Urban Utilities Planning: Water Supply, Sanitation and Drainage
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Module - 05
Water supply Distribution system and Plans
Lecture - 21
Distribution System and Layout

In module 5, Water Supply Distribution System and Plans will be covered.

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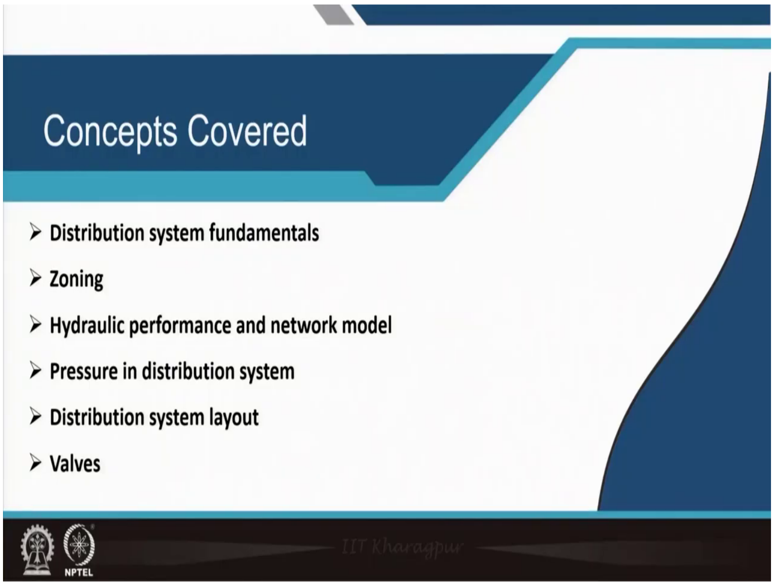

The different concepts involved include Distribution system fundamentals, zoning, Hydraulic performance and network model, pressure in the distribution system, Distribution system layouts and Valves.

Distribution system fundamentals

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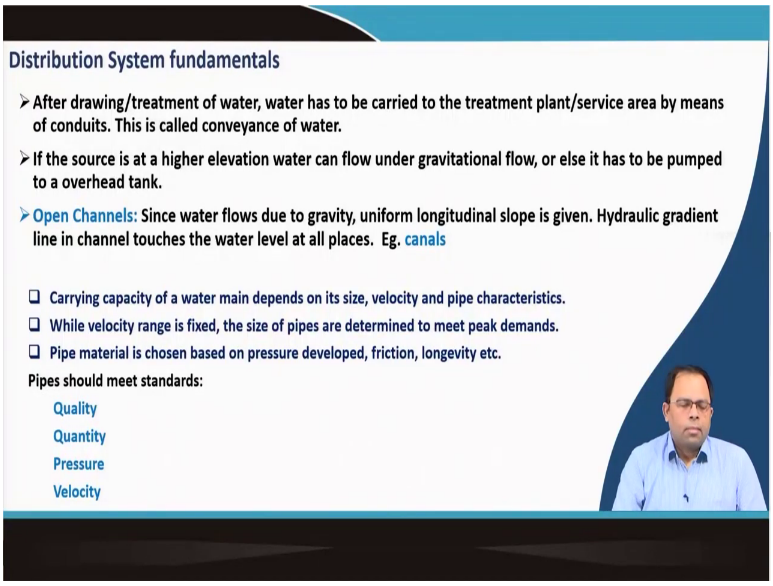

Conveyance of water refers to the carriage of water to the treatment plant/service area using conduits after drawing/treatment of water. If the source is at a higher elevation, water can flow under gravitational flow, or else it has to be pumped to an overhead tank. Open channels or closed conduits are employed for the conveyance of water. In the case of open channels (Eg. Canals) since water flows due to gravity, a uniform longitudinal slope has to be given such that the hydraulic gradient line (based on the piezometric surface) in the channel touches the water level at all places. However, in case of closed pipelines, this condition need not be considered as pressure-based supply is involved in the pipeline. Hence, it may be required to increase the thickness of the pipeline to handle such increased pressure.

The carrying capacity of the water main depends on its size, velocity and pipe characteristics. In most cases, a fixed range of velocity is tried to be maintained, and the size of the pipe is determined based on the requirement (peak demand). High speed or low speed causes issues such as scouring of the pipelines, friction-related issues, longevity issues etc. Demand is estimated considering average demand; however, peak demand determines the pipe sizes. Pipe material is chosen based on pressure developed in the pipeline, friction, pipeline longevity, etc.

Selection of pipe depends on:

- Quality of water
- Quantity of water
- Pressure in the pipe
- Velocity of water.

Ratings and standards should also be considered.

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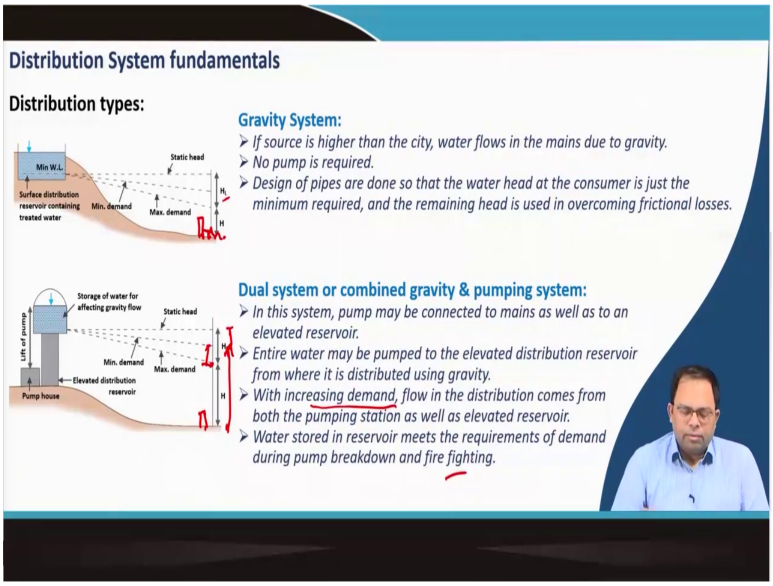

Types of Distribution systems:

Gravity system - If the source is higher than the city, water flows in the mains due to gravity. The design of pipes is done so that the water head at the consumer is just the minimum required, and the remaining head is used to overcome frictional losses. In the end, a minimum pressure has to be retained for the upward movement of water (without pumping) to either 3 or 4 storey height as fixed by the urban local body. No pump is required in the case of gravity systems. The total pressure that is required is the pressure, which is required at the delivery point, plus the pressure that is required to overcome the frictional losses in the pipeline. In the figure, H_L represents the amount of pressure to be overcome. The pressure required would be different during different times based on the varying demand. H_L is the head loss that is required to overcome frictional losses. So, H_L + H is the amount of pressure that is required in the system based on the height of this particular reservoir. So, the more the height or more the water level of the reservoir at a higher level, the more is the pressure available in that particular system.

Dual system or combined gravity & pumping system - In this system, the pump may be connected to mains as well as to the elevated reservoir from where it can be distributed using gravity. In order to create the pressure head ($H + H_L$), water is pumped at the pump house to lift the water from the reservoir to an overhead storage tank which is connected to the distribution system. But sometimes, during heavy demand or the peak demand, flow in the distribution system may be sourced from the pumping station as well as the elevated reservoir. Because during the peak demand period, the head loss increases than the initial pressure considered, resulting in an extra pressure requirement. In that case, the pumping from the pump house contributes to the extra pressure which is required. So, water stored in the reservoir meets the demand requirement during pump breakdown and pump fire firefighting.

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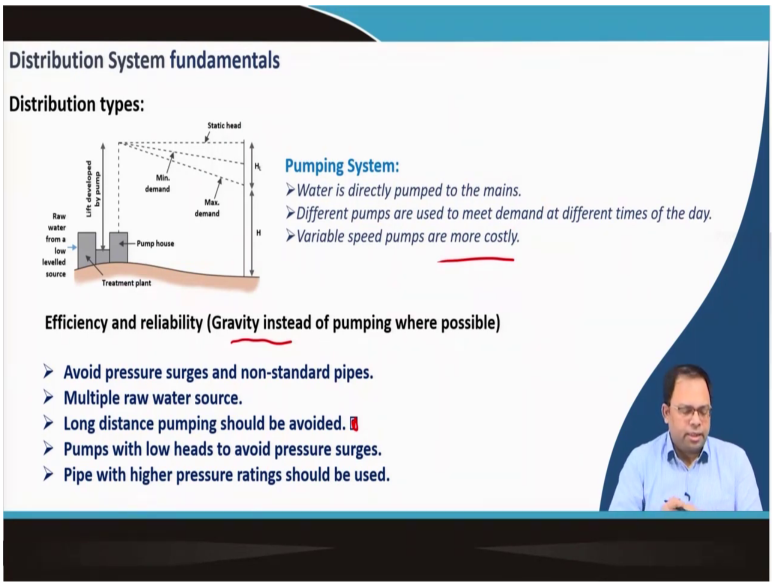

Pumping system – Here, water is directly pumped to the mains, and there is no overhead reservoir involved. Different pumps are used to meet demand at different times of the day.

Multiple size pumps may be employed and used to cater for the varying demands. Variable speed pumps can also be used; however, these are more costly.

Out of all the three systems, a gravity based system is the most efficient and reliable as there is no failure in the case of gravity, unlike the case of pumping systems which may fail either due to electricity or due to other reasons. So, whenever we select pipelines for designing this network, the water is transported from the overhead reservoir or from that pump house to the service area. In that case, the distribution system should avoid pressure surges. Non-standard pipes have to be avoided; at least for the mainline, uniform size pipes can be used to avoid such pressure surges.

If there are multiple raw water sources, water supply to different areas can be from different sources and different pipe systems and avoids long-distance pumping, which is energy-intensive. Also, pumps with low heads can be used to avoid pressure surges. Pipes with high-pressure rating should be used.

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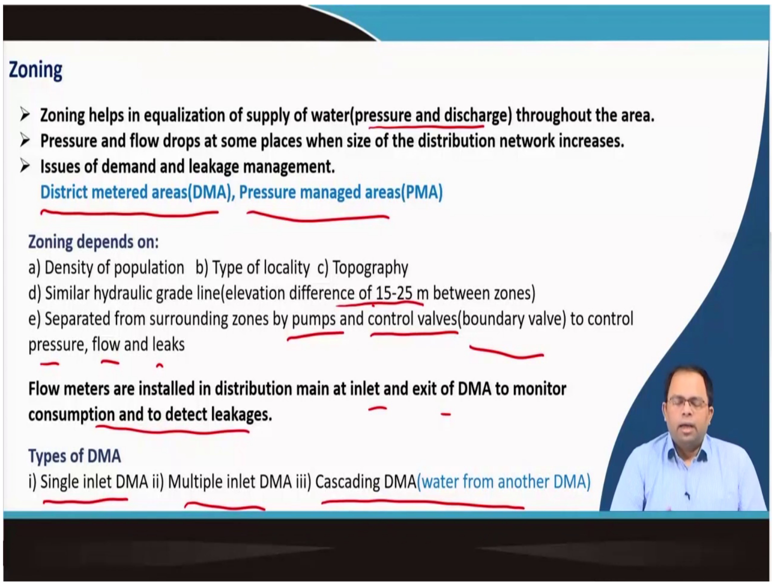

Zoning:

Zoning refers to either district meters area or pressure managed areas. Zones refer to the subdivision of an urban area for water supply. This division follows several criteria, and there may be more than one way in which the zoning can be done. The overall efficiency of the zoning considered needs to be tested. Multiple strategies can be adopted for the same. Zoning helps in the equalization of the supply of water throughout the area. Equalization refers to maintaining uniform pressure. This is required because the water, after travelling a large distance to reach the discharge point, may not have sufficient pressure. Earlier, large diameter pipelines had to be employed for supplying water to far distances; proper zoning can eliminate such large diameter pipelines required. It can also reduce the length of pipelines.

Pressure and flow drop at some places when the size of the distribution network increases. And, there are issues of demand and leakage management. These issues are also addressed with efficient zoning. There is a need to understand how much water is being supplied to a certain area and if leakage is developing in a certain part of the system. With zoning, the amount of water going into the zone can be calculated with metering. Meters are installed at both the entry and exit to know the water consumed in a particular area. This refers to the *district meter area.*

Similarly, if there is a fall in the pressure in that particular area, a leak can happen, with other areas remaining fine. Such identification becomes easy if the area is zoned otherwise, it becomes extremely difficult.

Zoning depends on:

- The density of population. – In areas with dense populations, the zone size may be smaller.
- Type of locality- such as whether it is a commercial area, neighbourhood residential area etc. Sometimes 80 percent of the neighbourhood can be of one sort, and another 20 may be another type. It is also divided on the basis of administrative boundaries.
- Topography - for example, if a river passes through a particular area, it is not possible to have the distribution network on both sides. Similarly, the contour of an area also plays a role; for example, if there is a hillock, it is better to consider the hillock into a separate zone. Otherwise, the pressure difference between the hillock and the surrounding area may become too high, and it is better not to have such pressure difference within one zone itself.

- Hydraulic grade line - it is usually followed to maintain the hydraulic grade line at similar levels. Within two zones, the elevation difference of 15 to 25 meters is possible. It is also important to consider the height of the buildings to which water has to be conveyed. So, to maintain a similar hydraulic grade line, it is necessary to make sure that different zones are at a different elevations.

- Separated from surrounding zones by pump and control valves to control pressure flows and leaks. So that means each zone could be separated; that means, water supply to each zone could be controlled. So, it is easy to cut off the water supply for a particular zone, for repair work or for extension work using control valves or boundary valves. Similarly, different zones may have different pumps to cater to that particular zones.

Flow meters are installed in the distribution main at the inlet and the exit of the district metered area to monitor consumption and to detect leakage.

Types of DMA:

- Single inlet DMA – One main distributes into the entire zone
- Multiple inlet DMA - Multiple lines from various direction serves various part of the DMA.
- Cascading DMA - water comes to one DMA, which is repeatedly connected to another one .

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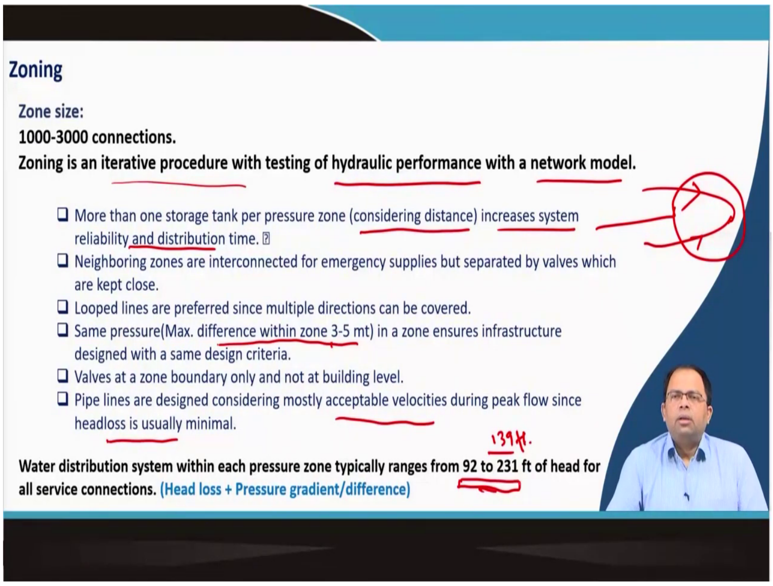

Zone sizes are considered around 1000 to 3000 connections, but sometimes it can go upto 5000 in some situations. For example, as cited in the example where 80 percent of the neighbourhood is of one type and another 20 percent is of another type and it is combined as one zone. Thus, it follows an iterative procedure. Once the zoning is fixed, the next step is to determine the network for that particular area. Assumptions regarding pipe sizes and pumps have to be made and then the hydraulic performance has to be tested. Based on the design, the software can be employed to test for complex networks where the entire supply is simulated for the peak period, nonpeak period etc. It may be noted that the pressure gets exceeded in certain nodes and has to be rectified. Changing the pipe diameter can be one option to achieve this. It is also important to keep the overall costing low.

- More than one storage tank per pressure zone (considering distance) increases system reliability and distribution time. If there are two tanks when one fails, the other can supply because all the network is connected. Multiple tanks reduce the pipeline length and thus the distribution time.
- Neighbouring zones are interconnected for emergency supplies but separated by valves that are kept close. During an emergency, water can be supplied from one zone to another by opening the valves.
- Loop lines are preferred; since multiple directions can be covered.

- Same pressure (maximum difference in pressure within 3 to 5 meters) in a zone ensures infrastructure design in the same design criteria. This helps in making sure that the pipe sizes are almost uniform.
- Valves can be given at the zone boundary and not at the building level
- Pipelines are designed considering mostly acceptable velocities during peak flow, since the head loss is usually minimum. So acceptable velocities have to be determined. During peak flow, the head loss is usually less, and hence the design mostly depends on velocity.

The water distribution system within each pressure zone typically ranges from 92 to 231 ft of the head for all service connections. (Head loss + Pressure gradient/difference constitutes this sum).

Hydraulic performance and network model

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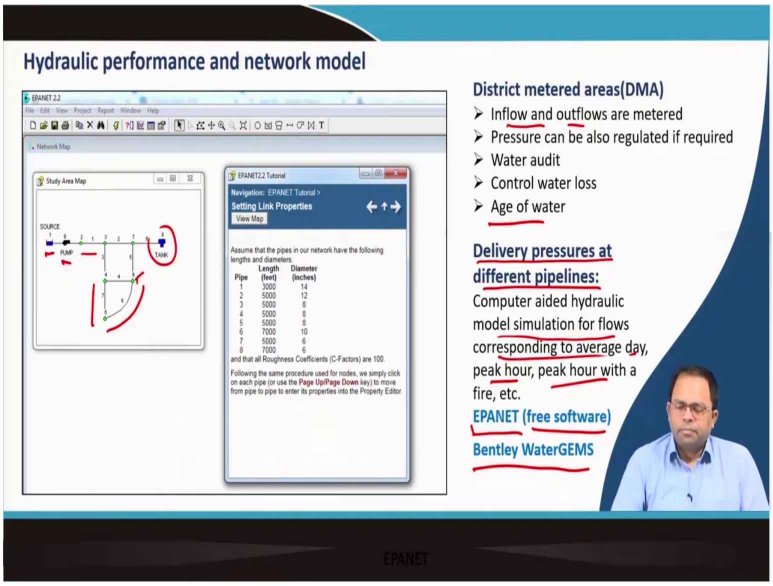

District metered areas

- DMA involves metering both the inflowing water and the outflowing water
- Pressure can also be regulated if required
- Water audit can be performed – the amount of water supplied at different times and how it varies from season to season etc., can be determined.

- Water loss can be controlled because leakage detection is much easier.
- Age of water can also be determined - if the distribution system is such that the water does not come back, then the water gets stored at certain sections or certain pockets of the network and becomes stale. That water has to be removed.

It is difficult to do the above-mentioned things manually. Hence, software models can be employed. So, the delivery pressures at different pipelines have to be determined. Various software are available. Hydraulic model simulation for flows corresponding to an average day, peak hour, peak hour with a fire etc., is conducted to determine the appropriateness of the design suggested. Two of the popular software involve Bentley WaterGEMS, which is commercial software, and EPANET, which is free software and is designed by the US environmental protection agency. EPANET is the most widely used software and is easy to use.

From the interface, source, pump, network, loop, tank etc. can be determined. The demands at each point can be added. A lot of information has to be added, and then, one can run a simulation and determine if the pressure is exceeding at certain points. From there, corrections can be made and thus, design can be performed.

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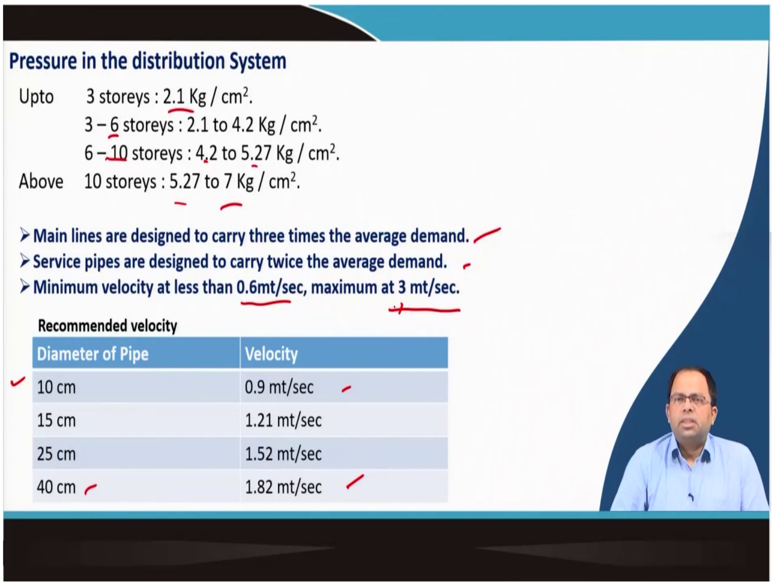

Pressure in the distribution system:

Upto 3 storeys: 2.1 Kg / cm^2

3 – 6 storeys: 2.1 to 4.2 Kg / cm^2.

6 – 10 storeys: 4.2 to 5.27 Kg / cm^2.

Above 10 storeys: 5.27 to 7 Kg / cm^2.

The main lines are designed to carry three times the average demand. The earlier discussion stating 1.8 times the hourly maximum demand can also be considered. Service pipes or branch pipes are designed to carry twice the average demand (that is, instead of 1.8 times, two times can be considered). The minimum velocity in the pipeline is designed as 0.6 meters per second, and the maximum is designed around 3 meters per second. So, this is the range within which velocity has to be maintained and based on that, different diameter of pipelines can be used. But, even though this range is suggested, there are certain recommended velocities that has to be adopted for different diameters of pipeline, because that will result in optimum cost and optimum efficiency of those pipelines. The following table gives the recommended velocity.

Diameter of Pipe	Velocity
10 cm	0.9 mt/sec
15 cm	1.21 mt/sec
25 cm	1.52 mt/sec
40 cm	1.82 mt/sec

<u>Distribution system layout</u>

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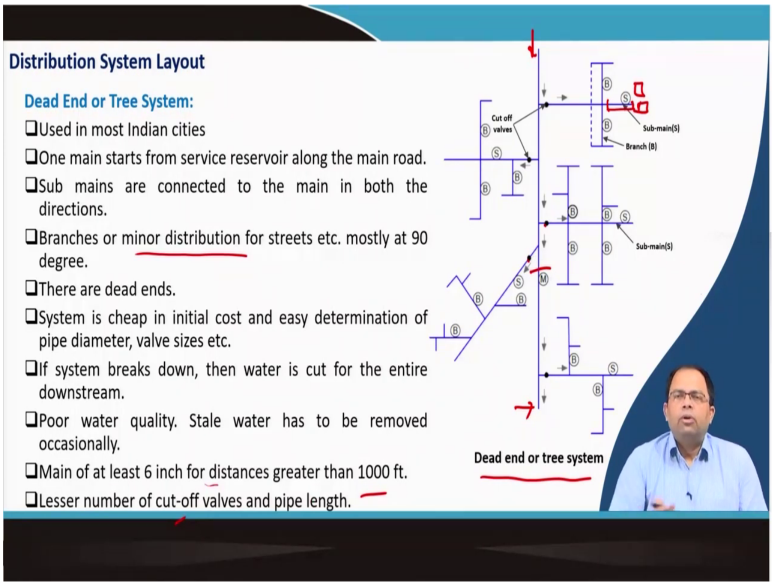

Dead end or tree system

The above image shows the various components of the system, including the Mains, Submains, Branches, and Cut off valves. The direction of the flow of water is also shown. Valves help in restricting or allowing water flow to a particular section of the pipeline during repairs etc. As the pipeline has got dead ends, there is a chance that water is not drawn. That means it may be serving dilapidated houses or unoccupied houses or other buildings etc. Thus, the water gets stagnant and deteriorates in terms of quality, affecting the other parts of the network. There are so many such issues with the dead end systems, but at the same time, this is the most convenient system. As the city grows, the network can also grow; Also, the number of valves required is less. However, it may not be as beneficial as systems such as loop systems.

- Most Indian cities show this kind of system
- One main starts from the service reservoir along the main road,
- Sub mains are connected to the main in both directions.
- branches or minor distributions for streets etc. mostly at 90 degrees
- There are dead ends

- The system is cheap in initial cost and easy determination of pipe diameter, valve sizes, etc. It is easier to design such systems. If water demand and the pumping rate is known, the pipe sizes can be determined easily.
- If the system breaks down, then water is cut off from the entire downstream.
- Poor water quality: stale water has to be removed occasionally.
- Mains of at least 6 inches for distances greater than 1000 feet
- Lesser number of cut off valves and pipelines. This is another reason for a low cost.

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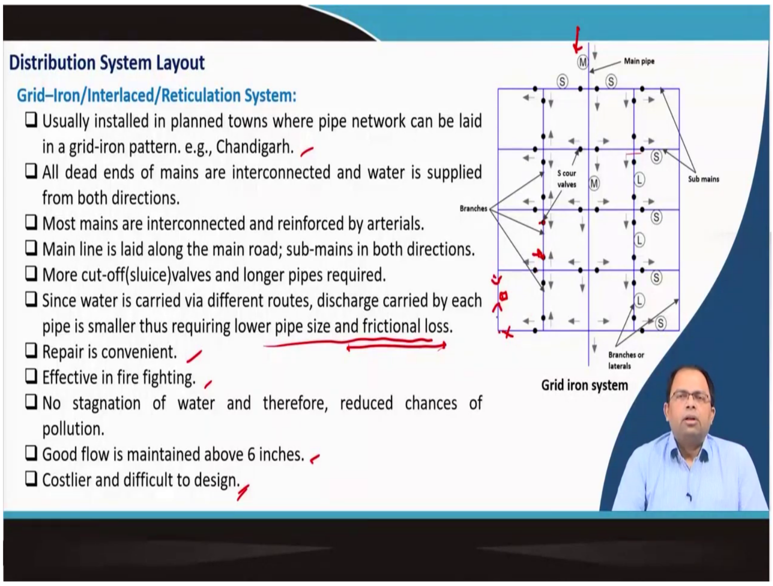

Grid iron/ interlaced/ reticulation system

The different components are labelled in the above figure. It is observable that there are a large number of pipelines and the total length of the pipeline is also much higher. This is beneficial in a way that a house can get water supply from two directions and enables the supply of water if one direction is cut off with valves due to repair work. In well-planned cities such as having a gridiron pattern, such a system is suitable and adopted because most of the pipelines will follow the road network.

Example: Chandigarh

- All dead ends of mains are interconnected, and water is supplied from both directions. Most mains are interconnected and reinforced by arterials

- Mainline is along the main road, and the sub mains goes in both directions.
- More cutoff valves and longer pipelines required
- As water is carried from different routes, discharge carried by each pipe is smaller, thus requiring smaller pump size and frictional losses. Smaller size causes lower frictional loses and saves cost. However, the length of the pipeline is more.
- Repair is better convenient
- Effective in firefighting, because you get water from multiple directions and pressure balance is better
- No stagnation of water and, therefore, reduce chances of pollution.
- Good flow is maintained above 6 inches; if the pipe diameter is given more than 6 inches, it becomes costlier and difficult to design.

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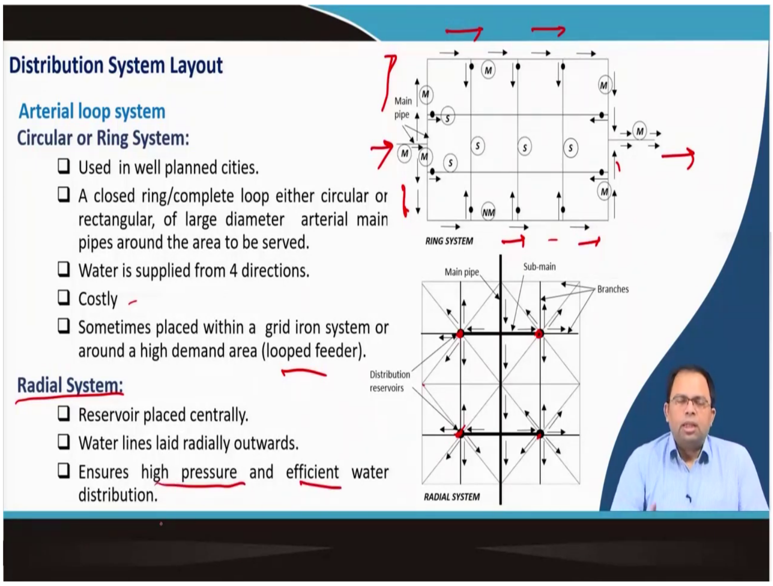

Arterial loop system - circular or ring system

A circular or ring system is similar to the grid network, but the difference is that main the incoming water and the outgoing water goes along the sides; instead of going along the main in the middle, it goes along the sides in both directions. And, water is supplied to the different zones.

- The benefit is that water is supplied from two directions and is supplied from four directions in this particular case. And, the other benefits of gridiron system is available in this system and is even more reliable.
- Used in well-planned cities.
- It is a closed ring or a complete loop, either circular or rectangle of larger diameter, with arterial main pipes around the area to be served.
- Costly
- It is sometimes placed within a gridiron system or around a high demand area or loop feeder.

Arterial loop system - radial system

- This is similar to the ring system; however, the reservoir from where different parts are supplied is located at the central part of the zone
- Water lines are laid radially outwards from the overhead reservoirs.
- Thus, it ensures high pressure and efficient water distribution compared to the other systems.

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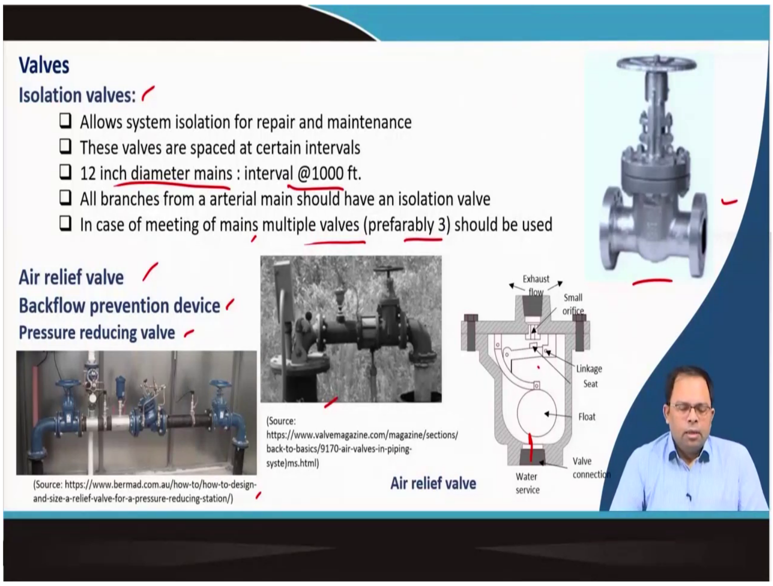

Valves

Isolation valves / sluice valves

- Allows system isolation for repair and maintenance
- These valves are spaced at certain intervals
- 12 inch diameter mains: at the interval of every 1000 feet. In case of a meeting of multiple mains, multiple valves, preferably 3 should be used and
- All branches from the arterial main should have an isolation valve.

So, this is the principle based on which valves are provided in a distribution network, and you can see the image of a valve.

Air relief valve - Consider the case of a dead-end system with an intermittent supply, air gets into the pipeline when its empty and blocks the movement of the water when the water supply resumes. Air relief valves can be used to release the air trapped. The figure shows that there is a float which rises up when there is water pressure allowing extra air to be released.

Back flow prevention device – restricts water to get back to the system

Pressure reducing valve - is used to reduce the pressure which is caused because of various reasons.

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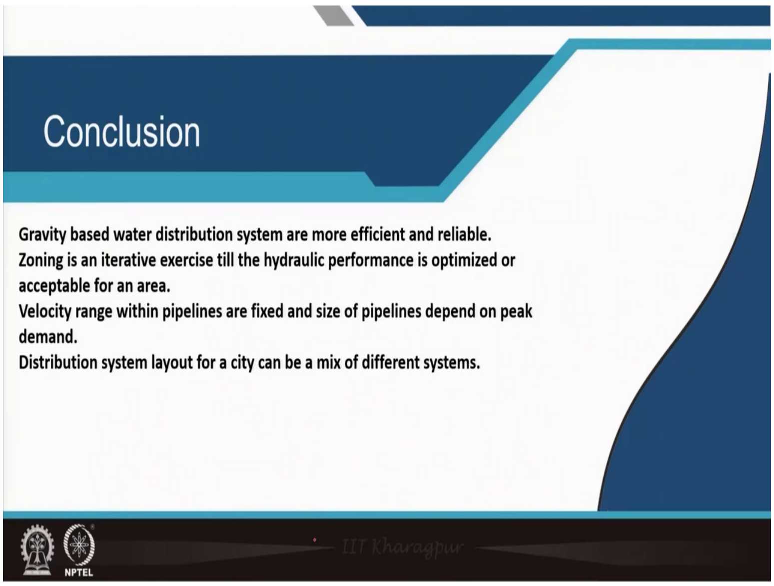

Conclusion

- Gravity based water distribution systems are more efficient and reliable.
- Zoning is an iterative exercise till the hydraulic performance is optimized or acceptable for an area.
- Velocity range within pipelines are fixed, and the size of pipelines depend on peak demand.
- The distribution system layout for a city can be a mix of different systems.

References

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