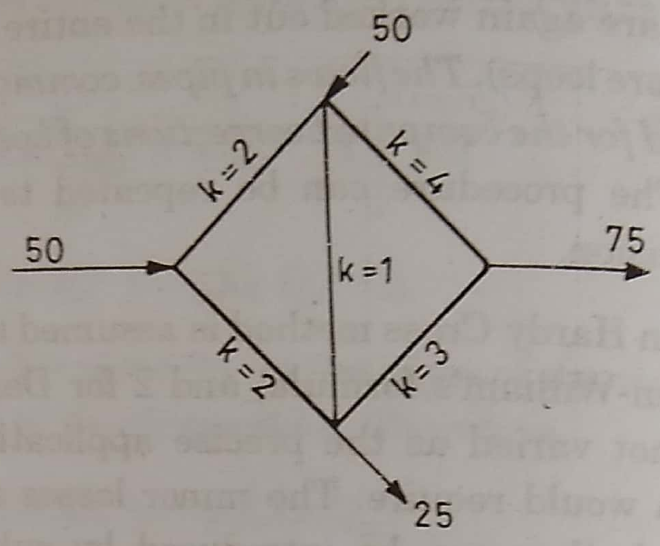


Fig. 10.25

each pipe is indicated in the figure. Use Hardy-Cross method.

(Engg. Services 1996)

Solution. First of all, the magnitudes as well as directions of the possible flows in each pipe are assumed keeping in consideration the law of continuity at each junction (*i.e.* the input equals the off-take at each junction). These assumed flows are shown in Fig. 10.26.

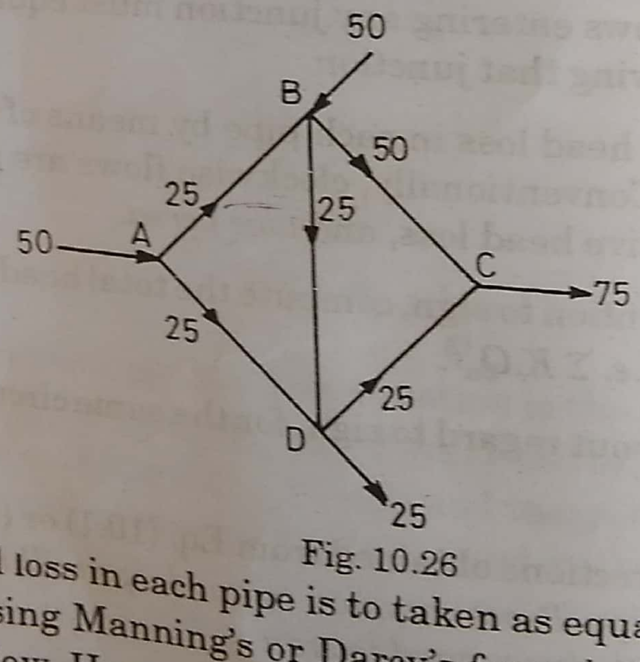


Fig. 10.26

The head loss in each pipe is to taken as equal to $K \cdot Q^n$. Assume $n = 2$ for using Manning's or Darcy's formula for rough pipes and turbulent flow. Hence,

$$H_L = K \cdot Q^2$$

The various K values for different pipes are given in the figure (Fig. 10.25), which can be used while analysing the two loops; *i.e.* loop $ABDA$ and loop $BCDB$. Both these loops are now analysed by Hardy Cross procedure in Table 10.1…

Table 10.19. Hardy Cross Procedure for 1st Correction

Pipe	Assumed Flows Q_a l/s	K (given)	$H_L = K.Q_a^2$	$\left\lvert\frac{H_L}{Q_a}\right\rvert$	Corrected Q after first correction = $Q_{a_1} = Q_a + \Delta_1$ l/s
(1)	(2)	(3)	(4)	(5)	(6)
For Loop ABDA (Loop I)					
AB	25	2	1250	50	(+) 22.5
BD (Common pipe)	25	1	625	25	+ 35.0*
DA	– 25	2	(–) 1250	50	(–) 27.5
		Σ	(+) 625	125	

$$\Delta_1 = \frac{(-)\,\Sigma H_L}{x\,.\,\Sigma\left(\frac{H_L}{Q_a}\right)}$$

or
$$\Delta_1 = \frac{625}{2 \times 125} = (-)\ \mathbf{2.5}$$

Pipe	Assumed Flows Q_a l/s	K (given)	$H_L = K.Q_a^2$	$\left\lvert\frac{H_L}{Q_a}\right\rvert$	Corrected Q l/s
For Loop BCDB (Loop II)					
BC	50	4	10000	200	37.5
CD	– 25	3	(–) 1875	75	(–) 37.5
DB (Common pipe)	– 25	1	(–) 625	25	(–) 35.0*
		Σ	7500	300	

$$\Delta_1' \text{ in 2nd Loop} = (-)\,\frac{7500}{2 \times 300}$$
$$= (-)\ \mathbf{12.5}$$

The corrected flows after 1st correction in various pipes of 2 loops are thus worked out in col. (6) of Table 10.19 as :

*Corrected flow in common pipe *BD*

$$= 25 + \Delta_1 + \Delta_1'$$

where Δ_1 for pipe BD = (–) 2.5 ; and Δ_1' for pipe DB is (–) 12.5 and hence Δ_1' for pipe BD will be (+) 12.5.

$\therefore\ Q_{BD} = 25 - 2.5 + 12.5 = \mathbf{35\ l/s}$.

Flows after first correction

Pipe	Corrected discharge after first correction l/s
For Loop ABDA	
AB	22.5
BD (Common pipe)	35.0
DA	(–) 27.5
For Loop BCDB	
BC	37.5
CD	(–) 37.5
DB (Common pipe)	(–) 35.0

These discharges are now again used to reanalyse both the loops for the second correction in Table 10.20.

Table 10.20. Hardy Cross Procedure for Second Correction

Pipe	Assumed Flows (Q_{a_1}) l/s	K	$H_L = K.Q_a^{\ 2}$	$\left\lvert \frac{H_L}{Q_a} \right\rvert$	Corrected flows after 2nd correction ; $Q_{a_2} = Q_{a_1} + \Delta_2$
(1)	(2)	(3)	(4)	(5)	(6)
For Loop ABDA (Loop I)					
AB	22.5	2	1012.5	50	19.8
BD (Common pipe)	35.0	1	1225.0	25	32.6*
DA	(–) 27.5	2	(–) 1512.5	50	(–) 30.2
		Σ	725	135	
For Loop BCDB (Loop II)					
BC	37.5	4	5625	150	37.2
CD	(–) 37.5	3	(–) 4218.75	112.5	(–) 37.8
DB (Common pipe)	(–) 35.0	1	(–) 1225	35	32.6*
		Σ	181.25	297.5	

$$\Delta_2 = \frac{(-)\ 725}{2 \times 135} = (-)\ \mathbf{2.7}$$

$$\Delta_2' = (-)\ \frac{181.25}{2 \times 297.5} = (-)\ \mathbf{0.3}$$

*Corrected flow in common pipe *BD*

$= 35 - 2.7 - (-\ 0.3) = 35 - 2.7 + 0.3 = \mathbf{32.6\ l/s}$

The corrected flows obtained in col. (6) of Table 10.20 after 2nd correction are now plotted on the pipe network in Fig. 10.27 to check balancing of flow at each point, to verify the answer.

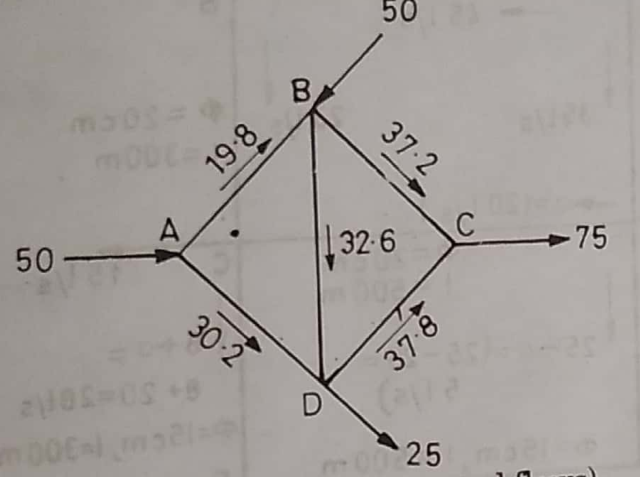


Fig. 10.27 (Corrected flows).

Example 10.12. *Calculate the head losses and the corrected flows in the various pipes of a distribution network shown in Fig. 10.28. The diameters and the lengths of the pipes used are given against each pipe. Make use of Hardy-Cross method with William Hazen's formula. Compute the corrected flows after two corrections.*

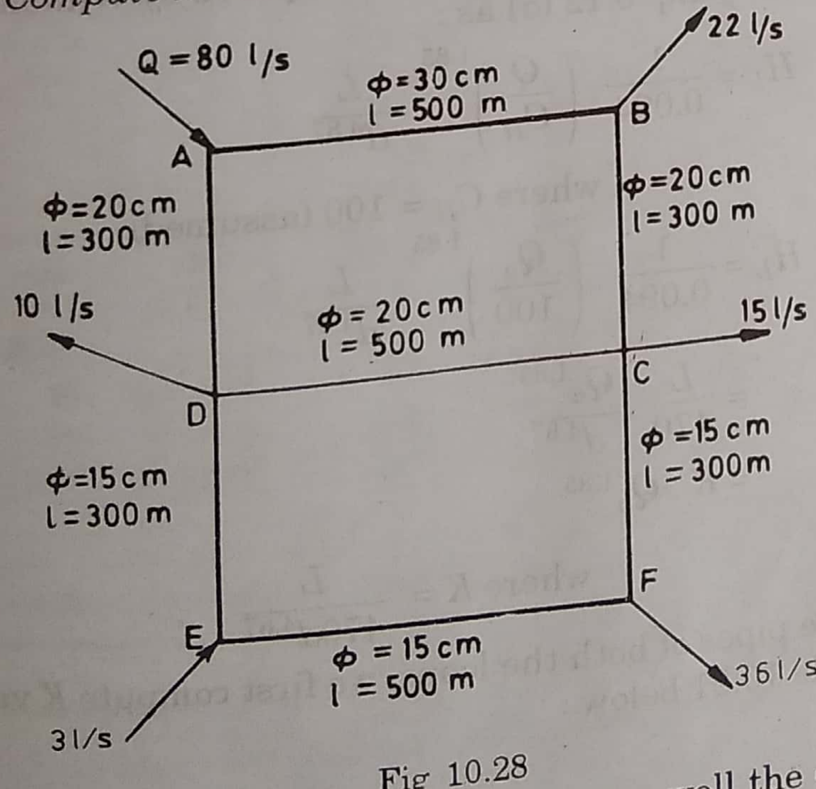


Fig 10.28

Solution. First of all, the magnitudes as well the directions of the possible flows in each pipe are assumed keeping in consideration the law of continuity at each junction (*i.e.* the input equals the off take at each junction). These assumed flows are shown in Fig. 10.29. The two closed loops, *i.e.* *ABCD* and *DCFE* are then analysed by Hardy-Cross method.