WATER DISTRIBUTION IN HIGH RISE BUILDINGS

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Introduction

The desire to build high into the sky has been a part of human existence for thousands of years. Just think of the pyramids in Egypt, the lighthouse of Alexandria in ancient Greece, or the Angkor Wat temple in Cambodia. High rise buildings have been used to represent political power and affluence, to honor statesmen or religious icons.

Over the last couple of hundred years, however, a more practical aspect has been built into these high-profile projects. High rise buildings reflected the need to make the best possible usage of a relatively small area of land in densely populated urban spaces across the world.

Further, with the increase in density of population in Indian cities, there is an exponential vertical development calling for high rise structures sprawling the city skylines. This poses a huge challenge when it comes to design of efficient water distribution systems in these high-rise structures. And when we talk about design of these distribution systems, it does not stop only with capacity calculation and piping design, but also on the intricacies of booster controls, which also avoids certain operating issues while running a booster system in high rise structures.

Water Distribution in general:

Pressure boosting can be necessary for one or more reasons as follows:

- Buildings placed on a hilltop where pressure supplied from mains is inadequate

Water pressure supplied from the mains is not sufficient to cover top floors

- Tall buildings where the height of the building prevents the community water from reaching the top floors. For example, a mains pressure of 3.0 bar should, theoretically, be sufficient for a 30-m tall building, but this is not the case. There must be sufficient surplus pressure

The principle of an elevated water tower
to cover resistance in riser pipes, single components such as shower heads, toilets and cooling towers

- The peak load flow might be greater than what is possible to supply from the mains. In these cases, a break tank is supplied to the building, from where one or more booster sets take the water and boost it to the required pressure level. The normal specifications are that the pressure on each floor does not fall below 1.5 bar and does not exceed 5 bar.

**Use of overhead tanks in high rise buildings:**

The use of overhead tanks to ensure adequate water pressure in buildings, and especially tall buildings, is very common. The alternative to overhead tanks is the use of pressurized systems, where several booster pumps provide the necessary pressure. Overhead tank solutions were originally created more than a century ago, as buildings grew taller and taller. The required water pressure for both fire-fighting and domestic use increased and mains water was insufficient to supply a whole building.

Moreover, reliable and efficient pumps for pressurized systems were not available. The immediate solution was to use standard pumps to lift the water to the tank. From the tank, gravity ensured a natural downwards flow and sufficient pressure. Despite improved and energy-efficient pressure booster technology, many buildings still have overhead tanks.

Overhead tanks allow the users to have both water pressure and water supply in situations where there is no electrical power. Overhead tanks vary greatly in size, but common to them all is that they feature "water at the ready", storing water for domestic purposes and fire-fighting.

The simple construction basically entails a tank, inlet and discharge piping, a float switch, and a pump. When the water level in the tank drops below a certain level, the float switch engages the pump, refilling the tank.

Though from a functional point of view, overhead tanks of today work adequately in many aspects, on the flip side, overhead tanks involve elements that are not always desired. Examples include higher capital costs due to the tank set-up and greater structural requirements, high operating costs, a lack of pressure control, and difficulty in maintaining the overhead tank itself.

In addition to serving as a storage device and creating pressure, roof-top tanks unfortunately can also serve as breeding grounds for bacteria constituting a major health risk. The exceptionally resistant bacteria legionella often appears as an unwelcome guest in water systems. To survive, the habitat for legionella and other micro-organisms arises in the biofilm created in the water system. Biofilm is created inside pipes and water tanks, serving as a protective barrier and breeding ground for the bacteria.

**System Elements & Layout**

**System elements:**

The booster system is based on several basic hydraulic elements that can be combined in different ways. Below, the most important elements are described briefly about the functionality and role in the booster application in general.

1) **Break tanks or Underground tanks**

Break tanks are implemented in boosting systems in order to supply the system if the mains supply becomes insufficient during peak demand, or if it is unstable. It is also used to ensure that a surge from starting and stopping pumps does not affect the mains distribution. Tanks are also implemented in series-connected boosting layouts to create...
manageable pressure zones. Here, the break tanks supply the taps in the tank’s own boosting zone as well as all the zones above it.

A major disadvantage with the break tank is that it is a pressure-neutral tank that absorbs the pressure coming from the public supply, removing any potential inlet pressure. This means that the booster system should supply all the pressure itself, instead of using some of the pressure coming from the inlet. Hygiene is also an issue for break tanks. Because of retention time, the tank should be cleaned regularly and break tanks often feature more than one compartment making it possible to clean the tanks. In some countries, it is not permitted to install booster sets directly on the incoming mains supply. This is primarily to ensure that water cannot be pressed back into the mains supply, thus avoiding the risk of contamination. In those countries, break tanks are a necessity in all booster installations. Normally, the break tank is sized by the consulting engineer and it is generally not regarded as part of the booster set.

A water tank is placed before the pump system and filled with water from the mains. This allows the capacity of the mains to be lower than the building’s peak demand, ensuring constant pressure even in peak flow situations. The break tank is filled with water during low-consumption periods, always ensuring even water supply to the booster pumps.

2) Booster Pumps:

Water distribution to buildings is vital for several reasons. People who live in multi-story buildings always need sufficient water and so does industrial processes. Therefore, high-quality pumps are crucial in booster systems.

What counts for all though, is the way the core of the pump is designed. Multi-stage pumps for boosters are all in-line multi-stage pumps. That means water pressure is gradually built up when the water passes through the different stages. When the final pressure level is met, the water exits the pump at the same level it entered. This is the in-line principle.

3) Risers and branches:

A building supply system is normally divided into risers and branches. In the risers, the geodetic height has been overcome, and the water is distributed to the different floors. The branches distribute water to each tap point. When using pressure reduction valves (PRV), the branches are often joined into main branches, creating a zone

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water always in stock</td>
<td>Pressure in mains is not utilized</td>
</tr>
<tr>
<td>Break tanks used on different floors in high rise buildings, makes sizing easier compared to single boosting from basement</td>
<td>Space is a scarce resource in modern high rise buildings, making it difficult to have the needed space allocated for break tanks</td>
</tr>
<tr>
<td>Break tanks must be kept clean and appropriately cleaning should be a scheduled activity</td>
<td>Break tanks must be kept clean and appropriately cleaning should be a scheduled activity</td>
</tr>
</tbody>
</table>
for each PRV to reduce the required number of PRVs. If the buildings are identical and with only one riser, PRVs will be needed at each floor. In the example shown to the right, we need to add PRVs on each branch on the building.

4) Pressure reduction valves (PRV)

To equalize pressure on all floors, PRVs are often used in multi-story buildings. The pressure is mechanically reduced directly by the spring, making it possible to adjust the pressure precisely for each floor. The PRV can either be used individually with one on each floor or in a branch of a riser supplying 2-3 floors. The PRV is a rather simple way of controlling the pressure throughout a tall building. However, there are some disadvantages when using PRVs:

- The PRVs also need maintenance and therefore they need to be placed at an accessible place
- Each PRV represents a loss, because of the energy consumed by creating higher pressure is wasted
- Risk of pipe damage and flooding if a pressure reduction valve fails and lets high pressure into a lower graded pipe net

This article delves more on the various system layouts that are practically used in water distribution in high rise buildings, indicating its merits and demerits.

System Layouts:

Booster systems may be designed in several different ways with the elements described above. Which layout to choose depends on many factors and the specific task in question, e.g. local legislation and traditions, flexibility requirements or the possibility for future expansions etc. Any one system layout is not ideal for all scenarios.

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- For each PRV needed in the building layout, the initial cost increases

Below, the advantages and disadvantages of some the most used system layouts are described.
Single booster system

Advantages
- Only one riser needed (simple design)
- No Space required on upper floors

Disadvantages
- Excess pressure on lower floors in buildings exceed ten floors (PRVs and high pressure graded pipes needed)

A single booster system is perhaps the simplest booster system available. It relies on a single set of pumps supplying pressure boosting from the basement to the point farthest away from the booster system. Basically, such systems may be configured with or without initial break tanks.

Zone-divided booster systems

The building is divided into pressure zones of ten floors or less with a booster supplying each zone from the basement through dedicated risers.

Advantages
- Manageable pressure zones
- Increased flexibility and security due to zoning
- No space required on upper floors
- Low-cost operation due to no residual pressure

Disadvantages
- Higher initial cost than single-zone systems
- Higher static pressure in upper zones (high-pressure graded pipes)

Overhead tanks with terrace booster system

Overhead tank systems use a transfer pump in the basement to fill the overhead tank by a level switch-operated control. The solution requires pressure reduction valves on each floor if the building exceeds approximately 15 stories, to avoid unwanted high static pressure at the taps in the lower floors. It also requires a terrace booster to provide the top floors with the required pressure, as static pressure there will be too low due to insufficient geodetic height at the overhead tank.

Advantages
- Mature Technology
- Small booster power due to roof tank working as buffer
- Reserve capacity in roof tank

Disadvantages
- Higher initial cost than single-zone systems
- High static pressure in upper zones (high-pressure graded pipes)

Series-connected systems with intermediate break tanks

Series-connected systems with intermediate break tanks draw on several other systems, utilizing centrally-placed break tanks to supply...
both the taps, the tank’s own boosting zone and all the zones above it. With this system, a building is divided into smaller and more manageable pressure zones. Every zone is then served by its own booster set.

Series-connected systems with intermediate break tanks.

Advantages

- Low pressure in each zone (no PRVs and less pressure-graded pipes needed)
- Manageable pressure zones
- Easy to size because each zone has its own supply tank

Disadvantages

- Higher initial cost than single-zone systems
- Space required for booster sets and tank on service floors
- Risk of Microbiological growth in tanks

Series-connected systems without intermediate break tanks

Advantages

- Low pressure in each zone (no PRVs and less pressure-graded pipes needed)
- Manageable pressure zones
- No space required for tanks
- Less excess boosting (low operation costs)

Disadvantages

- Higher initial cost than single-zone systems
- Space required for booster sets and tank on service floors
- Complex control

A series-connected system operates on the same principles as the previously mentioned system, but without the intermediate break tanks. This enables an effective usage of power as the water is only pumped to the part of the zone where it is used and not past it. However, complete control is very important. When a consumer draws water on the upper floors, the booster systems must be able to deliver the water from the bottom of the building.
Illustration

An example is given to illustrate the differences between the previously mentioned system layouts in terms of necessary hydraulic power (P4) and energy consumption (E4) for water transport in a high-rise building.

The Building footprint is 1,600 m² (40 m x 40 m)

Building case

The imaginary building case is 80 meters tall, comprising 19 floors and 5 different hydraulic zones as illustrated on the building to the left. The building footprint is 1,600 m² (40 m x 40 m).

Each of the five hydraulic zones has different users and thereby different consumption profiles, operating hours, peak flow requirements, etc. These conditions are listed below.

The zone weight-averaged load profile is shown in the graph below. The graph represents the combined water consumption pattern during a typical day (dark blue curve) for the whole building. Arranged as a cumulative load profile (light blue), the number of hours at different duty points are easily interpreted.

The total building peak flow demand is 46.8 m³/h. However, taking the load profile into consideration the peak flow is simultaneously corrected to 36.2 m³/h.

Evaluated booster layouts

- A: Single-booster system
- B: Zone-divided single booster system
- C: Single-booster system with roof top tank
- D: Series-connected booster system with intermediate break tanks in zones
- E: Series-connected booster system without break tanks

In this example, layouts with tanks (C and D) are designed so that the tank capacity equals 4 hours of peak load. This corresponds to approximately 60% of the daily water consumption.

<table>
<thead>
<tr>
<th>Booster zone</th>
<th>No. of floors</th>
<th>Zone height</th>
<th>Usage</th>
<th>Persons</th>
<th>Min. tap pressure</th>
<th>Peak flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 5</td>
<td>1 floor</td>
<td>4 m</td>
<td>Penthouse apartments</td>
<td>16 residents</td>
<td>200 kPa</td>
<td>0.3 m³/h</td>
</tr>
<tr>
<td>Zone 4</td>
<td>1 floor</td>
<td>4 m</td>
<td>Restaurant</td>
<td>160 seats</td>
<td>200 kPa</td>
<td>6.0 m³/h</td>
</tr>
<tr>
<td>Zone 3</td>
<td>7 floors</td>
<td>30m</td>
<td>Apartments</td>
<td>450 residents</td>
<td>150 kPa</td>
<td>8.3 m³/h</td>
</tr>
<tr>
<td>Zone 2</td>
<td>6 floors</td>
<td>25 m</td>
<td>Landscaped offices</td>
<td>640 employees</td>
<td>150 kPa</td>
<td>27.6 m³/h</td>
</tr>
<tr>
<td>Zone 1</td>
<td>4 floors</td>
<td>17 m</td>
<td>Shopping centres</td>
<td>100 employees</td>
<td>150 kPa</td>
<td>4.6 m³/h</td>
</tr>
</tbody>
</table>
Hydraulic booster size and energy consumption

The necessary hydraulic booster power (P4) and energy consumption linked to the building case varies per booster system configuration in question.

Also, equally important are the booster system controller’s capabilities to address to certain practical issues in high rise buildings, such as:

1. Avoiding surge in vertical pipe lines/shafts through Soft fill functionality

2. Proportional Pressure functionality to reduce higher pressures on pipes and fitting during low flow system conditions

3. Low flow stop functionality to avoid churning of pumps during low consumption periods

Generally, major operating issues occur in high rise structures since these factors are not taken into consideration while designing the booster systems controls.

To conclude, a properly sized, zone divided booster system would be more efficient for the operating life of a high rise building when compared to other systems discussed in this article.

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