

WATER DISTRIBUTION MANUAL

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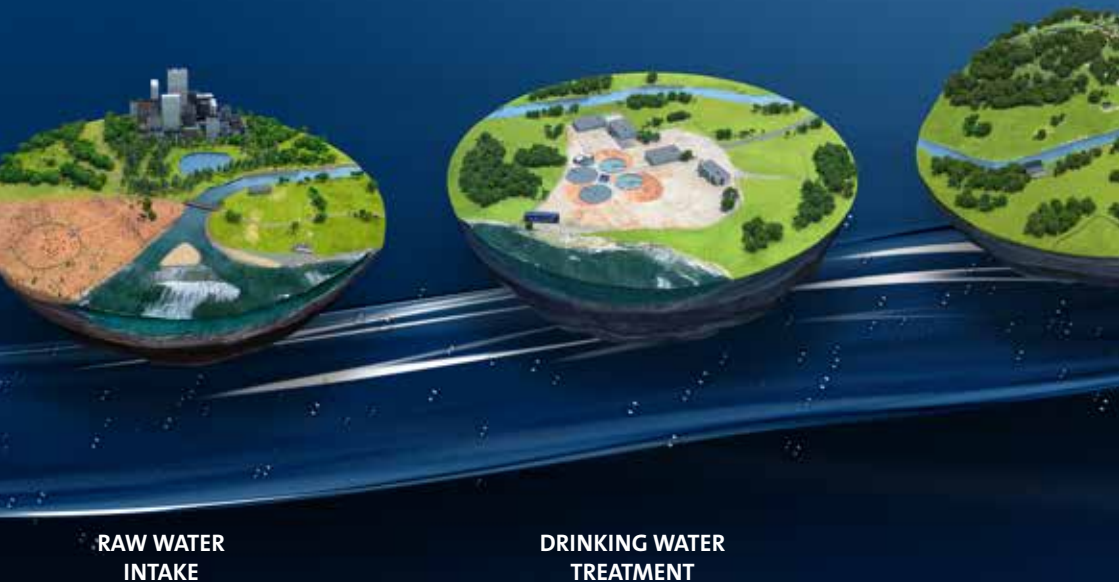
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OPTIMISED WATER SOLUTIONS



RAW WATER
INTAKE

DRINKING WATER
TREATMENT

About this manual

This manual covers Grundfos equipment and applications associated with surface water intake and water distribution. It consolidates over 70 years of application expertise in water supply systems.

You are guided through water intake pumping station layouts, for water sources ranging from rivers and lakes to seawater. We discuss how pump pre-selection and flow rate estimation are essential for an optimised system, and show the importance of pressure management solutions for delivering correct pressure at the end-user while reducing the risk of pipe bursts.

We present all the main equipment required for an optimised water supply system, and end with a look at the comprehensive range of Grundfos products and solutions.

Focus on the entire water cycle

Water utility applications for all stages of the water cycle fall, broadly speaking, into two categories: water supply and water collection. Within these, Grundfos chooses to follow the flow of the water cycle through 'application islands'. Each of these 'islands' is further divided into detailed application areas. For example, the raw water island can be divided into groundwater and surface water. Raw water can be further processed for human consumption or can be used directly for irrigation. The water distribution island can be divided into water transmission and water network distribution.

About Grundfos Water Utility

Grundfos Water Utility is a full-range supplier of intelligent pumps and systems for all water supply and wastewater applications. We optimise pumping solutions to provide maximum reliability and resource efficiency for our customers. Our solutions are made with tried and tested technology, and our expertise is part of any delivery.



**WATER
DISTRIBUTION**

**WASTEWATER TRANSPORT
& FLOOD CONTROL**

**WASTEWATER
TREATMENT**



SURFACE WATER INTAKE

1) Intake pumping stations

Intake pumping stations are used for surface water extraction and conveyance to irrigation, water treatment plants, water parks, fountains, cooling systems and for many industrial processes.

Intake pumping stations can be constructed to convey high volumes of water, requiring high-flow capacity pumps with considerably-sized motors. The pumping station can be off-shore, on the coast or inland with a channel approach or suction pipelines.

a) Rivers and lakes

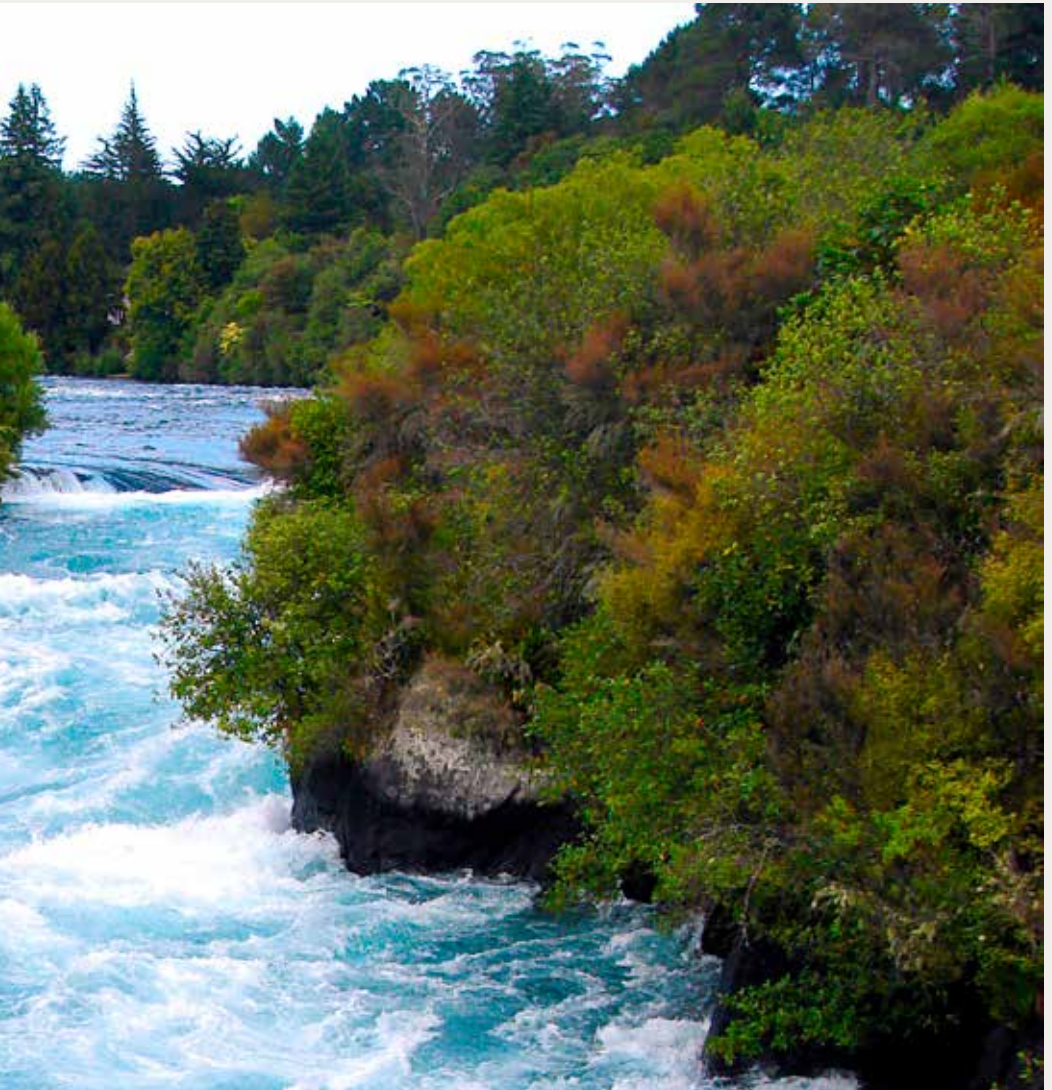
Intake designs are dependent on the site conditions. Water depth and water level variation are important factors to consider. Some challenging intakes are vulnerable to flooding and require costly civil construction offshore. Onshore above-ground installations are less costly, but require high suction lift and are therefore exposed to cavitation and priming issues. Intakes can also be onshore underground, increasing the construction cost and with risk of flooding in a confined space, but reducing the suction lift.



b) Channel lift stations

Approach channels are used to divert water into the pumping station. Taking the water inland and away from the coast reduces the flood risk, provides a uniform flow approach and facilitates the installation of appropriate screening systems. There is of course a cost impact as well as sedimentation issues in the approach channel.





c) Seawater pumping stations

With ongoing worldwide concerns about potable water scarcity, desalination of seawater in some areas is the only means of obtaining drinking water. The oceans contain 97.5 % of all water on Earth. Seawater pumping stations in general are similar designs to river intakes, but require additional features to deal with bacteria, coral growth and corrosion.

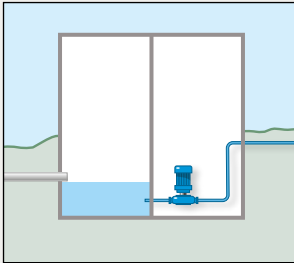
Seawater intakes can be designed as beach wells, where a series of beach wells along the shoreline becomes a beach wellfield. The benefit of beach wells as a solution compared to direct seawater intake is that there are no algae, less bacteria and lower salt concentration in the wells compared to direct intake from the off-shore splash zone. However not all sea shores are sandy beaches.

There is no preferred intake design. The intake design is highly dependent on the site conditions and careful consideration of the varying water levels. Low suction losses and appropriate pump selection are key to a successful pumping station design. Structures require an adequate hydraulic design to ensure a problem-free flow approach. The intake structure must also be designed to avoid ingress of solids to suction pipelines and pumps.

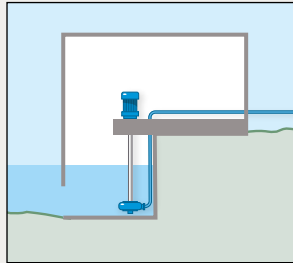


2) Pumping station layout

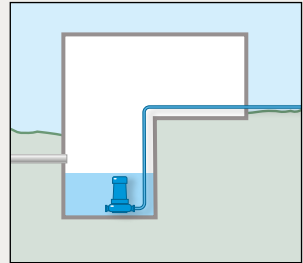
Pumping station layouts can be for wet or dry installations with a wide range of combinations.



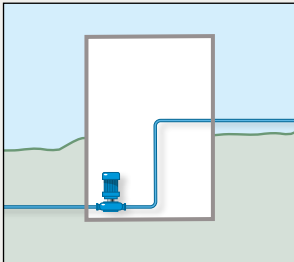
Pump and motor in dry pit
with suction from wet pit



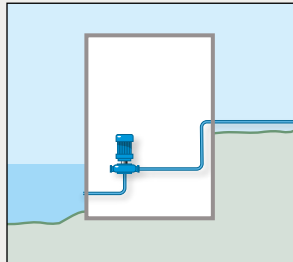
Onshore wet pit with pump
under water and motor
above water



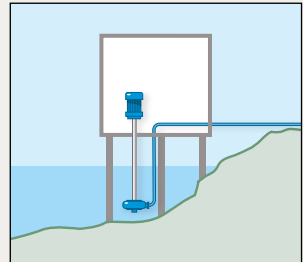
Wet pit with pump and motor
under water



Pump and motor in dry pit
with long suction pipeline



Pump and motor in dry pit
with suction direct from source



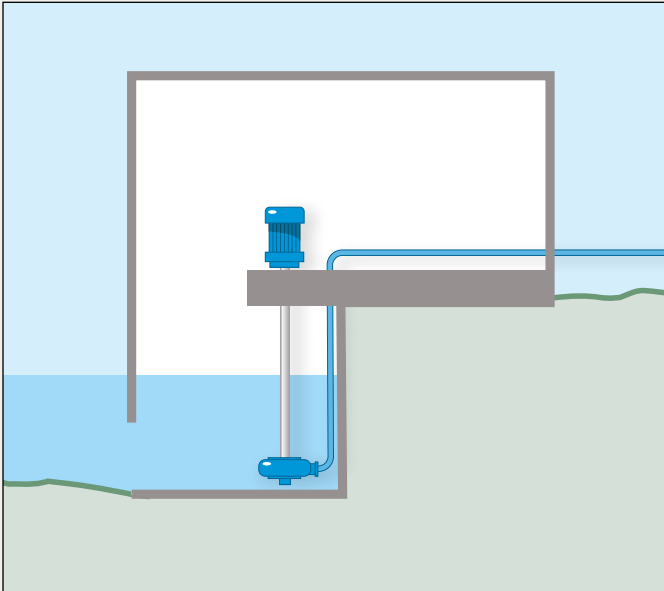
Offshore with pump under
water and motor above water

Examples of station layouts

- Wet pit
- Dry pit
- Above ground
- Above water
- Underground

a) Wet pit installations

Water levels in rivers and lakes will vary with seasonal changes, and daily tides and waves will also affect the water level. The pump impeller bowls or volute need to be filled with water (primed) before the pump can operate. The most common pump used to overcome water level variations are vertical pumps with submerged suction bowls and motor above water flood levels. Pumps with submersible motors can also be used for wet installations and reduce civil works cost and footprint.



Pumping station

Wet pit installation

Pump types:

- Vertical turbine pump
- Submersible well pump
- Submersible sewage pump

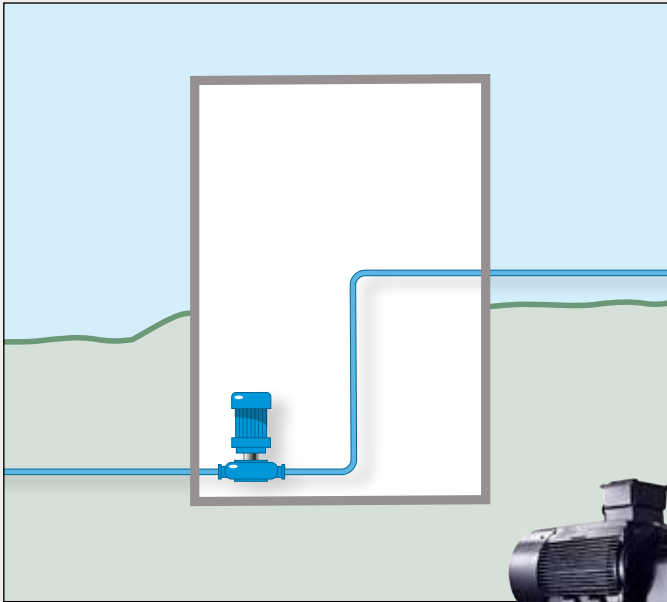
Design considerations:

- Flood level
- Minimum water level
- Air entrainment/vortices
- Humidity/corrosion
- Maintenance/road access
- Debris/screens
- Water current/turbulence
- Services/electricity



b) Dry pit installations

Dry pit/dry well installations are constructed above ground with deep excavations. Long suction pipes, approach channels, screens and strainers are often required, and all contribute to friction losses reducing the pump suction pressure. Pumping station designs must consider means of increasing the available net positive suction head (NPSH) by having underground structures. Pump selections with required low NPSH are necessary. Dry well installations are commonly equipped with double-suction split-case pumps, horizontally or vertically installed. The double-suction feature of the pump means the flow in the impeller eye is reduced by half, which is why these pumps can handle double the flow with a much lower NPSH requirement. End-suction or in-line pumps can also be used for dry installations, but the NPSH required by the pump will be higher.



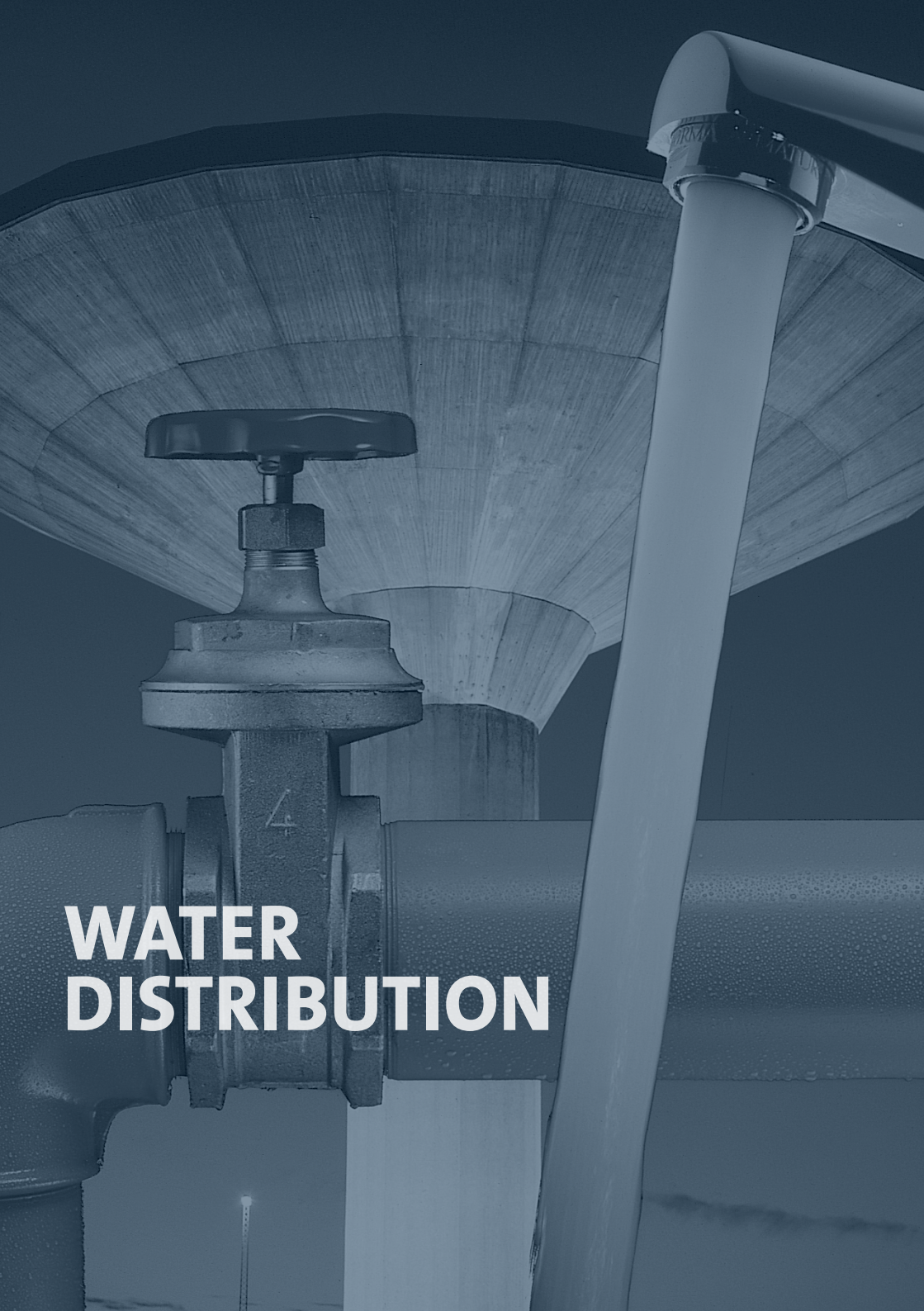
Pumping station Dry pit installation

Pump types:

- Double-suction split-case
- End-suction pump
- Inline pump
- Submersible sewage pump

Design considerations:

- Suction pressure/NPSH
- Start up condition/priming
- Suction strainer
- Maintenance
- Health & safety precautions



WATER DISTRIBUTION

3) Pump pre-selection

We will now look at pump pre-selection in a water distribution pipe network system. To select the right pump, we need to know several factors:

- An estimation of the total flow rate (Q) and head (H)
- The water source composition, for the material configuration of the pump
- The design of the pumping station, so we can select the pump type and number of pumps required

At the early planning stage of a project, however, no pump specifications are available, so this is initially an estimation. Grundfos offers engineering support in the early planning phase, liaising with the owners, planners, operators, consultants and civil and electromechanical engineers.

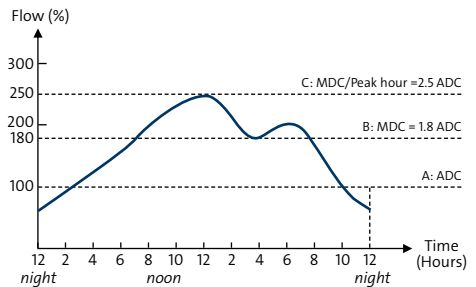
a) Flow rate estimation

In theory, readily-available statistical information could provide the basis for flow rate estimation, based on population and averaged water use for mixed domestic, commercial and industrial areas. However, this can be misleading for several reasons, and in practice, we need to know local requirements:

- The mix of water users in the area – only households, or commercial and industry as well?
 - The pumps need to be selected to meet peak consumption – is consumption constant, or varying heavily?
 - Is there a risk the installation will be undersized or oversized for future demand?
- Municipalities ought to be able to supply this information.

Factors used by planners for determining typical demand for residential areas

- **ADC:** Annual Average Daily Consumption, also known as 'design flow'
- **MDC:** Annual Maximum Daily Consumption – this figure is derived from the ADC
- **MDC/Peak hour:** Peak hour consumption on the Annual Maximum Day
- **Fire flow:** a measure of an exceptional load case

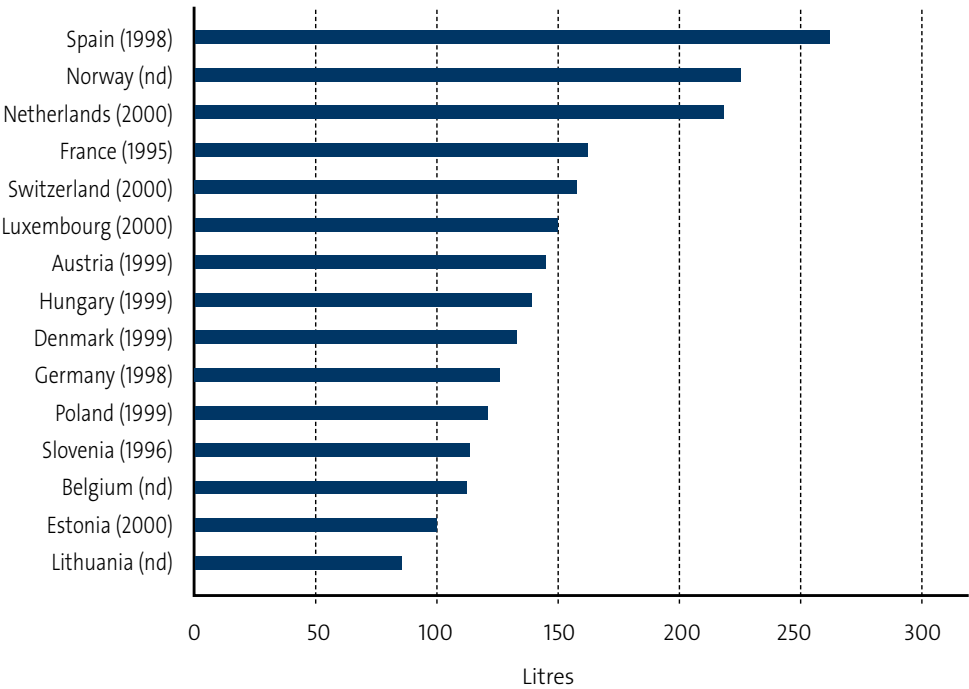


Although the term water consumption is commonly used, little of it is, strictly speaking, consumed. Most is discharged as wastewater. A breakdown of household flows is typically as follows:

- 41 % flushing toilets
- 27 % washing and bathing
- 6 % kitchen use
- 5 % drinking water
- 4 % washing clothes
- 7 % others (garden, washing cars, cleaning house)

The average daily water usage/consumption per person per day varies greatly from country to country, and mainly depends on climate and living standards. It can be less than 200 litres/person/day in some European countries and more than 500 litres/person/day in some areas of USA.

Average water use per person per day



Source: European Environmental Agency

i) Pipe leakage

Pipe leakage is one of the major problems in water distribution systems and other problems derive from it and is therefore important to consider when estimating flow rate.

Leaks do not only mean the loss of water but can also lead to contamination, polluting the drinking water. Leakage rates are higher than many expect, and are often budgeted as an unavoidable cost item.

Some typical examples of % leakage in water distribution networks:

Japan	>5 %
Germany	7 %
USA	>15 %
Great Britain	19 %
France	26 %
Italy	29 %



ii) Wide operation range

The reason for a flow rate estimation is so we can cover the expected wide range within which the pumps will operate.

The maximum flow in water distribution can in many cases be 15-20 times higher than the minimum flow. This depends on:

- Daytime (peak) consumption
- Seasonal changes
- The system dynamics and how demand develops in the future

The total flow rate estimation of a pumping station can be determined by statistical information or by usual planning factors, with the MDC/Peak level the relevant figure that gives us the total flow of the pumping station. The fire flow must be checked as well; it could be that pumps running in overcapacity will cope with it.

A much more complex task will be the selection of any single pump within the system to cope with the minimum flow (if not supplied by an elevated tank) and all intermediate operating points of the very wide operation range.

For this reason, it is not unusual to find different pump sizes in parallel (cascade) operation in an existing pumping station, with some of them equipped with variable speed drives to cope with the varying demand.

For pump pre-selection, it is sufficient to take two pump sizes:

- A small pump for the minimum flow and to pressurise the system. If the minimum flow rate is too low, we can apply a pressurised tank or a bypass with an orifice plate towards pump suction side
- Three to four pumps with 35 % of the MDC/ peak flow – the pump selection will be reviewed anyway at a later stage

b) Pump head estimation

Once we have a figure for flow rate estimation, we need to look at estimating the pump head (H).

Looking at a pump system we usually distinguish between:

- **The static head (or geodetic head):**

The difference in elevation between the water level at the pumping station and highest elevation of the distribution network. The highest elevation in the network is normally the water level in an elevated water tank.

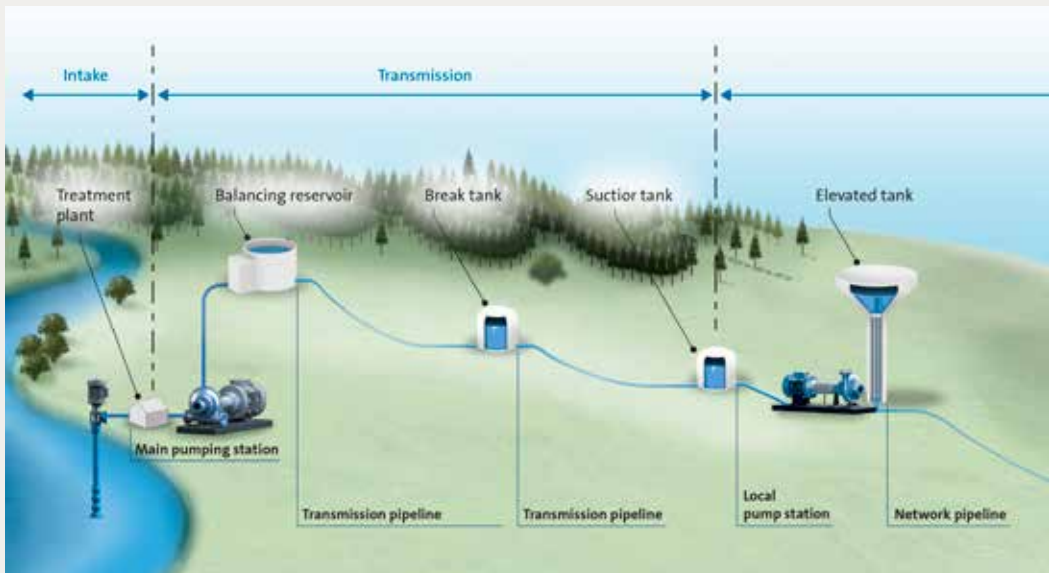
- **The dynamic head (or friction losses):**

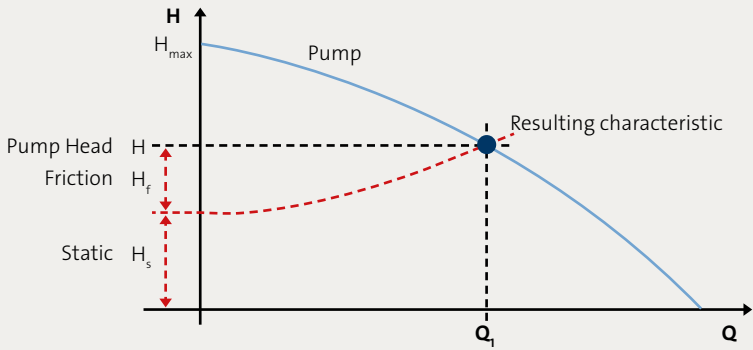
A function of the flow rate with the addition of all friction losses in the pipework related to a flow

To determine static and dynamic head, draw the system curve and see where it crosses our pump curve, we must take a closer look at the distribution system.

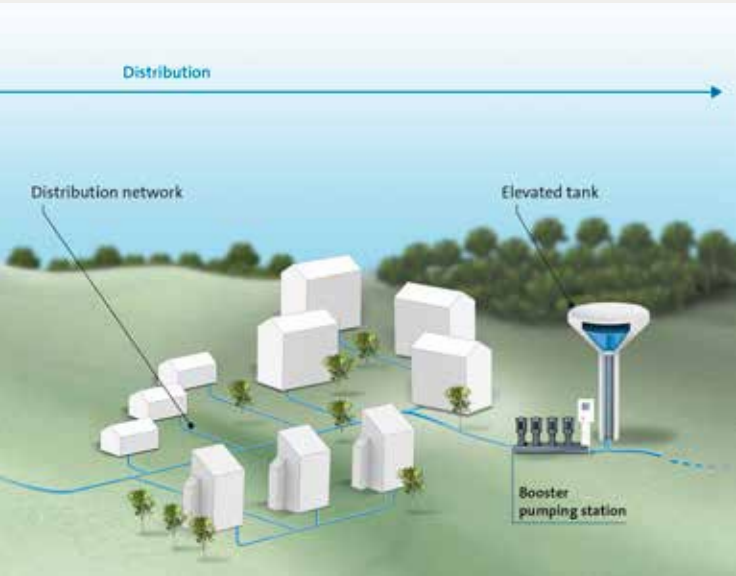
The requirements for a functioning water distribution system are:

- Water quality should not deteriorate in the distribution pipes
- Supply water to all taps at the consumer with sufficient pressure
- Supply the required amount of water during firefighting at a certain minimum pressure
- No consumer is without water supply during the repair of any section of the system
- All distribution pipes are preferably laid one metre away from or above the sewer lines
- Water-tight, to keep losses due to leakage to a minimum and to eliminate contamination





System characteristic together with the pump performance curve for the open system.



i) Layout of a distribution network

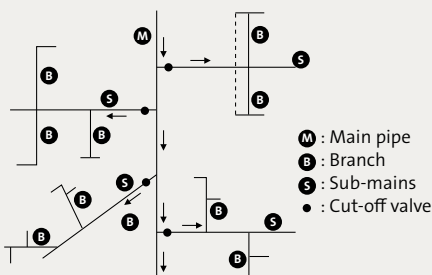
To estimate the pump head (H), we need to evaluate the layout of water distribution networks.

Distribution pipes are generally laid below road surfacing, and as such their layouts usually follow the layouts of roads.

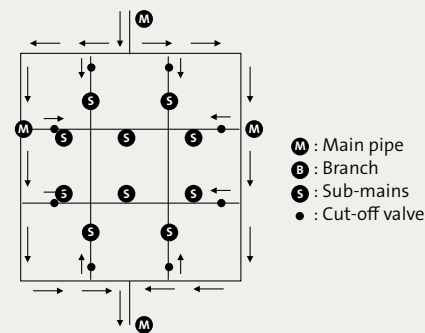
There are, in general, four different types of pipe networks; any one of which, either singly or in combination, can be used in any location:

- Branch, tree or dead-end system
- Ring system
- Grid-iron system
- Radial system (considered a variant of the grid system)

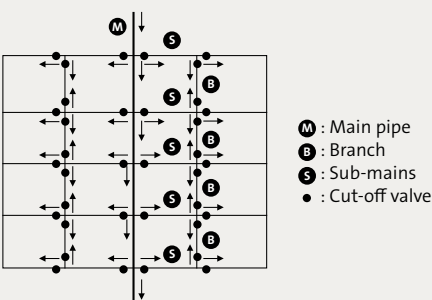
Dead-end or tree system



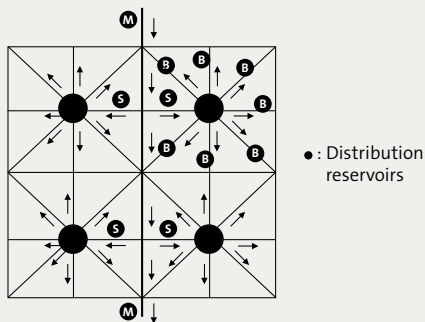
Ring system



Grid-iron system



Radial system



Branch, tree or dead-end system

Tree systems have large mains supplying an area, and smaller mains branching off from the large main. In less-developed communities, it will be harder to avoid dead-ends in the system because there is less of a need for infrastructure. This is where you will typically find tree systems.

This is a system where the trunk of the tree is one large water main that decreases in size as it extends away from the facility, with smaller branches of piping branching off the main at right-angles. From each of these branches, smaller sub-branches can extend out even further.

With this system, dead-end mains are unavoidable and will need to be regularly serviced to maintain good water quality.

This system is found in communities and cities with no definite pattern of roads and has the following advantages:

- Relatively cheap
- Determination of pressure drop due to friction losses is easier because of the simple network

The disadvantages of the system are that the many dead-ends result in stagnation of water in the pipes, and pipe repairs will leave consumers without service.

Ring system

Ring systems utilise large-diameter mains that surround the water network, supplying water from any direction towards the center. In a ring system, water is fed through large-diameter mains into a continuous loop that supplies water from any direction towards the center.

The continuous circulation in this system prevents any build-up of sediment or organic matter in the water supply.

The supply main is laid along peripheral roads, and sub-mains branch out from the mains.

Thus, this system also follows the grid iron system with the flow pattern similar in character to that of dead-end system. So, determination of the size of pipes is easy, however determination of friction losses is not that easy.

- The advantage of the ring system is that water can be supplied to any point from at least two directions
- This allows easy maintenance and pipe replacement while still supplying water to all customers.

The disadvantage of the system is the high capital cost of having redundant large diameter pipes.

Grid-iron system

Grid systems have interconnected water mains that can feed water to parts of the system from different directions. This is the most common type of design, especially in larger cities. The reason for this is that grid systems feed more water to a given area when you have a surge in the system, such as a fire emergency.

The layout is a grid, much like the street layout in city blocks, and the water flows openly through this grid from all directions. When one area is pulling a greater water flow from the system, the water can feed into that area from multiple directions. The downside to a grid system is that it can sometimes include dead-end mains.

This system is suitable for cities with a rectangular layout, where the water mains and branches are laid in rectangles, and offers the following advantages:

- Water is kept in good circulation due to the absence of dead ends
- In the cases of a breakdown in one section, water is available from some other direction

The disadvantage is that the exact calculation of sizes of pipes is not possible.

Radial system

We mention the radial system here, although it is often regarded as a variant of the grid system. Here, the area is divided into different zones. The water is pumped into the distribution reservoir kept in the middle of each zone, and the supply pipes are laid radially, ending towards the periphery.

This provides the advantage of reliable service.

Advantages of ring and grid-iron systems

To sum up, we can see the following general advantages when operating the hydraulically more complex ring and grid-iron (including radial) systems:

- Pipe repairs without affecting consumers
- Less vulnerable – safer operation
- Homogenous pressure distribution
- Lower pipe velocity during high demand
- Recirculation of water during low demand
- Water hammer compensation

District Metering Areas (DMA)

The distribution pipe network in cities is often divided into demand areas for better understanding and control of leakage. These areas are known as District Metering Areas, or DMA's. The flows into and out of each DMA is recorded and compared with the total water consumption billed in the area to the customers.

The difference between the total volume of water provided to the DMA and the billed consumption in the DMA is called Non-Revenue Water (NRW). The NRW represents the non-accounted water that can be due to free supply (not billed or non-metered), fire hydrants, stolen/illegal connections, pipe leaks or tank overflow and metering inaccuracy. Pipe leakage in many networks represents 90 % or more of the NRW.

ii) Pressure management

Depending on the variation of terrain elevations, the distribution network can be divided in pressure zones. All pipe branches within a network include an isolation valve. These valves can be closed as necessary to create the pressure zones. Parts of the network in terrains of low elevation such as around lakes, or in elevated areas within a city, will be divided in different pressure zones. This is done to avoid pipes in lower ground having higher pressure than needed, and pipes in higher elevations having insufficient pressure to satisfy customers.

Pressure and leakage are directly related. The higher the pressure the higher the leakage. So the key is to provide a constant minimum pressure while maintaining consumer satisfaction.

Pressure-reducing valves are commonly used to limit and provide a constant pressure in areas of the network.

Elevated tank for pressurisation

The traditional way to pressurise a water distribution system is to pump the water into an elevated tank – the emblematic ones are water towers – however a more common solution is a buried tank on a hill, which works hydraulically in the same way, can be built bigger and does not heat up during the daytime.

The working principle of an elevated tank is straightforward. 'Communicating vessels' is a name given when several tanks are connected to each other. When the water settles, it balances out to the same level in all the tanks regardless of the shape and volume. If additional water is added to one tank, the liquid will again find a new equal level in all the connected tanks.

This process is part of Stevin's Law and Pascal's Principle and occurs because the pressure at any point within a fluid at rest (hydrostatic pressure), depends only on the depth of that point and therefore equal water tank levels are maintained.

In cities, water towers are frequently used so that city plumbing will function as communicating vessels, distributing water to higher floors of buildings with sufficient pressure.

Pump selection for this case is rather simple; this is determined by the water elevation in the tank or tower, dominated by the static head. The dynamic losses are almost negligible.

Direct pumping into the network

Nowadays it is most common to connect the pumping station directly to the distribution system, so the pumps perform the triple task of:

- Water transportation towards and into the distribution system

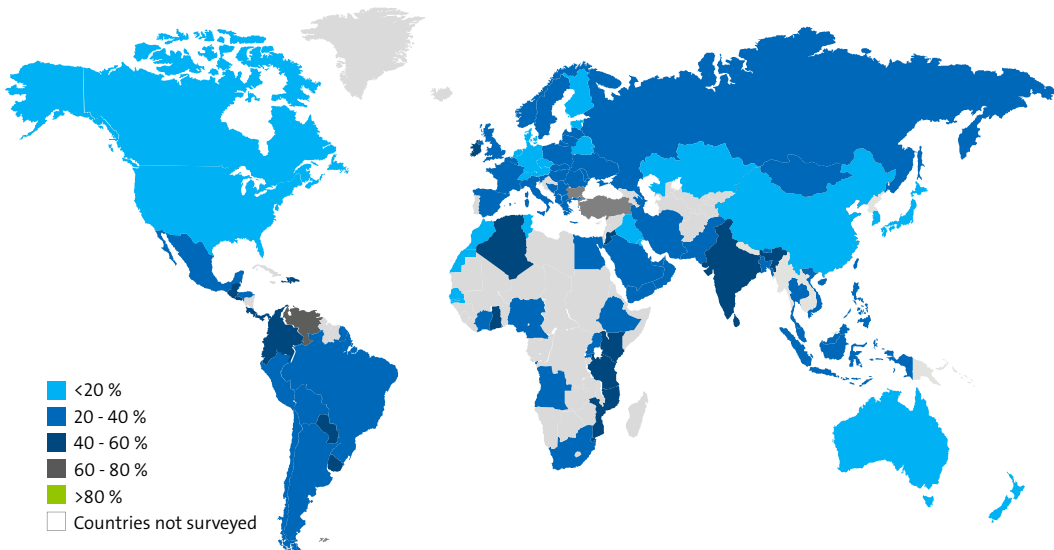
- Pressurisation and pressure maintenance of the system
- Water elevation to the highest points of the system, for example the elevated tanks

The elevated tanks may act as buffer tanks for minimum consumption, surge tanks at peak consumption and fire flow, and may act as emergency reservoirs in case of power cuts.

Static head is still dominant, as pump selection also orients on the highest point of the system, however in some cases, dynamic losses are not negligible.

The number of pumps in operation is used to sustain the network pressure under the varying flow conditions. Different pump sizes and variable speed drives (VFD – variable frequency drive) can also be implemented to keep pressure constant while flow demands vary throughout the day.

Non-revenue water rates:



iii) Summary

The manual calculation of a reliable system curve for pump selection is only feasible for a gravity system (elevation), or a simple pressurised tree system.

In a mixed pressurised grid system, the route taken by the flow is not clear, and it is inevitable that elements such as tanks and pumps interact, working against each other. Sophisticated software tools are then necessary to simulate the varying network pressures.

How then to determine the pump pressure? The best advice is to keep it simple and use:

- Pump head = Static head (height difference between the pumping station and the city) plus the required system pressure.

System pressure is the required pressure at the consumer's tap. System pressures commonly allowed in distribution systems are:

- Minimum of 1.5 bar at peak hour demand
- Maximum of 5 bar off-peak
- Maximum net network design pressures of 10 bar

Pumping stations with variable frequency drives (VFDs) pumping directly into the distribution network to maintain a suitable constant minimum pressure is the preferred method used today.

c) Number and size of pumps

A common question asked by municipalities at the planning stage is the number of pumps required. This is an iterative process, and the starting point is energy efficiency. This is because – when seen from the owners and investors point of view – the operation costs during a pump's lifetime are always greater than the initial investment cost.

i) Pump efficiency

The efficiency of a pump depends on three aspects:

- Ensuring operation close to the best efficiency point (BEP)
- Knowing (and reducing) internal losses: Shock, volumetric and friction losses
- Matching attainable efficiency of the pump hydraulics

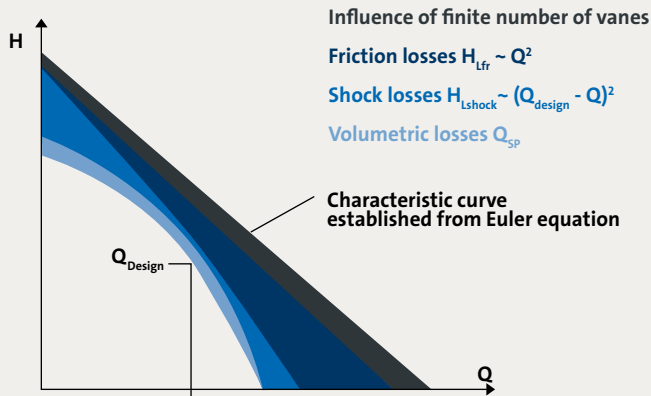
Pump curves show a Best Efficiency Point (BEP) and a preferred operational range with good efficiency around 80-110 % of the BEP Flow. To stay within this range, an existing hydraulic can be optimised by trimming the impeller.

Moving the operating point closer to the BEP by reducing the diameter by cutting the impeller blades optimises the efficiency in regard of this specific operation point, but total efficiency of the impeller hydraulic itself gets worse. Speed reduction using a variable frequency drive (VFD) is the better option.

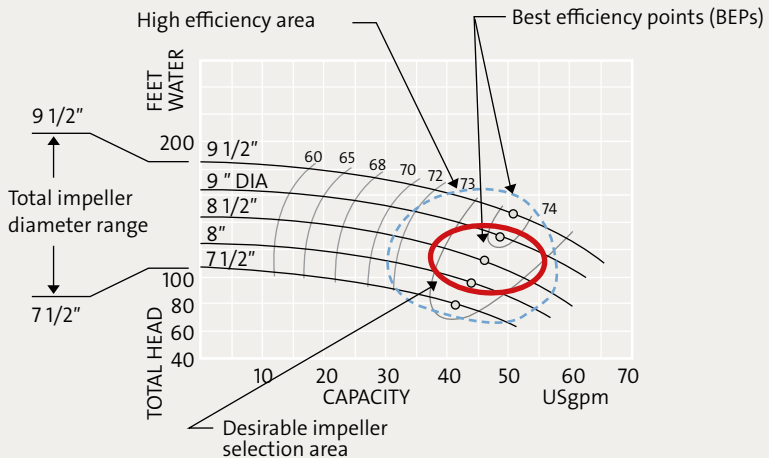
A closer look at internal losses

The shock, volumetric and friction losses in a pump can be optimised, but will never be perfect. Impeller blades, for example, guide the flow, and yet their material thickness places an obstacle in the hydraulic channel. As the incoming water enters the channels, it crashes against the front edges of the impeller causing shock losses. The surface of the blade is rough – causing friction losses.

Volumetric losses are caused by the inner recirculation from the discharge side to suction side of the impeller inside the pump casing. As the impeller rotates within the casing, we must allow for a gap, and the pressure difference causes water to pass through.



Pump efficiency reduction due to friction and volumetric losses



Preferred operational range when choosing an impeller

ii) Specific speed and impeller type

The specific speed of rotation (n_q) characterises an impeller by the ratio between flow and head. Specific speed and pump size together determine the attainable efficiency.

This is a parameter derived from a dimensional analysis which allows a comparison of impellers of various pump sizes, even when their operating data differ (flow rate Q_{opt} , developed head H_{opt} , rotational speed n at the point of best efficiency η_{opt}).

The specific speed can be used to classify the optimum impeller design and the corresponding pump characteristic curve.

n_q is defined as the theoretical rotational speed at which a geometrically similar impeller would run if it were of such a size as to produce 1 m of head at a flow rate of 1 m³/s at the best efficiency point. It is expressed in the same units as the speed of rotation:

$$n_q = n_d \cdot \frac{Q_d^{1/2}}{H_d^{3/4}}$$

Q_d in m³/s = Flow rate at η_{opt}
 H_d in m = Developed head at η_{opt}
 n_d in rpm = Pump speed
 n_q in metric units

As the specific speed n_q increases, there is a continuous change from the originally radial exits of the impellers to “mixed flow” (diagonal) and eventually axial exits. The diffuser elements of radial pump casings (e.g. volutes) become more voluminous, if the flow can be carried off radially. Finally, only an axial exit of the flow is possible (e.g. as in a tubular casing).

Approximate reference values:

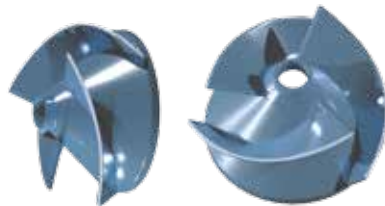
n_q up to approx. 25	Radial high-head impeller
up to approx. 40	Radial medium-head impeller
up to approx. 70	Radial-low head impeller
up to approx. 160	Mixed-flow impeller
approx. from 140 to 400	Axial-flow impeller (propeller)



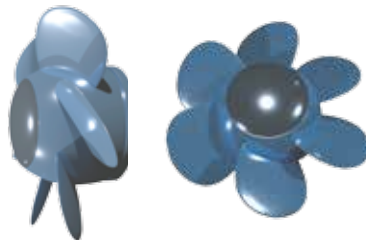
Radial impeller



Mixed-flow impeller



Mixed-flow impeller



Axial impeller

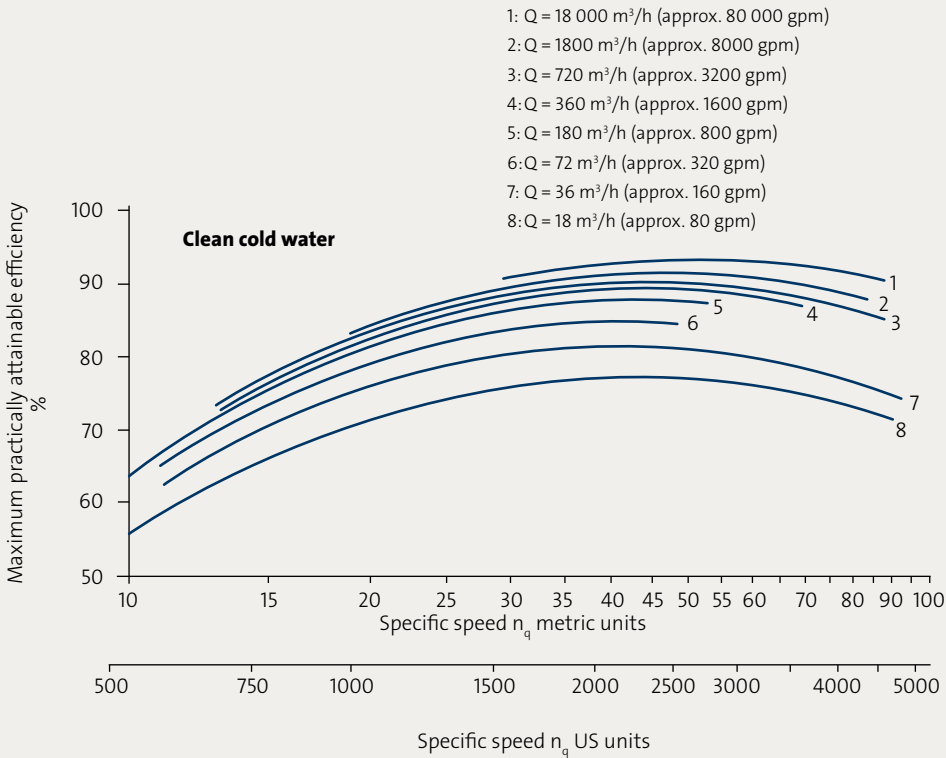
iii) Selecting for maximum attainable efficiency

The expected efficiency of a centrifugal pump varies as a function of specific speed size of the pump and operation near the BEP rate of flow. The theoretical values of maximum attainable efficiency from Europump (Association of European Pump Manufacturers) provides a good indication of what is typically achievable in the centrifugal pump industry with good design and manufacturing practices.

The figure shows that for a given specific speed, an increase in pump size results in an increase in expected best efficiency of that pump as we may expect lower internal losses.

Similarly, for a given flowrate, the increase or decrease of the designed specific speed of the pump may result in an increase in expected pump efficiency, up to a point. The graphic can be used as a guide to identifying the pump configurations that will yield the highest basic efficiency.

An indication is that n_q values between 40 and 55 tend to have good attainable efficiency.



iv) Pump determination, n_q : a practical example:

Our total flow (MDC peak) is 900 m³/h and the system pressure 3.1 bar (or 30 m); in accordance to US planning figures – minimum feeder pressure.

We can use the chart to determine the n_q .

Two possible pump selections look promising:

2 x 450 m³/h with 1450 rpm (n_q 42)

5 x 180 m³/h with 2850 rpm (n_q 50)

Both cases are leading to an n_q between 40 and 55 so should lead to a good efficiency.

The attainable efficiency for both cases is above 85 % and case a) looks better than case b) – due to the bigger size we can expect less internal losses.

Conclusion, n_q : a practical example (selecting these 2 pumps with Grundfos GPC sizing tool) Selecting the pump with the Grundfos Product Center gives the following pumps:

- a) Q: 450 m³/h and H: 30 m
(HS 200-150 381 eta 83 % or NK150-315 eta 82 %)
- b) Q: 160 m³/h and H: 30 m
(NK 80-180 eta 79 %)

Here, b) is close to the attainable efficiency, and offers the option for greater flexibility.

Why not a)?

A competitor could offer a pump with an efficiency of 85 %, which is attainable.

A consultant could take a mix:
1 x 450 m³/h and 3 x 180 m³/h
(one of them equipped with variable speed drive to cope with a very low minimum flow).

d) Summary of pump pre-selection

For the flow rate and the pump head we can obtain feasible values:

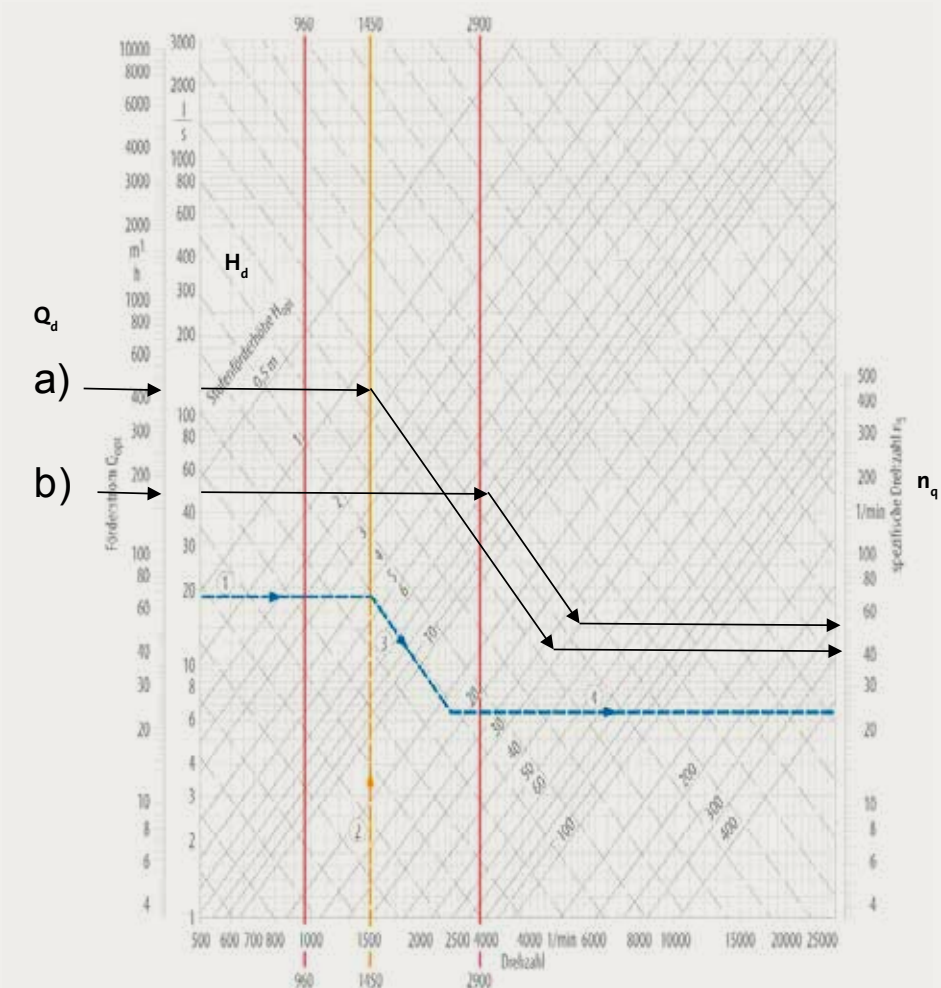
- The total flow rate is determined by the authority – it may be based on statistic (past) and prognostic (future) – if not given we may estimate it applying recognised planning factors.
- The pump head equals the required system pressure plus the difference in elevation (static head)
- The static head usually can be taken out of maps when not given by the planner or the authority
- The operating pressure of the pumps will be between 2-5 bar for system pressurisation (and the elevation of course)

For the extreme cases, we may estimate the counter pressure to be maximum 10 bar (zero flow) and 1.5 bar at pump run out. In case of absence of elevated tanks the size of the smallest pump is determined by the minimum flow rate.

All other pumps shall have a flow rate of approximately 35-50 % of the nominal flow rate – it is a common practise to cover 150-175 % of the nominal flow with 3-5 pumps operating in parallel with an n_q between 40-50.

The tendency nowadays leads to apply more smaller size pumps instead of a few bigger size ones.

It might not be a better solution for hydraulic reasons, but taking into consideration electrotechnical, civil and operational aspects, sometimes a 6-7 pumps leads to a better overall solution.



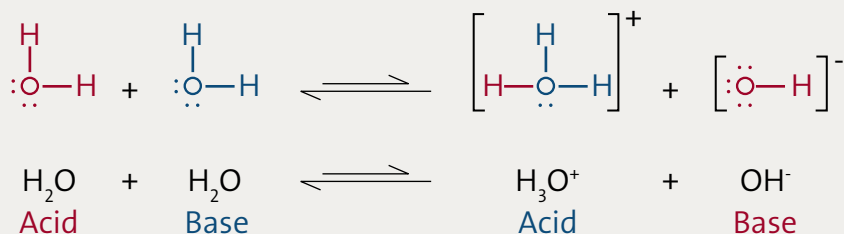
4) The pumped medium and corrosion

The standard material configuration for waterworks and water distribution pumps is a grey cast-iron casing with a bronze impeller, and in most cases this works fine.

However, experience shows that drinking water applications can also be hazardous for the pumps, so we will take a closer look at our

pumped medium and what might happen if we ignore the characteristic of our pumped medium – drinking water.

Water is an oxidant, and we have to know the relevant characteristics of water in order to measure its corrosive effects.



a) Corrosion

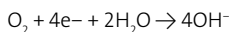
Corrosion is a natural process that converts a refined metal to a more chemically-stable form, such as its oxide, hydroxide, or sulphide. It is the gradual destruction of metals by electrochemical reaction with their environment

Rust is the most familiar example of corrosion:

- Rust is an iron oxide, usually red oxide formed by the redox reaction of iron and oxygen in the presence of water or air moisture

The rusting of iron is an electrochemical process that begins with the transfer of electrons from iron to oxygen via the water. The iron is the reducing agent (gives up electrons) while the oxygen is the oxidising agent (gains electrons). The rate of corrosion is affected by water and accelerated by electrolytes, and acidity.

The key reaction is the reduction of oxygen/oxidation of iron:



Because it forms hydroxide ions, this process is strongly affected by the presence of acid. Indeed, the corrosion of most metals by oxygen is accelerated at low pH.

i) Galvanic corrosion

When a corrosive electrolyte and two metallic materials are in contact (galvanic cell), corrosion increases on the least noble material (the anode) and decreases on the noblest (the cathode). The increase in corrosion is called galvanic corrosion. The tendency of a metal or an alloy to corrode in a galvanic cell is determined by its position in the

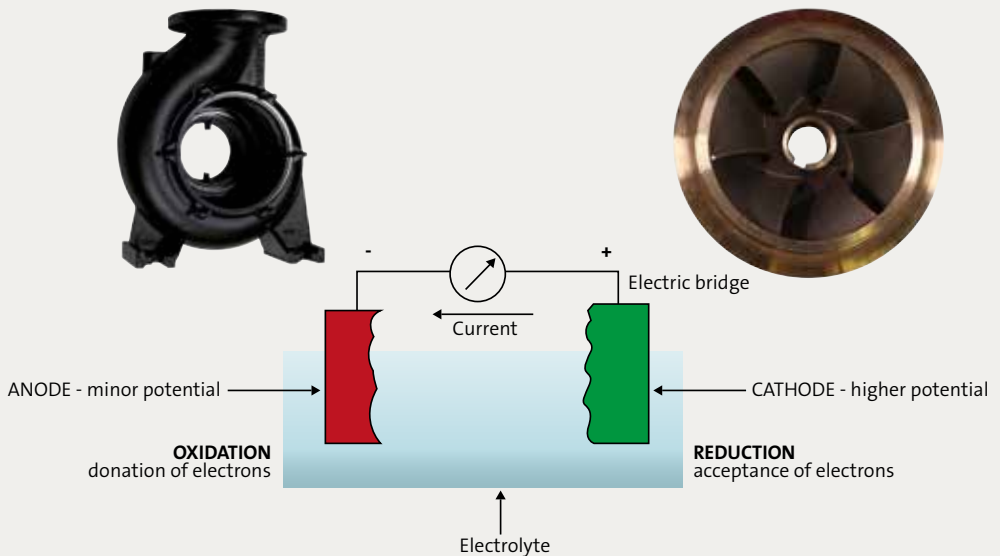
galvanic series. The galvanic series indicates the relative nobility of different metals and alloys in a given environment. The farther apart the metals are in the galvanic series, the greater the galvanic corrosion effect will be. Metals or alloys at the upper end are noble, while those at the lower end are least noble.

A galvanic cell, or voltaic cell, named after Luigi Galvani, or Alessandro Volta respectively, is an electrochemical cell that derives electrical energy from spontaneous redox reactions taking place within the cell. It generally consists of two different metals connected by a salt bridge. Volta was the inventor of the voltaic pile, the first electrical battery.

For mechanical engineers, a pump is a machine – from the chemical point of view it is a galvanic cell – a battery.

Corrosion in a pump cannot be avoided with a standard material configuration consisting of a bronze impeller (Cathode) in a grey cast-iron casing (Anode). As the potential difference is not too high and drinking water not a strong electrolyte, and last (but not least) the casing is much bigger in volume than the impeller, the velocity of the auto-destruction is slow.

However, this changes completely, if you use the pump in, for example, seawater, or where a high concentration of hypochlorite is injected on the suction side.



ii) Pitting corrosion

This is a localised form of corrosive attacks. Pitting corrosion forms holes or pits on the metal surface. It perforates the metal while the total corrosion, measured by weight loss, might be rather minimal. The rate of penetration may be 10 to 100 times that of general corrosion depending on the aggressiveness of the liquid.

Pitting occurs more easily in a stagnant environment. Remember, due to the load profile in water distribution, not all pumps are operated permanently. And the presence of halogens such as chlorine promotes this type of corrosion.



iii) Crevice corrosion

Like pitting corrosion, crevice corrosion is a localised form of corrosion attack. However, crevice corrosion starts more easily than pitting. Crevice corrosion occurs at narrow openings or spaces between two metal surfaces or between metals and non-metal surfaces and is usually associated with a stagnate condition in the crevice. Crevices, such as those found at flange joints or at threaded connections, are thus often the most critical spots for corrosion.



iv) Cavitation and Corrosion

A pumped liquid with high velocity reduces the pressure. When the pressure drops below the liquid vapour pressure, vapour bubbles form (the liquid boils).

When the pressure raises again, the vapour bubbles collapse and produce intensive shockwaves. Consequently, the collapse of the vapour bubbles removes metal or oxide from the surface.

The damaged surface corrodes more easily especially when the oxide is also removed constantly from the surface. As the counter-pressure in water distribution systems varies, it is unavoidable that the pumps are operated over a short period in partial load or overload with slight cavitation.

b) Water characteristics

In water distribution, we are dealing with tap-water. Following a treatment process for raw water in which specific chemical compounds are often taken out, the pH might be adjusted, contaminants are removed, and chlorine may be added to kill biological toxins. Local geological conditions affecting ground conditions are determining factors for the presence of various ions, often rendering the water “soft” or “hard”.

Water is an oxidant: It can be Acid pH <7, Alkaline pH >7 and Neutral (pH= 7), it contains sufficient H_3O^+ -ions, and oxygen is always in solution.

i) Calcium Carbonate ($CaCO_3$) content

Water as an oxidant is not only dependent on the pH value (the acidity); the calcium carbonate content (also called water hardness) determines whether the water is aggressive or problematic.

The Langelier Saturation index (LSI) provides a degree indicator of water saturation with respect to calcium carbonate. The Langelier saturation index is a way to determine if water is corrosive (negative LSI) or scale-forming (positive LSI). Ideal saturation is 0.0 LSI.

- If LSI is negative: No potential to scale, the water will dissolve $CaCO_3$. Lower than -0.5 indicates corrosive water
- If LSI is positive: Scale can form and $CaCO_3$ precipitation may occur
- If LSI is close to zero: Borderline scale potential. Water quality or changes in temperature, or evaporation could change the index

ii) Chlorine concentration

When adding chlorine, a critical value is 5 mg/l, which is the limit for ferritic material (steel). The chlorine content for drinking water usually is about 10 times lower than that.

When dosing with sodium and calcium hypochlorite:

- The usual content of 0.1-0.3 mg/l refers to tap water and is harmless
- To raise the content level to 1.2 mg/l, inject on the suction side of the pump for better mixing
- Shock chlorination (0.6 mg/l) means the injection of 6-10 mg/l

c) Corrosion protection

Now we will look at protecting the internal and wetted parts of the pump against corrosion, using coatings.

Usually, pumps for water distribution do not require special material variants or coatings. Natural surface water from lakes or rivers usually is harmless, and acidic waters (moorland, for example) are low in CaCO_3 content.

However, treated water can be critical. In sea water desalination plants, the pH is lowered in the RO process and the re-mineralisation incomplete, and so often the treated water has a very low CaCO_3 content and is slightly acid. This also applies to salty well water treated with reverse osmosis.

In these cases, stainless steel pumps might be needed. This can be determined from a water analysis.

To interrupt all electric flow, the casing must be 100 % covered to ensure electrical isolation. This means filling all gaps with an additional machining of the pump casing, also casing-wear-rings, the casing must be painted below them, and the paint must not be damaged when the wear ring is replaced. Take similar care with the threads of the drain plugs.

Grundfos ensures effective resistance against corrosion, erosion and chemicals with highly advanced ceramic coatings, for reliable operation and long lifetime of pumps.

If the size of the pump is not too big, it could be more economical to change the material to a stainless-steel casing and impeller.

i) Coating of internal pump parts

Experience has shown that coatings on the internal and wetted parts of the pump are only effective if the coating is complete. If the coating is incomplete, it could make a corrosion attack worse. This is because the pump acts as a galvanic cell, and if a very small surface is exposed, this concentrates the electrochemical activity and there is risk of crevice corrosion. The electrochemical-crevice corrosion starts in the gap and will creep behind the coating.



5) Main pumping station

Main pumping stations which supply water to the distribution system will be located near the water treatment facility or a potable water storage facility and will pump directly into the distribution system or into transmission lines. These pumping stations are normally rated for high flows and high heads.

Pumps which pump into transmission lines also are called main pumps or high-lift pumps.

Site location will be determined from evaluation of a topographic survey and flood plain analysis to determine if there are any flooding probabilities for the proposed plant site. The site must not be subject to flooding.

Major planning factors are:

- Availability of electric power
- Roadway access for maintenance and operation purposes
- Security
- Adverse impact, if any, upon surrounding occupancies

Site development will depend upon a site soils analysis showing adequate support for foundations or possible groundwater problems, and a grading and drainage plan for the area showing that runoff away from the structures is sufficient.

There are generally two types of pumps used for main potable water pumping stations:

- The vertical turbine pump, with line shaft
- The centrifugal horizontal or vertical split-case pump designed for waterworks service

If the pump station and intake structure are located within a surface or underground reservoir, vertical turbine pumps with the column extending down into the reservoir will be a logical choice. If the pump station is located at an above-ground storage facility, split-case double-suction centrifugal pumps will be the preferred selection. These pumps are normally horizontal but vertical split-case pumps are common where there is limited space.



a) Function and elements

The elements of the main pumping station must match the functions. Where the main pumping station is situated within or next to a water treatment plant, a wellfield or the main storage tank, water is delivered from the source to the consumers, and the pump must fulfil three functions:

- Water transportation
- Water elevation
- System pressurisation

We may find pumps of different sizes working in parallel to cope with the varying demand, and small pumps to pressurise the system and just delivering a minimum flow.

As pump motors are heat-emitters, a ventilation system is needed, and working with an ambient temperature dimensioned to interchange the air volume of the pump room at least 2 times an hour. In hot countries, the need for air exchange increases, and the frequency must be accelerated to 10 times per hour.

At the main motor control center, variable speed drives are also heat-emitters, and their switchboards need to be ventilated, and when closed-in to protect against inundation, climatisation is also required.

A list of all elements at the main pumping station looks something like this:

- Suction tanks
- Suction pipes with isolation valves
- Main Pumps (different sizes may apply)
- Discharge manifolds, each pump discharge with non-return and isolation valves

- Transformers, switchgear
- Motor control center (MCC), variable frequency drive (VFD)
- Instrumentation and controls
- Control room (SCADA, monitoring) can be in remote location
- Chlorine dosing
- Ventilation/climatisation
- Overhead crane
- Flow meter
- Surge vessel/pressure vessel

Generally, the machinery is operated unattended, so instrumentation for measurement is needed, including a small-sized local control unit for automation and communication devices for data transmission; at a minimum for warnings and alarms of malfunctions.

Even though chlorine dosing happens upstream in the water treatment plant, we find another unit in the pumping station, and here the task is a different one. Chlorine injection in the treatment plant is about ensuring potable water; whereas chlorine dosing in the pumping station is about disinfection of the pipes.

Surge vessels can be required and are installed downstream of the pumps and usually outside of the pumping station.

One or two electromagnetic flow meters are installed downstream of the manifold to measure total water pumped.

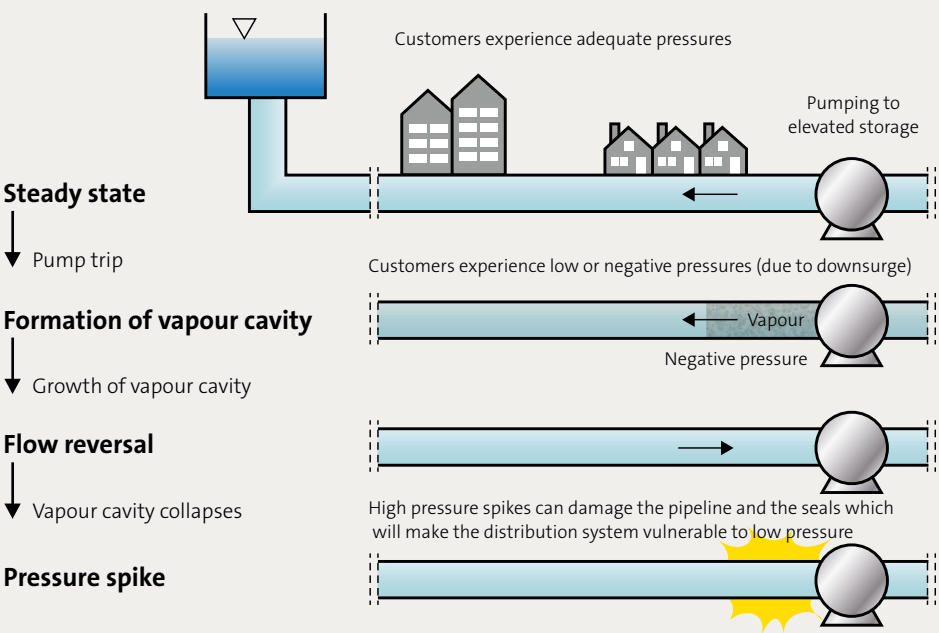
b) Downsurge and water hammer

Downsurge and water hammer are a usual phenomenon a of water transmission and high-lift systems. This cannot be ignored, as a height difference can be considerable even with a short transmission line between the main pumping station and the first branches of the distribution system. The main transmission pipe will have a higher flow velocity, and so the inertia of the accelerated water mass increases.

The worst case is a sudden pump stop, caused by an electrical failure, where the water will keep on moving, even though the pump is not pumping, and causing a vacuum behind. Pipework tends to resist high pressure; under-pressure or vacuum is often ignored and even more critical.

These surges, also called hydraulic transients, can range in importance from a slight pressure or velocity change to sufficiently high pressure or vacuum to rupture the piping system, damage pumping equipment and cause extensive shutdown time. Water hammer, a result of hydraulic transients, will occur when the total surge pressure exceeds approximately twice the value of the static pressure in the system when the fluid is at rest.

Surge protection analysis will be performed on critical sections of the piping system to verify design and surge control equipment selection. If excess transient pressures are predicted by the analysis, design and mechanical equipment application will be modified. Hydraulic surge control is a specialised field.



i) Downsurge and water hammer protection elements

There are several elements that protect against downsurge and water hammer.

A vacuum breaker is a cheap solution with big effect: it opens and lets air into the pipe destroying the vacuum, with the disadvantage of troublesome air entering the pipe, and not only in cases of downsurge, but also when the valve, due to dirt or a worn seat, is not closing properly.

A surge vessel is a better remedy, injecting water to fill the vacuum. The pipe system keeps hermetically closed, and it works in both directions:

- When, after a short period, a counter-reaction starts, a so-called pressure wave returns (remember a wave is energy transmission without material transmission; it is not movement of water but a discharge of its inner tension). In a closed pipe system,

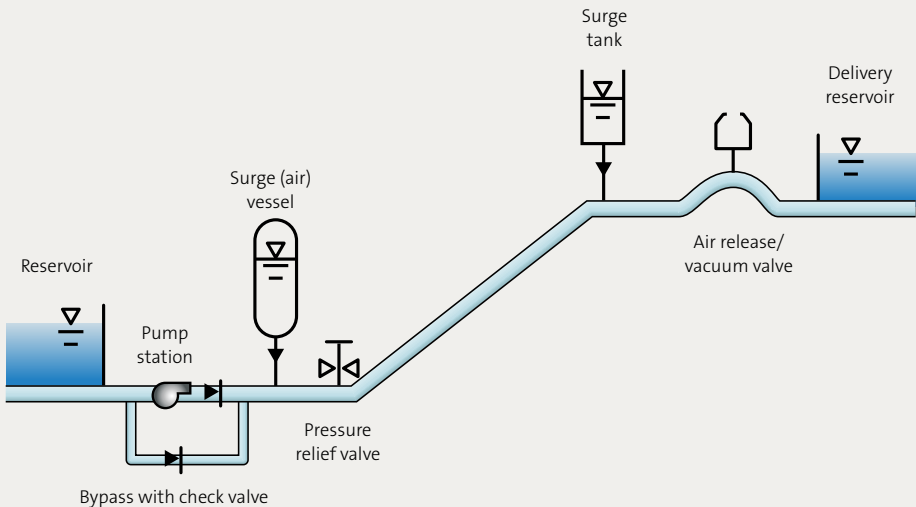
this force can cause damage and we have no opening to release it. It may enter the pressurised tank and compress the air cushion in there.

- We can also bypass the pump check valve and the pump towards pump suction side with a small orifice (and a rupture disc). Remember: we need to lead away pressure and not flow.

A simple option is also a spring-loaded overpressure valve. However, this brings with it similar problems as the vacuum breaker.

Another means of reducing the downsurge/vacuum after a pump trip is to install a fly wheel. A fly wheel is a solid mass installed on the pump or motor shaft that will increase the inertia, prolonging the rotating time of the pump before coming to full stop.

A pump bypass pipe with a check valve as shown below can also be implemented to reduce the down surge.



c) Surge vessel and surge tank

Surge is inevitable when pumping water; it can occur when the flow rate of pumps at a pumping station is altered, valves opened or closed along the pipeline, or uncontrolled pump stop due to power cuts. These can lead to extreme pressure fluctuations which, if not controlled, can lead to disastrous consequences, including burst pipes, unnecessary water loss and supply disruptions. Negative pressures are far more prevalent than high pressures, and considerably more destructive.

A surge vessel is a pressurised tank with compressed air inside (nitrogen sometimes used in pre-charged vessels). It is connected through a check valve held close by the pipe pressure with a bypass with an orifice plate, for tank filling and overpressure discharge into the tank. In case of a pressure drop in the pipeline, the check valve opens and water is injected into the pipeline.

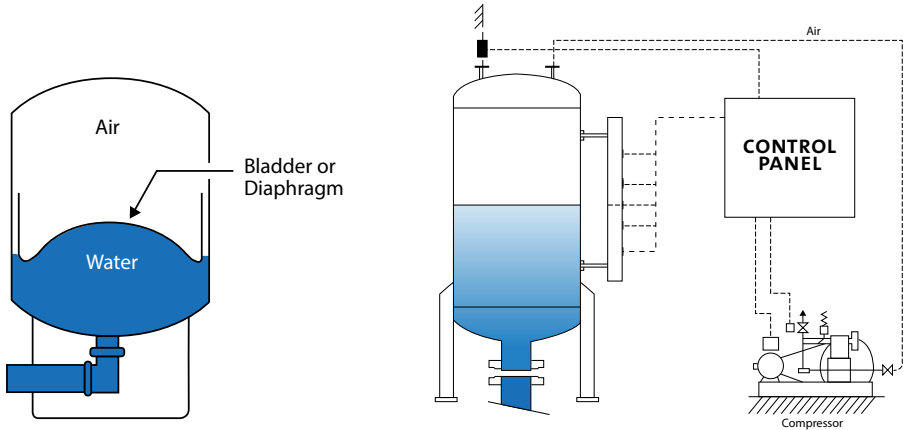
A surge tank is a storage reservoir situated at a high point of a closed aqueduct, to absorb sudden rises of pressure, as well as to quickly provide extra water during a brief drop in pressure when the water column runs away or a pressure wave causes an over or under pressure.

Small-sized tanks and vessels are easy to operate; they have a bladder separating the air cushion of the water the vessel can be pre-loaded with a hand pump.

Larger-sized vessels and tanks do not have a bladder, as the air is in contact with the water and gets dissolved. These tanks/vessels need measurement and control of the water level; in the case of the surge vessel, the water level can be adapted by increasing or decreasing the air pressure inside, requiring a compressor to be connected permanently. The water level in a non-pressurised tank can be adapted by using a float valve.

Dimensioning the surge vessel and surge tank is complex: The water volume in the tank must exceed the water volume “running away in the pipeline”, which is about the running-out time of the pump, depending on the moment of inertia of the water-filled pump impeller, and the size, the length and the slope of the transmission line and the flow velocity.

A surge analysis or transient flow calculation is done by computer simulation.



d) Pipe pressure

The graph shown on this page is the result of a surge simulation by a computer program. Three cases are indicated to illustrate the effect of an immediate pump stop with and without protective elements:

1) Red line: No protection

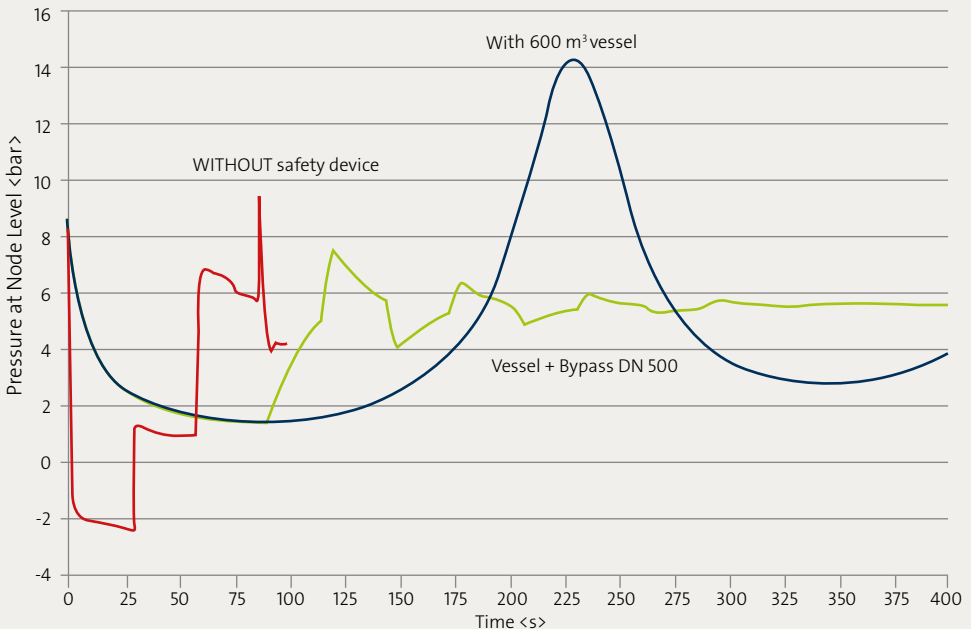
The immediate pressure decrease is immediately visible; effect of the downsurge up to a technical vacuum of -2 bar

Shockwaves arriving at 27, 54 and 81 seconds; the accumulated overpressure reaches 10 bar, 2 bar over the usual operational pressure of 8 bar

2) Blue line: A surge tank is connected to the pipeline

Also visible is the effect of the soon-to-arrive downsurge and the pressure drop being compensated for by the injection of pressurised water; which together with the returning shock waves increase the effect of the overpressure to 14 bar – 6 bar over the operational pressure

3) Green line: Surge vessel and by-pass with orifice, compensating the overcompensation of the surge vessel and releasing the effect of the water hammer



6) Water towers or elevated tanks

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 play a special role within distribution systems; however, the correct expression is 'elevated tank'.

Modern systems are pressurised directly by pumps, and elevated tanks are kept for emergency supply, in case of power cut or to offer an overcapacity in case of fire flow. These tanks are used to deliver a minimum flow too low to start a pump.



Water tower with booster set and control valve

a) Gravity feed for pressurised systems

The function of a water tower or an elevated tank in a water distribution system is comparable to a surge tank in a transmission line:

- When the pipe pressure drops, additional water is injected and the pressure kept up
- When the water level in the tank is low, and there is sufficient pressure in the pipe system, the tank is automatically refilled

A potential issue is that water towers were designed to pressurise the distribution system, and clearly are placed at extreme high points. In modern systems, using pumps to directly pressurise the system may result in the tank pressure always being above the necessary system pressure, and the water towers will remain empty and never refill. Water towers are, however, needed for emergency service.

A solution can be adopted to reintegrate the water tower or elevated tank back into the water distribution system:

- Install a booster pump to refill the tank, as the system pressure is insufficient
- Install a pressure control valve with a predetermined pressure set point that will open to maintain the distribution system pressure and allow water back into distribution; constant renovation of the water in the tank is important to avoid water stagnation
- Many tanks only have one common pipe for filling and emptying; in this case an additional filling pipeline connected to the booster pump is necessary



b) Control valve functions

Automatic control valves work with hydraulic actuators, also known as hydraulic pilots. These types of hydraulic actuators are equipped with a membrane which responds to changes of pressure or flow and will open and close the valve; the response is adjustable by a small valve in the piping towards the membrane, known as a pilot or needle valve.

Automatic control valves do not require an external power source, meaning that the fluid pressure is enough to open and close the valve.

Automatic control valves can be used for following functions:

- Pressure-reducing valves (PRV)
- Flow-control valves
- Back-pressure sustaining valves (PSV)
- Altitude valves
- Pressure-relief or safety valves

Flow-control valves prevent excessive flow by limiting flow to a preselected minimum rate, regardless of changing line pressure. The pilot control responds to the differential pressure produced across an orifice plate installed downstream of the valve. Accurate control is achieved as very small changes in the controlling differential pressure producing immediate corrective action of the main valve.

Pressure-reducing/pressure-regulating valves (PRV) automatically reduces a higher inlet pressure to a steady lower downstream pressure, regardless of changing flow rate and/or varying inlet pressure. PRVs are installed in water distribution systems throughout the world and are known for their superior performance, reliability and long service life. There are many variations on the basic pressure-reducing valve.





7) Local pumping stations

Local pumping stations are usually extensions to existing water distribution systems, either when they are extended or simply because the demand has grown.

A local pumping station is broadly speaking a sub-system for further pressurisation or elevation, and in this regard, is similar in function to a main pumping station. The local station design can also be equipped with local disinfection. Generally, a local pumping station will include a small reservoir connected to the suction of the pumps.

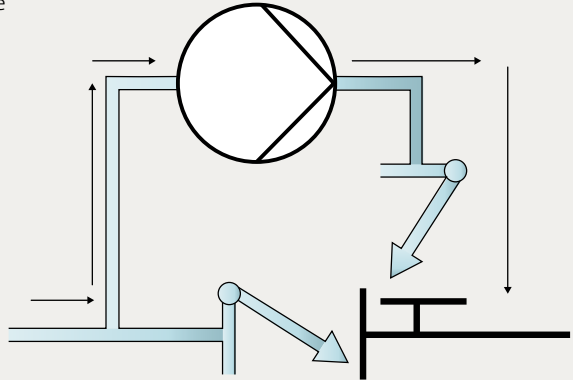


Local stations are usually located remote from the main pump station, as in hilly topography, where pressure zones are required or to handle peak flows in the outskirts of a municipality.

In general, the types of pumps used for local pumping stations are end-suction pumps, and multistage pumps. End-suction pumps are normally horizontal and multistage are normally vertical installations.

Local pump stations are often added into an existing installation, and must fit previous planning and design.

Diagram of an inline booster pump



a) Booster systems

A booster system is needed to provide a minimum or a constant water pressure in a distribution system, when the pressure of the water supply system is insufficient or oscillating too much.





PUMPING STATIONS

8) Pumping station design

In this section, we will look at the overall design of a pump station. We will consider the critical elements involved in designing a pumping station, including the role of Grundfos in selecting the correct products and as a solution provider.

a) Projects and solutions

The pump is at the heart of a pumping station, however the other elements – such as transformers, control panel, sensors, valves, piping, monitoring and the civil structure of the pumping station itself – require much greater investment.

Although the pump isn't the most expensive part of the pumping station, the design and selection of all other components are related to the pump, which means getting pump type, sizing and system optimising correct right from the start is very important.

As discussed under pump pre-selection, optimising the pump selection is a way to offer the most efficient equipment for a defined flow rate. However, an integrated design optimising overall costs is required.

During the design process, Grundfos will usually work with the following stakeholders, each with their specific focus:

- **Consultant:** Easy to plan, reliable technology, no risk, no questions
- **Contractor:** Cheapest price for materials and equipment compliance
- **Operator:** Lifecycle costs, long-term reliability

Often our contact with stakeholders takes another form:

- **EPC Contractor**
Consultant and Contractor in one entity, open for smart solutions (spend to save)
- **Build Operate Transfer (BOT) projects**
Investment and operation costs are both important

For example:

Examples of pump selection affecting cost:

- Deepening a pumping station by 1 m is usually more expensive than the price difference between end-suction and horizontal split-case pumps or changing from 2960 to 1480 rpm. Split-case or lower rpm means less NPSH required by the pump, and therefore, less depth needed to ensure $NPSH_{available} > NPSH_{required}$

- Six smaller pumps in parallel might need cheaper low-voltage electric installations than two big pumps, which due to power consumption must be operated on the medium or high-voltage grid, which may not be available.

This is why Grundfos iSOLUTIONS is so important, saving you money with an intelligent and optimised installation from the start.

b) Pump selection

Pump selection influences the overall design and determines the overall costs. By understanding other cost factors for the pumping station, we can review the initial pump selection to optimise overall costs.

These other cost factors include:

- Available ground area (footprint)
- Depth and width of main structure (affects construction costs proportionally)
- Kilowatt requirement (determines electrical installation costs)

From our preselection criteria, we can now go a step further and determine the pump type. The pressure range to feed water

towers or elevated storage tanks and for the pressurisation of distribution systems is typically between 1.5 to 5 bar, and this usually can be achieved by single stage pumps.

The choice is then between:

- End-suction pumps
- Horizontal split-case pumps

However, there are exceptions, for:

- Extreme ratio between flow (low) and head (high) requires a small multi-stage pump
- High geodetic head due to the topographic features requires multi-stage pumps
- Direct injection from the deep well into the distribution system (if no water treatment is needed) requires submersible well pumps
- Water tanks equipped with vertical turbine pumps



i) Horizontal split-case versus end-suction pumps

The pump selection determines the overall costs, and the pump dimensions affect the engineering design. Beyond this, the pump type and its suction and discharge pipe add costs.

From our pre-selection pump example in Section 3, we saw that the delivery of 250 l/s (900 m³/h) into a system pressurised with 3 bar can be done with:

- 2 pumps - 450 m³/h and 1450 rpm = N_q 42 (Horizontal split-case), or
- 5 pumps - 180 m³/h, 2900 rpm = N_q 50 (end-suction pumps)

Both solutions offer good efficiency. Or it can be a mix of both pumps to widen the operation range:

- 1 pump: 450 m³/h + 3 x 180 m³/h

Pumping station depth:

The measure of which pump type gives the cheapest engineering design is a question of:

- Less depth (NPSH) – wider span (piping)
- Deeper station – narrow construction

The following are standard building lengths of civil engineering design. Exceeding them increases the civil costs proportionally:

- Standard lengths of building span:
6 m/20 ft or 12 m/40 ft
- This case – required span:
Horizontal split-case pump: 7.2 m
End-suction pump: 5.5 m

The building for the end-suction pump will be a lot cheaper, the cross beams of precast concrete in standard length of 20 ft or 6 m is sufficient, and the overhead crane span will also be less.

- Depth required as per NPSH_{required}:
Horizontal split-case pump: 4.3 m
End-suction pump: 6.5 m

If the water suction tank is not elevated, the foundation level for the end-suction pump may need to be below ground level (requiring excavation), while the horizontal split-case pump could be fixed to a simple concrete foundation at ground level.

ii) $NPSH_{available}$ and $NPSH_{required}$

To work out $NPSH_{available}$ and $NPSH_{required}$ it is necessary to look at where the water is coming from, and then select a pump with a $NPSH_{required}$ less than the $NPSH_{available}$.

Without question, it is cheaper to optimise the $NPSH_{required}$ of the pump than having to lower the ground level of the pumping station:

- A horizontal split-case pump with double suction impeller needs less suction pressure than an end-suction pump
- A bigger pump with the same flow and head but actuated with a lower speed motor, for example with a 4-pole motor instead a 2-pole motor, also requires a much lower $NPSH$

In both cases, more expensive pump equipment is required. However, the extra cost is over-compensated by the cost savings in the engineering design and construction cost.

iii) Design when using a vertical turbine

If costs for the ground area (footprint) of the pumping station are prohibitive to an extent that the increased operating costs balance out, then a solution using a vertical turbine pump could be relevant, specifically in pressure boosting solutions.

However, although a narrow borehole for the pump is a plus, some critical aspects to consider with vertical turbine pumps include:

- Vibration resonance frequency when speed is reduced by a variable speed drive
- High maintenance costs due to the requirement for a crane to raise the pump, and time consuming disassembly and reassembly



Pump sump design

Most vertical turbine pumps have semi-axial impeller hydraulics, which are demanding for suction flow conditions (not a good n_q).

A minimum rectified flow velocity is needed to achieve satisfactory efficiencies.

- Pump chamber dimensions are related to the flow/size of the pump
- Vortex breaker to be positioned under the suction bell
- Pumps in parallel to be separated by baffle walls
- A minimum immersion depth must be respected

Formed Suction Inlet (FSI)

In situations where the sump design is not suited for a vertical turbine pump and the pump does not get a rectified flow – for example, if the distance between the baffle walls is too big and the velocity is almost zero – satisfactory

suction conditions can be achieved by mounting the pump in a tank with a prefabricated Formed Suction Inlet (FSI).

Do not use with a VFD

Unlike horizontal pumps with short shafts, which run with undercritical speed (vertical pumps are operated at overcritical speed), speed reduction by a frequency converter might bring the pump into its critical speed related to its Resonance Frequency. Operating the pump in this way can destroy the pump.

It is almost impossible to predict the resonance frequency to avoid the operation in the corresponding speed, it is often detected during pump operation, and is usually more than one frequency:

- The pump-resonance frequency
- The vertical motor resonance frequency
- The pump-motor group resonance frequency

The vibrations produced already near the resonance frequency can slowly destroy the structure, causing cracks in the concrete. Operating in the resonance frequency destroys the equipment.

Variable speed drives are used on vertical turbine pumps. However, if pump operation with a frequency converter to regulate the flow in an energy-efficient way is desired, a vertical turbine pump is not the best option. Use horizontal pumps such as end-suction or horizontal split-case pumps.



c) Optimising the costs of electrical equipment – AC motors, efficiency and VFDs

In a pumping station, the cost of the electrical equipment exceeds the cost of the pumps:

- **Relays** – low voltage is cheap; from medium voltage, considerable extra cost
- **Transformers** – considerable extra cost
- **Type of starter** – considerable extra cost
- **Electric motor** – considerable extra cost, even higher for medium and high voltage

If a medium voltage switchboard is required (>200 kW), costs increase proportionally. Power companies regulate the maximum amperage allowed for Direct Online (DOL) Start and maximum power consumption allowed for low voltage.

i) AC motors

The most common pump motor is the Asynchronous Current 3-phase induction motor, also called squirrel cage.

An AC motor is an electric motor driven by an alternating current (AC). The AC motor commonly consists of two basic parts, an outside stationary stator having coils supplied with alternating current to produce a rotating magnetic field, and an inside rotor attached to the output shaft producing a second rotating magnetic field. The rotor magnetic field may be produced by permanent magnets, reluctance saliency, or DC or AC electrical windings.

When an AC motor is in steady-state rotation (motion), the magnetic fields of the rotor and stator rotate (move) with little slippage (near synchrony).

The magnetic forces (repulsive and attractive) between the rotor and stator poles create average torque, capable of driving a load at rated speed.

Three-phase squirrel-cage asynchronous motors are widely used as industrial drives, in sizes relevant for water supply and distribution applications (<200 kW), usually with nominal speed:

- 3000 rpm (or 3600 at 60 Hz) – 2-pole motors
- 1500 rpm (1800 at 60 Hz) – 4-pole motors
- In old installations, 1000 rpm (1200 at 60 Hz) – 6-pole motors

They are manufactured in serial production and are reliable and economical. Squirrel cage induction motors are very widely used in both fixed-speed and variable-frequency drive (VFD) applications.

Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFDs). VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque and load applications such as centrifugal pumps.

ii) Efficiency classes

Along with the international discussion on energy efficiency, a worldwide harmonised energy efficiency classification system has been established for low-voltage three-phase asynchronous motors. The International Electro-Technical Commission IEC has developed and issued a new standard for the determination of motor efficiencies worldwide.

The new 2014 standard IEC 60034-30 defines and harmonises worldwide the efficiency classes IE1, IE2, IE3 and IE4 for low voltage three-phase motors in the range from 0.12 to 1,000 kW. IE4 has a super premium efficiency, IE3 premium efficiency, IE2 high efficiency and IE1 standard efficiency.

Grundfos IE3 motors comply with the EISA2007 legislation for USA and are ahead of the EU requirements legislated by the EuP directive.

IE4 and IE5 motors

The Grundfos MGE motors model H/I/J are the most energy efficient yet. These permanent magnet synchronous motors (PMSM) are designed especially for frequency converter operations and optimised for pump applications and high part-load efficiency. This results in lower energy and lifecycle costs and exceeds the IE4 level in IEC60034-30-1, even with frequency converter losses at medium.

iii) Motor start method

The power determines the cost of electric equipment; taking the voltage as fixed, the current is the critical dimension. The starting torque of an AC motor usually is above the required torque of a centrifugal pump with radial hydraulics. For that reason, we find a high potential in reducing the motor torque and so the starting current.

There are several starting methods for centrifugal pumps with radial hydraulics.

Direct online start

This starting method is only permissible for small consumers, and in some countries, is prohibited by law.

Star Delta

This is the cheapest way of reasonable reducing starting current. An issue can be no current (torque drop) for a few milliseconds. This affects pumps with a low moment of inertia such as multistage pumps, vertical turbine pumps, and pumps started against an open valve.

Transformer

Using a transformer to reduce voltage during motor starting is a good but expensive solution.

Soft-Starter

Soft start with current control is a state-of-the-art solution, where semi-conductor technology replaces copper wiring. Starting current is reduced to approximately 50 %.

Frequency converter start

A start using a variable frequency drive is a step-wise transition from one frequency to a higher frequency, resulting in a significant reduction of the required pump torque.

This allows for the smallest starting current of all methods, and this economical use offsets the extra initial cost.

iv) Variable frequency drives (VFD)

Let us look closer at variable frequency drives in frequent-use applications, and how the cost benefits arise.

At various speeds of rotation n , a centrifugal pump has different characteristic curves, which are related to each other by the affinity laws.

If the characteristics Head (H) and Power (P) as functions of the Flow (Q) are known for a speed n_1 , then all points on the characteristic curve for n_2 can be calculated by the following equations:

$$Q_2 = Q_1 \cdot n_2/n_1$$

$$H_2 = H_1 \cdot (n_2/n_1)^2$$

$$P_2 = P_1 \cdot (n_2/n_1)^3$$

With a change of speed, the operating point can be shifted. The operating point B moves along the system curve to smaller flow rates when the speed of rotation is reduced.

The expenditure for variable speed drives is not low, but it is amortised quickly for pumps which are used often and which are frequently required to run at reduced flows with small static head component.

This is particularly the case in flat water-distribution systems, however for regulating the flow rate in a water-elevation application with a high static head the variable- speed drive is not an option – as you see in the formulas.

Remember:

The flow rate reduces proportional with the speed, but the head drop is quadratic.

v) Summary

Power electrics

The main cost factor is current; a reduction of amperage leads to a significant cost reduction for electrical equipment. Remember, the substation is to be dimensioned for peak-consumption, based on either:

- The starting current of one pump motor
- The power consumption of all pumps minus one operated plus the starting current the remaining pump

The key issue for the pump supplier is to bring down the starting current. This can be done in 2 ways:

- Choose a good starting method (soft start or a frequency converter)
- Apply smaller motors, which means putting more pumps in parallel

The extra cost for the electromechanical equipment (pump motor groups) will be compensated for in the power electrics.

Cost factors for pumping station design

Looking at the engineering and design costs (width and depth of the pumping station), the cost factors of the power-electrical equipment is directly linked to the peak-power consumption. The key is to optimise the current (amperage).

The peak current for each unit is not reached at its operation, but at its start. As not all equipment is started simultaneously, but one-by-one, the size of each single pump in combination with the starting method carries a huge potential for cost savings.



9) Design tips

The following section presents some advice and tips to ensure the smooth operation of the pump and pumping station. It is certainly an advantage to consider these issues in the planning and design stage:

- How to connect a pump
- The suction pipe
- Valves in pumping stations
- Disinfection (Chlorination)
- Monitoring
- SCADA and control solution

a) Reduce nozzle forces

When connecting the pump, the mistake is often made to consider the pump the fixed point in the piping. This is misunderstood, as pump movement due to the transmission of pipe forces is the most common customer complaint following pump sales.

Unfortunately, many consulting engineers seem unaware of this, referring to API609 (API-American Petrol Institute), where Pump Nozzle Forces – very high nozzle forces – are defined, and then these API Norms are applied to water distribution projects.

Instead of foreseeing support-points for the water-filled pipe and thrust-blocks to bind lateral pipe forces from accelerating the water column, they calculate all pipe forces with a sophisticated software and state this as resulting nozzle forces to be taken by the pump. This may work for small pumps and flow rates; however, for larger pumps in waterworks, a non-restrained expansion joint may develop sufficient force to move a pump on its baseplate or, even worse, deform the pump casing. Pipes must always be supported, and the pump connected force and moment-free.

b) Essential elements for suction and discharge pipes

A proper pump connection is essential for a smooth operation of the pump, the following elements must be included on a drawing for a pumping station:

Minimum length of suction pipe (distance between pump and next functional element)

The suction pipe must be of sufficient length and correct diameter. The flow is pre-accelerated before entering the pump; for a 3600-rpm pump, this is from 0 m/s in the tank, to 1 m/s in the main pipe and suction header, around 2 m/s in the suction branch and 4 m/s in the suction nozzle of the pump.

Eccentric reducer on suction side, concentric reducer on discharge side

The reduction piece shall be eccentric and not mounted directly to the pump flange. A minimum distance between the pump and all functional elements such as valves, bends, tapers of 3-5 pipe diameters must be respected.

Pipe support and thrust block (fix point) to limit horizontal and vertical nozzle forces

Suspend the pipe and ensure a massive fix point (concrete block) near the pump on discharge side.

Dismantling pieces and bellows lockable against lateral movement

Pipe expansion joints must be restrained (3-flange type), to ensure all pipes are tied back to the fix support point.

c) Recommended length of suction tubing

You can find different measurements for the suction line, recommending 4-6 x the pipe diameter, as per ANSI HI 9.6.6. The distance between pump and the next functional element (in this case, the reducer) must be 2-3 x the pipe diameter.

In case of pumps driven by a 2-pole motor with acceleration by up to a factor of 5 (0.8 to 4.0 m/s), the line must be longer, and an NPSH_{available} reduction of 2 m considered.

For slow-turning pumps, it is common to fix the reducer directly to the suction flange of the pump.

d) Air pockets in pipework

Air in the pipes can cause an awful lot of noise and can reduce pump performance. The noise of air in the pipes is often a vibrating sound or a rapid ticking sound similar in pace to a machine gun firing – and can sound worse than water hammer.

Air in the pipes can be difficult to get rid of, as air tends to get trapped at high points in the pipe system, where it is difficult to push out. As the water moves in the pipes, it breaks the pockets of air up into tiny bubbles. Then the water flows past the bubbles, leaving the air still in the pipe. These tiny bubbles move around, expand and contract, creating the rapid vibrating sound you hear.

Pump efficiency is affected as the pump is not only moving water, but also compressing air bubbles, and these air bubbles are occupying space acting in the same way as a half-closed valve, reducing the water passage through the pipe.

e) Air-release valves

Air-release valves, or venting valves, slowly release the pockets of air that accumulate at high points in the piping system. In pumping stations, they are recommended on the upper casing of horizontal split-case pumps and on the discharge elbow of a vertical turbine pump. This type of valve is float-controlled, the float falling and opening the seat to vent when air accumulates in the valve body. Once the air is out and the water level rises, the float closes the valve.

f) Isolation (stop) valves

Isolation (stop) valves in pumping stations serve to isolate tube branches in case of repair or maintenance work. They are usually fully opened or fully closed. Valves that remain in one position for an extended period of time become difficult or even impossible to operate, unless they are exercised from time to time.

Isolation (stop) valves can be of different valve types:

- Globe valves
- Ball valves (like cone and plug valves)
- Butterfly valves
- Gate valves

All valve types are available in all diameters, and the selection criteria as to valve type is head loss (or friction coefficient ζ).

For all sizes, the ball valve is the best; especially for small sizes. The gate valve is the next best, and in larger sizes is the cheaper option. Over DN 150, the butterfly valve is comparable to the gate valve. Occasionally, isolation valves are also used for throttling (see below).

g) Isolation valves for pressure and flow regulation

Using isolation (stop) valves for throttling by 'strangling' the pipe is surprisingly common. This method is commonly used when the discharge pressure is too low, causing vibration and possible cavitation of the pump. This happens when the discharge pressure is below the operating pressure allowed for the pump, at a specific flow rate. Throttling solves the pump problem, but wastes energy and is certainly not recommended. Reducing pump speed, reducing pump impeller or even changing the pump could be a better option that will save money in the long term.

Operating the valve partially closed will result in very high velocity at the edge of the gate or disc, and can cause cavitation that will destroy the valve and pipe. Gate valves must not be used for throttling. The throttling effect is only in the last 5 % of the valve closure. Butterfly valves can be used for throttling, but do not provide good control.

Ball valves have better control characteristics, reducing the tube cross-section in a more constant and controllable way. This means that throttling works fine, but should not be practiced for permanent operation, as the accelerated flow through the reduced gap produces wear and tear.

For flow regulation, using a variable speed drive (VFD) is certainly recommended. However, we cannot escape the fact that isolation valves are used for flow regulation.

Changing the flow rate Q by throttle valve is the simplest flow control method, not only for a single adjustment of the flow rate but also for its continuous control, since it requires the least investment. But it is also the most energy-wasting method, since the flow energy is converted irreversibly to heat. By intentionally increasing the system resistance – changing the system curve – the pump is forced into another operation point.

If flow regulation must be done by valves in permanent operation, it must not be done with isolation valves. In the absence of variable speed drives or for special working conditions (also at the waterworks), you require the following flow control valves:

- **Small flow/size (DN 50 - 150)**

Globe valve with a throttling cone or a perforated cylindric throttling stem and inverse flow direction

- **Large size (DN 100 - 1400)**

Plunger valves or needle valves are usual

The perforated cylinder also can be found in the pilot operated flow control valves.

h) Check valves or non-return valves

A check valve usually is required to prevent reverse flow and prevent the pump working as a turbine on backflow, and protects it from shock waves from water hammer. It keeps the pipe filled when the pumps are not operating.

Compared to selecting other valves, the selection of the correct valve for check applications is far more difficult. However, the operation of a badly chosen and badly installed check valve is certainly to be avoided.

Check valves should be placed at a minimum distance of 4-5 tube diameters to the pump, to avoid pump turbulence causing the valve disc to flutter and wear its bearings. Check valves installed in vertical pipes can be covered by sedimentation when the pump does not operate – depending on type and quality - and this can be a serious problem.

There is a large variety of check valves available. The most common types are:

• Swing check valve	SCV
• Ball check valve	BCV
• Resilient hinge check valve	RHCV
• Tilting disc check valve	TDCV
• Dual disc check valve	DDCV
• Resilient hinge CW (spring)	RHCVs
• Silent check valve	SCV
• Nozzle check valve	NCV

Dynamic pressure loss is one of the criteria that determines their suitability in relation to pumping station design. As with isolation valves, head loss (or friction coefficient ζ) is a selection criteria. This differs a lot between the various check valve types, and from manufacturer to manufacturer. It is very important to check the closing characteristics of the valve.

Check valve slam

Check valve slam occurs after pump stoppage when the system flow reverses back towards the pump before the check valve is fully closed. The reverse flow causes the check valve to close rapidly through the remaining portion of its travel. The reverse flow is then stopped instantaneously by the closed valve causing a pressure surge/water hammer in the pipe.

To prevent check valve slam, a check valve must either close very rapidly before appreciable reverse flow occurs or very slowly once reverse-flow has developed.

To close rapidly:

- The disc should have low inertia and friction,
- The travel of the disc should be short, or
- The motion should be assisted with springs.

The answer to preventing check valve slam is not to find the fastest-closing check valve and make it the ‘standard’. Instead, the non-slam characteristics of the check valve must be matched with the pumping system. Every check valve has inherent advantages such as low cost, low head loss, or special flow characteristics. The best check-valve solution is not necessarily the fastest closing one and so with the least potential to slam.

For a low-head application with a long pipe length, there is less potential for rapid flow reversal, and the simplest and lowest-cost check valve may be used without slamming. On the other hand, a multiple-pump station sending water to a high-head system with a nearby elevated or pneumatic surge tank will experience an extremely rapid flow reversal, and only certain check valves can be used without slamming.

Calculating the deceleration is complex; it is a function of many parameters such as pump inertia, inertia (length) of the liquid column, friction losses in the piping system, the static head and slope of the pipe.

Engineers typically rely on a computer simulation of the system to compute deceleration.

VALVE TYPE	REVERSE VELOCITY	TYPE OF SLAM
Nozzle check valve	60 mm/sec	none
Silent check valve	100 mm/sec	none
Dual disc check valve	200 mm/sec	mild
Tilting disc check valve	240 mm/sec	mild
Swing-flex check valve	550 mm/sec	severe
Swing check valve	> 600 mm/sec	severe

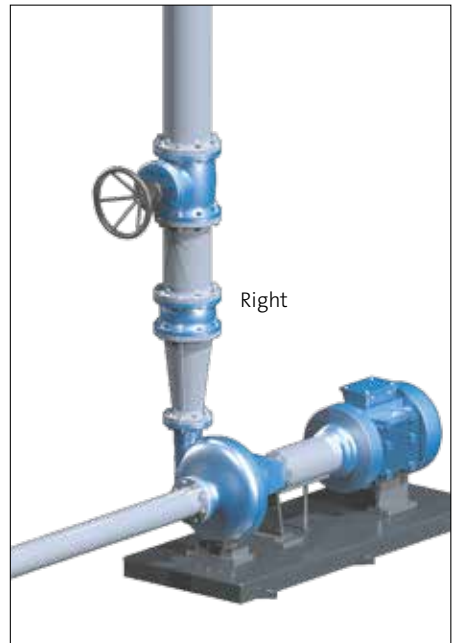
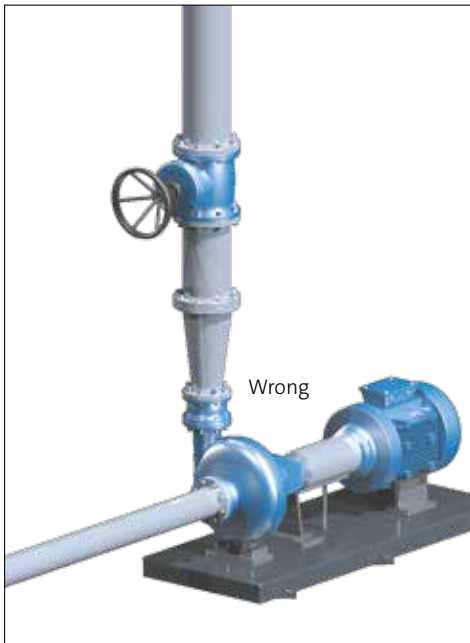
Good and bad practice, and the effect on operating costs

Good practice for the design of the suction and discharge pipe with their elements means determining the following:

- Diameters of the piping with the desired flow speed below 2 m/s, depending on the length of the pipe (the distance between pump and suction/discharge header)
- Immediate diameter expansion on the discharge flange
- A length of pipe to the check valve and the stop valve

The photo on the left shows an example of a really poor design.

The check valve is mounted directly on the discharge flange of the pump, with only a small diameter expansion of just one size. The increase in operating pressure due to the small check valve will result in an increase in electrical energy cost and in a very short time exceed the price difference for an investment in a larger check valve.



i) Chlorine disinfection

Effective drinking water disinfection – an assessment of chlorine-based methods – is as old as public water supply itself. Microbiological parameters for drinking water treatment include coliform bacteria and specific pathogenic species of bacteria, virus, and protozoan parasites.

Although the objective is the same – to provide safe clean water – the methods used to do so are numerous. The most common methods for water disinfection are chemical ones.

Chlorine disinfection in pumping stations

The purpose of disinfection/chlorine dosing in water distribution pumping stations, in contrast to water treatment plants, is not the purification of the water of germs and organic substances, but to combat bacterial contamination and fouling in the pipe system.

For that reason, the dosing is discontinuous and applied in a high concentration (called shock chlorination), often injected in the suction header to use the pump as a mixer.

Chlorine works by forming hypochlorite when dissolved in water. It is a fast-acting oxidant with a wide biocidal effect. It is highly effective at low concentrations. The excellent sustained-release of chlorine is of particular benefit, as it continues to disinfect a pipeline system over a relatively long period of time.

Chlorine dioxide (ClO_2) provides excellent and long-lasting water disinfection. As a bactericide, sporicide, viricide and algicide, chlorine dioxide is highly effective, also against microorganisms exhibiting chlorine resistance. In terms of sensory parameters, chlorine dioxide does not change the taste or smell of the water. It is less corrosive than hypochlorite in the water pipeline and is effective against biofilm.

This removes the nutrient source and haven for microorganisms and in doing so further prolongs the disinfection effect.

Hypochlorisation uses very high concentrations; chlorine dioxide injection is not corrosive.

Grundfos offers 3 different chlorine injection methods, and the decision as to suitability of one method over another is often not a matter of quality or result, but based on national or local laws, norms and regulations.

j) Pump monitoring (or instrumentation and control devices)

The major reason for pump monitoring is the supervision of operations and performance. Many pumping stations are operated unattended, and the potential property damage is significant if a serious malfunction occurs. Instruments should be selected for their inherent reliability and backup systems are required; the consequences of component failure must be carefully considered.

However, two other aspects are becoming increasingly important:

- Wear detection
- Data acquisition

Wear detection is about the concept of predictive maintenance which, in contrast to the classical maintenance interval, allows for replacement of wear parts when this is really needed. Data acquisition is a prerequisite to run a SCADA System.

What to monitor

The question of what to monitor can be considered from the following three areas that should be incorporated in a pump monitoring concept:

- Pump performance monitoring and pump system analysis
- Vibration monitoring and bearing temperature
- Visual inspections

Individually, each of these is an important indicator; collectively, they provide a complete picture as to the actual condition of the pump. It is important to look at:

- Flow rate
 - General function
 - Calculate efficiency
 - Load profile

- Inlet/outlet pressure
 - Dysfunction (cavitation)
 - Calculate efficiency
 - Load profile
- Bearing temperature
 - Dysfunction
 - Wear detection
- Vibration
 - Dysfunction (cavitation)
 - Misalignment
 - Wear (bearings)
- Amperage (power consumption)
 - General function
 - Calculate efficiency
 - Wear detection (wear rings)
- 3-phase supervision
 - Damage prevention
- Motor winding temperature
 - Damage prevention

For each measurement, two values need to be defined and programmed into the plc:

- Alarm
- Trip (switch off)

For pump performance, monitoring should ideally cover five parameters:

- Suction pressure
- Discharge pressure
- Flow
- Pump speed
- Power

Vibration and temperature measurement helps to detect mechanical malfunction, and visual inspection is inevitable in case of misinterpretation of the measurement.

Using the data and detecting wear

At a minimum, suction and discharge pressure are essential for determining the head of the pump. Understanding the pump head is critical to estimating where the pump is running with respect to its Best Efficiency Point (BEP) - even though the flow is not measured.

Power consumption calculated from the Amperage, measured together with the characteristic curve, can prove (or contradict) that the pump is running well. If the acquired data is inconsistent, the flow must be measured.

Bearing temperature and vibration monitoring are related to the preventative maintenance concept; however, they can be used for supervising operation. Partial load operation can increase both bearing temperature and vibration level. The loss of proper alignment – caused by water hammer, for example – can also be detected.

Visual inspection

A slow but constant increase of vibration, bearing temperature and power consumption (Amperage) with unchanged hydraulic data can indicate wear of bearings and an increase of the gap between impeller and casing wear rings. This can be confirmed by a visual inspection.

SCADA systems

A Supervisory Control and Data Acquisition (SCADA) system is not only used for the visualisation of a plant in a SCADA System but is also the most powerful format in pump station design; the 'process and instrumentation diagram', also called 'single line diagram'. This is especially the case at the concept stage.

Data Analytics and Management

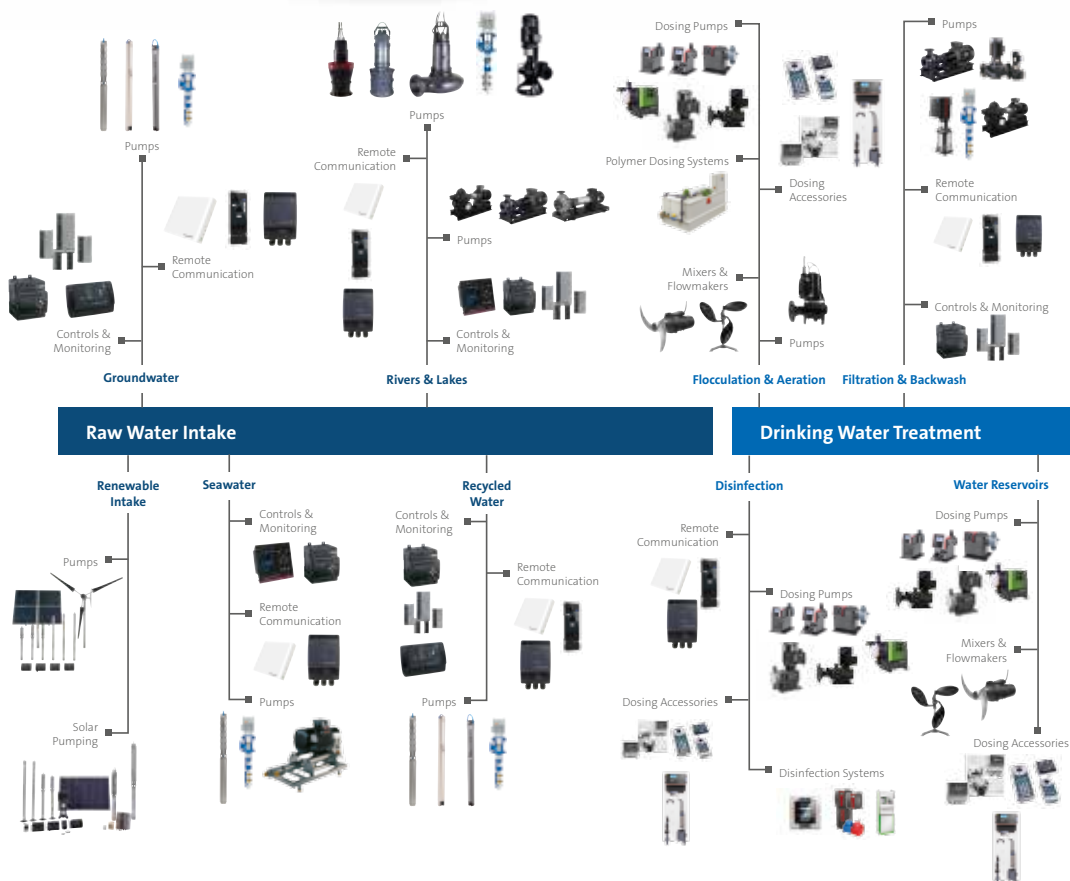
Today, data is being collected and analysed in many ways. Grundfos has and continues to develop intelligent controllers and platforms, using data for failure prediction, machine learning, trends, and early warning for pumping systems and networks.

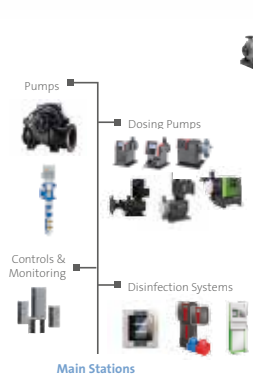
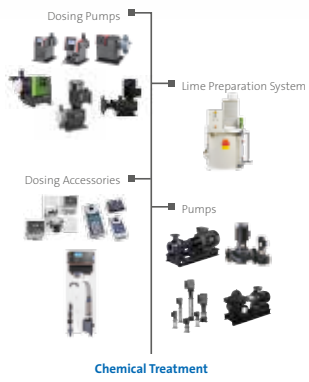
PRODUCTS AND SOLUTIONS





GRUNDFOS PRODUCTS IN WATER SUPPLY



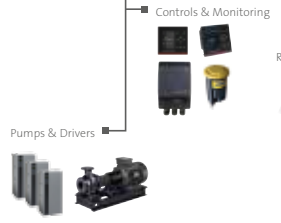


Water Distribution

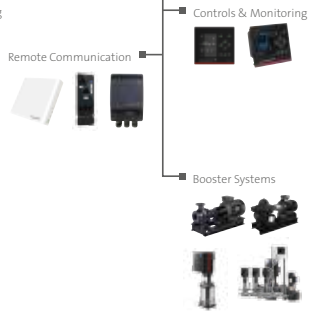
Sedimentation Desalination



Demand Driven Distribution



Grundfos iSOLUTIONS



8:20h
0:00h
0:00h
0:00h



System run
Alarm





GRUNDFOS iSOLUTIONS

Intelligent system optimisation is offered by Grundfos iSOLUTIONS. Built up around our comprehensive control and communication offerings, you get an intelligent water supply system offering savings from lower non-revenue water (NRW), greater efficiency and lower energy costs. We offer easy integrations and commissioning with your system with all components from one supplier.



PUMP MONITORING AND MANAGEMENT

— GRUNDFOS REMOTE MANAGEMENT

With the Grundfos remote management solution, you get remote monitoring, analysis and control included in a low-cost subscription. There is no initial cost and no additional hardware and software costs. All data are stored in secure facilities with access only to subscribing users. Different user profiles can be set up for different levels of access, depending on your system's complexity.

- Access from phone, tablet or PC, and quickly see and review the status of your pumps and locations
- Reduce maintenance costs by moving to a predictive workflow and go from routine service checks to planned and effective maintenance only when required
- Timely warnings enable preventive service before alarms occur, reducing costly breakdowns, and with access to key data, you can plan for service and maintenance



MOBILE PUMP CONTROL

— GRUNDFOS GO REMOTE

Designed to save time and effort for the pump owner, this is the most comprehensive platform for mobile pump on the market, offering intuitive, handheld assistance and access to the Grundfos online tools, saving valuable time in reporting and data collection.

- Group pumps, change configuration parameters and monitor pump data
- Descriptive error codes make trouble shooting easy and intuitive
- Time saving, with quick links to documentation, replacement tool, and automatic updates



DEMAND DRIVEN DISTRIBUTION – DDD

Grundfos Demand Driven Distribution is the first pressure management solution that combines precise measurement of the network pressure and advanced pump control at the pumping station according to these measurements. The solution compensates for excessive system pressure by adapting the setpoint to the actual flow. This is done by measuring pressure at critical points in the system.

- Reduced leakage (Non-Revenue water) – less water lost through leakage and pipe bursts
- Energy savings – reduce the excessive energy used because pressure is too high and for pumping water lost through leakage
- Reduced operation and maintenance costs – lower average pressure decreases costs of leakage repairs and extends system lifetime



MULTI-PUMP CONTROLLER – MPC

Grundfos Control MPC is a control cabinet with a CU 352 controller that permits monitoring and control of up to six identical pumps connected in parallel. The Control MPC is easy to install and configure and offers standby pump allocation, forced pump changeover and dry-running protection to help increase system reliability, reduce downtime and costly maintenance. Soft pressure build-up minimises risk of water hammer, reducing the risk of leakage and costs of pipe maintenance.

- Intelligent cascade controller based on pump efficiency
- Pump cut-in/cut-out is based on detailed pump curve data
- Leakage detection in non-return valves, protecting against water loss
- Reduced wear due to cavitation (pump outside duty range feature)



EXTERNAL FREQUENCY CONVERTERS

– CUE

A complete range of external frequency converters designed for speed control of a wide range of Grundfos pumps for water supply, wastewater and irrigation applications. A special start-up guide will lead you through the set-up of the CUE.

- Predefined control modes, sensor range and pump family data make it very easy to set up a system in only a few steps
- Shares the unique Grundfos intuitive interface with Grundfos control equipment
- Very easy installation and set-up – just 16 steps to get a system up and running



FIELDBUS COMMUNICATION INTERFACES

– CIM/CIU

The Grundfos fieldbus concept is the ideal solution for complete control of pumps and pump systems. The Communication Interface Module (CIM) and the Communication Interface Unit (CIU) enable data communication via open and interoperable networks.

- Ease of installation and commissioning, user-friendliness, and great value for money
- All modules are based on standard functional profiles for easy integration into the network and easy understanding of data points
- Supports a wide range of Grundfos products



MOTOR PROTECTION UNIT – MP 204

Reliable, easy to set up and easy to use motor protection for all Grundfos pumps and applications, for motors

ranging from 3 to 999 amps and voltages from 100 to 480 VAC that protects pump motors against under-voltage, overvoltage and other variations in power supply and overheating.

- Power factor measurement, giving an indication of clogging in the intake or impeller wear
- Motor power consumption continually checked with precision, stopping the pump before dry-running, preventing pump damage
- Alerts for ground failure/insulation resistance, allowing preventive maintenance of the motor, cables, or cable joints

INTAKE PUMPING STATIONS

The key characteristic for intake pumping stations is the **suction water level variation**. The requirement is for low NPSH from submersible non-priming pumps.





SUBMERSIBLE PUMPS

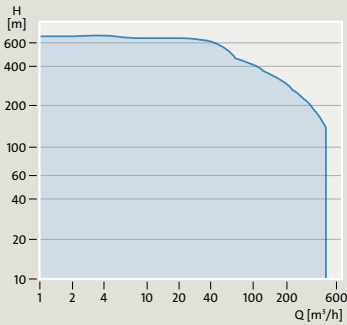
– SP

Complete range of submersible pumps for groundwater applications built to deliver optimum efficiency during periods of high demand, with long product life and easy maintenance.

- State-of-the-art hydraulics provide high efficiency and low operating costs
- Made entirely of stainless steel to ensure high reliability and long lifetime, even in corrosive environments
- One supplier of the pump, motor and controls for an optimal pumping system

TECHNICAL DATA

- Motor size: 0.37 kW to 250 kW
- Flow rate (Q): Maximum 470 m³/h
- Head (H): Maximum 670 m
- Liquid temperature: 0 °C to +60 °C
- Discharge diameter: 1" to 6"
- Diameter: 4", 6", 8", 10", 12"





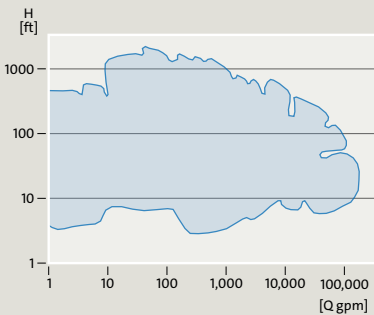
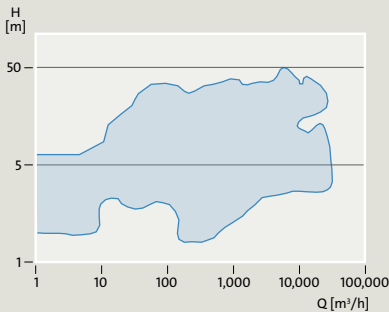
VERTICAL TURBINE PUMPS – VT RANGE

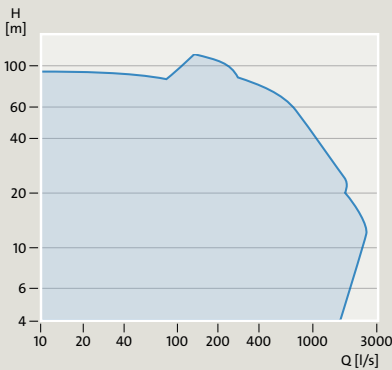
The VT pump range is for deep wells and has a dry motor connected to the submersed pump body using a line shaft. These pumps are robust and built for reliability and longevity. They are oil-lubricated and typically used in areas where noise is not an issue.

- For applications requiring low $NPSH_{required}$, high flow and high head
- Engineered- and configured-to-order for highly specific application requirements
- Hydraulic range from 4" to 72" with flexible and customised performance

TECHNICAL DATA

- Flow, Q : 25,000 m^3/h
- Head, H : 700 m
- Power: max. 2 MW





WATER TRANSFER PUMPS – S RANGE

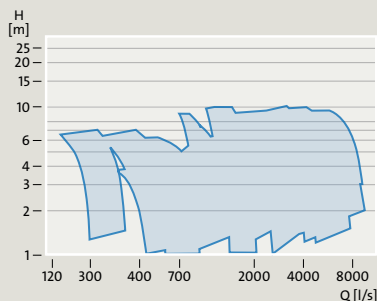
These powerful raw water transfer pumps are selected for their strength, their durability, and for innovative features such as the SmartTrim impeller clearance adjustment system and the Smart Seal for leakage prevention.

- High efficiency and durable water transfer pumps
- Patented SmartTrim system for extremely easy impeller adjustment keeps performance high and lifecycle costs low
- The SmartSeal auto-coupling gasket provides a completely leak-proof connection between the pump and the base unit

TECHNICAL DATA

- Motor size: Up to 520 kW
- Flow rate (Q): 2500 l/s (9000 m³/h)
- Head (H): 116 m
- Liquid temperature: 0 °C to +40 °C
- Discharge diameter: 80 to 600 mm
- Free passage: Up to 145 mm
- Insulation class: F (H on request)
- Maximum system pressure: PN 10
- Maximum hydraulic efficiency: 85 %

Does not have Potable Water Certification



AXIAL-FLOW PROPELLER PUMP – KPL

Submersible axial-flow propeller pump designed for the high flow at low head requirements of raw water transfer and other similar duty applications.

The Turbulence Optimiser™ reduces turbulence in the gap between the pump volute and the column pipe, increasing

- With the Turbulence Optimiser™, for best-in-class hydraulic efficiency of up to 86 %
- High-voltage motors for low installation costs
- High-precision one piece propeller with back-swept design reduces clogging

TECHNICAL DATA

- Motor size: 11 to 700 kW
(Up to 850 kW on request)
- Flow rate (Q): 9,200 l/s (33,120 m³/h)
- Head (H): 10 m
- Liquid temperature: 0 °C to +40 °C
- Discharge diameter: Up to 2200 mm
- Insulation class: F
- Maximum installation depth: 20 m
- Maximum hydraulic efficiency: 86 %

Does not have Potable Water Certification



MIXED-FLOW PUMP – KWM

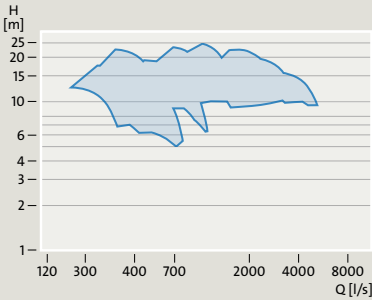
Submersible mixed-flow pump designed for the high flow at low head requirements of raw water transfer and other heavy-duty pumping applications.

- With Turbulence Optimiser™, for best-in-class hydraulic efficiency up to 86 %
- High-voltage motors for low installation costs
- Robust, reliable and efficient, offering maximum value for money

TECHNICAL DATA

- Motor size: 11 to 700 kW
(Up to 850 kW on request)
- Flow rate (Q): 5,555 l/s (20,000 m³/h)
- Head (H): 20 m (Up to 400 m on request)
- Liquid temperature: 0 °C to +40 °C
- Discharge diameter: column
(FPV up to DN 2,200)
- Insulation class: F
- Maximum installation depth: 20 m
- Maximum hydraulic efficiency: 85 %

Does not have Potable Water Certification

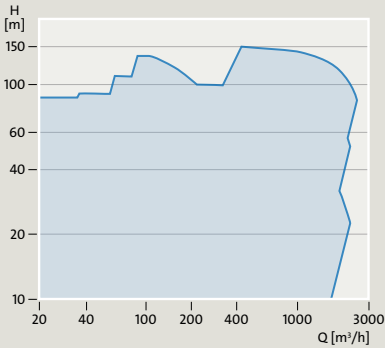


MAIN PUMPING STATIONS

For main pumping stations, the key characteristics is **bulk transport**. The requirement is for heavy duty and high efficiency pumps that can handle high flow.







HORIZONTAL SPLIT-CASE PUMPS – HS

This horizontal split-case pump is a single-stage, non-self-priming, between-bearing, centrifugal volute pump. The axially-split design allows easy removal of the top casing and access to the pump components without disturbing the motor or pipework.

- Low NPSH_{required}, high volume and high efficiency pump
- Heavy duty and low maintenance
- Double suction minimises axial load, extending the life of the wear rings, shaft seals and bearings
- Double volute reduces radial forces and minimises noise and vibration

TECHNICAL DATA

- Motor size: 1.1 to 630 kW
- Flow rate (Q): 2500 m³/h
- Head (H): 148 m
- Liquid temperature: 0 °C to +100 °C
- Discharge diameter: DN 50 to DN 450
- Maximum system pressure: 16 bar
- Maximum hydraulic efficiency: 90 %



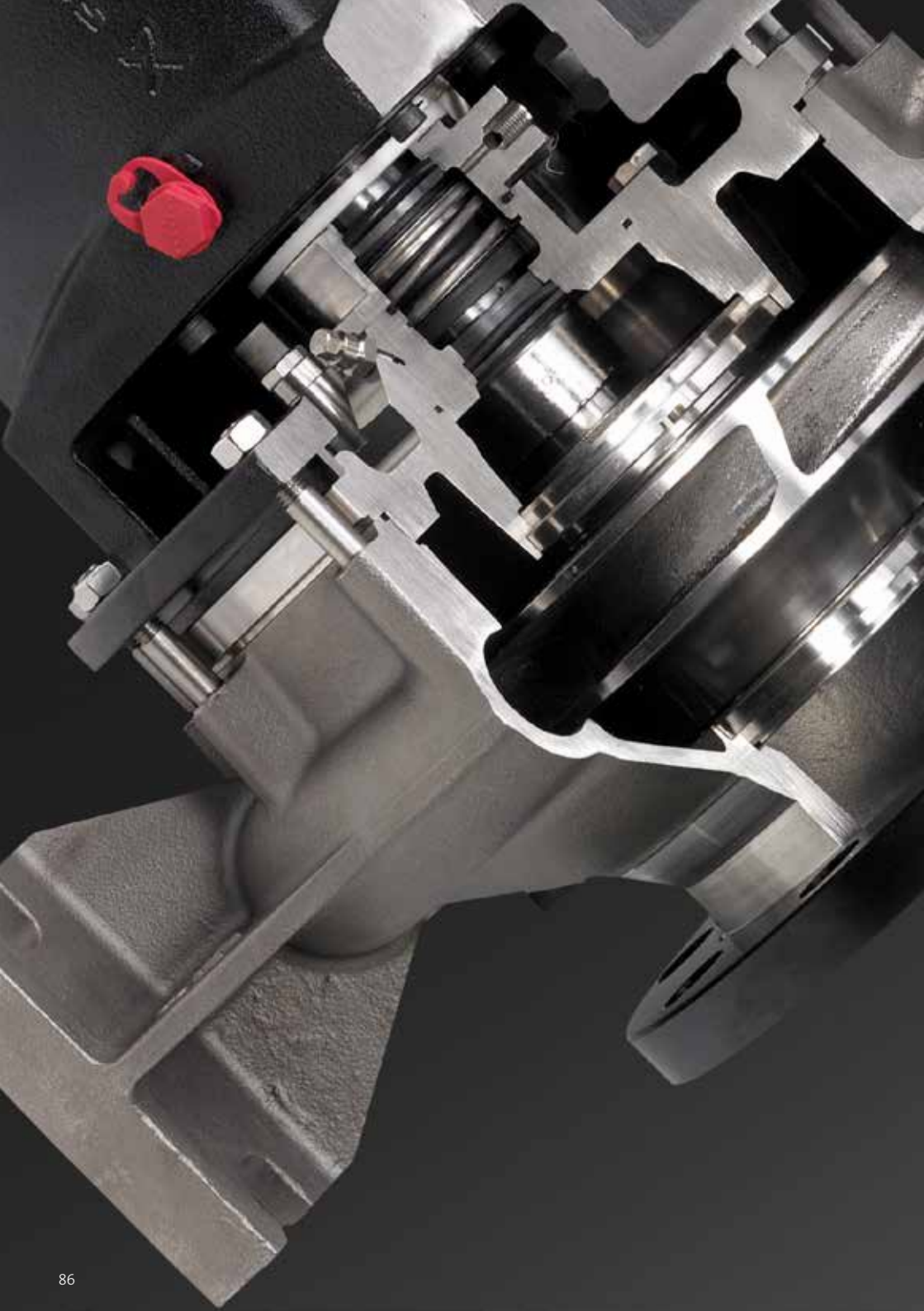
HORIZONTAL SPLIT-CASE PUMPS – LS

This horizontal split-case pump is a single-stage, non-self-priming, between-bearing, centrifugal volute pump. The axially-split design allows easy removal of the top casing and access to the pump components without disturbing the motor or pipework.

- Low NPSH_{required}, high volume and high efficiency pump
- Heavy duty and low maintenance
- Double suction minimises axial load, extending the life of the wear rings, shaft seals and bearings
- Double volute reduces radial forces and minimises noise and vibration

TECHNICAL DATA

- Motor size: 1.1 to 2,240 kW
- Flow rate (Q): 12 to 12,000 m³/h
- Head (H): 8 to 165 m
- Liquid temperature: 0 °C to +100 °C
- Discharge diameter: DN 50 to DN 800
- Maximum system pressure: 10 or 16 bar
- Maximum hydraulic efficiency: 91.5 %



A close-up, high-contrast photograph of industrial pump components, likely a centrifugal pump. The image shows a dark, cast metal housing with several circular ports, and a lighter-colored, possibly stainless steel, impeller or shaft assembly. The lighting creates strong highlights and shadows, emphasizing the metallic textures and complex geometry of the parts.

LOCAL PUMPING STATIONS

A local pumping station is characterised by **flow and pressure variation**. The pumping system must offer variable speed control.



SINGLE-STAGE END-SUCTION STANDARD PUMPS

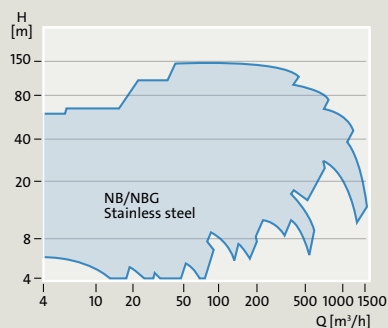
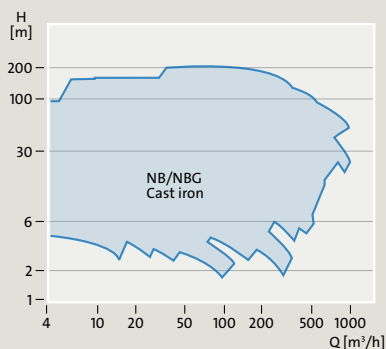
– NB/NBG/NBE/NBGE

Multi-purpose end-suction pumps for reliable and cost-efficient applications such as water supply.

- High efficiency
- O-ring seal between pump housing and cover means no risk of leakage
- Housing, impeller and wear ring in different materials for improved corrosion resistance, no sticking elements
- Also available with a permanent magnet MGE motor up to 11 kW with built-in variable frequency drive and IE5 efficiency

TECHNICAL DATA

- Motor size: 0.55 to 200 kW
- Flow rate (Q): Up to 2200 m³/h
- Head (H): 210 m
- Liquid temperature: -25 °C to +140 °C
- Discharge diameter: DN32 to DN250
- Free passage: 4 to 34 mm
- Maximum system pressure: 16/25 bar
- Maximum hydraulic efficiency: 88.5 %





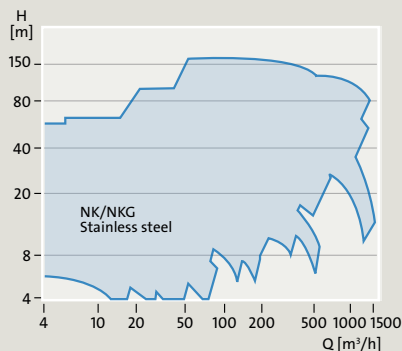
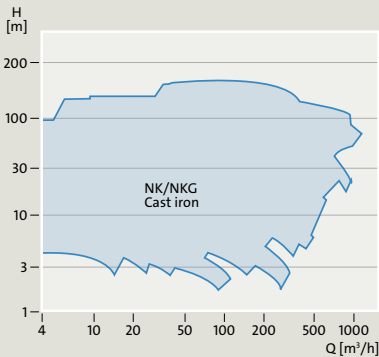
SINGLE-STAGE END-SUCTION STANDARD PUMPS – NK/NKG/NKE/NKGE

Multi-purpose end-suction pumps for reliable and cost-efficient applications such as water supply and irrigation. Back pull-out design enables removal of the motor, coupling, bearing bracket and impeller without disturbing the pump housing or pipework; these long-coupled pumps comply fully with either EN733 or ISO2858.

- High efficiency
- O-ring seal between pump housing and cover means no risk of leakage
- Back pull-out design for easy dismantling for service
- Also available with a permanent magnet MGE motor up to 11 kW with built-in variable frequency drive and IE5 efficiency

TECHNICAL DATA

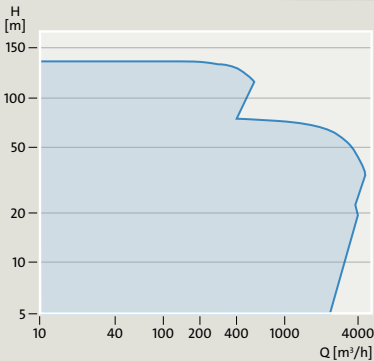
- Motor size: 0.55 to 460 kW
- Flow rate (Q): Up to 2200 m³/h
- Head (H): 210 m
- Liquid temperature: -25 °C to +200 °C
- Discharge diameter: DN32 to DN250
- Free passage: 4 to 34 mm
- Maximum system pressure: 16/25 bar
- Maximum hydraulic efficiency: 88.5 %





BOOSTER SYSTEMS FOR LOCAL PUMPING STATIONS

At the booster pumping station, the key characteristic is **pressure increase**. This requires inline and compact pumps.



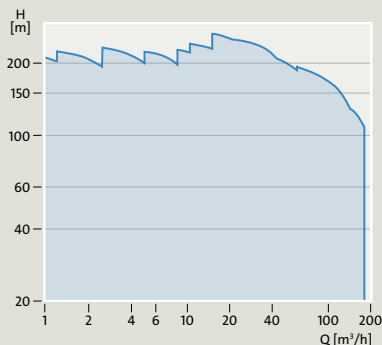
VERTICAL INLINE VOLUTE PUMPS – TP/TPE

Single-stage, in-line centrifugal volute pumps with standard motors and mechanical shaft seals. Compared to end-suction pumps, in-line pumps allow a straight pipework and thus often reduced installation costs and space. TP pumps up to 22 kW are available as TPE pumps with built-in Variable Frequency Drive.

- Optimised hydraulics for high efficiency and reliability
- Energy savings from reduced power consumption
- Reduced space required for installation
- Also available with a permanent magnet MGE motor up to 11 kW with built-in variable frequency drive and IE5 efficiency

TECHNICAL DATA

- Motor size: 0.12 to 630 kW
- Flow rate (Q): 4500 m³/h
- Head (H): 140 m
- Liquid temperature: -25 °C to +150 °C
- Discharge diameter: DN 25 to DN 500
- Maximum system pressure: 25 bar
- Maximum hydraulic efficiency: 90 %



MULTI-STAGE CENTRIFUGAL PUMPS

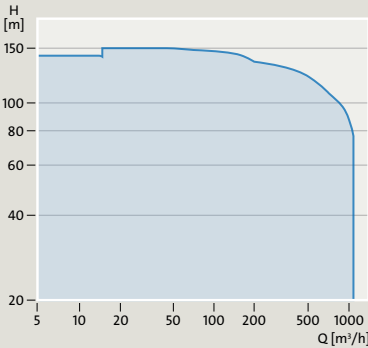
– CR/CRE

Modularity for a complete range of pump solutions; from four material variants, thirteen flow sizes (up to almost 50 bar of pressure), a variety of shaft seals, rubber materials, and supply voltages. Pump parts can be optimised and designed for specific requirements.

- Also available with a permanent magnet MGE motor up to 11 kW with built-in variable frequency drive and IE5 efficiency
- Multi-flange fits a variety of standard connections for a more flexible solution
- Uniquely designed cartridge shaft seal increases reliability, reducing downtime

TECHNICAL DATA

- Motor size: 0.37 to 75 kW
- Flow (Q): Maximum 180 m³/h
- Head (H): Maximum 500 m
- Liquid temp.: -40 °C to +180 °C (240° C, Thermal oil)
- Operating pressure: Maximum 50 bar
- Discharge diameter: Up to DIN 150
- Maximum efficiency: 80 %



HYDRO MPC

These pressure-boosting systems minimise energy consumption and cut energy costs straight out of the box. They are built on Grundfos CR and CRE centrifugal pumps and available with application-optimised functions for perfect performance in any given application. Hydro MPC booster systems are easy set-up and operate with monitoring and communication via BUS, SCADA or Grundfos Remote Management. Systems are built using high precision stainless steel manifolds and engineered precisely to your installation and system design needs.

- Reduced space required for installation
- Wide range of operation
- Grundfos MPC controller handles even the most difficult boosting jobs with ease and accuracy

TECHNICAL DATA

- 2 to 6 pumps
- Motor size: 0.55 to 75 kW
- Flow rate (Q): 1080 m³/h
- Head (H): 146 m
- Liquid temperature: 0 °C to +70 °C
- Discharge diameter: Up to DN 350
- Enclosure class: IP 54
- Maximum system pressure:
PN16 (standard) (up to PN 40 on request)
- Maximum hydraulic efficiency: 80 %
- Ambient: 0 °C to +40 °C

NOTES

NOTES

be think innovate



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