WATER BOOSTING IN COMMERCIAL BUILDINGS

APPLICATION GUIDE

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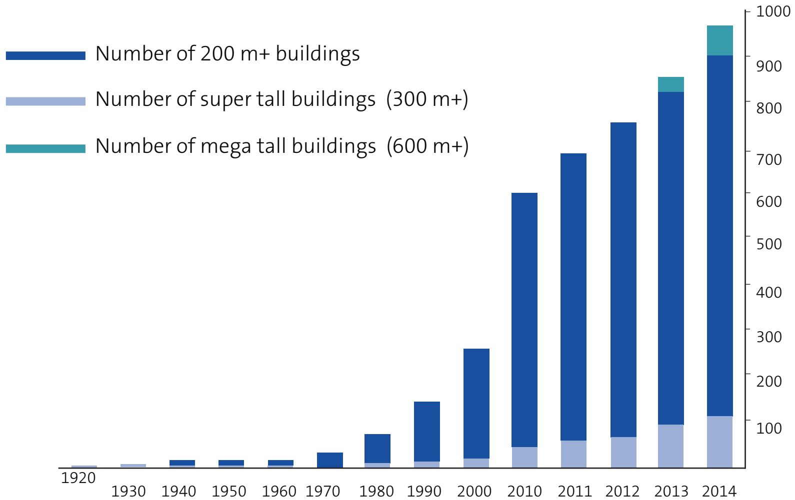
PREFACE

People move together at a pace like never before. Urbanisation is here to stay. Globally, city populations are growing by 65 million every year with most of this growth taking place in Asia and China. It is projected that by 2025, more than 2.5 billion people will live in Asian cities, which is half of the world's total city dwellers.
As people move closer together, buildings need to be taller. The acceleration in the numbers of tall buildings can be seen in the figure below.
The development and construction of these tall buildings increased from the start of the new millennium.
Tall buildings require water for tap water and cooling towers to function properly, and providing sufficient water to a tall building is a discipline of its own.
In addition, buildings in general account for 40% of the world's energy consumption so tall buildings is a good place to start if we want to save energy globally. We believe that water boosting is an overlooked area for optimisation and there is considerable difference between the best and the worst booster system designs.
How to evaluate the best way to do it will be examined in this water boosting guide, and we will present a number of arguments for water boosting.

Enjoy.



Yearly development in tall buildings

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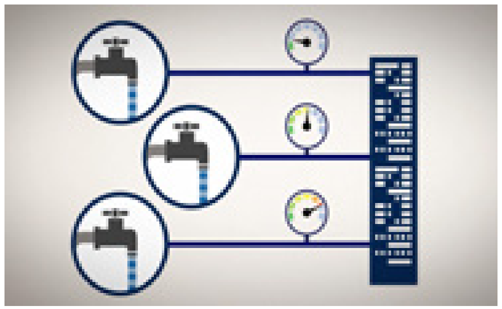
WHEN IS WATER BOOSTING NECESSARY?

Pressure boosting can be necessary for more reasons. Let us go through a few:

- Buildings placed on a hilltop where pressure supplied from mains is inadequate.
- 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 300 m tall building, but in reality this is not the case. There must be sufficient surplus pressure 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.

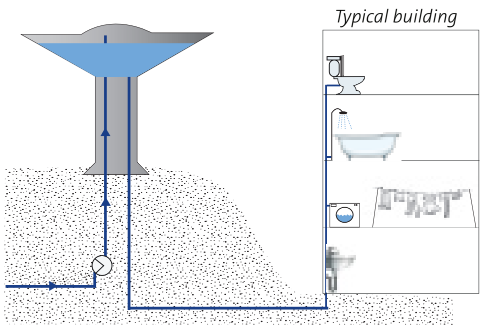
The normal specifications are that the pressure on each floor does not fall below 1.5 bar and does not exceed 5 bar.

In areas with buildings placed on hilltops, it can be necessary to boost water pressure.



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

Pont du Gard, a Roman aqueduct in France.



The principle of an elevated water tower.

History of Water Supply and Sanitation

Throughout history, people have devised systems for obtaining and using water more conveniently.

One early example is the Indus Valley civilisation in Asia, which showed early evidence of public water supply and sanitation. The system the Indus developed and managed included a number of advanced features. A typical example is the Indus city of Lothal where all houses had their own private toilet connected to a covered sewer network. Since then, engineering and plumbing have developed significantly.

Now, things have changed as we have water towers and pump stations.
The use of water towers increased drastically during mid-19th century.
A water tower is an elevated structure supporting a water tank constructed at a height sufficient to pressurise a water supply system for the distribution of potable water, and to provide emergency storage for fire protection. Water towers are able to supply water even during power outages, because they rely on hydrostatic pressure produced by elevation of water (due to gravity) to push the water into domestic and industrial water distribution systems. However, they cannot supply the water for longer periods without power, because a pump is typically required to refill the tower. A water tower also serves as a reservoir to help with water needs during peak usage times. The water level in the tower typically falls during peak usage hours during the day, and then a pump fills it back up during the night. This process also keeps the water from freezing in cold weather, since the tower is constantly being drained and refilled.

Insufficient coverage from the mains

Every building has its own load profile in the sense that peak flow occurs at a specific time of the day for the building in question.
The water work supplying water to the building may, however, be unable to provide the maximum flow required. In such cases, break tanks have to be installed. These tanks serve as storage tanks from where pump systems can provide the flow required for the entire building. An example of a typical booster application is shown on this page.

Water boosting applications

When do you need water boosting? The reasons for water boosting can be many:

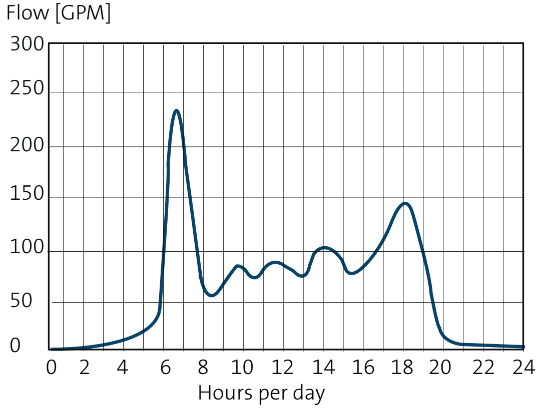
- High-rise buildings.
- HVAC; where water needs to be pressurised for heating and cooling applications.
- Fire fighting
- Irrigation; a golf course, for example.
- Commercial water supply.

This document will only focus on high-rise buildings.

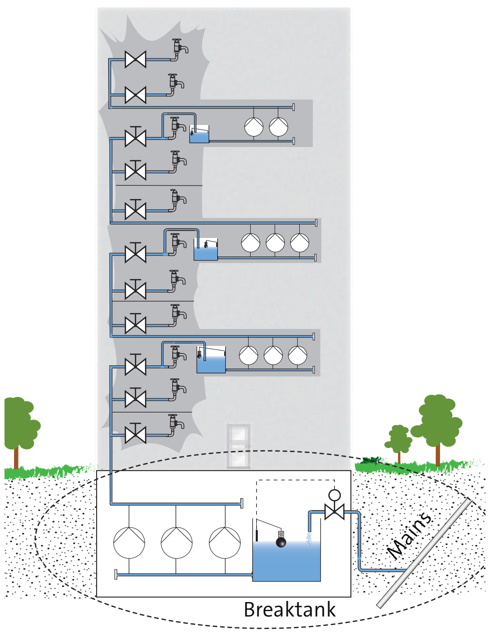
CONSUMERS

Load profiles

Different load profiles occur for different buildings as already described in the previous section.
In order to obtain a better overview on how much water is consumed based on use, the table below can serve as guidance. The more one knows about the actual use, the more likely it is that the final annual energy consumption can be as low as possible.



Water consumption load profile during a 24-hour period.



Typical booster application with break tanks and booster systems on service floors.

Q_{year} m³/year:
How much water is consumed on a yearly basis per person (e.g. 25 m³/year/person in an office building).

Consumption period, days/year:
How many days a year the building is projected to be in operation.

$Q(m)_{day}$ / m³/day :
How much water is consumed per person per

day (office building: 25/250= 0,1)
fd: Concurrency factor.
ft: Peak flow factor.
Max. flow rate, m³/h
Max. flowrate per hour per unit; e.g. 0.018 m³/h per employee in an office building.

Consumer	Unit	Q_{Year} m³/year	Consumption period days/years	Q_{day} m³/day	fd	$Q(m)_{day}$ m³/day	ft	Max flow rate m³/h
Residence building	Residence (2.5 persons)	183	365	0,5	1,3	0,65	1,7	0,046
Office building	Employee	25	250	0,1	1,2	0,12	3,6	0,018
Shopping centre	Employee	25	300	0,08	1,2	0,1	4,3	0,018
Supermarket	Employee	80	300	0,27	1,5	0,4	3,0	0,05
Hotel	Bed	180	365	0,5	1,5	0,75	4,0	0,125
Hospital	Bed	300	365	0,8	1,2	1,0	3,0	0,12
School	Pupil	8	200	0,04	1,2	0,065	2,5	0,007

Example of key numbers for various consumer types.
This figure is assumptions based on Danish legislation DS 442/1989 Code of Practice for common water-works. Calculation of water flow etc. may vary from country to country, depending on national guidelines and legislation.

Tap pressure

Normally, tap pressure is set to be within the range 1.5 - 5.0 bar,
Due to difference in height or elevation, in a tall building, pressure will gradually decrease as the water 'moves' upwards. Example:
When one booster zone covers, e.g., five 4.2 m floors, the pressure will as a minimum decrease 5 x 4.2 = 21 mWc

Firefighting

Fire protection is a highly regulated area and around the world there are different standards determining: the design; performance; system approval and maintenance of fire extinguishing systems.
The relation to pressure boosting is rather limited with one exception though. Hose reel systems are often connected to the booster system and, as such, this also affects the sizing of the booster system. Here, it is not possible to give solid advice on how to size booster systems when these need to supply hose reels. You should only emphasise that local regulations must always be addressed.

Cooling towers in operation with mist coming up from the cooling towers.

Supply of water for cooling towers

The relation to cooling seen from a water boosting perspective is the sum of:

1. **Evaporation in the cooling towers**.

2. **Water used for blow-down:** Water consumed for blow-down accounts for the majority of water usage. The actual amount is influenced by the level of water treatment, as the better the water treatment, the less water has to be wasted for the blow-down operation.

3. **Water drift due to wind:** Drift is water leaving the tower due to wind passing through the tower. The related loss is uncontrollable and is typically calculated as a percentage of the total recirculating flow. Depending on the tower design, this value can vary greatly, but figures like 0.008 % are used as a rule-of-thumb value for new systems.

4. The evaporated water has to be replaced by tap water, often referred to as make-up water. The amount of make-up water is influenced by several elements, e.g. where is the system placed, wet bulb temperature etc. In Denmark there is a rule of thumb, saying that approximately 1.12 m^3/h per MW of cooling capacity.

   According to an ASHRAE study, the below rule of thumb can be used:

   SI: 0,0004 L/s x kW.

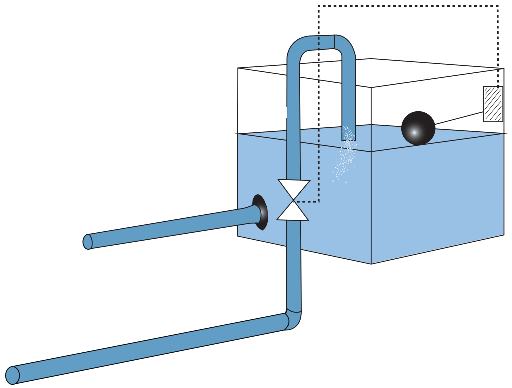
SYSTEM LAYOUT

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 as regards to functionality and role in the booster application.

Break 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 (see chapter on layouts).
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 has to 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 has to 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.



Break tank with level switch

Boosting with break tank

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, ensuring an even water supply to the booster pumps at all times.

Boosting with Break Tank
Advantages
Water always in stock
Break tanks used on different floors in high rise buildings, makes sizing easier compared to single boosting from basement
Disadvantages
Pressure in mains is not utilized
Space is a scare resource in modern high rise buildings, making it difficult to have the needed space allocated for break tanks.
Break tanks must be kept clean and appropriate cleaning should be a scheduled activity.

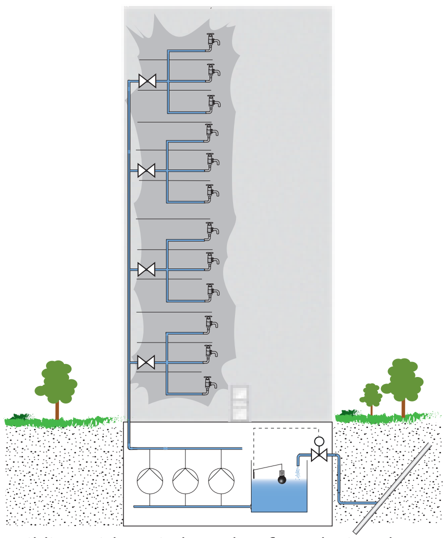
Boosting without Break Tank
Advantages
The inlet pressure from the mains is utilized thus lowering the amount of energy required from the booster.
Disadvantages
Sensible to unstable water supply

Booster pumps

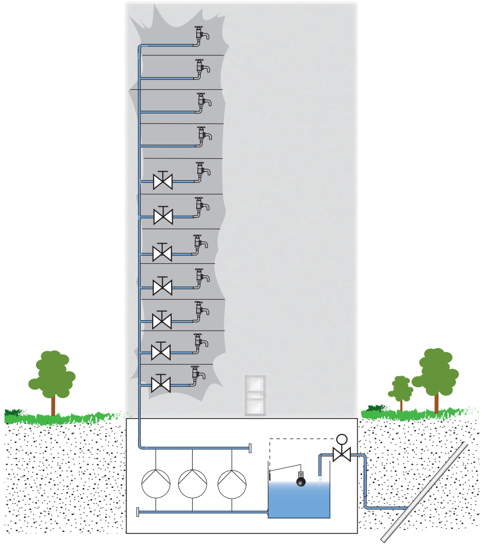
Water distribution to buildings is vital for several reasons. People who live in multi-story buildings need sufficient water at all times, and so do industrial processes. Therefore, high-quality pumps are crucial in booster systems. Grundfos uses different types of multi-stage pumps, one being the multi-stage type which again comes in a wide variety of models.
What counts for all though, is the way the core of the pump is designed. Multi-stage pumps for booster's 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.

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 for each PRV in order 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.



Building with main branches for reducing the number of pressure-reducing vales

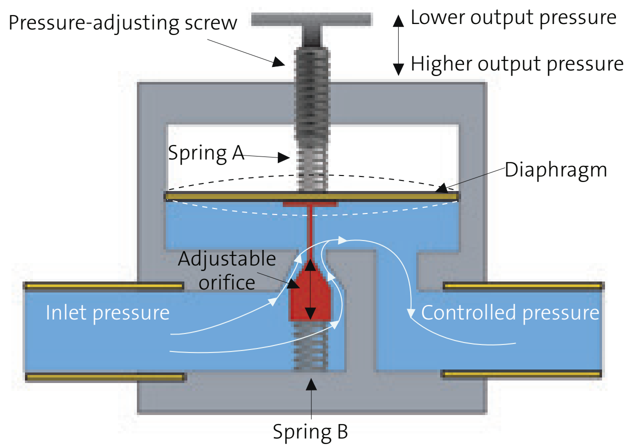


Building with one branch per floor

Pressure reduction valves (PRV)

To equalise pressure on all floors, PRVs are often used in multi-story buildings. The pressure is mechanically reduced directly in the string, 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 raiser 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:

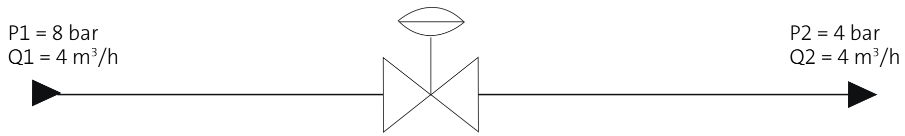
- For each PRV needed in the building layout, the initial cost increases.
- The PRVs also need maintenance and therefore they need to be placed at an accessible place.
- Each PRV represents a loss, because of the energy consumed by creating higher pressure is wasted.
- Risk of pipe damage and flooding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



In one type of PRV, a diaphragm flexes in response to the pressure on the outlet side of the valve. This diaphragm is attached to the moving part of a variable orifice valve. The movement of the diaphragm is counteracted by two springs and an adjustable screw to adjust the output pressure.

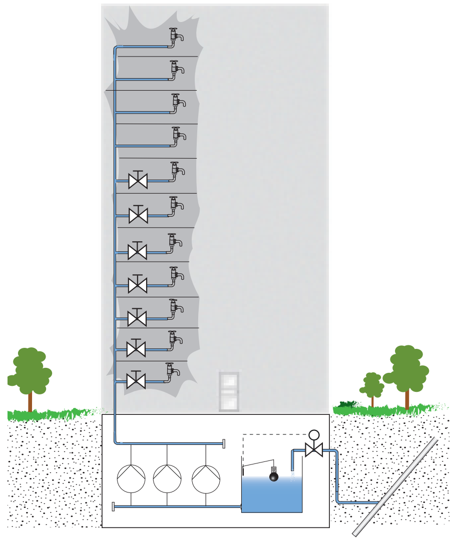
Example: Energy wasted in the pressure relief valve

The presence of PRVs will cause a waste of built-up pressure and thus energy. This is illustrated by a simple example.
A high-rise building needs pressure boosting from the basement floor. In the example, a maximum water tap pressure of 4 bar is allowed. However, due to the system layout, excessive pressure is present in the lower part of the system. This is dealt with by installing PRVs in main branches before the taps. Below it is illustrated how an excess pressure of 8 bar is reduced to the allowed 4 bar. The pipe will supply a water flow of 4 m^3/h.

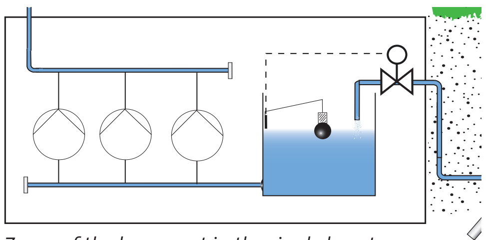


Available hydraulic power before the PRV:
$P1 = q1/3{,}600 \times p1 \times 10^2$
$P1 = 4\ m^3/h\ /\ 3{,}600\ s/h \times 8\ bar \times 102\ kPa/bar = 0.91\ kW$

After the PRV, the pressure is halved from 8 bar to 4 bar, resulting in only half the hydraulic power, P2 = 0.45 kW. As such, the PRV represents a power loss of 0,45 kW. Depending on the number of operating hours, this necessary excess pressure will potentially consume a lot of energy. For, e.g., 4,000 hours of operation per year, this PRV alone will ‘consume’ 1,800 kWh/year.



Single booster system with one branch per floor.



Zoom of the basement in the single booster 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. Not one system layout is ideal for all scenarios.
Below, the advantages and disadvantages of some the most used system layouts are described.

Single booster system

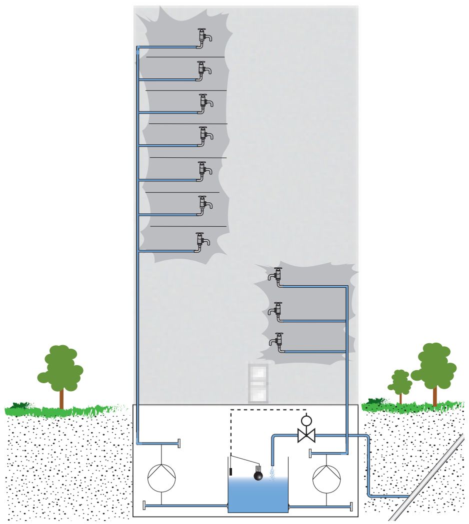
A single booster system is perhaps the most simple booster system available. It relies on a single set of pumps supplying pressure boosting from the basement to the point farthest away from the booster system. Basically, such systems may be configured with or without initial break tanks.

Single Booster System
Advantages
Only one riser needed (simple design)
No space required on upper floors
Disadvantages
Excess pressure on lower floors in buildings exceeding ten floors (PRVs and high-pressure graded pipes needed)

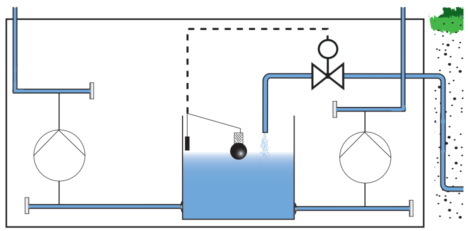
Zone-divided booster systems

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

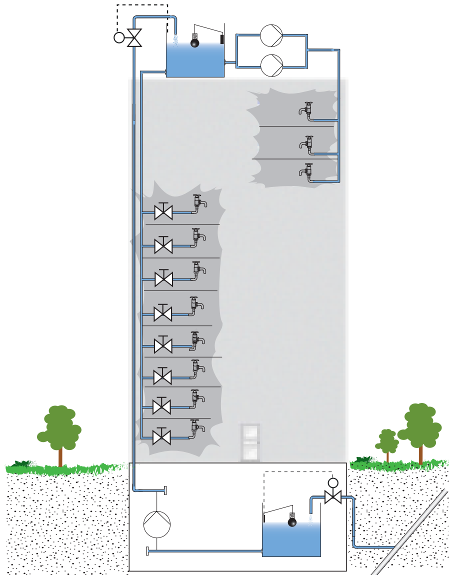
Zone-divided booster systems
Advantages
Manageable pressure zones
Increased flexibility and security due to zoning
No space required on upper floors
Low-cost operation due to no residual pressure
Disadvantages
Higher initial cost than single-zone systems
High static pressure in upper zones (high-pressure graded pipes)



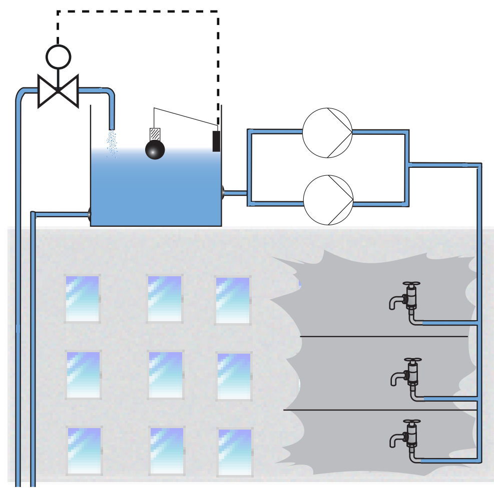
Zone-divided system



Zoom of the basement in the zone divided booster system.



Roof tank system



Zoom of the application on the roof in the roof tank system.

Roof tank systems

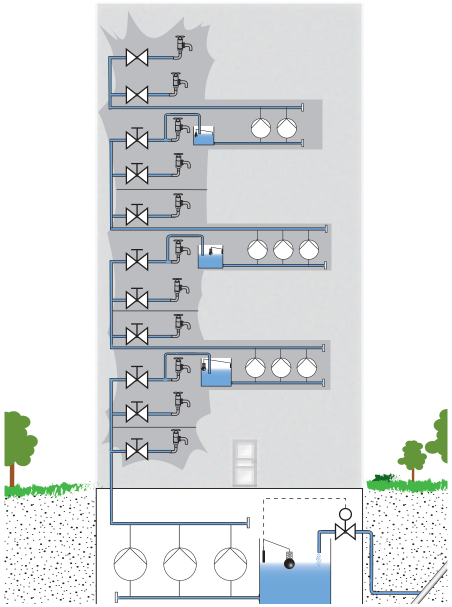
Rooftop tank systems are very common, especially in the USA, and uses a fill pump in the basement to service the roof tank by a level switch-operated control. This way the roof tank ensures water pressure as well as water supply. The solution requires pressure reduction valves on each floor if the building exceeds approximately 15 stories, in order to avoid unwanted high static pressure at the taps. It also requires a booster to provide the top floors with the required pressure, as static pressure there is too low due to insufficient geodetic height at the roof tank.

Roof-Tank Systems
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)

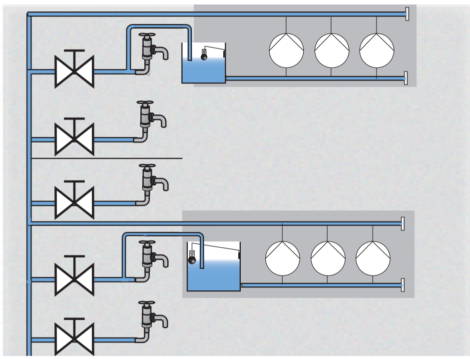
Series-connected systems with intermediate break tanks

Series-connected systems with intermediate break tanks draw on several other systems, utilising 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.

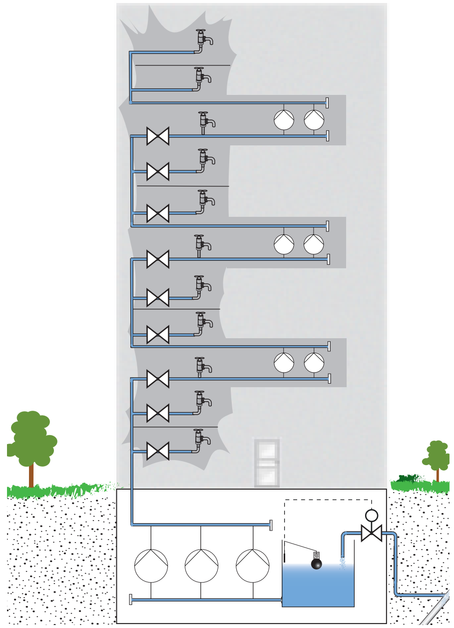
Series-connected systems with intermediate break tanks
Advantages
Low pressure in each zone (no PRVs and less pressure-graded pipes needed)
Manageable pressure zones
Easy to size because each zone has its own supply tank
Disadvantages
Higher initial cost than single-zone systems
Space required for booster sets and tank on service floors
Risk of microbiological growth in tanks



Series-connected systems with intermediate break tanks. In this example, we have three boost zones.



Zoom of the two first boost zones.
Note that the break tanks become smaller, as we move up in the building. This is due to a decreasing need for water.



Series-connected systems without intermediate break tanks

Series-connected systems without intermediate break tanks

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.

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

SIZING

Pressure head

The term 'pressure head' refers to the height of a column of fluid of specific weight required to give a pressure difference:

$$H = \frac{\Delta P}{\rho \times g}$$

where

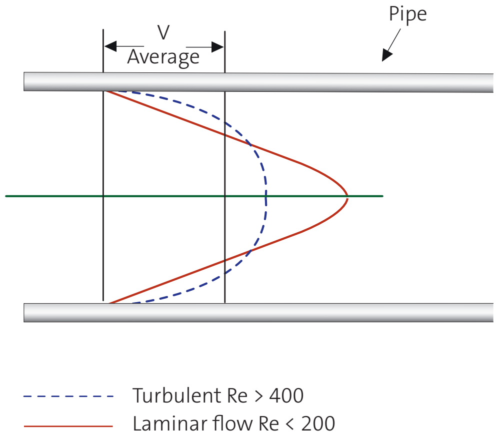
H = pressure head [m]
ΔP = pressure difference [Pa]
p = fluid density [kg/m³]
g = gravitation acceleration [m/s²]

Head Rise

Sizing a booster system is all about determining the necessary pressure rise that the pumps have to deliver in order to transport the fluid from one location with a given initial pressure to another with a required tap pressure, though a closed conduit.
The transportation of water through the pipe system requires the pumps to overcome the pressure head loss of the system. The head loss is a combination of friction loss in straight pipe and friction loss in system components.
In addition to the head losses, the booster also have to overcome any change in elevation (static height) from system inlet to outlet.
The necessary discharge pressure required of the booster set is calculated as:

$$h_p = h_{tap} + h_z + h_L - h_0$$

where
h_p = head rise by booster pumps [m]
h_{tap} = head at tap point (tap pressure) [m]
h_z = head elevation (static height) [m]
h_L = head loss in the pipe system [m]
h_0 = head at system entrance [m]



Velocity profile in pipe flow

Static height

Any elevation change in the transportation system requires an additional head rise equal to the height. This is also called the static height because it does not change and thus determines the minimum capacity of the booster set. The static height is determined as the elevation from the booster's discharge pipe to the highest tap point. If the building is divided into zones the static height of each zone has to be determined.

Major head loss

When transporting a viscous fluid (water) in a closed conduit (pipe), shear stresses appear in the intersection between solid wall and fluid due to friction, resulting in a velocity profile across the pipe diameter. Near the pipe wall, the fluid only experiences very little movement. However, closer to the centerline, the fluid flows more freely and thus at a higher speed. This friction loss has to be overcome by the booster pumps in order to generate the desired water pressure.
The nature of the flow, either laminar, turbulent or somewhere in between, is characterised by Reynolds number. In the illustration to the left, the velocity profile is shown for fully developed laminar and turbulent flows.

The very close area near the pipe wall is called the viscous sub layer. This is where the fluid touches the solid wall, and it is thus of key importance for the friction loss in straight pipe flow when considering turbulent flow. A rough wall (large contact area with fluid), e.g. pipes made of cast iron or concrete will generate large shear stresses and subsequently require more booster power for the same flow than had the pipe wall been made of a more

smoothmaterial as, for example, galvanised iron or, preferably, plastic.
The pressure loss in straight pipe flow is a function of the average fluid velocity, pipe length, wall roughness, fluid viscosity and fluid density. This pressure loss – the major head loss — is calculated as

$$h_{L\,major} = f \frac{l}{D} \frac{v^2}{2g}$$

Where

h_L major = major head loss [m]
f = friction factor [-]
l = pipe length [m]
D = pipe diameter [m]
v = fluid velocity [m/s]
g = gravitation acceleration [m/s^2]

The friction factor is the tricky part of the calculation. It is a complex function of the Reynolds number and the roughness of the pipe that cannot, as yet, be obtained from a theoretical analysis. In practice, exhaustive set of curve-fitted experimental data is used, often in its graphical form – the so-called Moody chart – or in the form of the Colebrook formula, which requires an iterative solution scheme.

It's not only straight pipes results in pressure losses, also bends and other components count is a factor when it comes to reduceing pressure loss.

Friction losses

Most pipe systems consist of considerably more than just straight pipes. These additional components (valves, bends, tees, etc.) add to the overall head loss of the system. Such losses are generally termed minor losses and are calculated as:

$$h_{L\,minor} = K_L$$

Where

$h_{L\,minor}$ = minor head loss [m]
K_L = loss coefficient [-]
v = fluid velocity [m/s]
g = gravitation acceleration [m/s^2]

The loss coefficient (KL) is a function of the Reynolds number and the geometry of the component. It is determined experimentally and may be found in tables.
As noticed, the head loss (both major and minor) is a function of the fluid velocity, which means that it will increase for higher flow rates – it is a so-called dynamical pressure head. Combined, it may be expressed as:

$$h_L = h_{L\,major} + h_{L\,minor} = \frac{v^2}{2g}\left(f = \frac{l}{D} + \sum K_L\right)$$

Determining pipe dimensions and required booster capacity

The pipe pressure loss from the booster to the farthest tap point in each zone has to be calculated in order to determine the required discharge pressure for the booster pumps. This is done on the basis of the highest flow rate in each part of the pipes and the dimension and roughness of the pipes, as well as the loss coefficient value from valves and bends in the system. The flow rate is determined based on a detailed calculation of the combined water consumption in the different tap points, flush valves, outlets etc.
An easy way to do this is to use the calculator in the Grundfos Product Center sizing tool. In Grundfos Product Center, the KL-value is termed 'Zeta'.

FRICTION LOSSES

Pipe	Pipe length	Pipe material	Pipe size	Roughness	Flow	Zeta	Friction losses
1	25 m	Galvanized	DN 100 (10(	1 mm	100 %	2 Calculate	0 m
2	60 m	Copper pipe		0.5 mm	100 %	Calculate	m
3	10 m	PE100 PN1(		0.25 mm	100 %	Calculate	m
4	0 m	PE100 PN1(		0.25 mm	100 %	Calculate	m
5	0 m	PE100 PN1(		0.25 mm	100 %	Calculate	m
6	0 m	PE100 PN1(		0.25 mm	100 %	Calculate	m
7	0 m	PE100 PN1(		0.25 mm	100 %	Calculate	m

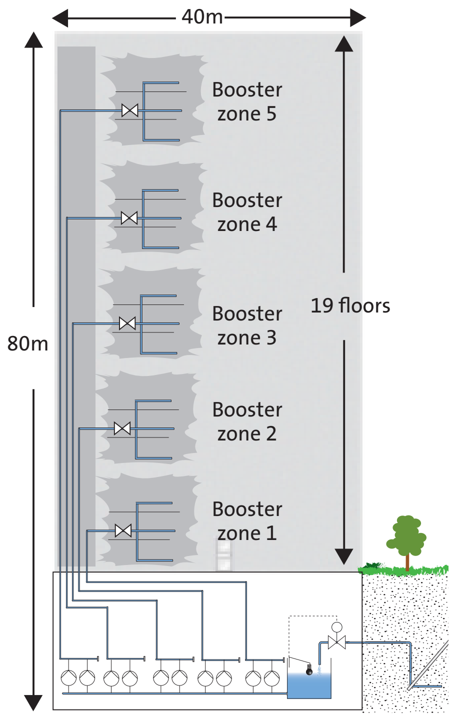
KL-value (Zeta) can be calculated in Grundfos Product Center

SYSTEM LAYOUT EXAMPLE

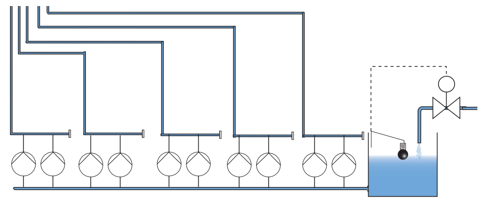
An example is given to illustrate the differences between the previously mentioned system layouts in terms of necessary hydraulic power (P4) and energy consumption (E4) for water transport in a high-rise building.

Building case

The imaginary building case is 80 metres tall, comprising 19 floors and 5 different hydraulic zones as illustrated on the bulding to the left. The building footprint is 1,600 m^2 (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 building footprint is 1,600 m^2 (40 m x 40 m)



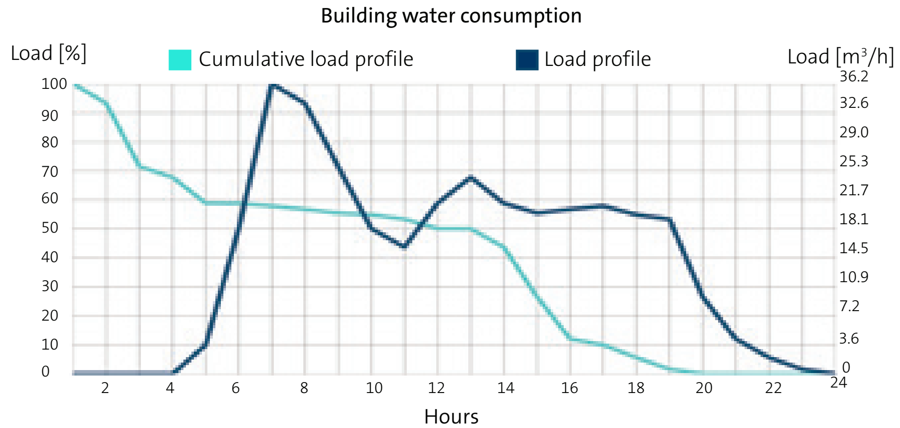
Zoom of the basement with 5 booster sets

Booster zone	No. of floors	Zone height	Usage	Persons	Min. tap pressure	Peak flow
Zone 5	1 floor	4 m	Penthouse apartments	16 residents	200 kPa	0.3 m^3/h
Zone 4	1 floor	4 m	Restaurant	160 seats	200 kPa	6.0 m^3/h
Zone 3	7 floors	30m	Apartments	450 residents	150 kPa	8.3 m^3/h
Zone 2	6 floors	25 m	Landscaped offices	640 employees	150 kPa	27.6 m^3/h
Zone 1	4 floors	17 m	Shopping centres	100 employees	150 kPa	4.6 m^3/h

Pressure losses in building

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 simultaneity corrected to 36,2 m³/h.



Zone weight-averaged load profile for the whole building.

Evaluated booster layouts

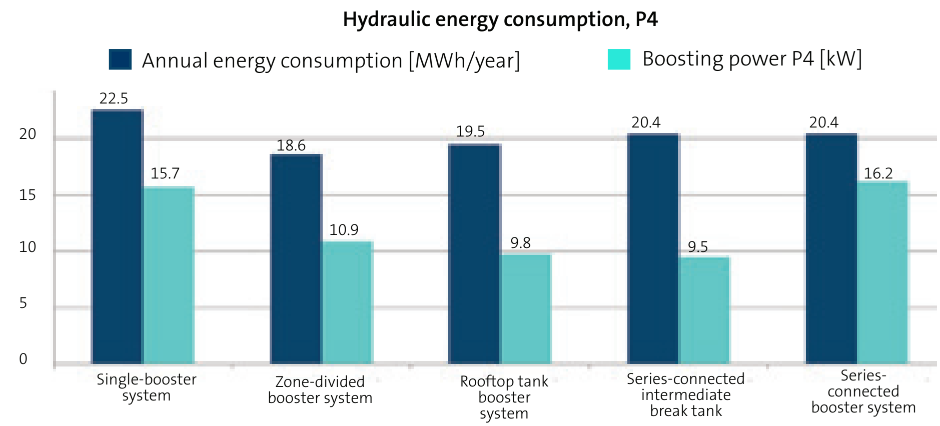
The evaluated system configurations in the design tool are:

- 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.

Hydraulic booster size and energy consumption

The necessary hydraulic booster power (P4) and energy consumption linked to the building case varies according to the booster system configuration in question.
The result of a rough sizing is shown in diagram below.



Energy consumption and required hydraulic booster power using different system layouts.

In this example, series-connected pressure boosting systems with break tanks require the smallest boosting power closely followed by the roof tank solution. However, choosing a zone-divided system, where each zone is supplied by its own booster system will reduce the annual energy consumption by approximately 10% and only require approximately 15% larger booster capacity. Additional benefits like eliminating the need of intermediate break tank, separation of system in hydraulic zones etc. could easily make such systems favourable.
The size of water tanks in booster systems greatly affects the necessary booster capacity and thus the result of the example given above would change with a different tank volume.

Key system parameters

The pressure boosting system consist of many parts all more or less influencing the system size, performance and energy consumption. However, which ones are most important to focus ones attention on in the design phase? Grundfos has recently carried out a research study investigating the sensitivity of such parameters on the hydraulic side of pressure boosting systems. This is done by means of an influence coefficient (IC) describing the influence of changes in a given parameter, e.g. pressure loss in riser pipes (Pa/m), on the total hydraulic booster power necessary in a system. As such, the IC value of a given input parameter describes the magnitude of total variability in the output parameter that is caused by the given input parameter. E.g. if the pressure loss in riser pipes constitutes an IC value of 5%, it means that only 5% of any change in pressure loss is 'felt' by the booster pumps. Such knowledge is vital when designing systems, as it enables the designer to focus on parameters that truly influence the result instead of spending time determining and sizing parts of the system that only influence the result marginally.

In the table below, some of the parameters often considered are listed and ranked according to their influence coefficient, when considering the hydraulic booster power, P4.
Parameters marked in green have an IC value above 50% and special attention should thus be paid to determining the correct value of those parameters. Likewise, parameters marked in red only constitute IC values below 10% and are, as such, negligible in the overall picture.

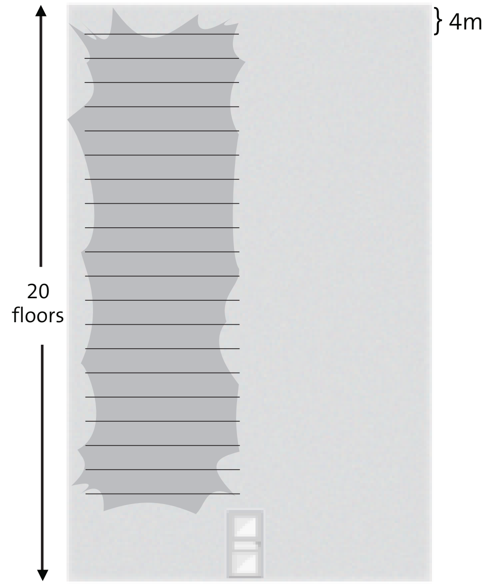
Hydraulic power, P4			
Rank	*IC*	*Parameter*	*Note*
1	*100%*	*Number of units (people)*	
1	*100%*	*Unit peak load*	
3	*61-80%*	*Building height*	
4	*52-66%*	*Tank volume (rooftop tanks and break tanks)*	*Only relevant for C, D and F*
5	*3-22%*	*Tap pressure*	
6	*13-20%*	*Number of subdivided hydraulic zones*	*Only relevant for B, D, E and F*
7	*4-19%*	*Hourly load profile (variation in 1 hour)*	*Only relevant for C and D*
8	*2-9%*	*Pressure loss in coupling pipes*	
9	*5%*	*Pressure loss in riser pipes and branches*	
10	*2-3%*	*Pressure loss in water meter*	
10	*2-3 %*	*Pressure loss in manifold*	
12	*0-2%*	*Distance from riser to manifold (horizontal)*	*Not relevant for any system*
13	*0%*	*Consumption period (days per year)*	

Sensibility of system parameters

Example: Sizing a booster system

A new hospital with 800 beds needs a booster system for the whole building. In this example, we will compare two solutions to see which is better in relation to total energy consumption. We will start by using Grundfos Product Center to calculate the data we need to size our booster pumps.

No. of beds: **800***
Water consumption per bed: **300/m³/year****
Min. pressure at tap's: **2.5 bar**
Max. allowable pressure at tap's: **4.0 bar**
No. of floors: 19 + basement = **20 floors**
Floor height: **4.0 m**
Building height (20 x 4) = **80 m**
Flow/floor = 100/20 = **5 m³/h**



* Total consumption for the building: (300* x 800*) = 240,000 m³/year

** Maximum hour consumption = Annual consumption x (fd/365) x (ft/24)
fd = days factor
ft = time factor
Maximum hour consumption = (300 x 800) x (1.2/365) x (3/24) = 98.6 m³/h (adjusted to 100 m³/h)

Example: Sizing a booster system - Zone divided solution

First, we will take a look at a zone-divided solution, where we use five booster sets to service the hospital.
The five boosters are all placed in the basement. Booster 1 will deliver flow and pressure needed around the basement. For example: Laundry room and cooling and heating activities ect.
The four remaining booster sets will handle the rest of the bulding and mainly cater for the needs of patients and doctors. The four boosters will service four floors each.

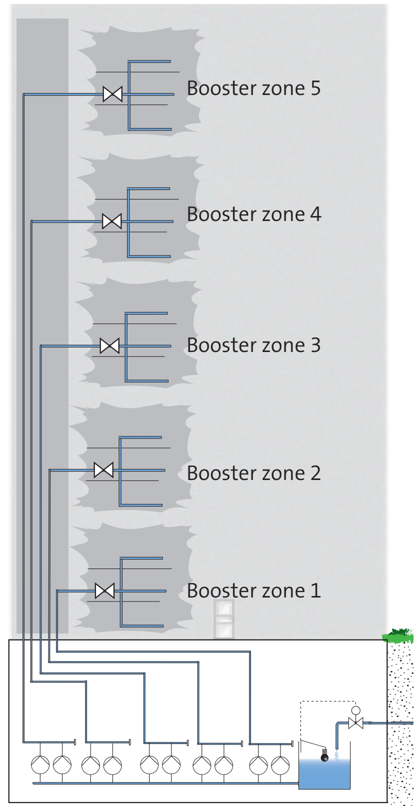
Booster 1 (60% of total energy consumption)

240,000 x 0,6 = 144,000 m³/ year
144,000 / 365 = 394.5 m³/ day
394.5 / 24 = 16.44 m³/ hour
16.44 x 1.8* = 29.59 m³/hour **

** = peak factor*
** = Max consumption

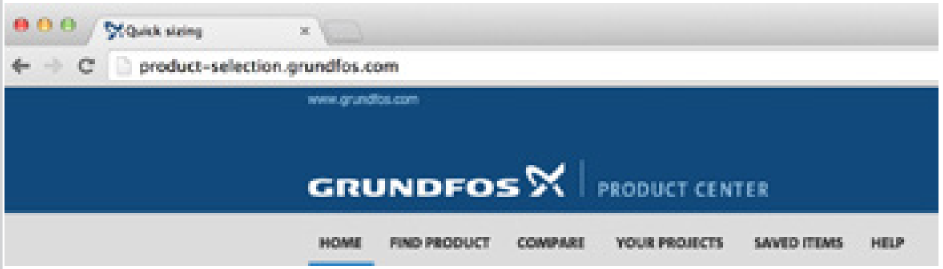
Booster 2 – 5 (40% of total energy consumption)

240,000 x 0,4* = 96,000 m³/ year
96,000 / 4 = 24,000 m³/year/booster
24,000 / 365 = 65.75 m³/ day
65.75 / 24 = 2.74 m³/ hour
2.74 x 1.8 = 4.93 m³/hour (max. consumption)



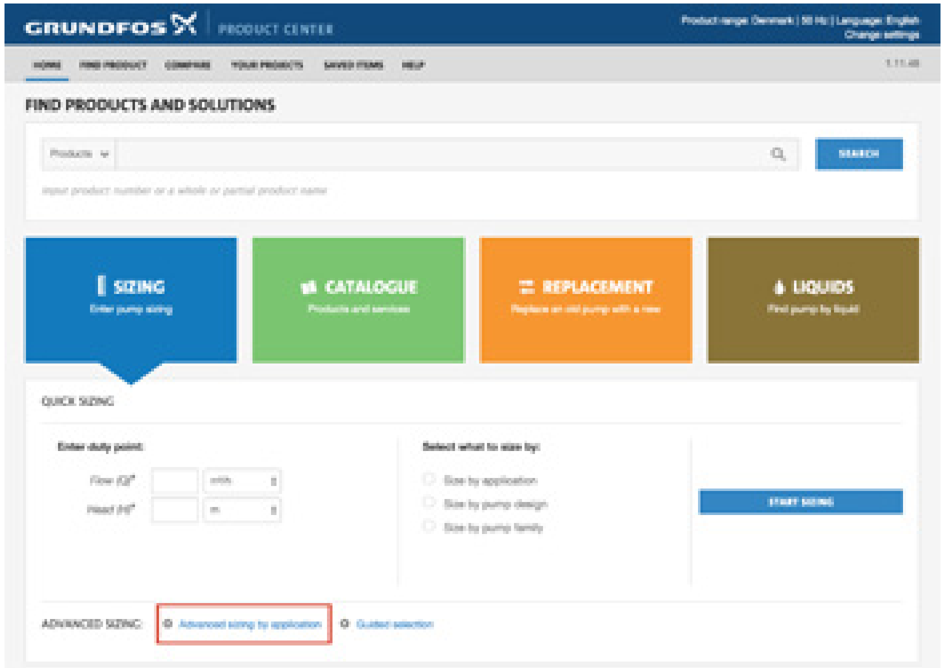
Example: Sizing a booster system – Grundfos Product Center

Now we know the values of Q and H, and we are ready to find the booster that matches the need of our building. Let us take a look in Grundfos Product Center.



Type www. product-selection.grundfos.com/ in your webbrower, or find Grundfos Product Center on www.grundfos.com

Step 2



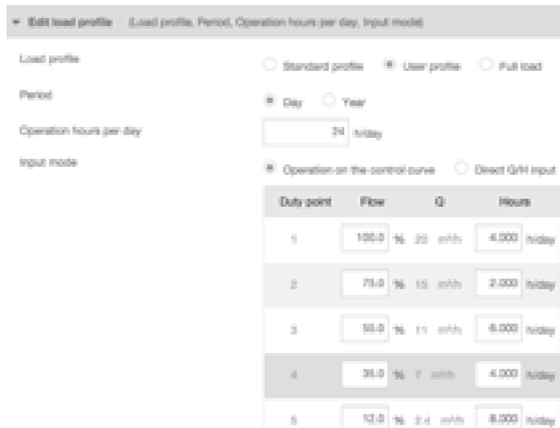
Select **Advanced sizing by application** *to start sizing your application*

Example: Sizing a booster system – Grundfos Product Center

Now we are ready to size the first of five booster pumps.
In this example, the installation we want is a **break tank** from the basement, as it is best suited for this hospital.

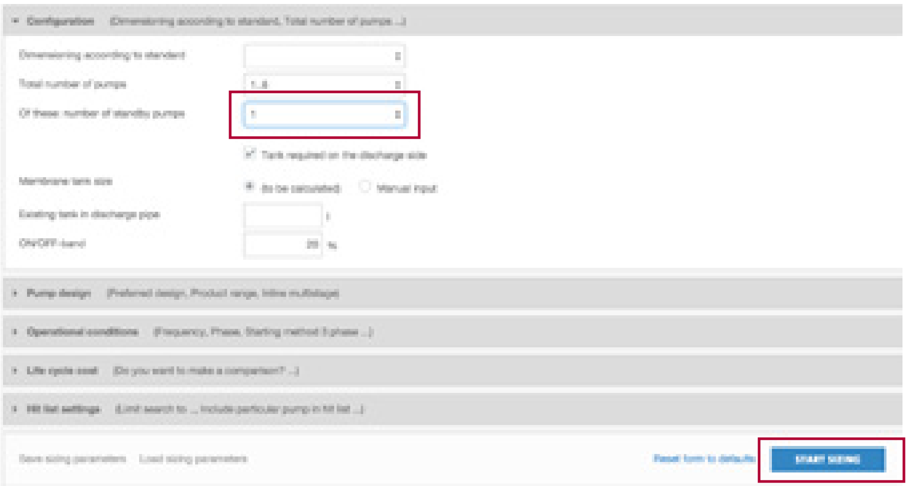
The water consumption is calculated whereas a beds in the hospital. This booster will handle the first 4 floors. (800 Beds / 19 floors = 42 beds per floor x 4 = 169 Beds
Each bed uses 800 l pr day.

The geodetic height is 80 m, friction loss on 0.8, and the discharge pressure for booster 1 is 2.5 bar

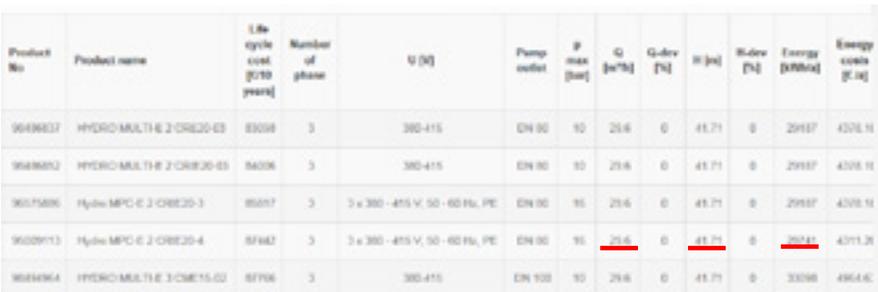


It is important to be as precise as possible when defining the actual load profile.

Example: Sizing a booster system – Grundfos Product Center

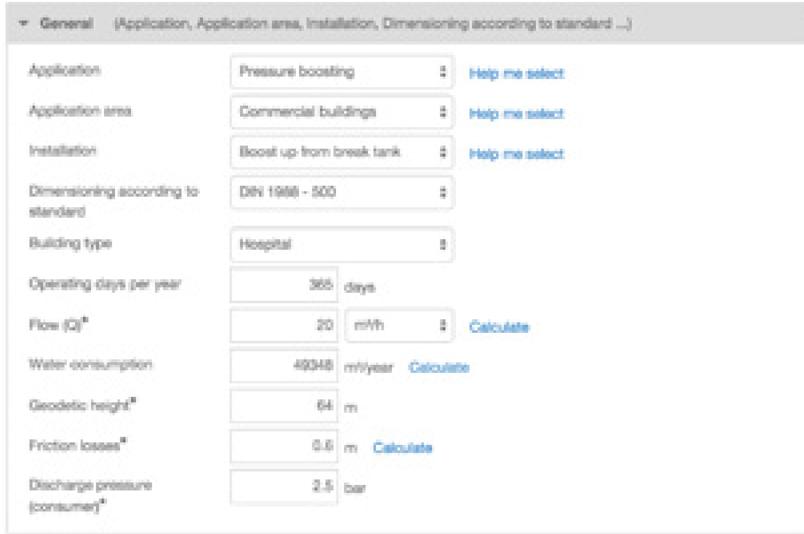


For hospitals, always use a standby pump.

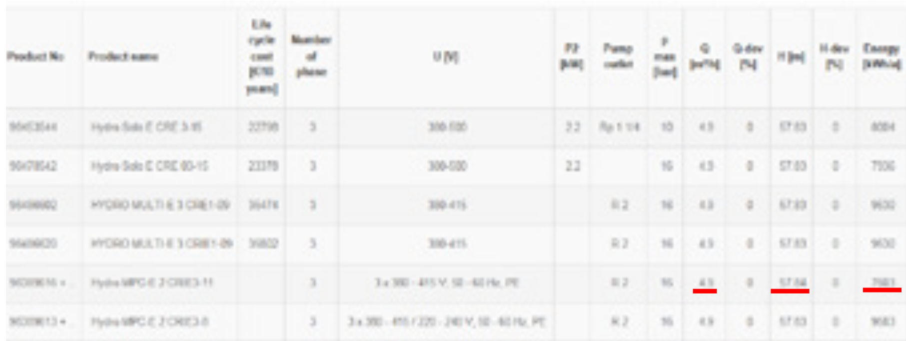


Sizing result for booster 1

Example: Sizing a booster system – Grundfos Product Center



Sizing data for booster 2



Sizing result for booster 2

Example: Sizing a booster system – Grundfos Product Center

▾ General	(Application, Application area, Installation, Dimensioning according to standard ...)	
Application	Pressure boosting	Help me select
Application area	Commercial buildings	Help me select
Installation	Boost up from break tank	Help me select
Dimensioning according to standard	DIN 1988 - 500	
Building type	Hospital	
Operating days per year	365 days	
Flow (Q)*	20 m³/h	Calculate
Water consumption	49348 m³/year	Calculate
Geodetic height*	48 m	
Friction losses*	0.5 m	Calculate
Discharge pressure (consumer)*	2.5 bar	

Sizing data for booster 3

Product No	Product name	Life cycle cost [€/10 years]	Number of phase	U [V]	P2 [kW]	Pump outlet	P max [bar]	Q [m³/h]	Q-dev [%]	H [m]	H-dev [%]	Energy [kWh/a]
98478546	Hydro Solo E CRE 05-09	30157	3	380-500	2.2		16	4.9	0	74	8	11311
98478547	Hydro Solo E CRE 05-12	31528	3	380-480	3		16	4.9	0	74.01	8	11656
98389616 + ...	Hydro MPC-E 2 CRE3-11		3	3 x 380 - 415 V, 50 - 60 Hz, PE		R 2	16	4.9	0	74.00	8	10130
98496685 + ...	HYDRO MULTI-E 2 CRE3-11		3	380-415		R 2	16	4.9	0	74.02	8	10561
98496721 + ...	HYDRO MULTI-E 2 CRIE3-11		3	380-415		R 2	16	4.9	0	74.02	8	10561

Sizing result for booster 3

Example: Sizing a booster system – Grundfos Product Center

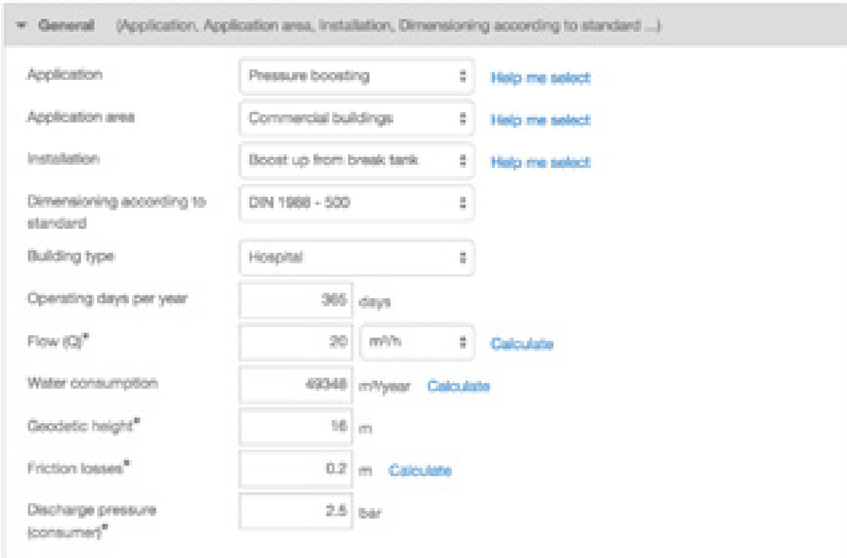
▾ General	(Application, Application area, Installation, Dimensioning according to standard ...)	
Application	Pressure boosting	Help me select
Application area	Commercial buildings	Help me select
Installation	Boost up from break tank	Help me select
Dimensioning according to standard	DIN 1988 - 500	
Building type	Hospital	
Operating days per year	365 days	
Flow (Q)*	20 m³/h	Calculate
Water consumption	49348 m³/year	Calculate
Geodetic height*	32 m	
Friction losses*	0.3 m	Calculate
Discharge pressure (consumer)*	2.5 bar	

Sizing data for booster 4

Product No	Product name	Life cycle cost [€/10 years]	Number of phase	U [V]	P2 [kW]	Pump outlet	p max [bar]	Q [m³/h]	Q-dev [%]	H [m]	H-dev [%]	Energy [kWh/a]	Energy costs [€/a]
98453614	Hydro Solo E CRE 5-12	37131	3	380-480	3	Rp 1 1/4	10	4.9	0	90.1	0	14640	2196.00
98478547	Hydro Solo E CRE 05-12	37086	3	380-480	3		16	4.9	0	90.1	0	14640	2196.00
98496744	HYDRO MULTI-E 2 CRE3-17	40141	3	380-415		R 2	16	4.9	0	90.13	0	12093	1813.94
98496771	HYDRO MULTI-E 2 CRIE3-17	40406	3	380-415		R 2	16	4.9	0	90.13	0	12093	1813.94

Sizing result for booster 4

Example: Sizing a booster system



▾ General (Application, Application area, Installation, Dimensioning according to standard ...)

Application	Pressure boosting		Help me select
Application area	Commercial buildings		Help me select
Installation	Boost up from break tank		Help me select
Dimensioning according to standard	DIN 1988 - 500		
Building type	Hospital		
Operating days per year	365	days	
Flow (Q)*	20	m³/h	Calculate
Water consumption	49348	m³/year	Calculate
Geodetic height*	16	m	
Friction losses*	0.2	m	Calculate
Discharge pressure (consumer)*	2.5	bar	

Sizing data for booster 5

Product No	Product name	Life cycle cost [€/10 years]	Number of phase	U [V]	Pump outlet	P max [bar]	Q [m³/h]	Q dev [%]	H [m]	H dev [%]	Energy [kWh/a]	Energy costs [€ /a]
98486744	HYDRO MULTI-E 2 CRE3-17	44915	3	380-415	R 2	16	4.9	0	106.3	0	14170	2155.45
98486771	HYDRO MULTI-E 2 CRIE3-17	45179	3	380-415	R 2	16	4.9	0	106.3	0	14170	2155.45
98486748	HYDRO MULTI-E 2 CME3-09	51431	3	380-415	R 1 1/2	16	4.9	0	106.3	0	19271	2890.65

Sizing result for booster 5

Example: Sizing a booster system - One booster solution

Now we will make the same sizing with a one-booster solution, and afterwards compare it to the zone-divided solution.

The one-booster solution is the most common solution in commercial buildings – especially in buildings before the widespread use of speed-controlled pumps.

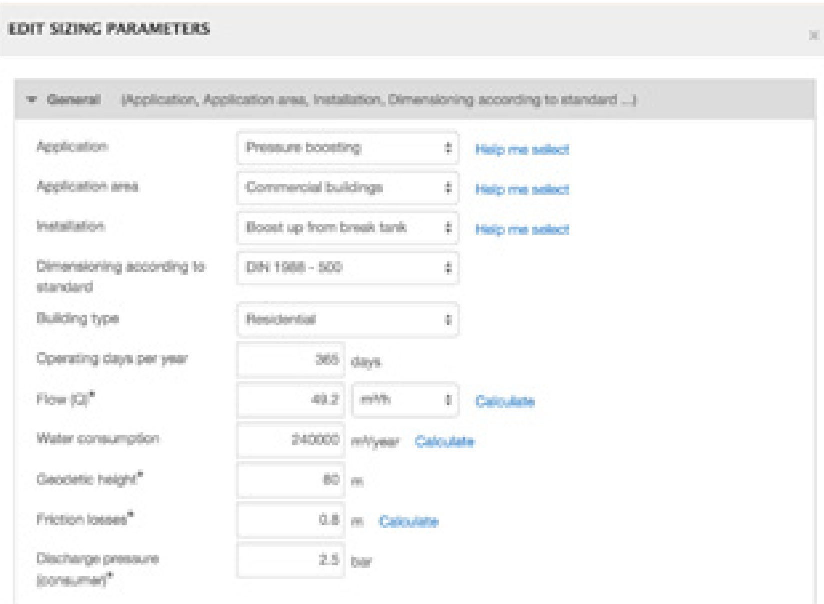
One booster
300 x 800 = 240,000 m³/ year
240,000 / 365 = 657,53 m³/ day
658 / 24 = 27.4 m³/ hour
27.4 x 1.8 = 49.3 m³/ hour (Max consumption)

One-booster info (floor 1 - 20)

Q: (4 x 5)	= 49.3 m³/h
H: Static height: (20 x 4)	= 80 m
Tap pressure	= 25 m
Pipe friction loss: 100 Pa/m (80 x 100)	= 0.8 m

One booster in basement covering the whole building.

Example: Sizing a booster system – one-booster solution

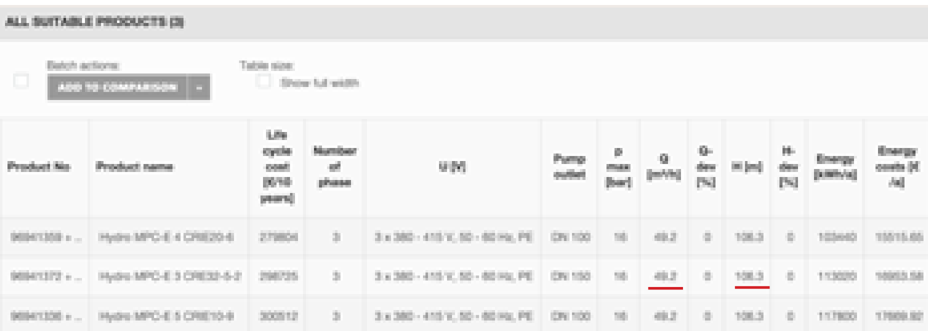


EDIT SIZING PARAMETERS

General (Application, Application area, Installation, Dimensioning according to standard ...)

Application	Pressure boosting	Help me select
Application area	Commercial buildings	Help me select
Installation	Boost up from break tank	Help me select
Dimensioning according to standard	DIN 1988 - 500	
Building type	Residential	
Operating days per year	365 days	
Flow (Q)*	49.2 m³/h	Calculate
Water consumption	240000 m³/year	Calculate
Geodetic height*	80 m	
Friction losses*	0.8 m	Calculate
Discharge pressure (consumer)*	2.5 bar	

Sizing data for one booster



ALL SUITABLE PRODUCTS (3)

Batch actions: ADD TO COMPARISON

Table size: Show full width

Product No	Product name	Life cycle cost [€/10 years]	Number of phase	U [V]	Pump outlet	p max [bar]	Q [m³/h]	Q-dev [%]	H [m]	H-dev [%]	Energy [kWh/a]	Energy costs [€/a]
98941359 + ...	Hydro MPC-E 4 CRE20-6	279804	3	3 x 380 - 415 V, 50 - 60 Hz, PE	DN 100	16	49.2	0	108.3	0	103440	15515.65
98941372 + ...	Hydro MPC-E 3 CRE32-5-2	298725	3	3 x 380 - 415 V, 50 - 60 Hz, PE	DN 150	16	49.2	0	108.3	0	113020	16953.58
98941336 + ...	Hydro MPC-E 5 CRE10-9	300512	3	3 x 380 - 415 V, 50 - 60 Hz, PE	DN 100	16	49.2	0	108.3	0	117800	17669.92

Sizing result for the one-booster solution

Example: Sizing a booster system – one-booster solution

The sizing result from Grundfos Product Center on the previous page shows the total energy consumption for the one-booster solution of 103.440 kWh/year

Please also note that there will be a need for several PRVs which will add to initial cost and maintenance for the one-booster solution.

Let us take a look at why the total energy consumption is so high, when using a one-booster solution.

The illustration below shows that the pressure increases as we move downwards in the building, creating residual pressure. We actually pay the booster to produce this pressure which is unnecessary as shown in the -/+ column.

Pressure	+/-
25 mWc	
29 mWc	
33 mWc	
37 mWc	
41 mWc	+1
44 mWc	+4
48 mWc	+8
52 mWc	+12
56 mWc	+16
60 mWc	+20
64 mWc	+24
68 mWc	+28
72 mWc	+32
76 mWc	+36
80 mWc	+40
84 mWc	+44
88 mWc	+48
92 mWc	+52
96 mWc	+56

Example: Comparison between one-booster and zone-divided systems

Let us take a look at at the totalt energy consumption for the five booster sets, and compare the results with the one-booster solution.

Total Energy Consumption 5 Booster sets:

Booster 1: 28.741 kWh/year
Booster 2: 7.603 kWh/year
Booster 3: 10.130 kWh/year
Booster 4: 12.093 kWh/year
Booster 5: 14.370 kWh/year

Total: 72.937 kWh/year

One Booster: 103.400 kWh/year *

Difference: (103.400 – 72.937) = **30.503 kWh/year** *equal to* 31 %

** Notice that there will be a need for several PRV's which will add to initial cost and maintenance for the one booster solution.*

SUMMARY

Providing water for people living and working in a modern city is a prerequisite for the city to function.
Pressure boosting is required for different reasons, whether being an extension to an existing building or part of a new high-rise building. Whatever the reason, the design of these systems vary. In this document, we wanted to offer inspiration for how this can be done.
Our aim has been to be as objective as possible and provide solid information about the pros and cons of different system layouts. However, local regulations must always be observed and therefore some of the suggestions might not be applicable in certain countries.
We hope that you found this material useful and that you will contact us should you have questions concerning pressure boosting.

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Based on 60 years of field experience, expert knowledge and a deep understanding of buildings services, we design solutions that boost the IQ of your building.

Grundfos Buildings Services has a holistic approach to buildings – we see pump requirements as part of a complete system. Our solutions take installation, commissioning, operation, monitoring, control and service into consideration. Grundfos Buildings Services offers intelligent products combined intelligently for increased comfort and lower costs.

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District Energy
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Wastewater
Water Disinfection
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