Plumbing System

Example Problem

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Given:

- 25 storey building, 10 ft floor to floor
- 50 psi at public main
- Men's and women's toilets on alternate floors
- 3 water closets or 1 water closet and 2 pedestal urinals and 2 lavatories on each floor.
  Flush valve fixtures except on 24th and 25th floors where flush-tank fixtures are used.
- Maximum pressure at any fixture is not to exceed 50 psi

Required:

Riser pipe sizes

Solution:

Determine a reasonable zoning. The lowest floors can be upfeed from main pressure. Upper floors must be supplied by downfeed risers from elevated tanks. The maximum number of floors to be served by a downfeed zone depends on the maximum pressure to be permitted at the lowest fixture.

Rate of flow and required pressure during flow for different fixtures

Fixture	Flow Pressure (psi)	Flow Rate (gpm)
Lavatory faucet	8	3.0
Lavatory faucet, self-closing	12	2.5
Sink faucet, $^3/_8$ in	10	4.5
Sink faucet, $^1/_2$ in	5	4.5
Laundry-tub cock, $^1/_2$ in	5	5.0
Bathtub faucet, $^1/_2$ inch	5	5.0
Shower, $^1/_2$ inch	12	5.0
Water closet, Ball cock flush tank	15	3.0
Water closet, flush valve type	10 to 20	15 to 40
WC FV, 1 inch @ 25psi	25	35
WC FV, 1 inch @ 15psi	15	27
WC FV, $^3/_4$ inch @ 15psi	15	15
Urinal, Flush valve	15	15
Garden hose, 50 feet and sill cock	30	5.0

In an upfeed zone, the pressure available at the main must equal the frictional pressure loss through piping and equipment plus the static head loss plus the required pressure at the top fixture.

Expressing this mathematically, we obtain

$$P = p + 0.434h + f$$

where P = service main pressure, psi;

p = pressure drop through piping and equipment, psi;

h = height from main to fixture, ft;

f = minimum permissible fixture pressure; psi.

In order to estimate friction drop, especially through a water meter, we must establish a tentative water service pipe size.

The probable rate of flow in the pipe is found as follows:

On each typical floor, the fixture unit load is

3 water closets, or 1 water closet and 2 urinals (flush valve)	30
2 lavatories	4
TOTAL	34 FU

And on the 24th and 25th floors, it is

3 water closets, or 1 water closet and 2 urinals (flush tank)	15
2 lavatories	4
TOTAL	19 FU

Fixture of Group[b]	Occupancy	Type of Supply Control	Weight in Fixture Units[c]
Water closet	Public**	Flush valve*	10
Water closet	Public	Flush tank*	5
Pedestal urinal	Public	Flush valve	10
Stall or wall urinal,	Public	Flush valve	5
Stall or wall urinal,	Public	Flush tank	3
Lavatory	Public	Faucet	2
Bathtub	Public	Faucet	4
Shower head	Public	Mixing valve	4
Service sink	Office, etc.	Faucet	4
Kitchen sink	Hotel or restaurant	Faucet	4
Water closet	Private**	Flush valve	6
Water closet	Private	Flush tank	3
Lavatory	Private	Faucet	1
Bathtub	Private	Faucet	2
Shower head	Private	Mixing valve	2
Bathroom group	Private	Flush valve for closet	8
Bathroom group	Private	Flush tank for closet	6
Separate shower	Private	Mixing valve	2
Kitchen sink	Private	Faucet	2
Laundry machine	Private	Automatic	2
Laundry machine	Commercial (8 lb)	Automatic	3
Laundry machine	Commercial (16 lb)	Automatic	4

The load on the service pipe is

23(34) +2(19) = 820 FU

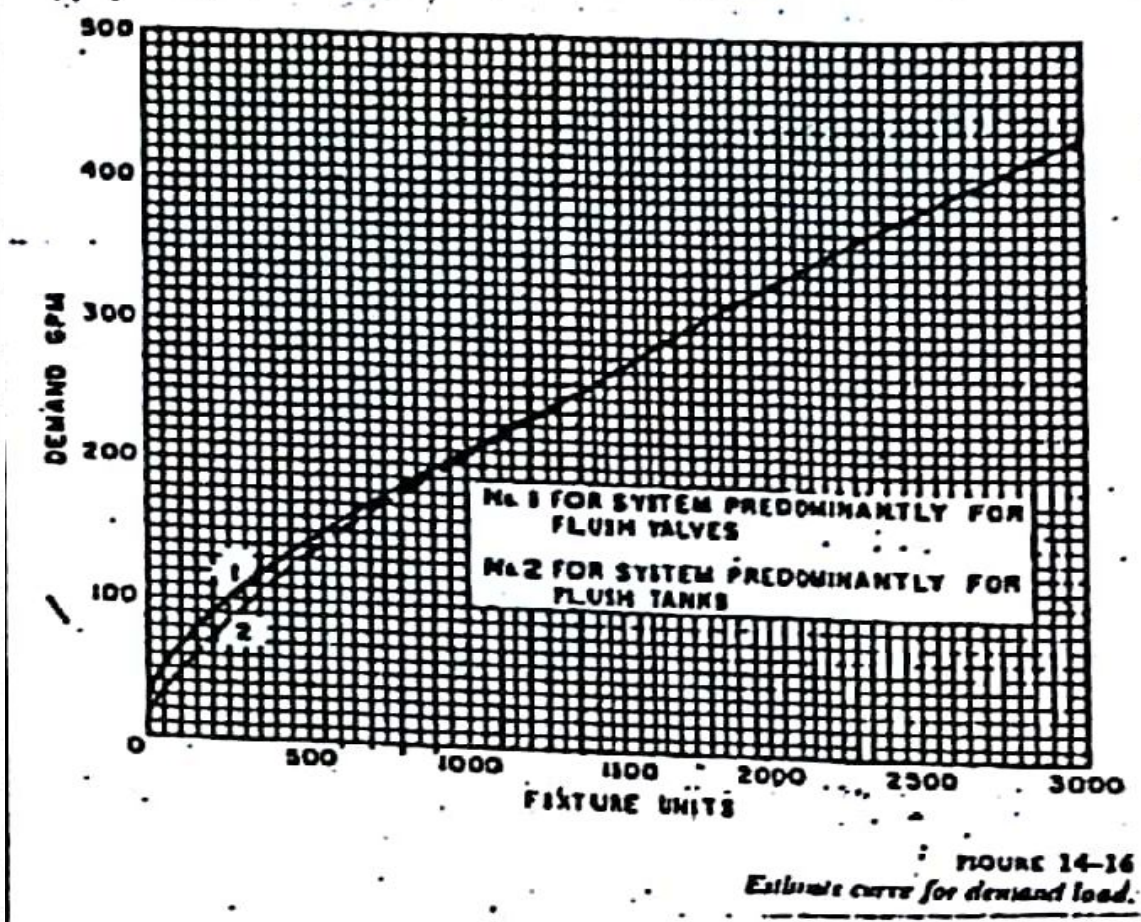


FIGURE 14-16
Estimate curve for demand load.

According to Fig. 14-16, the probable maximum demand is 184 gpm

If we use iron pipe, Fig. 14-19 indicates a 3-inch main for a drop of 6 psi per 100 ft or a 4-inch main for a drop of 1.4 psi per 100 ft.

Let us tentatively select the 4-inch main to conserve pressure for the upfeed zone.

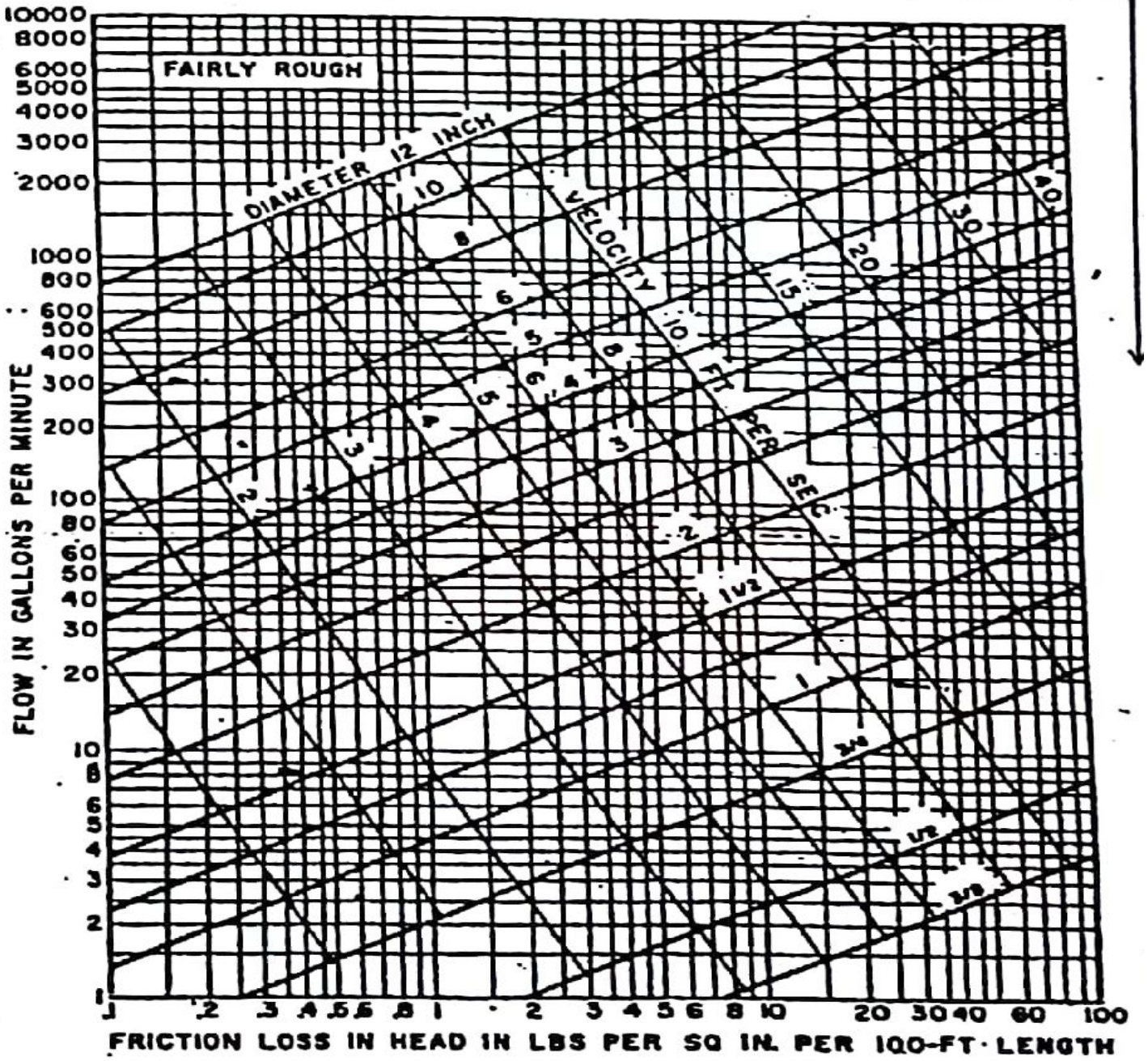


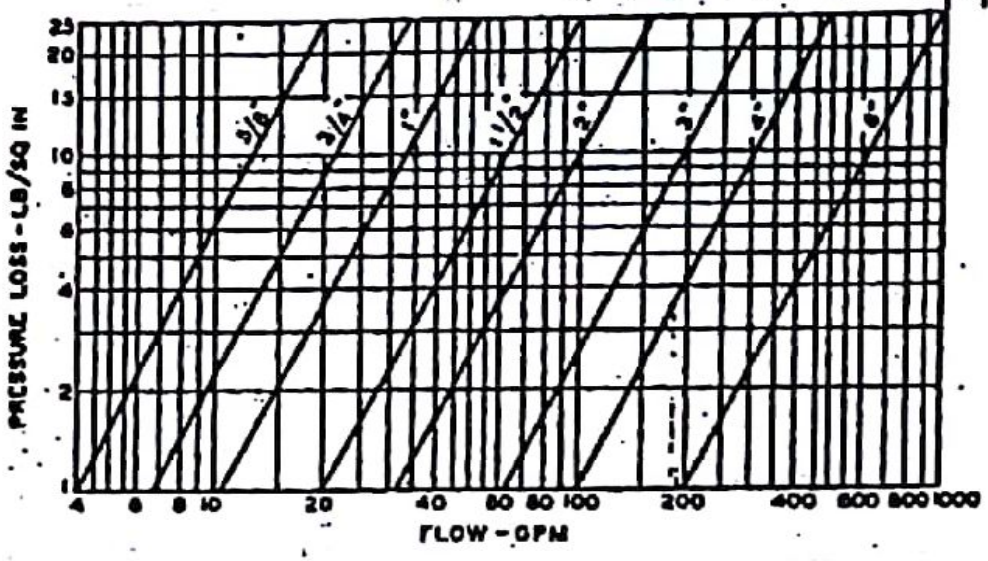
FIGURE 14-19
Friction losses in fairly rough iron pipe.

Figure 14-20 shows that about 3.5 psi drop occurs at a 4-inch meter when the flow is 184 gpm.

In Eq. (14-1), let us allow 1 psi drop in branch from the riser and calculate the friction loss through the service pipe, riser and fittings. For fitting friction, 50% extra length is considered as initial approximation. Therefore, the height of the upfeed zone is found from the equation

$$50 = 3.5 + 1.5\,(70 + h)\,(1.4 / 100) + 0.434h + 15 + 1$$

$$h = 29.03 / 0.455 \approx 64 \text{ ft}$$



(See manufacturer's data for exact value for meter used)

FIGURE 14-20
Pressure losses in disk-type water meters.

If the floor-to-floor height is 10 ft, 6 stories are indicated for the height of the upfeed zone.

We must remember that 64 ft is from main to top fixture. Therefore, a deep water main would limit us to 5 floors.

Now we should check the maximum height of a downfeed zone.

The maximum pressure on the lowest fixture occurs when all water flow is off and it is the static head obtained from the roof tank elevation.

Obviously, when water flows, frictional resistance lessens the pressure at the bottom of a riser. If the maximum pressure for a fixture is 50 psi, the maximum vertical distance from tank to fixture is 50/0.434= 115 ft.

Allowing a little extra height of the roof tank above the top-most flush tank fixture for overcoming friction loss through piping and fittings, about 20 to 25 ft of height between the top fixture and the roof tank is required, only 91 ft (= 115 – 24) is left to use for the floor-to-floor distances served by the riser. Hence, for 10-foot floor-to-floor heights, the maximum downfeed zone is 9 floors.

For our 25-story building, the use of two downfeed zones of 9 floors requires that the upfeed zone be (25 – 18) or 7 floors. But we found 5 floors as the maximum for the upfeed zone.

We have the choice between

(i) increasing the downfeed zones to three or

(ii) raising, slightly our maximum fixture pressure for a downfeed zone.

The latter alternative would take less equipment while the former would lessen the sizes of the units used.

If the maximum fixture pressure allowed is increased by 10 (0.434) or 4.34 psi.

Raising our 50 psi to 54.34 or, 55 psi is not objectionable.

Hence, we choose:

(i) Zone # 1
a 5-floor upfeed zone
(1st floor- 5th floor)

(ii) Zone # 2
a 10-floor downfeed zone
(15th floor – 6th floor)

(iii) Zone # 3
a 10-floor downfeed zone
(25th floor – 16th floor)

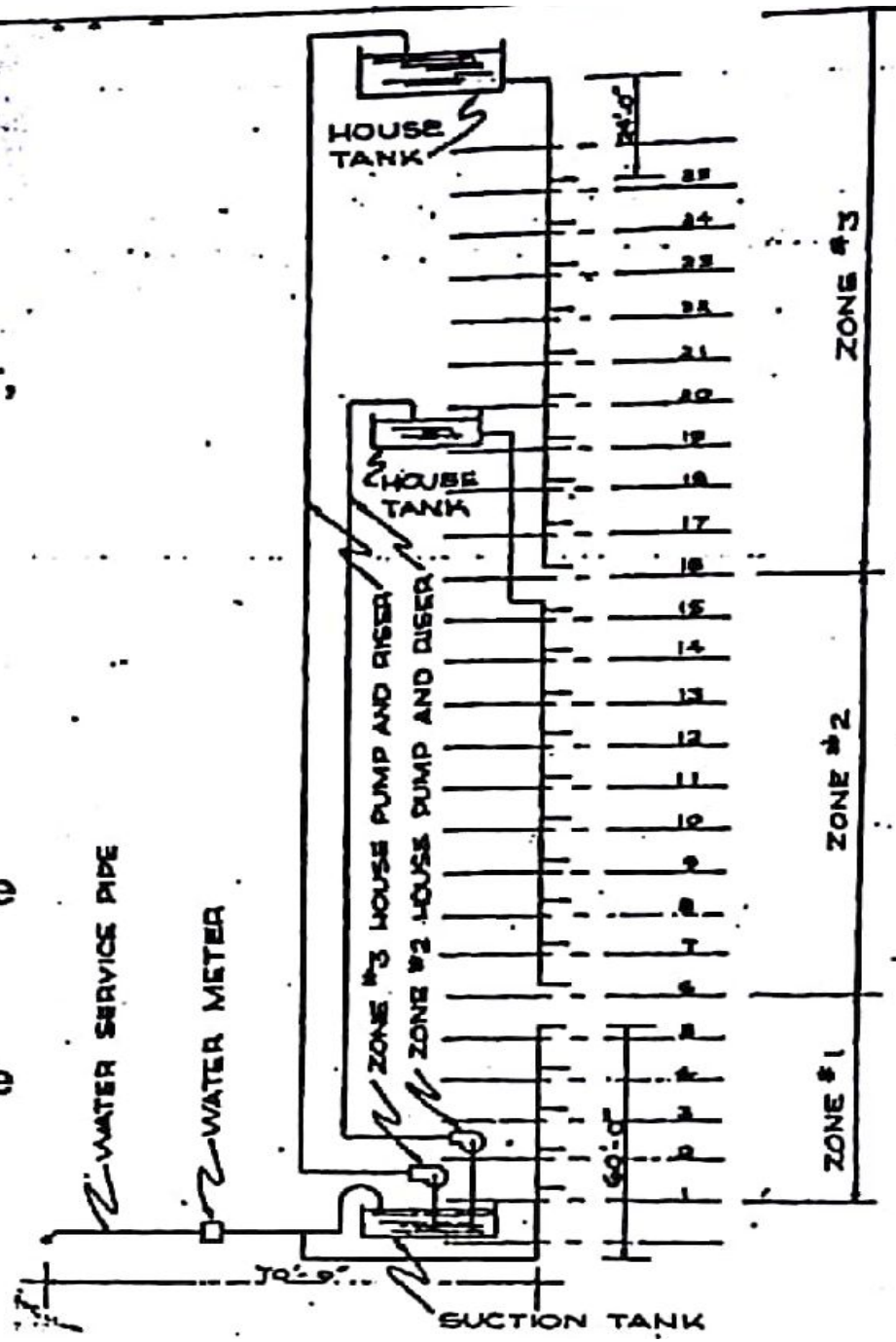


FIGURE 14–21
Water supply for a tall building.

Design of the Upfeed Zone

- First let us find the total pressure available for overcoming friction to flow in piping and fittings.
- It will be the main pressure less the sum of water meter pressure drop, static head loss, and minimum fixture pressure including pressure drop in branches from the riser for which allow 1 psi, or

$$p = 50 - [3.5 + 60\ (0.434) + 15 + 1] = 4.46 \text{ psi}$$

assuming that the top fixture is 60 ft above the main.

- The pressure of 4.46 psi can be utilized to overcome friction caused by flow through piping and fittings.

- We evaluate fitting friction by stating the length of straight pipe of the same size which will offer equal pressure drop at the same rate of flow.

At the moment, we do not know pipe or fitting sizes, hence, an estimate of equivalent length must be made.

The riser is a straight vertical run, and a low increase in actual length to allow for fittings is reasonable. If the measured length of pipe from main to foot of riser is 70 ft and the riser is 60 ft, the total actual length is 130 ft.

Let us add 50% for fittings. The total equivalent length is 130(1.5)= 195 ft.

Therefore, the pressure loss per 100 ft is

$$p = \frac{(4.46)(100)}{195} = 2.3 \text{ psi per } 100 \text{ ft}$$

The tabulation of the information for sizing the upfeed zone is given in Table 14-5.

Table 14–5. Pipe sizes for upfeed zone of water supply system.

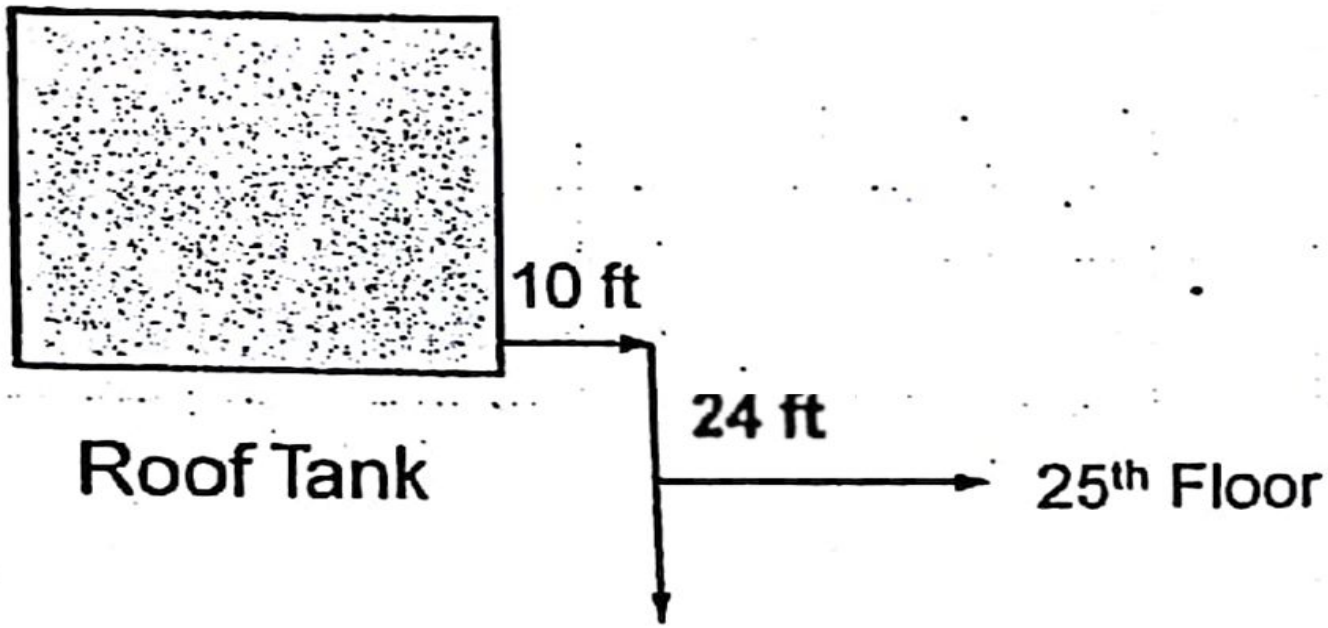
Floor	Fixture units	Accumulated fixture units	Demand flow (gpm)	Pipe size (in.)
Service pipe		820[a]	184	3½
1	34	170	85	3
2	34	136	77	2½
3	34	102	68	2½
4	34	68	58	2½
5	34	34	43	2

[a] Includes F.U. from zones 2 and 3.

- Each floor is listed.
- Then, the fixture unit load as previously determined is given to each floor. Calculate the accumulated fixture units corresponding to each floor.
- The rate of flow for each floor corresponding to the fixture unit demand load is determined from curve 1 of Fig. 14-17 for installations having flush-valve fixtures. From these rates of flow and a permissible drop of 2.3 psi per 100 ft, we can read the pipe sizes from Fig. 14-19.

Design of the Downfeed Zones

- Now, let us size downfeed zone 3.
- The problem is rather different from upfeed sizing. Two special conditions are to be satisfied
  - (i) We must limit pressure loss at the top of the zone so that top fixtures will receive their minimum pressure.
  - (ii) Lower down, we can size piping so that friction due to flow just balances the static gain.



- Let us set our tank at 24 ft vertically above the top fixture with 10 ft of horizontal pipe also required in the first section.
- Now, the permissible pressure drop in the pipe from the tank to the top floor is the static gain less the fixture pressure, 8 psi, and the fixture branch pressure, 1 psi.

- Therefore, $p = 24(0.434) - 8 - 1 = 1.4$ psi

- Assuming the fitting friction to be equal to a 50% increase in actual length, the drop per 100 ft is

$$\frac{1.4 \times 100}{1.5 \times 34} = 2.80 \text{ psi}$$

- We must remember that at the 23rd floor the minimum pressure for flush-valve fixture and branch is 15 + 1= 16 psi. Let us find the pressure drop from the 25th to the 23rd floor to obtain the 16 psi required at the 23rd floor.
- The static head gained is 10 + 10 = 20 ft or 20(0.434) = 8.68 psi. Therefore, 9 + 8.68 – 16 = 1.68 psi is available for overcoming friction.

The permissible pressure drop per 100 ft is

$$\frac{1.68 \times 100}{1.5 \times 20} = 5.60 \text{ psi}$$

- This pressure drop can be used to size the riser for the 23rd and 24th floors.
- From this point on, all piping can be sized to use up the entire static head gain. In other words, once we have 16 psi available, any additional gain from static head can be used to overcome friction.
- Permissible pressure loss, $p = 16 + 10 \times 0.434 - 16 = 4.34$ psi
- Thus, at each floor the gain is $10(0.434) = 4.34$ psi, and the loss per 100 ft is

$$\frac{4.34 \times 100}{1.5 \times 10} = 28.9 \text{ psi}$$

- Table 14-6 illustrates a convenient tabular form for the riser pipe sizing. We find the fixture unit loads present at each floor and the accumulated load on the riser at each floor using Table 14-3 as we did for the upfeed zone. From the fixture unit loads, we find the corresponding probable flow rates from Figs. 14-16 and 14-17.

Table 14-6. Pipe sizes for downfeed zone 3 of water-supply system.

Floor	Fixture units	Accumulated fixture units	Demand flow (gpm)	Actual pipe length (ft)	Equivalent length due to fittings (ft)	Total equivalent length (ft)	Pressure drop (psi/100 ft)	Pipe size (in.)
25	19	310	110	34	17	51	2.80	3
24	19	291	107	10	5	15	5.60	2½
23	34	272	103	10	5	15	5.60	2½
22	34	238	98	10	5	15	28.90	2
21	34	204	92	10	5	15	28.90	2
20	34	170	85	10	5	15	28.90	2
19	34	136	77	10	5	15	28.90	2
18	34	102	68	10	5	15	28.90	1½
17	34	68	58	10	5	15	28.90	1½
16	34	34	43	10	5	15	28.90	1¼

(i) Calculate the permissible pressure loss per 100 ft in the riser pipe of the topmost floor of a seven storied building from the following data:

- the water supply is intermittent
- the fixture pressure ranges from 5 psi to 10 psi
- floor to floor height is 10 ft

Assume reasonable value for any missing data.

(ii) In a down-feed zone of water supply, the pressure available in the riser at a certain floor is 8 psi. Calculate the permissible pressure drop per 100 ft of riser to supply for a floor 22 ft floor below where the pressure requirement is 14 psi.

(iii) The roof tank of a 30 storied tall building is placed 26 ft above the top-most fixture whose pressure requirement is 9 psi. The maximum fixture pressure requirement of the two top-most floors is 9 psi. The top-most zone covers 8 floors and the floor to floor height is 10 ft. The maximum fixture pressure requirement of each floor is 16 psi except the two top-most floors. Calculate the permissible pressure drops in the concerned riser pipe. Assume reasonable value of any missing data if required.

(iv) Given:

* 30-story building 12 ft floor to floor.
* 55 psi at public main.
* Flush-valve fixtures except on 29th and 30th floors where flux-tank fixtures are used.
* Maximum pressure at any fixture is not to exceed 55 psi.
* Minimum permissible fixture pressures vary from 5 psi to 8 psi for flush-tank fixtures.
* Minimum permissible fixture pressures vary from 7 psi to 14 psi for flush-valve fixtures.
* Pressure loss in the water meter is 4 psi.
* Public main is 50 ft away from the foot of the riser.
* The pressure loss is 7 psi/100 ft for a 3-inch main and that is 1.6 psi/100 ft for a 4-inch main.

Assume reasonable values for missing data if required.

Determine zoning of the tall building.

(v) You need to design the water distribution system of a 4-storied Apartment building by downfeed system. The main pressure is 40 psi and the minimum fixture pressure is 5 psi.

Each storey has the following fixtures:

Bathtub 1, Water Closet 3, Shower 2, Tap 4, Kitchen Sink 1

(i) Determine the minimum height of the Roof Tank of the building.

(ii) Determine the water distribution pipe sizes of the building.

(Table, Graph, Nomographs are attached).

Table: Fixture Unit values

Type of Fixture	Fixture Unit Value	
	Private	Public
Lavatory	1	2
Bath tub	2	4
Water Closet (Flush tank)	3	5
Water Closet (Flush valve)	6	10
Urinal	----	5
Shower	2	4
Kitchen Sink	2	4
Hand wash basin	2	4
Ablution Tank	1	1

(c) Calculate the height of up-feed zone of a tall building form the following data.

Floor to floor height = 10 ft

Service main pressure = 55 psi

Pressure loss in water meter = 3.5 psi

Pressure loss in service pipe = 4.5 psi per 100 ft

Fixture pressure varies from 4 psi to 10 psi

Length of pipe form street water main to the foot of riser = 45 ft

Assume reasonable value of any missing data if required.

(d) Calculate the available pressure loss to supply water to the top most floor of a 7 storied building from the following data:

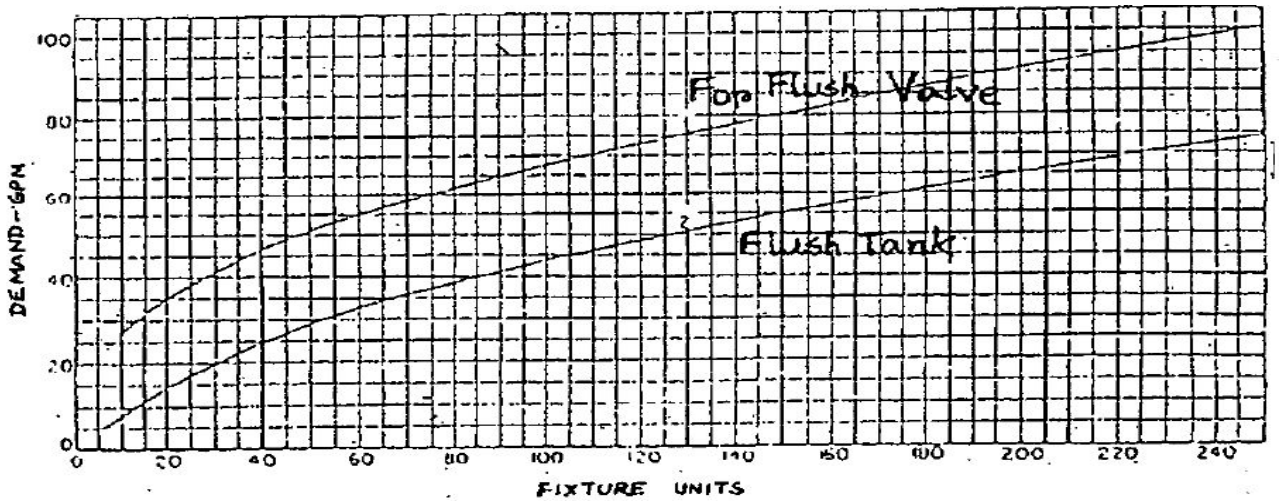
Water supply in the street main is intermittent.

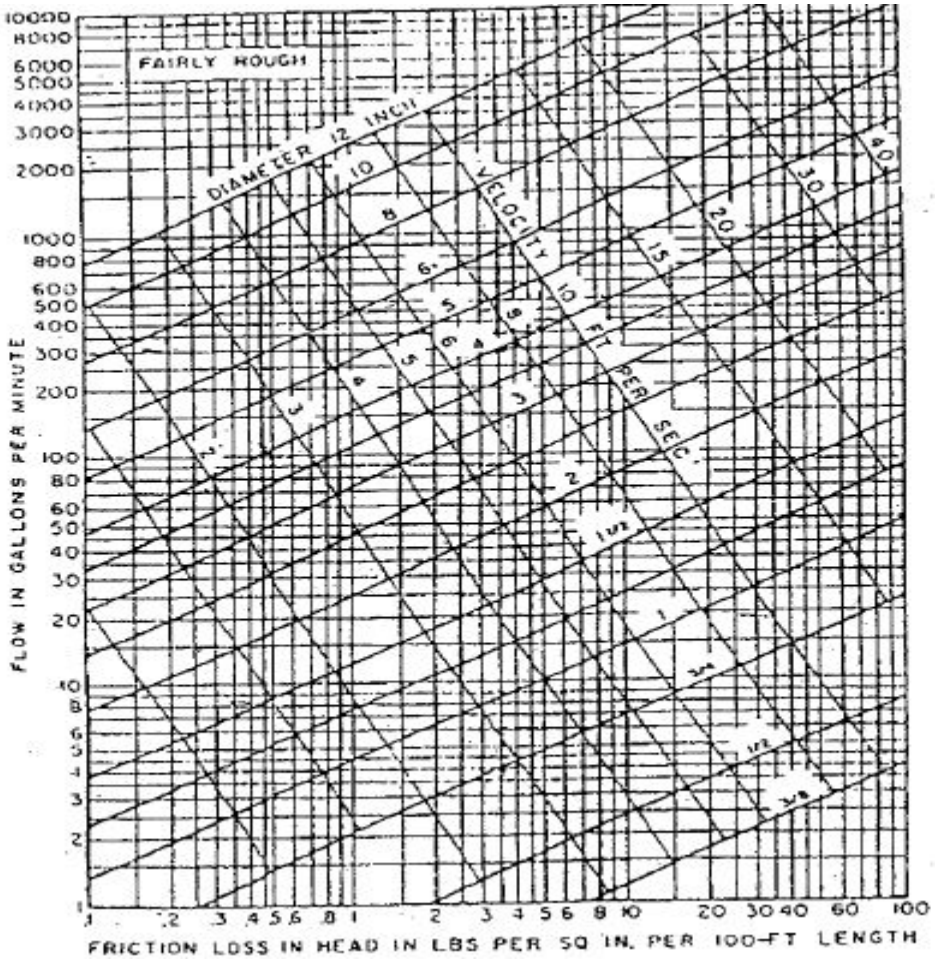
Service main pressure = 40 psi

Floor to floor height = 9.5 ft

Fixture pressure varies form 4 psi to 7 psi

Assume reasonable value of any missing data if required.


For Flush Valve
Flush Tank
DEMAND - GPM
FIXTURE UNITS
0
20
40
60
80
100
120
140
160
180
200
220
240


FAIRLY ROUGH
DIAMETER IN INCH
VELOCITY IN FT PER SEC
FLOW IN GALLONS PER MINUTE
FRICTION LOSS IN HEAD IN LBS PER SQ IN. PER 100-FT LENGTH