Grundfos Distributed Pumping

Applied to chilled water systems in Commercial Buildings

Application guide –
Grundfos Distributed pumping

GRUNDFOS

Possibility in every drop

Preface:

The fossil fuels that are used for power, HVAC (Heating, Ventilation and Air Conditioning) and transport have contributed 80% of increased greenhouse gas (GHG) emissions since 1970, according to the Global Environment Facility.*

Buildings alone account for almost one-third of global energy use, and nearly 30% of total GHG emissions, including energy end-use emissions, electricity generation emissions and HVAC.

Grundfos puts sustainability at the heart of everything it does. We are continuously developing new ways to reduce energy used in pumping through more efficient products and full system solutions as part of our commitment to the United Nations Sustainability Goals 6 and 13.

The Grundfos Distributed Pumping system is an example of how we've applied technical innovation to deliver huge efficiency gains.

Grundfos Distributed Pumping is a paradigm shift towards decentralised pumping for commercial buildings' chilled water systems, removing traditional balancing-, control- or pressure-independent control valves (PICV) and replacing them with intelligent, connected pumps - generating flow and pressure only when and where it's needed.

This results in an automated, and significantly more efficient chilled water system in regard to pump energy used, flow balancing and ease of use.

With Grundfos Distributed Pumping, you can improve indoor climate, lower maintenance costs, and reduce your climate footprint.

This application guide explains how Grundfos Distributed Pumping improves performance in chilled water systems and removes many of the shortcomings of conventional valve systems. It provides a technical description of best practices in system design and control modes of distributed pumping topology for combined heating and chilled water systems.

** https://www.thegef.org/topics/energy-efficiency*

Table of contents

1. Introduction to hydronic HVAC systems for commercial buildings

2. Plant configurations and system design - conventional vs. distributed pumping

3. Chilled water pumping control

4. Design Example DPS

5. Value propositions DPS

1. Introduction to hydronic HVAC systems for commercial buildings

This section introduces hydronic systems, which are also known as water systems.
Hydronic systems, in this text, are systems using water as the heat transfer medium.

1.1 Energy production side

The production side of the chilled water system contains chillers and chilled water pumps (Evaporator). In this circuit, the chillers cool the water circulated by the primary pumps in a continuous loop.

1.1.1. Chilled water systems (CHWS)

A chilled water systems provide cooling to a building by using chilled water to absorb heat from the building's spaces by using chilled water to transfer its energy to air which flow to the building.

Chilled water systems provide cooling to a building by using chilled water to absorb heat from the building's spaces, by using chilled water to transfer its energy to air which flow to the building.

1.1.1.1. Basics of chilled water systems (CHWS) with different components

From the early years of HVAC design in commercial buildings, chilled water (CHW) has been effective in transferring heat from areas of higher loads - such as building loads at air handler coils and industrial equipment loads at heat exchangers - to a condensing water loop or a cooling system for heat rejection. The size of the cooling load determines chiller capacity requirements, which can then be met by one or more chillers.

Commercial aircon or cooling systems are mostly rated in Tons of cooling (TR). Cooling systems also may be rated in kWh or BTU/hr.

Chilled water systems consist of the following:

- **Chillers** - refrigeration machines used to cool water or brine (water containing an antifreeze)
- **Condenser** - either air-cooled or water-cooled
- **Condenser water pumps** - for distribution of water to the condenser side (for water-cooled chillers)
- **Heat rejection component** - a cooling tower (or condenser)
- **Chilled water pumps** - for distribution of water from the evaporator to the building
- **Chilled water piping** - either direct return or reverse return
- **Condenser water piping** (for a water-cooled system) or refrigerant-based piping (for an air-cooled or evaporative-cooled distribution system) - used to move the separate fluid systems between the respective components

Chilled water systems (CHWS) typically supply a chilled water supply temperature (CHWS-T) between 5.5°C/42°F and 12°C/53°F (adjustable).

If a commercial building requires a set temperature, the chilled water system will be enabled manually or by the building management system (BMS/BAS). Occasionally, this will be set to an occupancy schedule, such as office hours. Chillers are enabled after commanding ON chilled water pumps and condenser water pumps. Normally chilled, water-cooled water systems work with cooling towers, which are a source of condenser heat rejection. Chilled water pumps and cooling tower fans are often controlled using variable frequency or variable speed drives (VFD/VSD), altering speed to meet demand.

In Figure 1.1, the warm condenser water of 35°C/95°F flows into the cooling tower from the chiller condenser side via the condenser water pumps.

It is then sprayed over a fill before being collected in the tray at the bottom.

The water then returns to the chillers at a temperature of 29.5°C/85°F (adjustable).

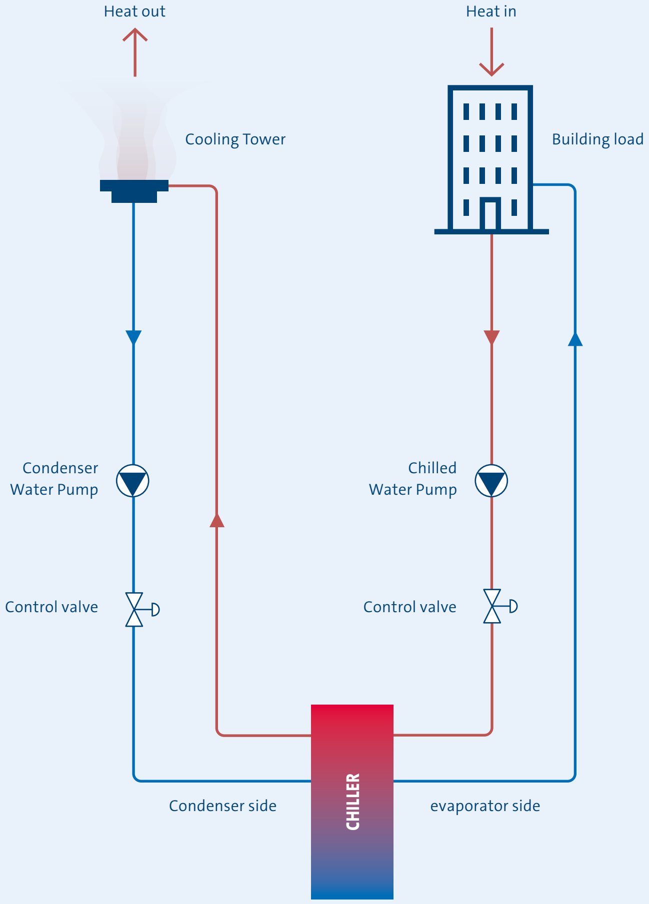


Figure 1.1 *Operation of conventional chilled water systems CHWS (Water-cooled chillers)*

1.2 Energy consumption side

1.2.1 Air Handling Unit (AHU)

An Air Handling Unit (AHU) is used to recondition and circulate air as part of a HVAC system. The AHU takes in outside air, conditions it, and supplies it as fresh air to a building.

The supply fan (SF) is the main component of an AHU. If the supply fan is set to ON (check the supply fan status, or ensure the SF-S is on), the AHU is considered operational.

1.2.1.1 Operation

When the supply fan is on, and the AHU is fully operational, the cooling coil control valves and the heating coil control valves will, in most situations, adjust the system to maintain the discharge or supply air temperature (DA-T) at the correct setpoint (13°C/55°F, DA-T, SA-T).

In a distributed pumping system, where the pumps, replace control valves, the pump speed is adjusted to meet the setpoint based on the discharge air sensor. In a anti-freezing condition, the conventional system-cooling coil control valve and heating coil control valve will adjust to either a fixed or partially-open position (for example, 100% open or 50% open) to prevent coils from freezing and keep water flowing in low-temperature conditions.

Multiple systems working together

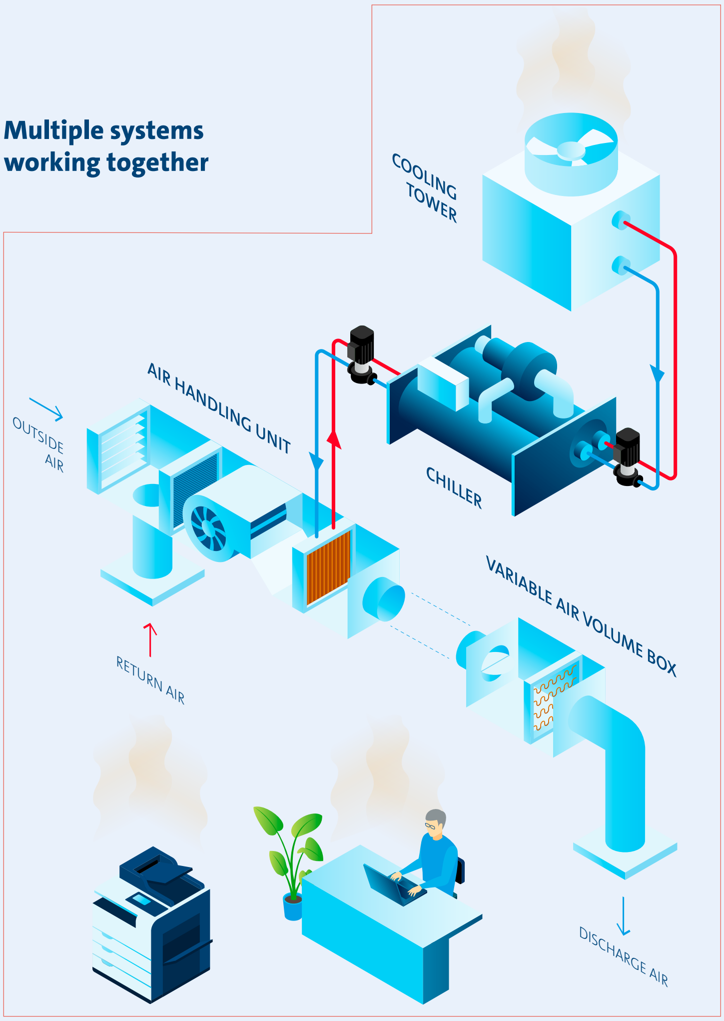


Figure 1.2 The figure shows how the water side (chillers, pumps and cooling towers) is connected to the air side (air handling unit and variable air volume box).

1.2.1.2 AHU types

1. Mixed air: mix of outdoor and return air from the space/atrium, to supply air to the space/atrium.

2. 100% outdoor air: only outdoor air is taken into the system. There is no return air, and no mix.

1.2.2 Fan Coil Unit (FCU)

An FCU is part of a HVAC unit commonly used in residential and commercial applications for small spaces such as offices or pump rooms. The device consists of a set of heating and/or cooling coils, and a fan to blow air over them. Simply put, an FCU is small air handling unit.

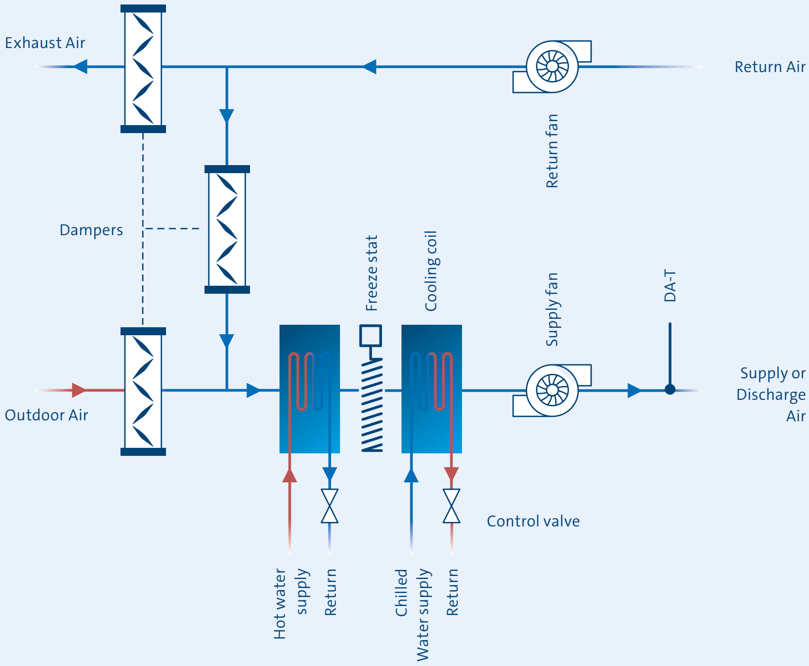


Figure 1.3 *Mixed air AHU*

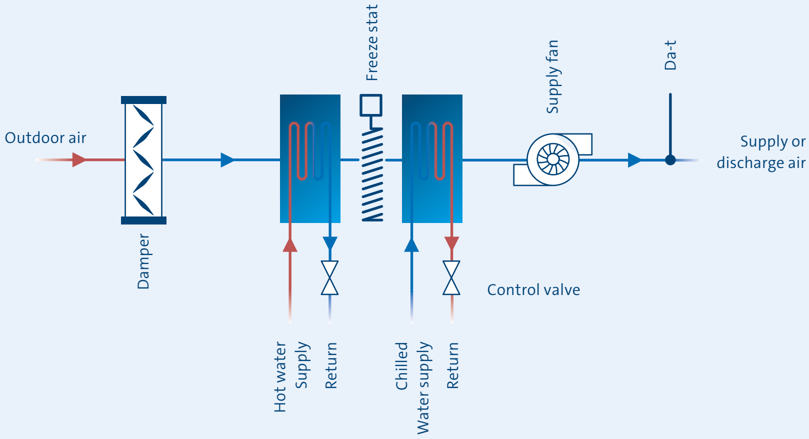


Figure 1.4 *100% outdoor air AHU*

1.2.2.1 FCU application and installation

- Fan coils can be used for both heating and cooling. For both the fan coils are connected to a room where a thermostat turns the fan coil fan ON or OFF or modulates the control valve according to the room temperature setting.
- Fan coils can be mounted against the wall or on the ceiling

1.2.2.2 Operation

In a high end building installation a direct digital controller (DDC) uses a space/zone temperature sensor to control the modulating control valves for hot water and chilled water, and maintains the temperature in that space.

The DDC has separate heating and cooling setpoints.

- When the temperature is below setpoint, the controller closes the chilled water valve. When the chilled water valve is fully closed, the hot water valve opens to maintain the setpoint temperature
- When the temperature is above setpoint, the controller closes the hot water valve. And when the hot water valve is fully closed, the chilled water valve opens to maintain the setpoint temperature.

The DDC offers a start/stop function to cycle the fan on for heating or cooling. When the desired temperature is reached, the fan switches off. When the fan coil fan is switched off, heating and cooling coil valves must be closed.

In simpler buildings a room thermostat simply opens or closes a valve and turns on the fan in a fan coil. (cooling scenario) When the temperature is above the desired temperature the valve will be fully open. Once the room temperature is reached the valve will close.

A) FCU for cooling and heating

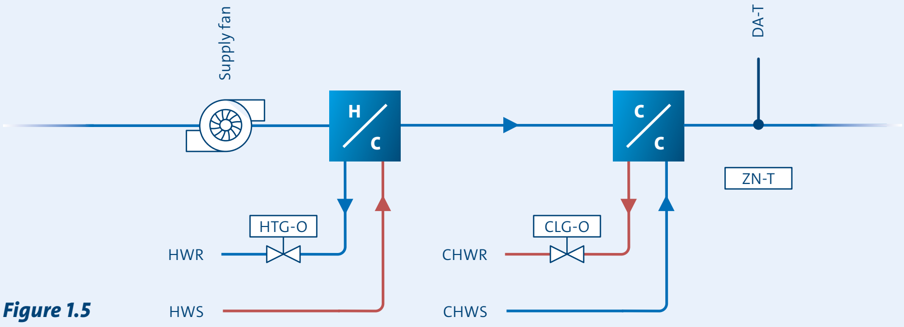


Figure 1.5

B) FCU for cooling only

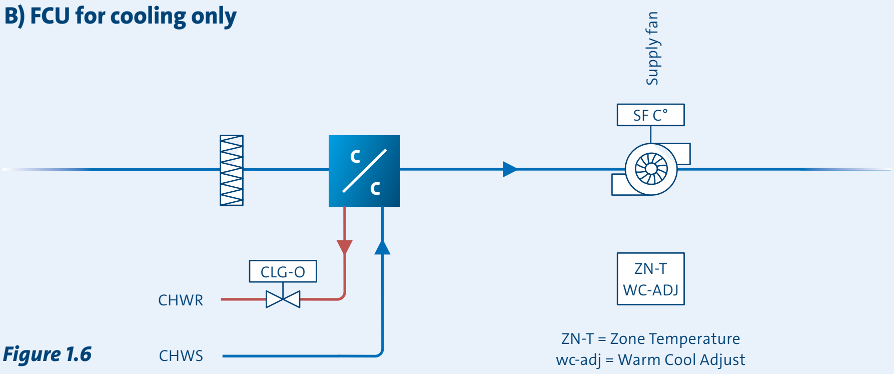


Figure 1.6

2. Plant configurations and system design

In this section, we will compare conventional and distributed pumping systems.

Introduction to DPS

In a typical chilled water hydronic system, fluid is moved throughout the piping network by pumps and controlled by a series of balancing and control valves.

The most common arrangement for pumps is primary with secondary (variable or constant speed) or variable primary. In such arrangements, the balancing and control valves are located throughout the network of chilled/hot water piping and are used to control flow to either terminal units or zones.

With Grundfos Distributed Pumping, these control valves are replaced by intelligent circulation pumps. Without valves, flow cannot be inhibited, and unnecessary system pressure losses cannot occur.

By adding pumps instead of valves we eliminate the equipment that limits flow and thereby eliminate unnecessary pressure losses. Replacing the valves with pumps also reduces the friction losses in the system, lowering the amount of energy required to operate the system.

Distributed pumping is more than replacing valves with pumps. It is a new way to distribute flow throughout the entire chilled or hot water system. To control system flow, distributed pumps require some specific control abilities that are key to flow control and energy efficiency.

2.1 Chilled water system plant configurations

2.1.1 Variable-primary flow chilled water system, VPF

2.1.1.1 Conventional VPF systems

The Variable Primary Flow (VPF) design eliminates the need for constant-flow chiller pumps by using variable flow pumps to circulate water throughout the entire chilled water loop (see Figure 2.1).

VPF systems are sometimes referred to as primary-only chilled water systems.

The key components of this system are:

1: Valves - a two-way control valve on Air Handling Units (AHU) and Fan Control Units (FCU) acting as a pressure-modulating device to adjust branch flows during changes to a building's heat load, and a balancing valve to perform hydraulic balancing for each branch. The control and balancing valves can be replaced by a pressure-independent control valve (PICV)

2: A Differential Pressure (DP) sensor - typically used to control the speed of the primary pumps. The location of the DP sensor is an important choice during the building's design stage; we have assumed it is sited either at the bypass or at the index loop

3: Primary pumps - sized to circulate the water to the highest pressure drop loop (index loop) in the building. The speed of the primary pumps is controlled via sensor feedback from the DP sensor. If the chilled water flow drops below the minimum chiller flow, the valve in the bypass line will open, allowing flow to bypass from the supply line to the return line to ensure the chiller's minimum flow is maintained.

The VPF design is capable of separating pump control (delivering enough water) from chiller sequencing (ensuring water is cold enough).

Like the secondary pump in a primary-secondary system, pumps in a typical VPF system maintain a target differential pressure (ΔP) at a specific point in the system (see Figure 2.1).

This pressure difference tends to decrease when the air-handler control valves open in response to increasing loads. To restore ΔP across the system, the pump controller increases the speed of the pump. Conversely, when the air-handler control valves close in response to decreased coil loads, the pump controller slows the pump speed to maintain the target ΔP.

Meanwhile, the plant controller stages the chillers on and off to match cooling capacity with system load.

If the air handlers operate properly, the difference between the return and supply water temperatures (ΔT) remains nearly constant.

Therefore, increasing the water flow through the chiller evaporators increases the load on operating chillers.

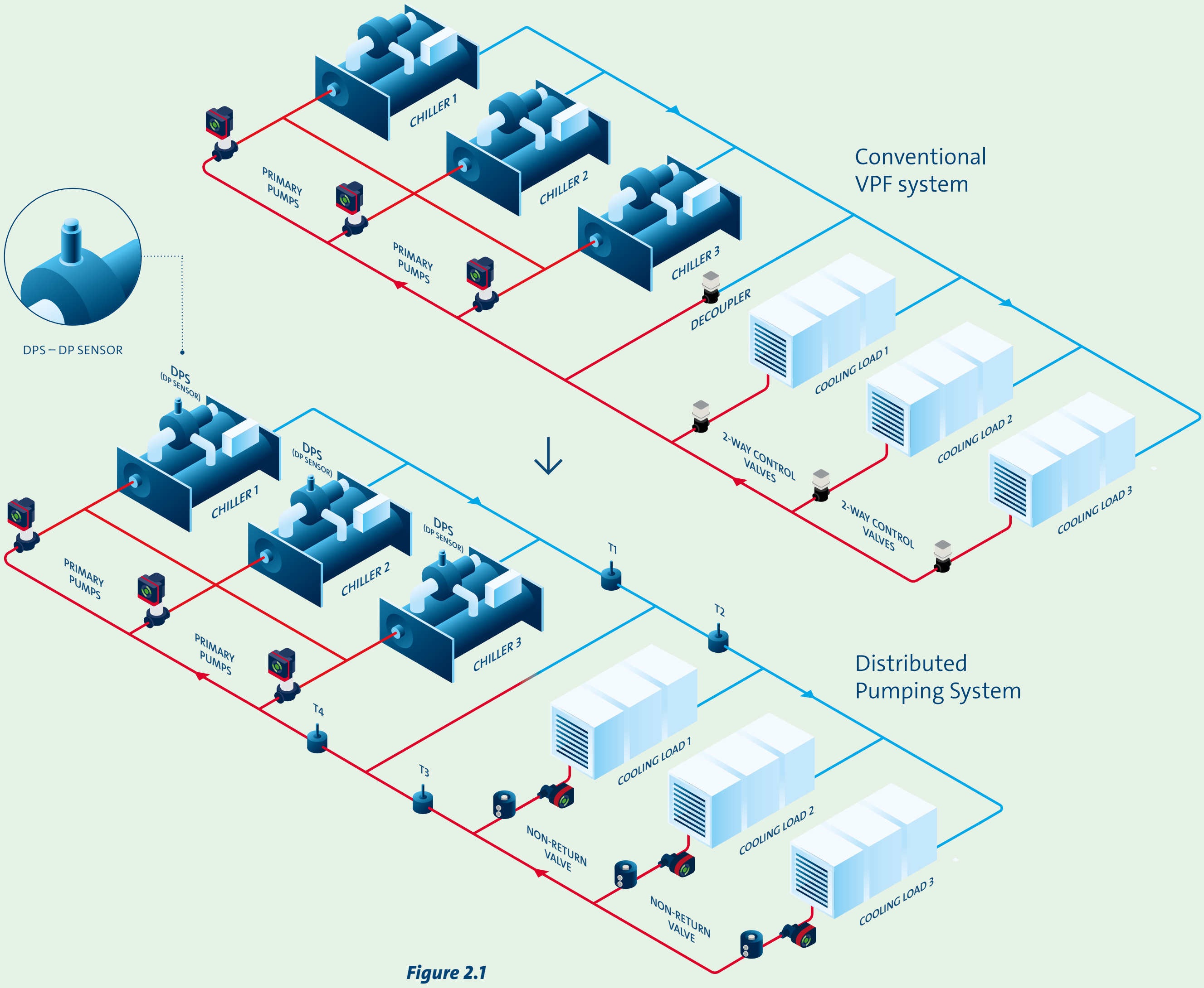


Figure 2.1

Serial no.	Chilled water system	Conventional System	Distributed pumping	Distributed pumping advantage
1	Primary Side	Primary pumps	Primary pumps of a smaller size	The pressure head for primary pumps is lower because they are sized to overcome frictional losses on the primary loop.
2	Primary Side	Two-way bypass valve (Modulating)	Bypass valve not required	Like a primary-secondary system, DPS uses a decoupler line to separate primary and secondary sides. Water should not be flowing in the decoupler pipe. The main objective in decoupler loops is to detect and equalise flows between primary and distributed pumps while maintaining minimum flow to chillers (Delta T1 = Delta T2).
3	Secondary side	Cooling coil control valves	Circulator pumps (Grundfos MAGNA3 & TPE pumps)	The chilled water network will have lower frictional losses and requires less system pressure. Intelligent pumps automatically balance the flow to individual terminal loads' requirements. The integrated controller and VSD in the inline pump regulate the pump's speed, adjusting the chilled water flow rate to the AHU's load demand.
4	Secondary side	Balancing valve	Balancing valve not required	Grundfos' intelligent pumps are automatically balanced. Commissioning is much easier and faster.
5	Secondary side	NRV/check valve (Non-return valves are not required)	Non-return valves required	Correct use of non-return valves, key components in a distributed pumping system, will help to ensure a stable solution – and that the system does not suffer from back-flow through terminal units shut off during operation Distributed pumping systems only have non-return valves for pressure losses. A primary-only system offers a balancing control valve unless a pressure independent control valve (PICV) is used.

Overall summary: Since less work is required by secondary coil pumps, the distributed pumping system reduces overall energy consumption.

Distributed pumping systems require less commissioning time than conventional VPF systems, in:

– Balancing the system
– Siting and installing a remote DP sensor
– Determining the DP setpoint value for primary pump controls
– Selectingthe location of and installing a remote DP sensor
– Determining the value of DP setpoint for primary pump controls

2.1.2 Constant primary, variable secondary

Figure 2.2 shows a conventional primary-secondary chilled water system. The control and balancing valves have the same functionality as a Variable Primary Flow (VPF) system.

In a chilled water system with a primary–secondary design, a decoupler line hydraulically 'decouples' the constant flow production side of the chilled water loop from the variable-flow distribution side. In this context, decoupled means that flows in the chiller circuit do not influence flows in the load circuit.

The bypass line in a primary-secondary system ensures constant chiller flow at all times.

The difference between variable and constant primary flow can be found in how the system operates. In a primary-secondary system, a chiller and its primary pump typically operate in tandem.

Secondary pumps are sized to circulate the chilled water in the index loop by sufficiently pressurising the supply line. These secondary pumps are typically either controlled to maintain a certain differential pressure across the index loop branch or set to run at a fixed speed, which means they will be 'riding the pump' curve. This topic will be covered in the chapter on pump control settings.

The individual primary pump's speed
is adjusted to deliver a fixed flow equal to the rated flow of the chillers, and the number of active pumps is equal to the number of active chillers. The primary side follows the rule of flow in that it must always be higher or equal to the secondary side flow. For more information on pump control settings, see chapter 3.8.

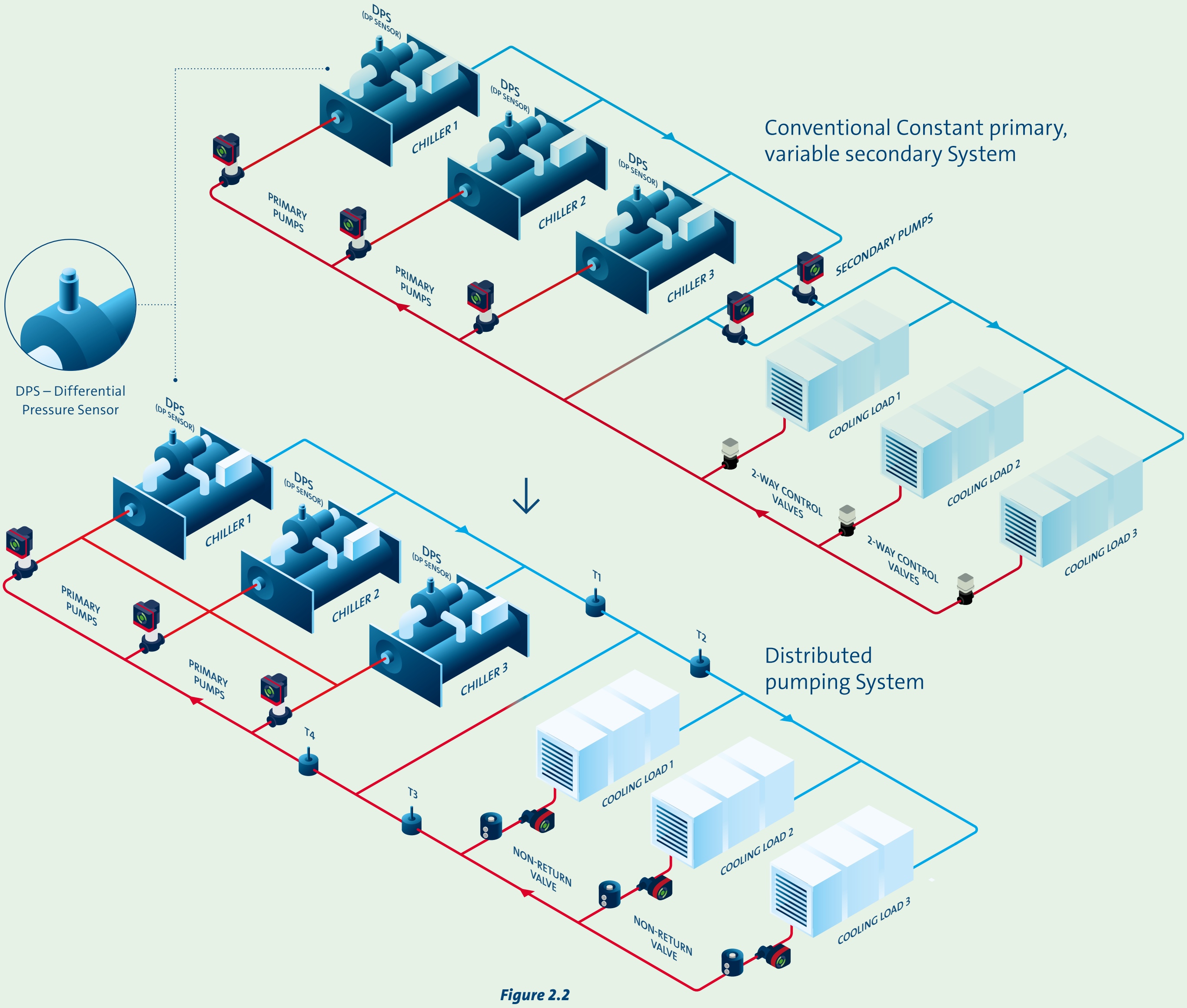


Figure 2.2

Serial no.	Chilled water system	Conventional System	DPS system	Benefits of DPS system
1	Primary side	Primary pumps	Primary pumps	No change
2	Secondary side	Secondary pumps	Circulator pumps (GF MAGNA3 & TPE Pumps)	Compared to a conventional system, DPS offers the following advantages: 1: A chilled water piping network offers lower frictional losses 2: The system water balancing is not required because each secondary coil pump is controlled based on the individual AHU's load requirement 3: The integrated controller and VSD in the coil pump regulate its speed, and, as a result, the water flowrate is set according to the AHU's load demand 4: Each secondary coil pump in the system operates independently to meet the flow demand of its own circuit, subject to the variation of system pressure 5: Grundfos' range of intelligent pumps are automatically balanced, making commissioning much easier
3	Secondary side	Cooling coil control valves		
4	Secondary side	Balancing valve	Balancing valve not required	DPS only has a non-return valve for pressure losses, while a primary-secondary offers a balancing control valve, unless they use a PICV.
5	Secondary side	NRV/check valve (Non-return valves are not required)	Non-return valves required	Non-return valves **are key components** in a distributed pumping system, and using them properly will help to ensure a **stable solution.** Moreover, it is the non-return valves that ensure that the **system does not suffer from back-flow though terminal units** that are shut off during operation.

Overall summary:
Since less work is required by the circulator coil pumps, DPS reduces the overall energy consumption.

DPS also significantly slashes commissioning time, meaning that you'll save time on:
– Balancing the system
– Selecting the location of and installing a remote DP sensor
– Determining the value of the DP setpoint for primary pump controls.

Conventional systems vs. DPS systems

The DPS is the ideal design for both series and parallel configurations of a water-side economiser as the source remains the same.

> Whether the source is the chiller or the water-side economiser heat exchanger has no significance for the DPS. As previously mentioned, distributed pumping is more than replacing load side valves (AHU's and FCU's) with intelligent Grundfos pumps, it is a new way of distributing flow throughout the entire chilled water system.

2.2 Challenges in HVAC systems

Hydronic flow optimisation is a prime way to reduce HVAC energy consumption, while increasing overall building efficiency and operational performance.

The HVAC industry has changed the way buildings are designed, installed, constructed, and used optimally. Subsequently, modern technological and electronic developments have reformed how these systems are installed, operated, and maintained. One of many reasons why so many systems are out of balance is because the commissioning of air conditioning systems is generally poorly done.

Another reason is if that if pumps are not monitored or integrated into Building Management Systems (BMS), there is a potentially critical consequences of outdated and worn pumps resulting in low pump efficiency in HVAC systems.

Again, this has implications for the total cost of ownership with increased costs across the board, for example from operations, service and an inability to optimise the system. The above challenges can also contribute to low Delta T syndrome, and this is the most critical challenge for any air conditioning system. Low Delta T syndrome occurs when the chilled water temperature range for which the system is designed is not maintained.

Here are a few of the main causes that can lead to low Delta T:

- The HVAC system is out of balance and there is overflow or starvation between the zones, meaning the system is not properly cooled
- Undersized or dirty cooling coils that are not able to achieve the required return temperatures
- Oversized or faulty control valves
- Hidden or forgotten bypasses in the system such as leaking heat exchangers and malfunctioning non-return valves
- Oversized, uncontrolled pumps or pumps operated in the 'wrong' control mode, not allowing the pump to adapt performance to load variations

This can lead to, among other issues, the building's actual energy consumption exceeding the designed energy consumption, resulting in low comfort.

The issues that arise from not maintaining the system-designed Delta T range can result in excessive chilled water overflow as well as components operating outside their design frame and, thus, outside the best efficiency point. This leads to poor system performance, excessive energy usage and reduced comfort.

If the Delta T range in a chilled water system drops too low, the flow rate must be increased to maintain sufficient cooling in the building.

3. Chilled water pumping control

The purpose of this section is to describe the impact that the control strategies of the different chilled water pumping designs have on the system pumping power at various building load situations.

A similar study also has been done for a Grundfos Distributed Pumping scheme. We will go through a comparison of the pumping power needs in all the different schemes and control strategies.

3.1 Pressure gradient

The purpose of this section is to describe the impact that the control strategies of the different chilled water pumping designs have on the required pumping power for various building load situations. A similar study also has been done for a Grundfos Distributed Pumping scheme, and finally, we will go through a comparison of the pumping power needs in all the different schemes and control strategies.

Chilled water pumping schemes can be visualised through gradient charts showing pressure changes across the chilled water network.

To create these charts you need to document:

- Pipe lengths, diameters, and fittings (such as strainers, gate valves and bends)
- Flows throughout the network
- Rated pressure drops of various loads (such as the cooling coil's pressure drop)

You can then use methods like pipe-sizing charts and equivalent pipe length for fittings to determine individual pressure losses for each section of the pipe and pipe fittings. A simple example is shown in Figure 3.1.1, highlighting a single line of a DN150 with constant flow. Here, the pressure drop of all the pipe fittings has been calculated via the 'equivalent pipe length' method.

The coil pressure drop is set to a value which is listed in the appropriate data sheet. Lastly, the piping gradient is defined as [Pa/m] and the specific value is found via standard pipe sizing charts.

At this point no flow control is considered, meaning there is control valve or pump. The purpose of this example is purely to get an insight into how a pressure gradient chart is created and to understand the influence of the flow.

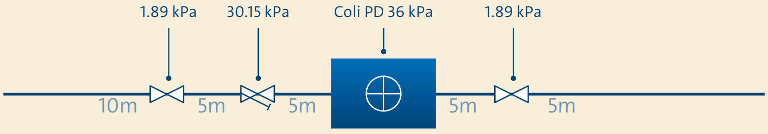


Figure 3.1.1 *DN150 pipe with 75 L/s flow with a 900 [Pa/m] pipe gradient*

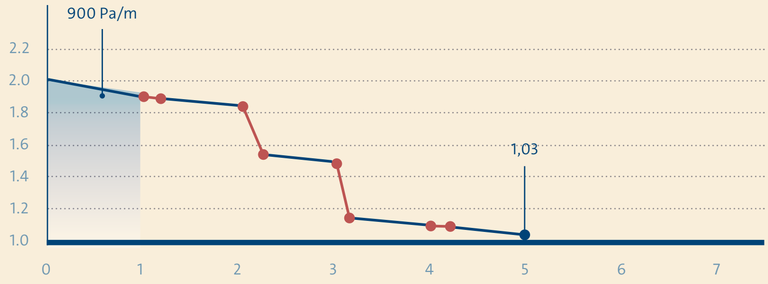


Figure 3.1.2 *Pressure gradient Chart for the single pipe-line example*

Figure 3.1.2 *shows a pressure gradient chart for a single pipeline. The starting pressure of 2 bar is defined as an arbitrary value, which, in this case, is 2 bar. Moving from left to right, the slope of the blue line is the defined 900 [Pa/m] and at each pipe fitting the pressure drops with the amount of the specific fitting. The total losses in this pipeline come to a total of 97 [kPa].*

When the flow is reduced in the branch, the pressure losses are also reduced.

When only the flow is reduced, you would follow the same procedure as before. This is shown in Figure 3.1.3, where flow is reduced to 20 [L/s] and a new pressure loss gradient is added to the chart.

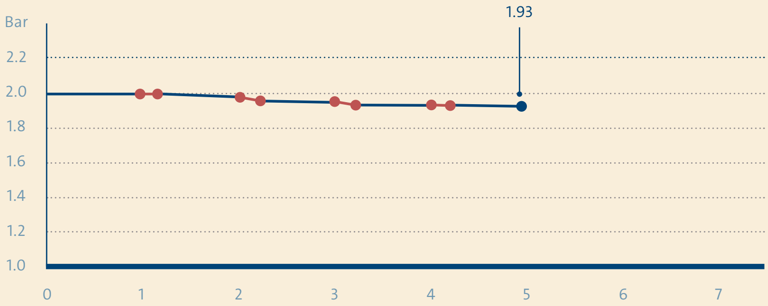


Figure 3.1.3 *Pressure gradient chart for the pipeline with reduced flow*

Figure 3.1.4 shows total pressure losses are reduced to 7 [kPa], a 93% reduction compared to the 73% reduction in flow. In this example, because there is no modulating valve, all fittings and pipes can be considered fixed orifices, meaning Affinity Law can be applied to describe the relation between pressure losses and flow reduction:

$$\frac{H_1}{H_2} = \left(\frac{Q_1}{Q_2}\right)^2 \Leftrightarrow H_1 = H_2 \left(\frac{Q_1}{Q_2}\right)^2 = H_2 * X^2$$

Here, H and Q respectively describe head loss and flow, while x is the relationship between the new flow and the original flow.

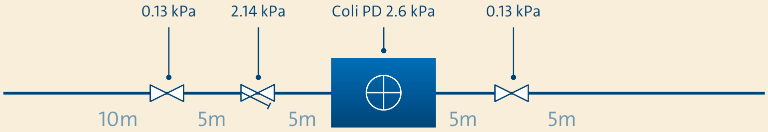


Figure 3.1.4 *DN150 pipe with 20 L/s flow with a 70 [Pa/m] pipe gradient*

3.2 Chilled water distribution schemes comparison

In this section, we will compare a distributed pumping system to the two conventional chilled water distribution designs: variable primary and fixed primary, variable secondary. Conventional systems are most commonly controlled based on a differential pressure setpoint in the network.

The location of this sensor can vary, and it is impossible to cover every single possibility. For this comparison, three different sensor locations are considered, which represent the most common locations:

1. Differential pressure across the bypass line for variable primary systems and constant secondary head for fixed primary, variable secondary.
2. Differential pressure at two-thirds of the way to the furthest branch in the network.
3. Differential pressure across the furthest branch in the network, commonly called the index.

It is assumed that conventional systems use pressure independent control valves (PICV), and hydraulic balancing can be overlooked. It is still necessary to consider pressure losses generated by PICV on the index loop, as this affects the conventional pump head.

PICV's rated pressure varies between manufacturer and models, but generally lies at around 20kPa - the value used for this comparison. The purpose of this comparison is to benchmark different schemes at full system flow and part loads.

For the part load, all branches are equally unloaded, simplifying the comparison. Following this exercise, points will be discussed for uneven branch unloading.

Piping design, loads and chillers are the same for all designs. The only difference is the quantity and/or location of the pumps in the system. The chiller minimum flow is considered to be low enough to not have an influence.

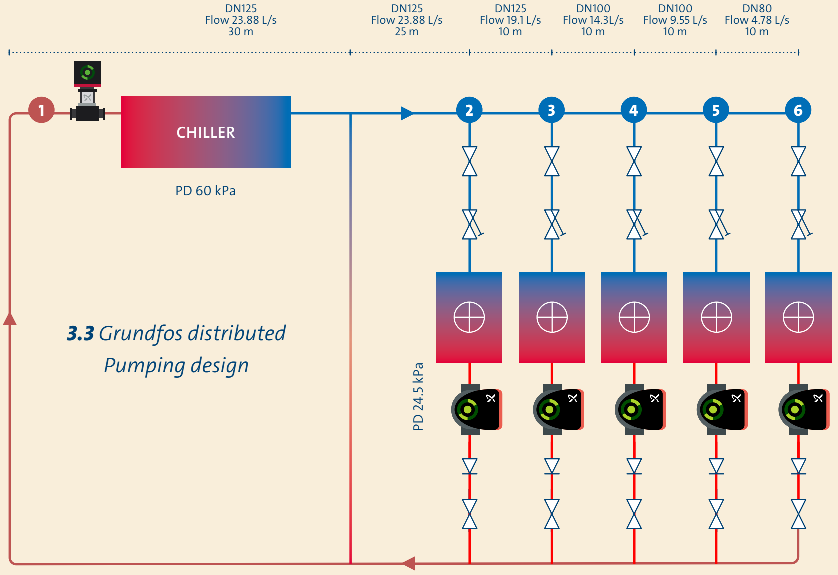
3.3 Grundfos Distributed Pumping design

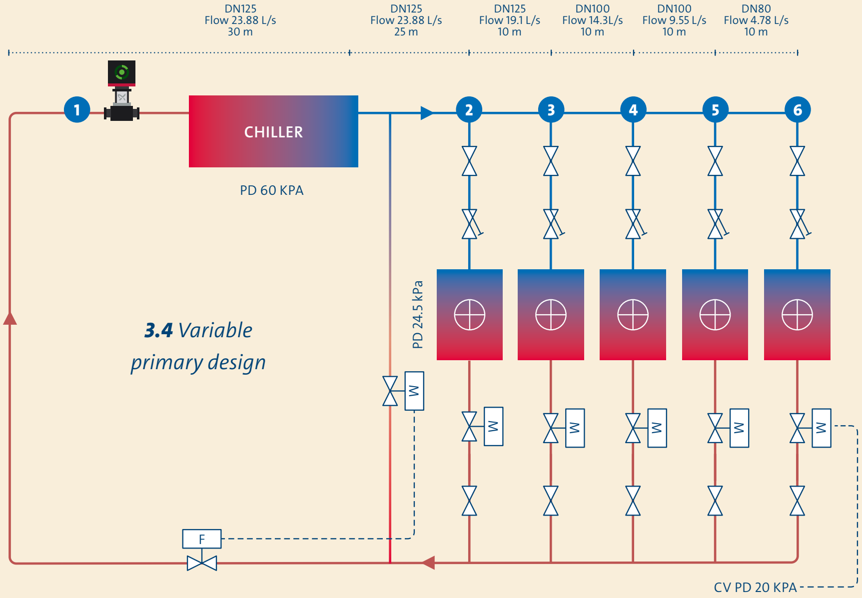
3.4 Variable primary design

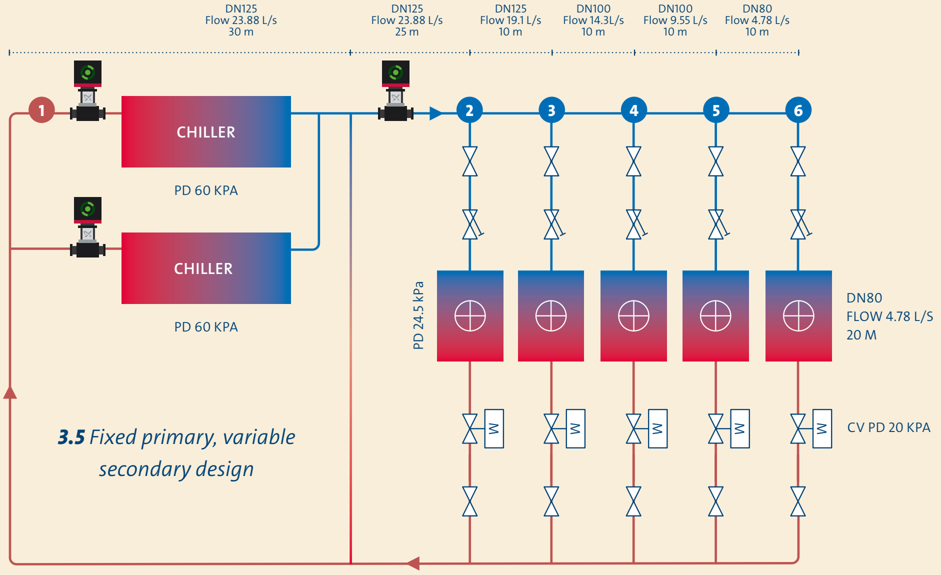
3.5 Fixed primary, variable secondary design

The piping network, fittings and equipment were added to Grundfos' hydraulic sizing tool to calculate pressure losses in all pipe sections.

This information is used to plot pressure gradients for the three different designs in situations of 100% flow.







3.5.1 Grundfos Distributed Pumping

In the distributed pumping system design, the decoupler line has no differential pressure difference in a steady state load.

This is due to the push-pull design, in which the primary pump pushes water through the chiller to the decoupler, while coil pumps pull water from the decoupler. Each coil pump delivers a pump head equal to overcoming the pressure difference between the return line and the supply line, and the coil drop. The dip in pressure at each coil pump is caused by pipe fittings, particularly the y-strainer which introduces pressure losses before the pump.

A unique feature of the distributed pumping system is the return side’s higher pressure than the supply line. Since pressurisation happens at each coil pump, a Non-Return Valve (NRV) is necessary along with the coil pump to avoid backflow.

It also means that if a coil pump is shut off, there will be no leakages through the coil, as the higher return line pressure ensures the NRV is always fully closed, even if the coil pump is turned off.

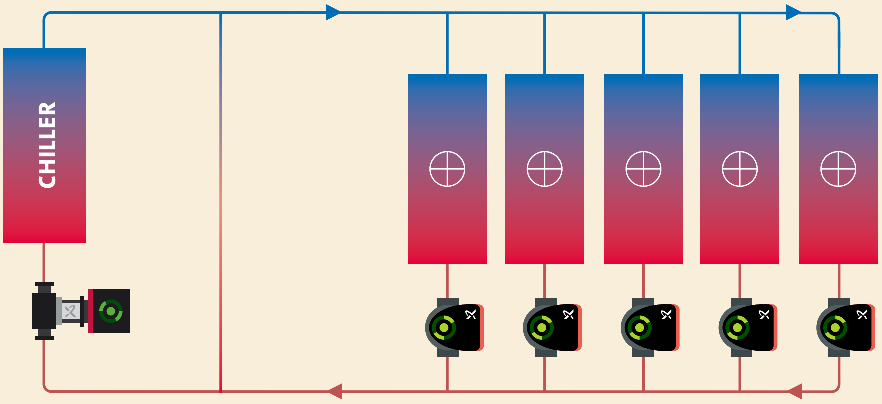


***Figure 3.5.1.1** Simplified Grundfos Distributed Pumping design*

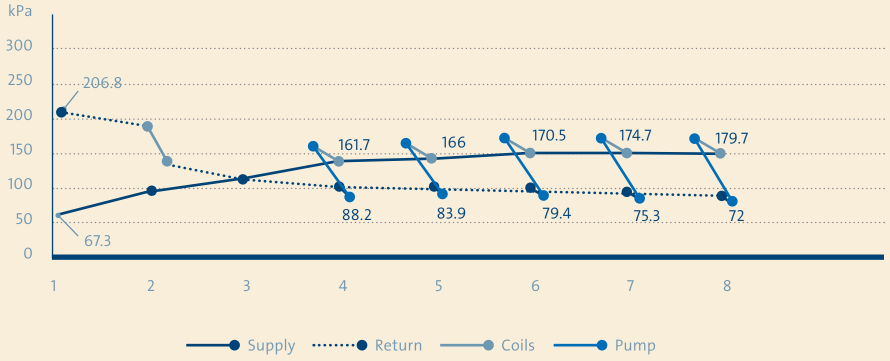
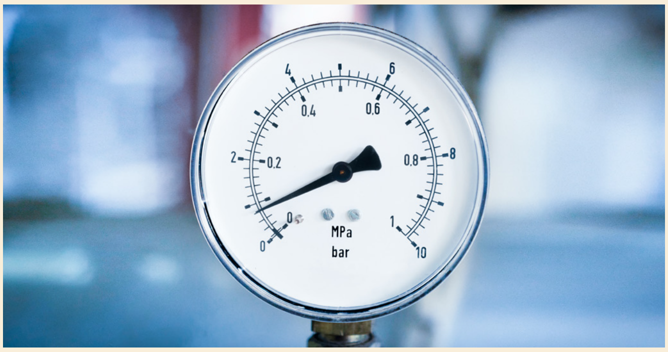


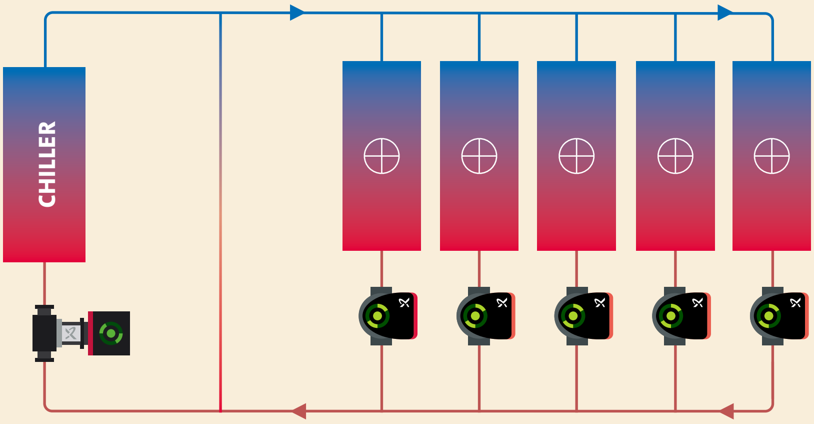
***Figure 3.5.1.2** Pressure gradient for a distributed pumping system design at 100% flow*



Because there are no pressure-modulating valves, a DPS design can be fully described by the Affinity Law.

This means that as the flow is reduced, the pump head reduces significantly, and as the above figure shows, pump heads are reduced by about 75%.

Such reductions to both flow and head for all the pumps significantly reduces the overall pumping power.



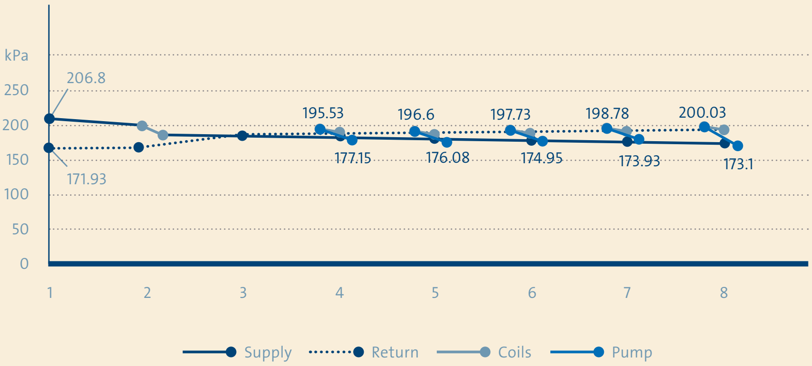


Figure 3.5.1.3 *Pressure gradient for a distributed pumping system design at 50%*

3.5.2 Variable primary design

When commissioning a variable primary design, the pumps are ramped up to 100%. If not, the design flow and commissioning team notes the differential value at the point which is used for controlling the speed of the pumps.

Figure 3.5.2.2 shows the three different locations for the DP sensors. The pressure gradient indicates the actual calculated pressure at these locations. As the PICV closes and the system flow reduces, the pump reduces its speeds, and thus, its pump head, maintaining the designated differential pressure.

The following examples show the difference of the pump head at 50% for each of the DP sensor locations.

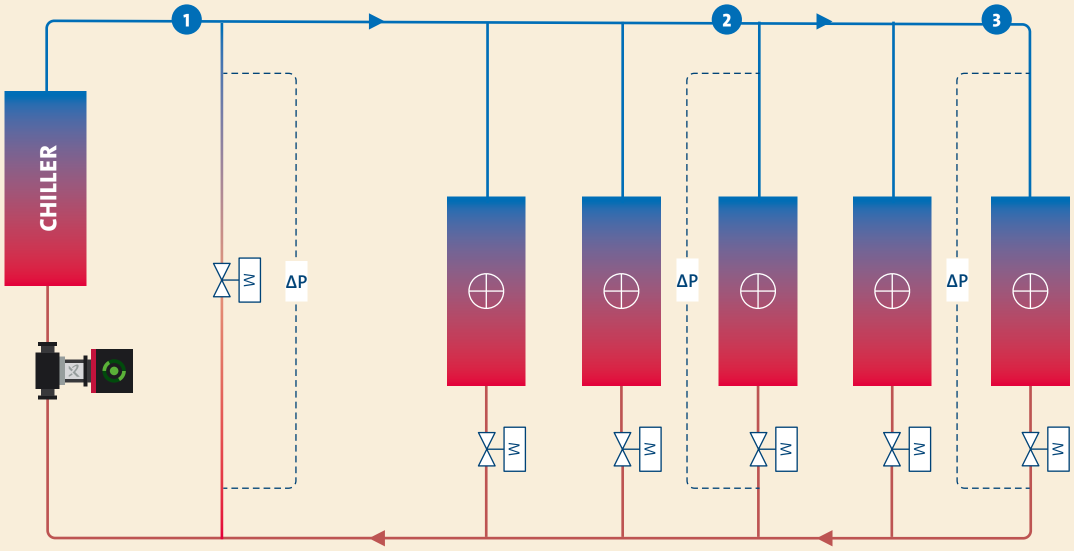


Figure 3.5.2.1

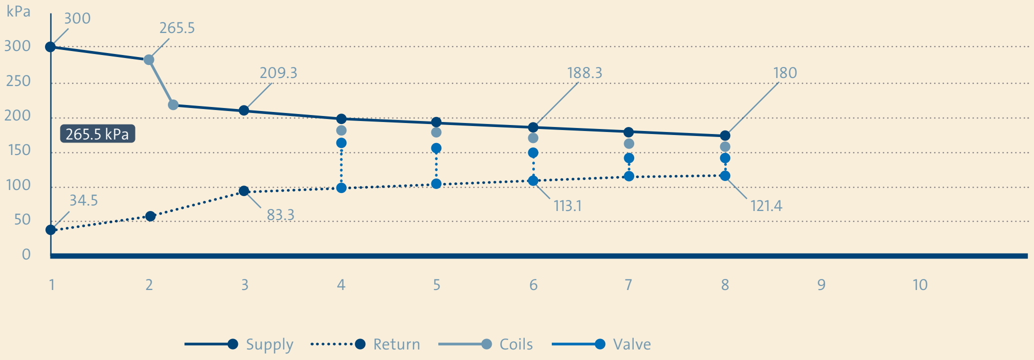


Figure 3.5.2.2 *Pressure gradient for a variable primary design at 100% flow*

As the PICV valves close, they increase the pressure losses which, in turn, reduce the flow through the branch. The pipe fittings and coil's pressure loss is reduced as the flow reduces, as these still follow the Affinity Law.

The reduced flow also means that the pressure loss across the chiller and in the piping reduces, so the variable primary pump's head is reduced to maintain the distributed pumping setpoint at the bypass. Because the bypass is close to the pump, the head reduction is limited and the supply pressure is high. This gives the pressure gradient chart a square look, as there is a higher pressure loss across the valves.

Moving the DP sensor further downstream reduces the pump head further, and the pressure gradient looks sharper. Pressure loss across the valves is also reduced.

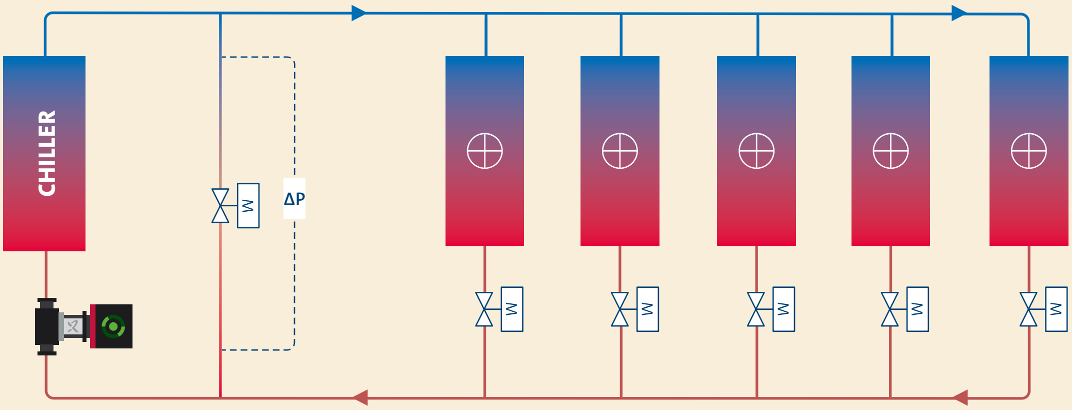


Figure 3.5.2.3 *Simplified variable primary design with fixed differential pressure at the bypass*

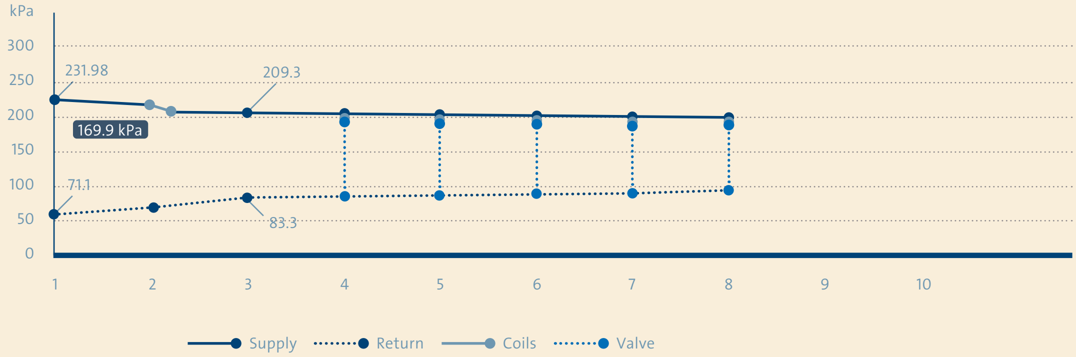


Figure 3.5.2.4 *Pressure gradient for a variable primary controlled by a distributed pumpings sensor at the decoupler - 50% flow*

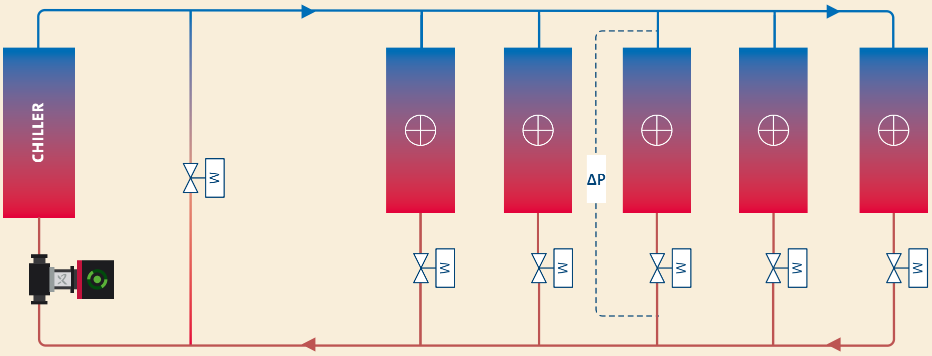


Figure 3.5.2.5 *Simplified variable primary design with fixed differential pressure at the 2/3-way*

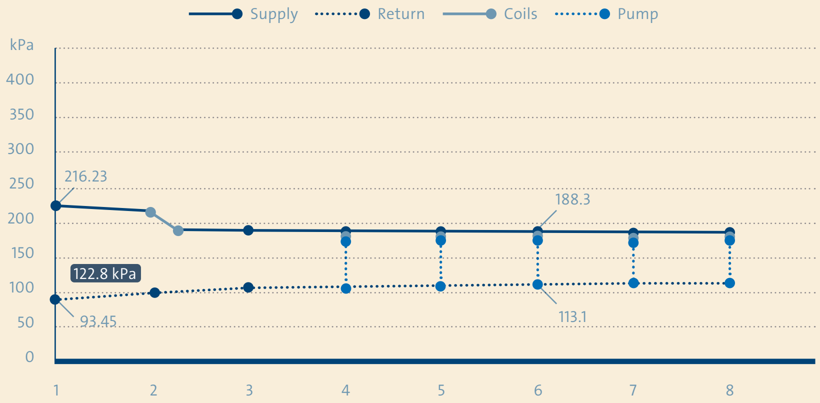


Figure 3.5.2.6 *Pressure gradient for a variable primary controlled by a DP sensor at 2/3 of the downstream – 50% flow*

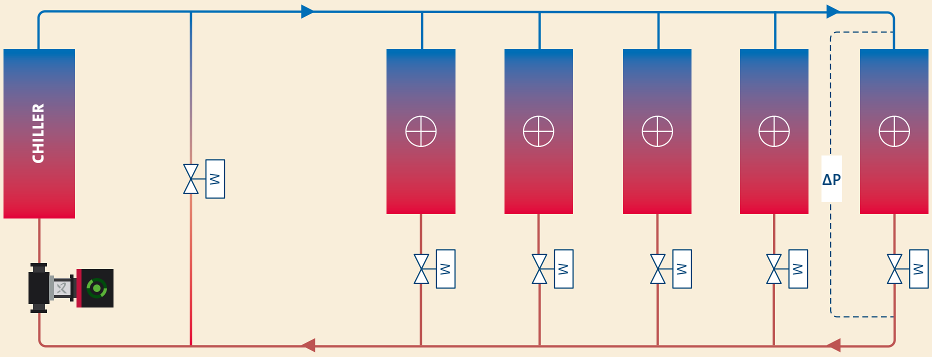


Figure 3.5.2.7 *Simplified variable primary design with fixed differential pressure at the index*

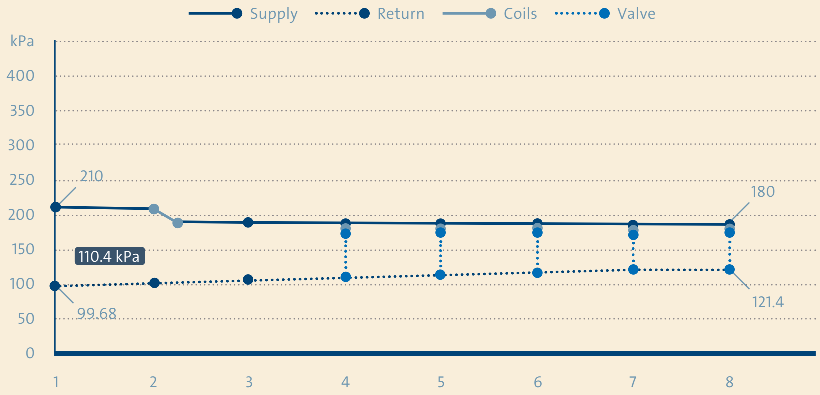


Figure 3.5.2.8 *Pressure gradient for a variable primary controlled by a DP sensor at the index – 50% flow*

With the DP sensor at the index, the pump head reaches its lowest value. Using the index distributed pump to control the variable primary system provides the lowest pump head at part loads, but it can also introduce zone starvation.

Zone starvation is not shown on these pressure gradients, but it can occur during uneven loading of the different branches, such as when the index branch requires a low flow, but other branches require a high flow. The pump is controlled by the index, so its head is reduced and because of this, there is insufficient pressure and flow for the branches that require a higher flow than the index.

Because of this, many systems choose to use a DP sensor located either at the bypass or 2/3 downstream. This does not mean that the pump head and power is higher, but it does ensure there is no zone starvation which would compromise comfort within the building.

3.5.3 Fixed primary, variable secondary design

As with the variable primary system, secondary pumps are controlled via a differential pressure setpoint or a constant pump head. The setpoint is determined as part of the commissioning by operating the pumps at 100% or at the design flow rate.

The primary pumps are controlled by the principle commonly referred to as the Law of Flow, which states that primary pumps are staged on/off at a fixed speed, and that the primary side must always deliver the same or higher flow than the secondary side demands.

In this example it is assumed there are two primary pumps, each providing half the total flow. This means that if the secondary side flow is at 50% or lower, only one primary pump is operated.

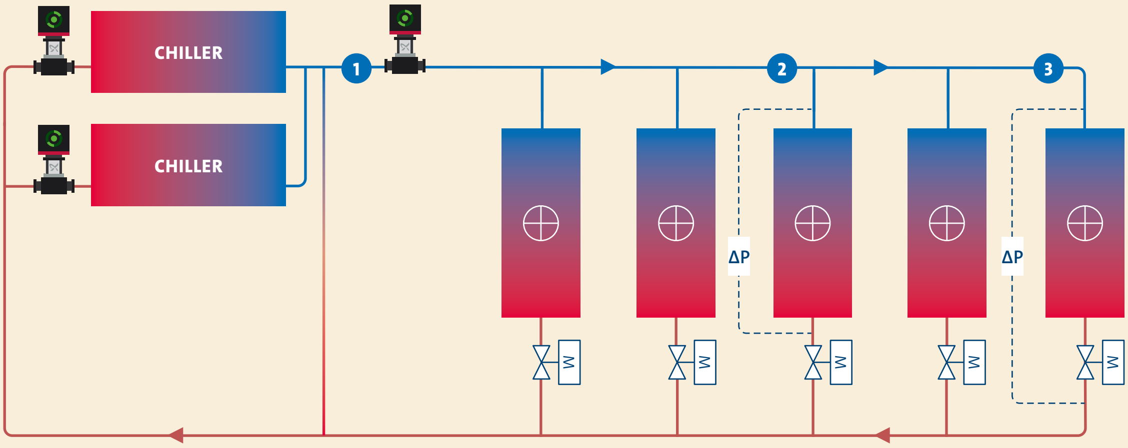


Figure 3.5.3.1 *Simplified fixed primary, variable secondary design*

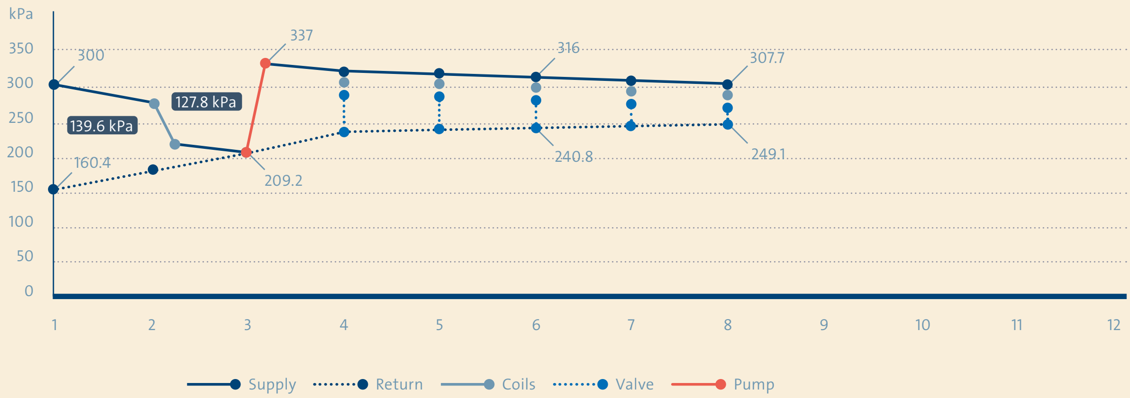


Figure 3.5.3.2 *Pressure gradient for FPVS at 100% flow*

When the flow is reduced to 50% as shown below, only one of the primary pumps and the chillers are used. Because the chillers have equal pressure drop and the flow through them remains the same, the pressure drop does not change.

This means the fixed primary pump operates at the same flow and similar head at all part loads. Losses in piping on the primary side reduce when the flow is lowered. In this example they are negligible compared to chiller pressure losses.

The secondary pump in figure 3.5.3.4 is operated in fixed pump head control mode, so between 100% and 50% flow, the head remains unchanged. This gives the pressure gradient a square look with a high supply pressure.

PICVs experience high pressure losses to achieve required flow in the branches.

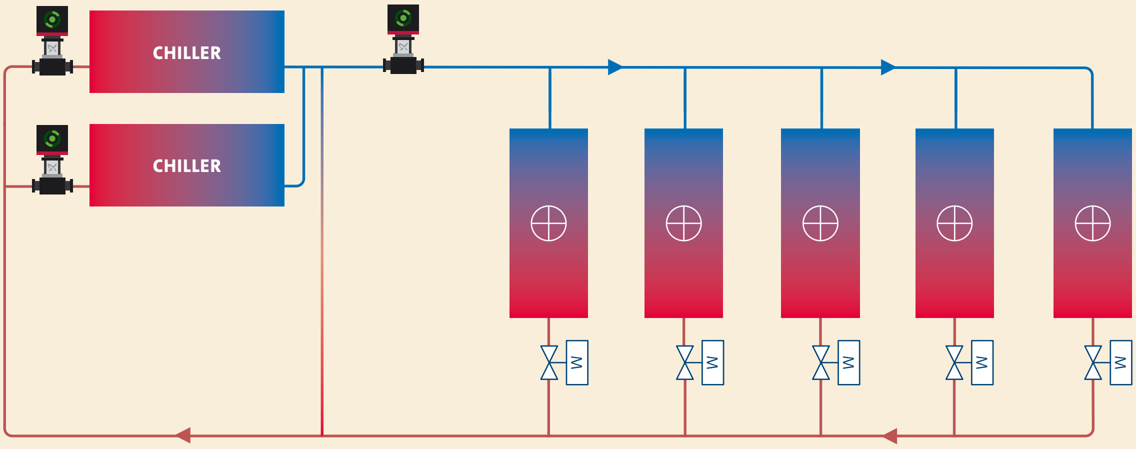


Figure 3.5.3.3 *Simplified fixed primary, variable secondary design with fixed head*

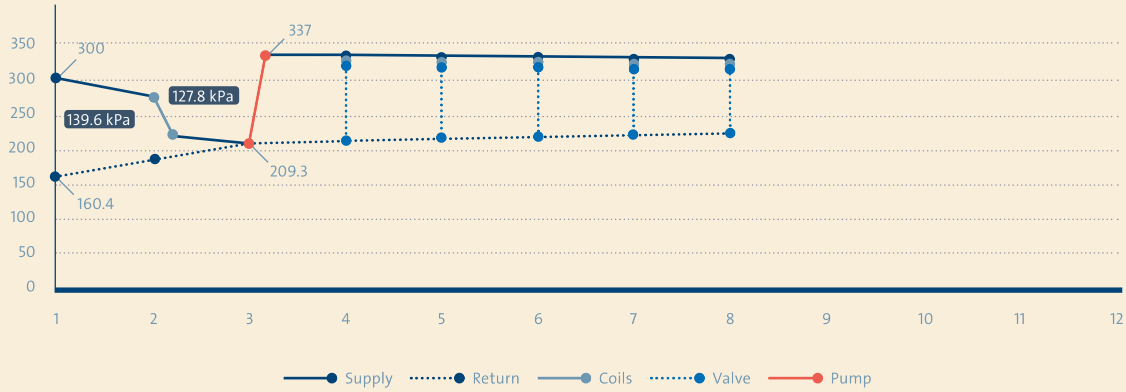


Figure 3.5.3.4 *Pressure gradient for FPVS with fixed head at 50% flow*

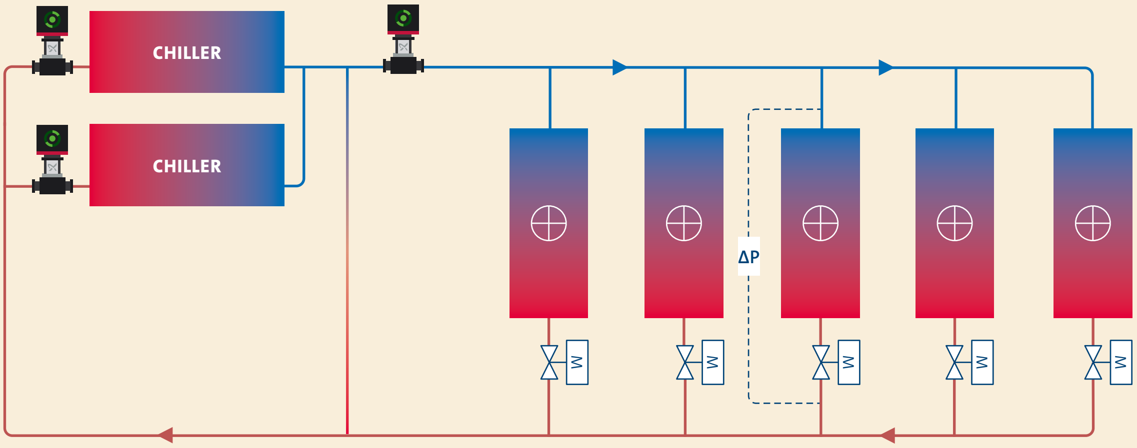


Figure 3.5.3.5 *Simplified fixed primary, variable secondary design with fixed differential pressure at 2/3 way*

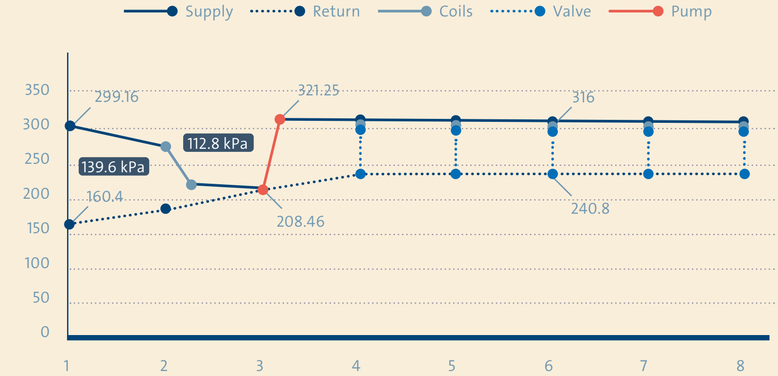


Figure 3.5.3.6 *Pressure gradient for FPVS with DP sensor 2/3 downstream at 100% flow*

However, when the 2/3 downstream DP sensor is used, the secondary pump head reduces similarly to what we described for the variable primary design. Lastly, when the DP sensor at the index is used, the pressure gradient narrows further and the pump head reaches the smallest value of the three scenarios.

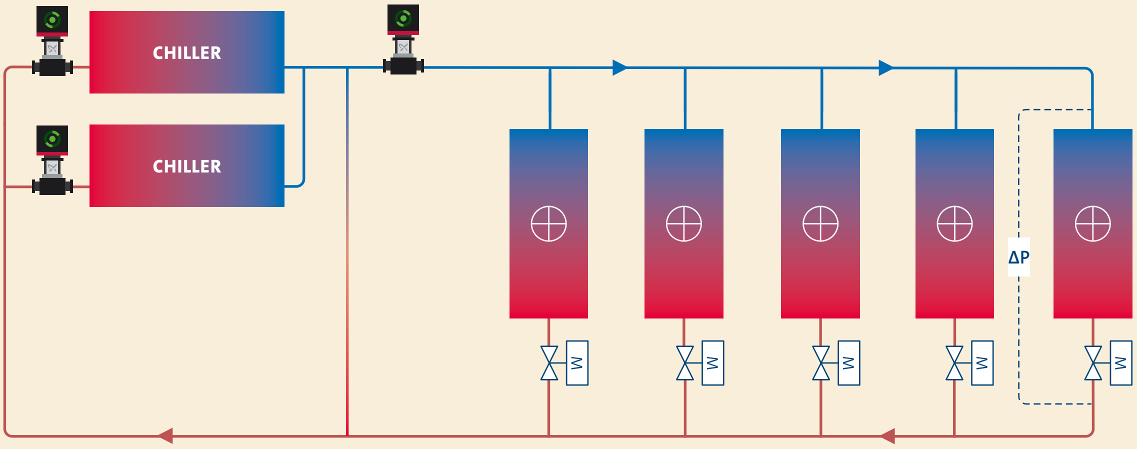


Figure 3.5.3.7 *Simplified fixed primary, variable secondary design with fixed differential pressure at the index*

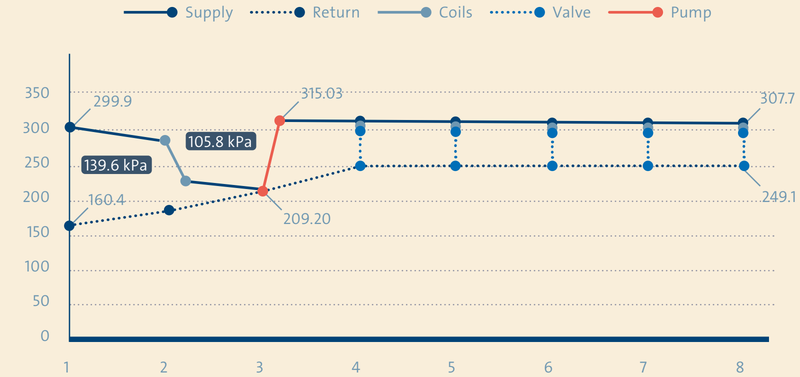


Figure 3.5.3.8 *Pressure gradient for FPVS with DP sensor index at 100% flow*

The secondary side in an FPVS behaves similarly to the variable primary, and, therefore, it can experience the same issue with zone starvation if the index DP sensor location is used.

Traditionally, the FPVS is a popular system thanks to the simplicity of the primary side, which ensures that chiller safety is always maintained.

Fixed speed chillers are generally more affordable in CAPEX terms than chillers with variable compressors. With pumps on the primary side operating at a fixed speed, an FPVS will always use more power than a variable primary system. In general, a mix of chilled water and return water runs through the decoupler, so the differential temperature is often lower than in other chilled water pumping designs.

3.6 CHW pumping scheme – pumping power

The purpose of this section is to demonstrate how to use information from the previous section and determine the power use of each design and control method.

The choice of chilled water pumping design combined with the applied control strategy affects the overall power use and efficiency of the chilled water distribution.

Overall, the pumping power at a given head and flow can be calculated with the theoretical pumping power equation:

$$P_{pump} = \frac{Q * H * S.G * 10^{-3}}{\eta_{total}}$$

Here, Q and H are, respectively, flow and head. S.G is the water's specific gravity, and η*total* is the total efficiency of the pump - the total efficiency of hydraulics, motor and Variable Frequency Drive (VFD).

Efficiency needs to be calculated based on equipment specification. For this purpose, we use Grundfos Product Center: *https://product-selection.grundfos.com* to directly calculate the pumping power at a given duty point based on actual pump data. GPC generates a control curve showing how the pump head changes as the flow lowers.

For the conventional system, variable primary and FPVS, and Grundfos Distributed Pumping, pumps are sized using GPC and pumping power determined at 100% and 50% flow.

This section concludes with an overall pumping power comparison between all configurations of the conventional and distributed pumping systems.

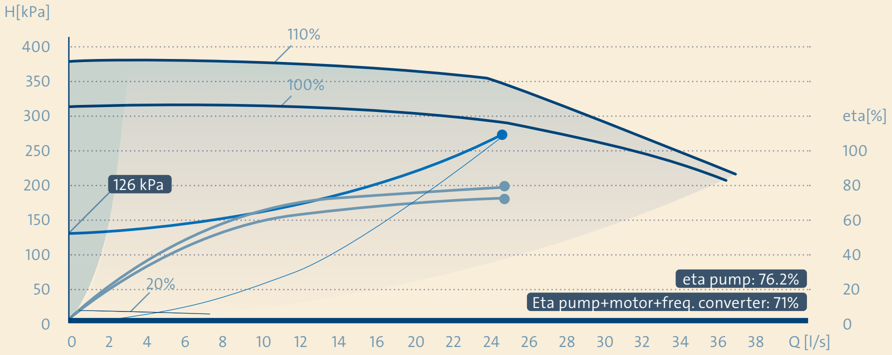
3.6.1 Conventional pumping systems

Sizing of the variable primary pump is based on the duty point from figure 3.5.2.2, and the control curve is plotted based on the DP sensor location at the bypass. The result is seen in figure 3.6.1.1.

The control curve is indicated by the solid orange line, and adjusted to represent the DP sensor location at the bypass.

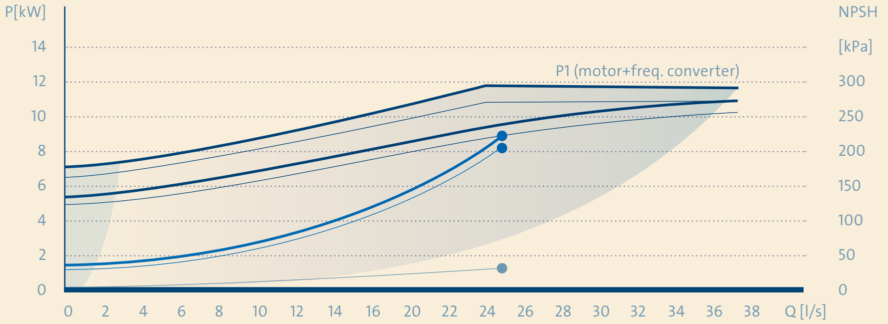
The control curve's value of 0 [L/s] flow represents the desired distributed pumping value across the bypass, and as the flow increases, the vcontrol curve dictates the necessary pump head to maintain the fixed distributed pumping value. In other words, imagine that all the valves in the system are fully closed, which means the flow is 0.

In such an event, the pressure gradient would be completely flat and the pump would build up a pressure equal to the setpoint value at the bypass. As the valves begin to open, the pump head will increase in line with piping losses.



TPE 80-330/2.3*400V
Q = 23.88 l/s
H = 265.5 kPa
n = 97% / 2839 rpm

Pumped liquid = Water
Liquid temperature during operation = 293 K
Density = 998.2 kg/m³



P1 (motor+freq. converter) = 8.931 kW
P2 = 8.323 kW
NPSH = 32.83 kPa

Figure 3.6.1.1 *Variable primary pump curve based on duty point*

With the control curve, you can accurately predict the pump duty point when the flow is at 50%, as shown in figure 3.6.1.2.

P1 energy is the total pump power. When comparing the P1 value in figures 3.6.1.1 and 3.6.1.2, the decrease in pumping power is more than 50% for the variable primary system.

By adjusting the control curve, the P1 for the different DP sensor locations can be determined, and for the FPVS the process is the same.

We will cover this in the overall results a little later.

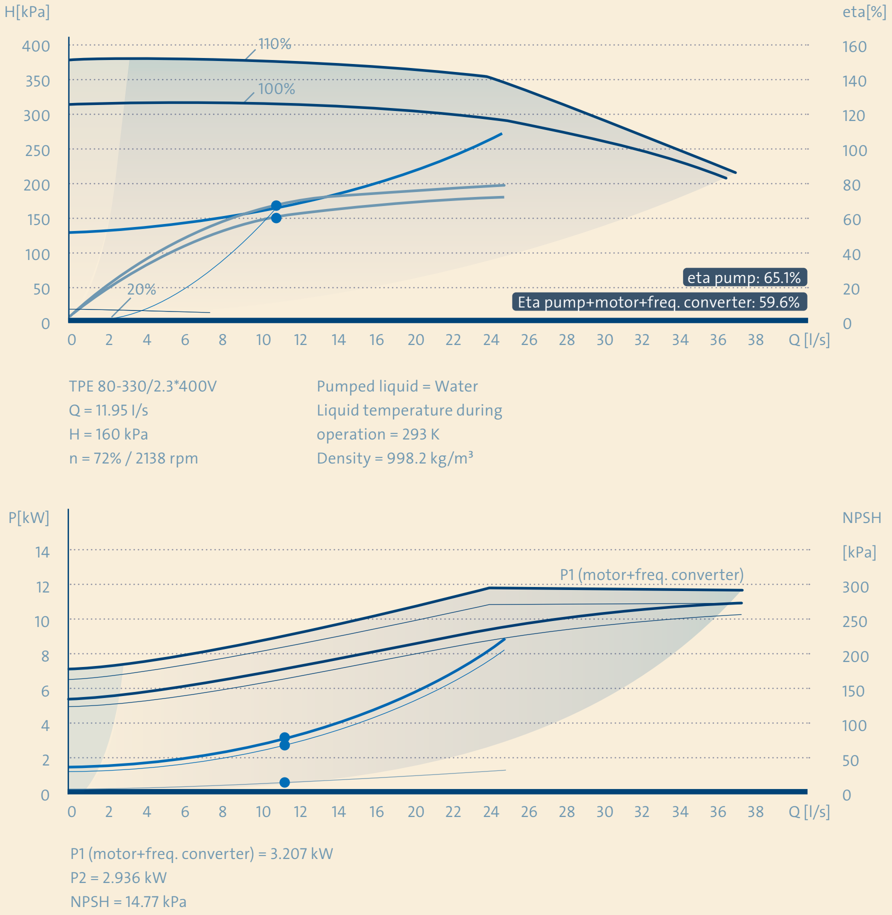


Figure 3.6.1.2 *Variable primary pump curve based on duty point at 50% flow*

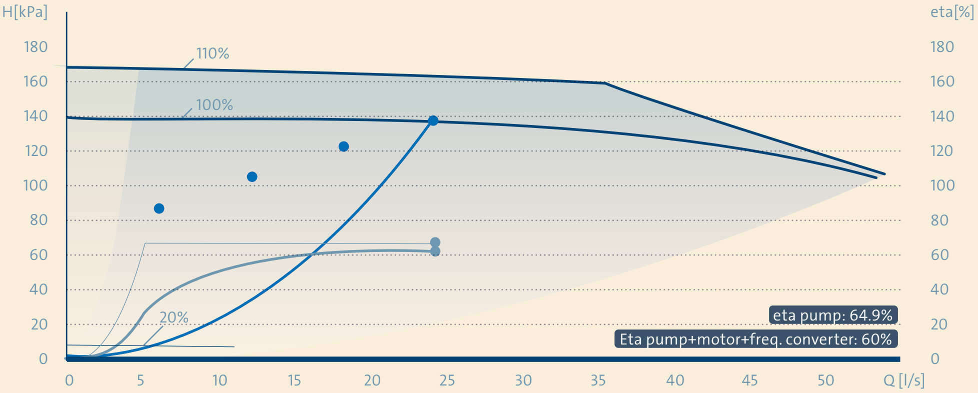
3.6.2 Distributed Pumping System

In distributed pumping systems, you need to size the primary pump and all individual coil pumps.

Individual pumps' P1 power is then combined to calculate the system's total pumping power.

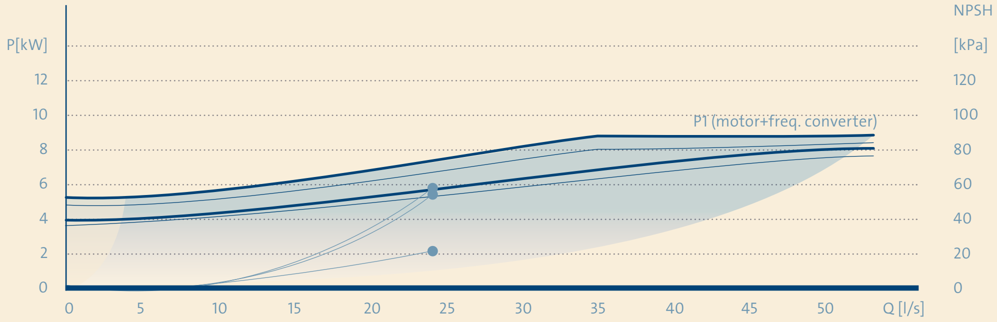
Since there is no pressure modulation in a distributed pumping system, all system curves remain unchanged at any load situation, and the pumps follow system curves as their speed reduces.

For the primary pump, the sizing result can be seen in figure 3.6.2.1.



TPE 125-160/4, 3*400V
Q = 23.88 l/s
H = 137.4 kPa
n = 101%/1473 rpm

Pumped liquid = Heating water
Density = 983.2 kg/m³



P1 (motor+freq. converter) = 5.413 kW
P2 = 5.053kW
NPSH = 19.68 kPa

Figure 3.6.2.1 *Distributed pumping system primary pump curve*

Here, the light blue curve represents the system curve. Using this curve makes it possible to determine the pump's duty point at 50% flow, which is shown in figure 3.6.2.2.

Here the pump head is drastically reduced and P1 power for the primary pump is reduced by more than 80%.

Coil pumps are sized individually based on the duty point calculated in figure 3.5.1.3. Starting with the pump with the highest head, the result of the sizing can be seen in figure 3.6.2.3.

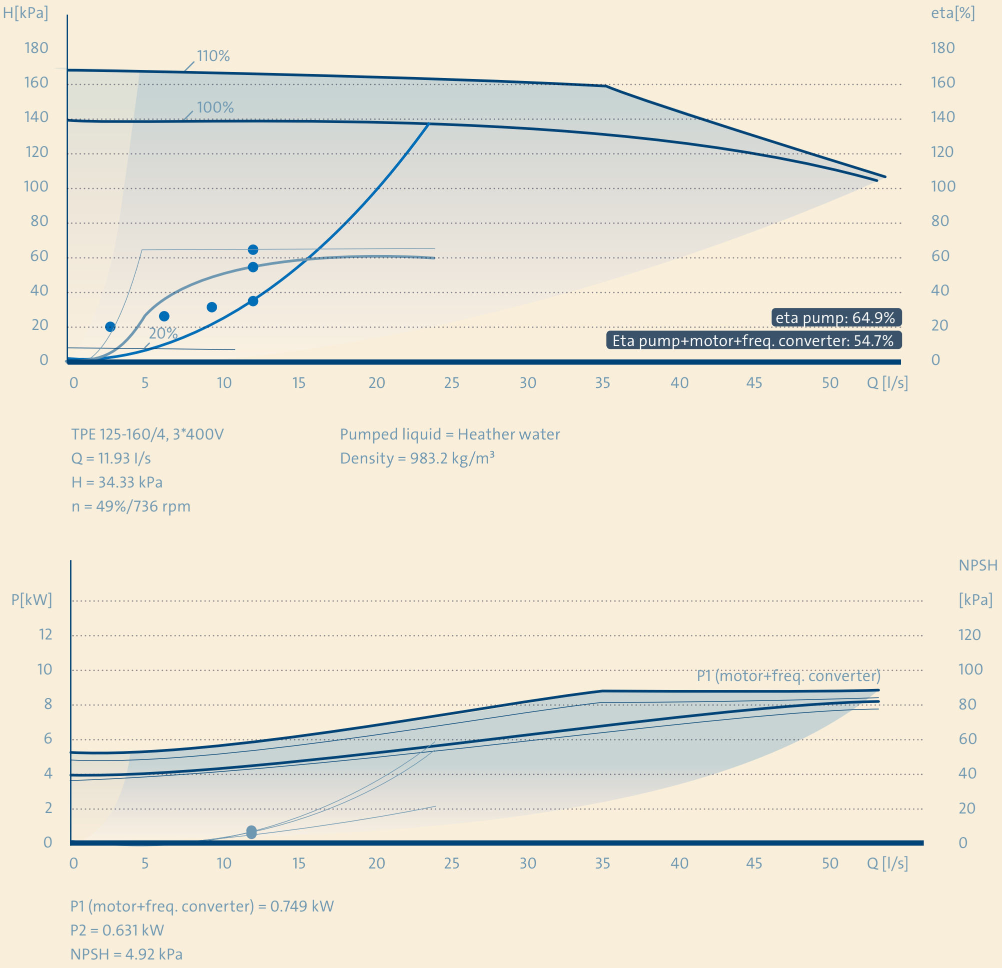


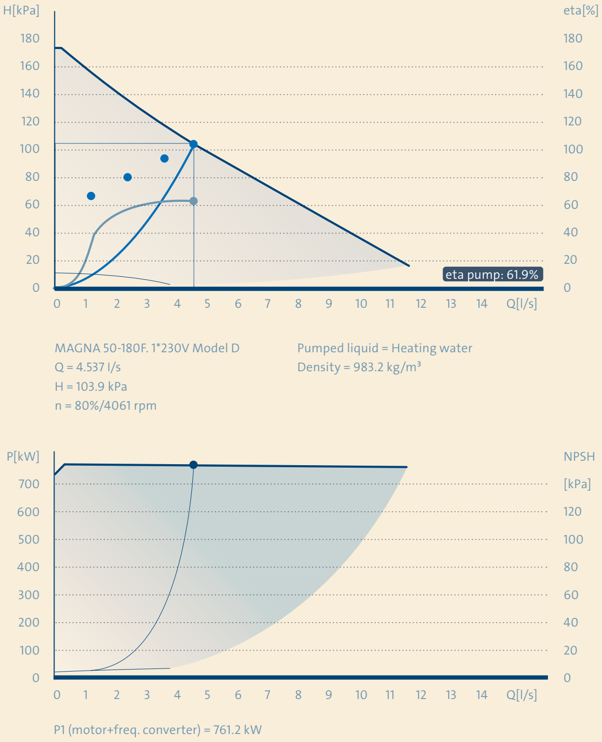
Figure 3.6.2.2 *Distributed pumping system primary pump curve at 50% flow*

The MAGNA3 circulator pump is suitable for a distributed pumping system design as it is designed to maintain high efficiency in a low flow, high head situation.

Since the pump follows the system curve, this high efficiency remains throughout most of the part load situations, as shown in the efficiency curve (eta) indicated by the black line in the pump curve.

Therefore at 50% flow the power is reduced tremendously, as shown in figure 3.6.2.4.

For a coil pump at 50% flow, the P1 reduction amounts to approximatly 85%, with the pump using a total of just 105.4 W. Other coil pumps achieve similar performances.

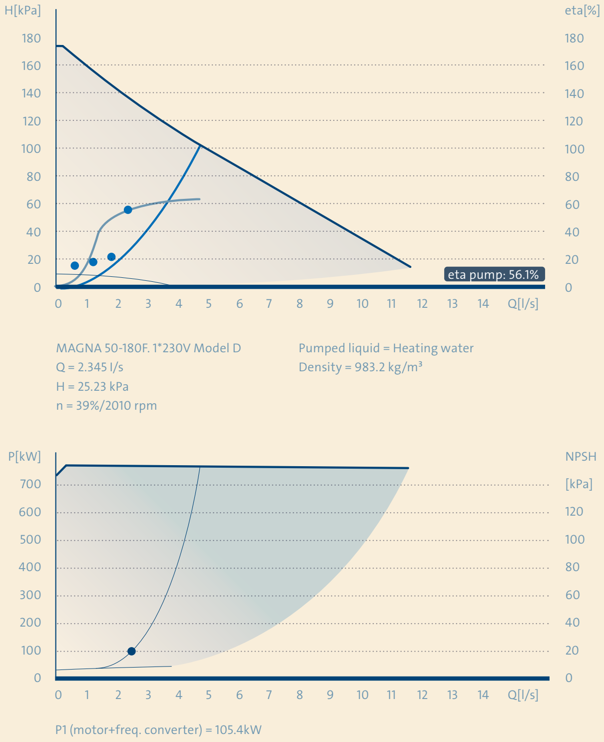


MAGNA 50-180F. 1*230V Model D
Q = 4.537 l/s
H = 103.9 kPa
n = 80%/4061 rpm

Pumped liquid = Heating water
Density = 983.2 kg/m³

P1 (motor+freq. converter) = 761.2 kW

Figure 3.6.2.3 *Distributed pumping system coil pump's curve*



MAGNA 50-180F. 1*230V Model D
Q = 2.345 l/s
H = 25.23 kPa
n = 39%/2010 rpm

Pumped liquid = Heating water
Density = 983.2 kg/m³

P1 (motor+freq. converter) = 105.4kW

Figure 3.6.2.4 *Distributed pumping system coil pump´s curve at 50% flow*

3.7 Chilled water pumping scheme: power comparison

By applying the previous method and GPC data, the total pumping power for each of the different designs and their different control modes have been determined. Results of this exercise can be seen in figure 3.7.

At 100%, distributed pumping systems use less energy than the two conventional systems experiencing pressure losses introduced by the PICV.

Since piping and equipment are the same, the theoretical power needed for chilled water circulation would also be the same.

The difference between distributed pumping systems and conventional configurations is obvious as soon as the flow reduces. Each coil pump only pressurises enough to overcome actual system losses and provide the required flow, resulting in chilled water distribution in optimal conditions and zero power wasted.

On the other hand, conventional systems tend to over-pressurise, with excess pressure removed by the valves and pump power wasted. Having the DP sensor further downstream in conventional systems does reduce pumping power, but not to the same degree of efficiency delivered through distributed pumping.

Commercial buildings rarely operate at 100% load; in fact, international standards show load to be below 75% most of the time.

Buildings using distributed pumping systems will benefit from energy savings in the region of 50% compared to conventional alternatives.

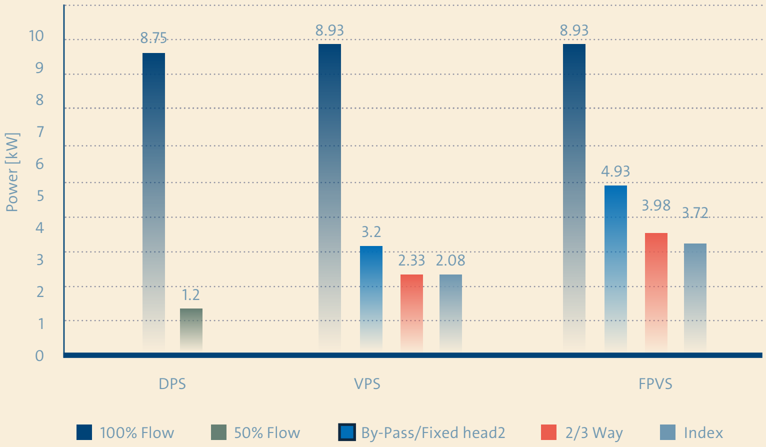


Figure 3.7 *CHW pumping scheme and control power comparison*

3.8 Primary pumps controls

Grundfos Multi Pump Controller (MPC) can be used to manage all primary pumps. Control logic is integrated within the MPC to detect and equalise flows between primary and secondary (distributed) pumps while ensuring minimum flow to chillers.

There are three requirements for the main pump control in distributed pumping with Grundfos controls:

- All pumps must be of the same size
- All pumps must be subject to variable speed control
- The pump set must be in the manifolded/headered configuration

This does not mean that distributed pumps will not work with dedicated pumps in a chiller configuration or in a configuration which features fixed speed pumps for chillers and distributed pumps. However, in these cases it is not always possible to balance primary side flow with secondary flow; thus the function for the control MPC will not be a proper fit.

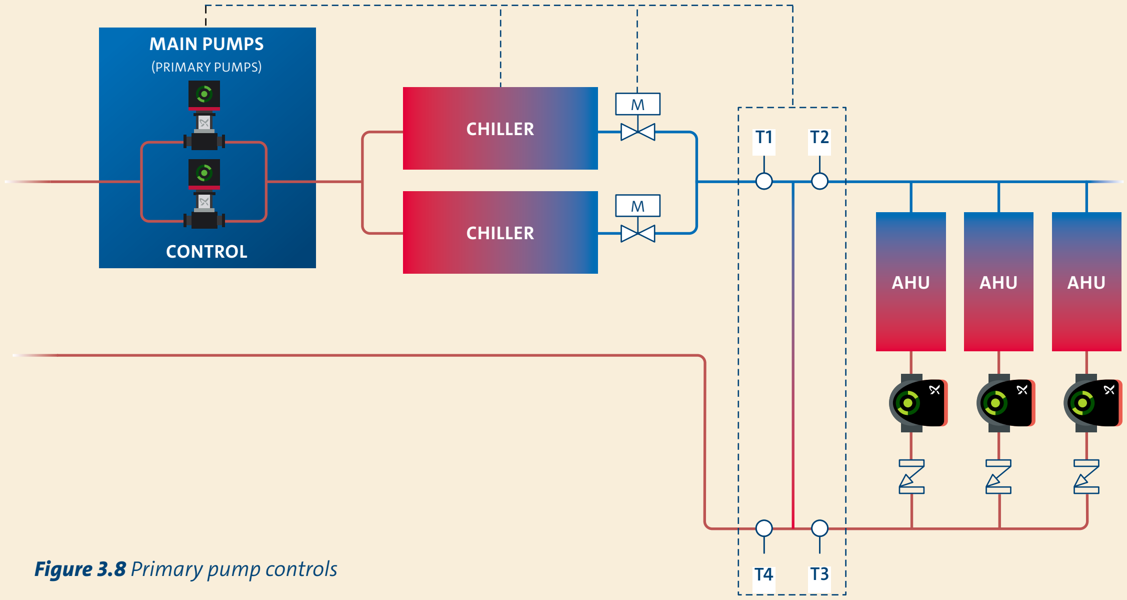


Figure 3.8 *Primary pump controls*

3.9 Air handler units – cooling coil controls

In distributed pumping systems, a MAGNA3 circulator pump replaces the control valve.

The MAGNA3 pump modulates the VFD based on an discharge/ supply air temperature sensor, to meet the setpoint (55°F or 12°C; see Figure 3.9.1).

The pump uses the constant temperature control mode, used in air handler systems to control the flow, maintaining a fixed temperature in the system. See figure 3.9.2 below.

When this control mode is used, no balancing valves need to be installed in the system.

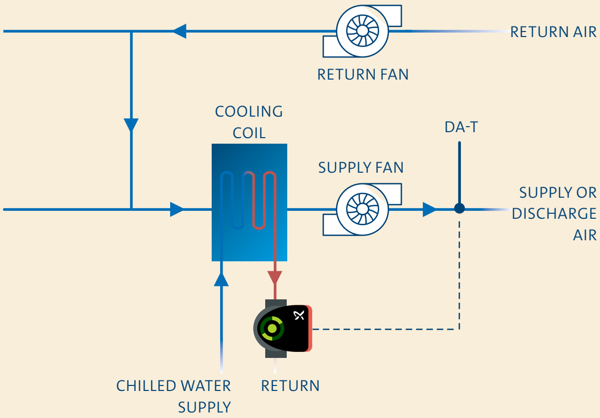


Figure 3.9.1 *MAGNA3 controlling cooling coil at constant temperature*

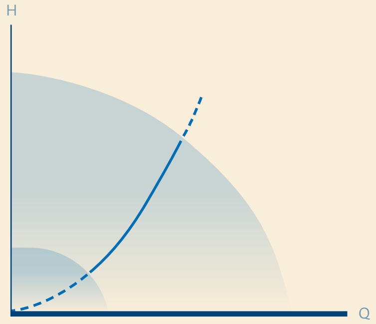


Figure 3.9.2 *Constant Temperature Control Mode*

3.10 Fan coil units – cooling coil controls

In systems with more than one unit (typically fan coil units) there will typically be two different ways to control the pump running in a closed loop:

1. Proportional pressure mode, with a feedback signal from the built-in sensor in combination with the flow limit to limit maximum flow. The pump will always run unless it receives a start/stop signal from the BMS system, either as a digital signal or from BUS. When the water demand decreases, the pump head is reduced, and when the water demand rises, the pump head is increased (See Figure 3.10.2).

2. Constant pressure mode, with a feedback signal from an external differential pressure sensor at the most critical point, such as the unit furthest from the pump or with the highest differential pressure demand. Constant pressure mode restricts the flow limit to the maximum total flow of all units (see Figure 3.10.3). The pump will always run unless it gets a start/stop signal from the BMS system, either as a digital signal or from BUS.

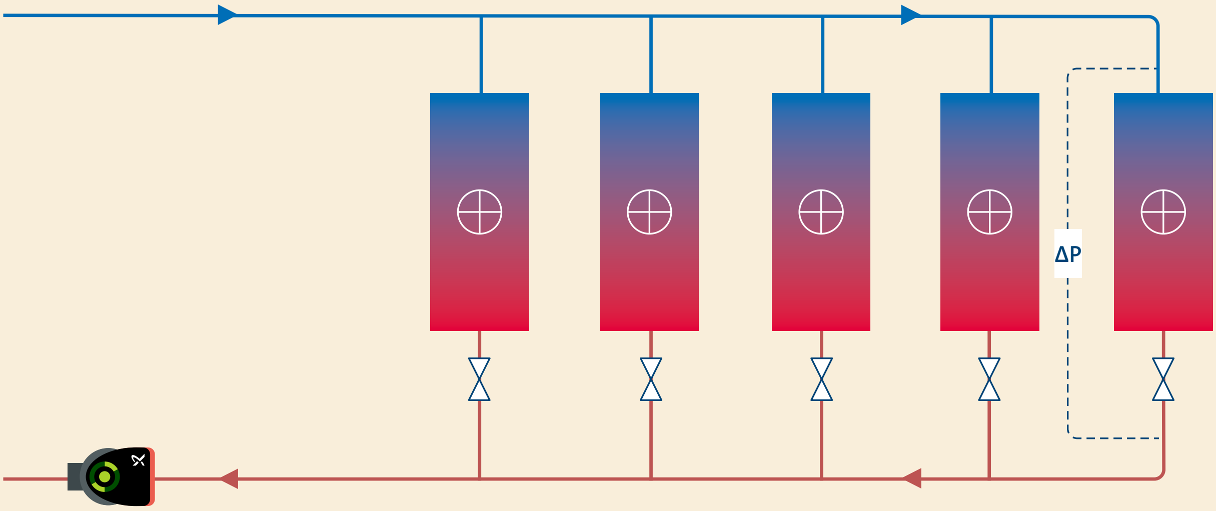


Figure 3.10.1 *Grundfos Circulator Pump MAGNA3 controlling Pressure at FCU*

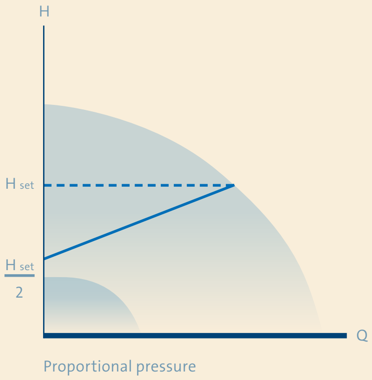


Figure 3.10.2 *Proportional pressure Control mode*

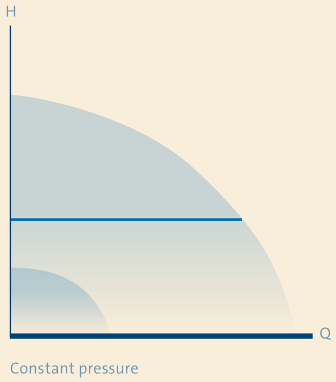


Figure 3.10.3 *Constant pressure Control mode*

4. Designing a distributed pumping system

This section will run through the process of using this sizing tool with a sample design.

4.1 Grundfos pump sizing tool

Designing a distributed pumping system requires additional hydraulic calculations since head losses must be calculated across all individual loops in the system to ensure coil pumps are sized correctly.

Grundfos' online sizing tool product-selection.grundfos.com makes this process easier. It automatically calculates duty head and flow for all pumps, using piping and equipment information from design drawings.

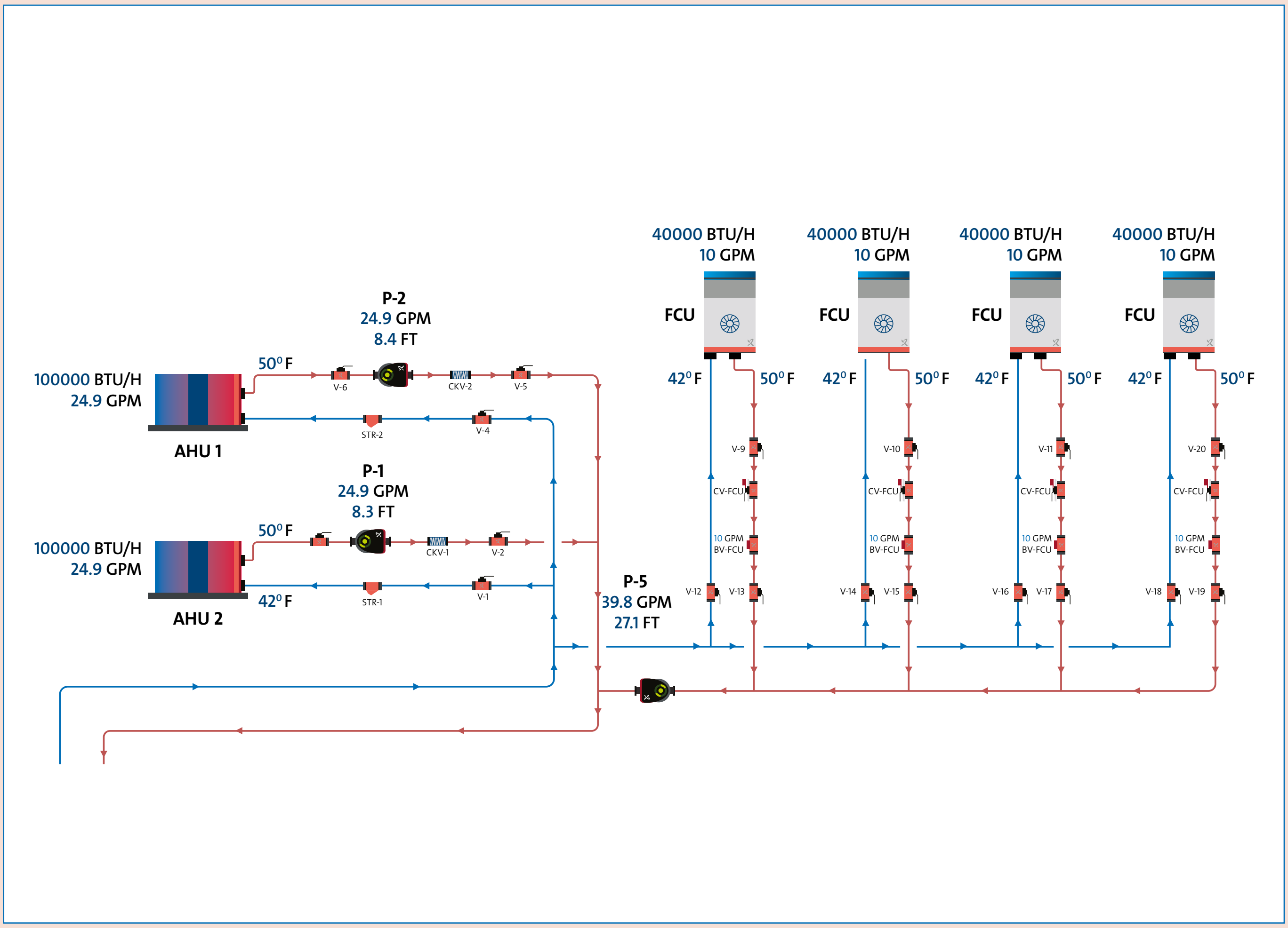


Figure 4.1 *Distributed pumping system design example in the Grundfos sizing tool (screenshot)*

4.1.1 Project design drawings and schedule

HVAC design and equipment information is required to use the Grundfos sizing tool for a distributed pumping system.

Depending on what stage the project is at, you may find that not all requested information is available. In this case, the tool will make assumptions based on data you provide in order to deliver a partial design which can be updated as work progresses.

It is common to require documentation for distributed pumping designs across all new building projects. Documents may have different naming conventions, so you might find it useful to see this terminology which is used by Grundfos experts around the world:

1: Schematic overview:
A 2D side view of the building providing an overview of equipment and piping connections. Your project is laid out in the Grundfos sizing tool to match the schematic overview, making it easier to compare Grundfos and consultant designs.

2: Layout drawings:
2D top view of the building which indicates the piping layout in scale, with information such as piping diameter and equipment locations and labels. This is used to measure piping section lengths, and input to in the sizing tool to calculate the head of pumps.

3: Equipment schedule and data sheets:
Technical information about equipment served by the pumps, where the relevant information is the rated flow and rated pressure drop of each piece of equipment included in the sizing tool. Often data sheets are necessary to find information such as rated pressure loss.

For a distributed pumping project, which only affects the chilled water distribution part of a building design, there are generally three stages:

1: Initial stage:
Building heat load is determined and schematic overview is finished, but equipment might not be selected and layout drawings only partially completed. In this case, piping lengths and equipment pressure losses are estimated, to provide a draft distributed pumping design and pump selection inventory which can be used for budgetary reviews.

2: Before tender release stage:
Piping layout drawings are completed, and the initial distributed pumping design is updated with correct piping lengths and dimensions, and pump list. Equipment pressure losses might still be unavailable, in which case they'll be estimated in the sizing tool.

3: Contractor awarded:
The contractor selects equipment for the HVAC and can provide data sheets with rated flows and pressure losses. This information will provide the final update for the distributed pumping design, confirming optimal pumps for the project.

There are often design updates between the first and second stages, which may affect data supplied by the sizing tool. But the three phases detailed above serve as general milestones for all distributed pumping projects.

4.1.2 Using the sizing tool

The first step is to specify loads, typically defined either as Air Handling Units (AHU) or Fan Coil Units (FCU).

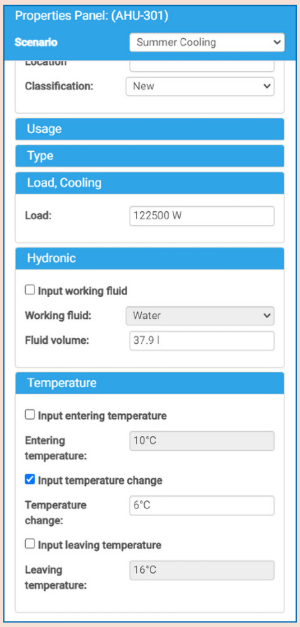
Loads are used to define the flow needed for each unit which can be identified in two different ways depending on what project information is currently available:

1: Define flow in the Properties Panel

2: Define load in watt or BTU and temperature change, or entering and leaving temperature. The tool will calculate flow based on this information

The labelling of loads is completely customisable and will generally be in line with the project schema. Once all loads are defined in accordance with project information, they will be laid out and connected in a similar manner to the schematic overview of the project. See Figure 4.1.

The Grundfos sizing tool automatically tallies flow in each piping section. Flows are used to calculate pressure losses in each piping section. In each piping section the information from layout drawings is entered to specify the length and diameter of piping. The sizing tool can also calculate the pipe sizing automatically based on maximum allowed head loss per section.



Properties Panel: (AHU-301)

Scenario: Summer Cooling

Classification: New

Usage

Type

Load, Cooling

Load: 122500 W

Hydronic

☐ Input working fluid

Working fluid: Water

Fluid volume: 37.9 l

Temperature

☐ Input entering temperature

Entering temperature: 10°C

☑ Input temperature change

Temperature change: 6°C

☐ Input leaving temperature

Leaving temperature: 16°C

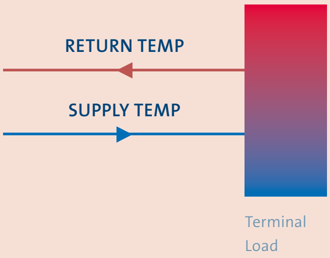


Figure 4.1.2.1 *An AHU in the sizing tool together with the properties panel for the AHU-301*

4.1.2 Using the sizing tool

The relevant properties for the piping calculations are:

- **Head loss:**

Defines the maximum allowed head loss in [Pa/m] or [Ft/100Ft] and maximum allowed fluid velocity in the section. By default the sizing tool will determine an appropriate pipe size for the specific section, and indicate actual head loss and fluid velocity. Head losses are automatically calculated using the Darcy-Weisbach equation:

$$h_f = f\left(\frac{L}{D}\right)\cdot\left(\frac{v^2}{2g}\right)$$

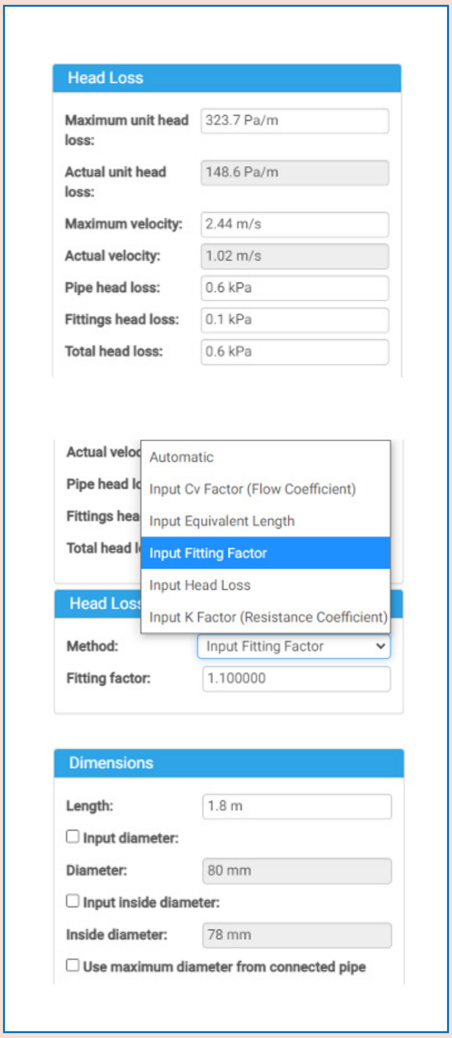
h is the head-loss
f is the friction factor
L is the length of pipe
D is the diameter
v is the fluid velocity
g is the gravitational acceleration.

- **Head loss fittings:**

This parameter handles the fitting in the piping, such as bends, tees and couplers. Bigger fittings like isolation valves and strainers are placed in the design. Fittings are often not fully captured in a layout drawing, unless precise isometric drawings are available, but even then, as-designed and as-built may differ. While it is possible to use a method like equivalent length to account for fittings, often a fitting factor is used instead. The sizing tool will firstly calculate the head loss for a section, and then multiply this head with the fitting factor. For straight risers, the fitting factor will typically be in the range of 1 to 1.1, while for branches it is typically 1.2 to 1.4. A fitting factor higher than 1 will increase the head loss in a piping section, which will account for the bends, tees and couplers which are not included in the model.

- **Dimensions:**

In this parameter, the measured piping section length from the layout drawings is entered and the diameter can be defined.



Maximum unit head loss: 323.7 Pa/m
Actual unit head loss: 148.6 Pa/m
Maximum velocity: 2.44 m/s
Actual velocity: 1.02 m/s
Pipe head loss: 0.6 kPa
Fittings head loss: 0.1 kPa
Total head loss: 0.6 kPa

Method: Input Fitting Factor
Fitting factor: 1.100000

Length: 1.8 m
☐ Input diameter:
Diameter: 80 mm
☐ Input inside diameter:
Inside diameter: 78 mm
☐ Use maximum diameter from connected pipe

***Figure 4.1.2.2** Pipe section properties*

4.1.2.1 Distributed Pumping design and sizing

Once loads, pipe lengths and fitting are defined, pump sizing will be provided by the tool.

Pumps' relative position in the schematic matches their position in the actual design. From this position, the software automatically determines the load the pump is serving, as well as the loop-path.

Figure 4.1.2.3 shows an example of this feature.

The blue path highlights piping sections through which the pump will pull and push water and determining the total pump head. Pumps pull water from the decoupler line, also indicated in the sizing tool. Changes to pipe dimensions or fittings will automatically trigger a recalculation of all pump heads in the design.

For groups of smaller loads, such as FCU, the sizing tool will determine the path and unit yielding the highest pressure loss and define required pump head. The duty flow is automatically tallied as the sum of all the FCUs, as shown in Figure 4.1.2.4.

Adding or changing pump locations is easily done in the sizing tool, making it an ideal resource for HVAC projects where project schematics and layouts might experience changes between the initial and pre-tender release stages.

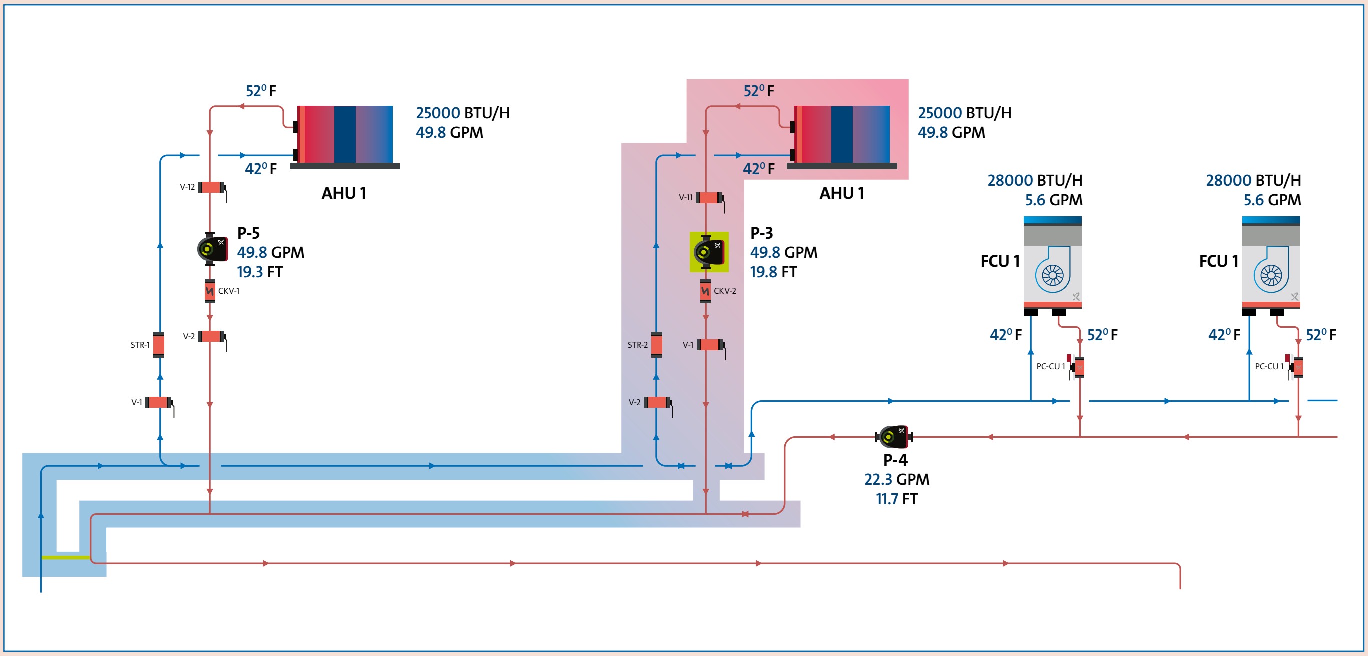


Figure 4.1.2.3 *A loop-path used to size a pump in the sizing tool (screenshot)*

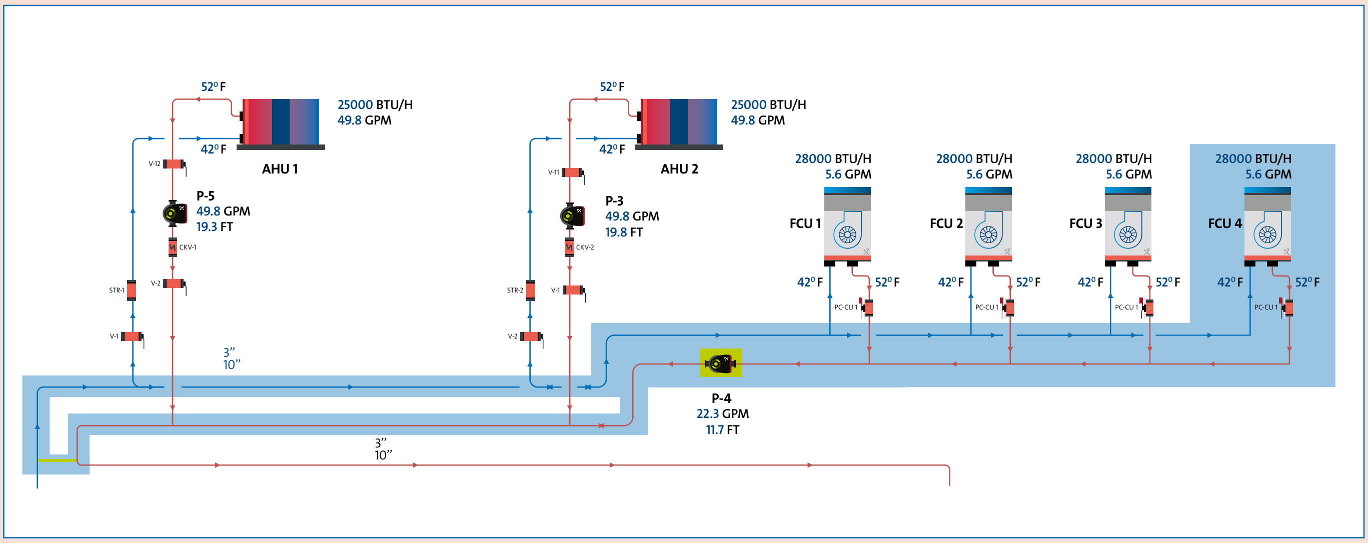


Figure 4.1.2.4 *Loop-path with the highest pressure-loss for a group of FCUs (screenshot)*

4.1.2.2 Coordination documents

The sizing tool offers several coordination documents supporting project design submission. These files can be integrated into consultants' Computer-Aided Design (CAD) drawings or BIM models, or provided as separate files. Coordination documents and file formats are:

Coordination documents

- Equipment Schedule – DXF
- Equipment Schedule – XLSX
- Grundfos Energy report – XLSX
- Materials List – DXF
- Materials List – XLSX
- Schematic – JPG
- Schematic – PDF

Figure 3 *Coordination Document options in the sizing tool*

The pump schedule for the distributed pumping design example is shown in the table below. This schedule is used later in this application guide to generate the Grundfos Energy report.

Variable Speed Primary Pump

Pump Model	kW Per Pump	Power Supply	Qty (1 Duty + 1 Stand-By)
TPE 150-155/4 A-F-B-BAQE-NX3	11	3 Ph X 380-500V	2

Terminal Unit Pumps

Pump Model	kW Per Pump	Power Supply	Qty (1 Duty + 1 Stand-By)
TPE 150-155/4 A-F-B-BAQE-NX3	11	3 Ph X 380-500V	2
MAGNA3 25-80	0.12	1 Ph X 220-240V	3
MAGNA3 25-120	0.19	1 Ph X 220-240V	8
MAGNA3 32-120 F	0.33	1 Ph X 220-240V	16
MAGNA3 40-120F	0.43	1 Ph X 220-240V	1
MAGNA3 50-150F	0.60	1 Ph X 220-240V	1
MAGNA3 50-180F	0.76	1 Ph X 220-240V	1
MAGNA3 65-150F	1.38	1 Ph X 220-240V	1
TPE 100-120/2 S-A-F-A-BQBE-IDB	2.2	1 Ph X 220-240V1	1

Table 1 *Pump Schedule for the sample distributed pumping design project*

4.2 Grundfos Distributed Pumping energy report

In section 3, we presented a basic design and we determined the required pumping power by selecting pumps in the Grundfos Product Center or in Grundfos Express, so that we could display power consumption for a specifit duty point.

The Grundfos Distributed Pumping energy report is an alternative approach for determining the power consumption of chilled water projects. This report benchmarks conventional designs and control approaches against Grundfos Distributed Pumping in a similar manner to section. But instead of selecting pumps to get the power use, the report uses the theoretical pumping power equation:

$$P = \frac{Q \cdot H \cdot SG \cdot 10^{-3}}{\delta}$$

Where Q and H are, respectively, the duty flow and head, SG is the specific gravity of water, and δ is the total efficiency of pump, a product of hydraulic, motor and frequency drive efficiency.

This equation can be used for any duty point of a pump, so also a part load situation, and it is assumed total efficiency is constant. This assumption is acceptable, as the purpose here is to create a benchmark between chilled water pumping designs so power and energy savings between designs can be presented in a proper framework.

For accurate energy use reports it would be necessary to not only use manufacturers' pump curves such as those available via the Grundfos Product Center, but also determine an accurate load profile - which is rarely available unless energy studies have been completed.

The Grundfos Distributed Pumping energy report uses pump duty points calculated in the Grundfos sizing tool to calculate both the total pumping power for the distributed pumping design and the desired conventional design and control.

Conventional design options are:

- **Variable primary:** Fixed differential pressure across the bypass line
- **Variable primary:** Fixed differential pressure across the index branch
- **Fixed primary, variable secondary:** Fixed differential pressure across the index branch
- **Fixed primary, constant speed secondary**

While these options don't cover every single control methodology of conventional systems, the most common approaches are addressed.

4.2.1 Information required to generate the Grundfos Distributed Pumping energy report

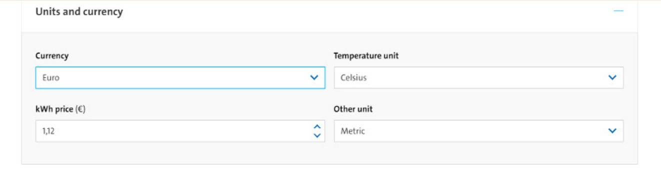
The Grundfos Distributed Pumping energy report is a combination of pump duty points from project design documentation. These different inputs are:

4.2.1.1 Units and currency

The report can be exported with different currency and units to fit the local market demands. It is also necessary to define a normal or average tariff in kWh, as this price is used to calculate annual operational savings.

The report uses a constant tariff to simplify the process. It does not support variable tariff pricing since the output is only intended as a benchmark.

For buildings or areas where tariff prices vary throughout the day, or there are different pay levels depending on total energy use, we recommend choosing an average tariff price.



Units and currency

Currency	Temperature unit
Euro	Celsius
kWh price (€)	Other unit
1,12	Metric

__Figure 4.2.1.1__ Units and currency

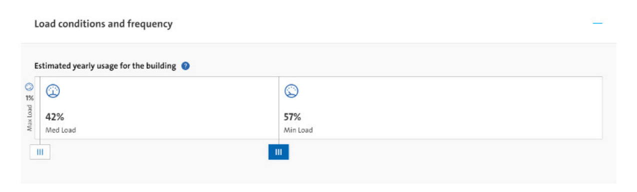
4.2.1.2 Load conditions and frequency

While buildings are designed for 100% capacity it is a known fact they rarely operate at maximum load. Therefore it is necessary to define a load pattern, used to calculate energy savings achieved by Grundfos Distributed Pumping.

Load options are set at 100%, 75%, and 50% or lower. Your entry needs to account for the usage split:

- 1% of the time is 100% load
- 42% of the time is 75% load
- 57% of the time is 50% load or less

This data is based on the international rating framework for chillers, called Integrated Part Load Value (IPLV) - but the distribution can be changed to fit the expected load pattern of the project's building design.



Load conditions and frequency

Estimated yearly usage for the building

1% Max Load

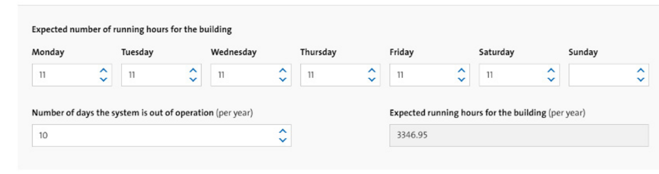
42% Med Load

57% Min Load

__Figure 4.2.1.2__ Load conditions and frequency

4.2.1.3 Running hours

With the load pattern established, the next step is to define the typical weekly operational hours of the building, and for how many days the system is expected to be shut down on an annual basis. This information is used to calculate annual operational hours for energy saving calculations.



Expected number of running hours for the building

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
11	11	11	11	11	11	

Number of days the system is out of operation (per year): 10

Expected running hours for the building (per year): 3346.95

__Figure 4.2.1.3__ Running hours

4.2.1.4 Pump duty

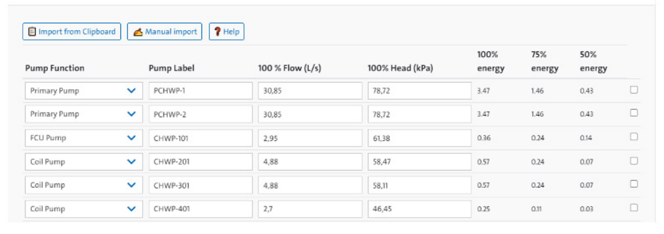
A specialised pump schedule is generated by the Grundfos sizing tool. This schedule includes both the pump label, duty point and a function. The function column is used to identify the pump type and its control mode.Available modes are:

- **Primary pump:** Installed in the plant room and acts as the primary pump. They follow the affinity law in achieving part load. These pumps are typically large and with a higher total efficiency than coil pumps. The fixed total efficiency is defined as δ = 0.7.

- **Coil pump:** A circulator pump directly serving a cooling coil, and typically using the constant temperature control mode. In achieving part loads, they follow the affinity law. The total efficiency of coil pumps is defined as δ = 0.5.

- **FCU pump:** A circulator pump serving a group or zone of Fan Coil Units (FCU) using a proportional pressure control curve, and small ON/OFF valves on the FCUs. This pump follows a pre-defined proportional curve to determine part load flow and head, with energy usage calculated using the Pumping Power equation. The total efficiency for this pump is defined as δ = 0.5.

Pump duty



Pump Function	Pump Label	100 % Flow (L/s)	100% Head (kPa)	100% energy	75% energy	50% energy	
Primary Pump	PCHWP-1	30,85	78,72	3.47	1.46	0.43	☐
Primary Pump	PCHWP-2	30,85	78,72	3.47	1.46	0.43	☐
FCU Pump	CHWP-101	2,95	61,38	0.36	0.24	0.14	☐
Coil Pump	CHWP-201	4,88	58,47	0.57	0.24	0.07	☐
Coil Pump	CHWP-301	4,88	58,11	0.57	0.24	0.07	☐
Coil Pump	CHWP-401	2,7	46,45	0.25	0.11	0.03	☐

Figure 4.2.1.4 *When pumps' functions and duty points are defined, the remaining three columns automatically show pumping power at the three pre-defined loads (50%, 75% and 100%).*

4.2.1.5 Conventional Design

In this final section, we will compare a conventional design to the Grundfos Distributed Pumping system design.
First choose which conventional design and control method should be used.

View energy reports showing specific inputs and their purpose.

Common to all conventional designs are fields for valve authority. The value is used to calculate pressure loss over the theoretical control valve that would be placed in the index loop on the conventional design.

This control valve pressure loss would be added to the duty point of the conventional pumps, shown in the formula as duty point*.

In the previous section,the values for primary pump head and highest coil pump head are determined from the energy calculation tool.

For the sample design example, these values are:
Primary pump head:
78.72 kPa
Highest coil/FCU pump head:
79.89 kPa

This field is calculated as

$$Duty\ point = primary\ pump\ head + highest\frac{coil}{FCU}pump\ head * (1 + valve\ authority)$$

The valve authority value can be used in two different ways depending on the specific project.

For some projects, the conventional design is already agreed and the pump head determined. In this case, the valve authority should be used to adjust the value of the duty point head field to match the designed conventional pump head.

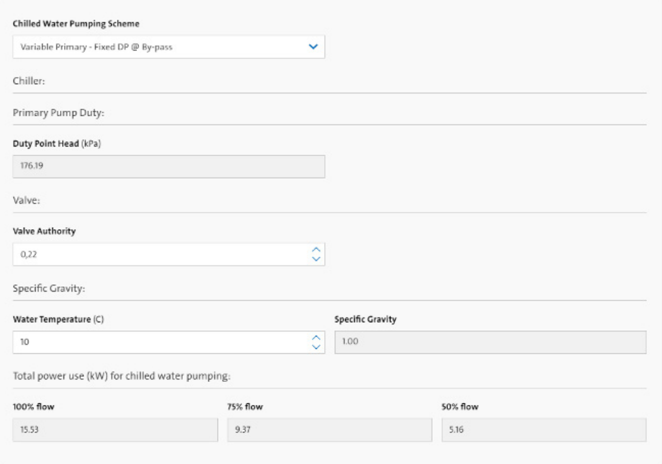
When project designs have yet to identify conventional pump heads, the valve authority should be used to determine an appropriate value for the duty point head field either by directly choosing a valve authority value or increasing it.

In this sample report, it is assumed that the conventional design would use pressure independent control valves (PICV) adding just 18 kPa pressure loss to the system (depending on brand and model). As seen in Figure 4.2.1.5, the duty point head value is 176.19 kPa - about 18 kPa higher than the sum of the primary pump and highest coil/FCU head.

This gives the option to try different values for the valve authority. The impact can be seen in the lowest fields, indicating total power use for the conventional system at three different loads.

The last input is the water temperature in the supply line, which will affect the specific gravity of the water. Normally this can be left at the default value as small changes will not affect the specific gravity. But for systems switching between hot and chilled water, it is necessary to split these two scenarios into two different energy reports.

Conventional design



Chilled Water Pumping Scheme
Variable Primary - Fixed DP @ By-pass

Chiller:

Primary Pump Duty:

Duty Point Head (kPa)
176.19

Valve:

Valve Authority
0,22

Specific Gravity:

Water Temperature (C)
10

Specific Gravity
1.00

Total power use (kW) for chilled water pumping:

100% flow	75% flow	50% flow
15.53	9.37	5.16

Figure 4.2.1.5 *Conventional Design input fields*

4.2.1.6 Power, Energy and report creation

Once all the above inputs are entered, you can see savings available through Grundfos Distributed Pumping by selecting either Compare Power Consumption, or Compare Energy Costs.
The power comparison shows the power at the three different loads between the choosen conventional design and the Grundfos Distributed Pumping system.

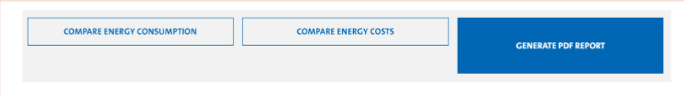


Figure 4.2.1.6.1 *See savings by choosing Compare Energy Consumption, or Compare Energy Costs*

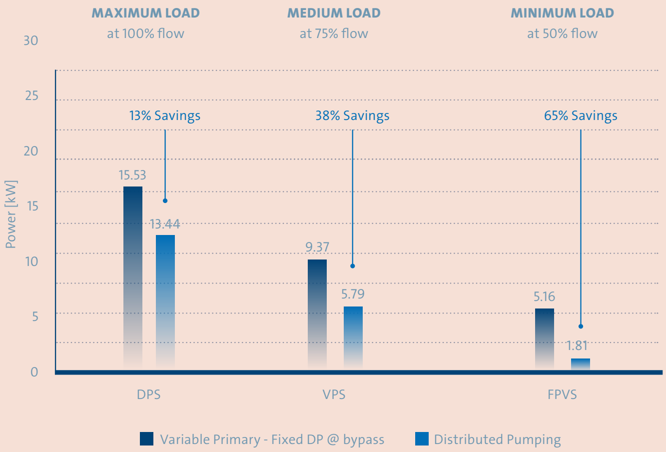


Figure 4.2.1.6.2 *Energy Use at the three loads Based on the required flow of the units in the building design and the calculated pressure drops in the system, the pumping power use for distribution of chilled water in the building is plotted below for the three defined load categories and then used for yearly power use and energy savings respectively.*

The energy cost comparison shows the yearly energy use and cost for both the chosen conventional design and Grundfos Distributed Pumping, based on annual operating hours and defined load pattern.

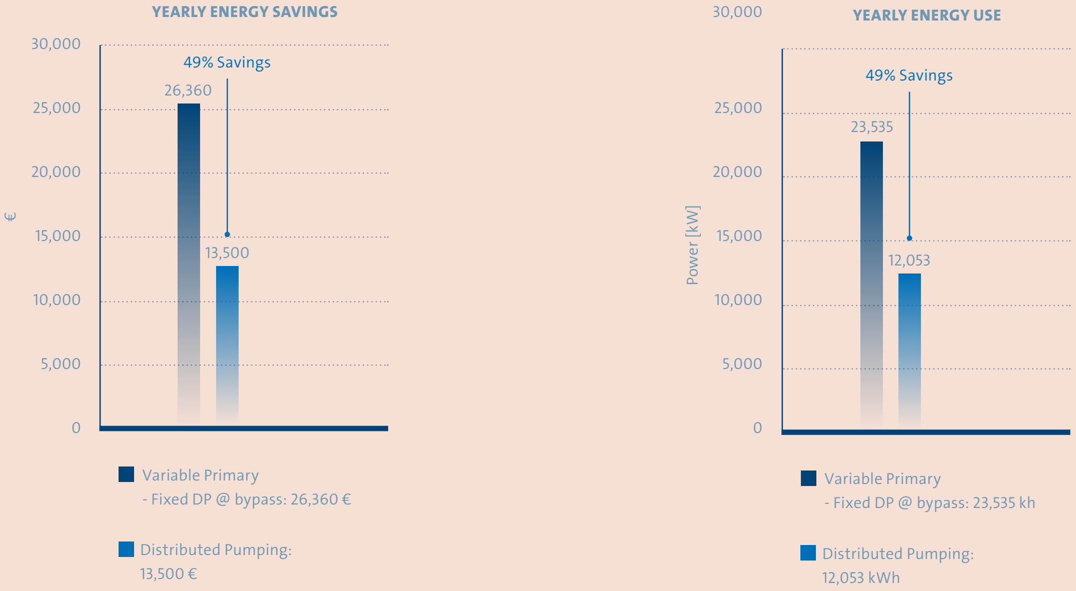


Figure 4.2.1.6.3 *Yearly estimated energy savings and cost saving based on local currency and the tariff price you entered*

5. Why choose Grundfos Distributed Pumping?

There are six reasons why Grundfos Distributed Pumping makes sense for your systems, from ease of commissioning at the start of the pumps' life cycle, through to lower maintenance and energy costs while they are running.

See for yourself:

- Energy savings
- Automatic balancing at any load
- Easy commissioning
- Easily extendable
- Maintenance free
- Cost effective

5.1 Energy savings

Distributed Pumping system lowers energy demands drastically by reducing the amount of pressure modulating components in the pipe system. That means the Grundfos system saves energy every single second the terminal unit is in operation. Over time, this means that there will be equally dramatic savings in your energy bills.

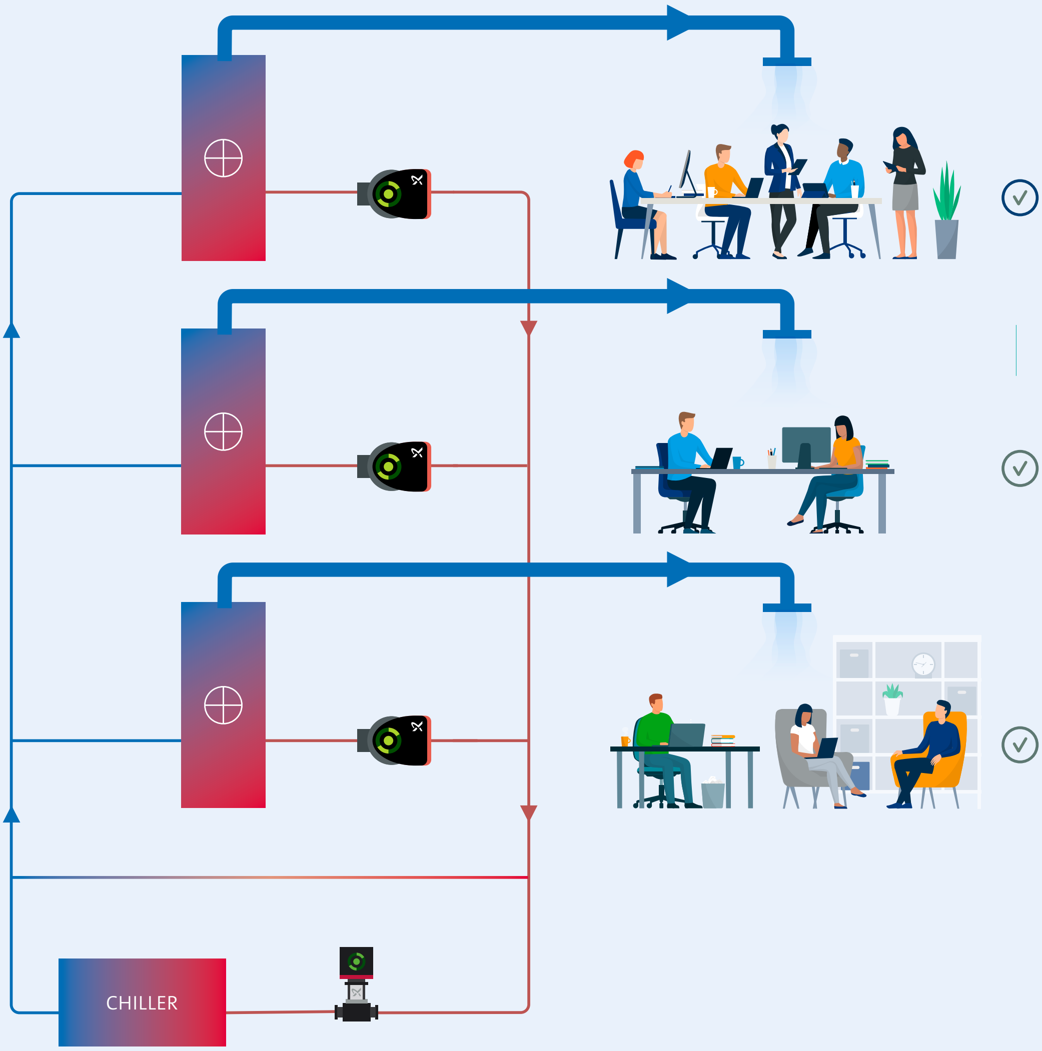


***Figure 5.1** Drawing of a Distributed Pump System with small primary in-line pump and a distributed pump for each circuit on the secondary side*

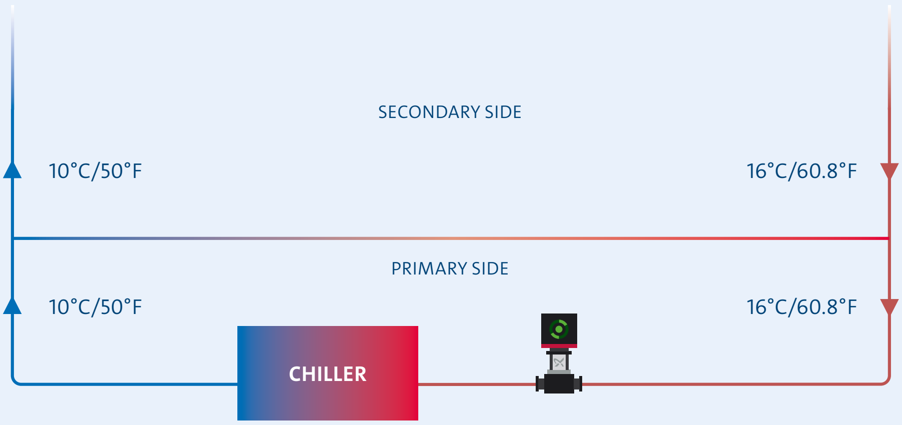


Figure 5.2 *The control logic of the primary pumps reduces bypass flow to a minimum, ensuring equal flow between primary circuit (production side) and secondary side (load side) provided minimum flow requirements for active chillers are fulfilled.*

Pump power	Load 100%	Load 75%	Load 50%
Conventional system (kW)	16.50	12.11	8.07
Distributed pumping (kW)	13.99	5.90	1.75
Savings percentage	**15.21%**	**51.27%**	**78.34%**

Figure 5.3 *Compared to conventional systems, Grundfos Distributed Pumping delivers average energy savings of more than 50%, depending on system architecture and load scenarios.*

5.2 Automatic balancing at any load

The control logic for primary pumps works so that, first of all, minimum flow for active chillers is ensured, and secondly, energy expended to balance the flow across the decoupler is kept to a minimum.

Coil pumps automatically balance the load side by varying pump/motor speed according to the setpoint, at any terminal load, at any time. During commissioning , the coil pumps' maximum flow must be set to avoid over pumping the coil and causing inadequate energy transfer which leads to lower efficiency.

With the automatic speed regulation to any load, we avoid starving the coil. By ensuring that pumps are configured carefully during the commissioning phase, the system maintains a level of self balancing, ensuring optimal user comfort, and optimal Delta T on the load side.

5.3 Easy commissioning

Setting up an intelligent pump can be done directly on the display touch buttons or remotely using the Grundfos Go app on a mobile phone. Once the settings for the operation mode and communication with the BMS have been established, the pump is ready to operate. The whole process takes around 30 minutes to complete, offering maximum convenience for minimum effort.

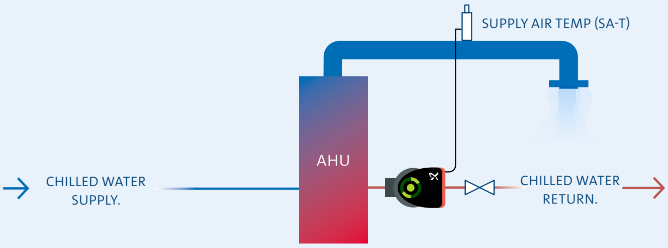


Figure 5.4 *Distributed pump installed in front of an Air Handling Unit AHU, obtaining temperature signal from airduct as input signal to adjust pump speed.*

0123/CBS/4014173-Brandbox

GRUNDFOS Holding A/S
Poul Due Jensens Vej 7
DK-8850 Bjerringbro
Tel: +45 87 50 14 00
www.grundfos.com