ITT

Energy optimization of systems by using variable speed driven pumps

Johann Kneissl
Product Manager - Monitoring & Controls
Residential & Commercial Water – EMEA
ITT Corporation

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Agenda

- Energy saving potential by using variable speed systems compared to systems using fixed speed pumps
- General – Life Cycle Costs (LCC) calculation
- Advantages by using integrated drives - HYDROVAR® introduction
- Selection of the optimum control system for various applications and their benefits
- Optimization of system efficiency by selecting the right pump
  Differences for various control systems
- Retrofitting of integrated variable speed drives on existing pumps
- Practical examples for energy efficient system design and resulting reduction of LCC
  Realized energy saving projects in water supply and HVAC systems

General data - Global Power Consumption - Pumps

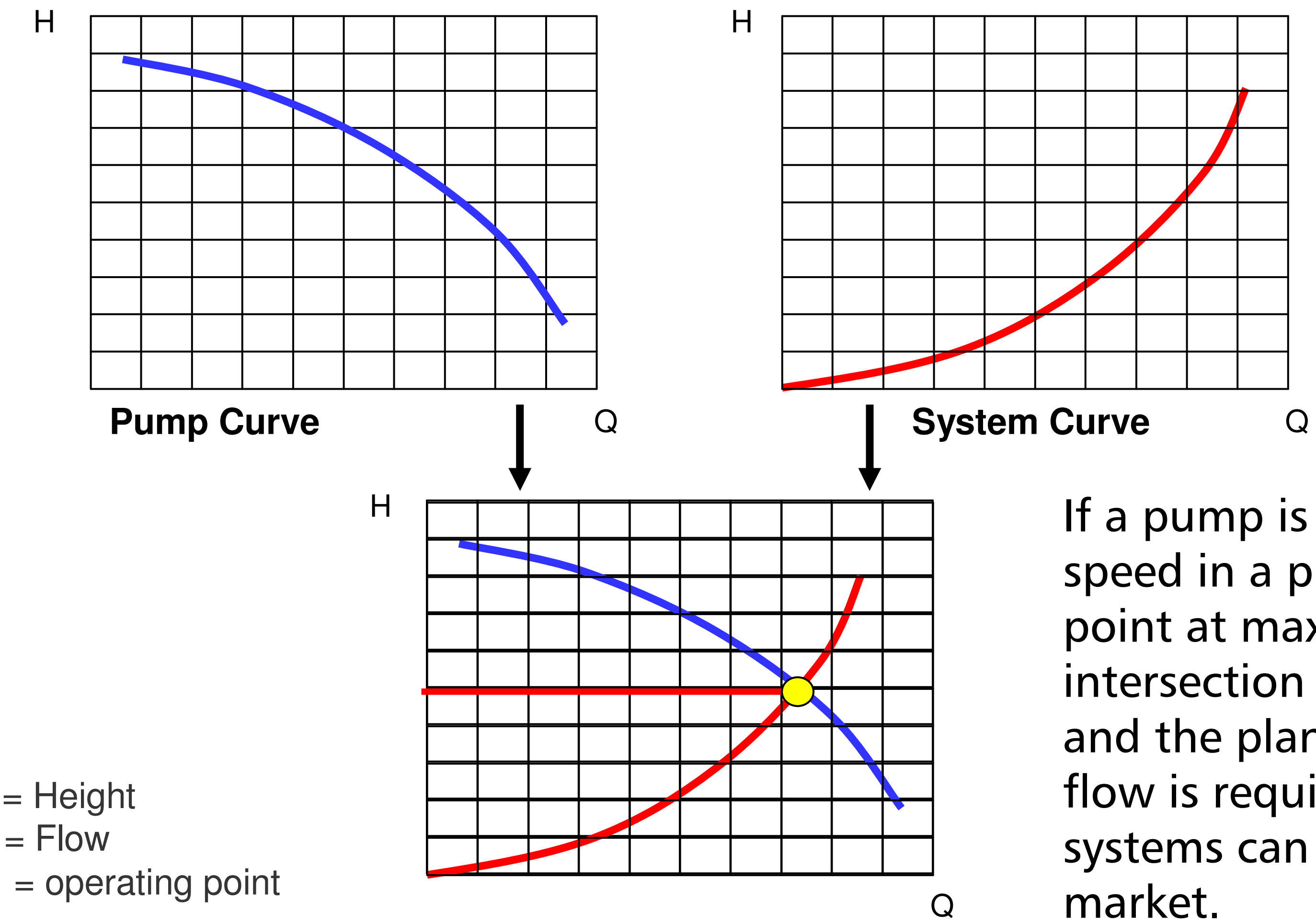
- [1]40% of total electricity consumption is used for electric motors
- [1]Total global electricity consumption by motors – 7,400 TWh p.a.
- [1]Energy savings potential – 20% to 30%
- [2]Pump motors consume ~ 30% of all electric motor consumption in the UK (representing WE standard)
- [3]Estimates for global electricity consumption by pump motors varies but could be in the region of 1,100 TWh p.a.
- Pump motors therefore consume ~ 15% of the global motor electricity consumption

1. Source: Paul Waide, International Energy Agency, EEMODS, Beijing, June 2007 – www.emods.org
2. UK Market Transformation Programme – Report BNMO8
3. “Energy Reduction” Paper: Steve Schofield (BPMA) IMechE Conference 18th October 2007

Energy saving potential by using variable speed versus fixed speed pumps

Comparison of various control systems

Basic pumping curves



If a pump is working with full speed in a plant, the working point at maximum flow is the intersection of the pump curve and the plant curves. If a lower flow is required, various control systems can be found in the market.

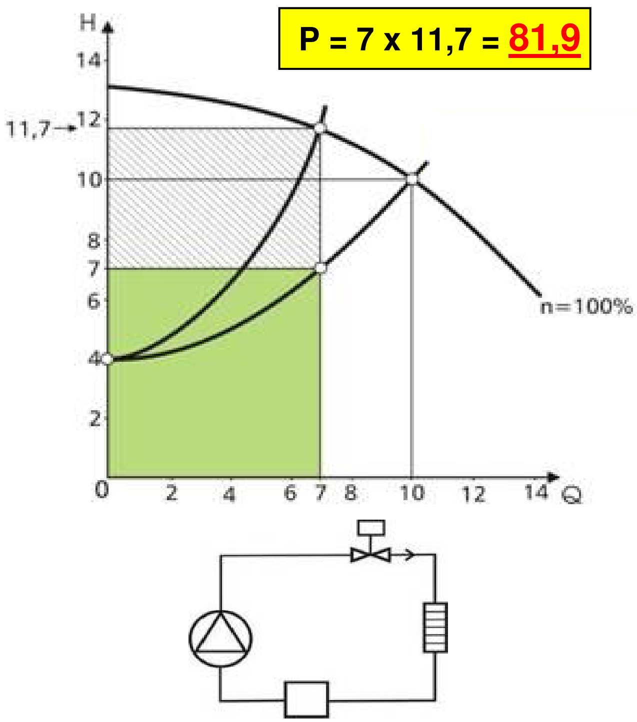
H = Height
Q = Flow
= operating point

Conventional control methods – Water supply / booster systems

For conventional control systems, all the time the system curve is adapted to the actual requirements ➔ higher system losses ➔ reduced system efficiency

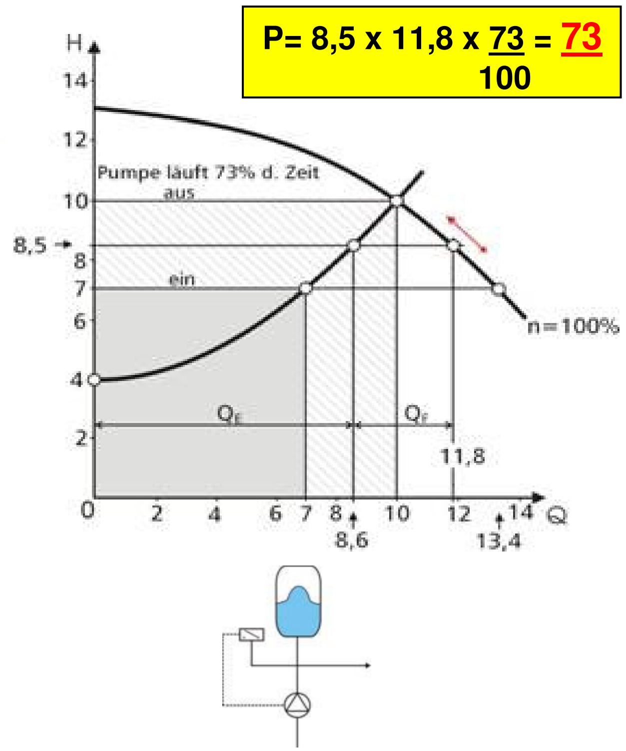
Throttle control

(use of pressure reduction valves)



On/Off control

(pressure switch controlled together with large tank)



Throttle control:

The pump is working at 11,7bar and the higher pressure is "destroyed" in the throttle valve!

➔ ***resulting power consumption is 81,9%***

On/Off control:

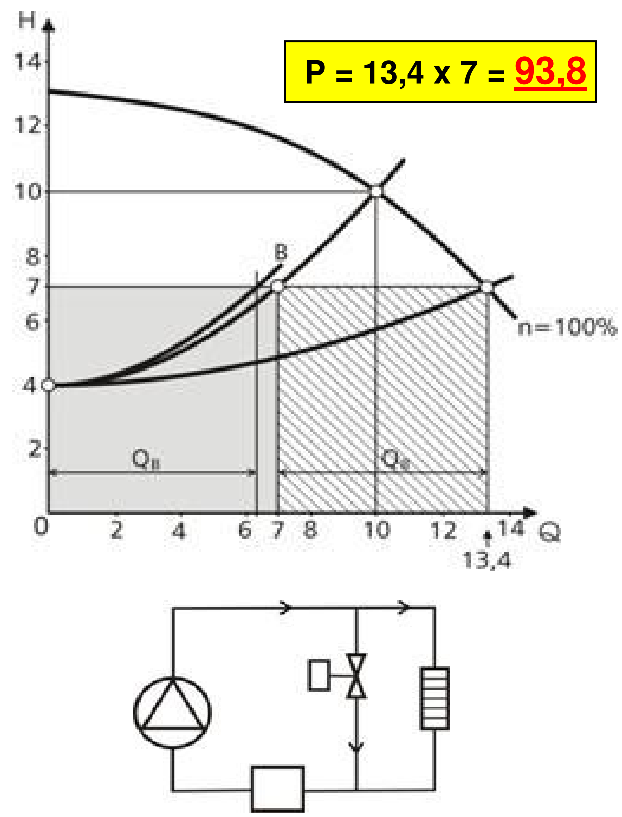
The pump is running when filling up the large pressure tank for about 73% of the time to provide required flow!

➔ ***resulting average power consumption is 73%***

Conventional control methods – HVAC systems

For conventional control systems, all the time the system curve is adapted to the actual requirements ➔ not required higher flow, where energy was already put in, is feed back into suction tank/pipe ➔ reduced system efficiency

Bypass control
(use of 3-way valves)



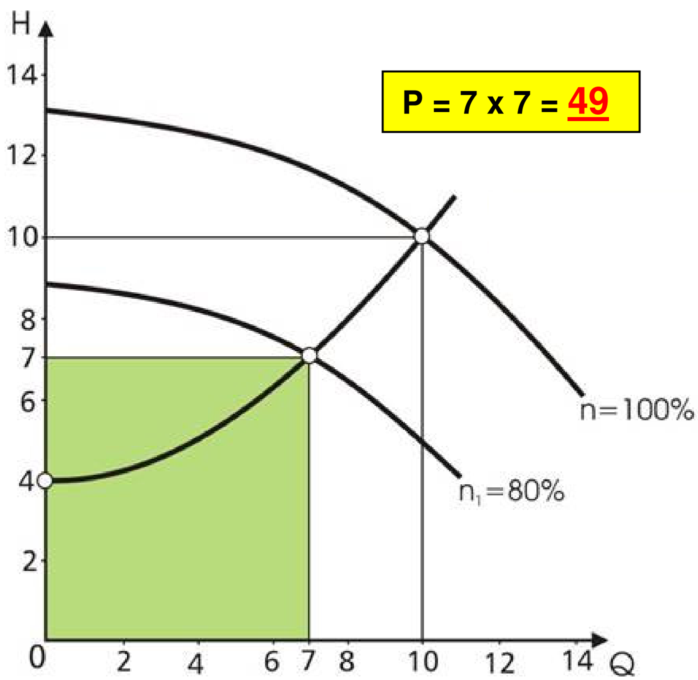
Bypass control:
The pump is working at 13,4m³/h and the higher flow is feed back to suction side, where the already invested power will be “destroyed”!

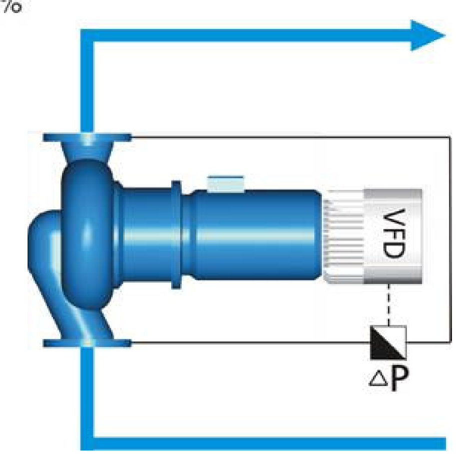
➔ **resulting power consumption is 93,8%**

➔ as shown, this control system is worst from system efficiency level of all shown control systems!

Control systems using variable speed driven pumps

In control systems using variable speed pumps, the pump performance curve is adapted to the actual requirements ➔ no additional losses in the system ➔ highest system efficiency





Using variable speed pumps:
The pump is running exactly at the required working point to meet demand for pressure and flow.

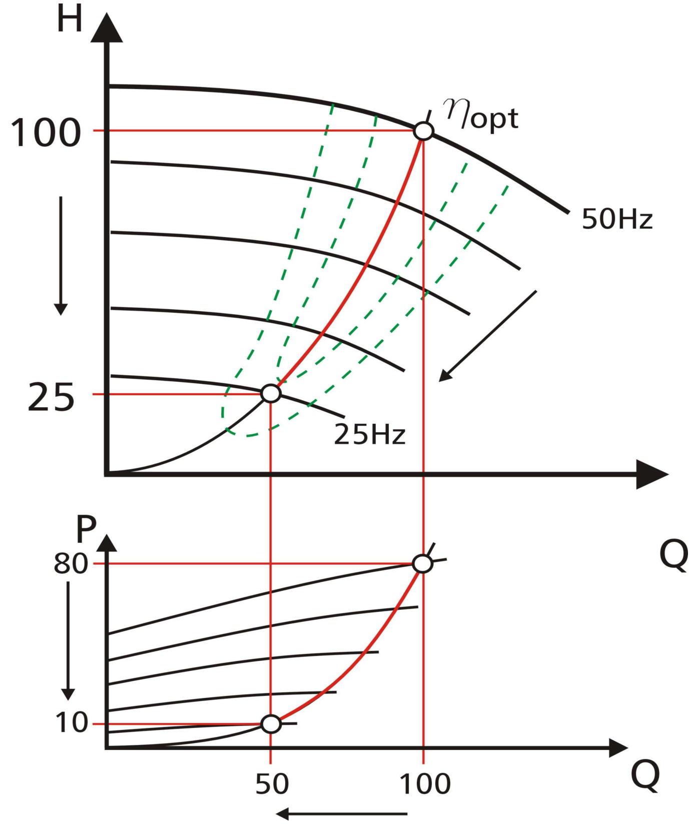
➔ **resulting power consumption is 49%**

Only by selecting the "right" control system, **energy savings in the range from 25 – 45%** can be achieved!

Fundamental rules – affinity laws

Significant energy savings at partial load are possible due to the affinity laws for centrifugal pumps.
<u>The reduction of the pump speed provides:</u>

- a lowering of the flow acc. to a **linear function**
- a reduction of the head according to a **quadratic function**
- and a resulting reduction of the power consumption acc. to a **<u>cubic function</u>!**



$$\frac{Q_x}{Q} = \frac{n_x}{n} \qquad Q = Qx\,\frac{n_x}{n}$$

$$\frac{H_x}{H} = \left(\frac{n_x}{n}\right)^2 \qquad H_x = Hx\left(\frac{n_x}{n}\right)^2$$

$$\frac{P_x}{P} = \left(\frac{n_x}{n}\right)^3 \qquad P_x = Px\left(\frac{n_x}{n}\right)^3$$

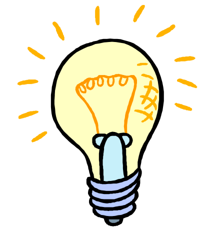
n = full speed rpm
nx = variable speed rpm

Q = flow rate at full speed of the pump
Qx = flow rate at variable speed

H = pump head at full speed of the pump
Hx = pump head at variable speed

P = power consumption of the pump at full speed
Px = power consumption at variable speed

Why using variable speed pump?



Note:

The electrical power consumption of a variable speed driven centrifugal pump is only 50% compared to a full speed pump when running at 80% of its maximum speed!

Additional energy saving potential:

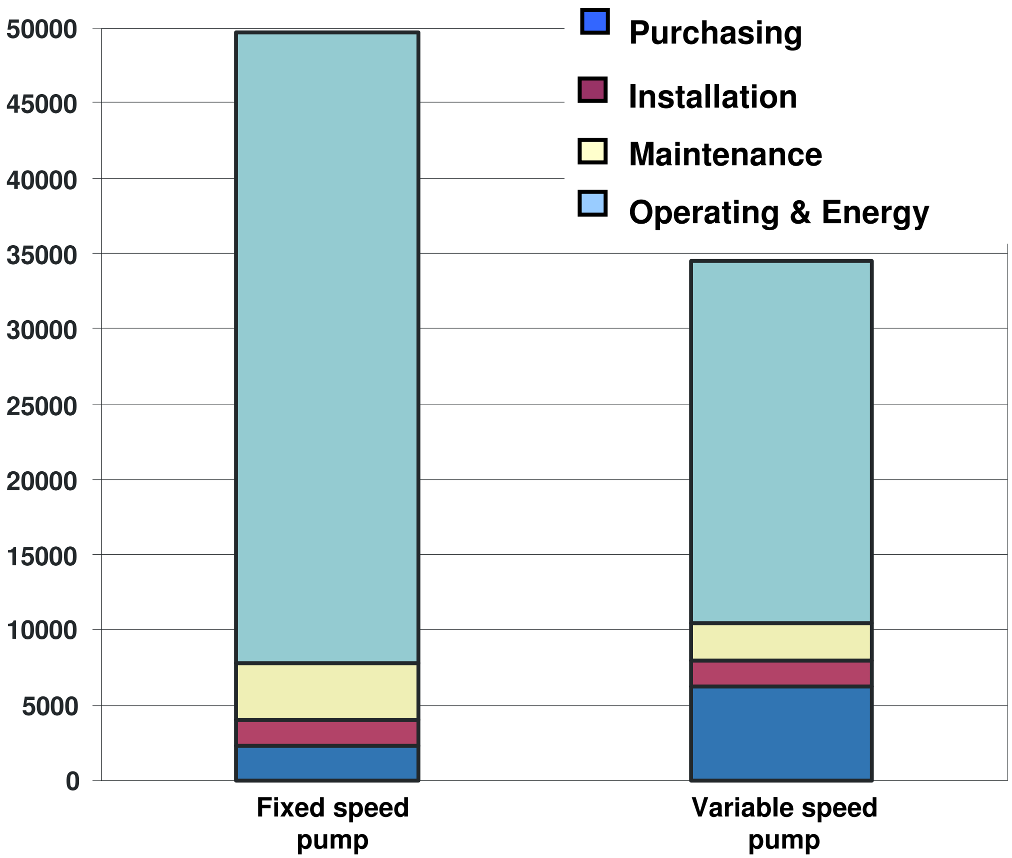
Due to broad safety factors during specification of the system or after optimization of an existing system, **many pumps are over dimensioned** and will never work at their specified maximum working point.

➔ **By optimization of the system and adjustment of the speed of the pump by using VFDs, energy savings can also be realized in systems with constant working conditions!**

General – Life Cycle Costs (LCC) calculation

Calculation of Life Cycle Costs (LCC)

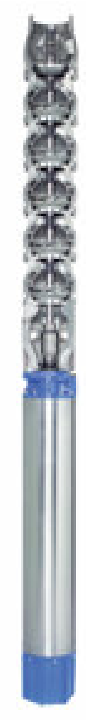
LCC are normally calculated over a 10 or 15 years working period. Costs for operation and maintenance, with up to 80% of the total costs, are representing the lion's share for pumping systems, as shown in the graph below.



The graph on the left shows the comparison between a fixed speed pump and a speed controlled pump during their LC

Based on costs per kWh for industrial consumers with avg. 0,10 €/kWh
(Source: Eurostat, 2007)

Reduction of Life cycle costs (LCC):

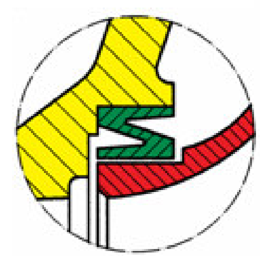


➔Trend for development of pumps = <u>highest possible efficiency level</u>

This target is achieved by:

- **New optimized hydraulic design**
- **Precision investment casting with high surface finish**

- **Minimizing of internal losses by using the new "dynamic wear ring"**



➔Use of <u>high efficiency motors</u> with efficiency-class1 (IE3)

➔ By replacing the "old" and less efficient pumps with new units and use of high efficiency asynchronous motors, total energy savings in the range of 10% to 15% can be achieved!

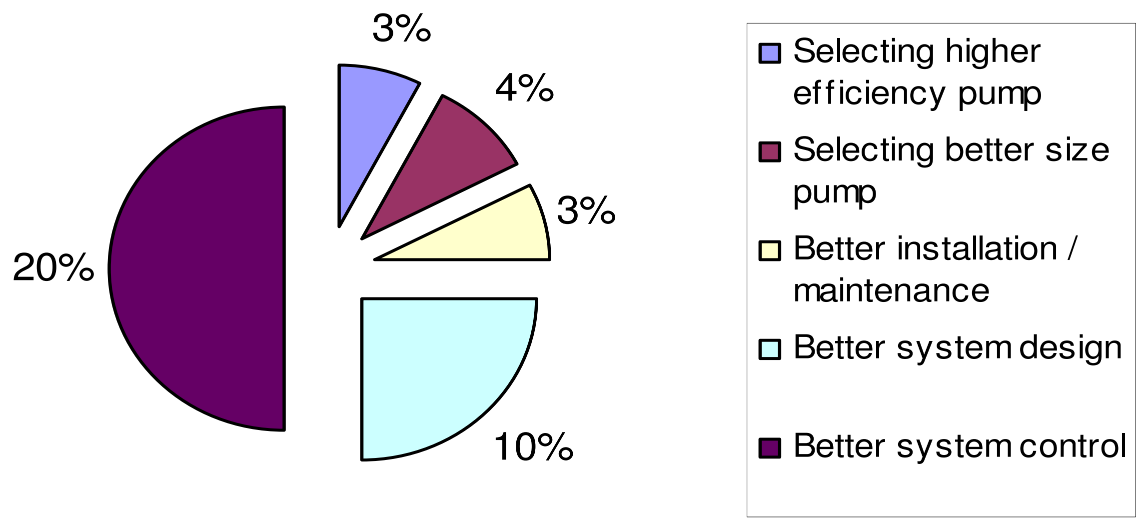
Pumps Energy Saving Potential Within Pumping Systems
(Data for centrifugal pumps)

Shows potential energy savings achievable from various actions

Source: MTP consultation document BNMO8

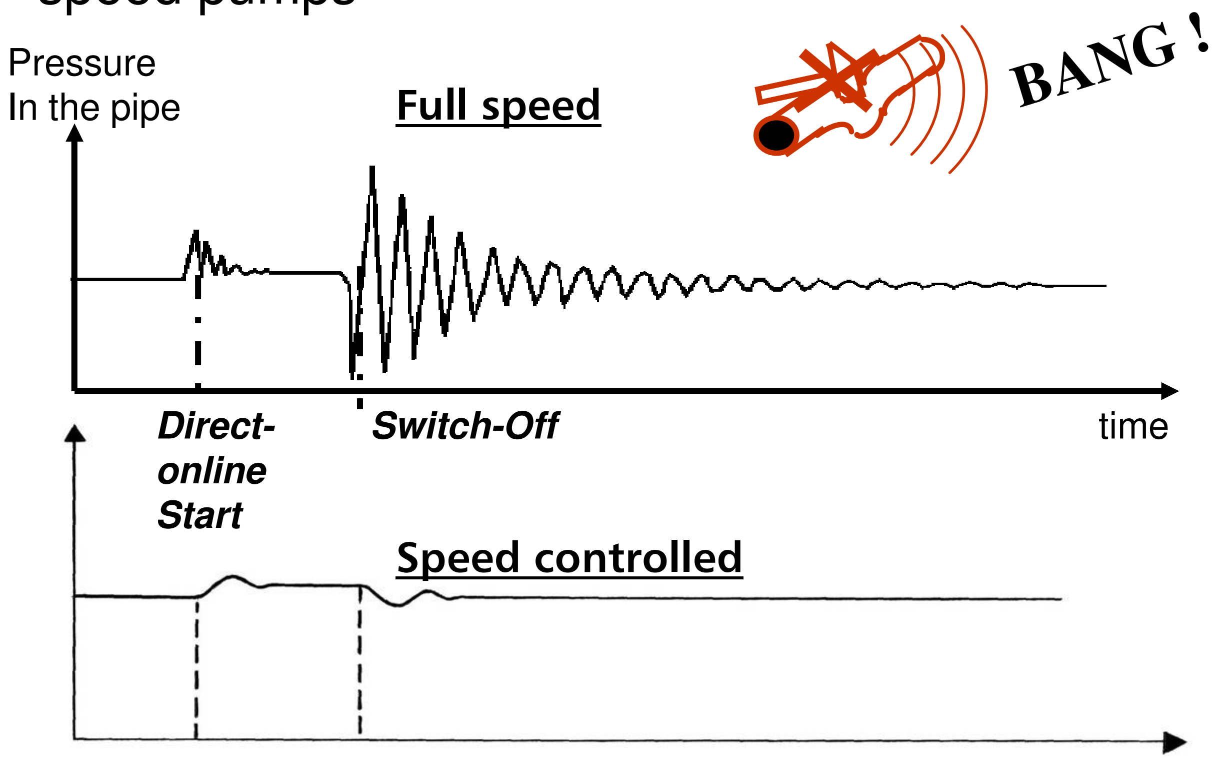
- Selecting a higher efficiency pump gives some potential, but delivers only a low portion of total savings

- Better system design and optimizing the control delivers a 30% saving
  – for various applications (like HVAC) this portion can be even more!



Reduction of maintenance costs:

➢ Prevention of **water hammer** which normally occurs during stop of full speed pumps



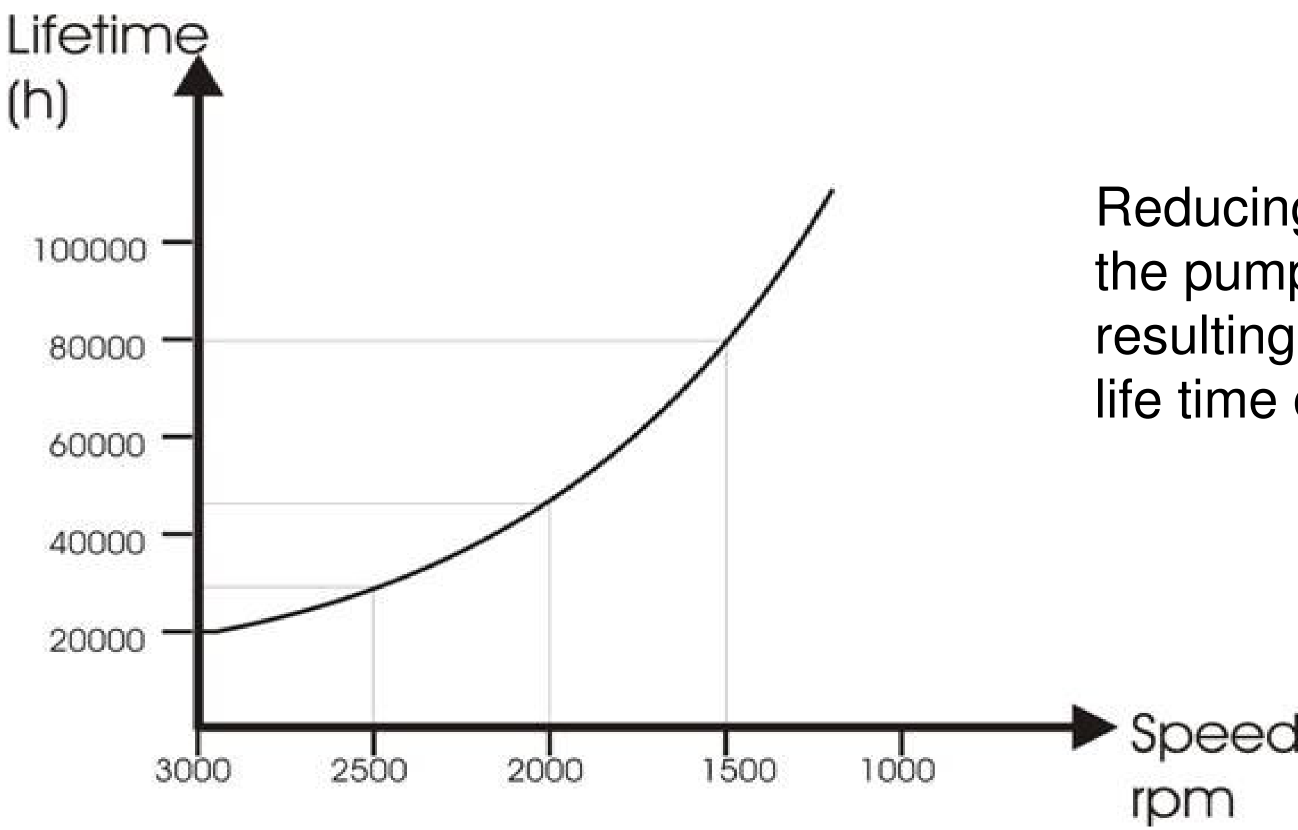
Repeated pressure spikes are reducing the lifetime of a system

The soft start and stop of speed controlled pumps avoid pressure peaks and prevents pipe fractures

➢ To **avoid high peak current** up to $10xI_N$ during start of full speed pumps compared to maximum of $1{,}2xI_N$ for variable speed pumps which at the end reduces electrical stress to the motor (overheating)

Reduction of maintenance costs:

- Extension of the bearing - life time



Reducing the speed of the pump (bearings) is resulting in extended life time of the bearings

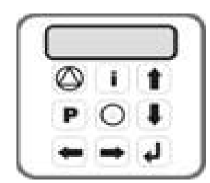
Advantages by using integrated drives –

HYDROVAR® overview

Integrated drive: all components – one unit

Centrifugal pump + motor

Frequency converter (IP55 enclosure)



Sensors for actual value

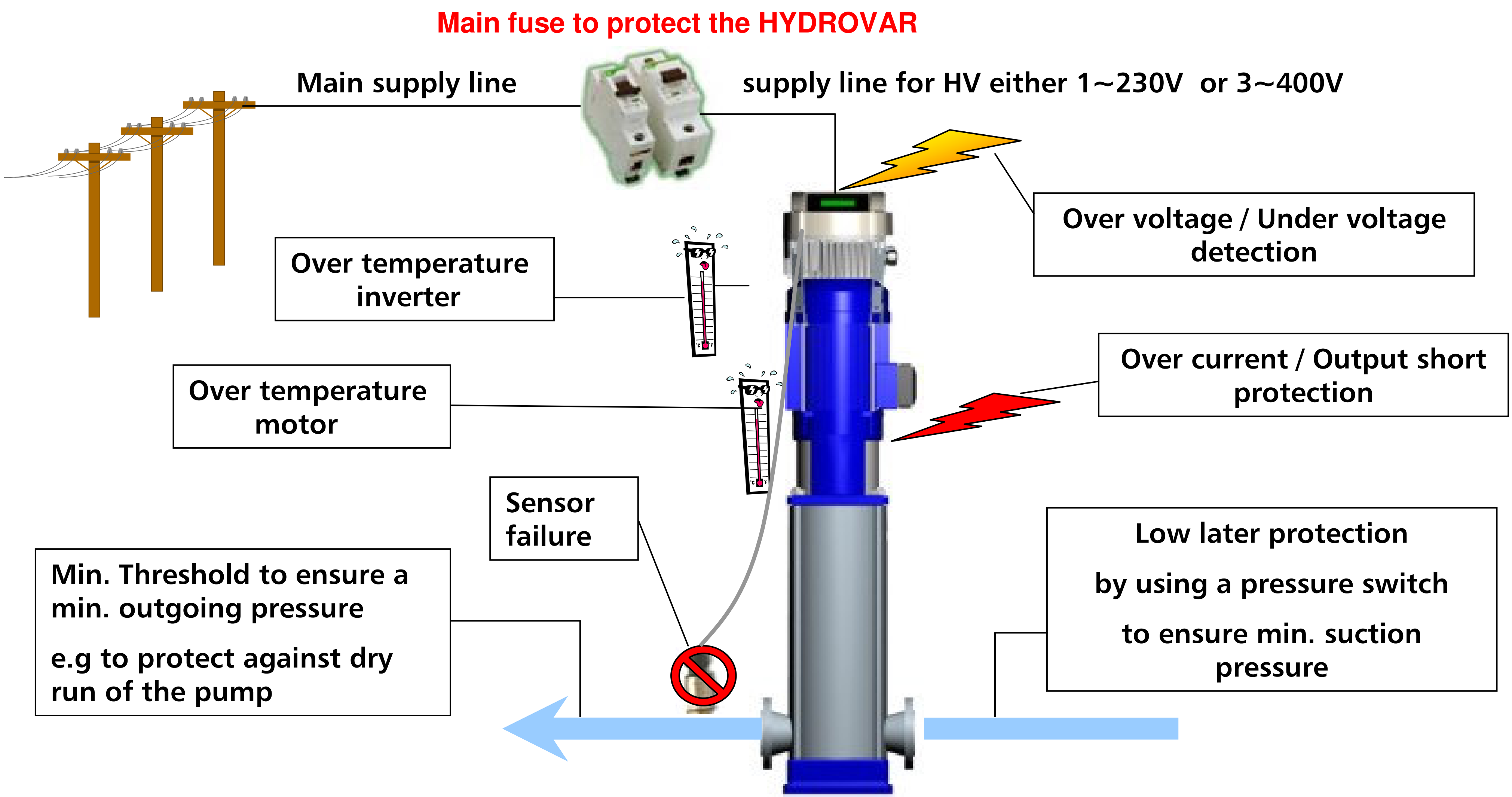
Control by microcontroller especially designed for pump applications

HYDROVAR®: what is the difference?

HYDROVAR® is not only a simple speed controller which can be mounted directly onto the pump.

HYDROVAR® means more than that – it is an intelligent pump control system that manages the motor speed and match pump performance to a range of hot and cold water applications.

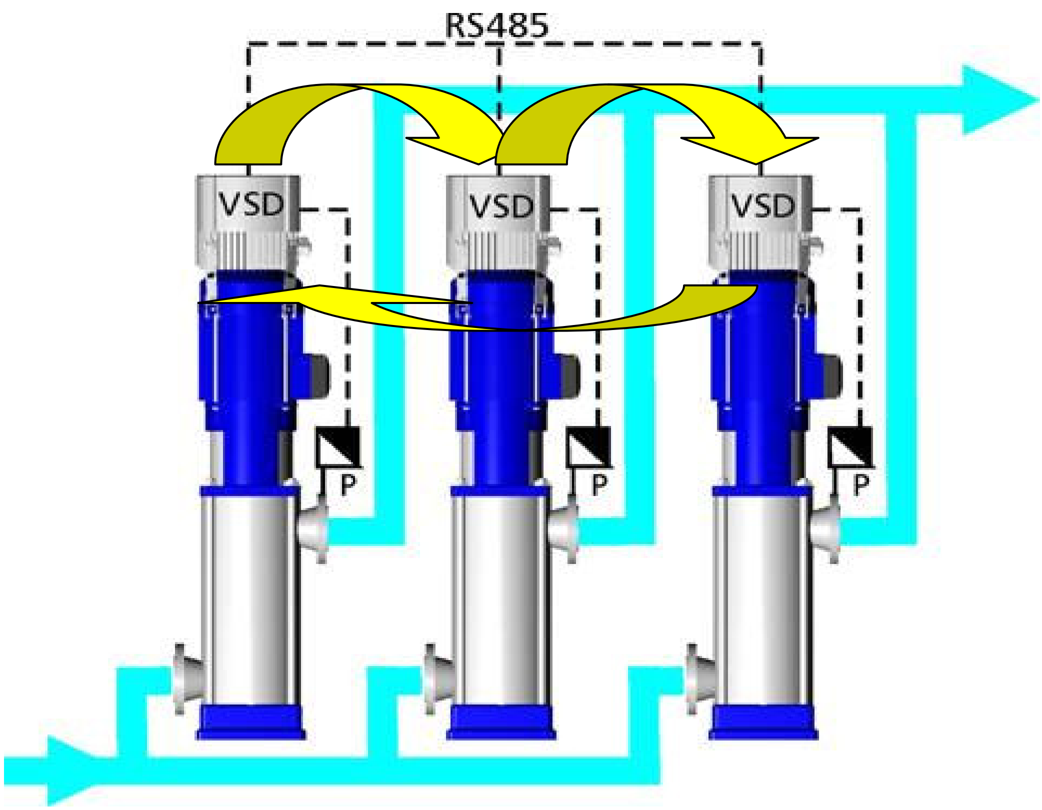
Built in product and system protections as standard



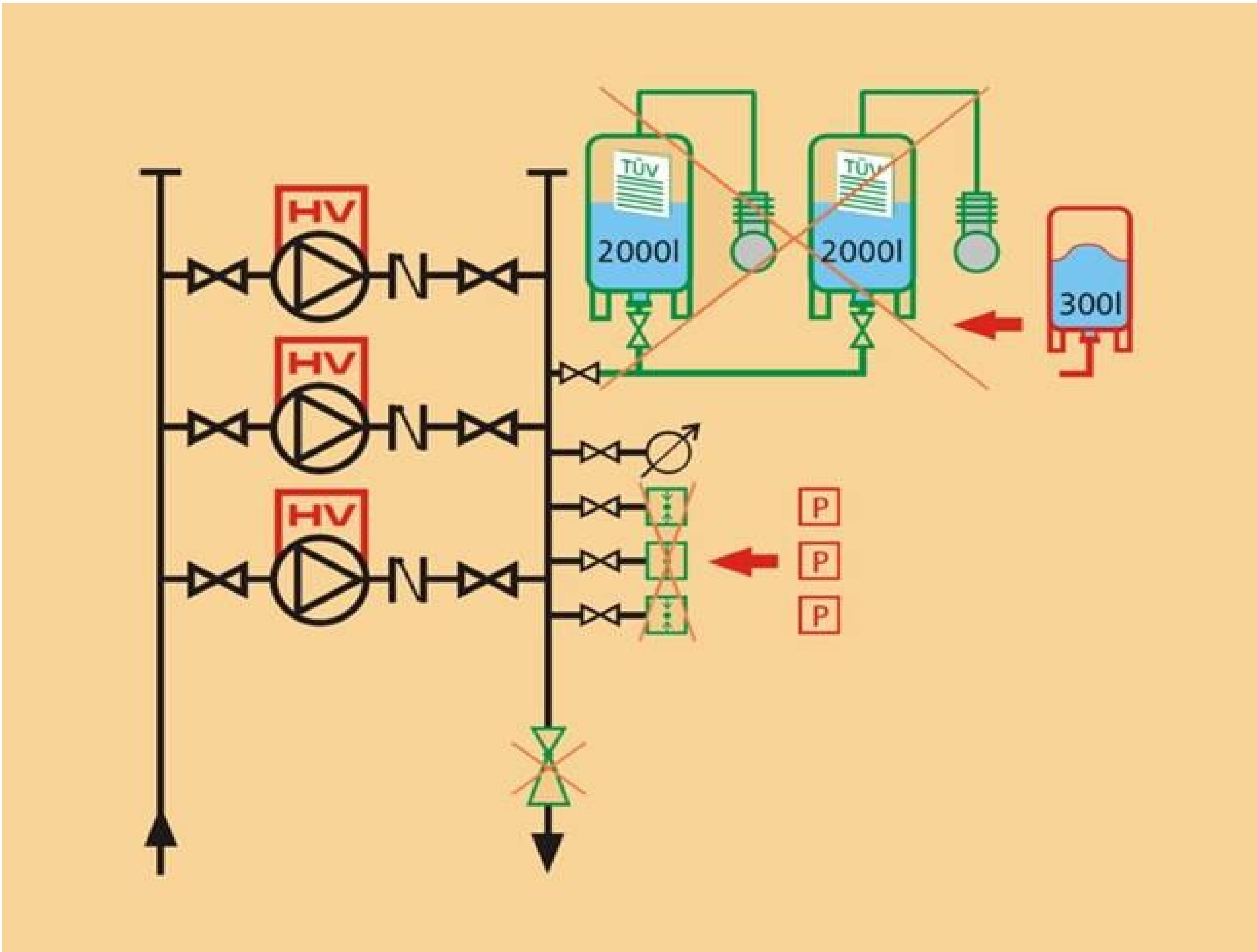
Multi-pump system without any external controller

Simple design of multiple pump units (up to 8 pumps) by incorporated processor and interface connection (RS 485) which allows:

- Full redundancy within the system because of the Multi-master philosophy
- Cyclic change of lead and lag pumps and automatic start and stop of lag pumps following the actual demand
- Synchronous mode option to run the pumps within best efficiency range
- Automatic switch over in case of pumps being out of order
- Easy integration into BMS systems using the MODBUS-Interface, available as standard

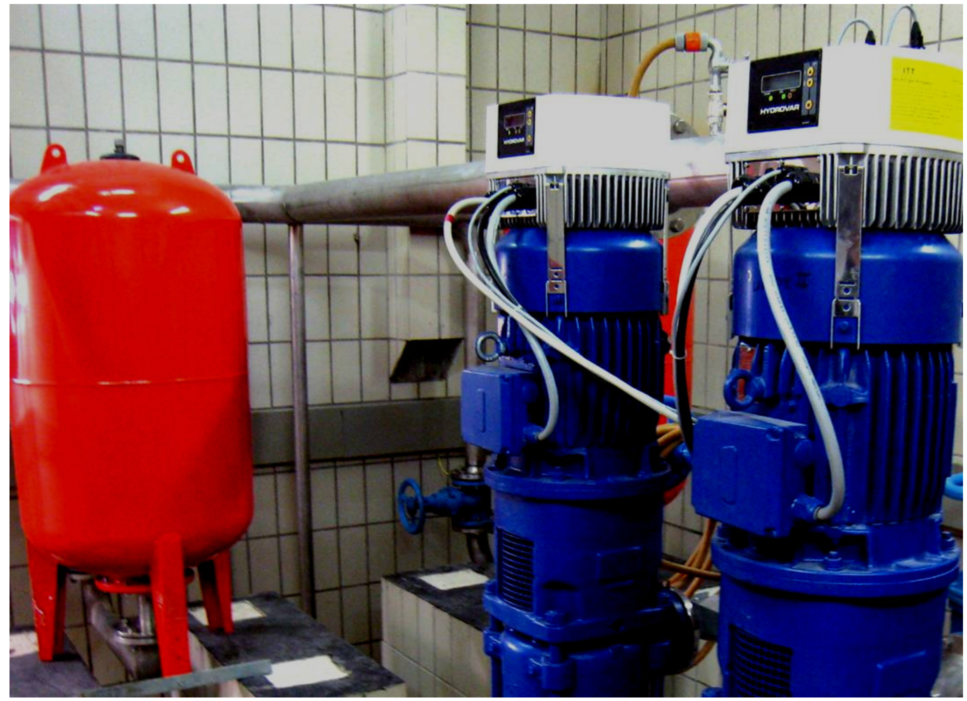


Reduction of space:



Reduction of space: (application example)

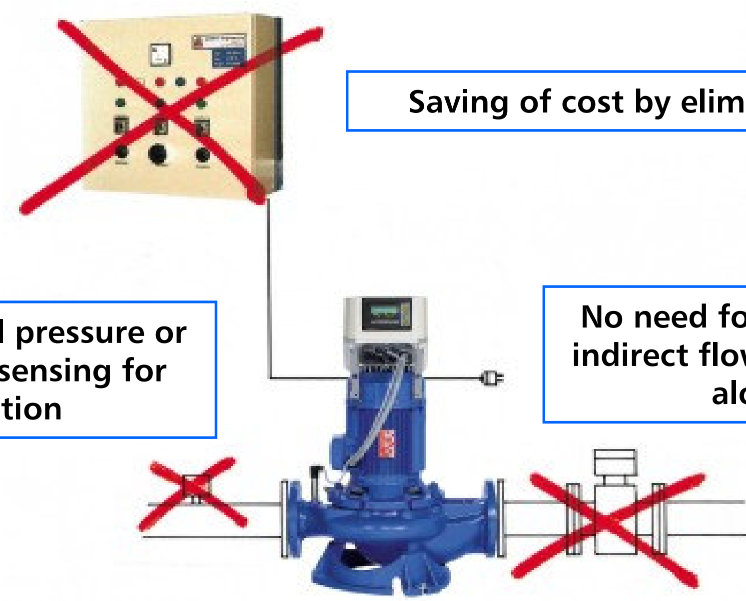
Fixed speed system
with large pressure tanks and
necessary air compressor



Variable speed system

HYDROVAR® – Installation

No additional control panels and control equipment



Saving of cost by eliminating of panel

No need for additional pressure or differential pressure sensing for dry run protection

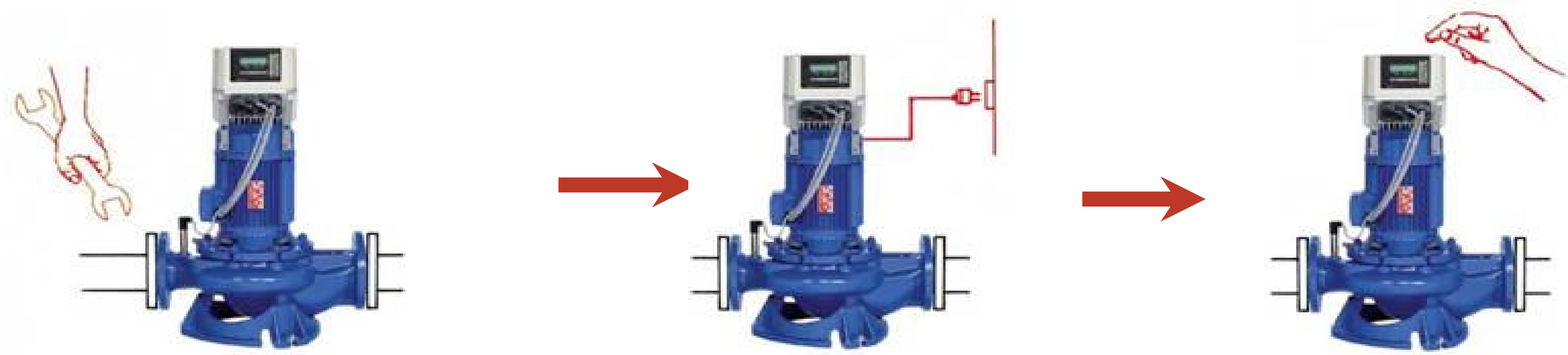
No need for flow metering because of indirect flow sensing, when controlling along a system curve

Simple handling at sight

Assembling

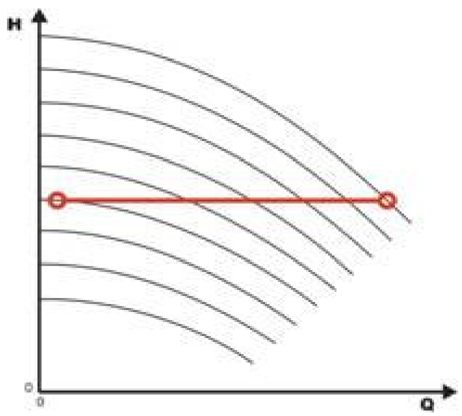
Connection to power supply

Adjusting of required pump duty and start up



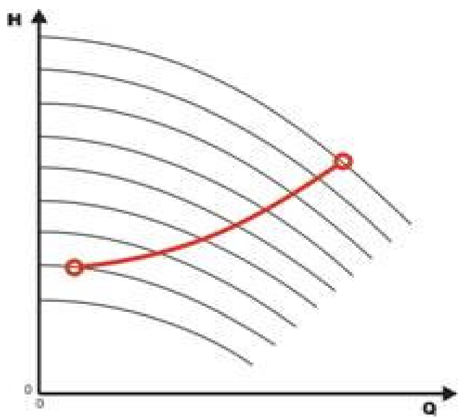
Selection of the optimum control system for various applications and their benefits

Applications – available control systems



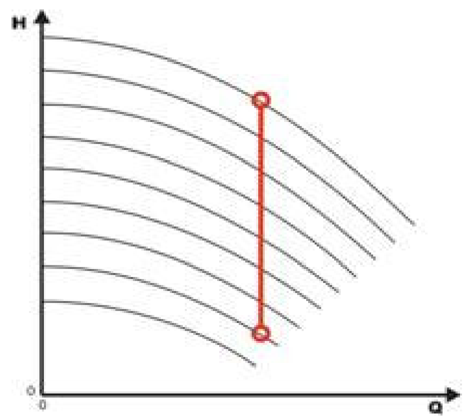
Control on constant pressure at variable flow

Water supply & boosters
Irrigation



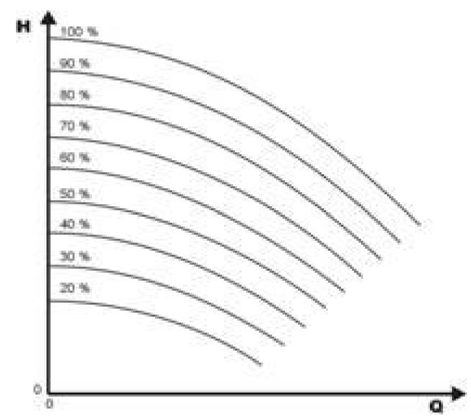
Control on constant differential pressure along the system curve

HVAC systems



Control on constant flow at variable pressure

Filter systems

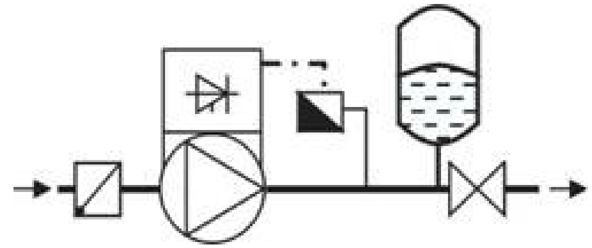


Speed adjustment 0-100% via central controller of the Building Management system (BMS)

Building services
HVAC
Process industry

+ other systems with control on constant level, constant temperature,…

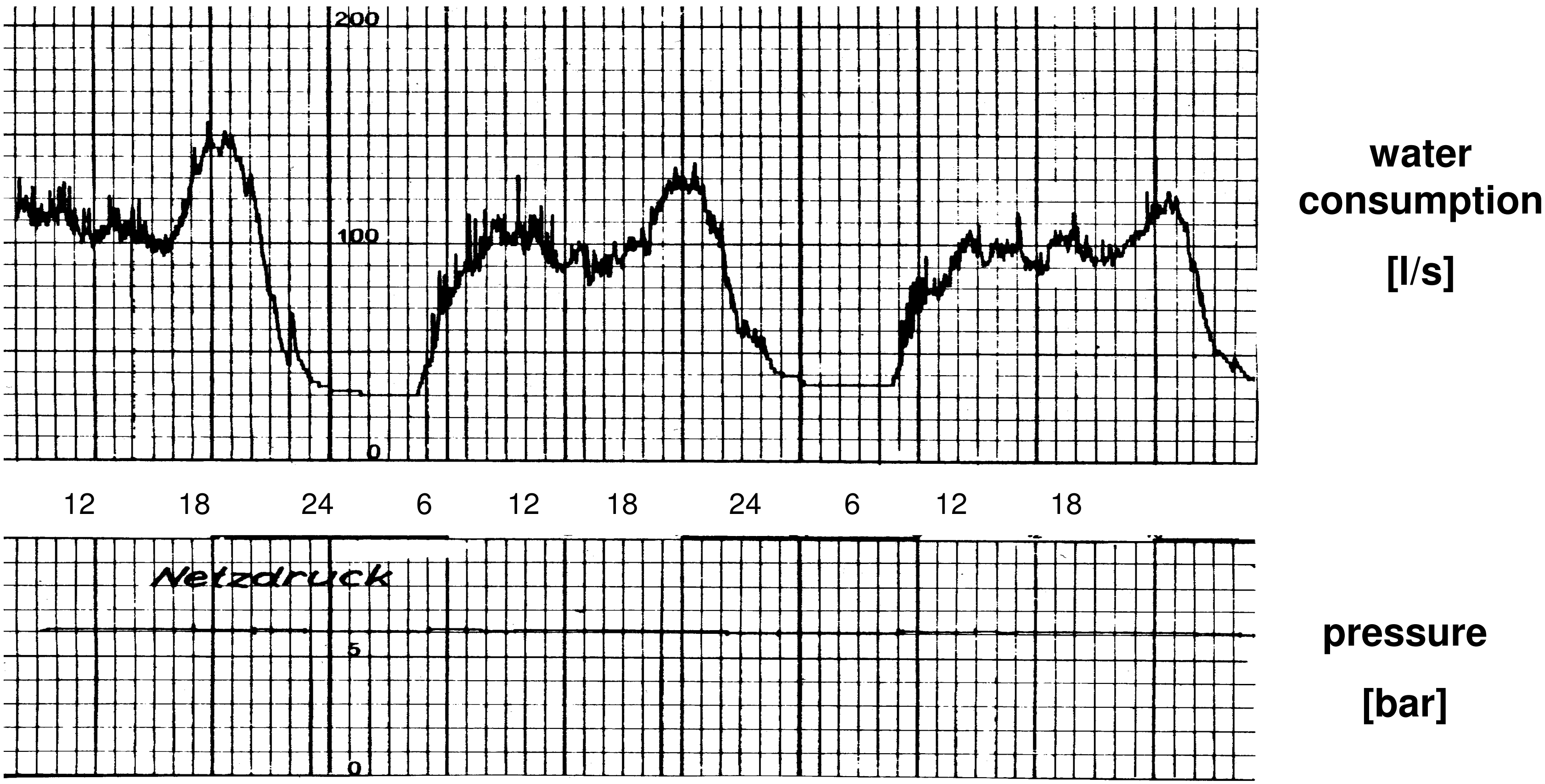
Water supply and Booster systems
Constant pressure control



During the day, the water consumption changes, but the pressure should always be constant. Traditionally this problem is very often solved by using fixed speed pumps controlled by pressure switches with the need for big pressure vessels. Such systems are still in use; however they are very inefficient and waste precious energy.

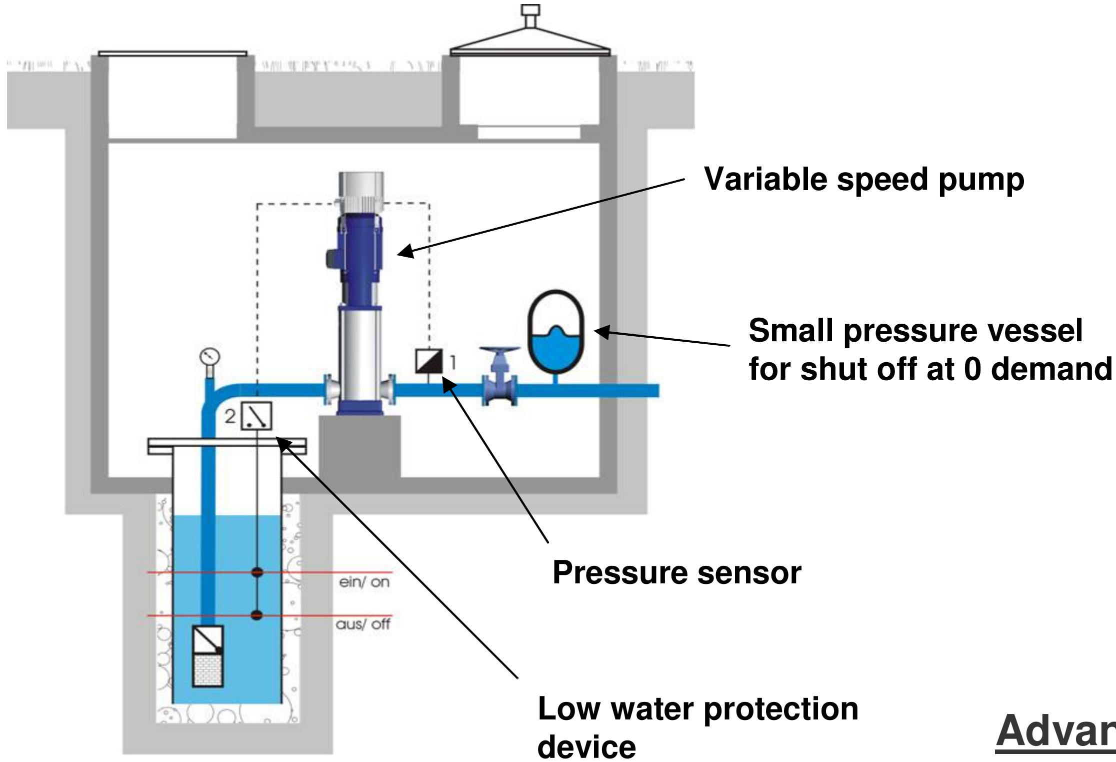
By using variable speed driven pumps and optimized Start/Stop of lag pumps in synchronous mode based on demand, energy savings of up to 40% can be realized. In this case the pumps only deliver the power, required by the system.

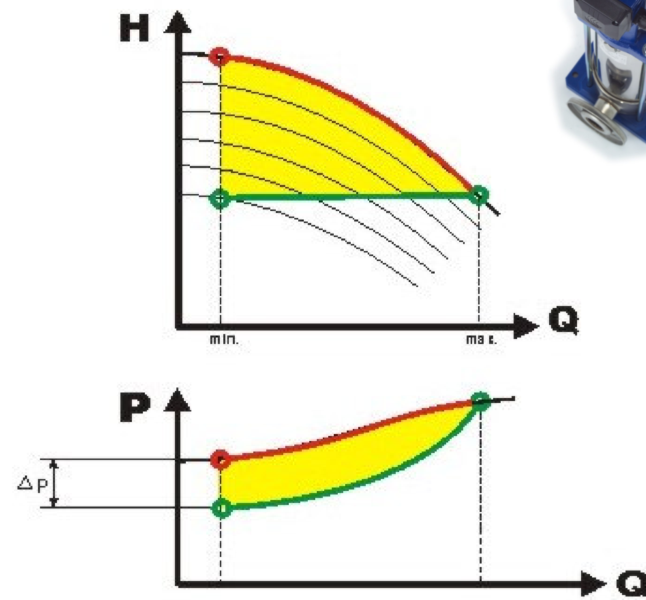
Overview about daily water consumption



Control on constant pressure

with automatic switch off at zero flow (HYDROVAR® Patent)





Application:
Drinking water and irrigation installations, where constant system pressure is required at fluctuating consumption and incoming pressure.

Advantages:
Constant system pressure at variable flow rates with energy savings compared with full speed applications.
Immediate shut off of the pump when there is no water consumption *(HYDROVAR® patent)*

Applications: water supply systems

Water supply Loicht

Water supply Klosterneuburg

Booster system Hotel Hilton in Vienna

Applications: Booster set / Water supply system

Booster set / Water supply
Hunter‘s Lodge, UK

Water supply
Absdorf, Austria

Applications: irrigation systems & water displays

Water fountains
Vienna, Austria

Greenhouse irrigation
Perth, Australia

HVAC systems

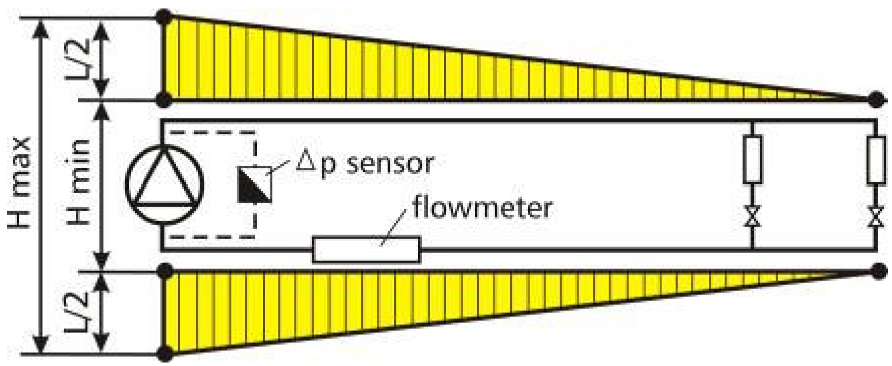
Differential pressure control along a system curve

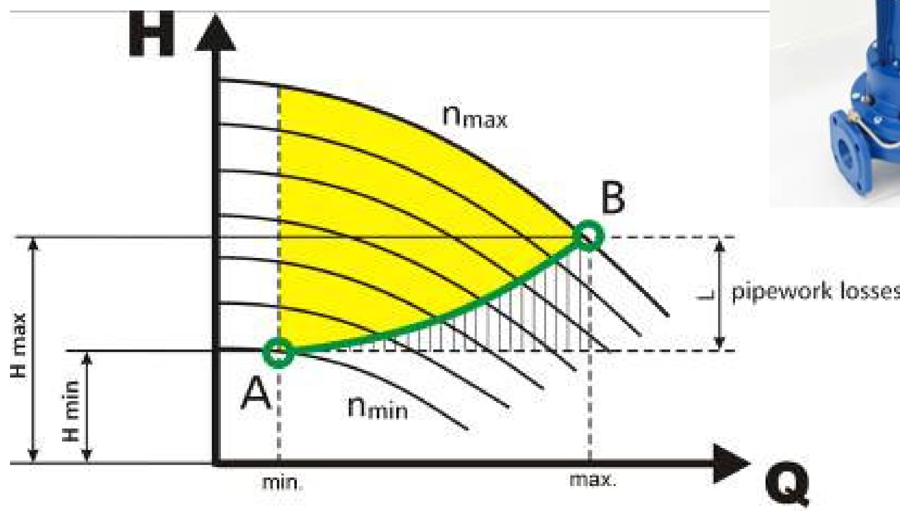
As the main part of the differential pressure and the resulting power for these applications is required to overcome the friction losses in the system (pressure losses in the pipework and in valves), additional energy savings can be realized by controlling the differential pressure following the system curve.

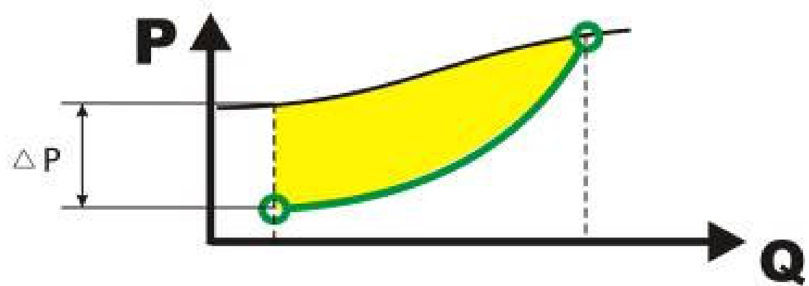
Energy saving potential up to 70%[1)] for HVAC systems!

1) Certified by TUEV Austria

HVAC system – control along system curve



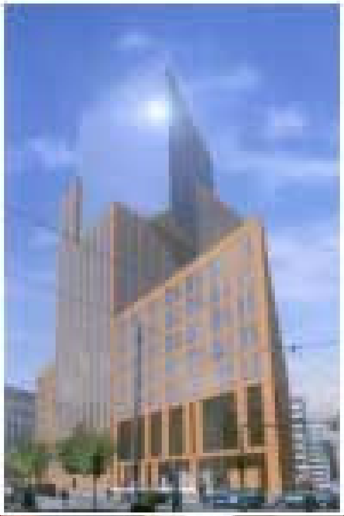




Application:
Closed or open loop circulation systems for heating or cooling (air conditioning) applications

Advantages:
Huge potential of energy saving compared to throttle or bypass control systems at partial load. Following the real system curve is also reducing the differential pressure in the system at on the valves which leads into reduced noise of the system.

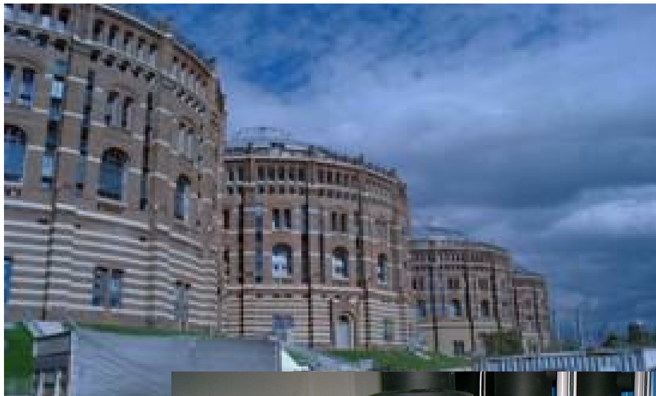
Applications: HVAC system – heating



Heating circulation pumps
Hotel Hilton, Vienna

Heating circulation pumps
Citytower, Vienna

Applications: HVAC system
(Gasometer buildings Vienna - air condition / heating)



The air conditioning system for the Gasometer complex (entertainment center with cinemas, shops, offices and apartments) is designed for total cooling power of 6.000.000 kWh per year.
There are a total 8 x 18.5 kW Hydrovar-equipped ITT pumps used for this site.

Air conditioning

Heating system

Applications: HVAC system – heating
(central district heating Vienna)

More than 450 circulating pumps with HYROVAR® control units from ITT are responsible for an efficient heat distribution of the district heating network of Vienna.

Applications: HVAC system – heating
(central district heating Vienna)

<u>Some data around the district heating network in Vienna:</u>

- In 1969 there was the start to install the district heating network in Vienna
- Today 2 big thermal waste treatment plants (the Spittelau plant has a throughput capacity of 250.000 tons of waster per year), together with another 8 heat producing stations, are producing in total heating power of 2.800MW – also the waste heat of 2 caloric thermal power plants is used to heat up the water in the network
- About 5.800 office or public buildings (schools, hospitals, museums…) and further 290.000 apartments are supplied with heat also for warming up the potable water
- Length of heating pipework is more than 1100km and is installed underground between 1 and 15m deep
- About 76.300m³ of heated water with temperature up to 160℃ are circulating in the pipework
- All around Vienna there are a few hundreds of stations with heat exchangers to supply the various regions in the city
- More than 450 circulating pumps in the power range from 1,5 up to 22kW equipped with HYROVAR® control units from ITT are installed in the secondary loop of the heating system and are responsible for an efficient heat distribution in the various regions of the city – all pumps are remotely controlled via MODBUS-interface

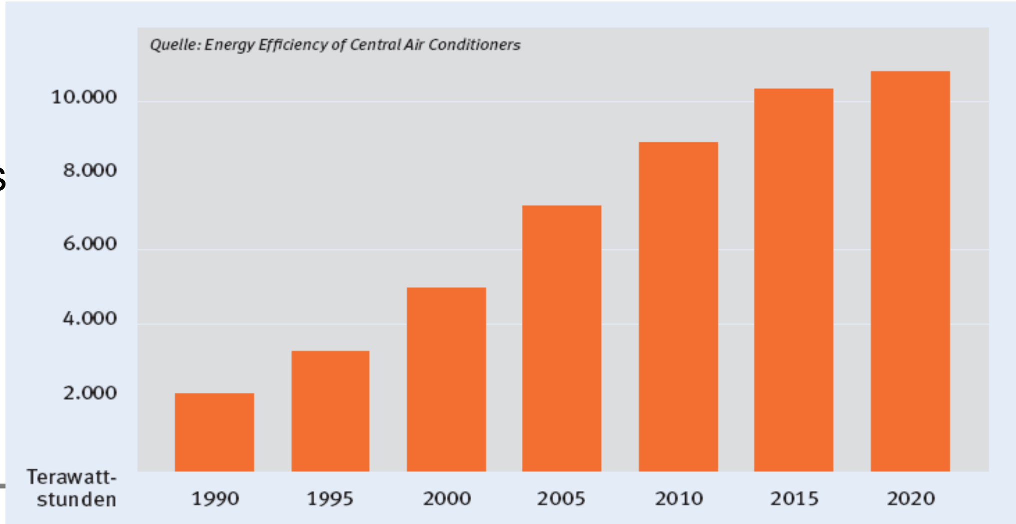
Applications: HVAC system – cooling
(district cooling Vienna)

In September 2009 the first part of the planned network for district cooling in Vienna has been put into operation. Similar systems are already in operation in Paris, Stockholm, Helsinki, Amsterdam and Barcelona.

With an output power of about 17MW (equal to 115.000 refrigerators) the network is supplying the largest hospital in Vienna (AKH) together with a university, the head office of the Austrian broadcast and some other public buildings in the 3rd district of the city.
The construction time has been 10 months with an investment of about 10M€.
Till 2020 there is the plan to expand the total cooling network up to 200MW.

In general the need for cooling energy is rapidly increasing within the last years and will reach a level of 10.000TWh in 2020 for EU15 countries

For 2010 the required cooling power for Vienna has been calculated with about 240MW



Applications: HVAC system – cooling
(district cooling Vienna)

Main advantages of central district cooling systems:

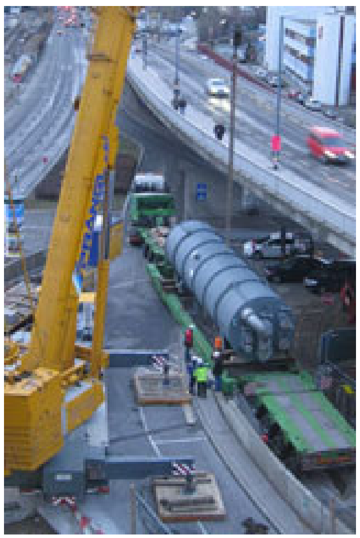
- The main part for producing the cooling water are adsorption chillers. They are driven by hot water and therefore compared to electrically powered chillers, they have very low electrical power requirements.
  ➔ Instead of electric power, the source of energy is thermal heat, produced by burning waste and therefore only needs 1/10 of the fossil fuel resources of conventional air conditioning systems
  ➔ This offers a big impact for reducing the CO_2 emission level for cooling systems

- No need for large cooling tanks on top of buildings, no noise pollution – no need for expensive maintenance of cooling aggregates
  ➔ offers less operating costs for the customers - payback within a few years

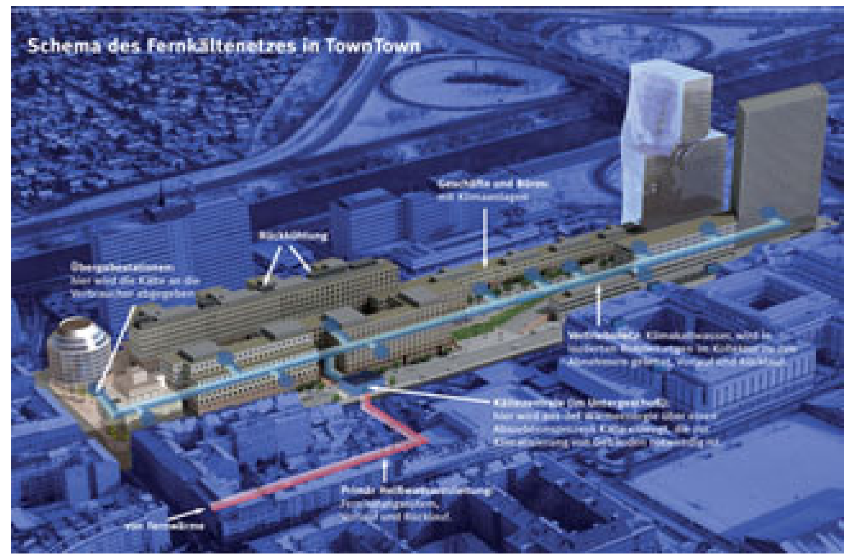
- Adsorption refrigeration systems only use pure water in the pipework – the temperature of the cooling water in the main distribution pipework is in the range of 6℃-16℃ - no need of any environmental harmful additives

- Security of supply for cooling energy due to several production sites

Applications: HVAC system – cooling

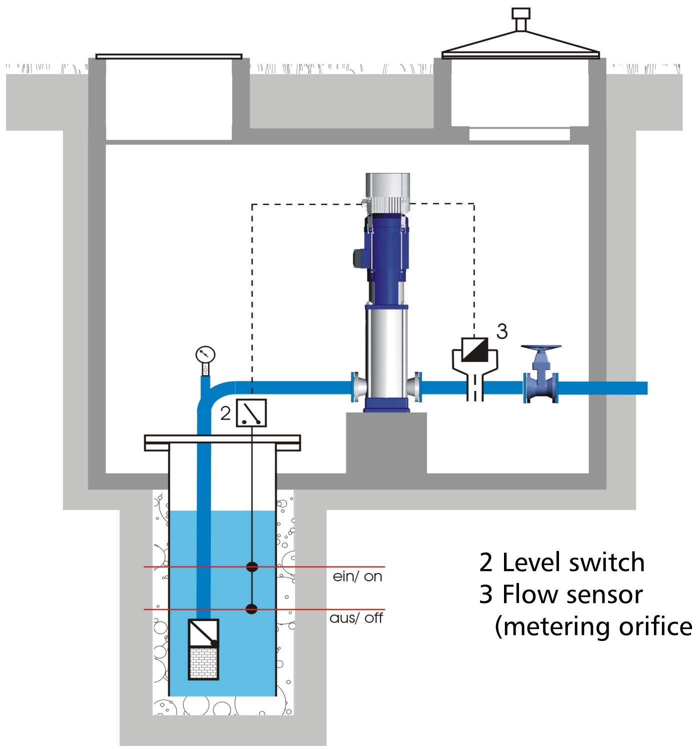


Construction work in thermal waste treatment plant Spittelau

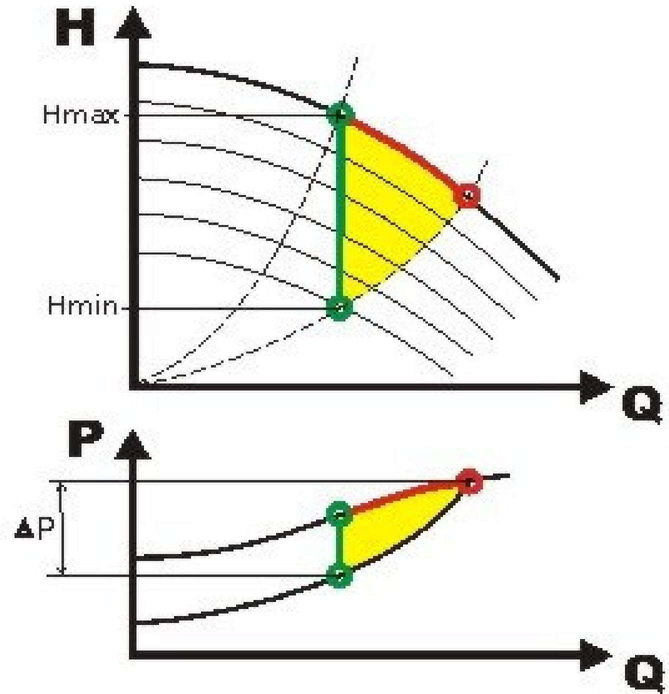


TownTown Vienna –
First district connected to district cooling network

Control on constant flow



2 Level switch
3 Flow sensor
(metering orifice plate or IDM)



Application:

- All filter system versions for constant filter loads, regardless to different pressure and contamination levels
- Filling of high level tanks

Advantages:

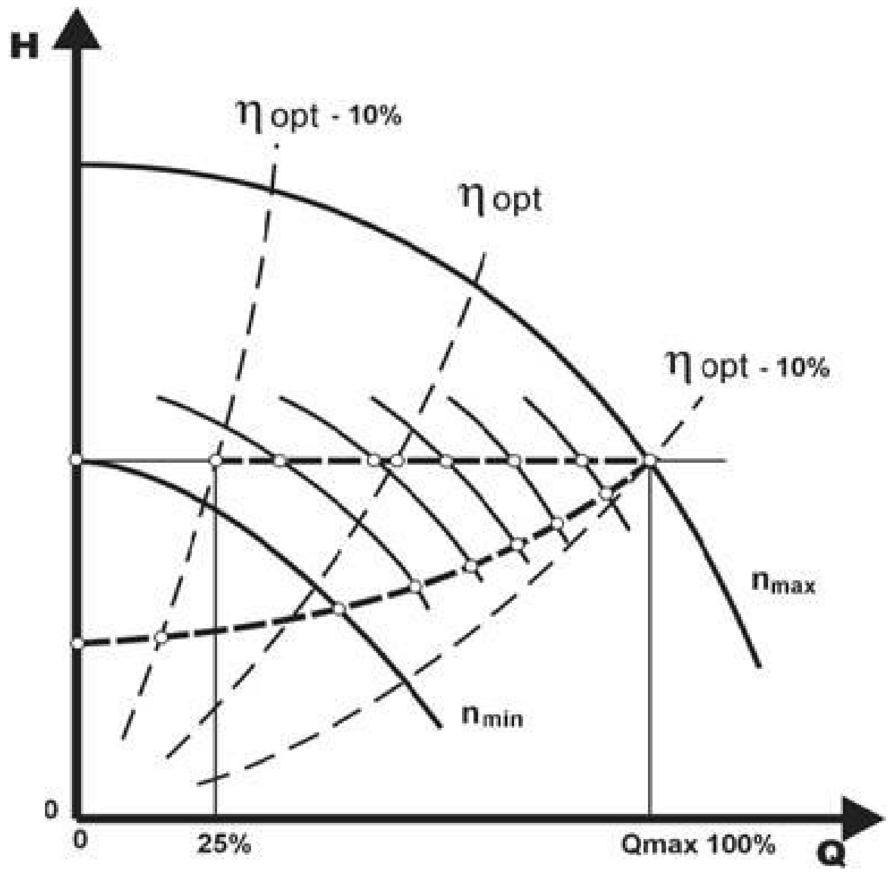
- Operation of the filter system at highest efficiency all the time
- Prevention of excess flow rates and cavitation
- Energy savings compared to throttle valve controls up to 50%.

Optimization of system efficiency by selecting the right pump

Differences for various control systems

Correct selection of speed controlled pumps

(Constant pressure or differential pressure controlled systems)



For selection of the right pump for variable speed controlled systems, the whole working range of the pump has to be taken into consideration.

As the pump is mostly working in partial load, the best efficiency point also should no be at the maximum duty point.

The selection shall be that the maximum duty point is right of the best efficiency point within an acceptable range (e.g. ηmax –10 %).

This guarantees that the pump is working at high efficiency within a wide range in partial load.

When very low load conditions over longer periods are possible, the system should be split into 2 pumps or a jockey pump shall be used.

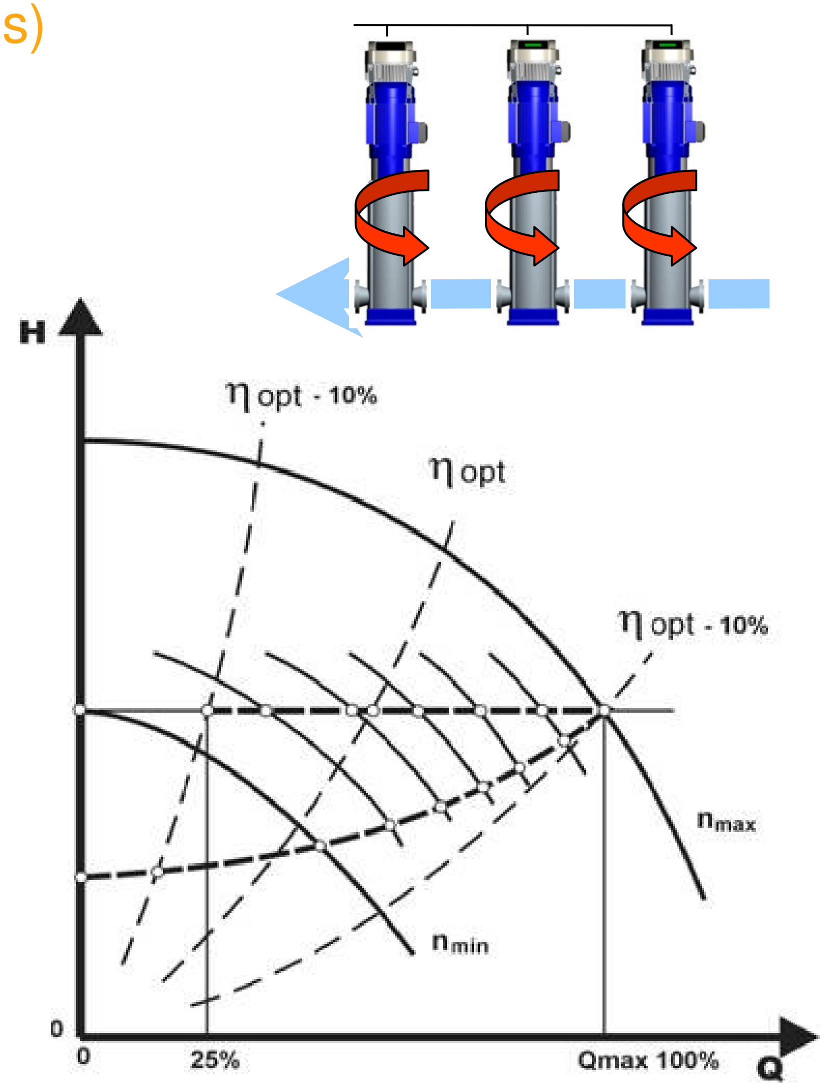
Synchronous mode for multi-pump applications

(Improved system efficiency for HVAC systems)

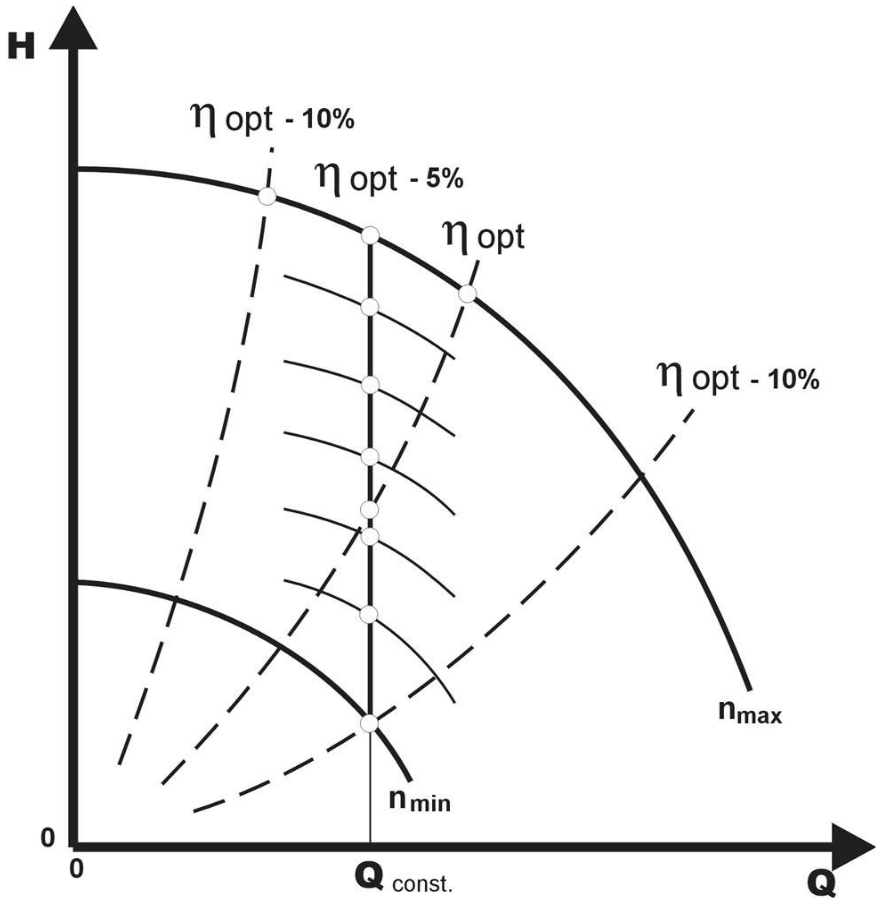
For multi pump systems in HVAC applications, the synchronous mode should be selected to further improve system efficiency. This means all running pumps shall run at the same speed.

When operating at this mode in partial load, both pumps are operating closer to the best efficiency point than compared to the other mode where one pump is running full speed (at the right end of the pump curve) and the other one is working in variable speed mode (maybe on the very left part of the pump curve) to meet system requirements.

➔ **additional energy savings of about 10% are possible by selecting the synchronous operation mode.**



Correct selection of speed controlled pumps
(Constant flow controlled systems)



For selection of the right pump for variable speed controlled systems, the whole working range of the pump has to be taken into consideration.
As the pump is mostly working in partial load, the best efficiency point also should no be at the maximum duty point.

The selection shall be that the maximum duty point is left of the best efficiency point within an acceptable range (e.g. ηmax –5 %).
This guarantees that the pump is working at high efficiency within a wide range in partial load.

Retrofitting of integrated variable speed drives on existing pumps

Application examples

Now everyone knows about the advantages of variable speed pumps in systems with varying load conditions -

➔ **Why not improving energy efficiency of existing pump systems by retrofitting variable speed drives?**

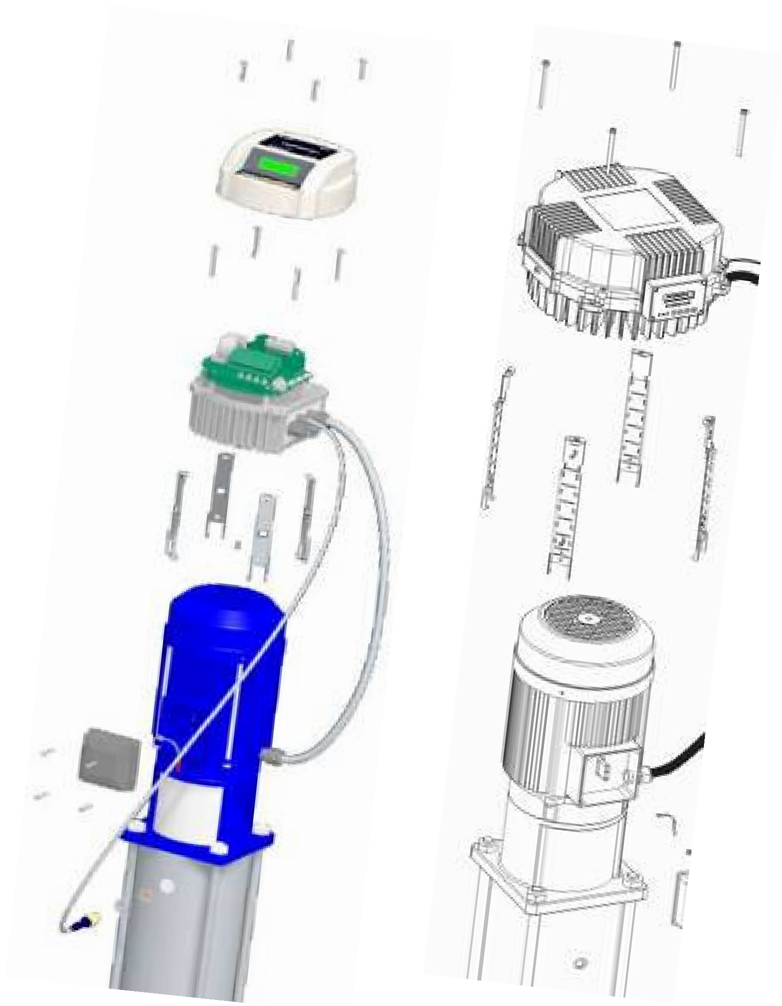
HYDROVAR®

Why retrofitting variable speed drives on existing pumps

- **Many pumps are over-dimensioned and the higher energy consumption will mostly be destroyed in control valves**
- **Existing pumps and motors (when already high efficient types) don't have to be changed, which reduces investment costs**
- **No hydraulic adaptations required**
- **Only small electrical work required**
- **Increasing the performance of the installed hydraulics by running at higher speeds, when allowed. In this case the motor has to be changed to the next power size together with a VFD.**

➔ **In most of the projects the payback time is within 1-2 years**
(Depending on system layout and power range)

HYDROVAR® – Installation



Simple mounting

Thanks to the very simple mounting method by using the 4 mounting clamps, a very fast and easy mounting
is possible also for existing pump stations (retrofit market)!

The Hydrovar® can be mounted and installed on each standard three-phase asynchronous motor!

Realized Retrofit-projects: 2-pump booster set

Original:

Afterwards:

Realized Retrofit-projects: Hot water circulation

Original:

Afterwards:

Realised Retrofit-projects: Hot water circulation

Final project:

Realised Retrofit-projects: Twin circulators

Before:

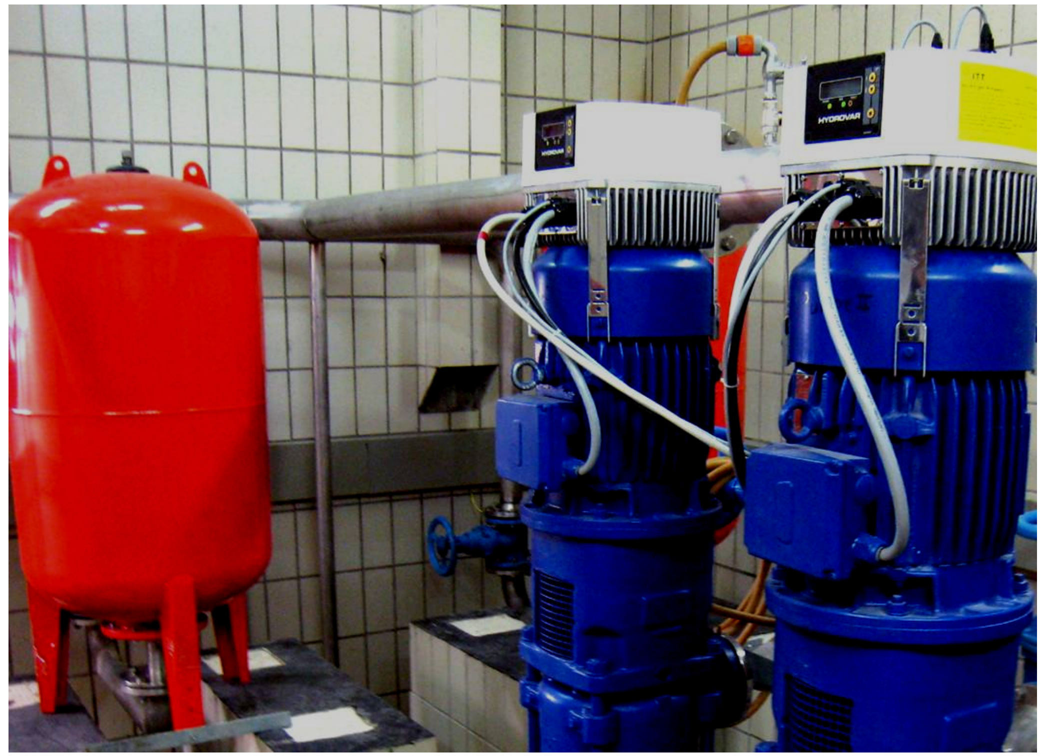
Afterwards:

Practical examples for energy efficient system design and resulting reduction of LCC

Realized energy saving projects in water supply and HVAC systems

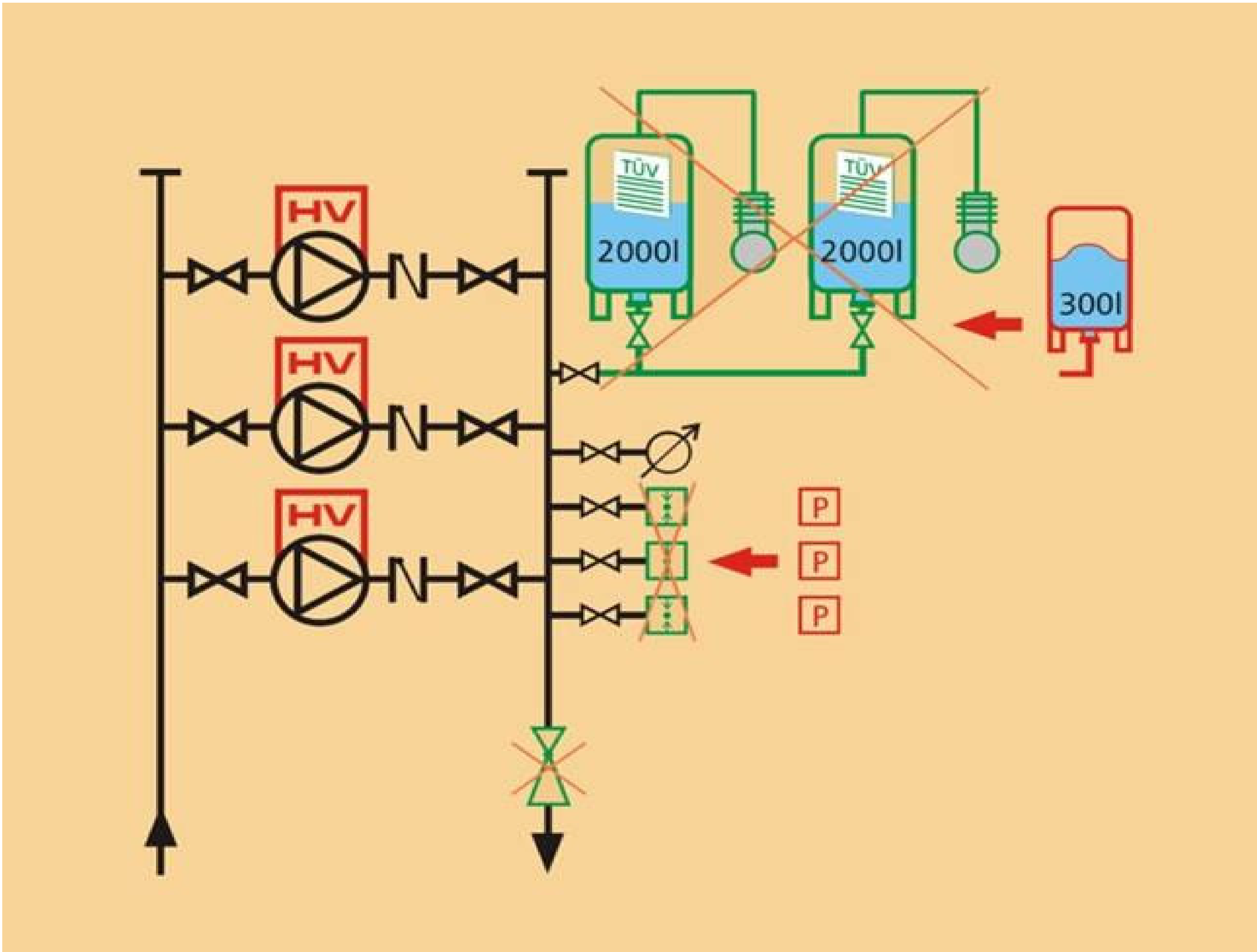
Practical example: **Water supply with daily consumption of 1250m³**

Before



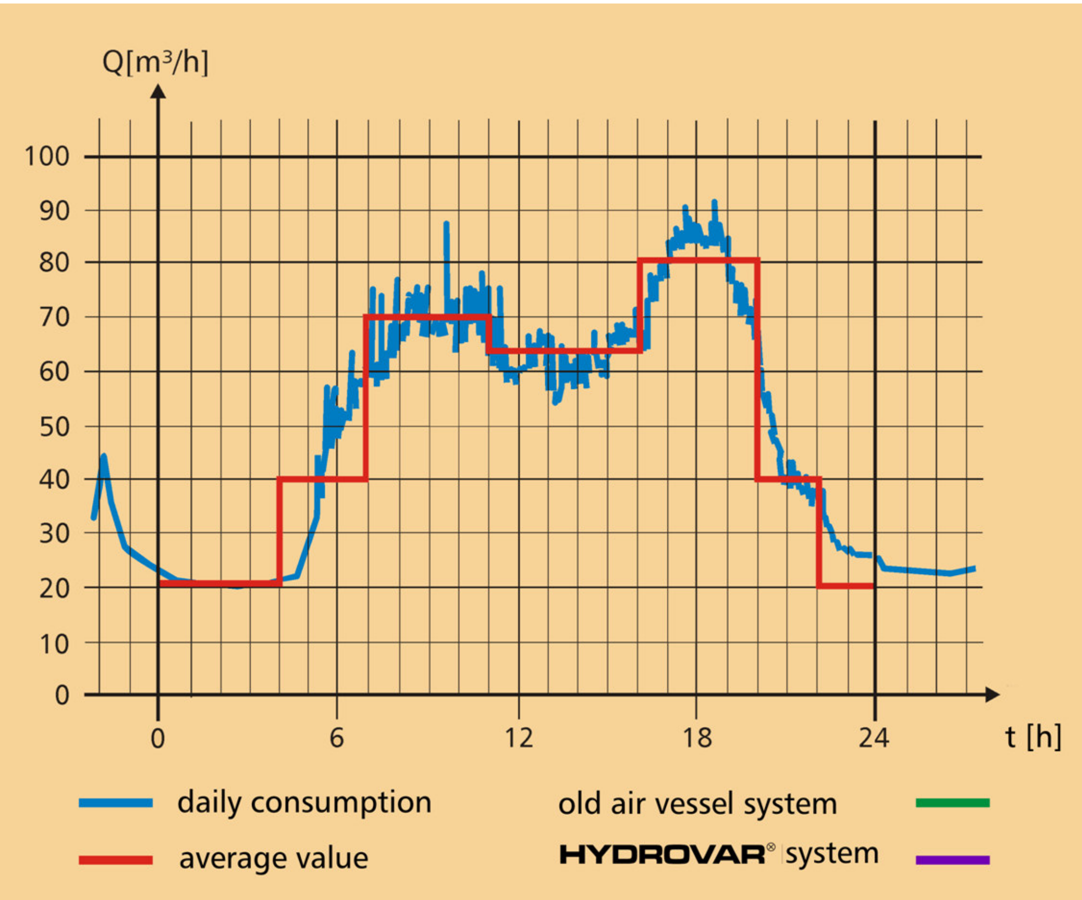
Afterwards

Reduction of space:

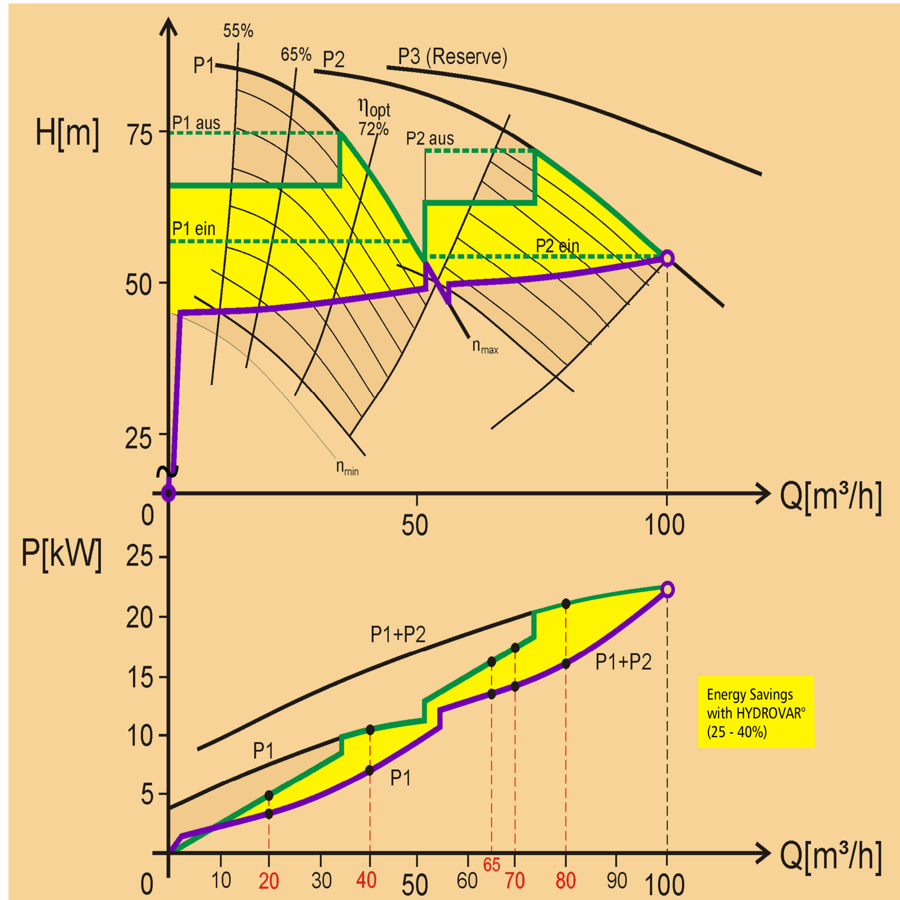


Practical example: **Water supply with daily consumption of 1250m³**

Daily water consumption



Comparison energy consumed



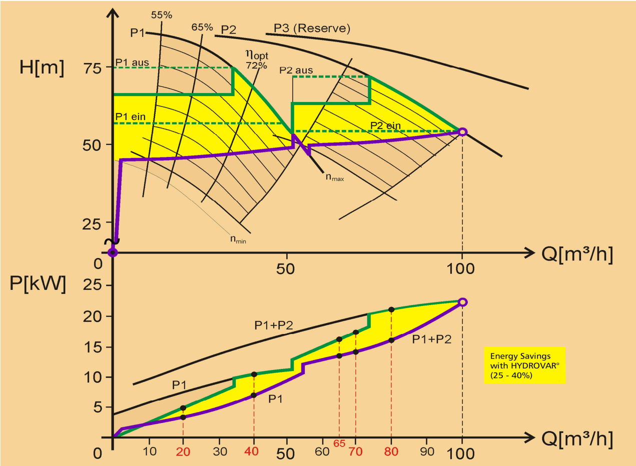
Practical example:

Water station with daily consumption of 1250m³

<u>Calculation of energy savings:</u>

2 pumps 11kW nominal power each

➔ Energy savings of about 24% has been realized

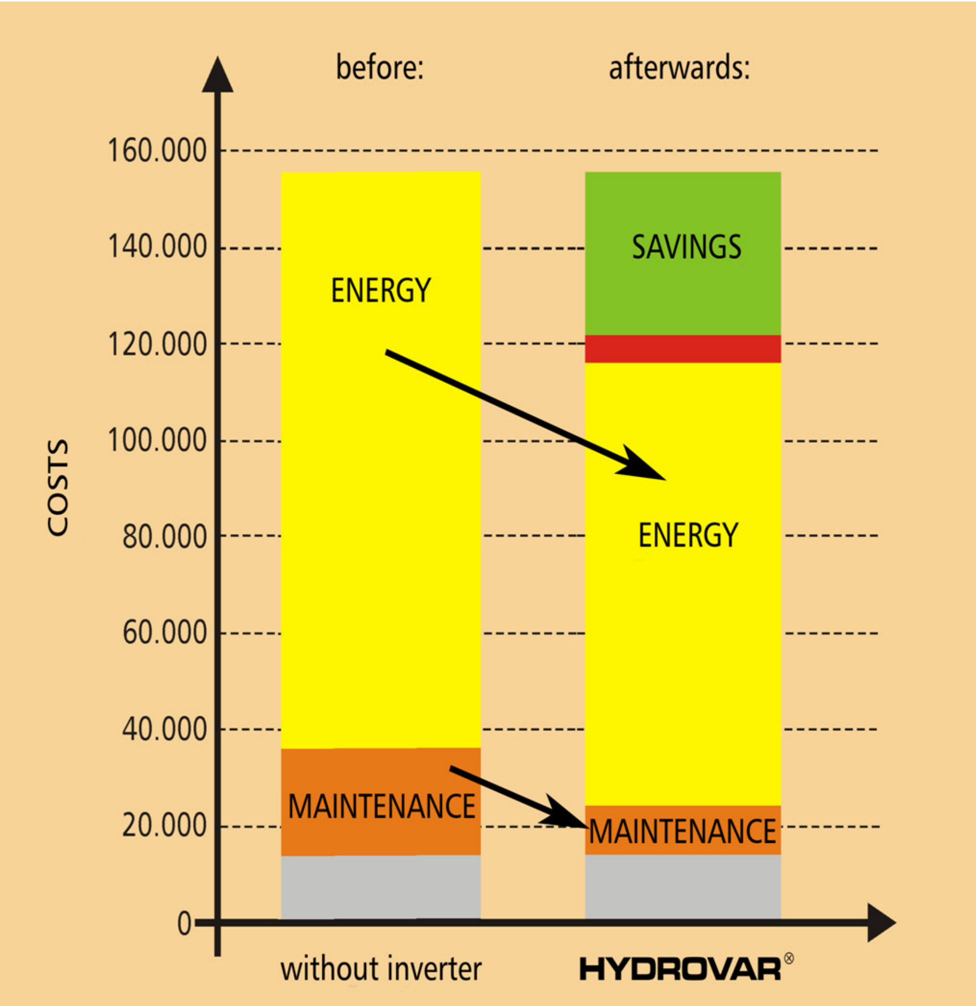


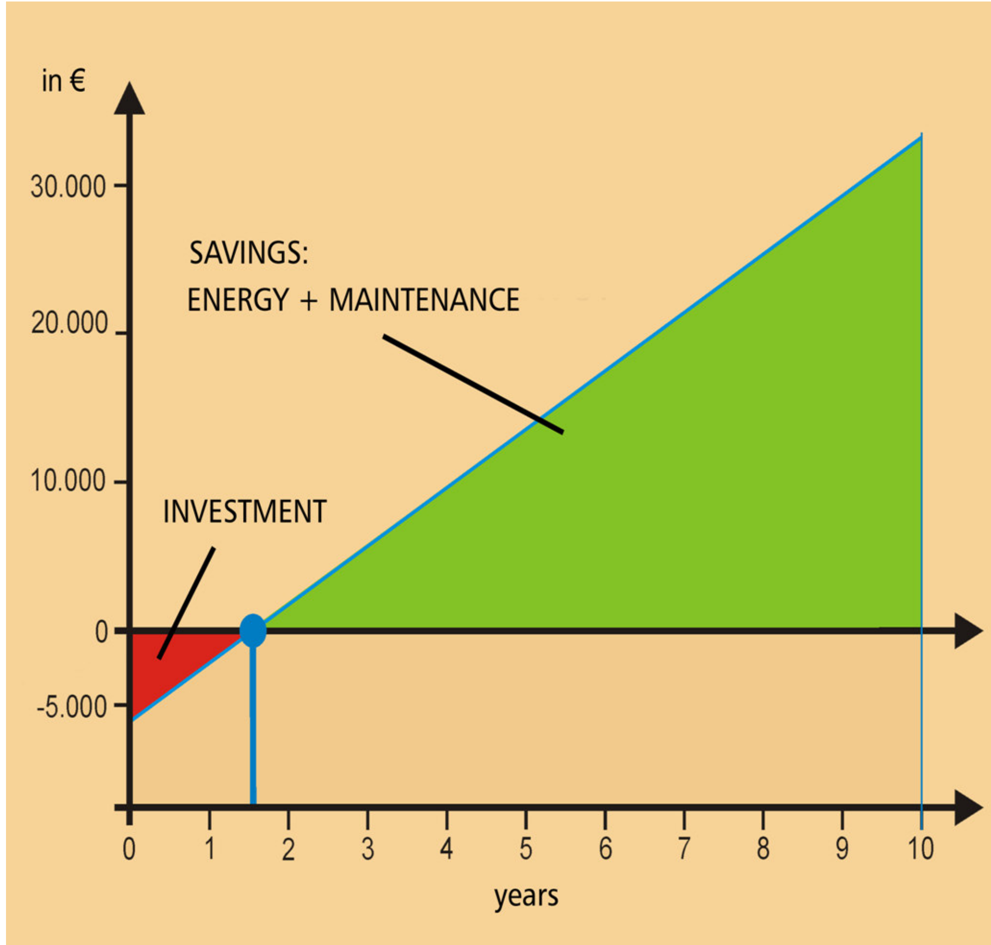
Water consumption Average	Energy consumption			Period	Savings
	Full speed	Variable speed	Difference		
at 20 m³/h	5,0 kW	3,5 kW	1,5 kW	6h	**9,0 kWh**
at 40 m³/h	10,5 kW	7,0 kW	3,5 kW	5h	**17,5 kWh**
at 65 m³/h	16,0 kW	13,0 kW	3,0 kW	5h	**15,0 kWh**
at 70 m³/h	17,0 kW	14,0 kW	3,0 kW	4h	**12,0 kWh**
at 80 m³/h	21,5 kW	16,0 kW	5,5 kW	4h	**22,0 kWh**
				Savings per day:	**75,5 kWh**
				Yearly savings:	**27.557,5 kWh**

Because of the price for energy of 0,10 EURO/kWh, a reduction of the costs for energy of about 2.800,-- EURO / year has been realized!

Practical example: **Water supply with daily consumption of 1250m³**

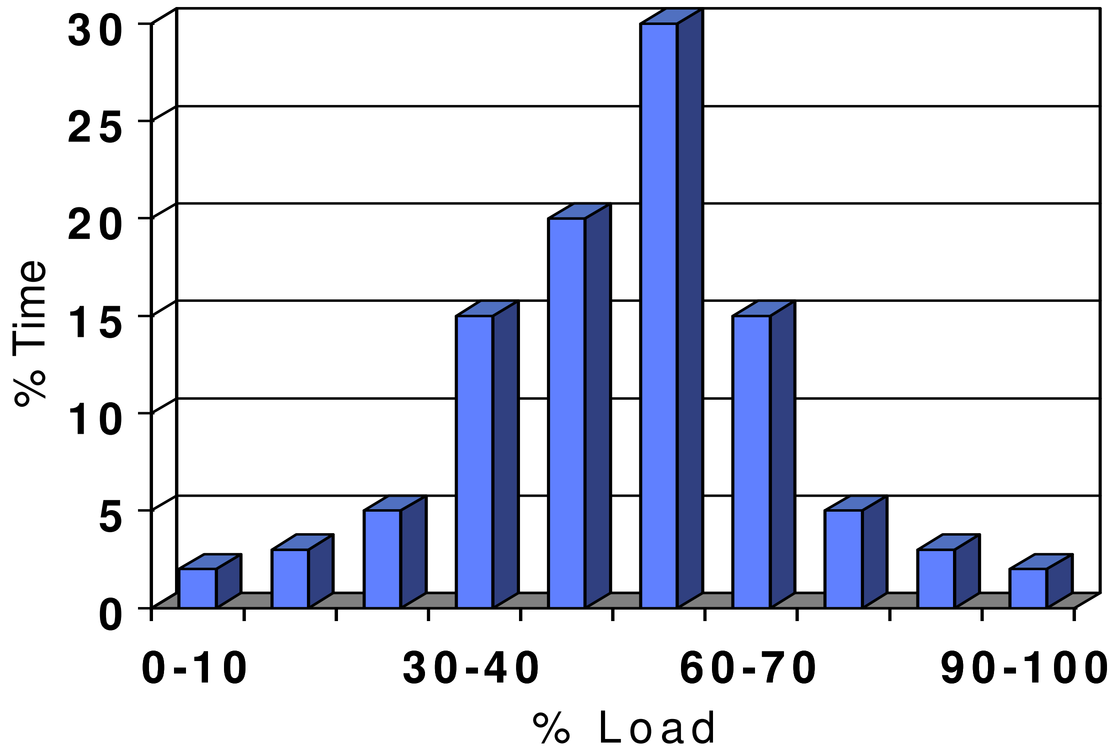
LCC-Calculation over a 10 years period & payback time





Practical example: **Heating, Cooling, Air Conditioning (HVAC)**

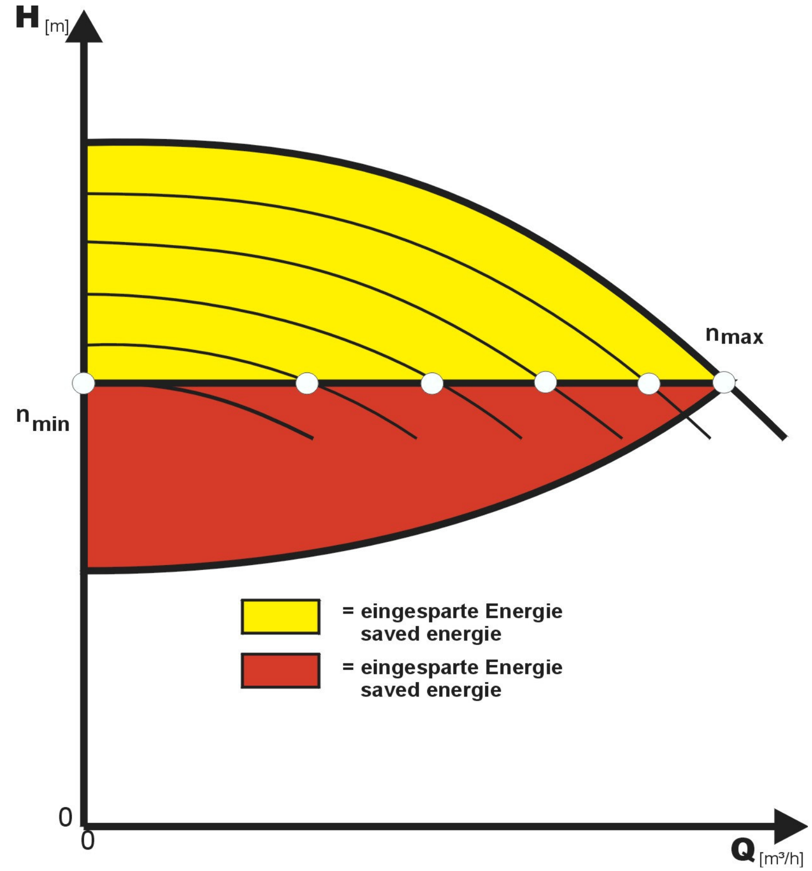
Many circulation systems in the HVAC market are realized by using constant speed pumps, even peak demand is required only for a few hours or days within the year.



Typical load profile of HVAC systems over a heating/cooling season

Practical example: Heating, Cooling, Air Conditioning (HVAC)

For many HVAC applications, variable frequency drive (VFD) speed controllers are a good choice. They offer precise flow control, quick response, soft-start capabilities and high power factors, and are efficient over a wide range of speeds.

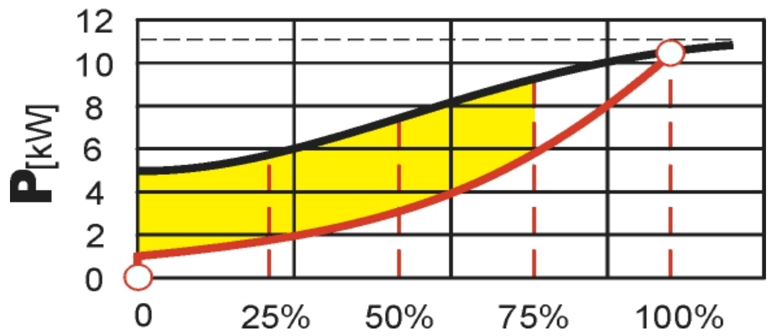


The more the required flow rate of the system is varying, the higher are the achievable energy savings by using variable speed driven pumps together with intelligent controllers.

Following the system curve by using speed controlled pumps, shown in the left graph, will even increase the potential for energy savings of the system.
NOTE: A pump running at 80% speed only use 50 %of the energy compared to a full speed pump

Practical example: HVAC system

Circulation pump with nominal power of 11kW for heating application (40% of the time out of operation)



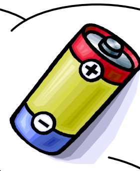
Capacity Average	Energy consumption			Period	Savings
	Full speed	Variable speed	Difference		
at 25 %	5,8 kW	1,8 kW	4,0 kW	1314 h (15%)	5256 kWh
at 50 %	7,6 kW	3,2 kW	4,4 kW	2190 h (25%)	9636 kWh
at 75 %	9,2 kW	5,7 kW	3,5 kW	876 h (10%)	3066 kWh
at 100 %	10,6 kW	11,0 kW	- 0,4 kW	876 h (10%)	-350 kWh
				Yearly savings:	17.608 kWh

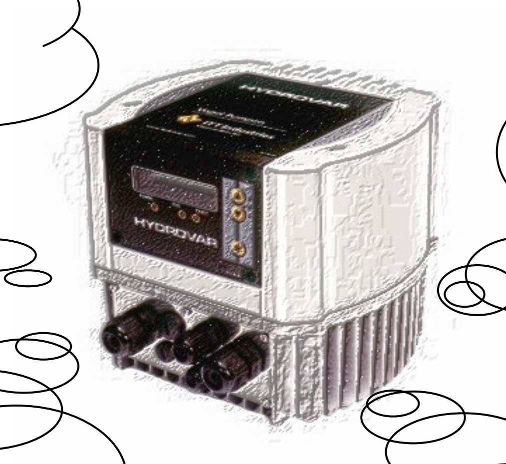
Based on the price for energy of 0,10 EURO/kWh, a reduction of the costs for energy of about 1.800,-- EURO / year has been realized which at the end results in a payback time of 1 to 2 heating seasons!

SUMMARY

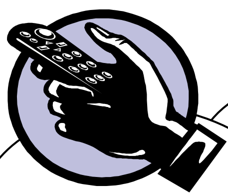
Advantages to use HYDROVAR® on pumps

Significant Energy Savings

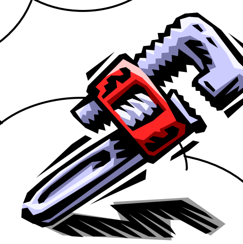




- No Star/Delta starter
- No extra valves required
- cos phi ~ 1



- built in controller to manage the pump system
- easy bonding to BMS-system
- step less speed control



- Decrease Mechanical stress
- Avoid water hammers
- Reduce Start and Stops
- Reduce Starting current

ITT

THANK YOU
for your attention

Johann Kneissl
Product Manager – Monitoring & Controls
R&CW EMEA

ITT Austria GmbH
A 2000 Stockerau, Austria

www.itt.com
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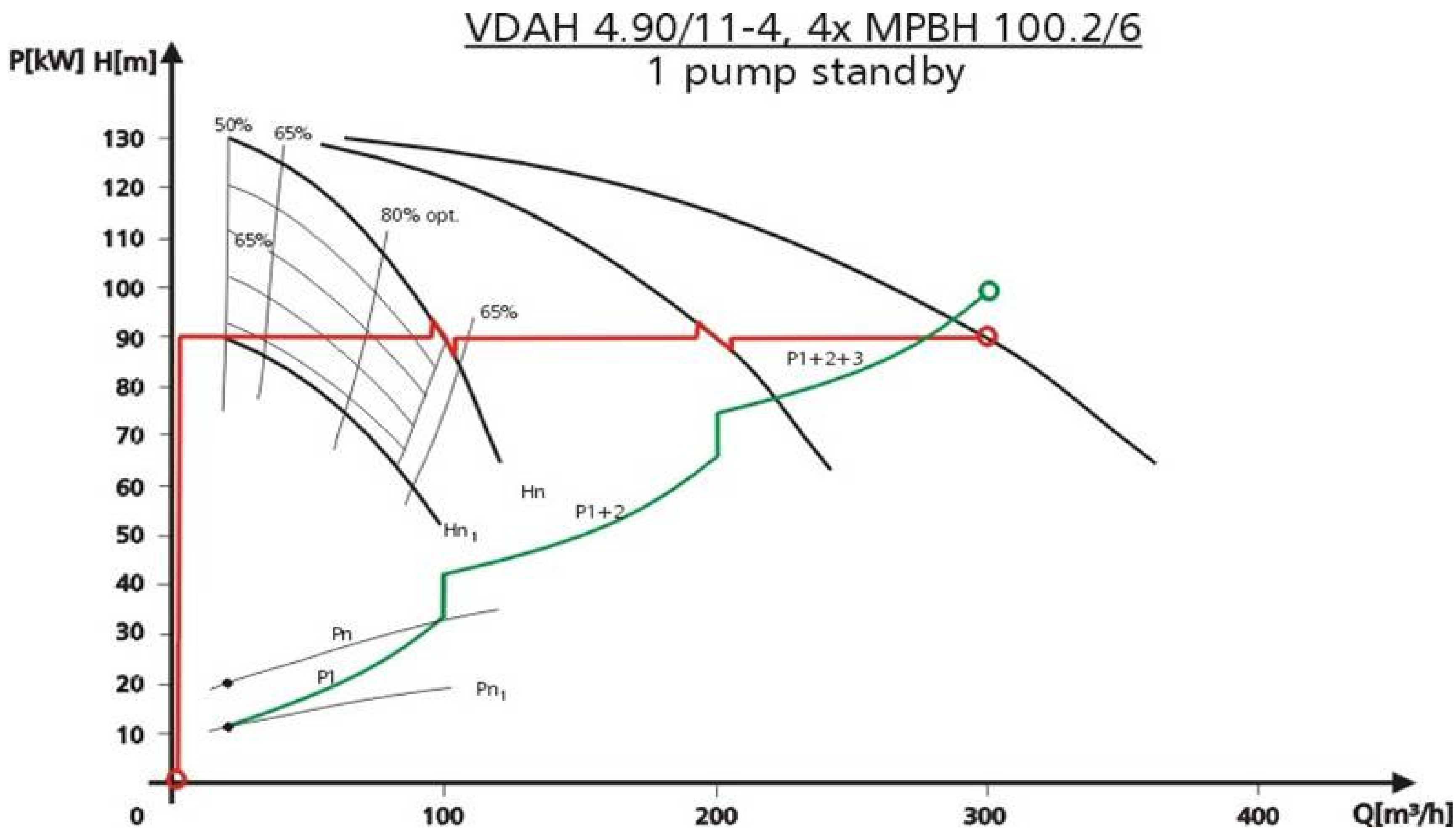
Engineered for life

Installed Speed Controlled Pump Stations

Booster package unit – VDAH 4.90/11-4

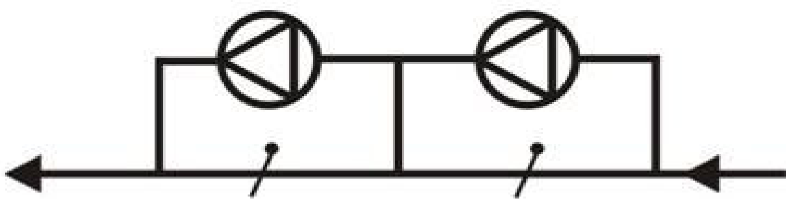
Booster package unit – VDAH 4.90/11-4

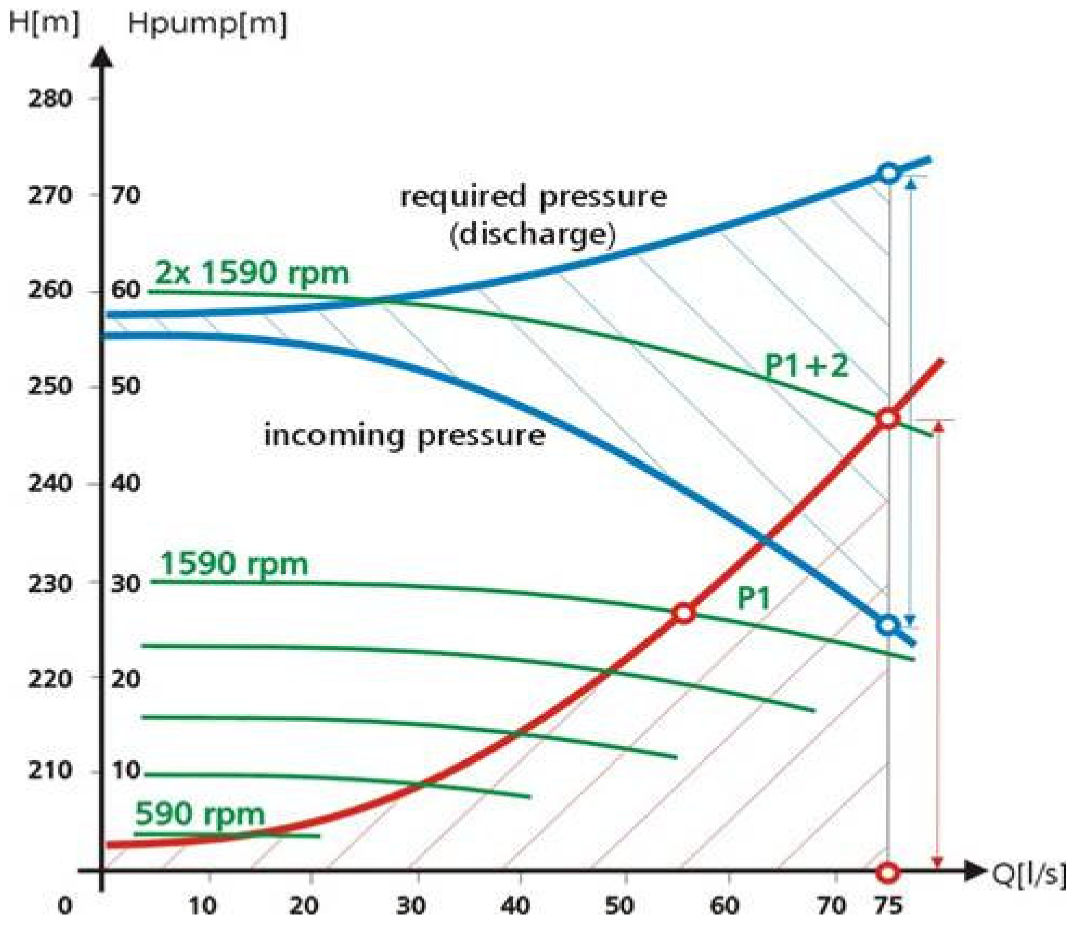


Water supply system - WVA Brunn am Gebirge

Water supply system - WVA Brunn am Gebirge

Hydraulic schema





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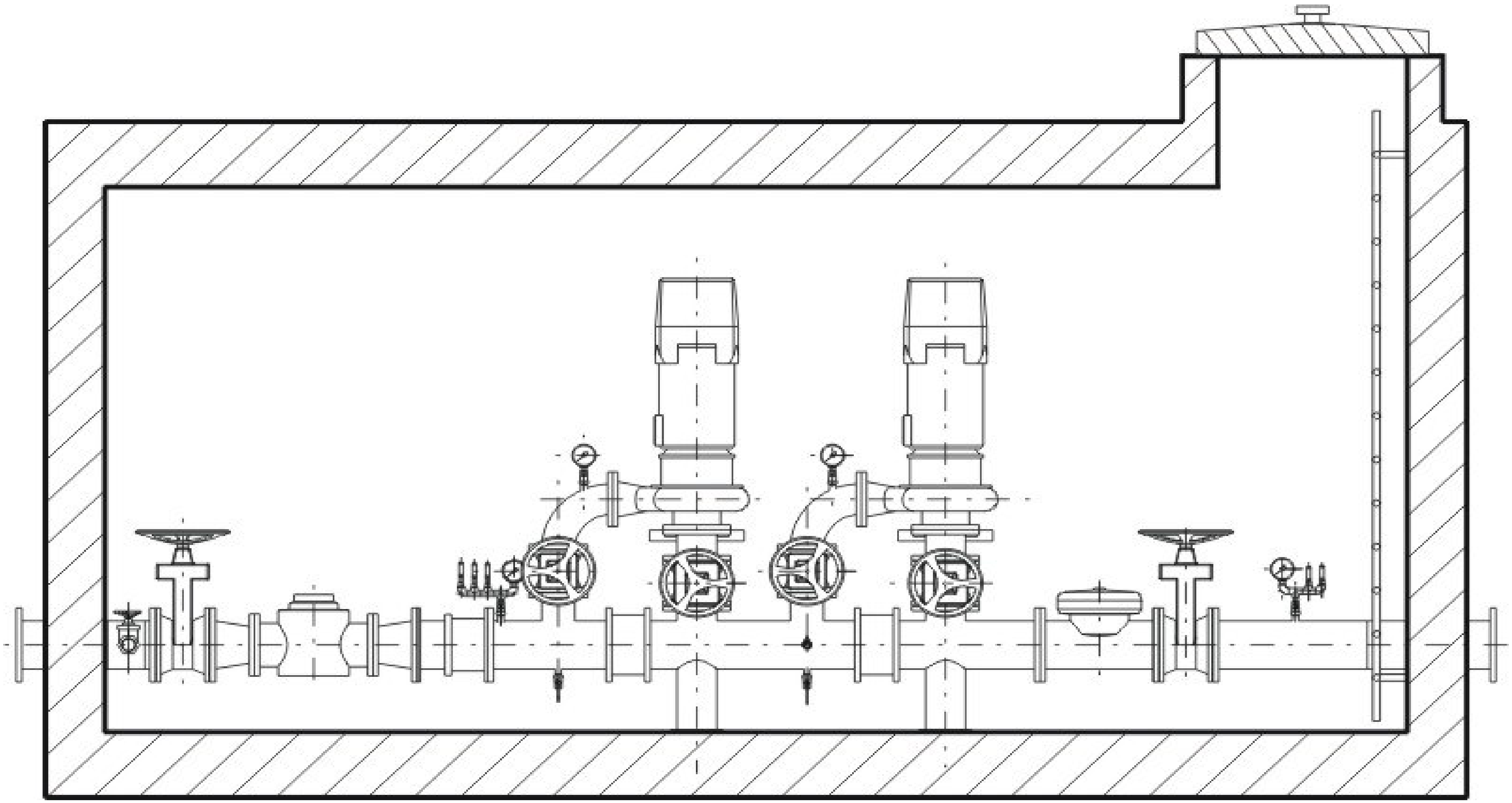
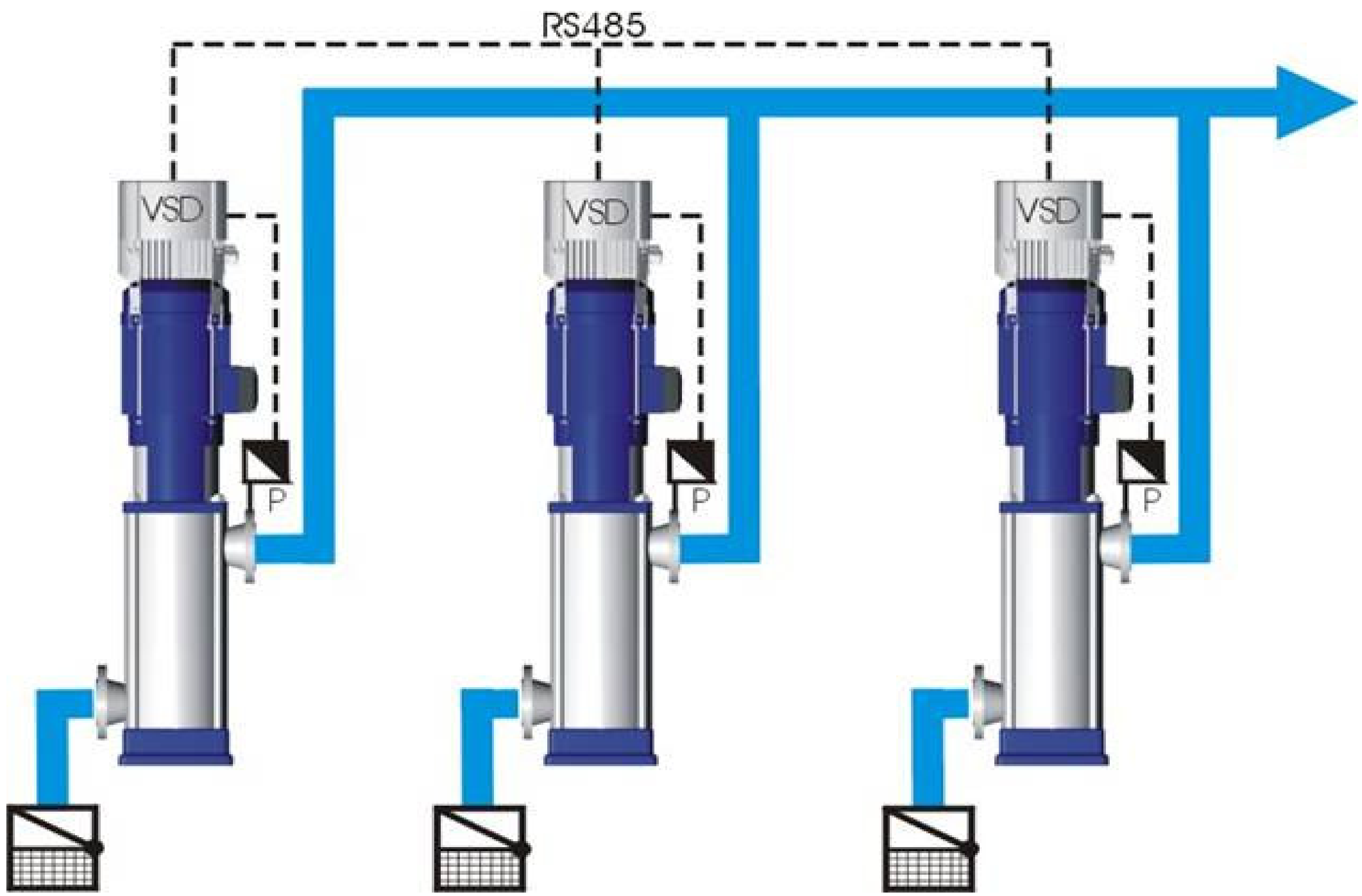
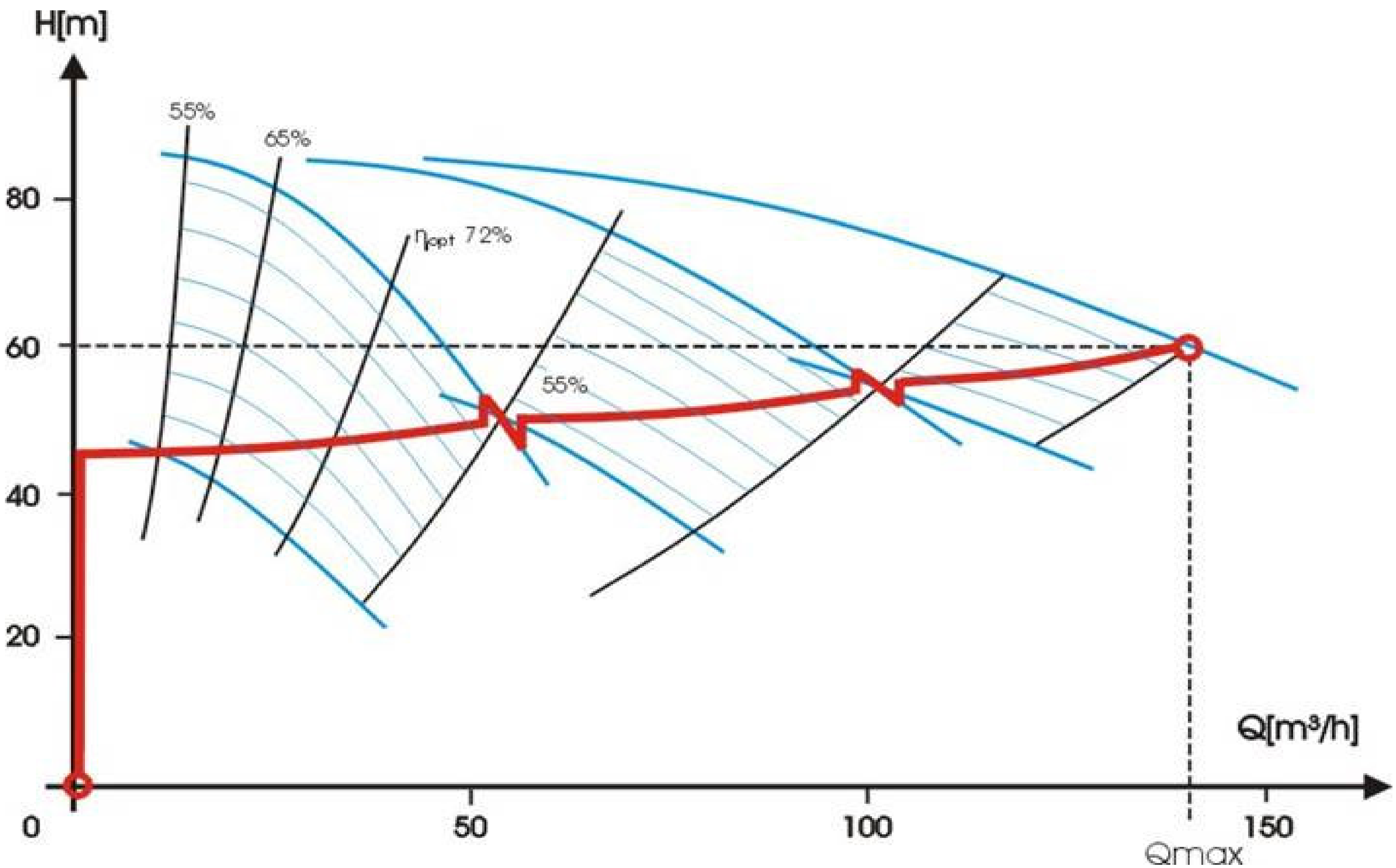


Water supply system - WVA Absdorf



Water supply system - WVA Absdorf



Water supply system - WVA Absdorf

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