Smart Controlling in Hydraulic Systems

GRUNDFOS South East Europe Kft.
Geyer Szilveszter
+36-30-212-1282
szgeyer@grundfos.com

be
think
innovate

GRUNDFOS

What does make water moving In a hydraulic system (HVAC)?

A. Natural water flow in heating system due to pressure/temperature difference

B. By pumping solutions (usually centrifugal pumps)

Why pumps are used?

A. Low temperatures and Dt are used in heating systems -> insufficient pressure difference

B. Low temperature heating systems and high temperature cooling systems

C. Large hydraulic networks represents great challanges.

Do we need to control the pump?
Do we use same flow all the time?

A. Some applications needs constant flows, therefore, a basic control (ON-OFF) is enough. Easy to ballance.

B. Sometimes constant flow equipments works in cascade, each system should have its constant flowrate – ballancing!

C. Most of the secondary systems are working with variable flow, due to variable needs.

How can we control the flow in a system? (pipe sizing is not enough)

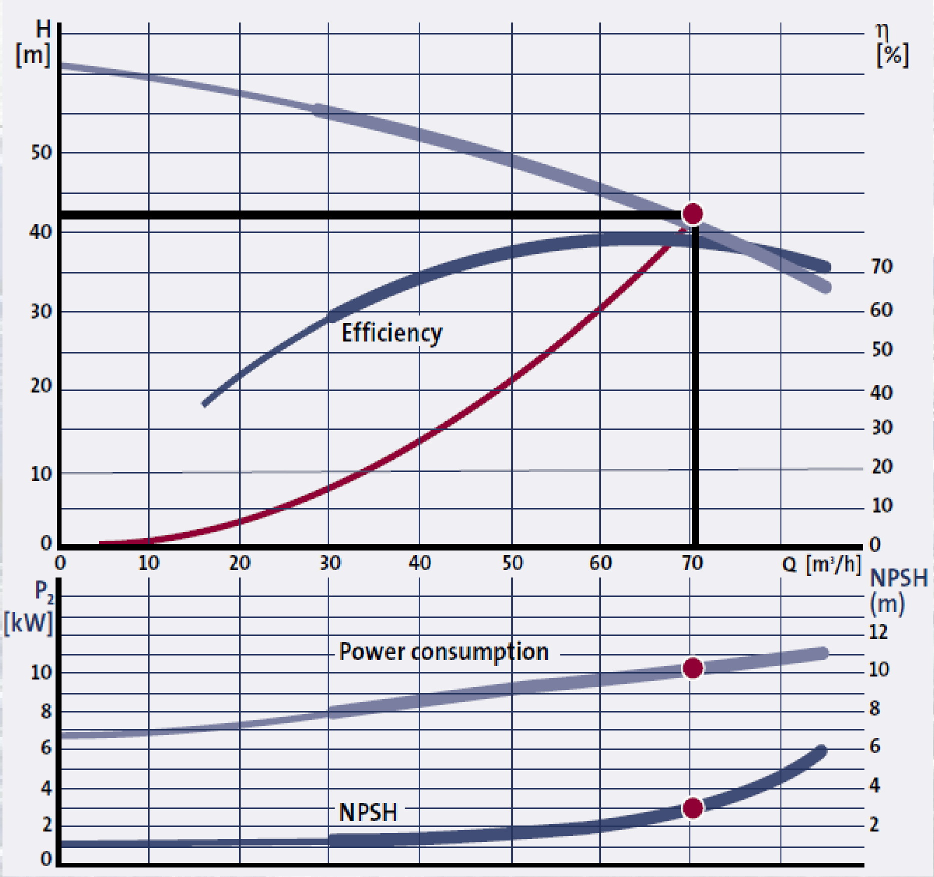
A. By switching ON/OFF some valves (2/3 way valves)

B. By controlling a pump performances (see different control modes)

C. By using a combination of those two

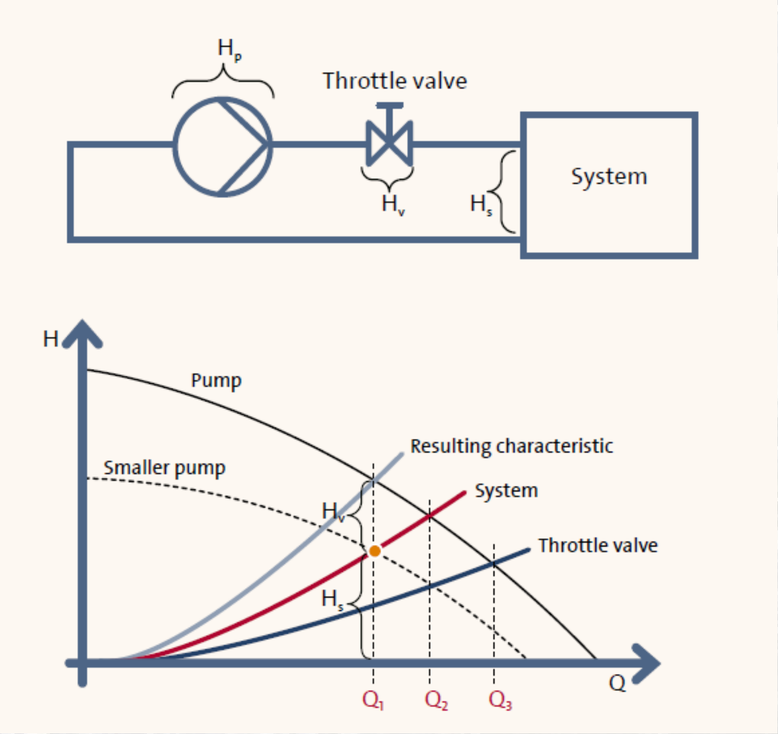
D. By using alternative C + zoning the system + using right number of pumps for matching the duty.

How to control the flow of a pump?



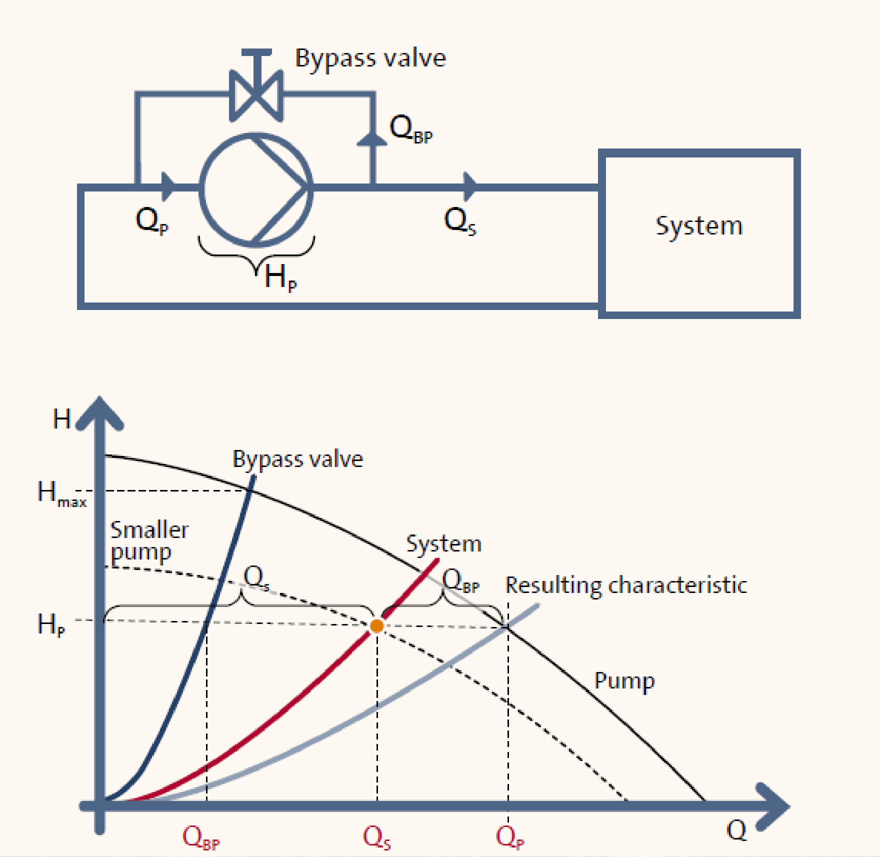
A. Throttling valve (adding extra losses)
B. Using Bypass line
C. Trimming impeller
D. Using multiple pumps in paralel operation
E. Using VFD for varying performances.

How to control the flow of a pump? Throttle valve method



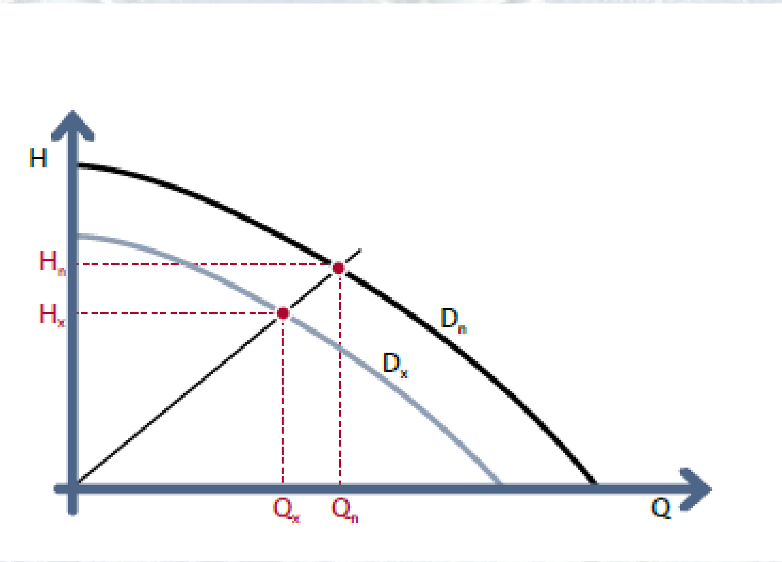
A. Cheap solution
B. Commonly used – see ballancing valves along circuits.
C. Not very energy efficient, however it is still needed in large quantities.
D. It is not always dynamic (e.g. simple throttle valves vs differential pressure valves)
E. Not dynamic system!

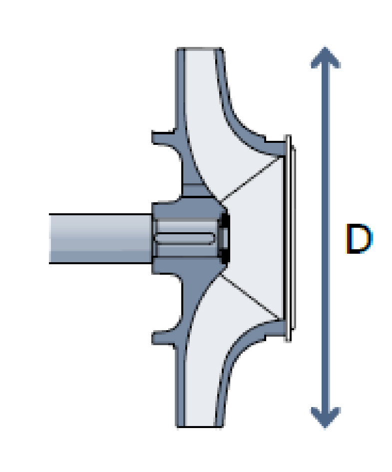
How to control the flow of a pump? Bypass valve



A. Cheap solution
B. Resulted flow over pump will be higher
C. Resulted flow in system will match the demand (constant flow)
D. Energy consumption will be high.
E. Not dyanmic system

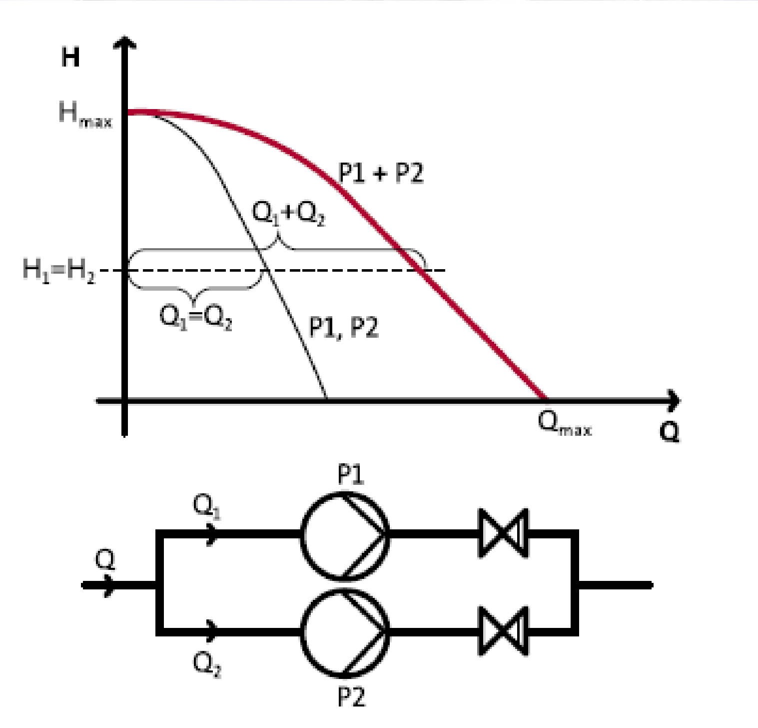
How to control the flow of a pump? Modifying impeller diameter





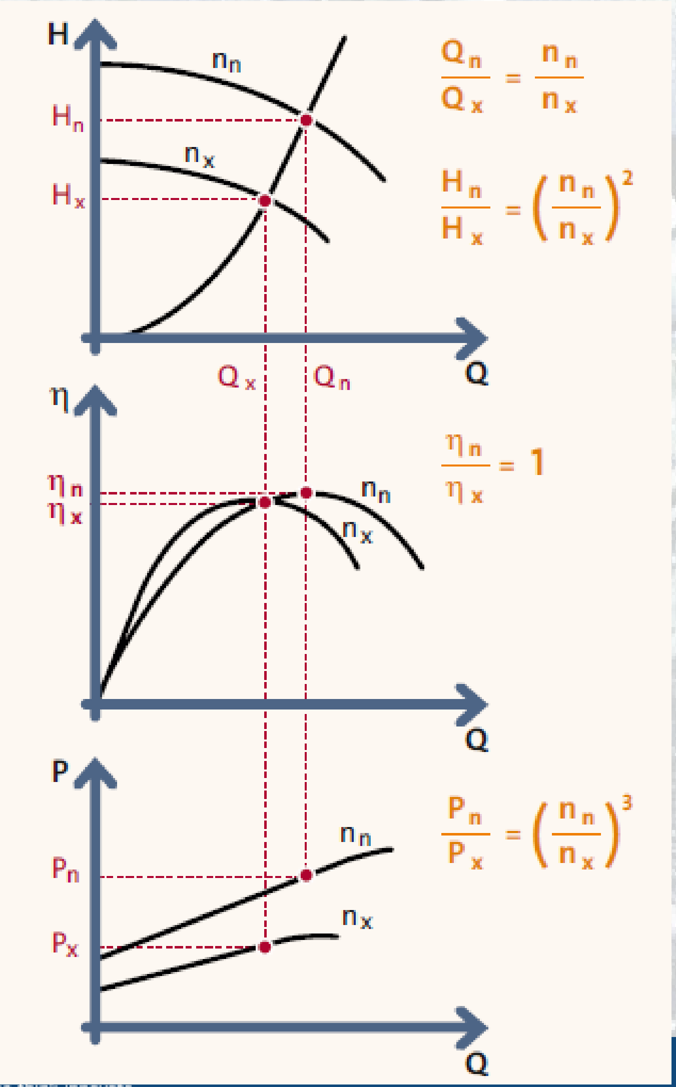
A. Cheap solution – if ordered accordingly
B. Best solution to keep efficiency at high rate
C. QH curve will be as close as possible to optimal
D. Good energy consumption
E. Later changes are not really possible (replacing impellers involves labour cost + new impeller)
F. No dynamic system

How to control the flow of a pump? Multiple pump solution



A. Single speed pump systems or variable speed pumps might be used.
B. Parallel installed pumps flow will sum (not necessary double the flow)
C. Efficiency could be high
D. Could be risk in part load conditions – cavitation could occur in some cases if system curve goes outside the pump curve.

How to control the flow of a pump? Variable speed pump



A. Highest investment cost
B. Flexible solution.
C. Variable flow and adaptation to the system demand
D. Can be used with different controlling algorythms
E. Might not be able to solve all problems alone

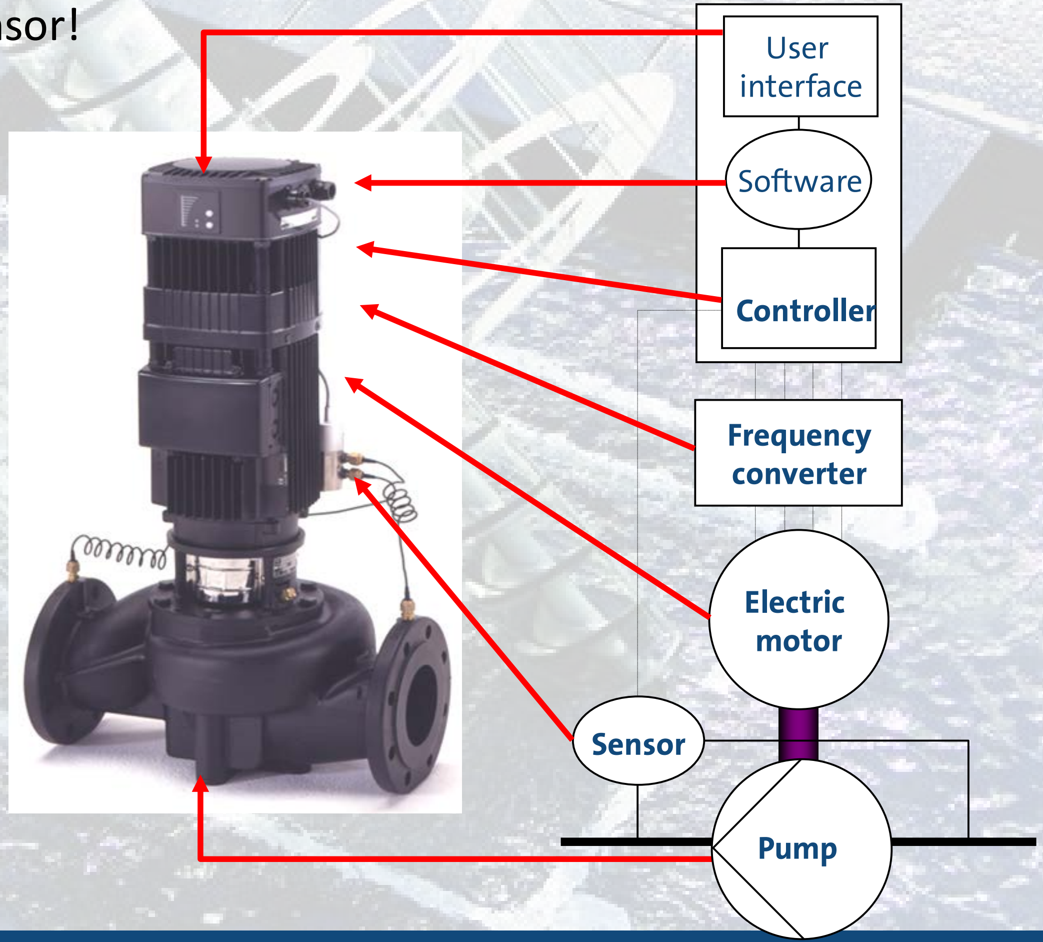
LCC comparison of different pump control

Initial pump flow	100,00 m3/h					
Pump height	30 mWS					
Desired flow	80 m3/h					
Desired pressure	19 mWS					
Reference pump	Grundfos NB65-160/159 A-F2-A-BAQE				4x NB40-160/149	4x NB40-160/149
P1	15				4	4
Efficiency	0,828				0,638	0,638
P1 in duty point	10,54				14,24	14,24
NPSH	3,85				2,06	2,06
Nr. Of pumps	1				4	4
Control mode	Throttle valve	Bypass line	Trimmed impeller	VFD	Multiple pumps	Multiple pumps with VFD
Impeller diam.	159	159	134	159	149	149
Resulted Flow	80,00 m3/h	134,00 m3/h	80,00 m3/h	80,00 m3/h	91,40 m3/h	80,00 m3/h
Resulted Pressure	32,52	25,11	19,36	18,96	24,91	18,96
Pump efficiency	0,782	0,819	0,777	0,83	0,73	0,732
P1	9,51	11,79	5,753	5,606	9,44	6,46
NPSH Resulted	3,18	5,18	4,69	2,43	3,25	2,52
Notes	Throttle valve closed partly	Bypass line opened	Impeller modified	VFD set	2 pumps been stopped	2 pumps at 87%
COST CALCULATION						
Pump	1 954,00 EUR	1 954,00 EUR	1 954,00 EUR	1 954,00 EUR	4 200,00 EUR	4 200,00 EUR
VFD	0,00 EUR	0,00 EUR	0,00 EUR	1 382,00 EUR	0,00 EUR	3 100,00 EUR
Bypass line	0,00 EUR	200,00 EUR	0,00 EUR	0,00 EUR	0,00 EUR	0,00 EUR
Throttle valve	250,00 EUR	0,00 EUR	0,00 EUR	0,00 EUR	0,00 EUR	0,00 EUR
Impeller trim. Cost	0,00 EUR	0,00 EUR	640,00 EUR	0,00 EUR	0,00 EUR	0,00 EUR
Total cost of syst.	**2 204,00 EUR**	**2 154,00 EUR**	**2 594,00 EUR**	**3 336,00 EUR**	**4 200,00 EUR**	**7 300,00 EUR**
Annual working hours	4320					
Total energy consumption/yr	41083,20 kWh	50932,80 kWh	24852,96 kWh	24217,92 kWh	40780,80 kWh	27907,20 kWh
Energy Consumption 15 yr	616248,00 kWh	763992,00 kWh	372794,40 kWh	363268,80 kWh	611712,00 kWh	418608,00 kWh
Electric rate	0,10 EUR					
Electrical costs	61 624,80 EUR	76 399,20 EUR	37 279,44 EUR	36 326,88 EUR	61 171,20 EUR	41 860,80 EUR
Service costs-15 yr	2 200,00 EUR	2 200,00 EUR	2 200,00 EUR	2 200,00 EUR	3 000,00 EUR	3 000,00 EUR
Life Cycle Cost	**66 028,80 EUR**	**80 753,20 EUR**	**42 073,44 EUR**	**41 862,88 EUR**	**68 371,20 EUR**	**52 160,80 EUR**

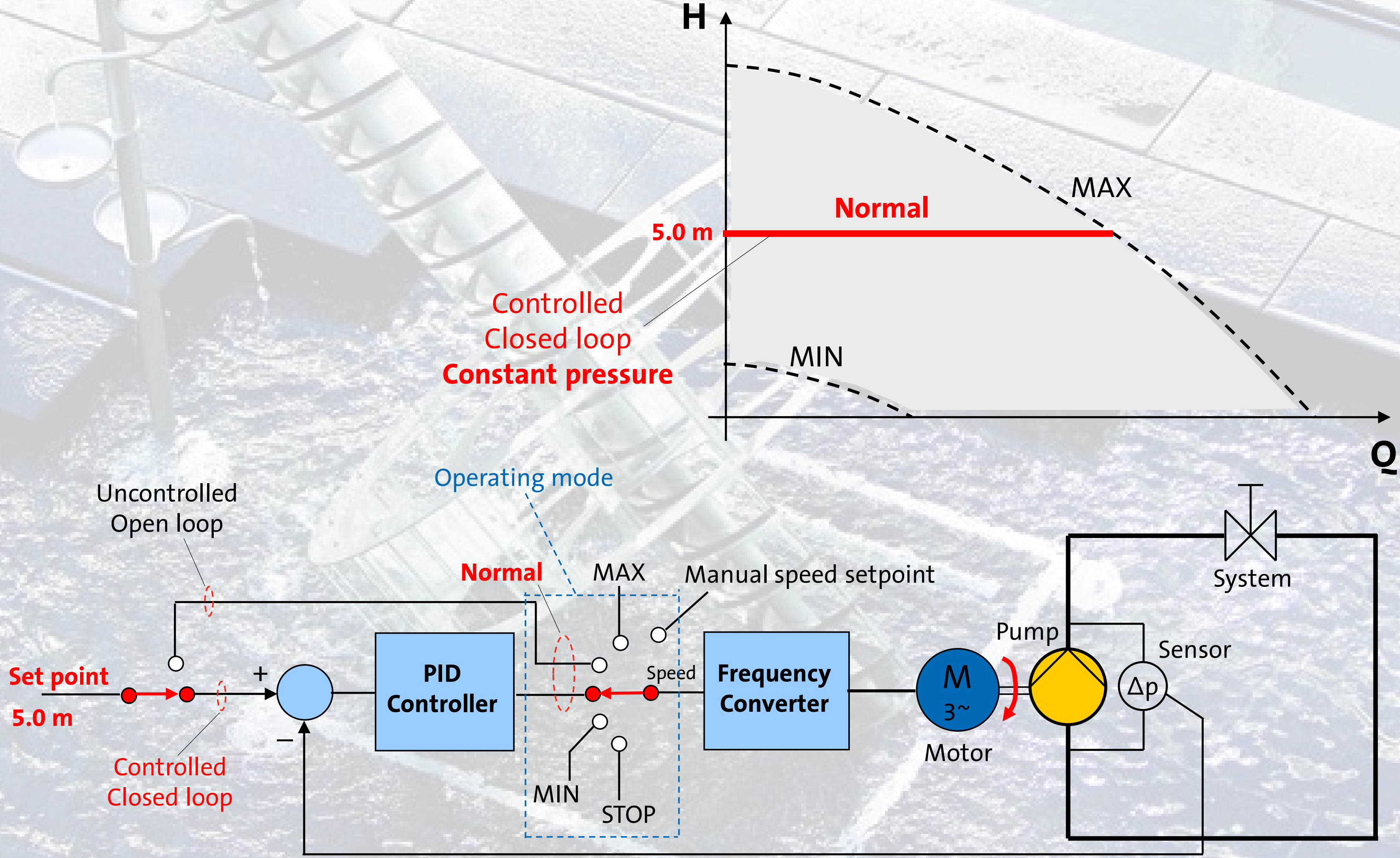
Larger pump or 2 smaller pumps?

Is a VFD equipped pump enough to ensure variable flow on system?

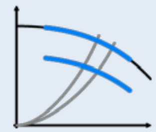
Electronic pumps (with VFD) does not guarantee variable flow/conditions unless there is a feedback sensor!



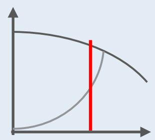
Working Schematic of VFD controlled pump



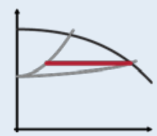
Basic pump control modes.
Where and when to use them?



Constant curve

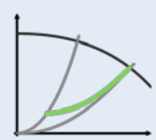


Constant Flow

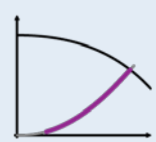


Constant pressure

Proportional differential pressure (calculated)



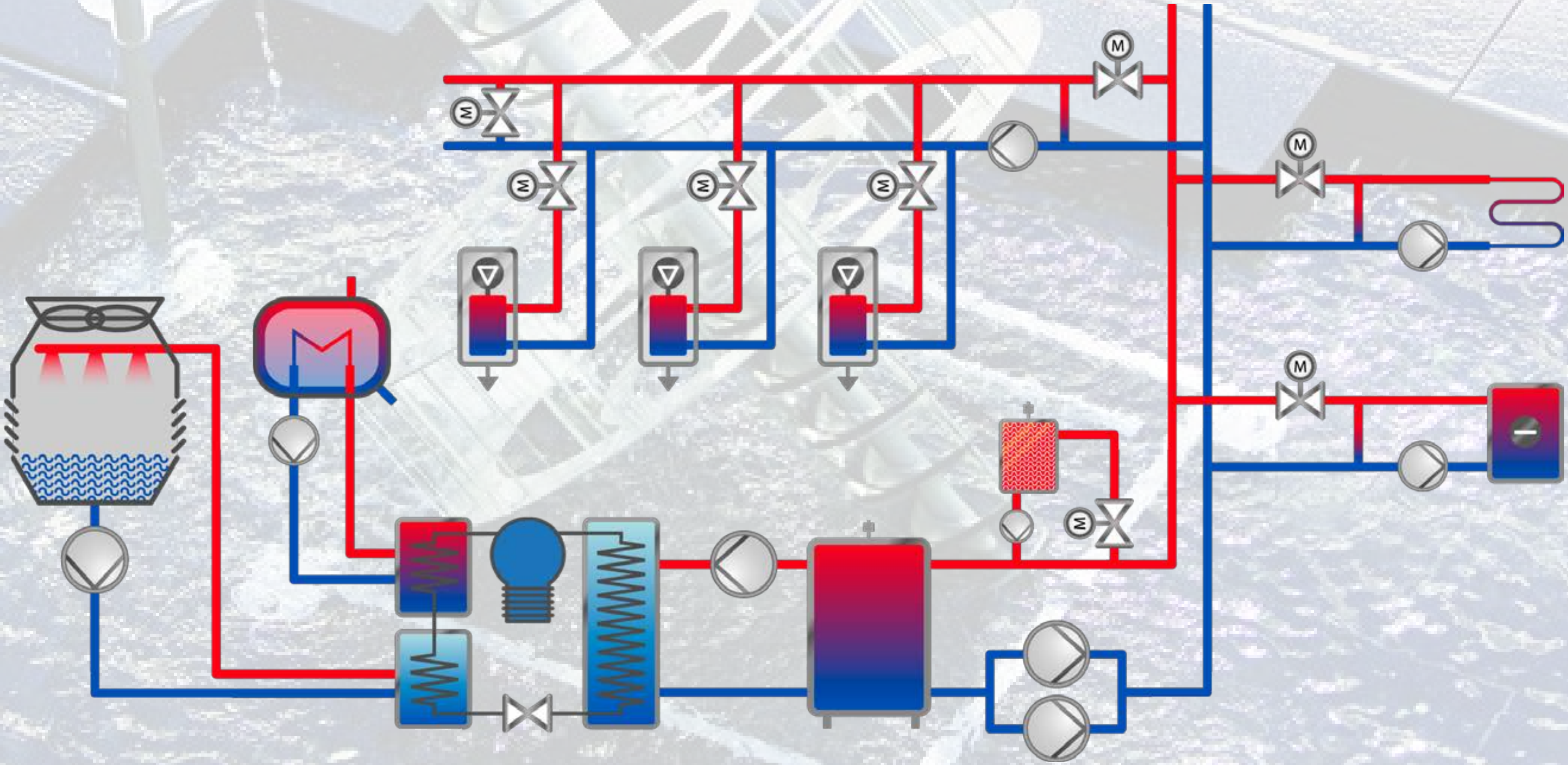
Proportional differential pressure (measured)



Temperature control

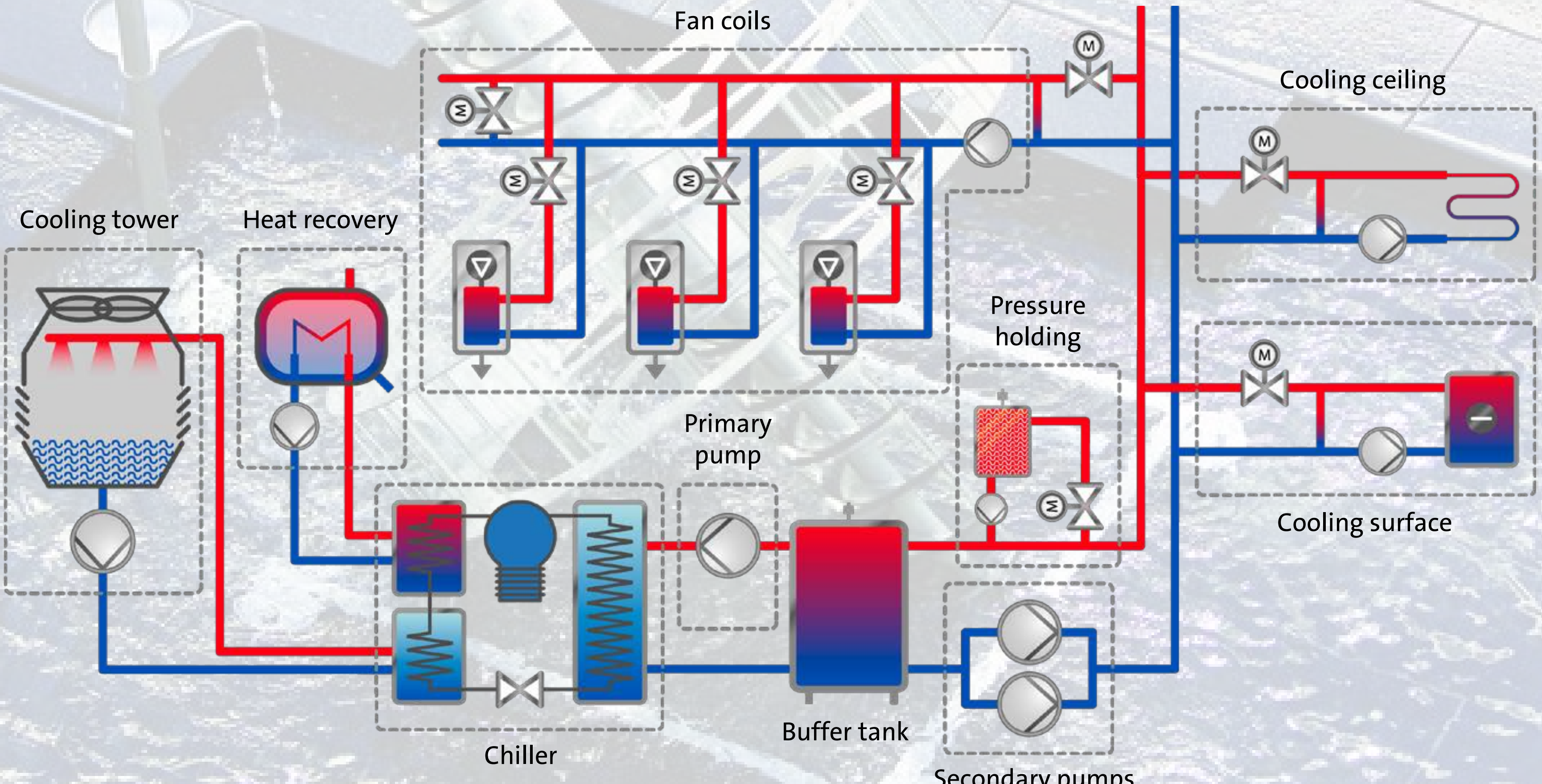
Air Con system – choosing control modes

An advanced air conditioning system consists of a number of elements, and the control mode you choose for each one is important to the overall energy consumption in the system.



System components

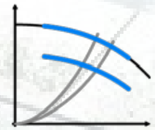
As an example we will look at a variable flow system with a constant flow chiller.
The system consists of the elements shown below.



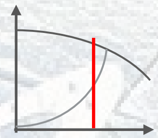
Control modes

Each unit in the system runs on its own pump, and for each pump you can apply one or more control modes.

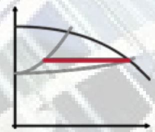
The control modes are listed here, and in the next slides we will look at the different control modes and explain their characteristics.



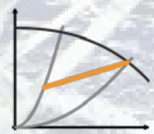
Constant curve



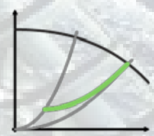
Constant Flow



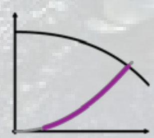
Constant pressure



Proportional differential pressure (calculated)



Proportional differential pressure (measured)



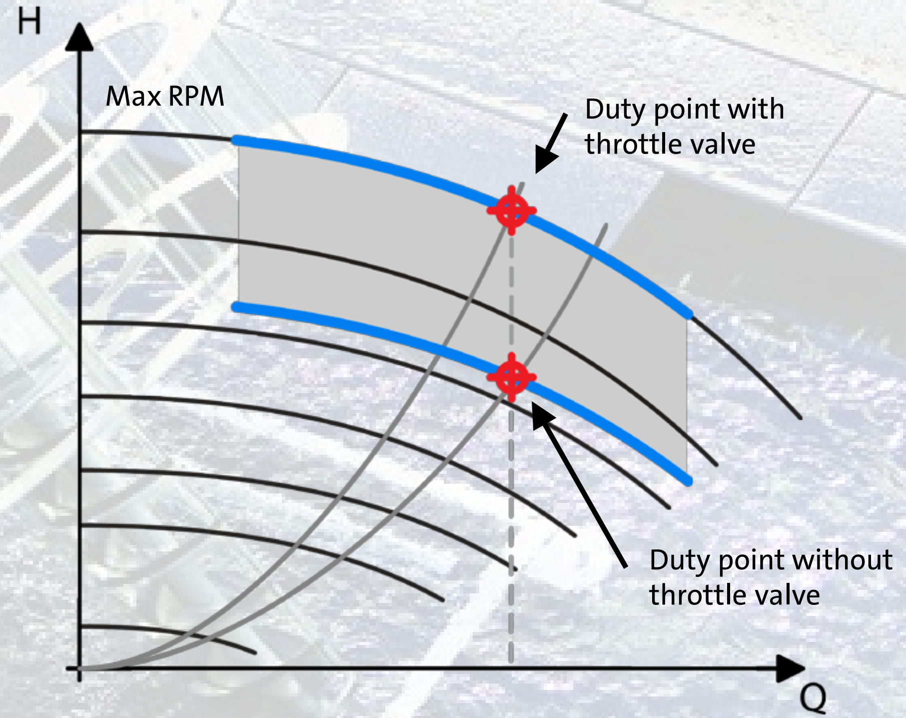
Temperature control

Constant curve mode

- Pump is adjusted once and for all
- Usually no need for sensors
- No need for throttle valve
- Used when there is a demand for constant flow and head

Suitable for

- Primary pumps
- Cooling coils
- Cooling towers

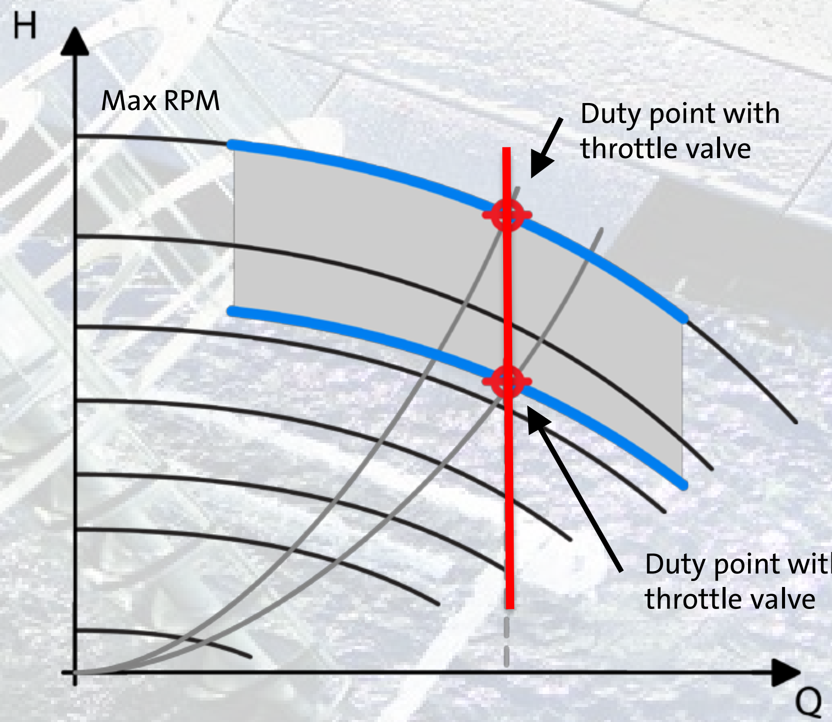


Constant flow mode

- Pump will keep constant flow depending on system resistance variation
- No need for throttle valve
- Used when there is a demand for constant flow and head

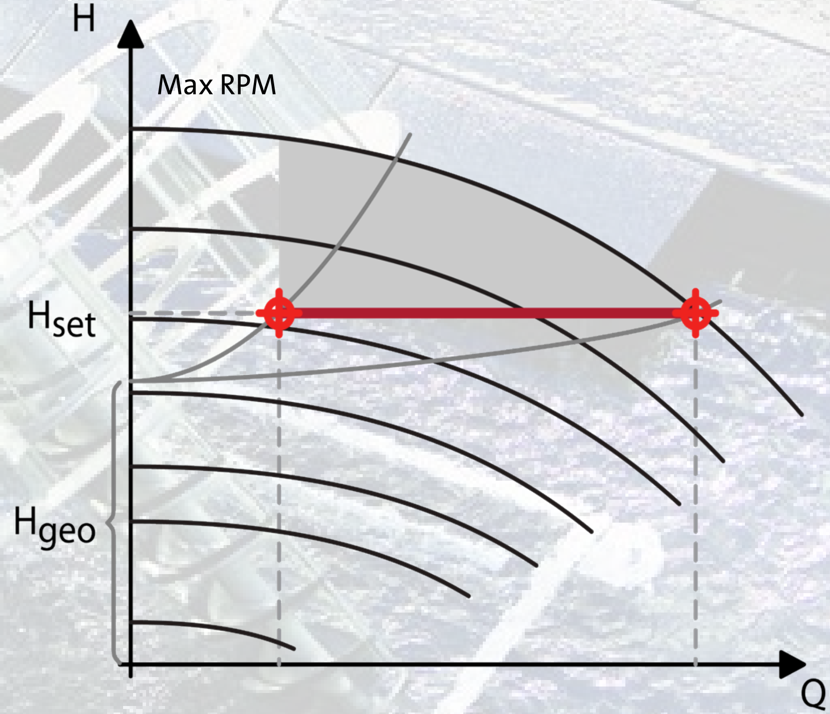
Suitable in case of cascade systems

- Primary pumps
- Cooling coils
- Cooling towers



Constant pressure mode

- Pump speed provides constant pressure at the pressure sensor
- Suitable for
  - Pressure holding systems
  - Surface heating/cooling systems
  - Parallel distribution systems

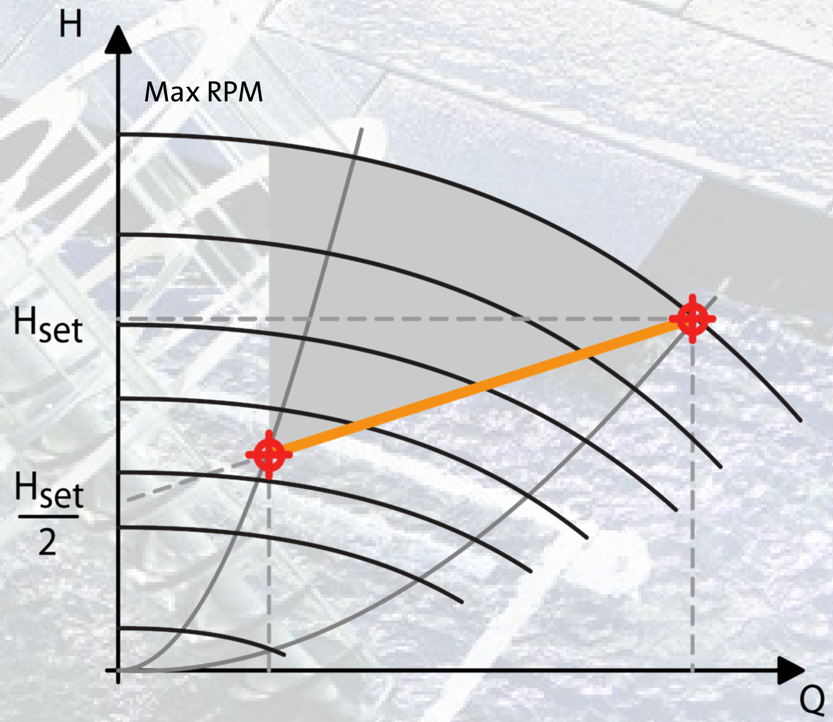


Proportional differential pressure mode (calculated)

- Head and speed are adjusted according to the differential pressure setpoint

Suitable for

- Secondary pumps
- Mixing loop pumps for fan coil and cooling ceiling systems

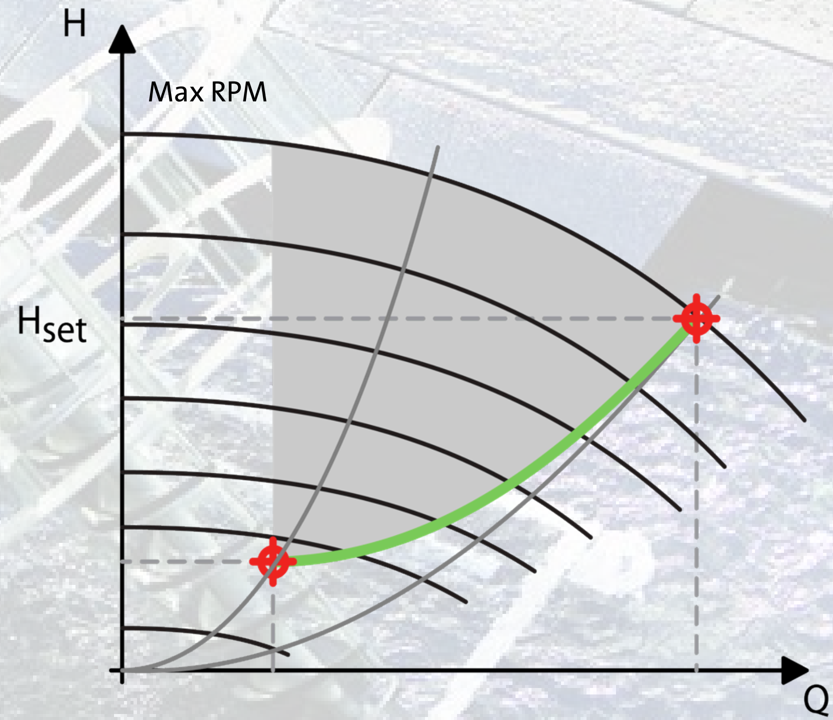


Proportional differential pressure mode (measured)

- Head is dependent on a differential pressure sensor in a reference point
- Head decreases when flow is reduced

Suitable for

- Secondary pumps
- Mixing loop pumps for fan coil and cooling ceiling systems

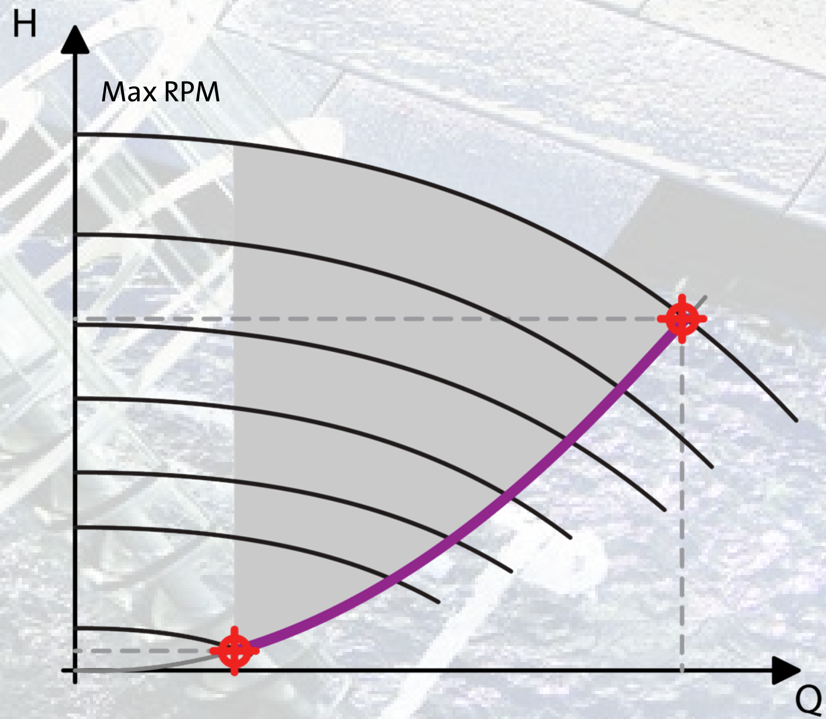


Differential Temperature mode

- Here the pump speed is controlled according to a temperature in a certain reference point. For example pre-heating water in a hot water tank

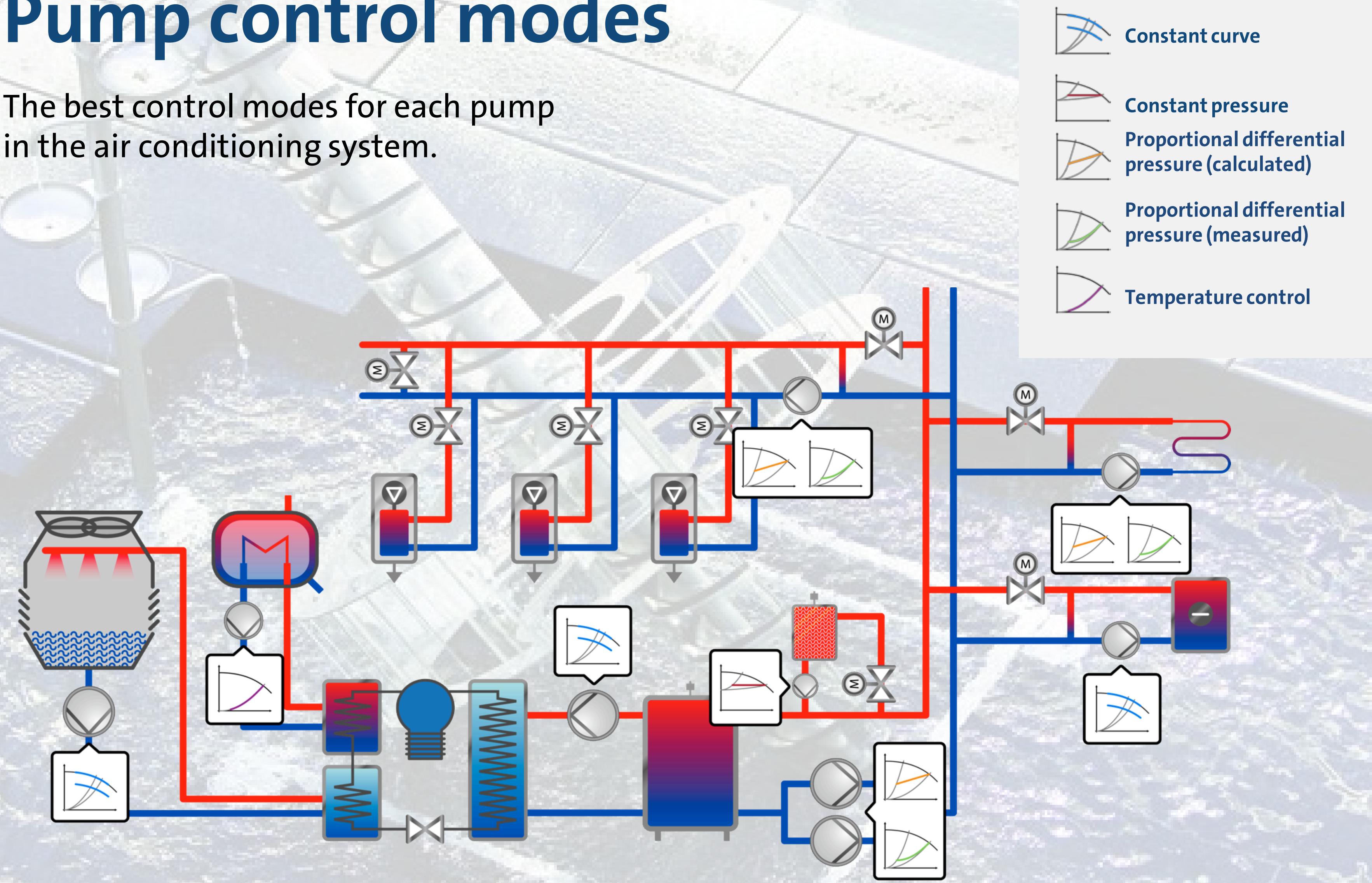
Suitable for

- Heat recovery system
- DHW recirculation
- Boiler shunt pump
- etc



Pump control modes

The best control modes for each pump
in the air conditioning system.



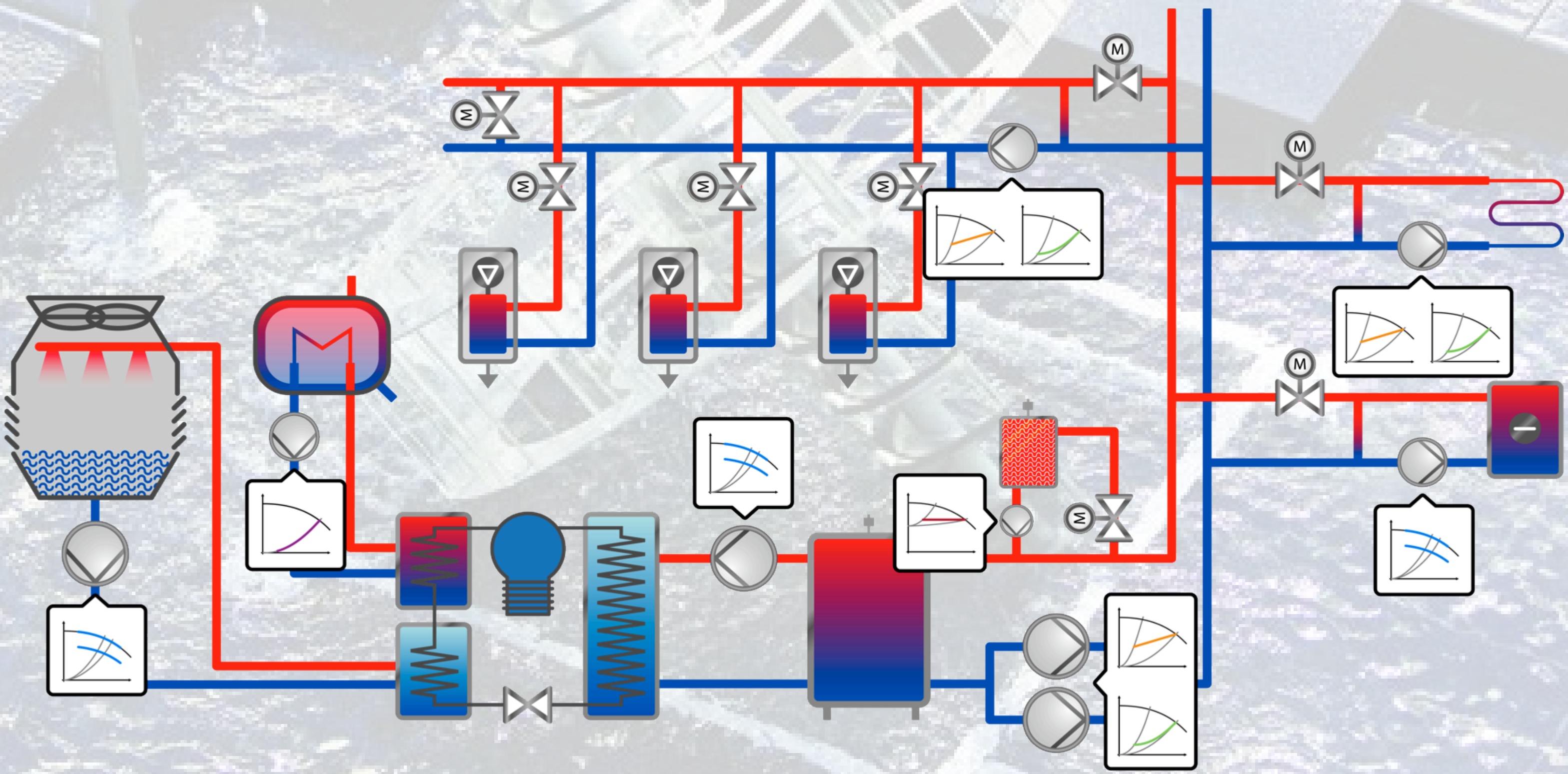
Who is generating the different conditions?

Control valves will add/cut pressure by closing or opening themselves.

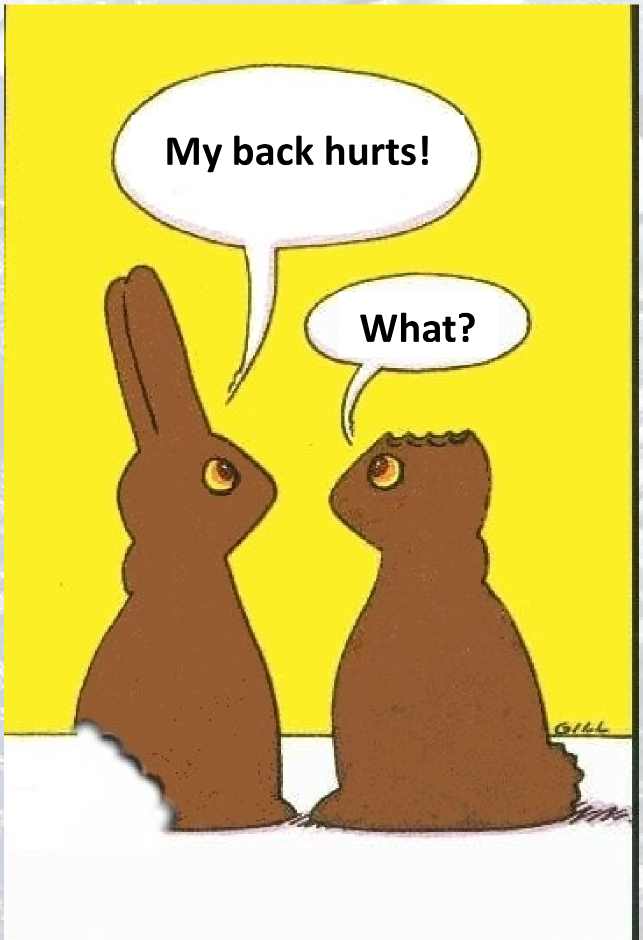
Valves are either controlled by thermostatic systems or BMS systems.

Complex controlling system is a must in every modern building.

Smart regulation can not be achieved using only mechanical equipments.



That is why we need smart pumping and controlling solutions.



Electronic solutions are not smart enough to work alone.

Many years HVAC systems was consisting on individual equipments, where fine tuning was missing.

A HVAC system must be seen as a SYSTEM, together with all other elements of the building

Two way communication is a must.

Unist must work proactively!

Smart Pump Features

- Self learning and Automatic adaptation
- Two way communication and with different platforms – e.g. smartphones
- System optimisation and diagnostics
- Information instead of data!

iSolution – the smart platform of Grundfos

E-pumps

iSolution

Pump + Drive + Control + Measurment + Communictaion

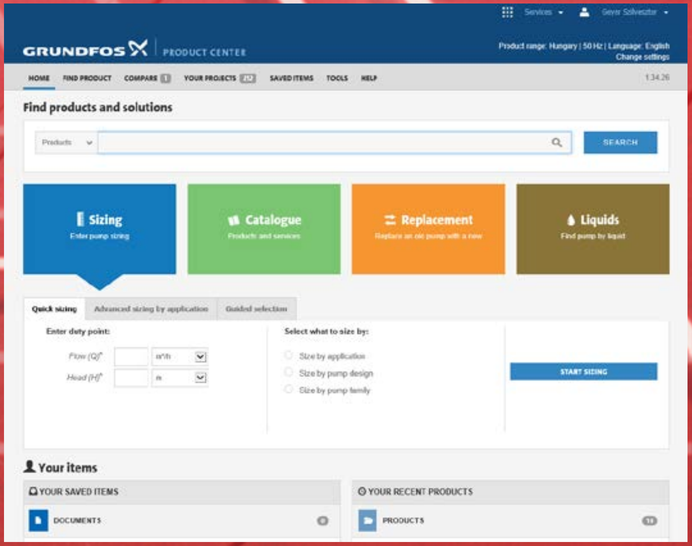
iSolution – the smart platform of Grundfos

Sensors available for pump control

Communication interface

Standard Communciation Protocols for integration in BMS or with Cloud monitoring systems and smart phones

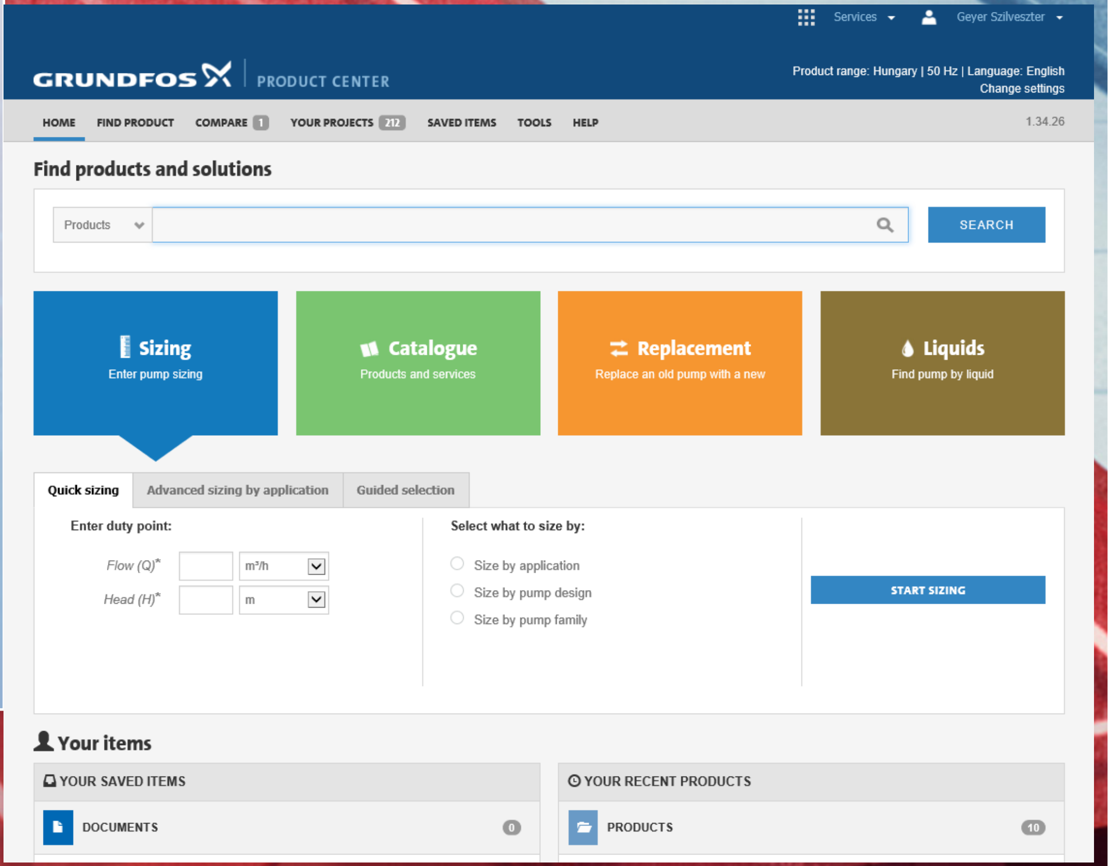
Online software package for design support.



Grundfos Product Center

Complete online pump selector platform

- ✓ Comprehensive sizing tools
- ✓ Replacement Tool
- ✓ Available on smart phones, tablets and PC
- ✓ All informations at your hand – datasheet, documents, drawings
- ✓ LCC Calculation
- ✓ Project modules
- ✓ Sharing information
- ✓ List Prices and ETA
- ✓ Comparison modules



Smart Communication interface – software + GPC Access

Grundfos GO

- Using Smart Phone for increased user experience
- Pump control and diagnose in wireless mode
- User Friendly
- Data Collections
- Pump sizing and search functions

Pump Setting Reports via e-mail

Grundfos GO report

Title
1-2-es szivattyu

Author
Geyer Ehrenberg Szilveszter Zoltan

Date
April 24, 2018

Number of Images
2

Service report ID

Warranty
Available

Lifecycle
Normal operation

Notes:
Nyomáskül. Távadó feltehetőleg eldugult. Javaslom cseréjét.

Unique product identification data

Product specific information	Info value
Product type	MGE Series 3000
Production code	2007-7

Product information

Product information	Info value
Type	4/TP(D)100-390/3R430/3000/22
Product type	MGE Series 3000
Serial number	45
Software	HMLarge V010500
Software	GMDS V10400
Configuration	95139461
Production code	2007-7
Config. date	837

Values/settings:

Parameter	Value
Next service, Time to next service	In 6 months
Next service, Service type	Lubricate bearings
External setpoint	Not active
Actual setpoint	54 %
Controlled from	Grundfos GO
Sensor value	60.0 m
Motor speed	1600 rpm
Motor torque	19.5 Nm

Grundfos GO report

Energy consumption	17598 kWh
Power consumption	3.5 kW
Operating hours	2788 hours
Motor current	13.0 A
Max. motor current	28.2 A
Number of starts	32
Operating mode	Normal
Control mode	Constant curve
Setpoint, Resulting setpoint	54 %
Setpoint, Set setpoint	54 %
Limit 1 exceeded	Deactivated
Limit 2 exceeded	Deactivated
Relay 1 activated during	Fault
Relay 2 activated during	Fault
Buttons on product	Active
Number	-
Digital input 2	Maximum
Motor bearing monitoring	Not active
Bearing temperature, DE	Disabled
Bearing temperature, NDE	Disabled
Standstill heating	Disabled
Ramps, Ramp-up time	20.0 s
Ramps, Ramp-down time	20.0 s
Max. No. of lubrications	5
Previous service work, Bearing replacements	0
Previous service work, Number of lubrications	0

Type	Description
Alarm code	**0: No active alarm**
Alarm log 1	**88: Sensor signal outside range 2 minutes ago, April 24, 2018 at 1:27 PM**
Alarm log 2	**88: Sensor signal outside range 4 minutes ago, April 24, 2018 at 1:25 PM**
Alarm log 3	**88: Sensor signal outside range 14 minutes ago, April 24, 2018 at 1:15 PM**
Alarm log 4	**88: Sensor signal outside range 16 minutes ago, April 24, 2018 at 1:13 PM**
Alarm log 5	**88: Sensor signal outside range 16 minutes ago, April 24, 2018 at 1:13 PM**
Warning code	**0: No active warning**

Grundfos GO report

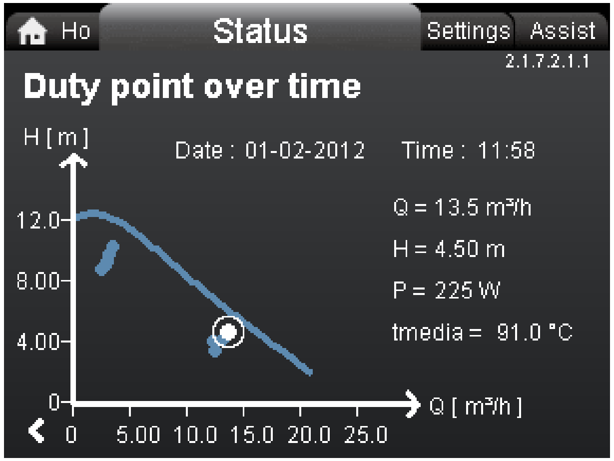
Image 1

Circulation Pumps using iSolution platform

MAGNA3 – High Efficiency Wet Runners

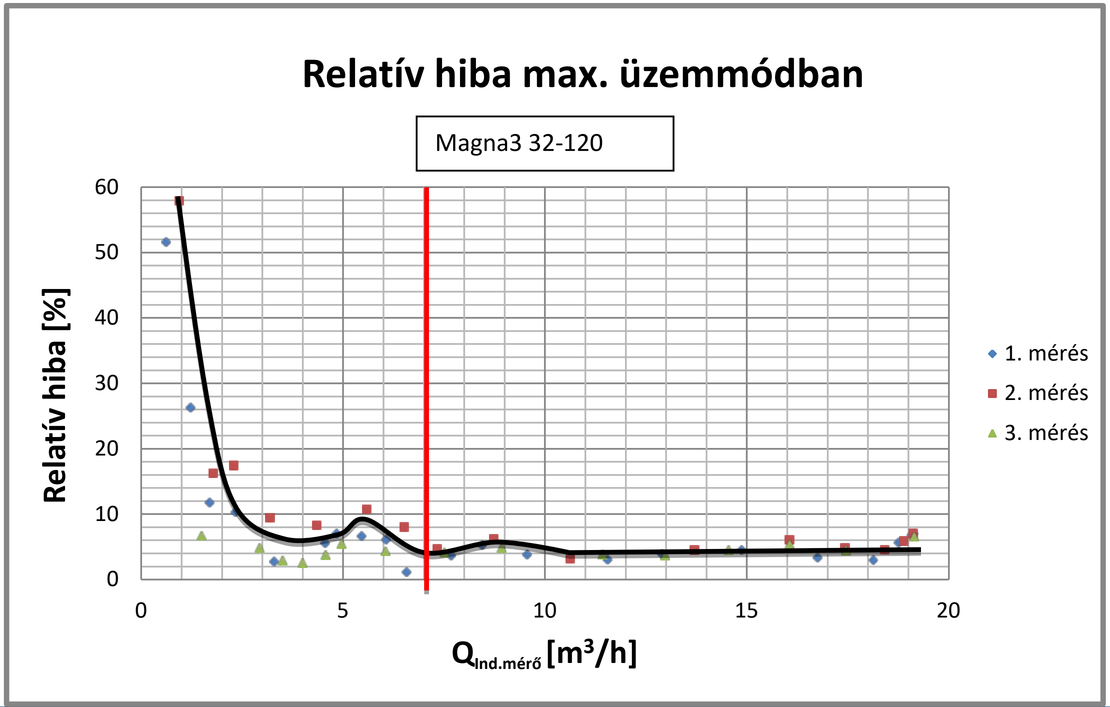
- Self Learning (AutoAdapt) Function and System Diagnose
- Built in measurement functions: Flow, Pressure, Power, Energy, Temperature, Heat Energy,
- Special Control Modes – FlowLimit and Flow Adapt
- Communication with Smartphone
  Wireless Cascade Communication
- Buszkommunikáció

Diagnose and Optimisation in Magna3 and TPE3



System Hydraulic

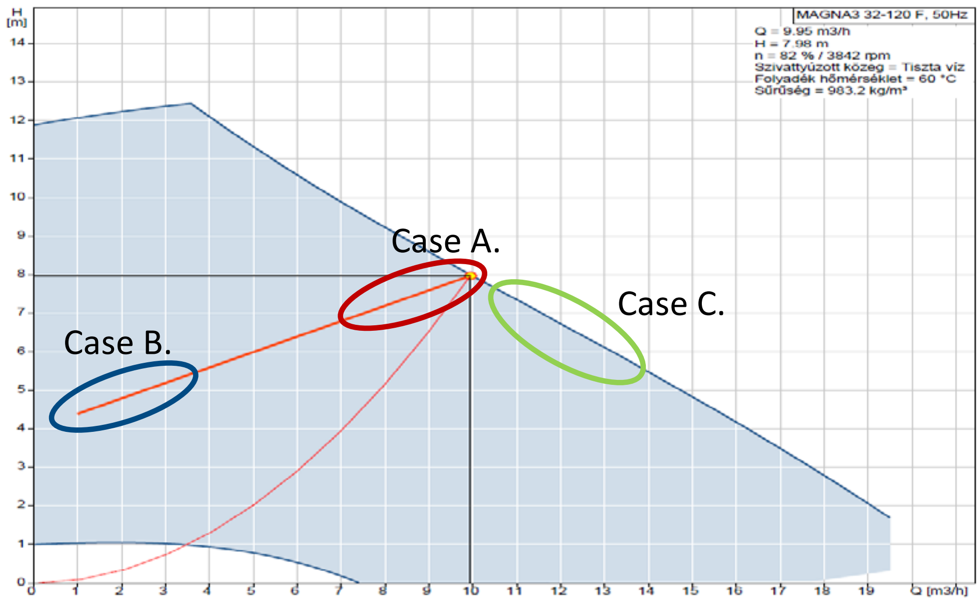
- Pressure measurement (built in sensor)
  Accuracy: 2% (FS)
- Flow Measurment (calculated)
  Accuracy: 3-5% (FS), in 90% of the curve

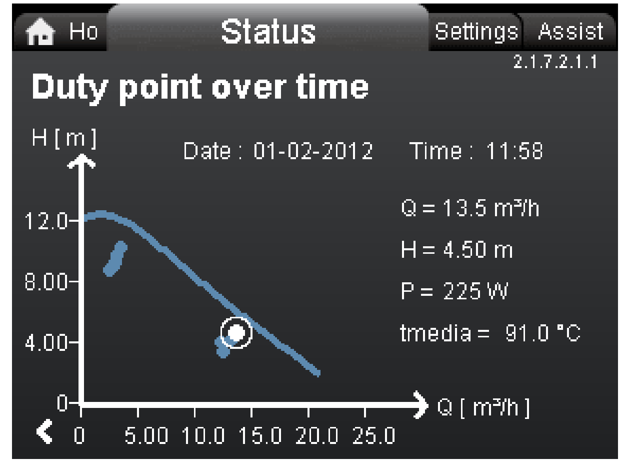


GRUNDFOS iSOLUTIONS

Diagnose and Optimisation in Magna3 and TPE3

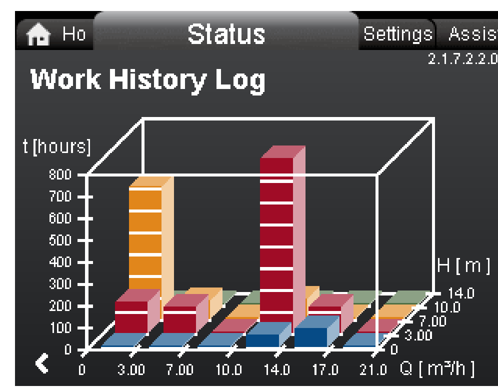
Optimisation using trend data





Shows historical data presentation over time compared to curve

<u>Real system processes!!!!</u>

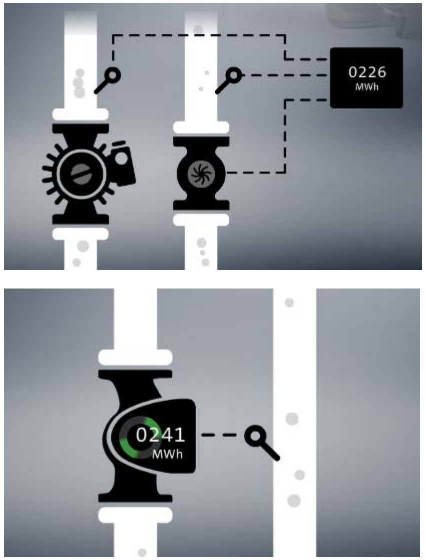


Case A. : $Q > Q_{Design}$, unballanced system, high value setpoint (Static ballan.), Low flow temperature (weather compensation control.)

Case B.: overside pump, higher pressure losses than design val. ($Q < Q_{Design}$)

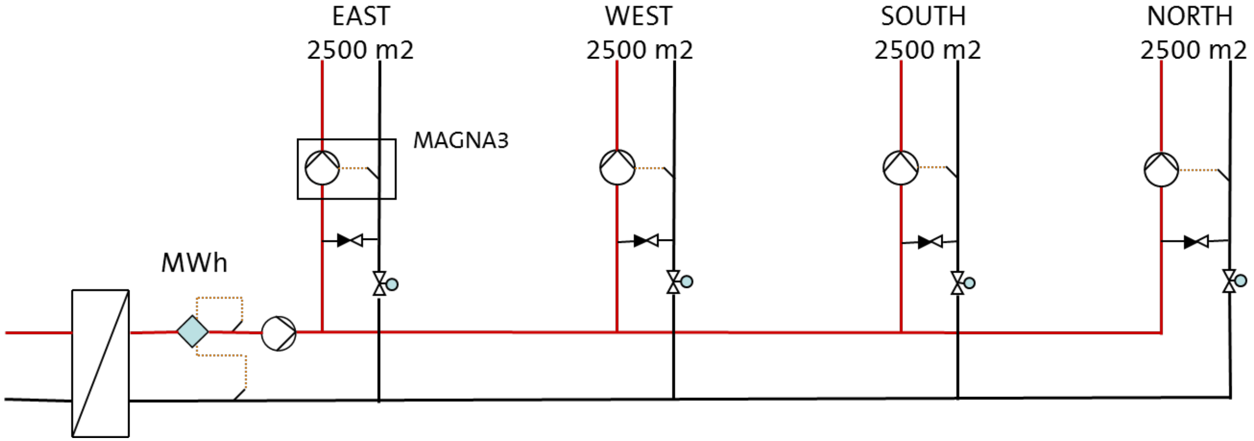
Case C.: High value setpoint, Ballancing issues (FLOWlimit)

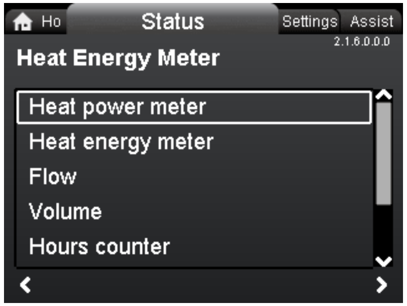
Diagnose and Optimisation in Magna3 and TPE3



System Energy Ballance

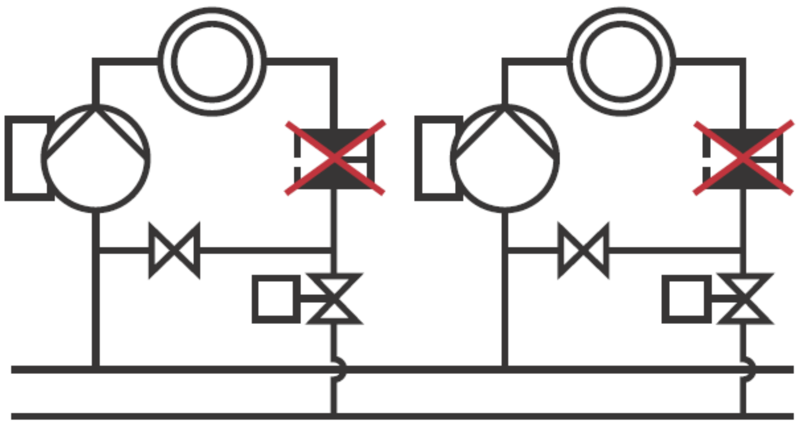
- Heat Energy Monitor function:
  - Measurment accuracy +/-1% és +/-10% varying on system conditions.
  - External temperature transducer (on return pipe) directly in pump.
  - Very good for Energy Balance

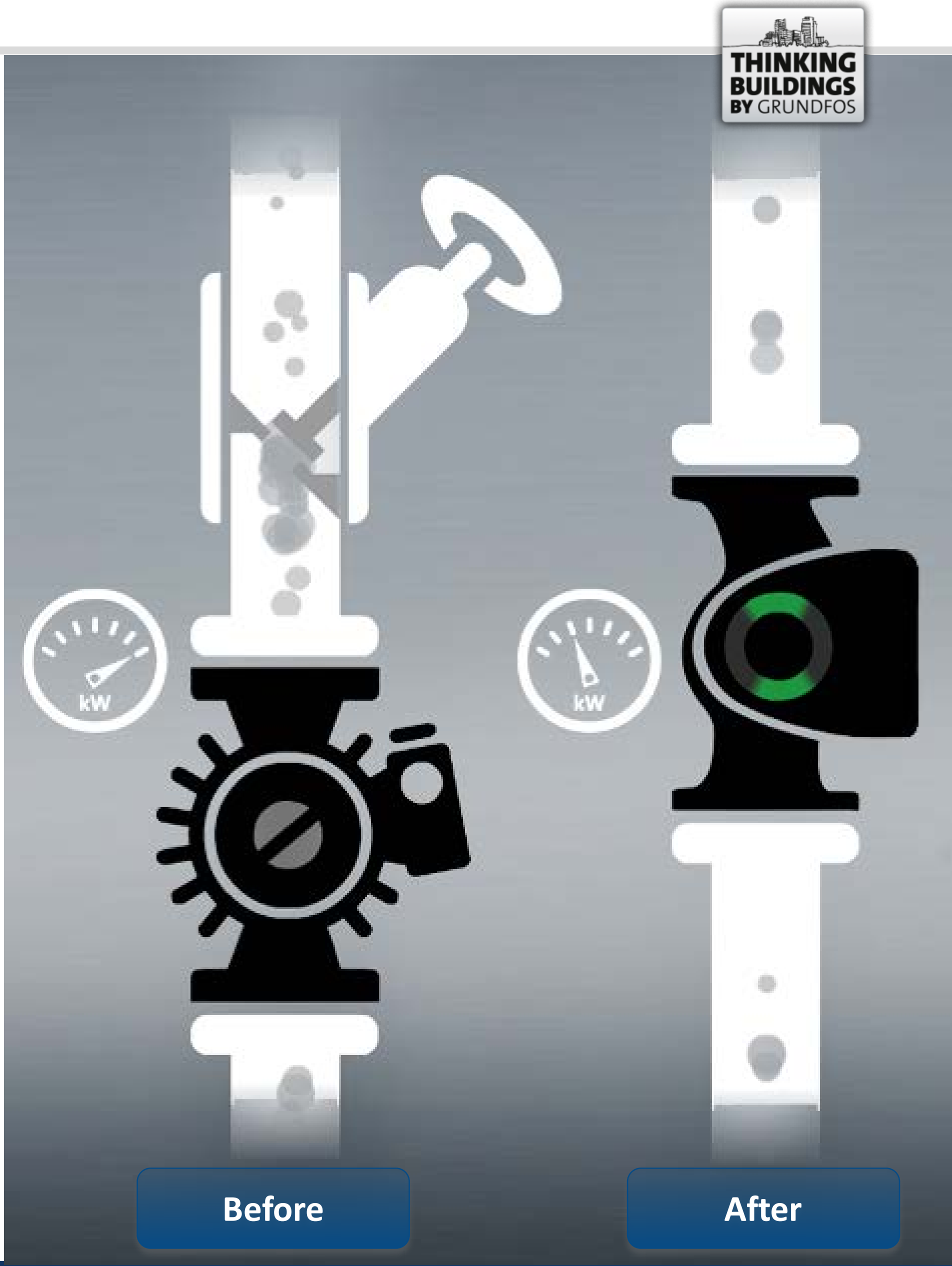




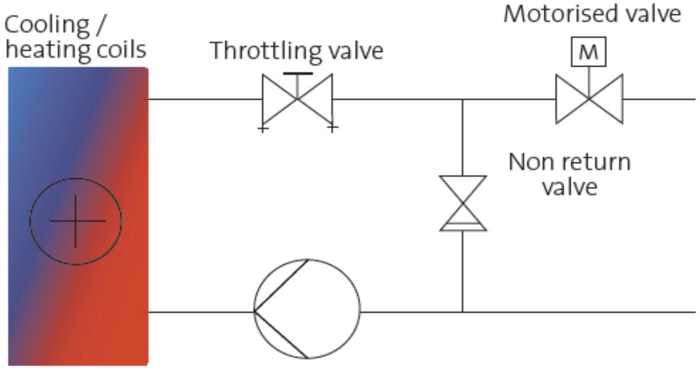
FLOW*LIMIT*

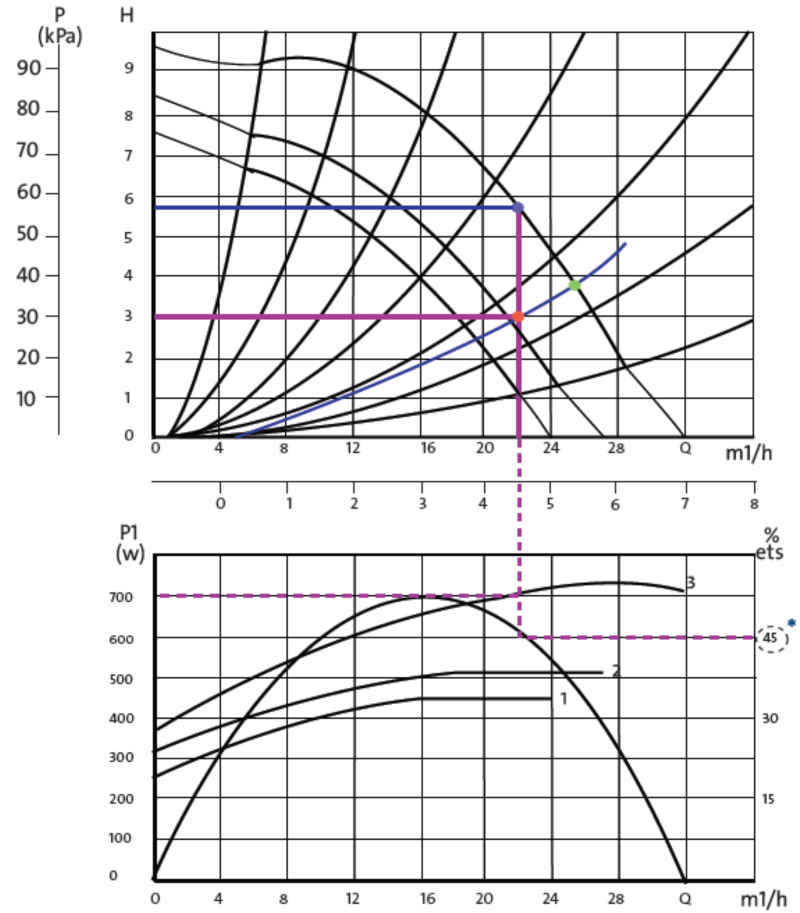
- FLOW*LIMIT* can set maximum system flow allowed without throtling valve.
- Usable in case of static ballancing of system (e.g. AHU bypass pump, main circulation branches).





Magna 3 – FLOWlimit function
Bypass Pump ballancing in as in good old days...





- Design duty point
- Real duty point (with no throttling valve or FLOWLIMIT)
- New duty point

<u>Resulted annual energy consumption of pump with ballancing</u>

$$E_{electricity} = \frac{700 \cdot 8760}{100} = 6132\ kWh$$

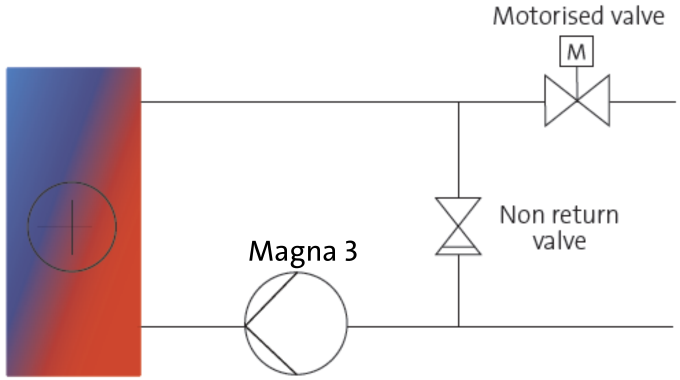
<u>Resulted energy loss on the pump ballancing</u>

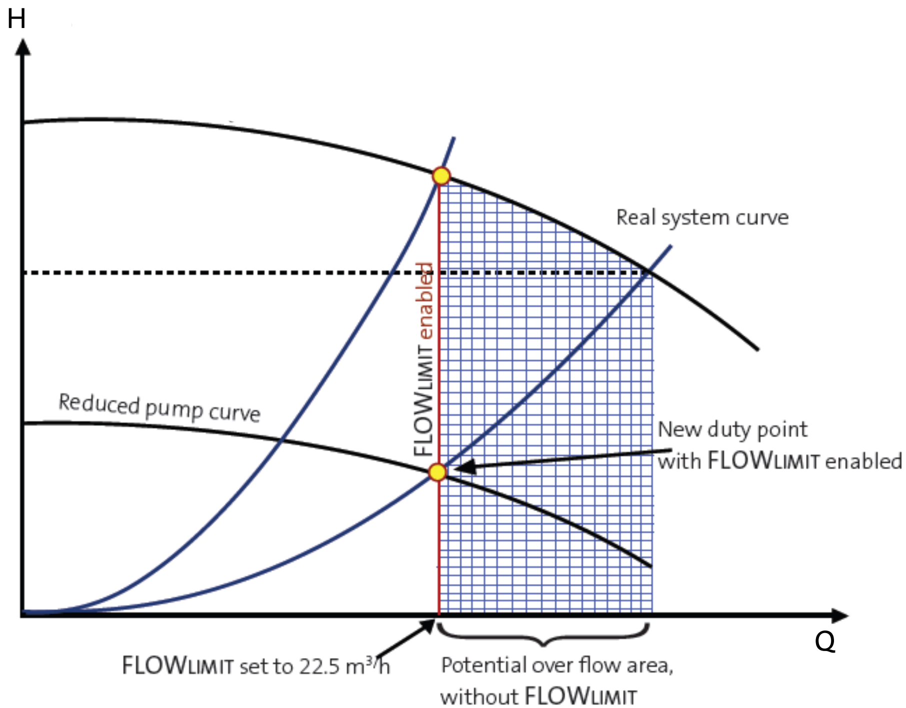
Ph = q ρ g h / (3.6 10⁶) = Hydr. Power (kW)
q = Volume Flow (m3/h)
ρ = density (kg/m3)
g = grav. acc (9.81 m/s2)
h = delivered pressure(m)

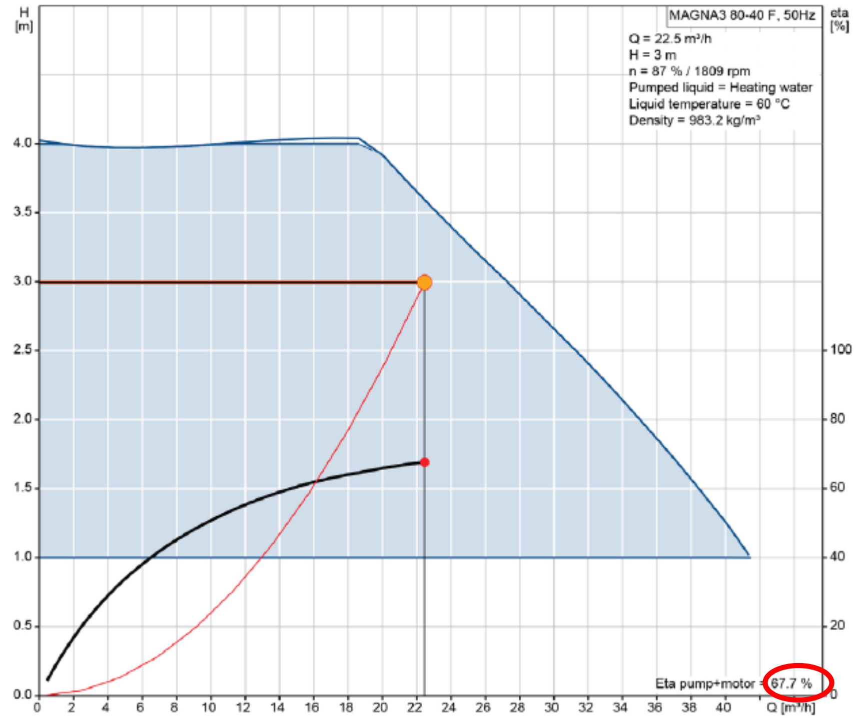
$$Ph = 22{,}5 \times 1000 \times 9{,}81 \times 2{,}5 / 3{,}6 \times 10^6 = \frac{0{,}153\ kW}{0{,}45} = 0{,}34\ kW$$

Annual energy losses: 0,34 X 8760 = <u>2978 kWh</u>

Magna 3 – FLOWlimit funtion
Bypass pump ballancing using FlowLimit and no valve



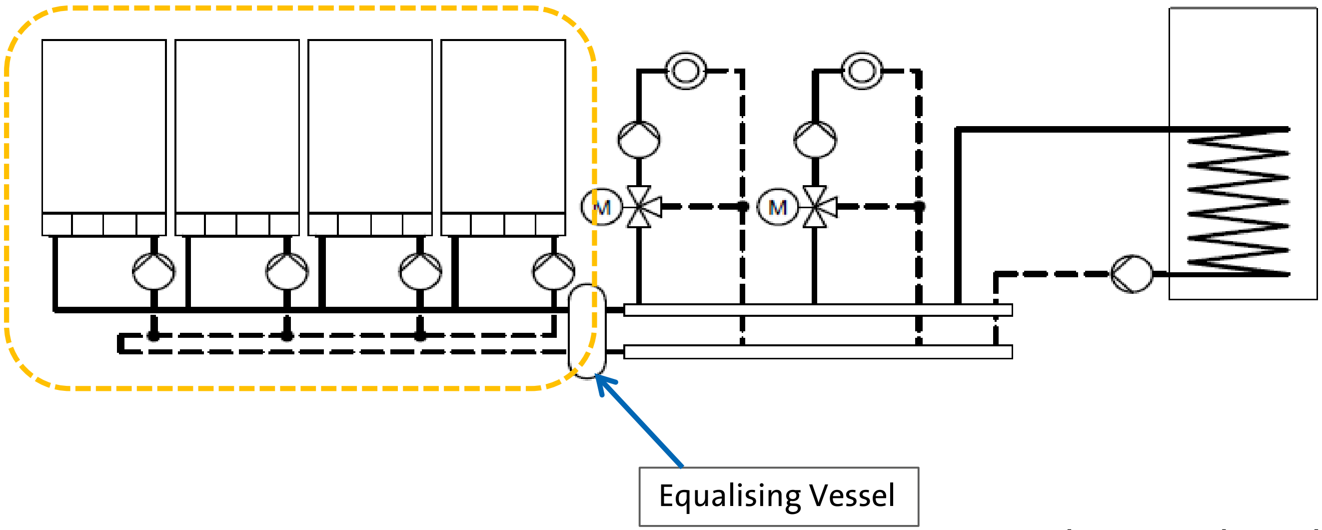


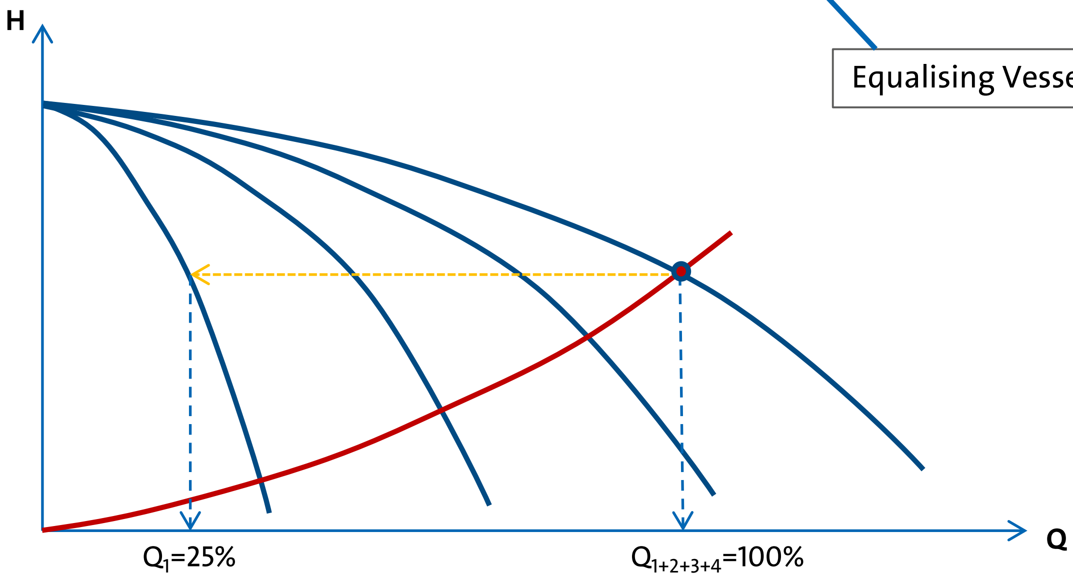


Chosen Pump: MAGNA3 80-40
Annual Consumption : 2331 kWh/yr

Basic solution energy:	6132 kWh
New solution energy:	2331 kWh
Savings:	3801 kWh = 62%

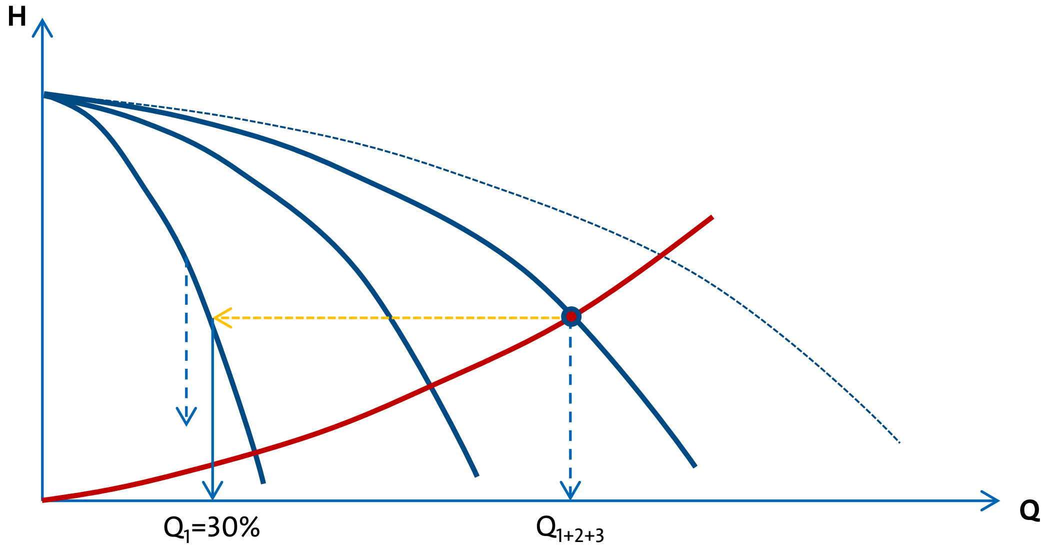
Magna 3 – FLOWlimit Function
Gas fired boilers



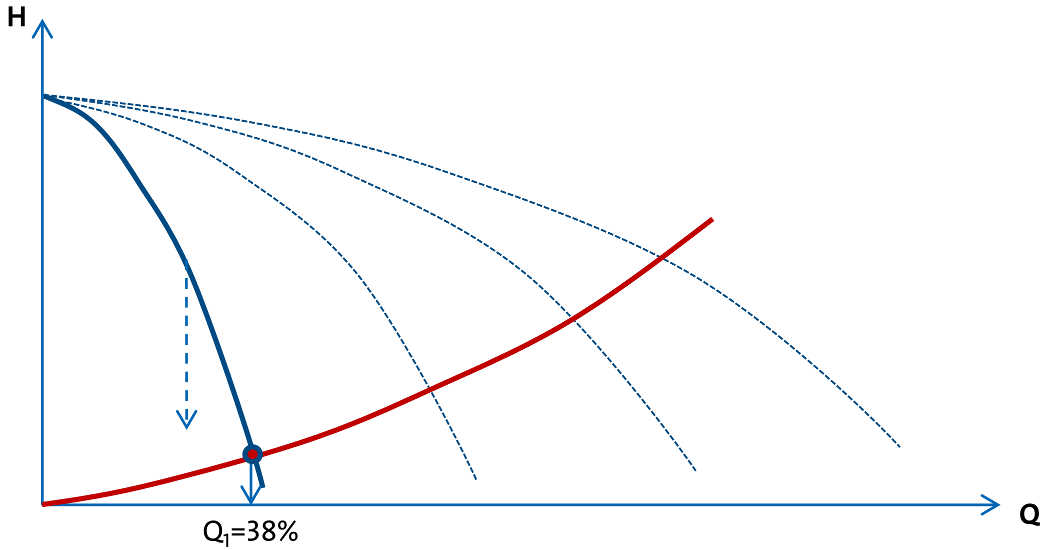


- Each pump does the flow of one boiler (25%)
- On partload conditions the flow for each boiler will increase due to adaptation on the system curve.
- Larger flow will increase the return temperature making boiler efficiency worse.

Magna 3 – FLOWlimit Function
Gas fired boilers

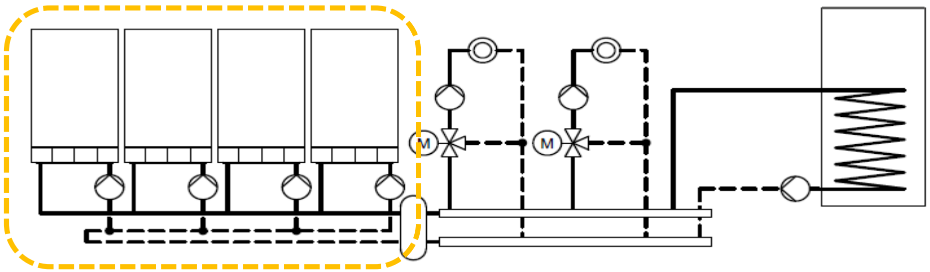


- ➢ *3 boilers working*
- The specific flow for one boiler could be 20% higher than design flow

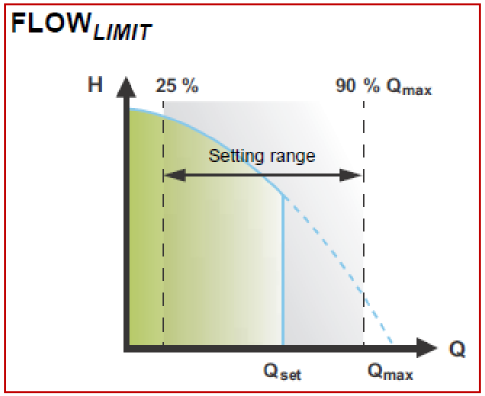


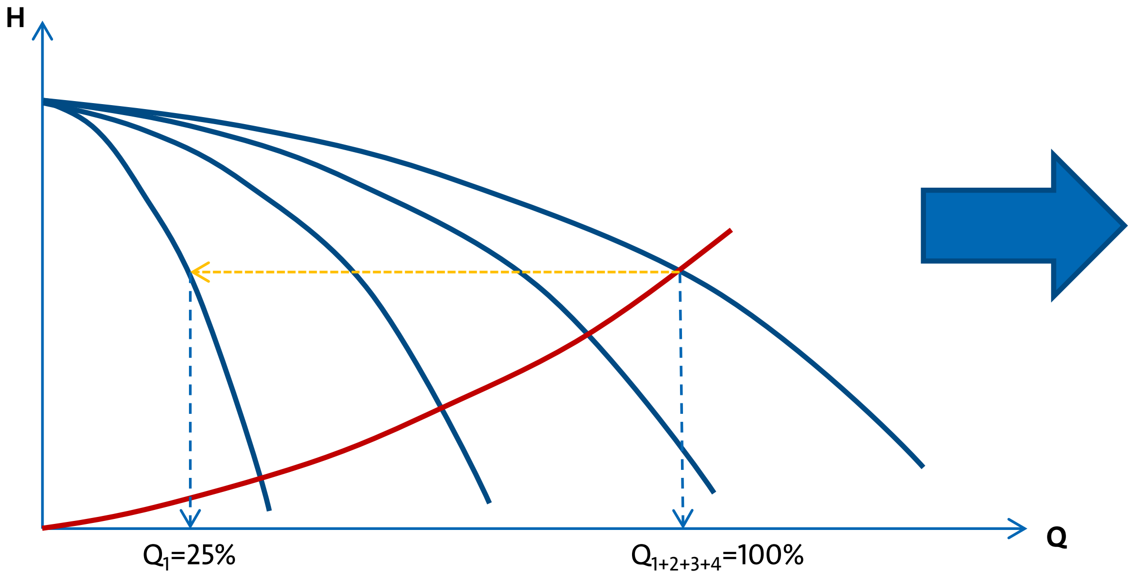
- ➢ *1 boiler working*
- One single boiler out of 4 on function could result 50% higher flow without flow limitation.

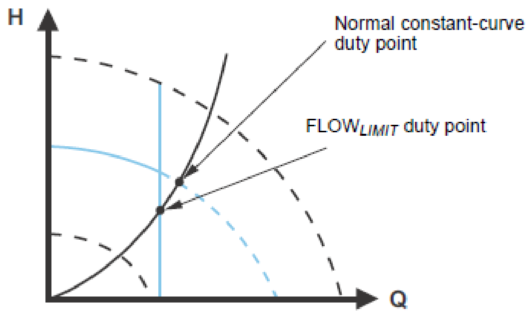
Magna 3 – FLOWlimit Function
Gas fired boilers



- MAGNA3 / TPE3 pumps with FLOWlimit function
- Maximum flow does not exceed set value







System curve + FlowLimit

be think innovate

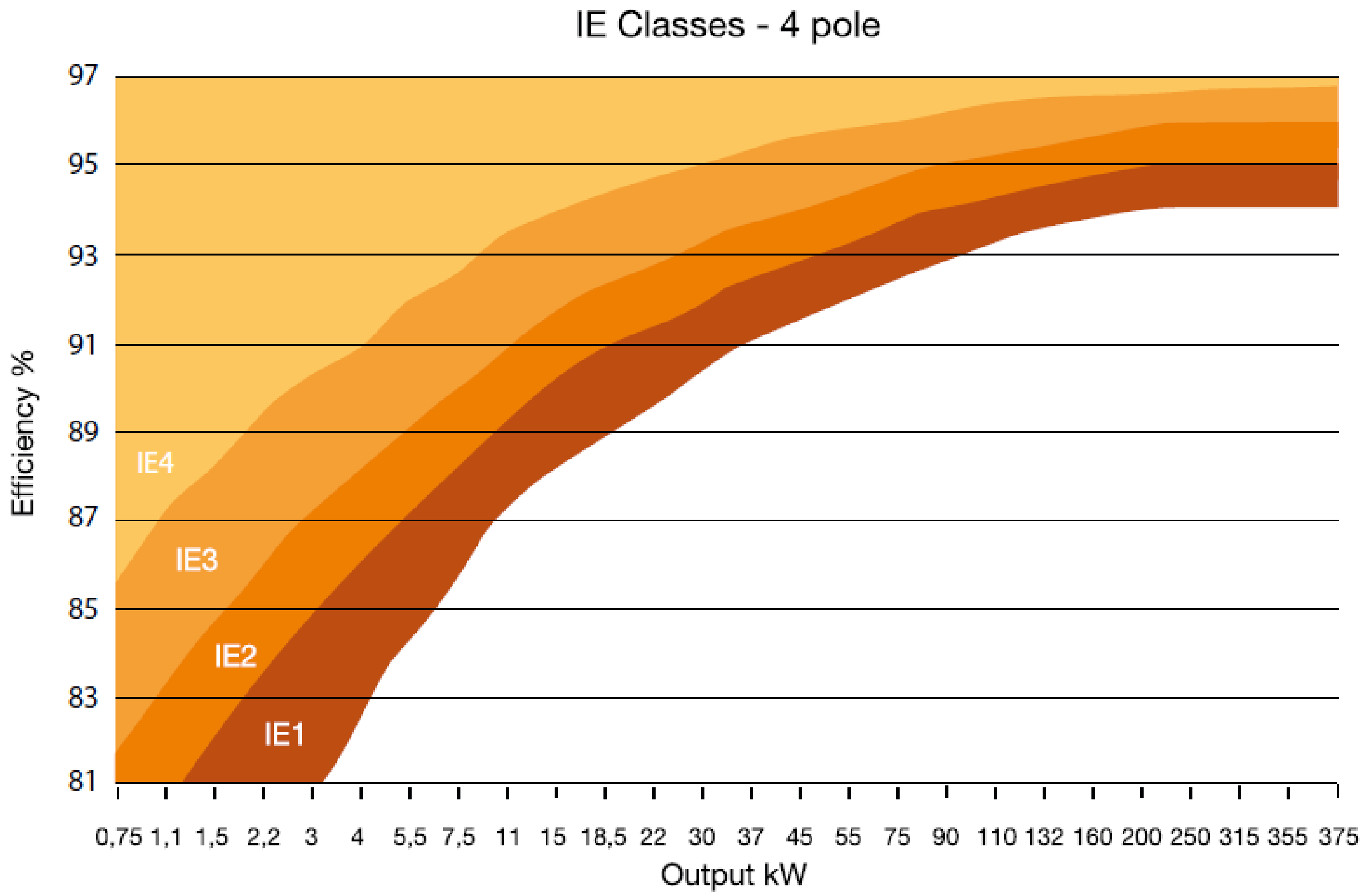
GRUNDFOS

Pumps with High Efficiency MGE motors up to 11kW

TPE(3)(D), NBE, NKE, CRE, CME

- High Efficiency with PM Syncron motors up to 11kW
- Wide Application range
- Integrated Measurments and Diagnose features
- Comprehensinve control solutions with no External PLC needed

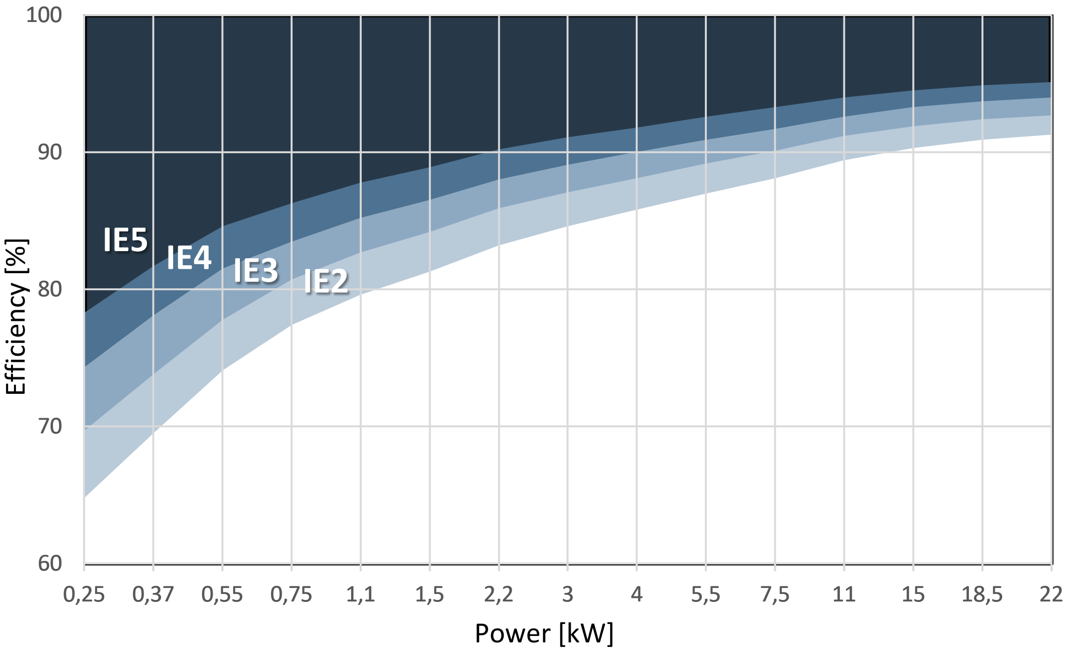
IE motor eff. Classes until 31.12.2016



New Development– IE5 MGE motors

Állandó mágneses szinkron-reluktancia motorok beépített frekvenciaváltóval

- 11 kW power
- IEC 60034-30-2 only with integrated frequency drive

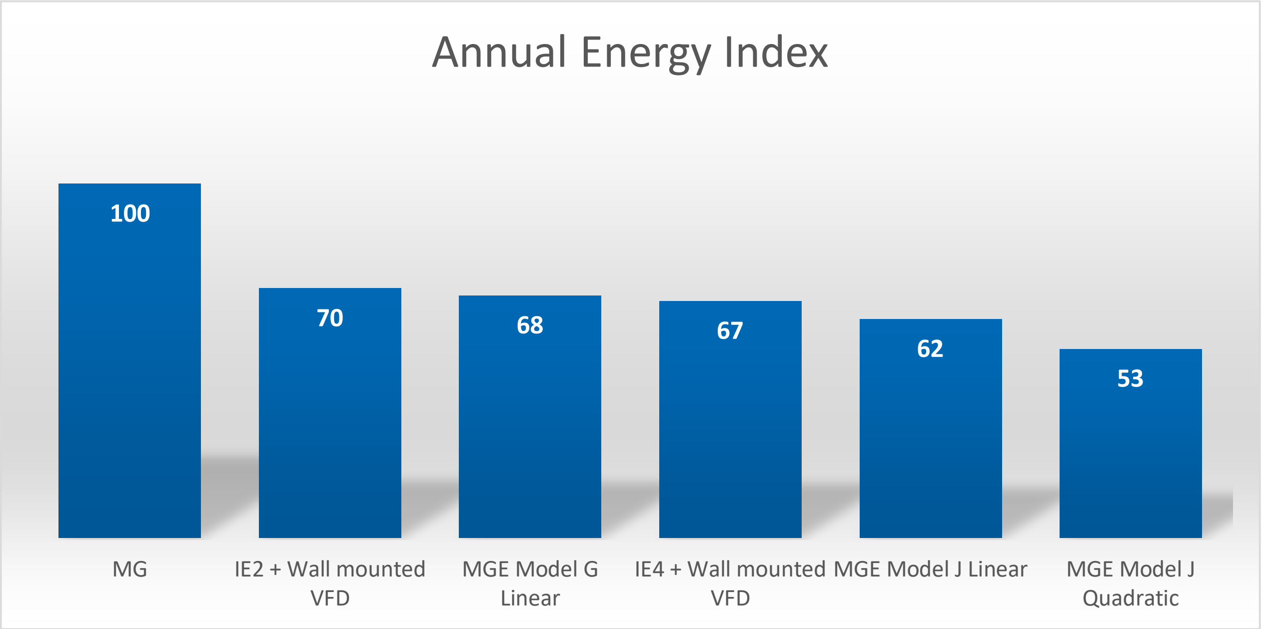


Efficiency

- Is it worst to use VFD up to 11kW?

Comparison of external VFD vs. MGE

IE2 and IE4 motors with VFD Compared with MGE and new MGE Motors



		MG	IE2 + ext. VFD	MGE Model G Linear	IE4 + ext. VFD	MGE Model J Linear	MGE Model J Quadratic
kWh:	kWh:	18.528	13.055	12.680	12.395	11.447	**9.890**
Index:	Index:	100	70	68	67	62	53

Inteligent solution – Complex solutions

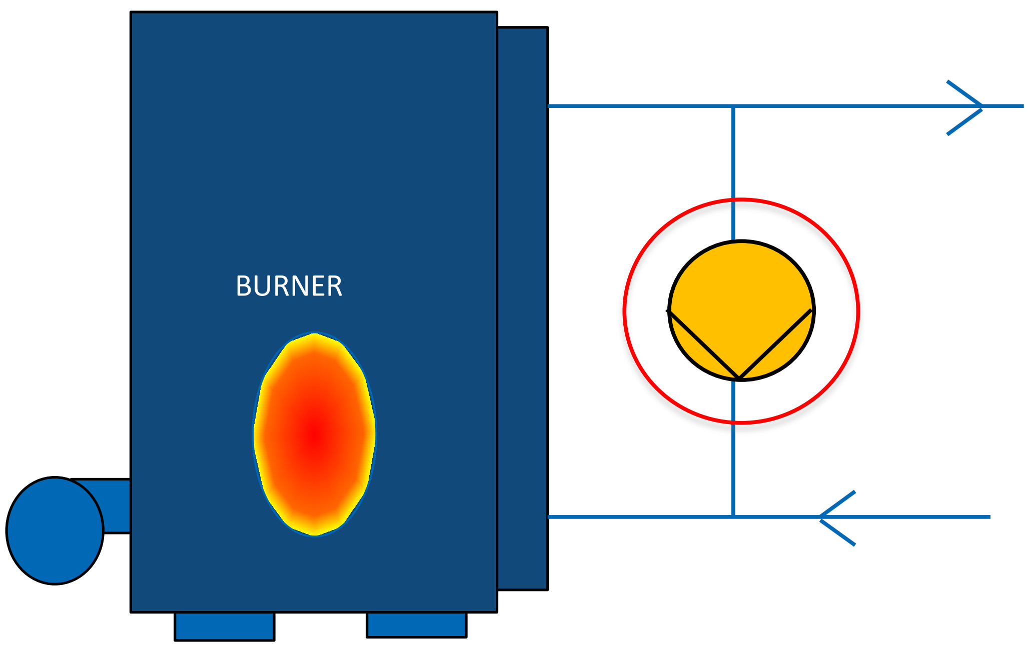
- What is beyond the pump? Can I do more than simply moving the water?

Inteligent solution – Complex solutions

- Boiler shunt pump control

BOILER SHUNT SOLUTION
STANDARD SCENARIO

CONVENTIONAL BOILER – SHUNT PUMP SOLUTION

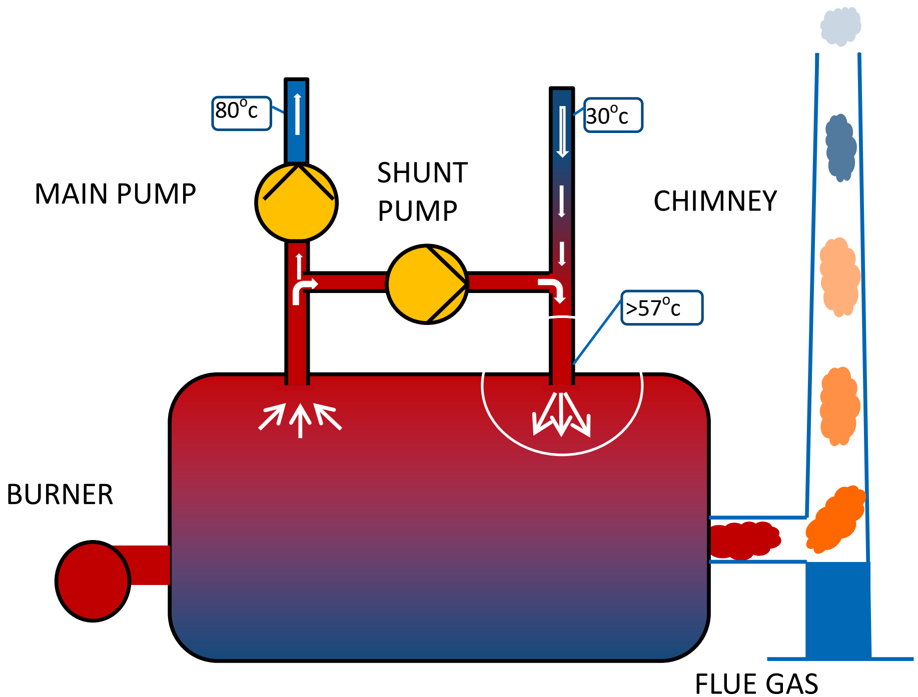


TARGET
Adjust return water temperature to installation requirements…

MEANS
Boiler shunt – connection between the flow and return pipe, equipped with a pump creating a mixing loop

BOILER SHUNT SOLUTION
STANDARD SOLUTION

SHUNT PUMP INSTALLATION SETUP SOLUTION



Sizing Example:

Power Boler: 1000 kW
Flow temp.boiler: 80°C
Return temp. system: 30°C
Min. return to boiler: 60°C

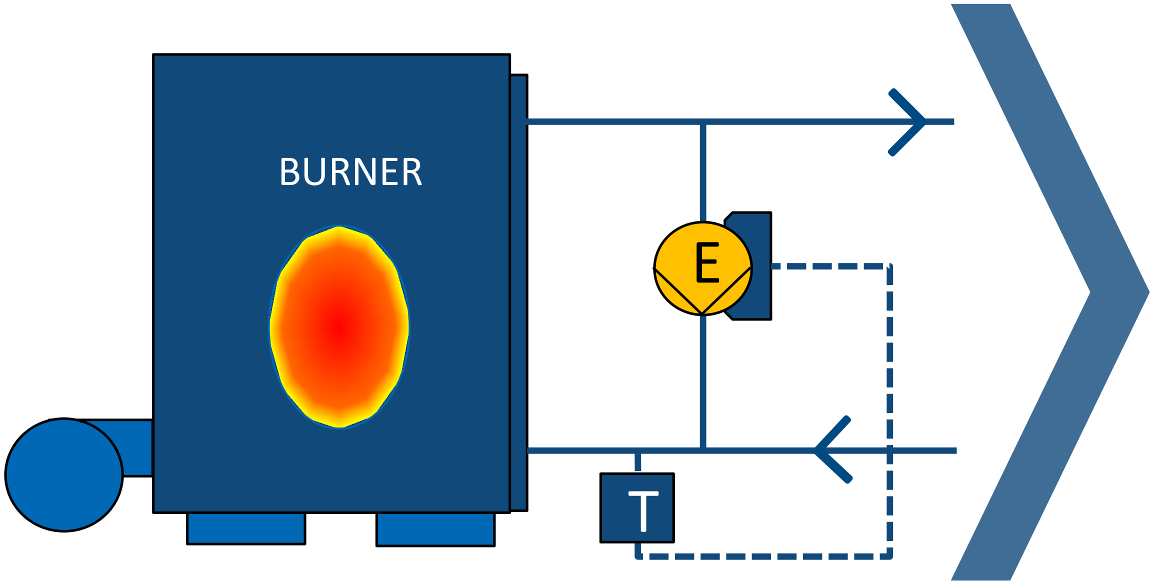
Flow "system": $\frac{1000 \times 0,86}{50}$ = 17,2 m³/h

Flow "boiler": $\frac{1000 \times 0,86}{20}$ = 43,0 m³/h

Flow shunt pump: (43,0 – 17,2) = 25,8 m³/h

BOILER SHUNT
DYNAMIC SOLUTION

SHUNT PUMP INSTALLATION SETUP SOLUTION

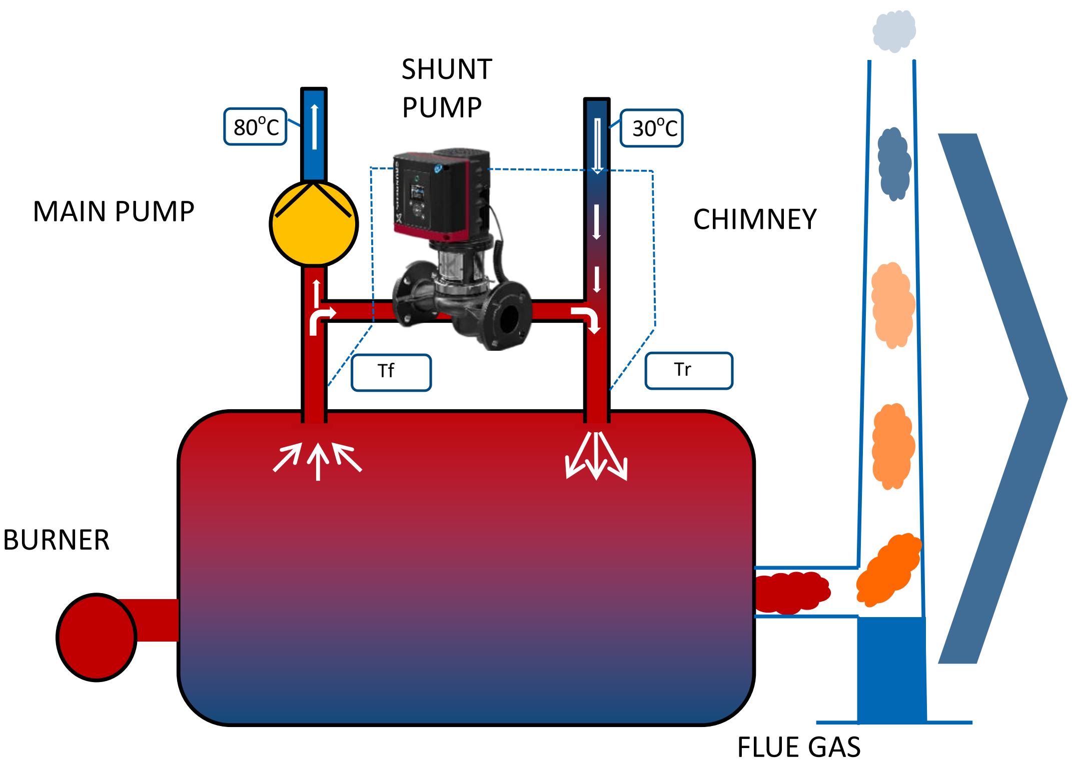


- **Temperature controlled boiler shunt pump**

•Some energy savings

•Dynamic operation

BOILER SHUNT
GRUNDFOS SOLUTION



Optimal dynamic operation

- *Constant T operation*
  - T_{set} = 60°C
- *Automatic pump start/stop*
  - Limit exceed function
  - T_{stop}=65°C, T_{start}= 60°C

Monitoring and diagnostics

- *Fault in operation warning*
  - *Limit exceed function*
  - ΔT ≥ 30K
- *2 external temperature sensors, T_f T_r*
- *Vast operation data access through pump*

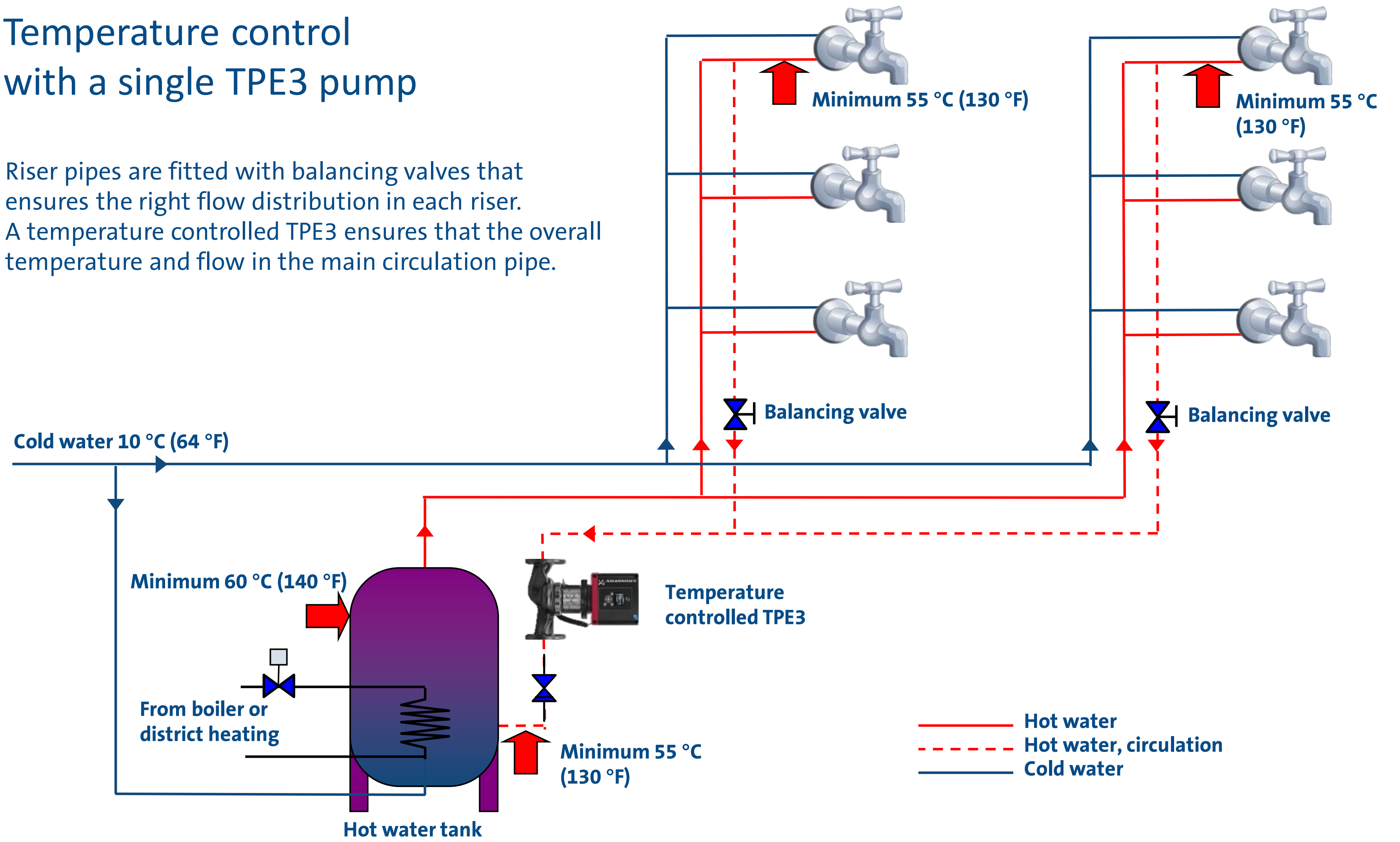
Inteligent solution – Complex solutions

- Domestic Hot Water System

DHW system control

Temperature control with a single TPE3 pump

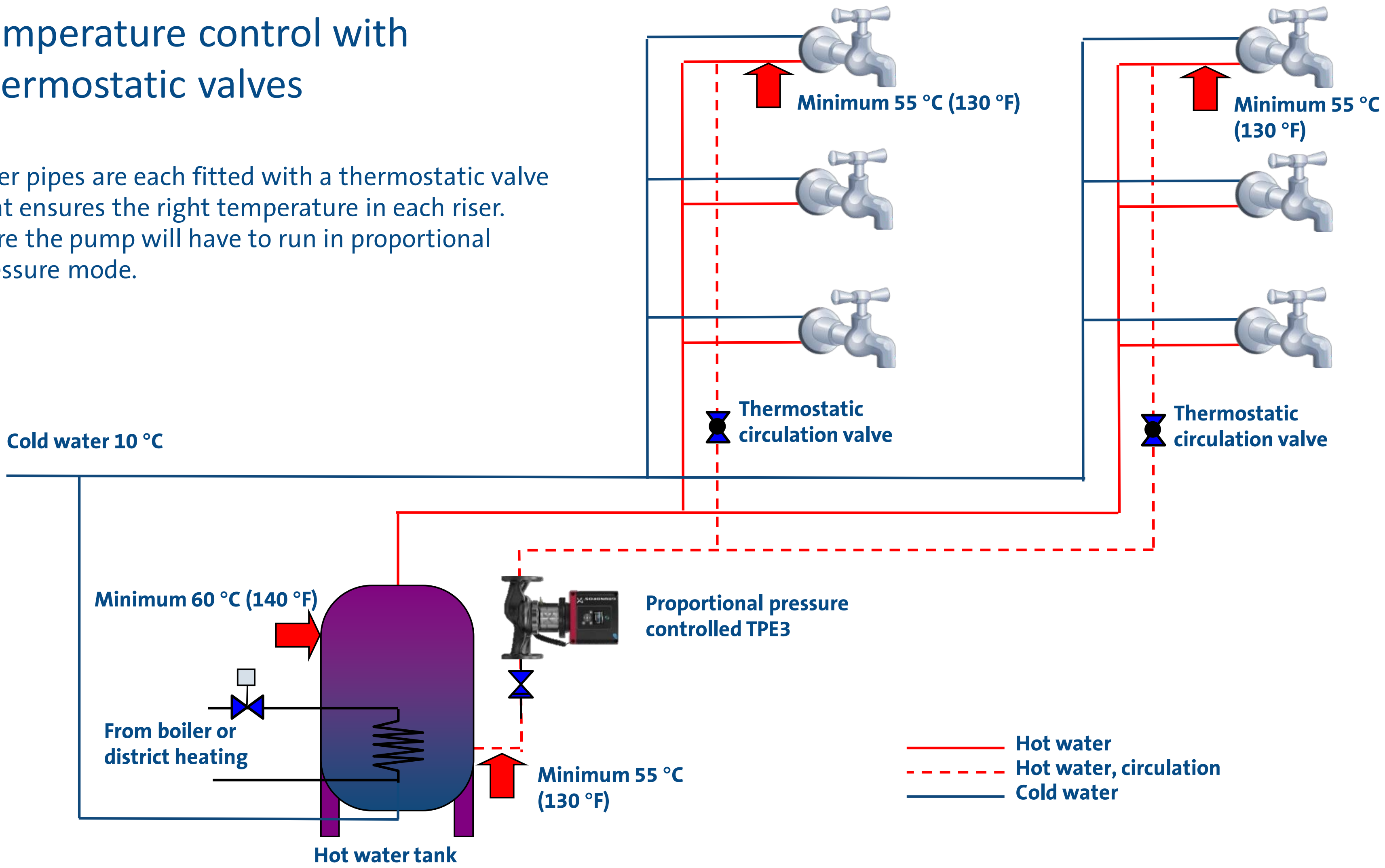
Riser pipes are fitted with balancing valves that ensures the right flow distribution in each riser.
A temperature controlled TPE3 ensures that the overall temperature and flow in the main circulation pipe.



DHW system control

Temperature control with thermostatic valves

Riser pipes are each fitted with a thermostatic valve that ensures the right temperature in each riser. Here the pump will have to run in proportional pressure mode.



How to make your system bad using electronic pumps?

- How not to do examples

Cooling tower pumps cavitating

Why:

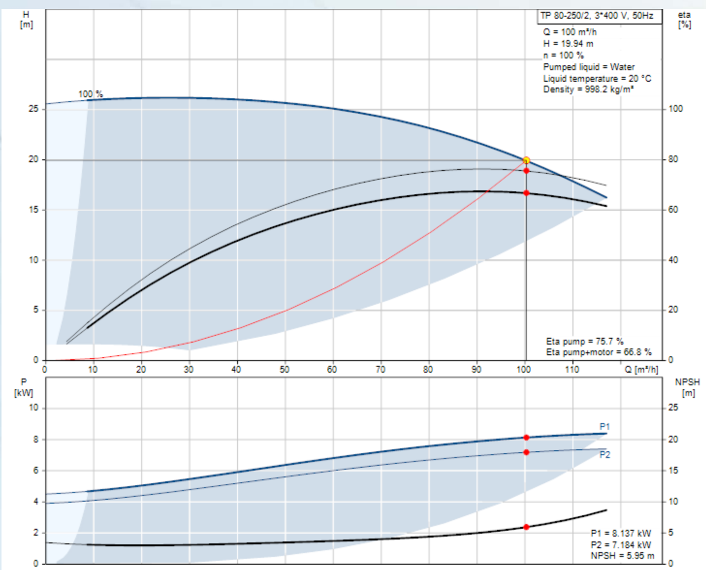
- Pressure losses smaller than designed => different system curve.
- Open loop control mode – no feedback from system, only based on condened water temp.

Effects:

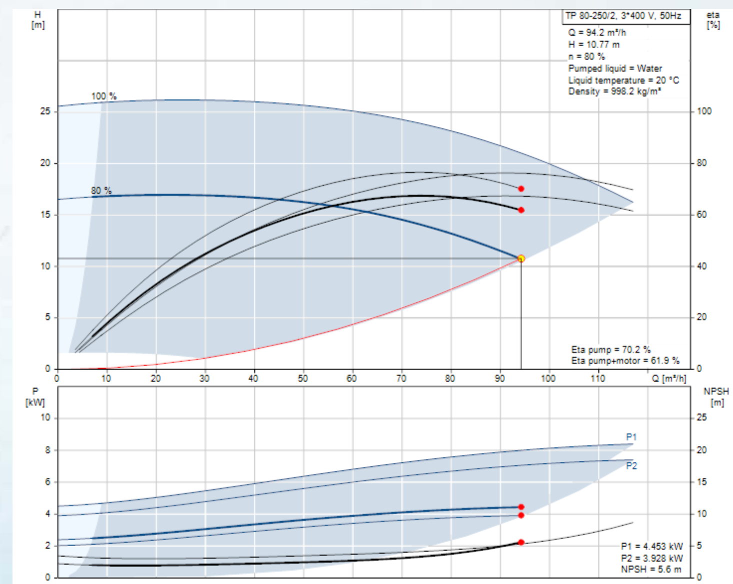
- 1 pump failure in first 12 months – impeller distroyed
- 2 set of 4 NRV destroyed in 12 months

Solutions:

- Defining real system curve – using PA kit
- Applying Constant diff. Pressure with temperature influence from chiller



PROIECT
vs.
REALITATE

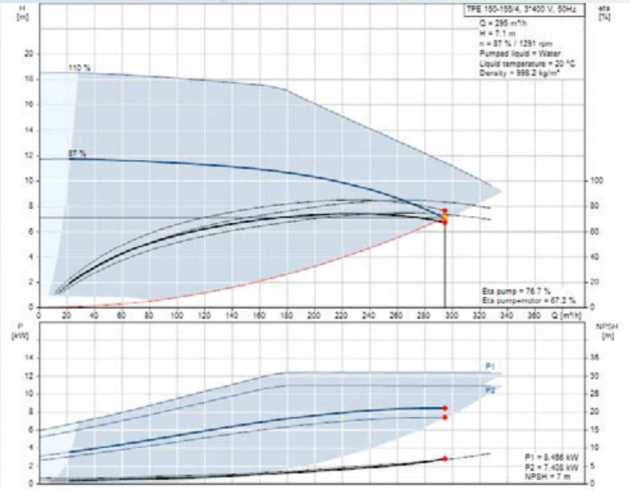


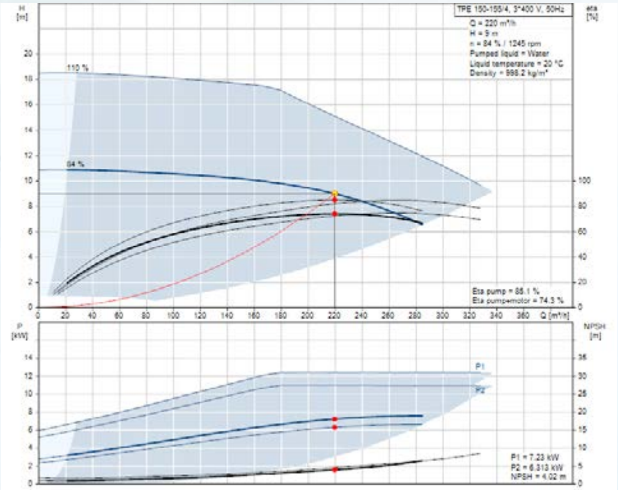
5MW wood fired boiler – efficiency issues

Why
- Smaller system pressuredrop => different system curve
- Electronic pump without pressure sensor
- No balancing valves

Results:
- At 80% speed pump get out of QH curve – high noise, high bearing loads, possibly cavitation
- Boiler thermal capacity decrease (bad efficiency) due to higher water flow than designed

Solutions:
- Installing DP sensors, setting correct DP to avoid pump runing outside of range.
- Hydraulic balancing must be done with existing equipments.





Recap

- Using electronic pumps let us reduce electrical consumption if right control mode is selected
- Using electronic pumps will not replace balancing valves, but might reduce their number.
- Using zoning of systems will allow you to get better global efficiency
- Use of added value functions will allow you to diagnose the systems weak points and give a better feedback.
- **Smart solutions will let you do your job better, but it won't do your job!**
- Better LCC level will lead you to more valuable buildings and systems.

Take away message:

Smart Building Era is the present. Using of smart technologies is no longer just a fancy thing. It will make the difference between good solutions and best solutions!

Questions?

Thank You!