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Differential Pressure Control

Hydronic College

by IMI Hydronic Engineering Inc.

Engineering GREAT Solutions

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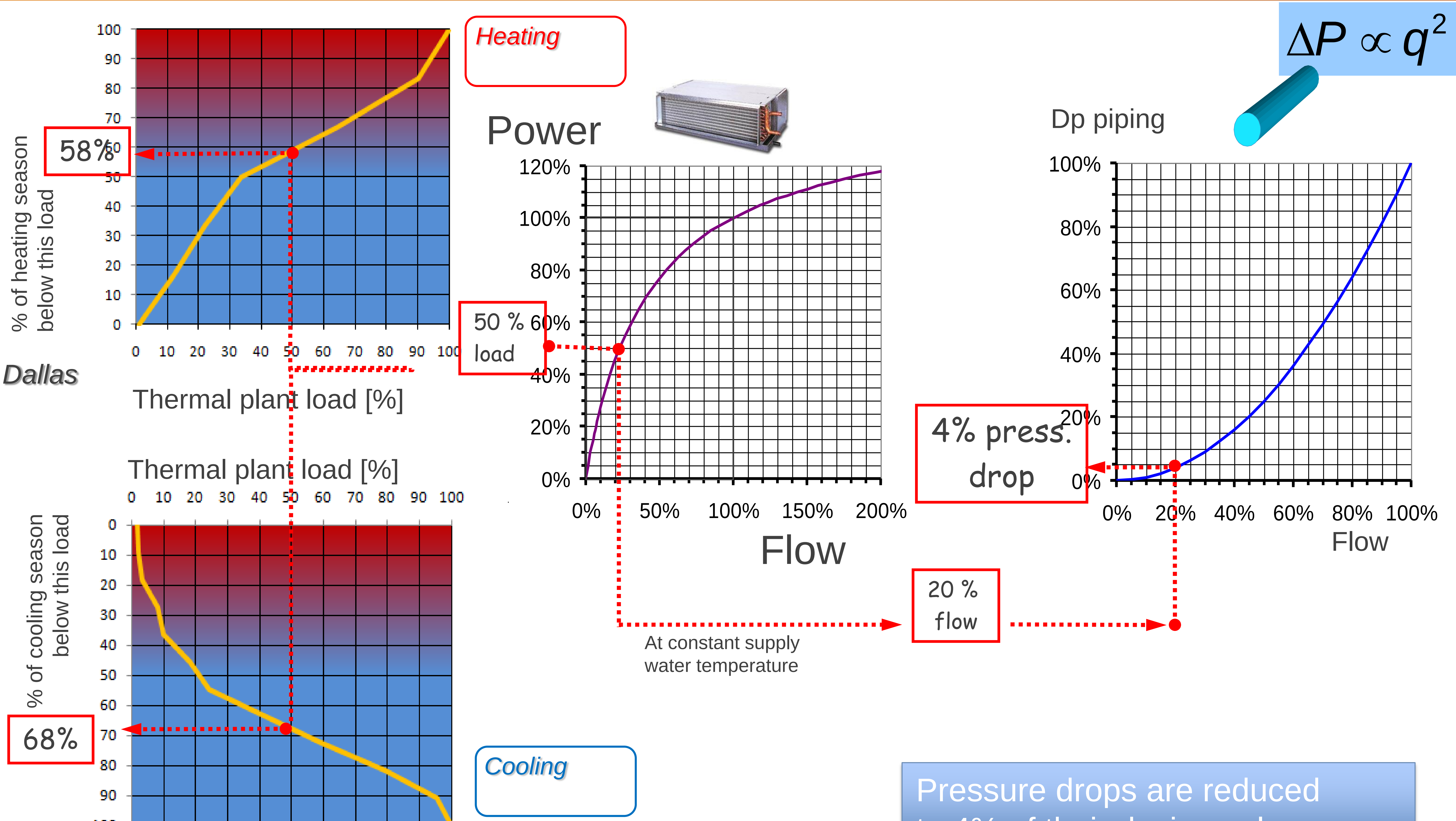
Why differential pressure control?

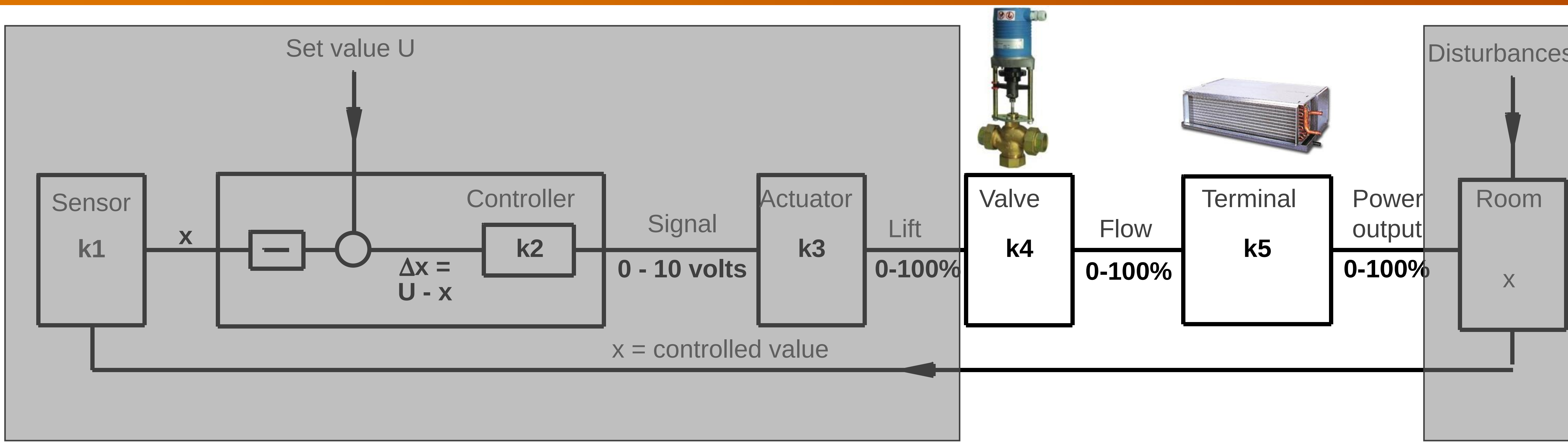
- Control valves work with improved authority, therefore their performance is improved
- Reducing pump head and keep high controllability in the system
- Control valves are pressure relieved, so low force (= lower cost) actuators can be used
- Noise in control valves is reduced or removed completely
- Based on stabilized differential pressure across the circuit, the flow is limited.
- Circuits is a pressure independent modules. Which means:
  - *That the changes in other parts of the system do not affect the circuit*
  - *Large plants can be balanced module by module independently*
  - *New modules can be added to the system without rebalancing*

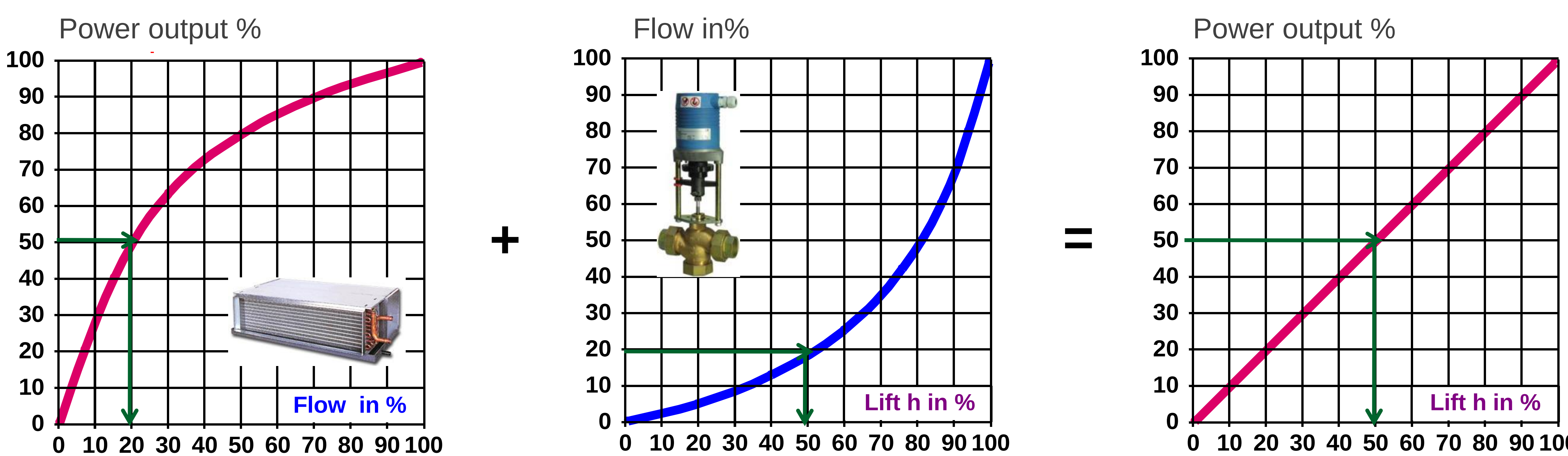
Differential pressure variations



Pressure drops are reduced to 4% of their design value.

Control loop

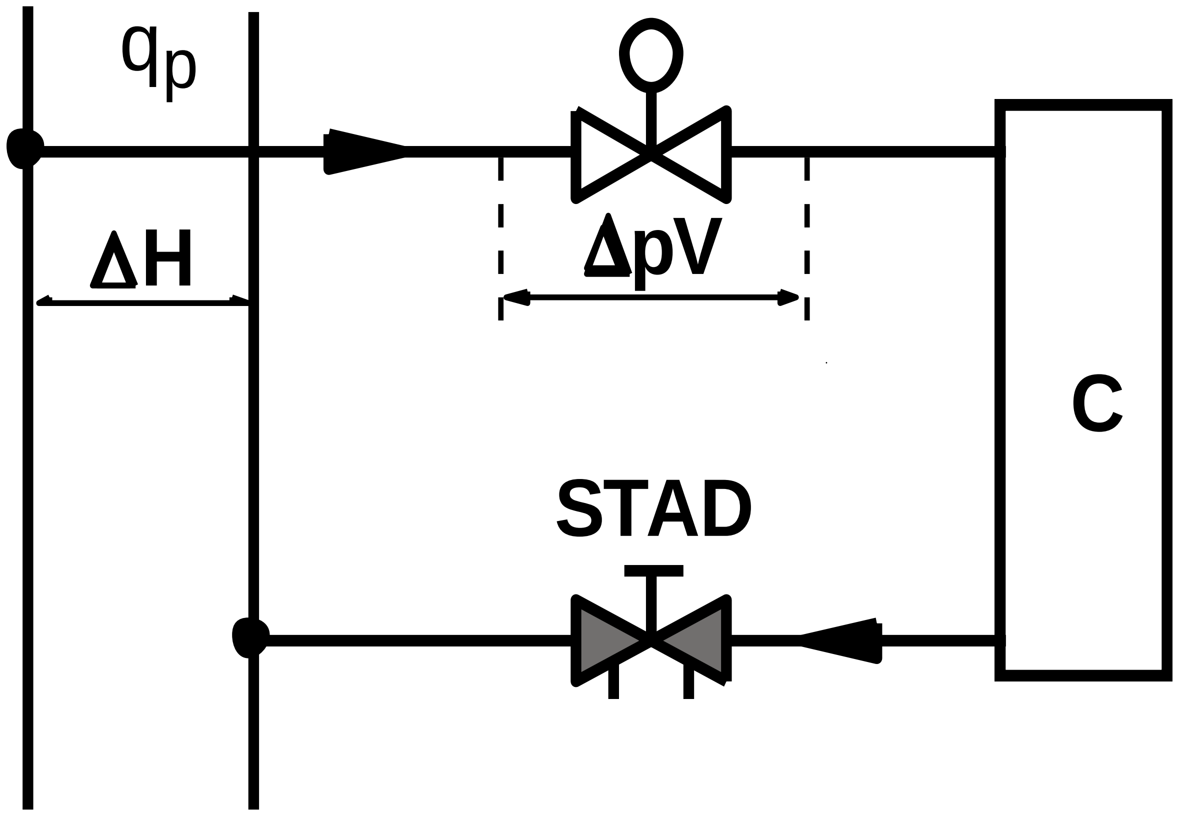




Terminal unit characteristic

Control valve characteristic

Control valve authority

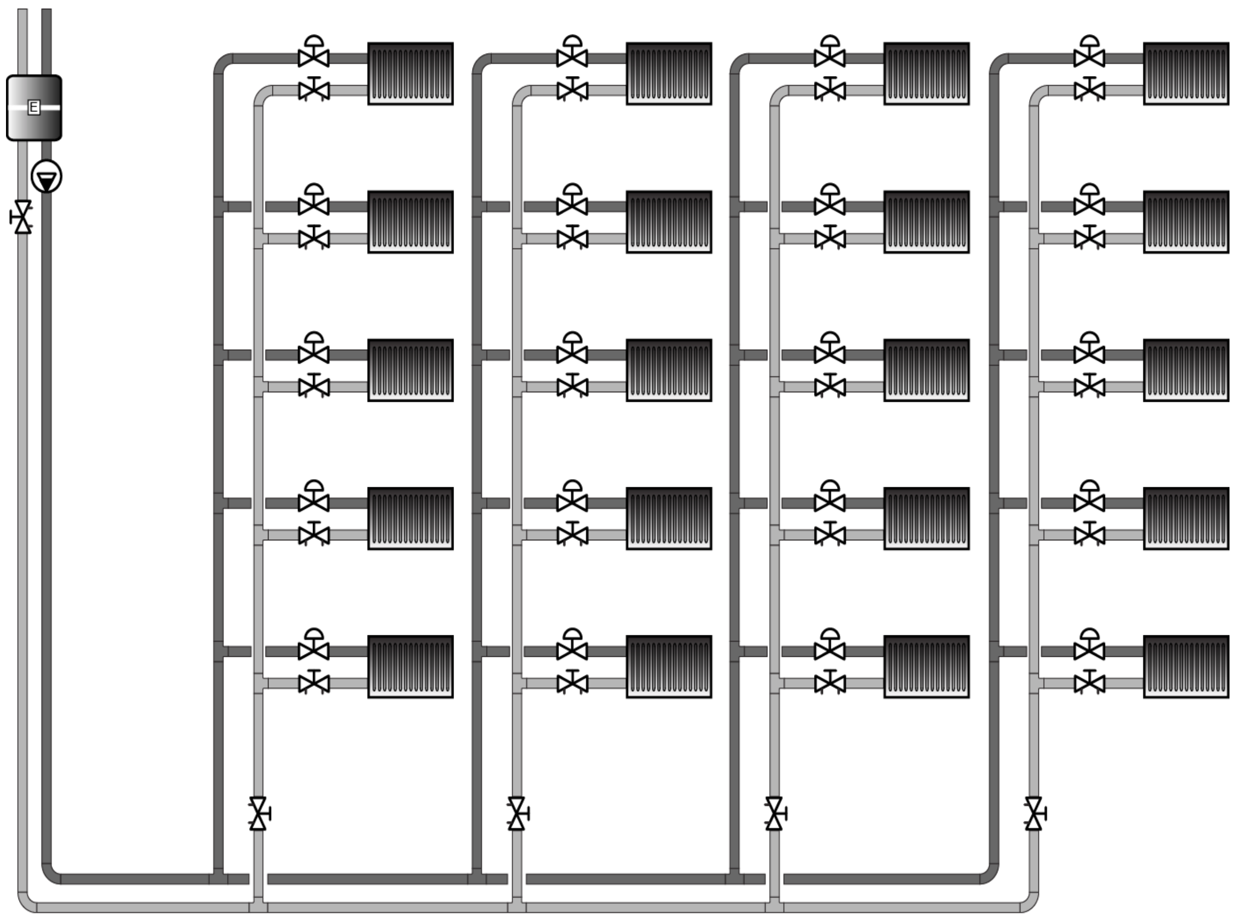


$$\beta = \frac{\Delta P_{\text{Control valve fully open and design flow}}}{\Delta P_{\text{Control valve fully shut}}}$$

The authority (β) formulates how much the differential pressure builds up on the control orifice of a control valve when it is closing

Its value indicates how effectively the control valve can reduce the flow while it is closing.

2-way control valve authority (variable flow)



Constant as soon as the valve Cv is chosen (Δp_V).

$$\beta = \frac{\Delta P_{\text{Control valve fully open and design flow}}}{\Delta P_{\text{Control valve fully shut}}}$$

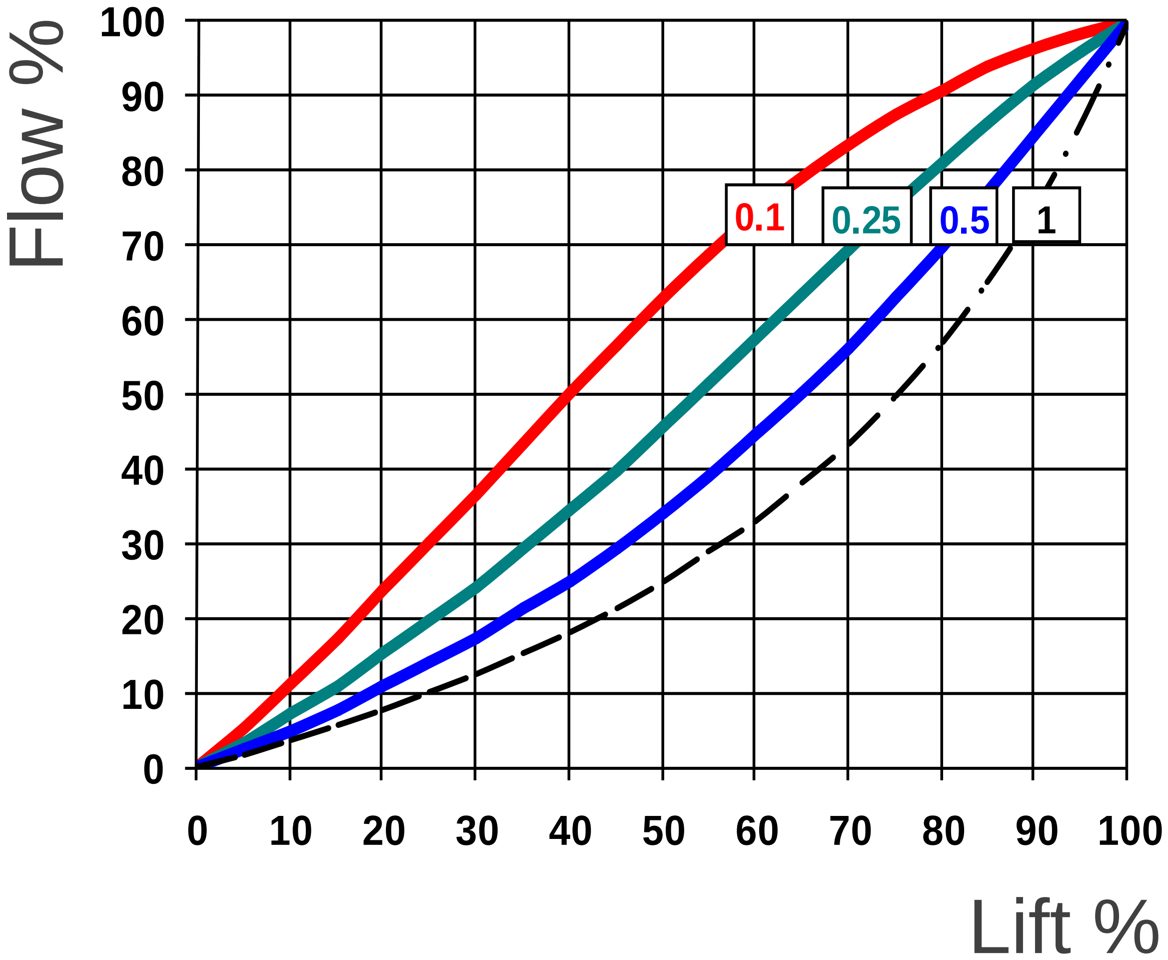
Variable, depends on flows in the piping,

thus also on the opening of all the other control valves.

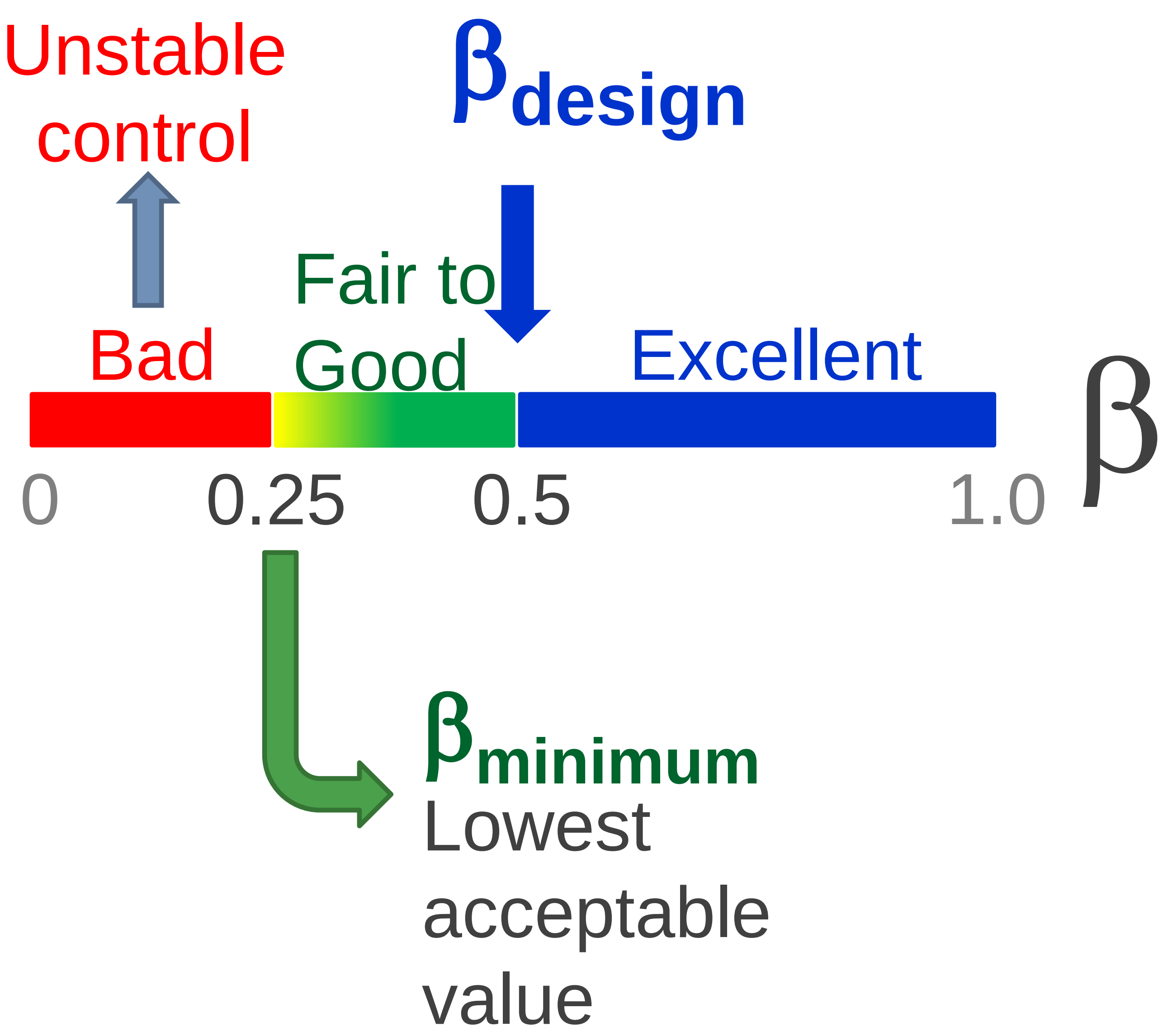
In a *variable* flow distribution, the authority of a control valve is *variable*.

Distortion of valve characteristic

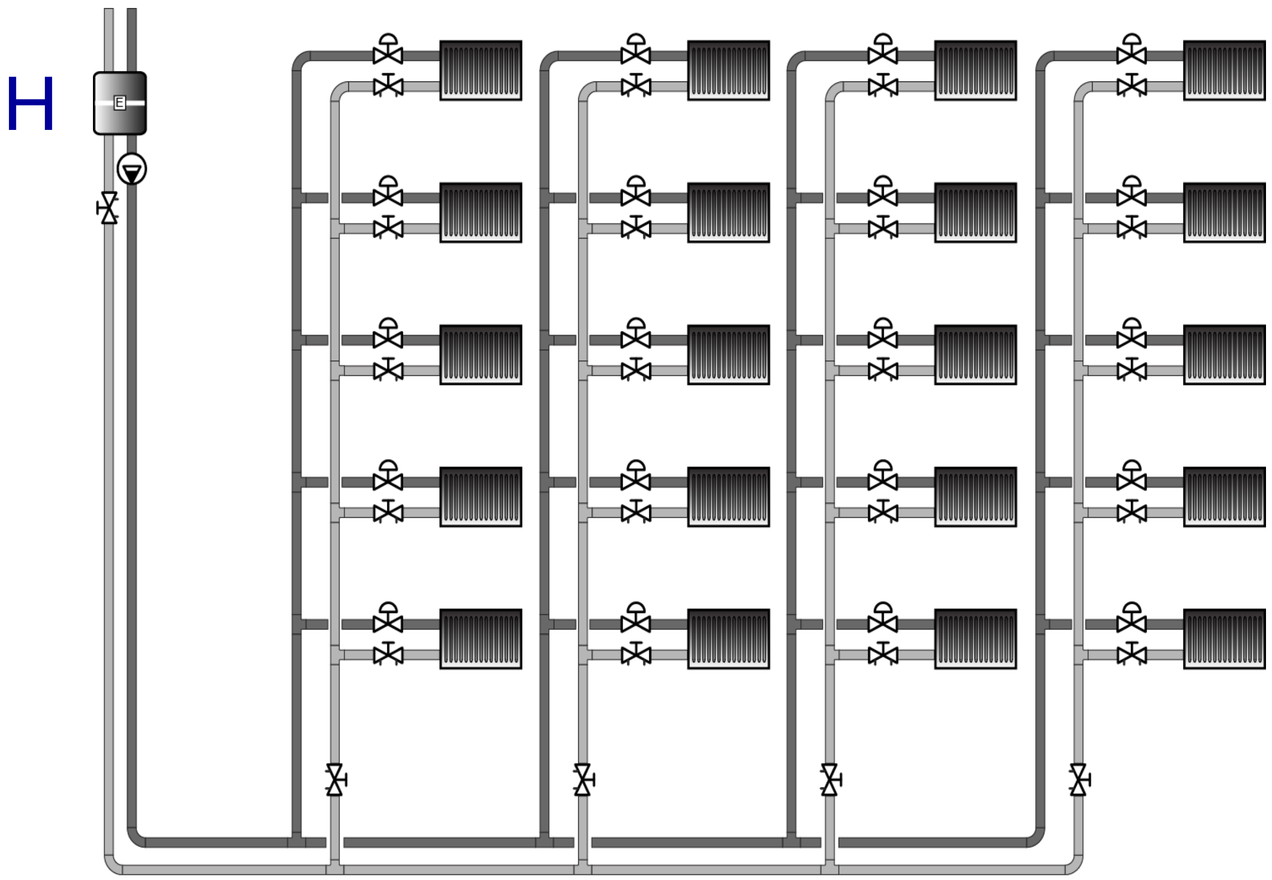
The lower the authority,
the larger the Δp variations on the control valve,
the larger distortion of the valve characteristic



Control valve with
Equal-percentage characteristic (EQM)



Variable authority of 2-way control valves

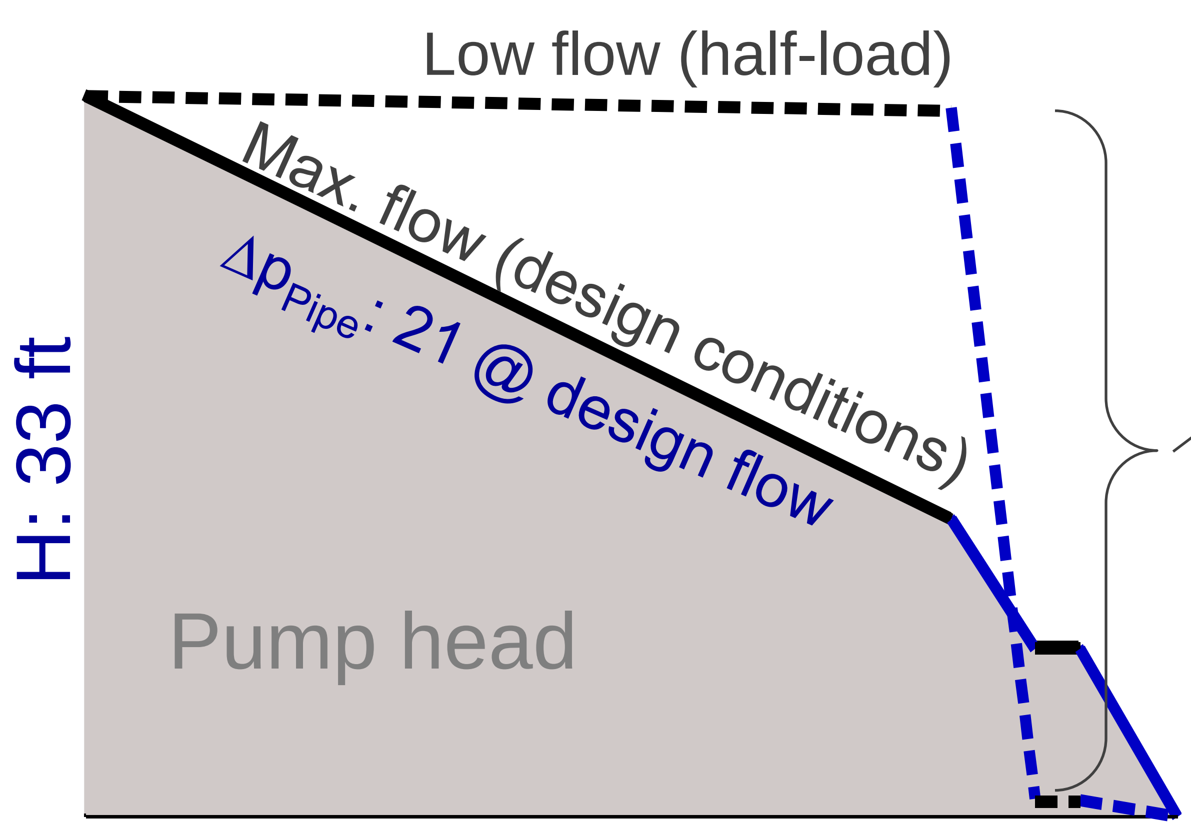


Authority in design conditions:

$\beta \approx 5/(5+7) =$ **0.42**

Authority at half-load:

$\beta = 5/(5+7+0.96*21) =$ **0.15 !**



0.96*21 ft +0.96*7 ft ≈ 26.9 ft in excess in the valve at half-load

5 ft in the valve

7 ft in the circuit

VSP does not allow to compensate for all local Dp variations in the plant

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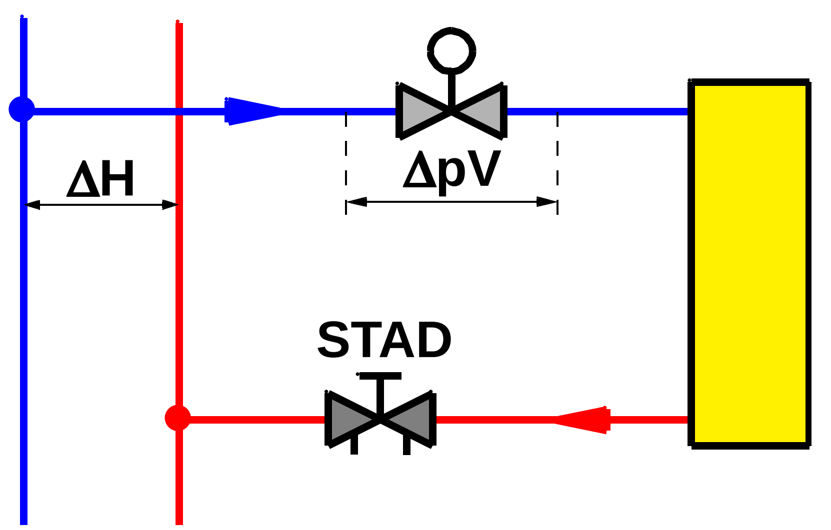
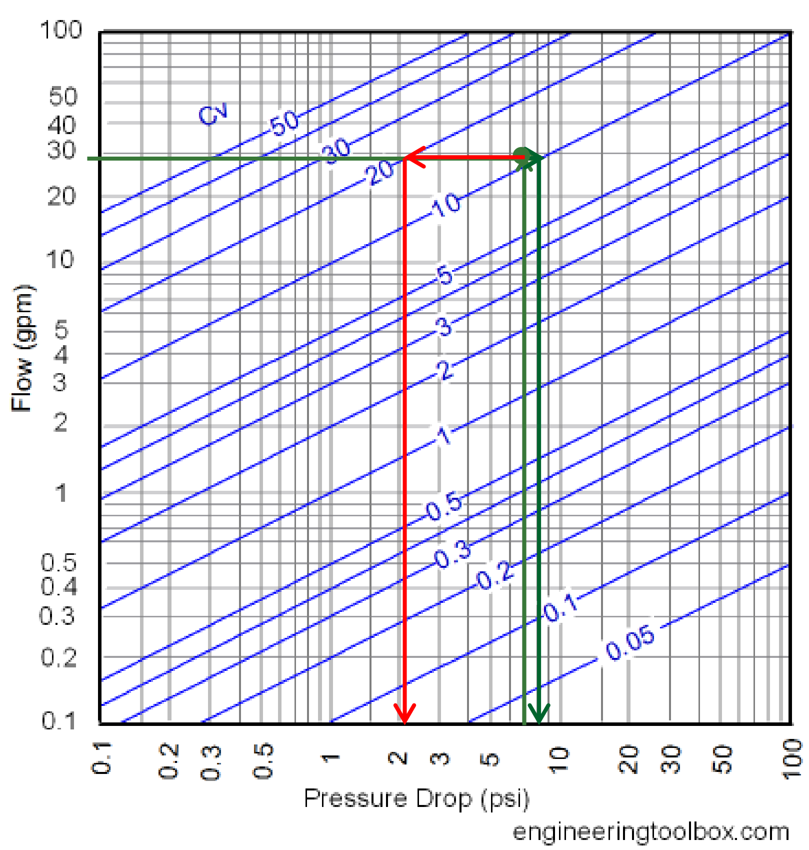
Control valve oversizing

Control valves are commercially available with Cv values increasing according to the Reynard series: **Cv:....... 2.0 3.0 4.0 5.0 10 20 30**



Flow to a FCU of 29 gpm, Δp 5 psi and 2 psi in connecting pipes. the commercially available control valves create a design ΔpV of:

Cv:	11	20	10	
ΔpV [psi]	7	2.12	8.49	NOTHING in between
β_{design}	0.5	0.23	0.55	
ΔH [psi]	14	9.12	15.49	

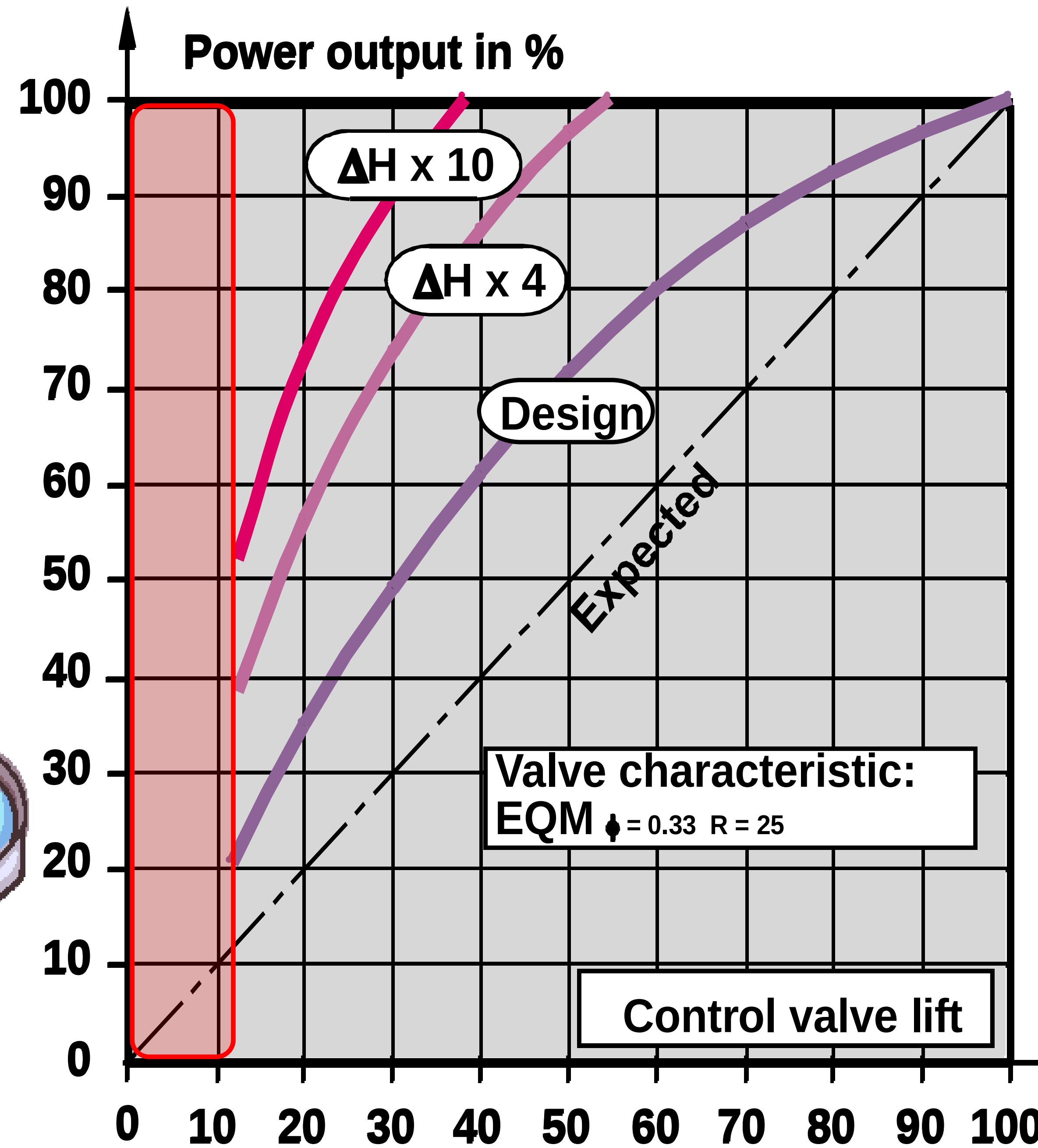


Conclusion:

Control valves are generally **oversized**.

Effect of Dp variations on controlled heat output

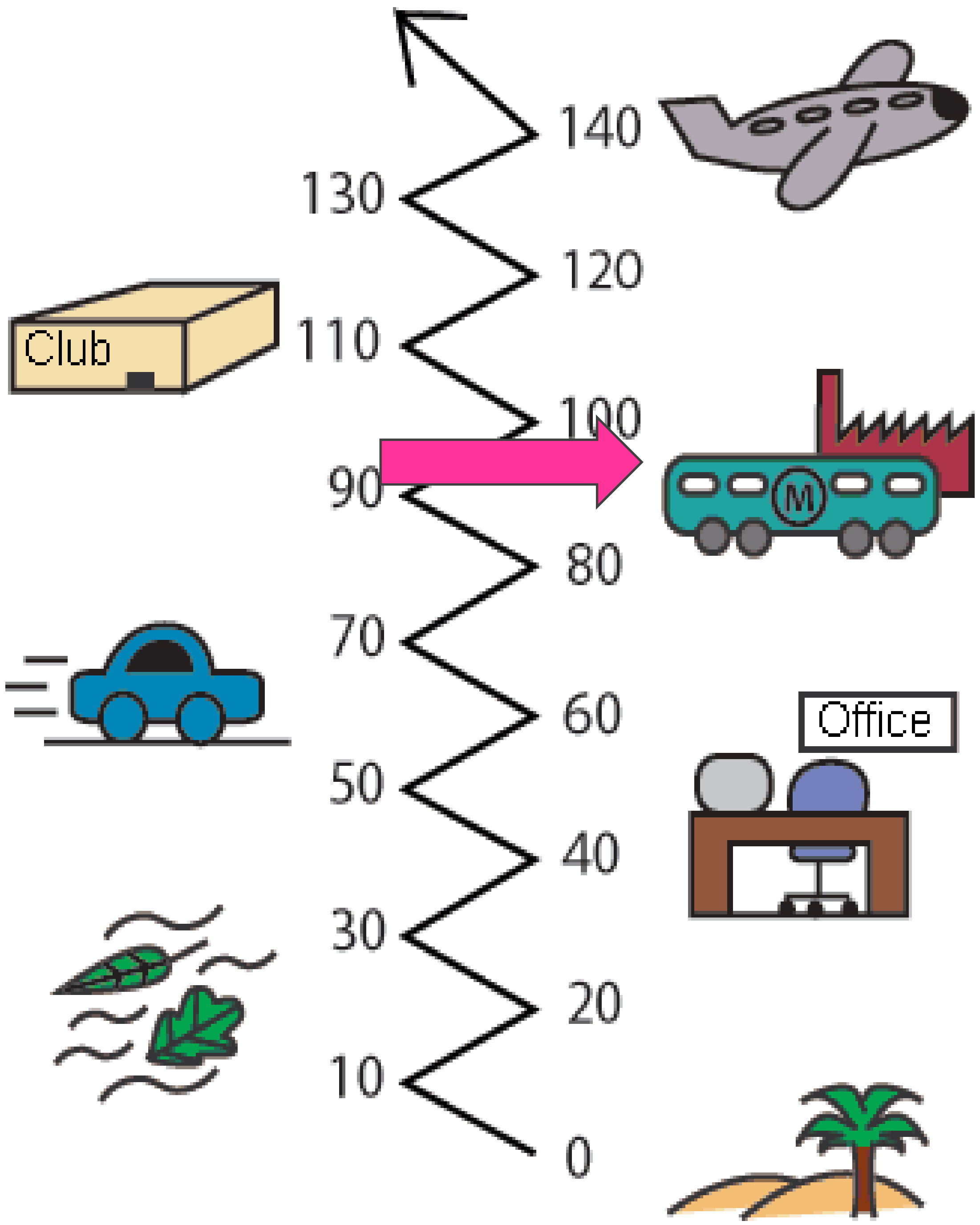
Δp variations distort the characteristic of the control valve
⇨ the nonlinear characteristic of the terminal unit is no longer compensated



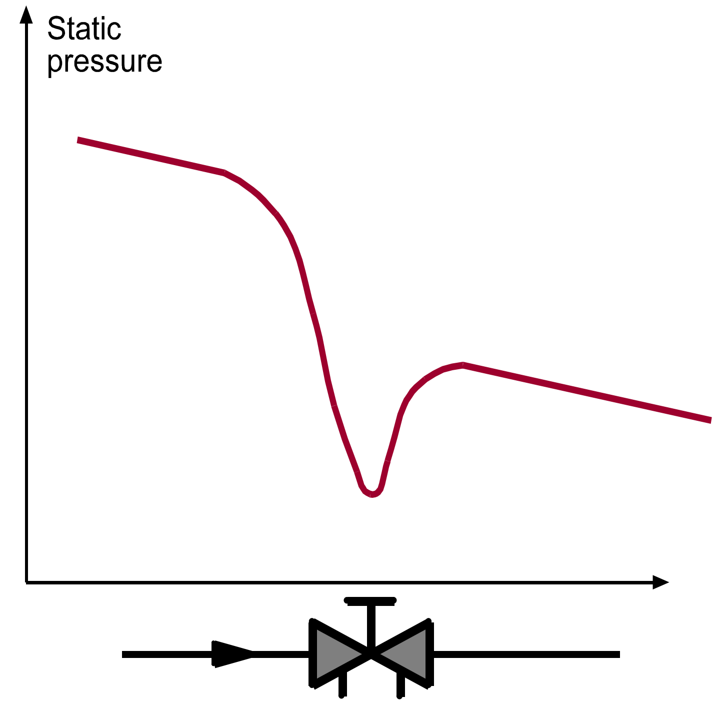
Rangeability area of the control valve

Noise

Sound pressure level [dB]



Cavitating valve



RULE OF THUMB : Static pressure at the inlet of the valve should be at least twice the pressure drop in the valve.

Closing of control valves

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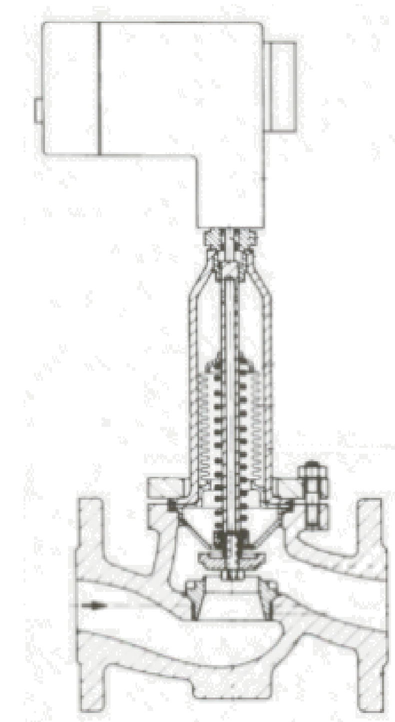
According to its design, each valve has a required actuation **close-off force or torque** that depends on:

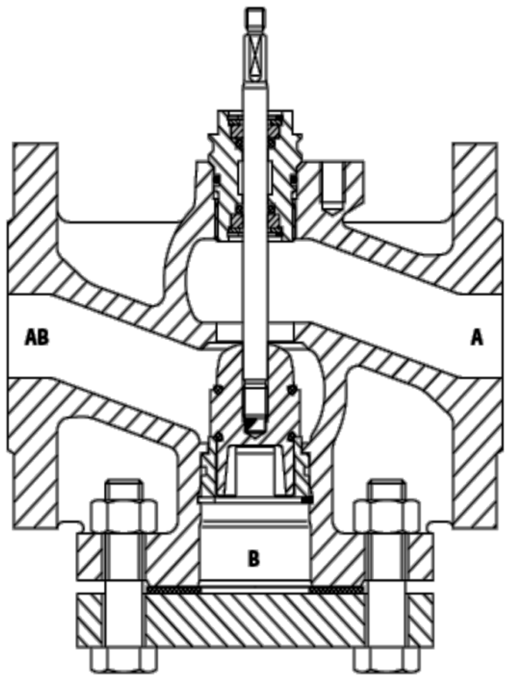
- Tension of the return spring, if any,
- Friction with o-rings and seals,
- Differential pressure applied on the plug.

Each control valve/actuator combination has a certain **close-off differential pressure**



Summary and Max. close-off differential pressure ΔPc

Type	Conn. DN	in.	Kv	Cv	Kv	Cv	MZ18L / 18A / 18B 180 N (40 lbf.) Max. ΔPc kPa	psi	MZ10T 96 N (22 lbf.) Max. ΔPc kPa	psi
VZ22	15	½"	0.16	0.19			1600	232	600	87
VZ22	15	½"	0.25	0.29			1600	232	600	87
VZ22	15	½"	0.40	0.47			1600	232	600	87
VZ22	15	½"	0.63	0.74			1600	232	600	87
VZ22	15	½"	1.00	1.17			1200	174	180	26
VZ22	15	½"	1.6	1.9			1200	174	180	26
VZ22	20	¾"	2.5	2.9			400	58	50 1)	7.3
VZ22	20	¾"	4.0	4.7			400	58	50 1)	7.3
			A-AB:		B-AB:					
VZ32	15	½"	0.25	0.29	0.16	0.19	800	116	500	73
VZ32	15	½"	0.40	0.47	0.25	0.29	800	116	500	73



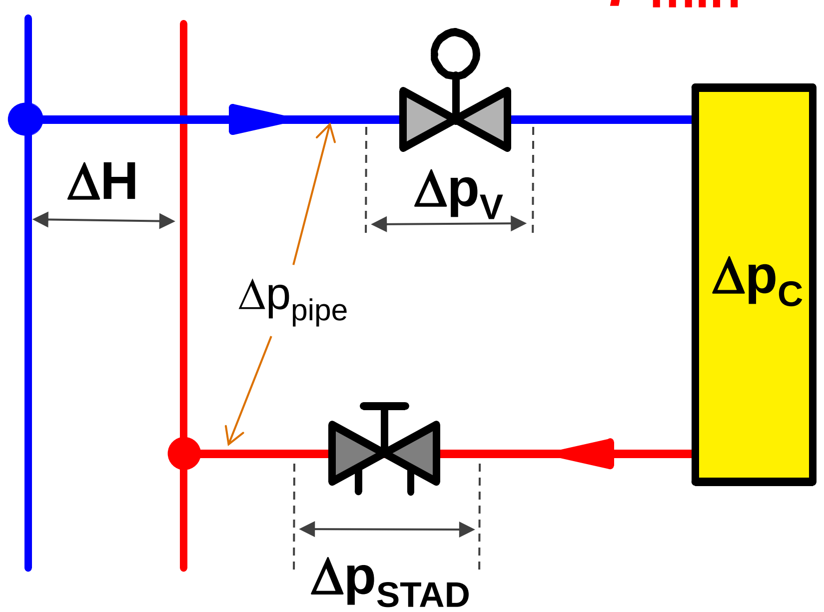
Hydronic condition no. 2

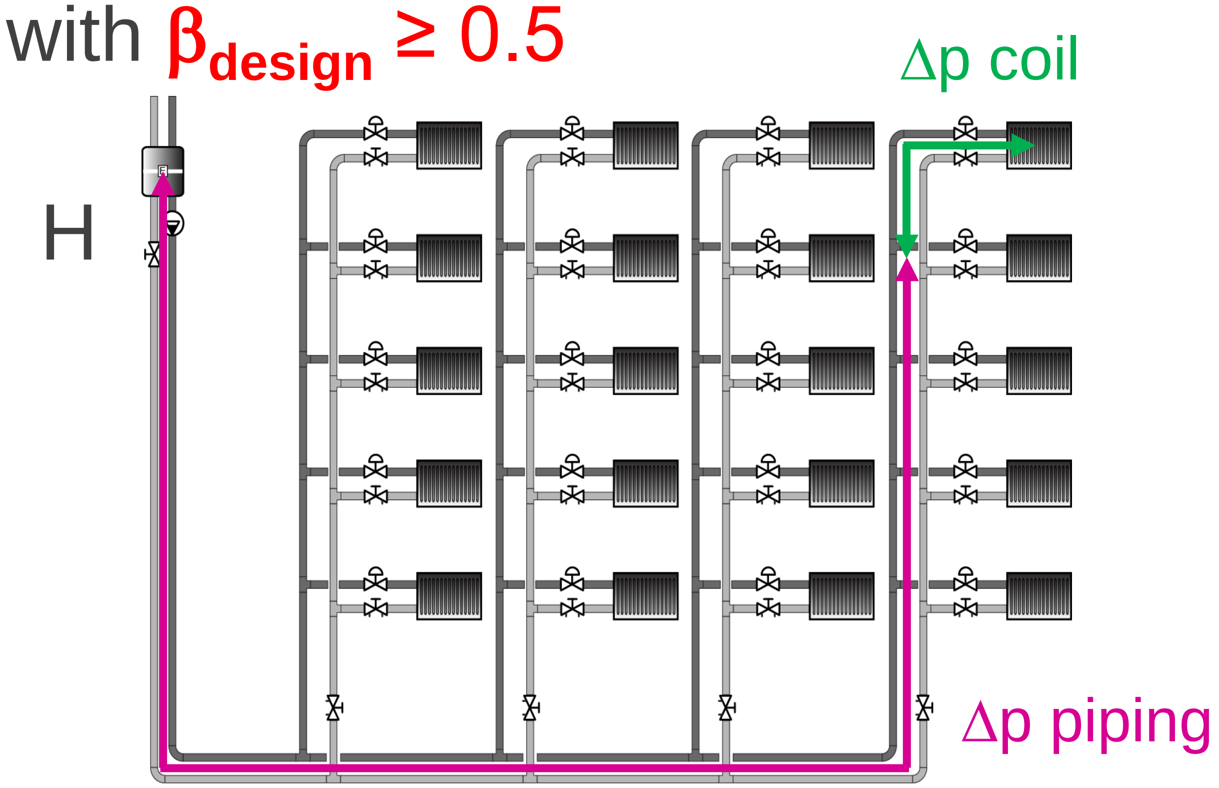
The differential pressure across control valves must not vary too much.

Control valve authority

To acheive good control it's recomended to fulfill two rules on authority:

1. Size the control valve with a Cv with $\beta_{design} \geq 0.5$
2. Ensure that $\beta_{min} \geq 0.25$





Rule no 1:

$$\Delta p_V \geq \Delta p_C + \Delta p_{pipe} + \Delta p_{STAD}$$

or

$$\Delta p_V \geq 0.5 \times \Delta H$$

$$\boldsymbol{\beta_{design} \geq 0.5}$$

Rule no 2:

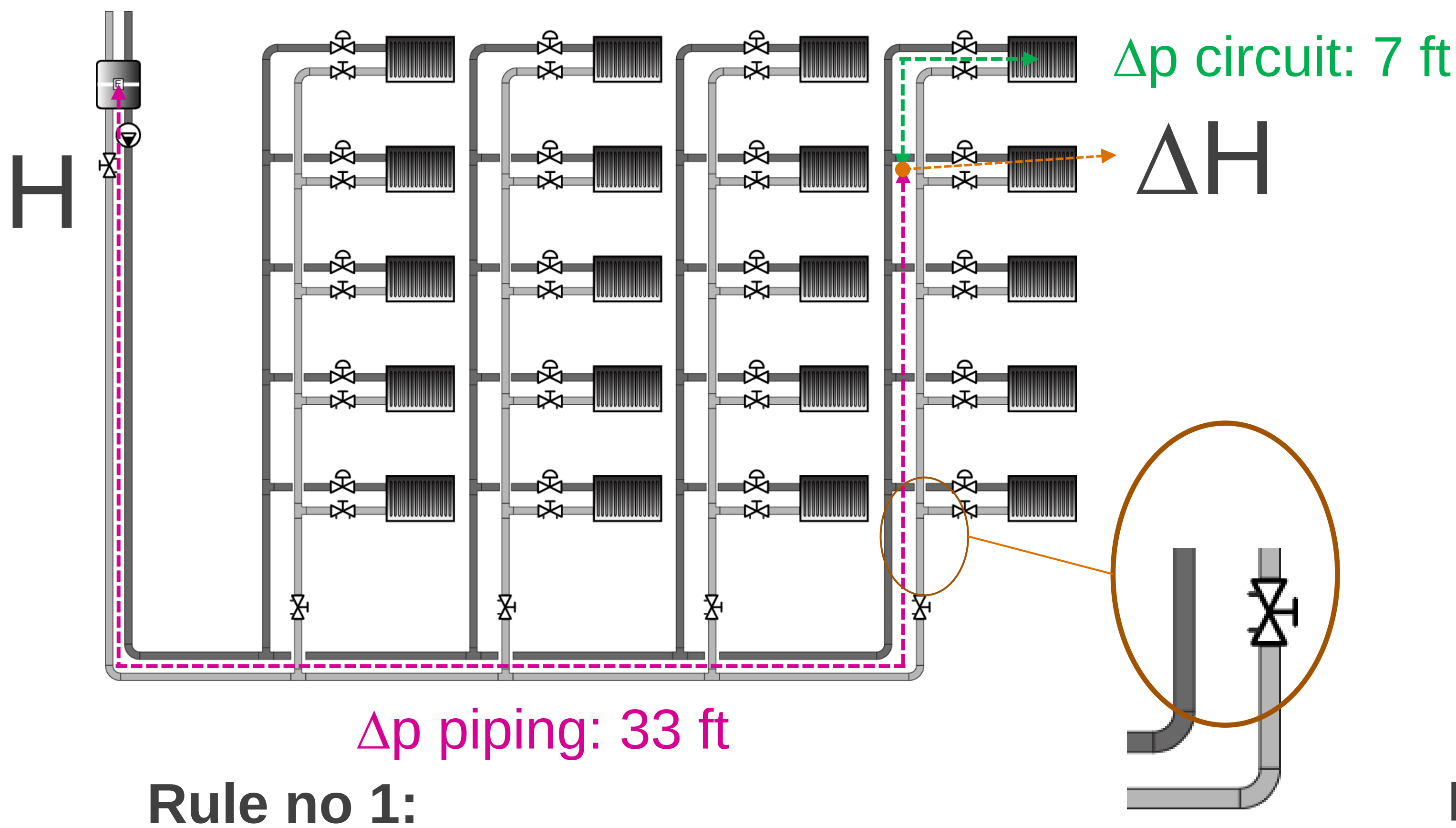
$$\Delta p_V \geq (\Delta p_{piping} + \Delta p_C)/3$$

or

$$\Delta p_V \geq 0.25 \times H$$

$$\boldsymbol{\beta_{min} \geq 0.25}$$

Improved control by correct control valve sizing



IDEA

Ensure **design** authority of **at least 0.5** and **minimum** on **0.25** in **all** control valves in the **worst** conditions.

$$\beta_{design} = \frac{\Delta P_{\text{Control valve fully open and design flow}}}{\Delta H}$$

$$\beta_{min} = \frac{\Delta P_{\text{Control valve fully open and design flow}}}{H}$$

Rule no 1:

For obtaining a design authority of 0.5:

Δp in control valve must be ≥ 0.5×ΔH

Since Δp circuit = 7 ft,
Δp in control valve must be ≥ 7 ft

Final pump head = 40 + 7 = **47 ft**
β_{design} = 7/14 = 0.5 but
β_{min} = 7/47 = 0.15

Rule no 2:

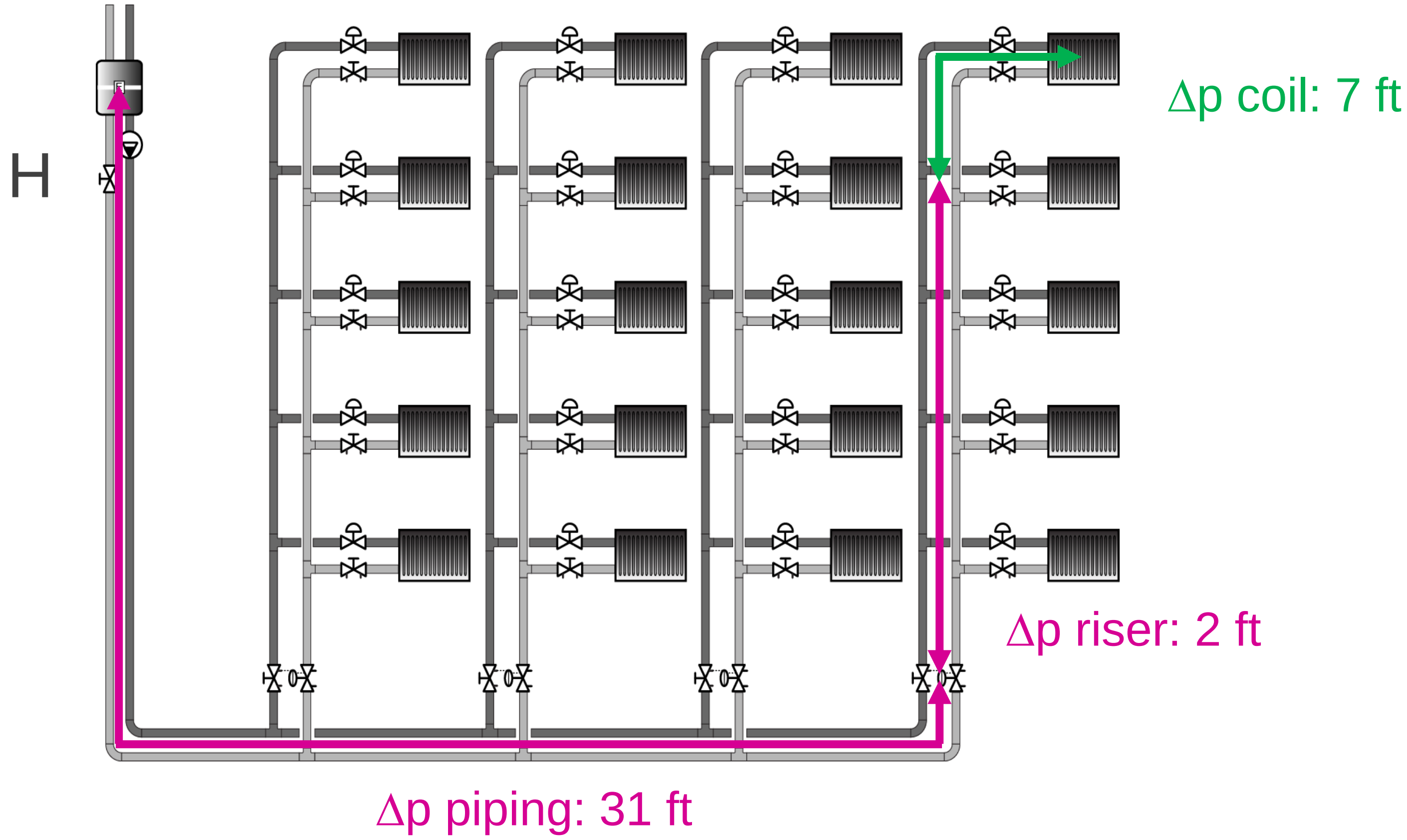
For obtaining a minimum authority of 0.25:

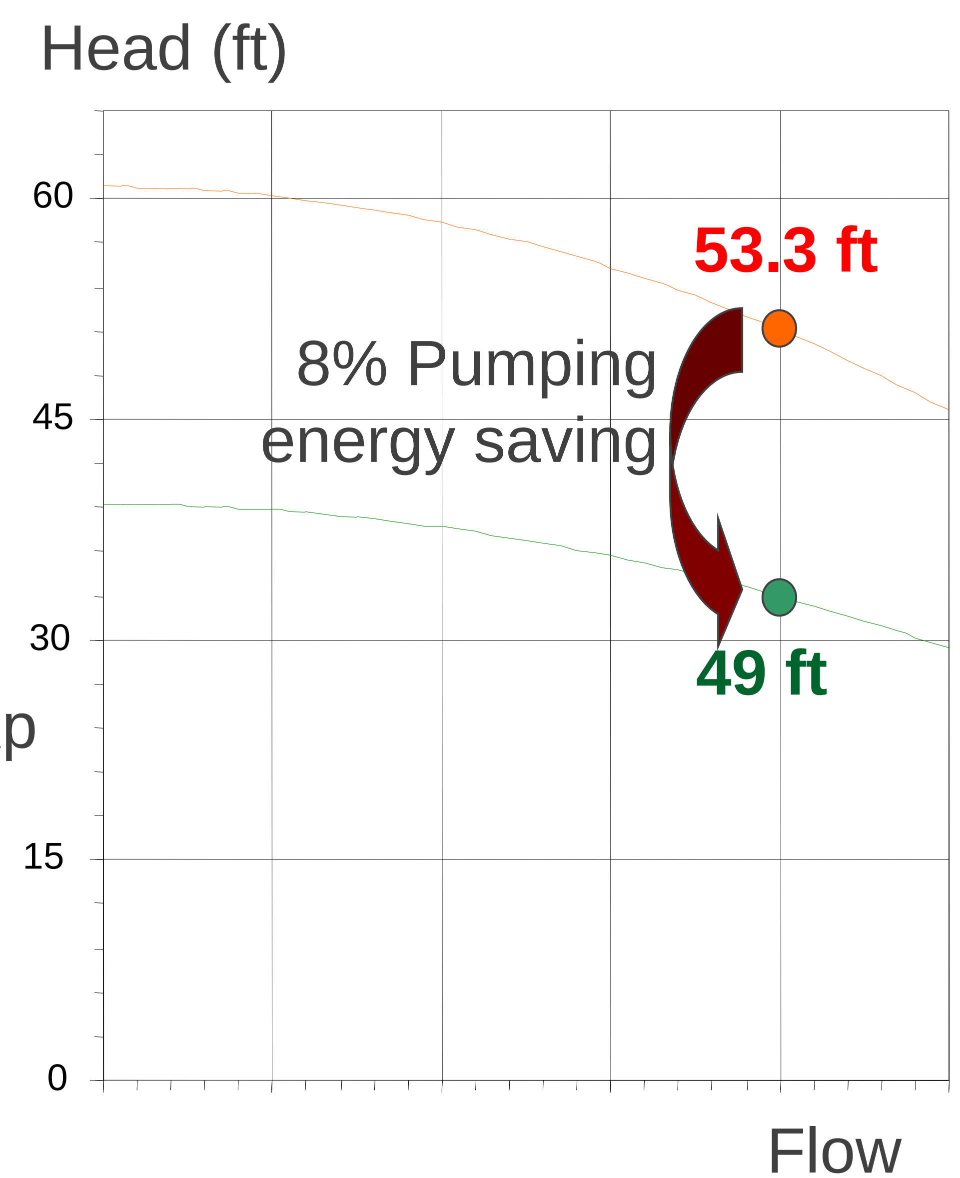
Δp in control valve must be ≥ 0.25×H

Since Δp piping + circuit = 33 + 7 = 40 ft,
Δp in control valve must be ≥ 13.3 ft *(40/3)*

Final pump head = 40 + 13.3 = **53.3 ft**
β_{design} = 13.3/20.3 = 0.66 and
β_{min} = 13.3/53.3 = 0.25

Improved control with reduced pumping energy





Control valve sizing with Dp control:

For obtaining a design authority of 0.5 and min of 0.25:

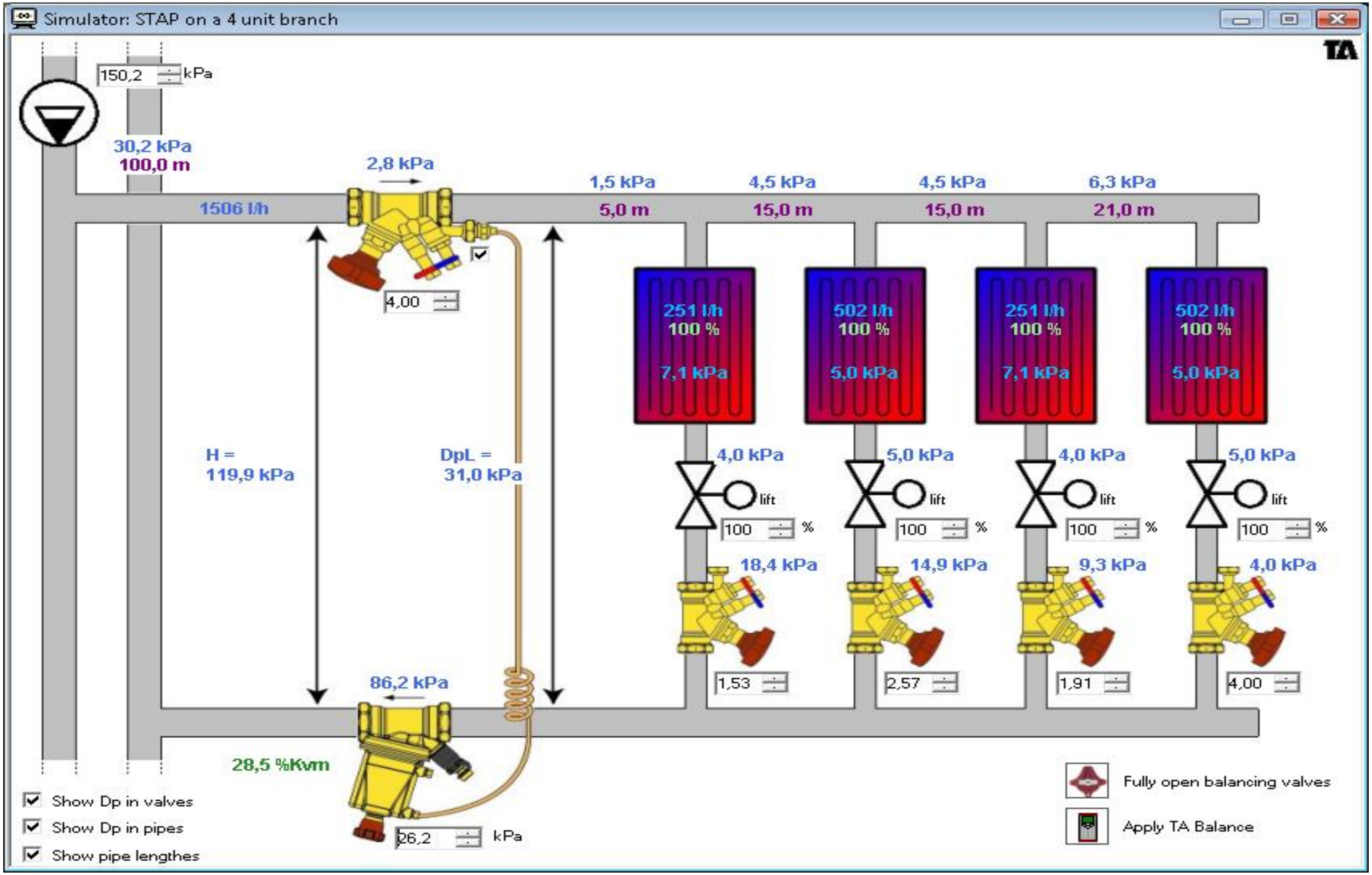
Δp in control valve must be ≥ 0.5×ΔH and ≥ 0.25 of stabilized Δp

Since Δp piping + Δp circuit = 7 ft,
Δp in control valve must be ≥ 7 ft

Final stabilized Δp = 7 + 7 + 2 = 16 ft
β_{design} = 0.50 and β_{min} = 0.44

Final pump head = 31 + min Δp of DpC (2 ft) + 2 + 7 + 7 = **49 ft**

Simulation

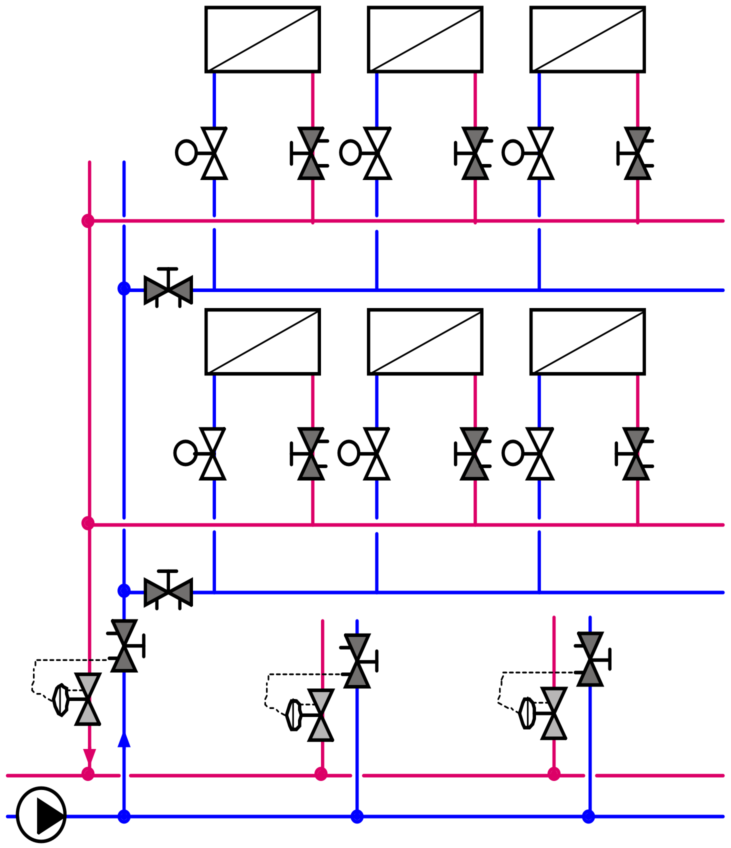


Simulator: STAP on a 4 unit branch
150,2 kPa
30,2 kPa
100,0 m
2,8 kPa
1506 l/h
1,5 kPa
5,0 m
4,5 kPa
15,0 m
4,5 kPa
15,0 m
6,3 kPa
21,0 m
4,00
251 l/h
100 %
7,1 kPa
502 l/h
100 %
5,0 kPa
251 l/h
100 %
7,1 kPa
502 l/h
100 %
5,0 kPa
H =
119,9 kPa
DpL =
31,0 kPa
4,0 kPa
5,0 kPa
4,0 kPa
5,0 kPa
lift
100 %
18,4 kPa
14,9 kPa
9,3 kPa
4,0 kPa
1,53
2,57
1,91
4,00
86,2 kPa
28,5 %Kvm
26,2 kPa
Show Dp in valves
Show Dp in pipes
Show pipe lengthes
Fully open balancing valves
Apply TA Balance

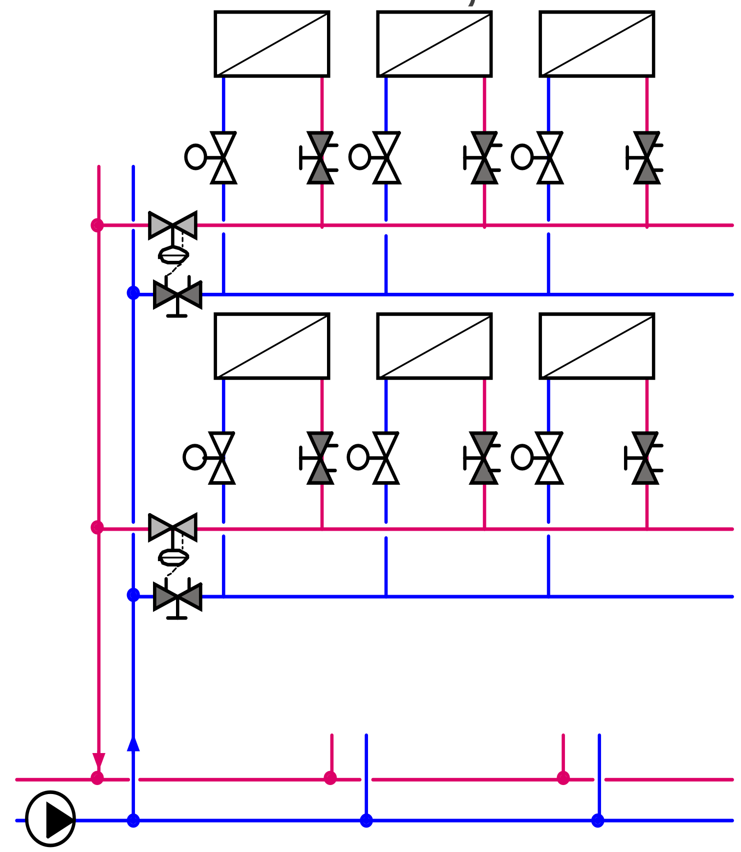
Dp controller position

Depending on project structure, Dp control will be applied:

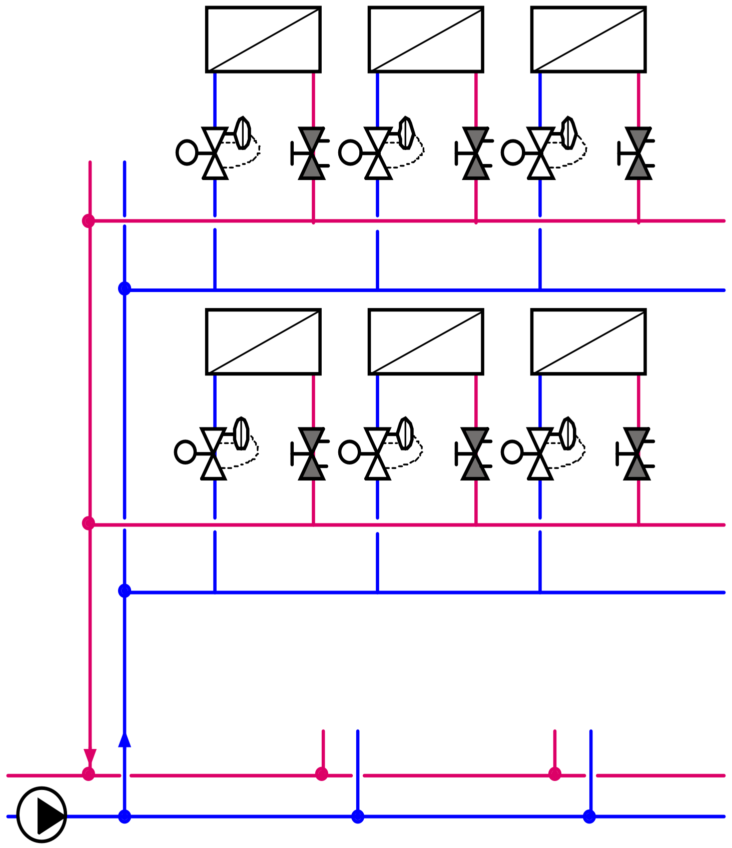
On risers,



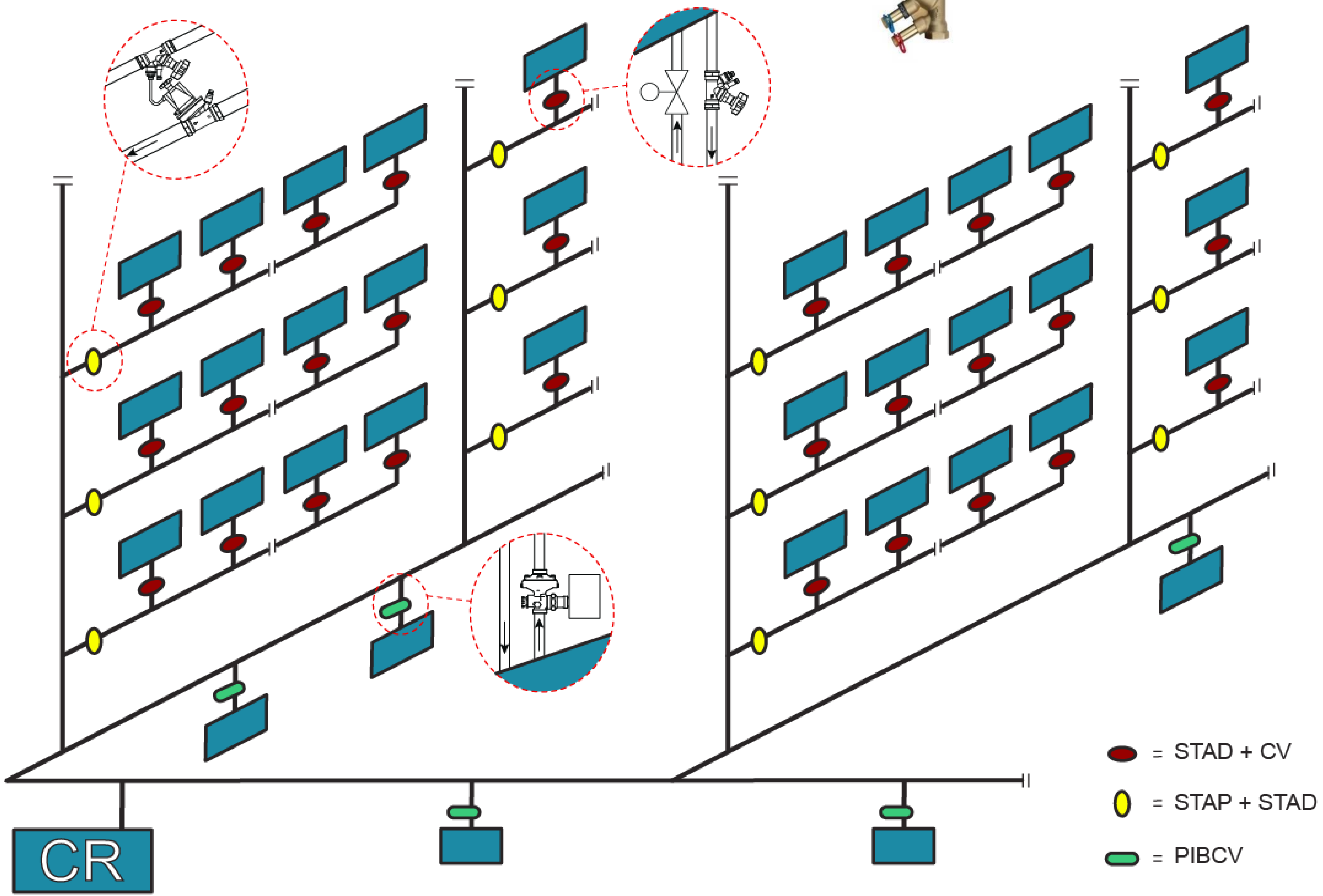
On branches,



On control valves.



Bigger plant with different Dp control configurations

Find the best Dp control solution…

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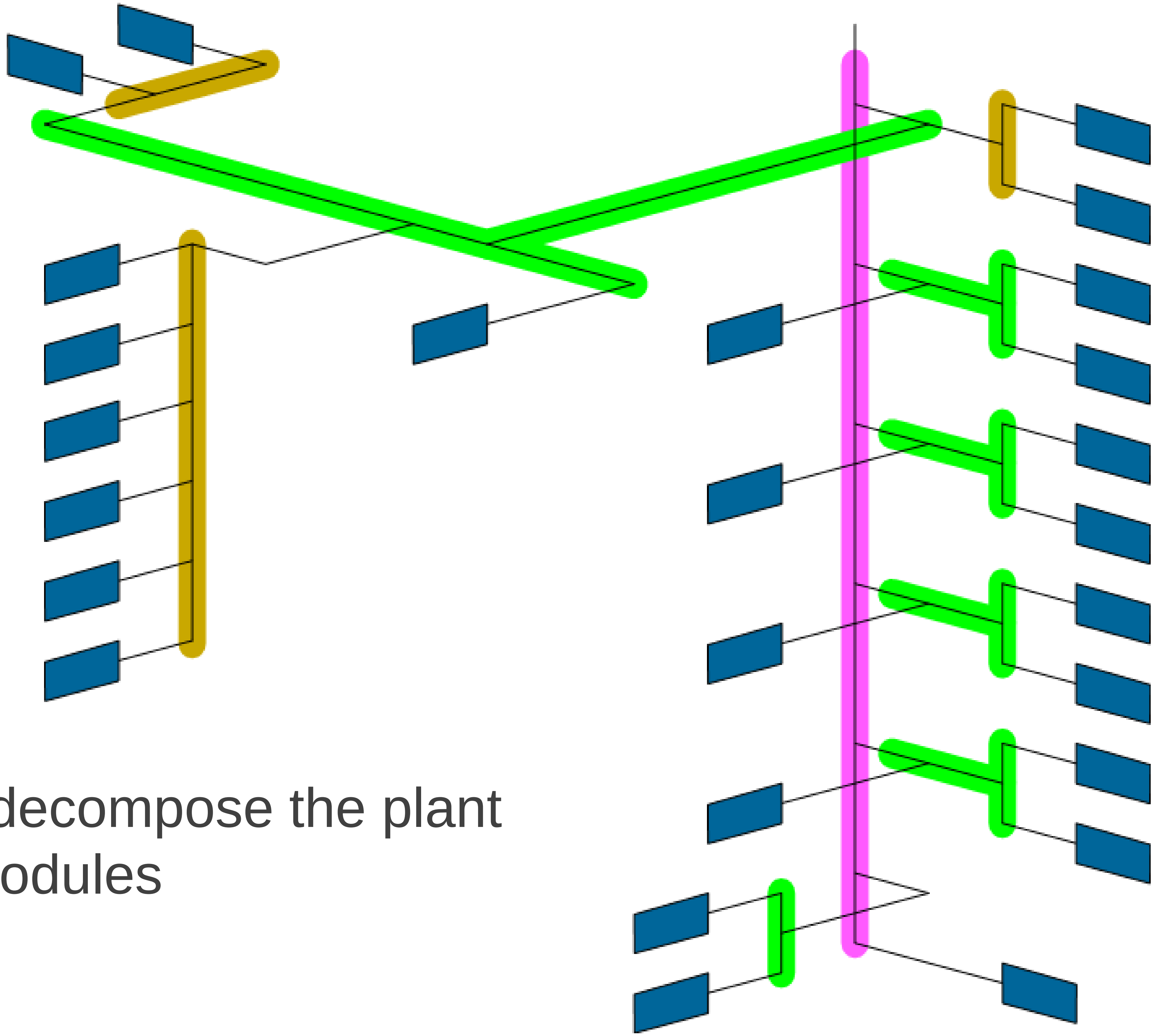


First, decompose the plant into modules

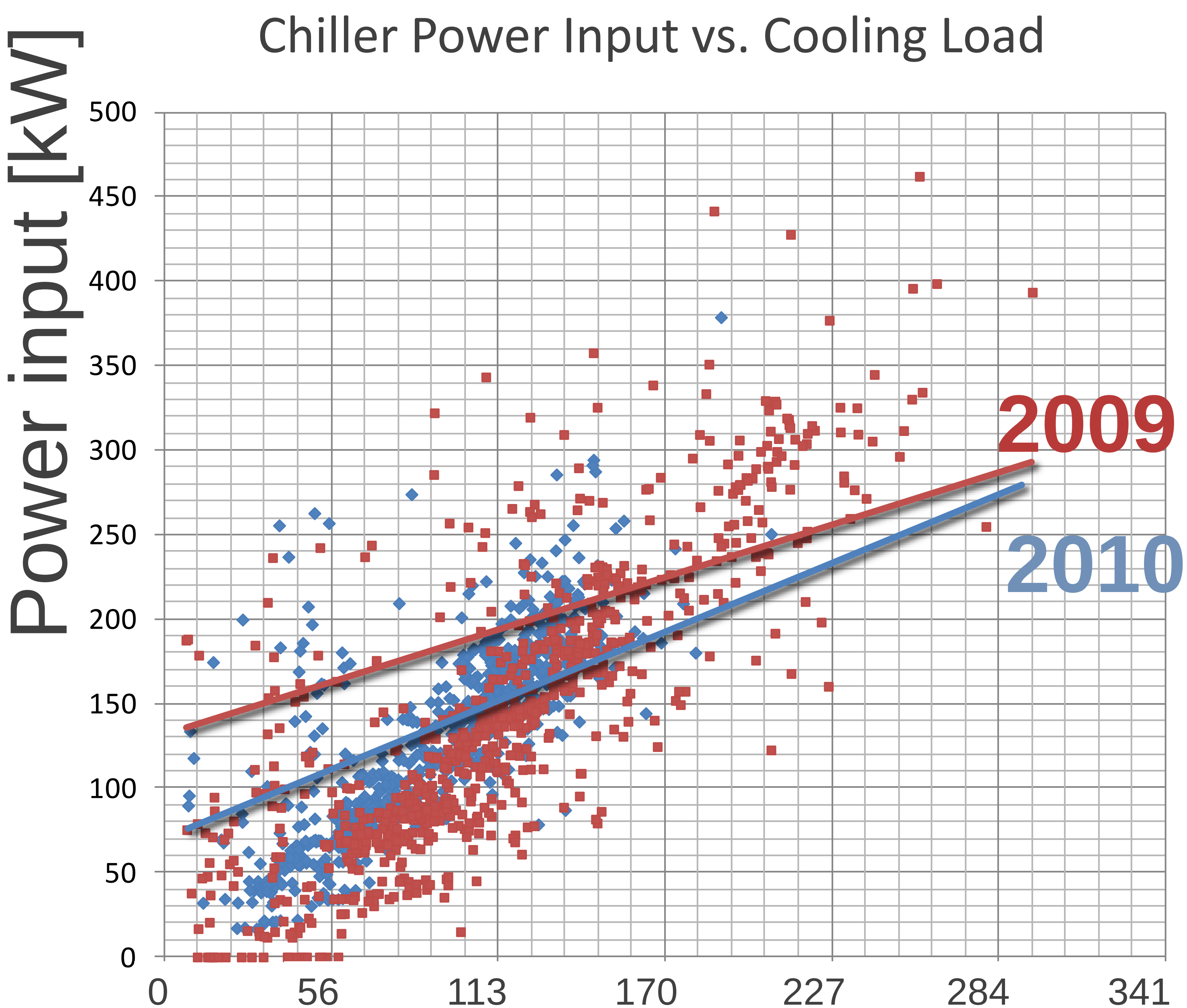
Case Studies

The savings are real!!

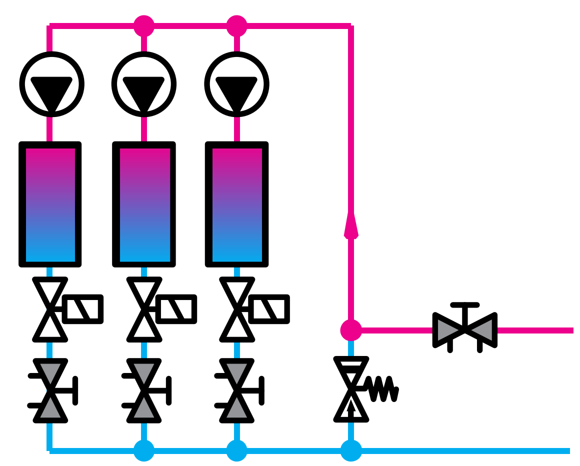
Hong-Kong PolyTech University

- Renovation of 2 University buildings with a total of 106000 ft2 (9840 m2)
- Installed cooling capacity:
  - Building 1 : 1452 tons refrig.
  - Building 2 : 1730 tons refrig.

Local University campus building 1 – chiller saving

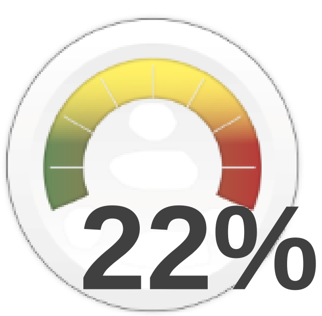


- Variable secondary flow with differential pressure bypass

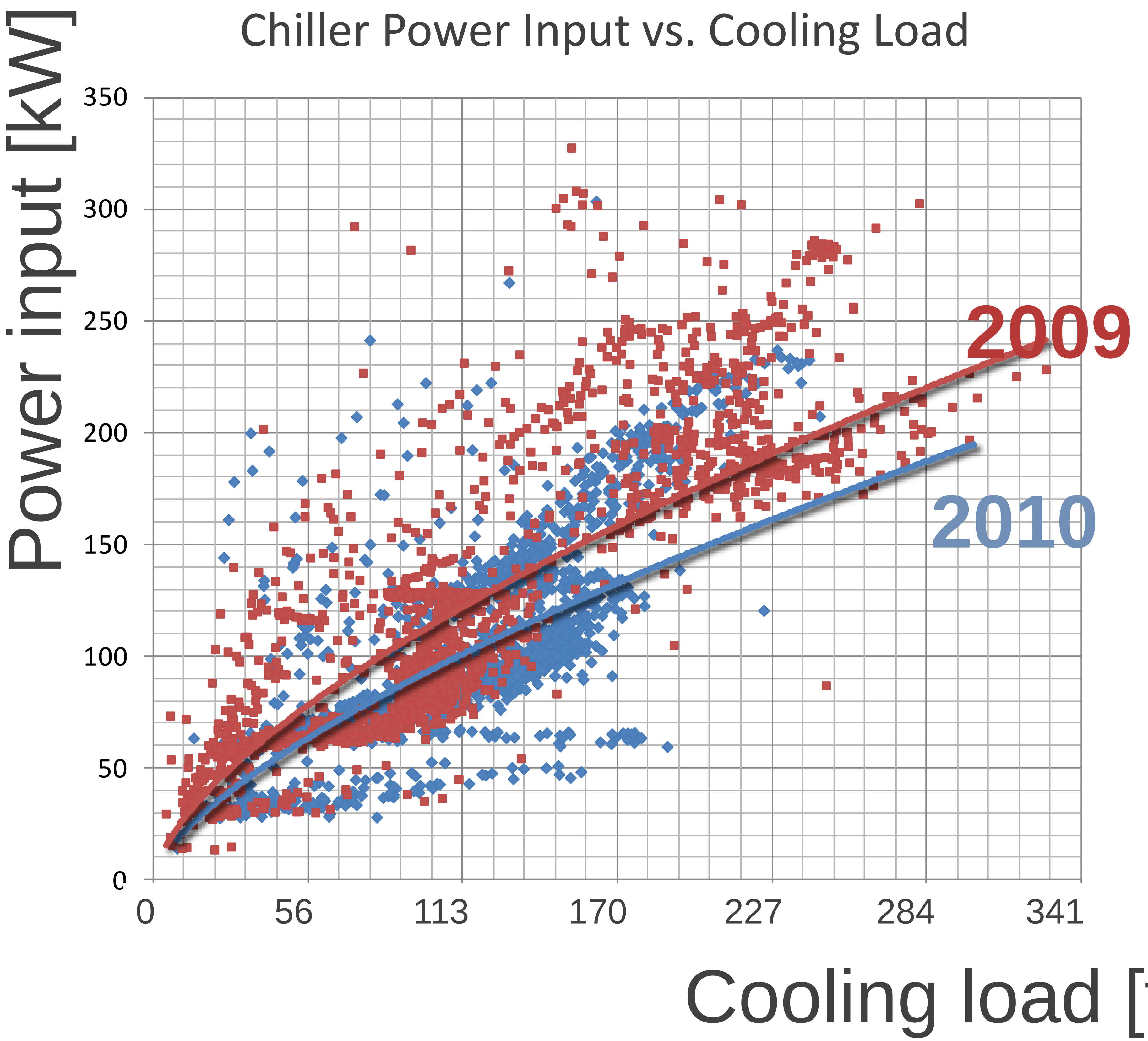


- Dp controllers at on-off control FCU groups and PAU/AHUs and re-balanced

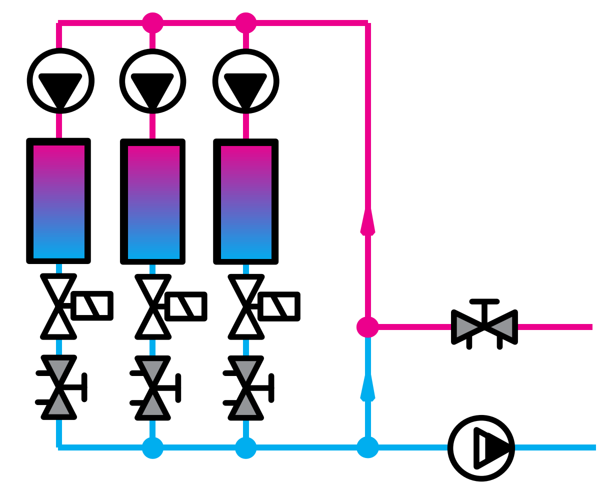
- Annualized 22% chiller energy saving



Local University campus building 2 – chiller saving

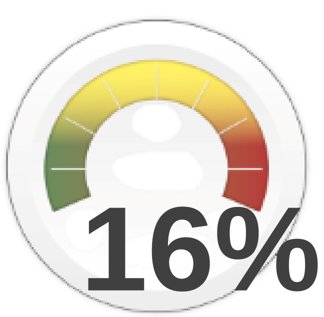


- Variable flow primary-secondary system



- Addition of Dp controllers at FCU groups zones and pressure independent control valves for PAU/ and re-balanced

- Annualized 16.5% chiller energy saving



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Questions?