Water Distribution Network Design

The purpose of distribution system is to deliver water to consumer with appropriate quality, quantity and pressure. Distribution system is used to describe collectively the facilities used to supply water from its source to the point of usage. The transmission of water from the source (or sources) to the various consumers is usually done in two stages: distribution and reticulation. The former term is generally used to describe the system of bigger (or trunk) mains, reservoirs and, in some situations, pumping systems whereas reticulation refers to the interconnected pipe network through which water finally reach to the consumers.

Requirements of Good Distribution System

- Water quality should not get deteriorated in the distribution pipes.
- It should be capable of supplying water at all the intended places with sufficient pressure head.
- It should be capable of supplying the requisite amount of water during fire fighting while maintaining acceptable pressures for normal service.
- The layout should be such that no consumer would be without water supply, during the repair of any section of the system.
- All the distribution pipes should be preferably laid one meter away or above the sewer lines.
- It should be fairly water-tight as to keep losses due to leakage to the minimum.

Pressure in the distribution system

Proper water line pressure ensures enough supply for customers and for fire fighting, while protecting treated water from ingress of untreated groundwater. Minimum pressure for domestic flow during peak demand should be **at least 30 psi**. Fire hydrant should be operated at **40 psi,** at least 10 psi at low pressure condition. **Maximum 100 psi** pressure is acceptable in small low-lying areas. Otherwise pressure reducing valve has to be used

Layouts of Distribution Network

The distribution pipes are generally laid below the road pavements, and as such their layouts generally follow the layouts of roads. There are, in general, four different types of pipe networks; any one of which either singly or in combinations, can be used for a particular place. They are:

1) Branched Network - Dead End System
2) Looped network –
    a. Grid Iron System
    b. Ring System
    c. Radial System

1. Branched/ Dead-end System

It comprises a transmission main starting from service reservoir or source and laid along the main road with sub-mains branching off from the main along other roads joining the main road. It is suitable for old towns and cities having no definite pattern of roads.

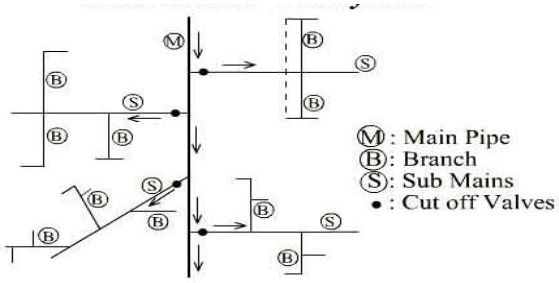


Fig- 1: Branched or dead-end system

Advantages:

1. Relatively cheap as length of pipe required is less.
2. Determination of discharges and pressure easier due to less number of valves.
3. Can be easily expanded to connect newly developed area with the distribution system.

Disadvantages

1. Due to many dead ends, stagnation of water occurs in pipes which in turn promote sedimentation and water contamination.
2. Frequent blow-off or flushing is needed to keep the system clean.
3. Repair work in mains and sub-mains cuts off water supply downstream.

2. Looped Network

Looped distribution network is an improvement over the dead-end system. Here the ends of mains and sub-mains are connected. This network is suitable for a well-planned developed area with a definite pattern of road network.

2. a) Grid Iron System

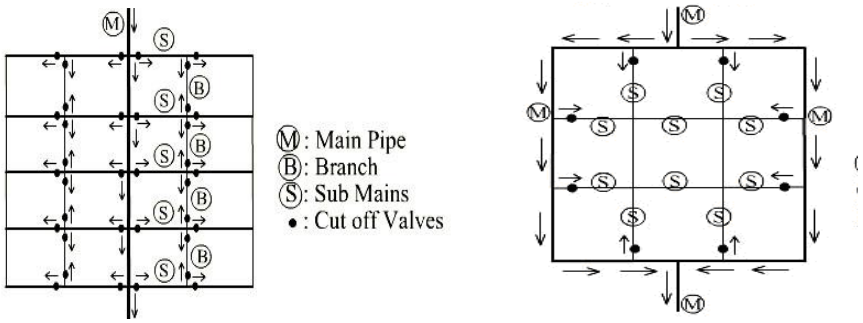
It is suitable for cities with rectangular layout, where the water mains and branches are laid in rectangles.

Advantages:

1. Water is kept in good circulation due to the absence of dead ends.
2. In the cases of a breakdown in some section, water is available from some other direction.
3. Have good control over flow of water

Disadvantages

1. Initial cost relatively high.
2. A large number of valves needed to control the flow.
3. Exact calculation of sizes of pipes is not possible due to provision of valves on all branches



(a) (b)

Fig-2: (a) grid-iron system, (b) Ring system

2. b) Ring System

The supply main is laid all along the peripheral roads and sub mains branch out from the mains. Thus, this system also follows the grid iron system with the flow pattern similar in character to that of dead end system. So, determination of the size of pipes is easy.

Advantages:

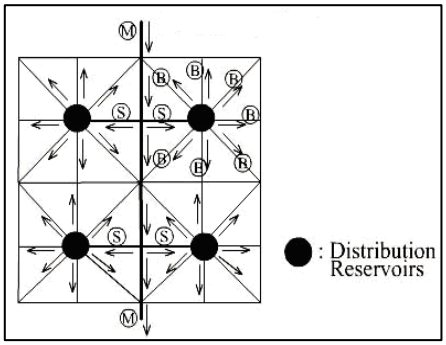
1. In addition to the advantages of grid iron system, in ring system water can be supplied to any point from at least two directions.

Disadvantages

1. Initial cost relatively high.
2. A large number of valves needed to control the flow.

2.c) Radial System

The area is divided into different zones. The water is pumped into the distribution reservoir kept in the middle of each zone and the supply pipes are laid radially ending towards the periphery.



Advantages:

1. It gives quick service.
2. Calculation of pipe sizes is easy.

3. Presence of several reservoirs makes it easy to meet the emergency water demand.

Disadvantages

1. Presence of a number of distribution reservoirs increases the cost of the system.

Distribution System Layout Design Procedure

Branched Network Design:

The following design procedure may be adopted for branched network:

1. Collect/prepare a map of the area to be served with roads, streets and other features and make a layout of mains, sub-mains and branches including location of valves and other accessories.
2. Estimate the **peak flow** at different points and estimate the quantity flowing through each section of the network.
3. Assume the pipe size for each section of the using continuity equation

$$Q = Av$$

- To calculate approximate pipe size the velocity (v) may be assumed to be around **1 m/s or 3 fps**

[Note:

According to BNBC 2006

Assume the probable maximum velocity of flow (v) or tentative diameter of pipes (d), considering maximum permissible head loss of 1.5 -1.6 m/ 100 m

- For 13 mm and 50 mm diameter pipe: 0.30 - 0.60 m/sec
- For 75 mm and 100 mm diameter pipe: 0.75 - 0.90 m/sec
- For 150 mm and 200 mm diameter pipe: 1.15 - 1.30 m/sec]

4. If calculated diameter is less than the minimum size requirement for water distribution, consider

$$D_{required} = D_{min}$$

Usually,
Diameter of distribution main = 4 inch and
Diameter of supply pipe up to house connection = 2 to 1.5 inch

5. Calculate frictional head loss per unit length of pipe and then multiply by pipe length of the pipe to find the total head loss.

Pressure loss due to friction, $h_f = \frac{4fLv^2}{2gD}$ (ft)

So, pressure loss in psi = h_f (ft) x 62.4 (lb/ft^3) /144

Here,
L= length of pipe (ft) ;
v = velocity (fps) ;
Assume friction factor, f = 0.01 ;
D = diameter of the pipe (ft)

6. Check pressure requirement at the **furthest point** from the beginning of distribution point (here overhead tank).
7. Determine the terminal pressure head taking the change in the elevation of the pipe into account.
8. In case of a difference between the computed terminal pressure and the permissible pressure head, revise the pipe size.

Example:
Calculate the pipe size for the following dead-end water distribution system

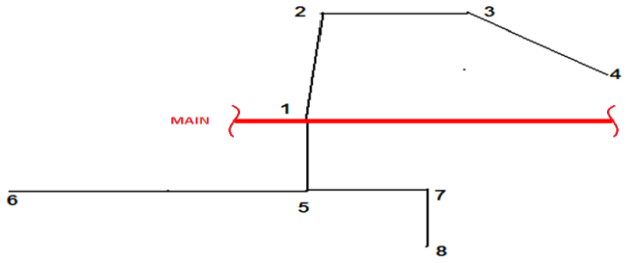


Table 1: Calculating Diameter of pipes required for supplying water to the Residential zone and common facilities						
Node	**Peak Demand (lpd)**	**Peak Demand (ft^3/sec)**	**Length (ft)**	**Area of Pipe Required($inch^2$)**	**Diameter of Pipe Required (inch)**	**Diameter of provided pipe (inch)**
1,2	928585	0.379	385	18.2042	4.8144	5
2,3	100823	0.041	345	1.9766	1.5864	2
3,4	67163	0.027	390	1.3167	1.2948	2
1,5	1891719	0.773	190	37.0856	6.8716	7
5,6	943794	0.385	600	18.5023	4.8536	5
5,7	444060	0.181	240	8.7054	3.3293	4
7,8	186060	0.076	240	3.6476	2.1550	3

Table 2: Checking for Available Pressure								
Path	**Node**	**Length (ft)**	**Diameter of provided pipe(ft)**	**Head Loss (ft)**	**Head Loss (psi)**	**Total head loss (psi)**	**Available Pressure (psi)**	**Comment**
Path I	1,2	385	0.417	5.198	2.252	13.00	40-13= 27	NOT OK to be revised
	2,3	345	0.167	11.644	5.046			
	3,4	390	0.167	13.163	5.704			
Path II	1,5	190	0.583	1.832	0.794	4.304	35.7	OK
	5,6	600	0.417	8.100	3.510			
Path III	1,5	190	0.583	1.832	0.794	4.90	35.1	OK
	5,7	240	0.333	4.050	1.755			
	7,8	240	0.250	5.400	2.340			

Looped Network: Hardy Cross Method of Approximation

In any looped network following two conditions must be satisfied:

1. Flow entering into a junction must equal the flow leaving it.
2. Algebraic sum of head loss in a closed loop will be zero.

$$\sum \text{inflow} = \sum \text{outflow}$$

Head loss in each pipe is calculated using the Hazen-William equation –

$$\mathrm{H} = L \cdot \frac{10.67}{C^{1.85}} \frac{Q^{1.85}}{d^{4.87}}$$

If $$\mathrm{K} = L \cdot \frac{10.67}{C^{1.85} \quad d^{4.87}}$$

Head loss $H = kQ^x$ (m) ------ (1)

Where ,
H = Head loss
k = is a constant depending on length, diameter and roughness of the pipe as well as fluid property. Here, we are assuming k = 1
Q = Assumed flow in the pipe (m^3/sec)
X = 1.85 for Hazen-Williams equation

The procedure for the Hardy Cross method of pipe network analysis is given below:

1. Carefully examine the network and assume reasonable rates of flow (Q_a) in each pipe such that inflow equals outflow at each junction.
2. In each loop, determine the head loss, H and H/Q for all pipes. Use eq-1 for calculating H.

   [Alternate method: For calculating H use nomograph (Figure -5), for assumed Q and consider velocity v= 3 fps]

3. With due attention to sign, compute the total head loss, *Σ(H)* around each circuits.
4. Compute *Σ(H/Q)* for the same circuit without giving any consideration to sign.
5. Calculate correction Δ using the following equation-

   $$\Delta = - \Sigma H / (x \Sigma H/Q_a)$$

   - Apply correction Δ to each loop.

- *When the sign of Δ is negative, '-', decrease the clockwise flows and increase the counterclockwise flows.*
- *When the sign is positive '+' increase clockwise flows and decrease counterclockwise flows.*
- Pipes that are common to two loops require double correction

6. With adjusted flows, repeat the procedure for the second approximation. The procedure is continued until the desired accuracy is attained
7. After obtaining final flow for each loop, pipe size can be calculated using head loss determination diagram (Figure -4)
8. If roughness coefficient C = 100, the values obtained from the nomograph can be used directly. But if C is other than 100 then multiply the obtained values from nomograph by the ratio of 100 to the given value of C

**(you can also check the example given in “Water Supply Engineering by M.A.Aziz” in chapter -9)

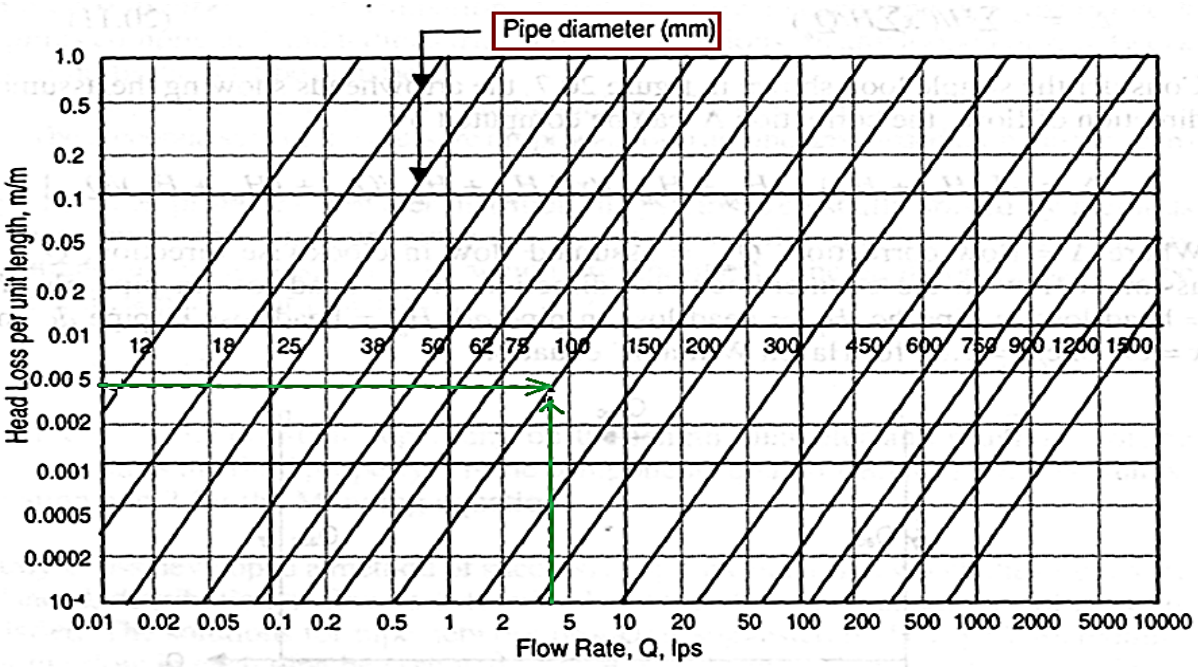


Figure -4 : Head loss determination diagram (for roughness co-efficient, C = 120)

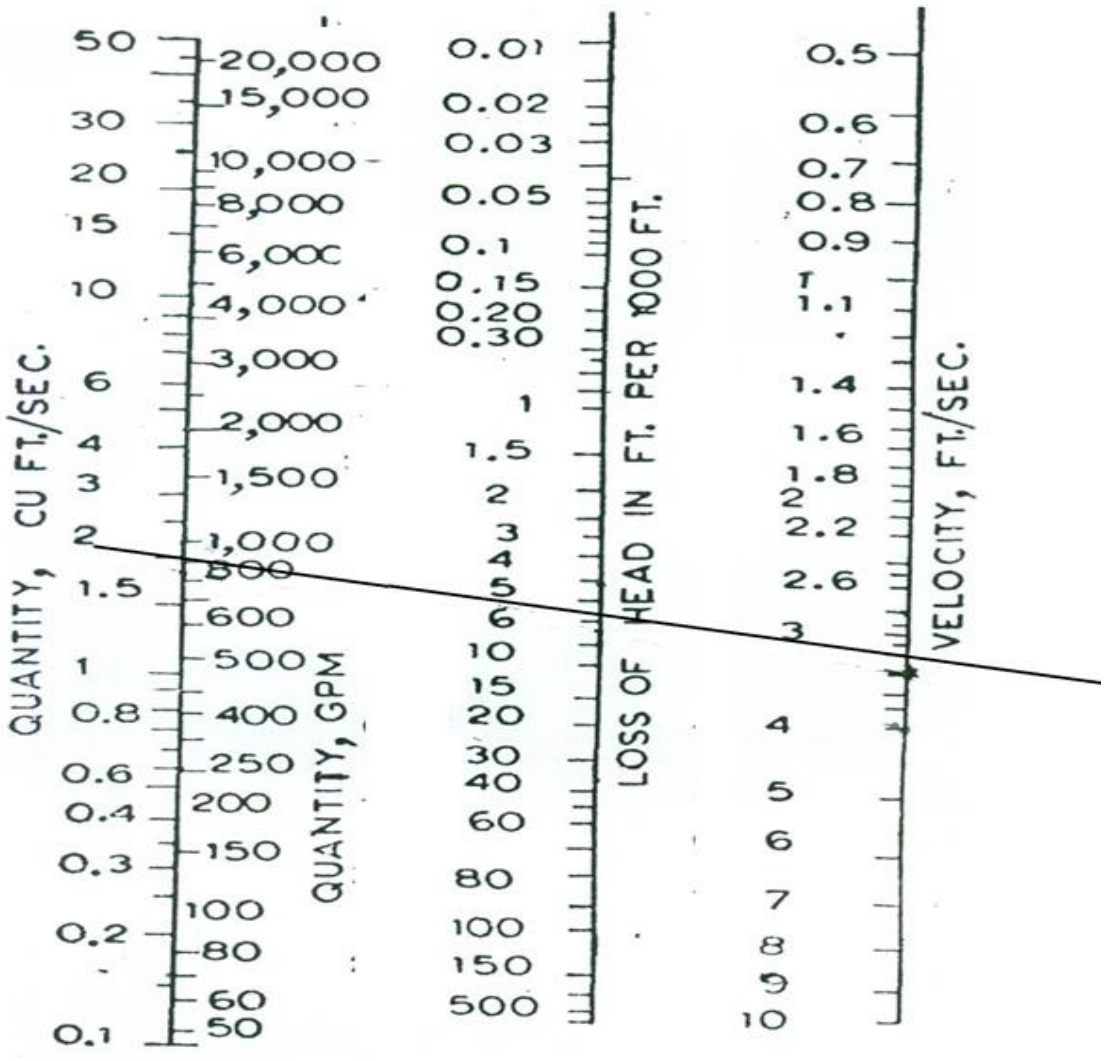


Figure – 5: Nomograph for Hazen-Williams formula (C =100)