Top Solution, Top Choice

TOP FLOW

VARIABLE VOLUME SYSTEMS

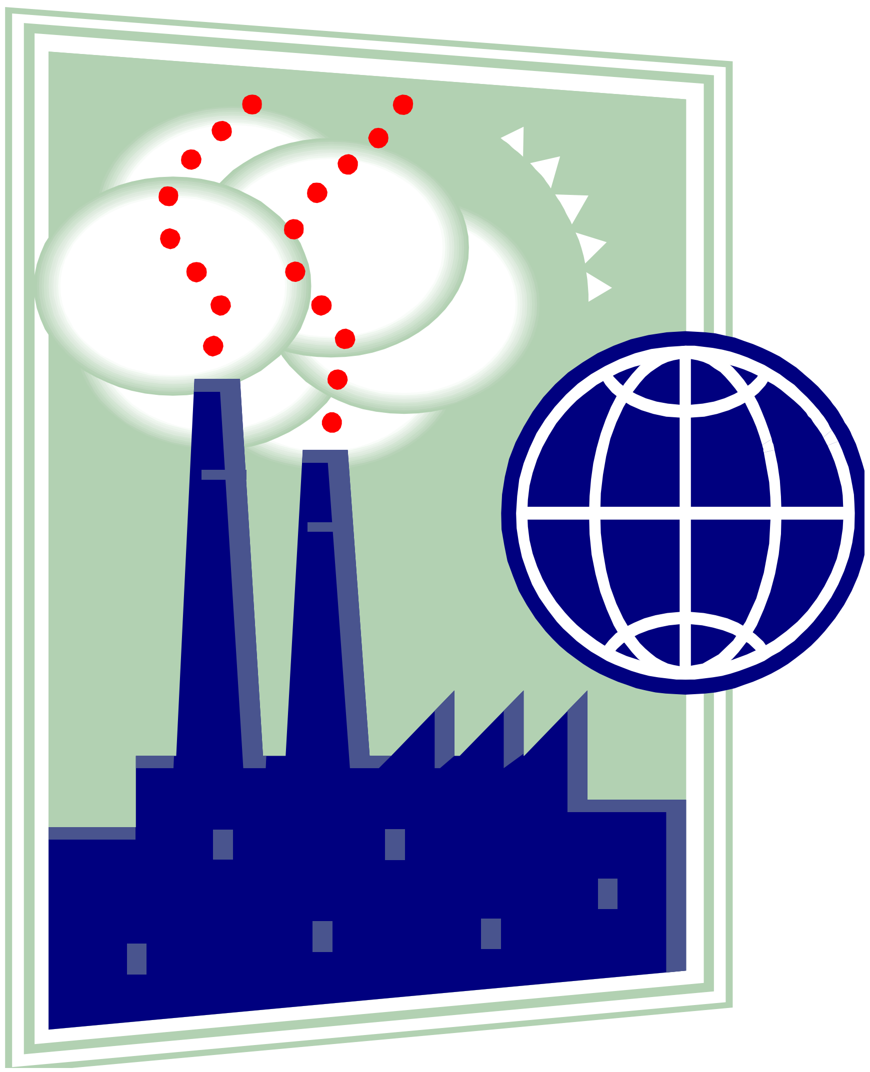
0933705533
Tinh.pham@Topflow.vn

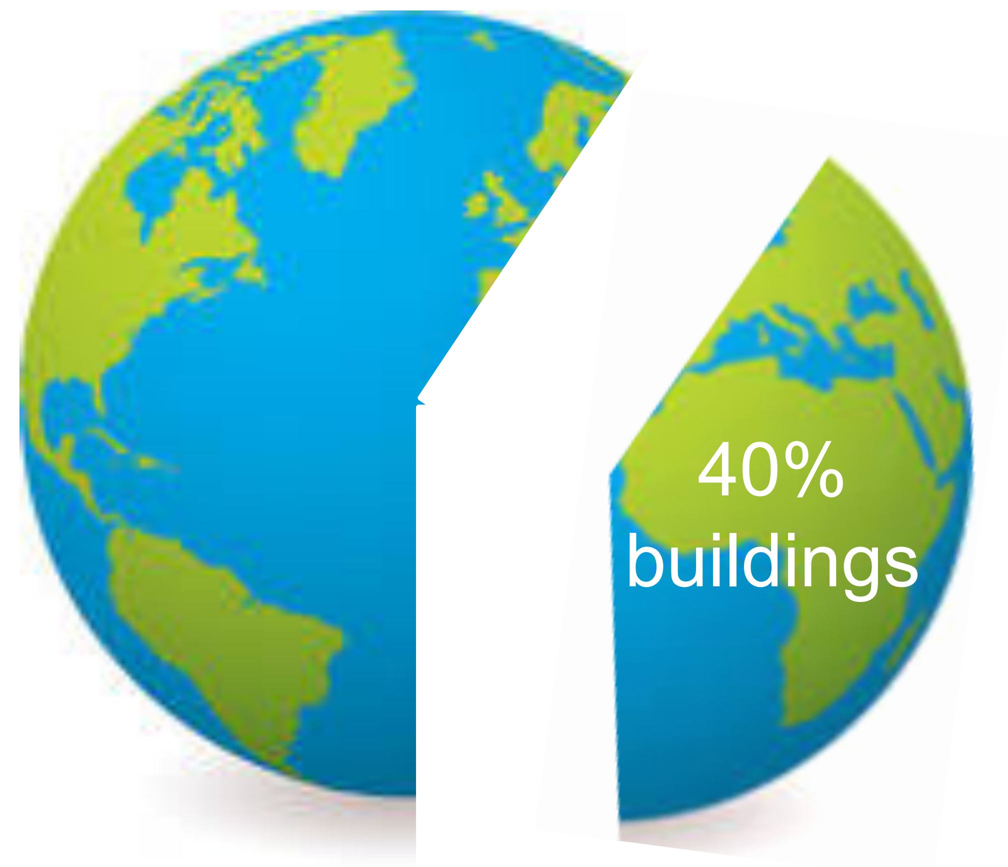
The Bigger Energy Issue

- Environment
- Climate change
- CO_2 emissions
- Who is the biggest culprit?
  - Cars?
  - Planes?
  - No, actually, it's buildings

0933705533
Tinh.pham@Topflow.vn

World Energy Consumption





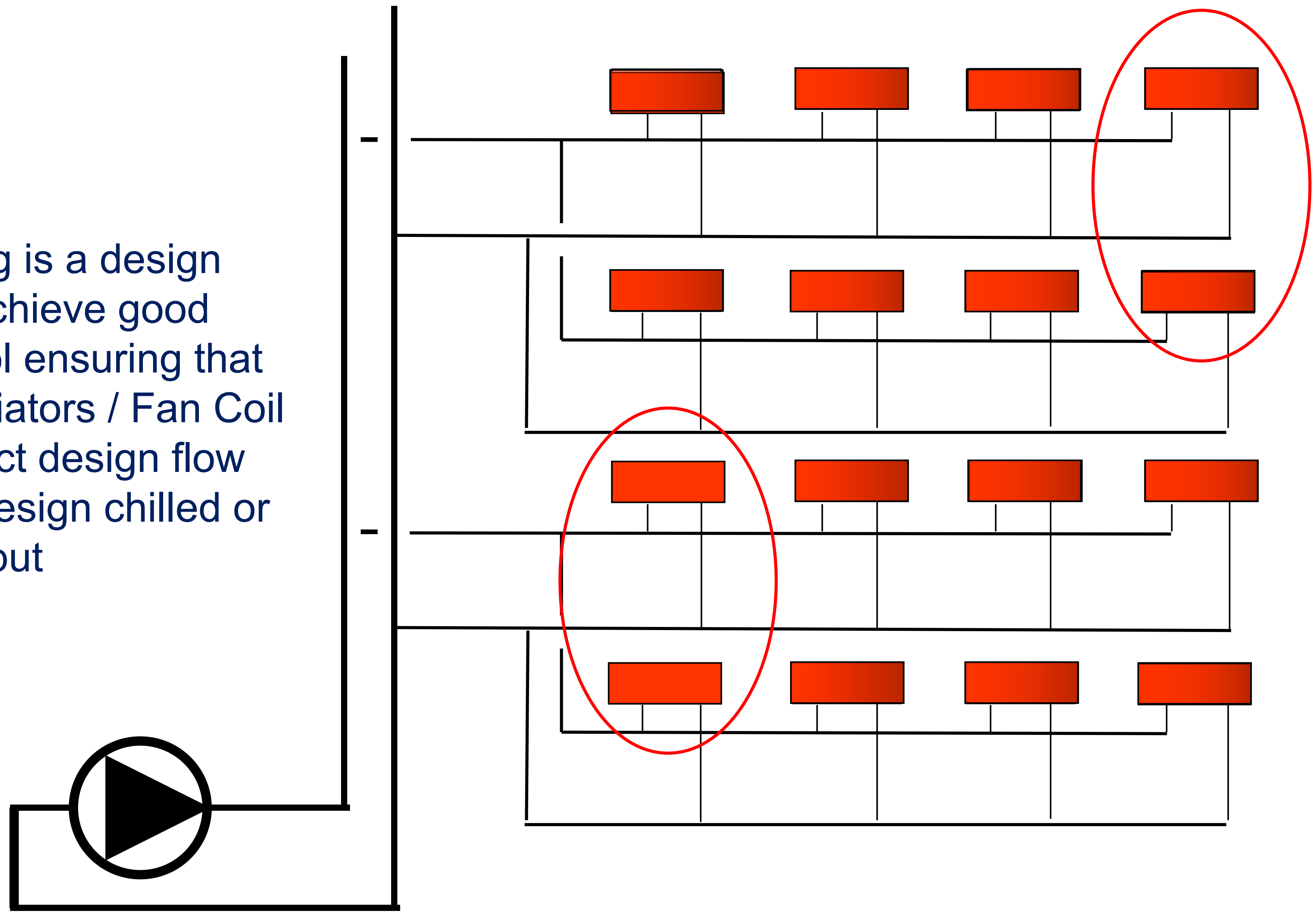
40% of world energy consumption goes into buildings

0933705533
Tinh.pham@Topflow.vn

Alleviating the Energy issue: Dynamic Balancing

Dynamic Balancing is a design methodology to achieve good environmental control ensuring that all terminal units (Radiators / Fan Coil Units etc.) get correct design flow rates and therefore design chilled or heat output

unbalanced
balanced



0933705533
Tinh.pham@Topflow.vn

Why do we need Dynamic Balancing?

Move from Constant Volume to Variable Volume systems

- driven by Government legislation
- energy conservation
- subsequent CO_2 emissions

The move from constant to variable flow design enables pump energy savings

0933705533
Tinh.pham@Topflow.vn

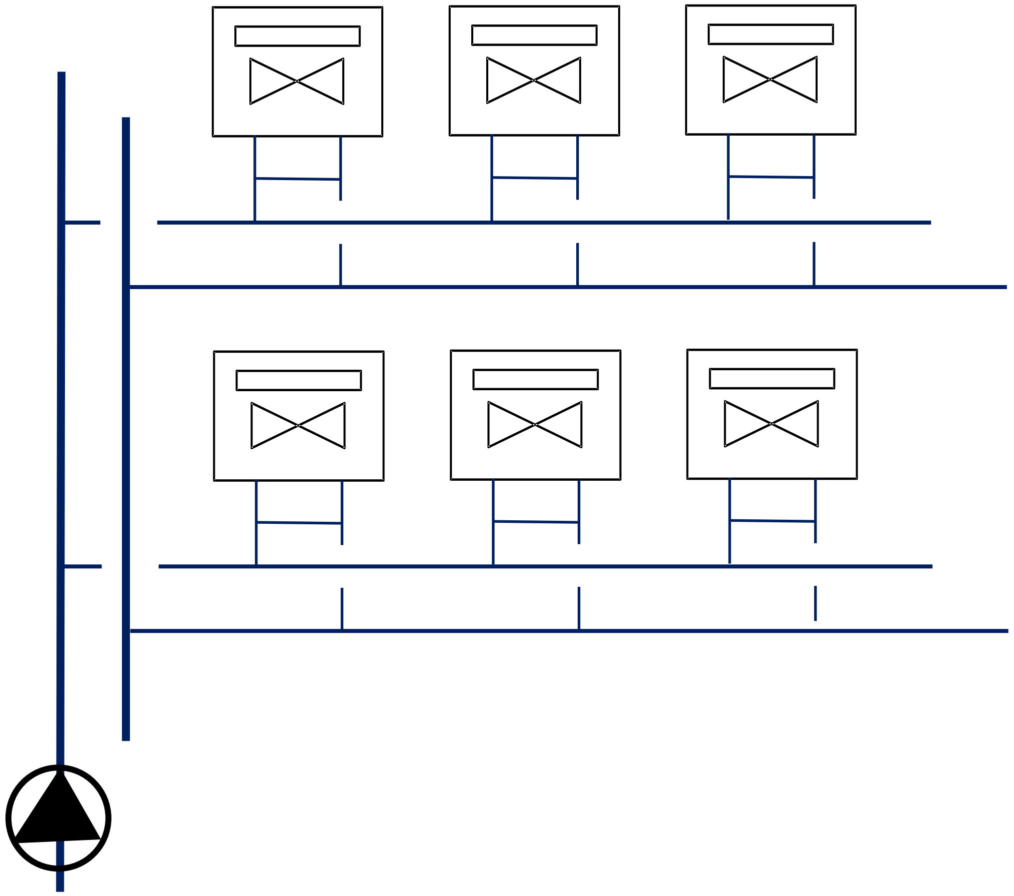
Top Solution, Top Choice
TOP FLOW

Why do we need Dynamic Balancing – constant volume

inherently very *stable*

constant pressure drops in distribution pipework

constant pressure drops in circuits at part load



constant control valve authority

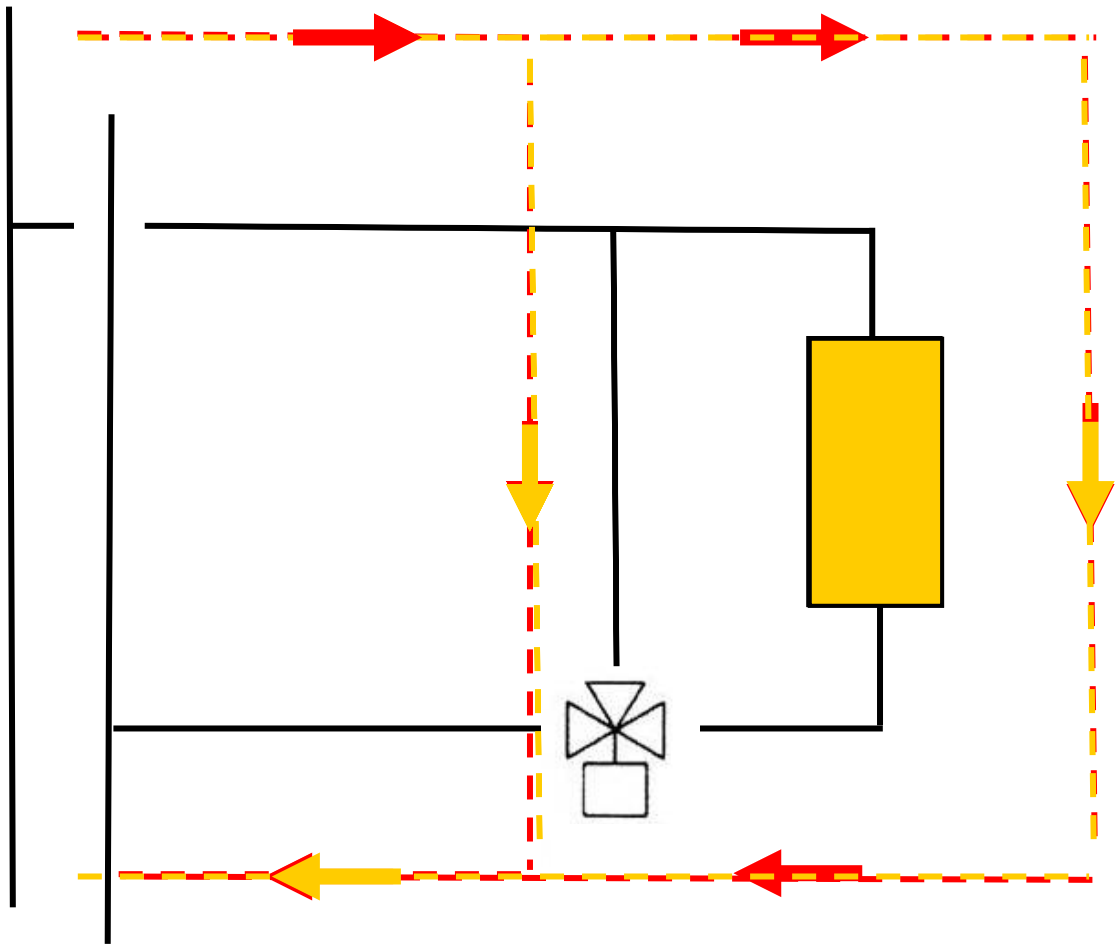
constant pump head

Control valves easy to size with constant authority

0933705533
Tinh.pham@Topflow.vn

Top Solution, Top Choice
TOP FLOW

Why do we need Dynamic Balancing – constant volume



constant amount of water pumped around a system controlled by 3 or 4 port control valves and would be

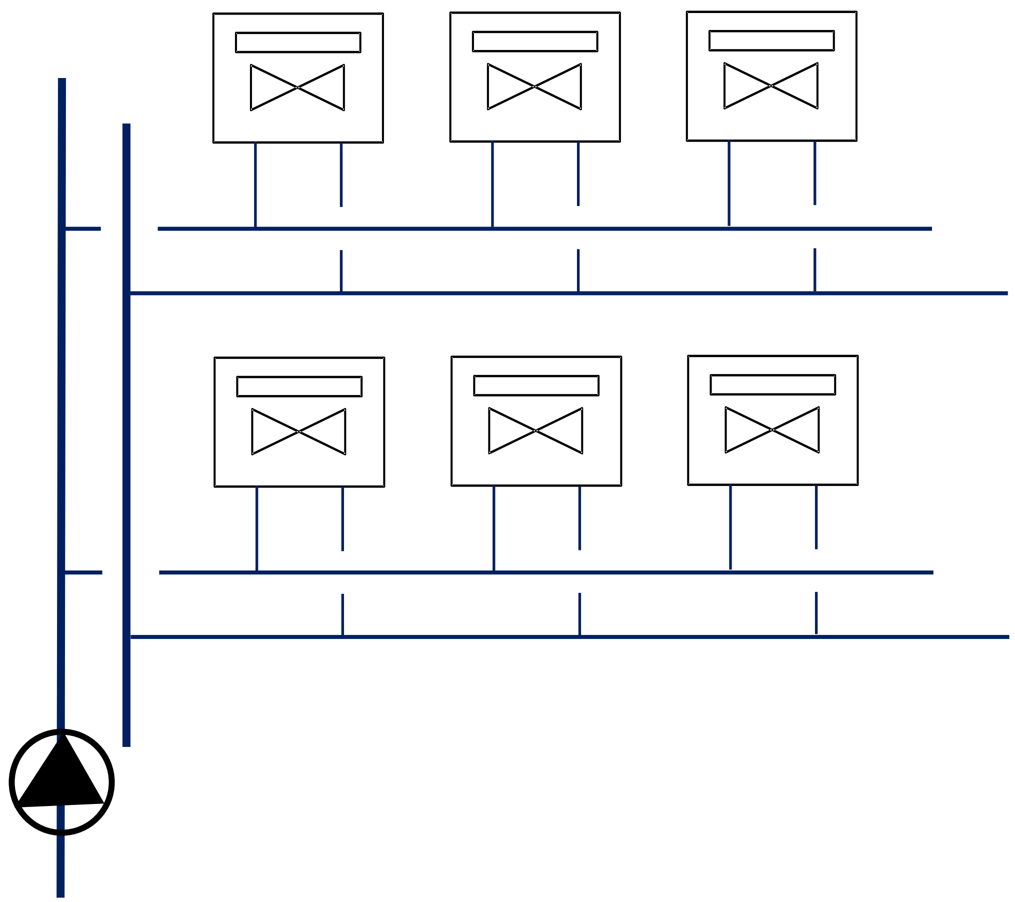
- through terminal
- split between terminal and by-pass
- diverted back if not required

0933705533
Tinh.pham@Topflow.vn

Why do we need Dynamic Balancing – variable volume

inherently very *unstable*

variable pressure drops in distribution pipework



variable pressure drops in circuits at part load

variable control valve authority

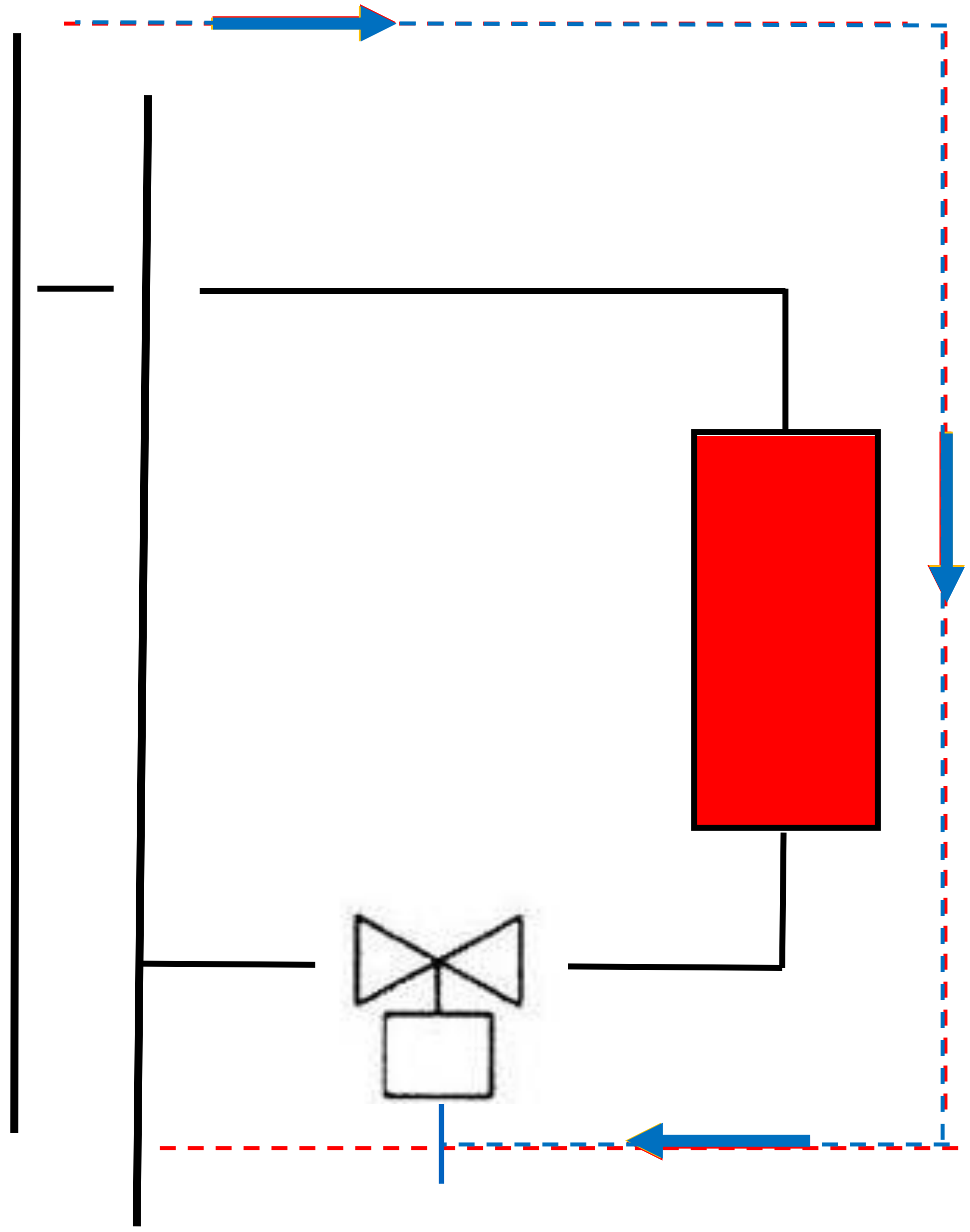
variable pump head

Control valves difficult to size with variable authority

0933705533
Tinh.pham@Topflow.vn

Why do we need Dynamic Balancing – variable volume

Variable amount of water pumped around a system now controlled by 2 port control valves



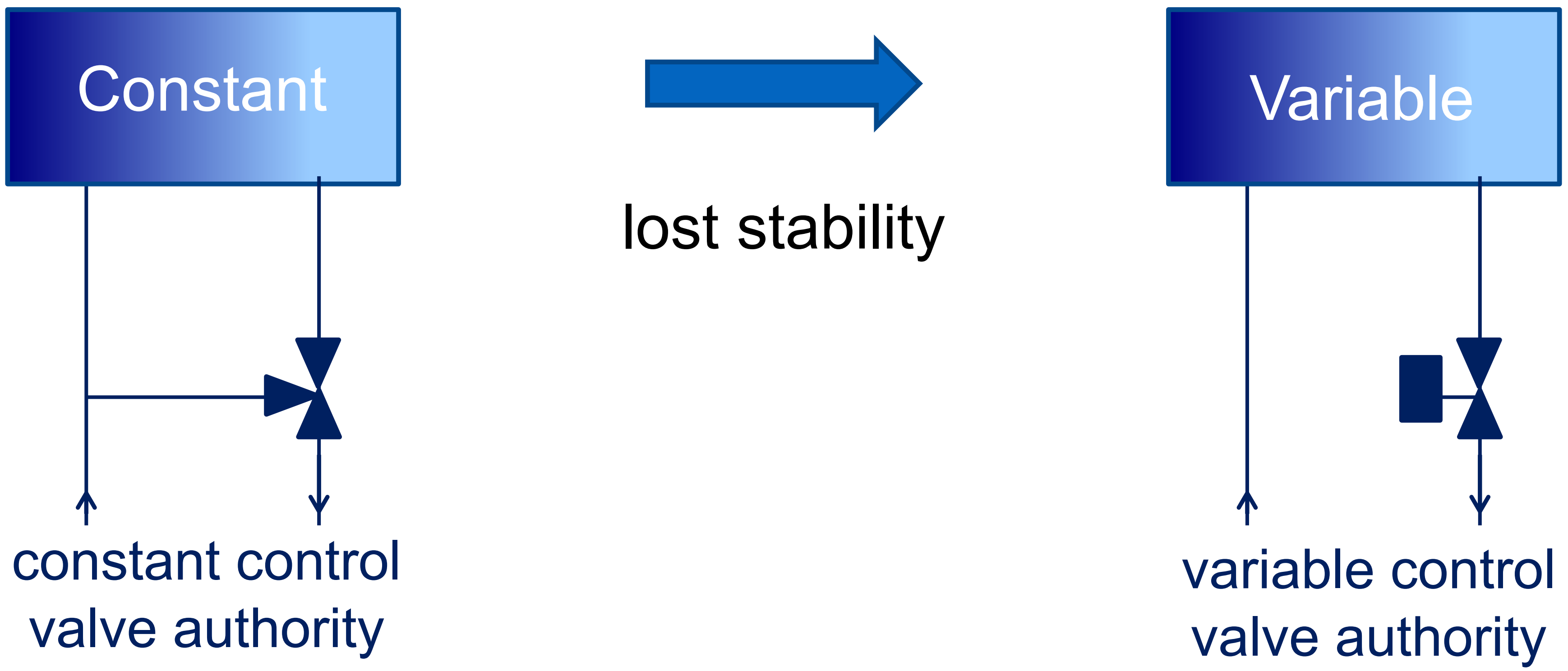
open

Modulating between open and closed

closed

0933705533
Tinh.pham@Topflow.vn

Why do we need Dynamic Balancing Valves



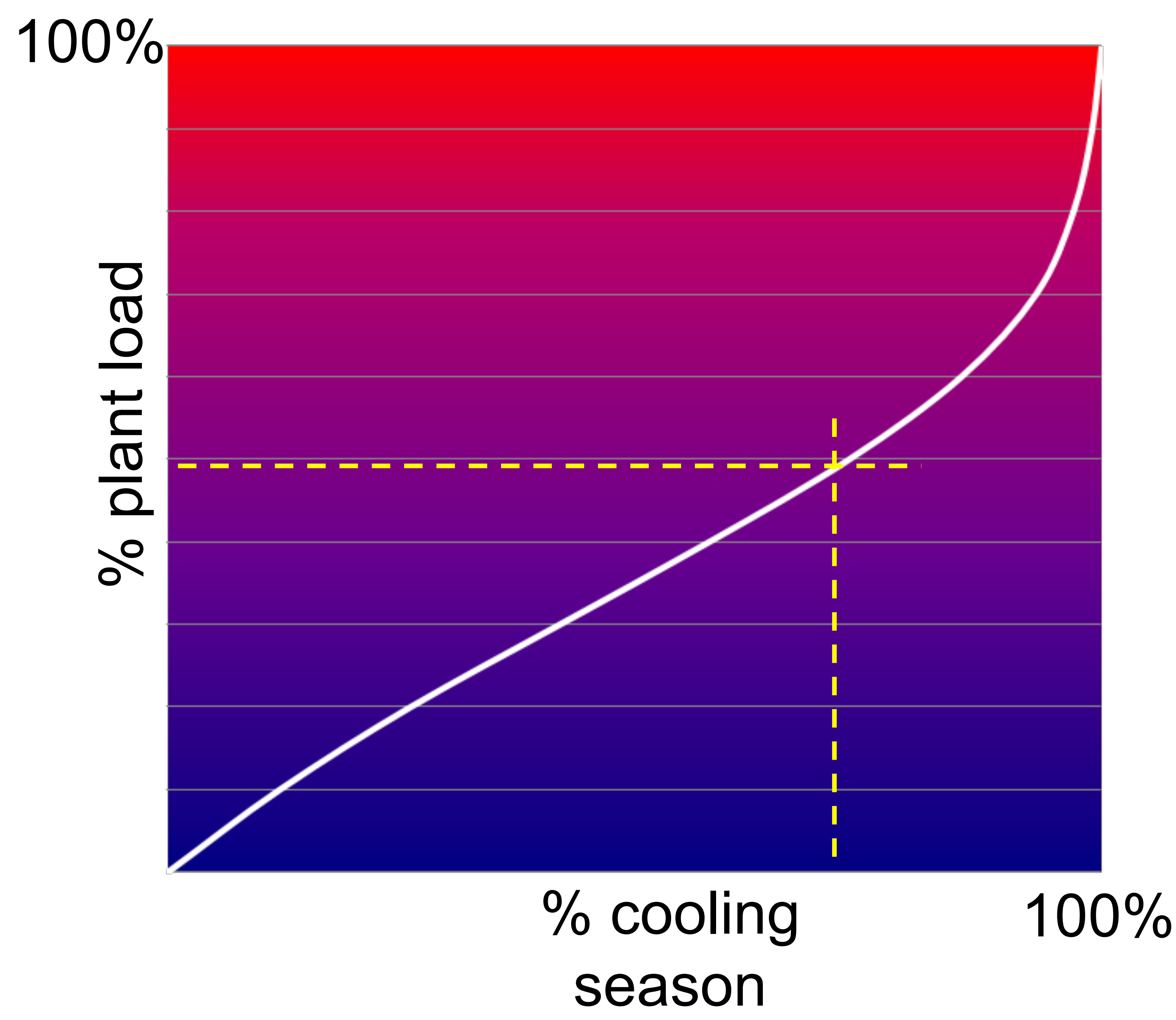
DPCV installed to protect 2 port control valve authority
or
PICVs installed to replace commissioning / control valves

0933705533
Tinh.pham@Topflow.vn

Why do we need Variable Volume Systems

Temperature variations

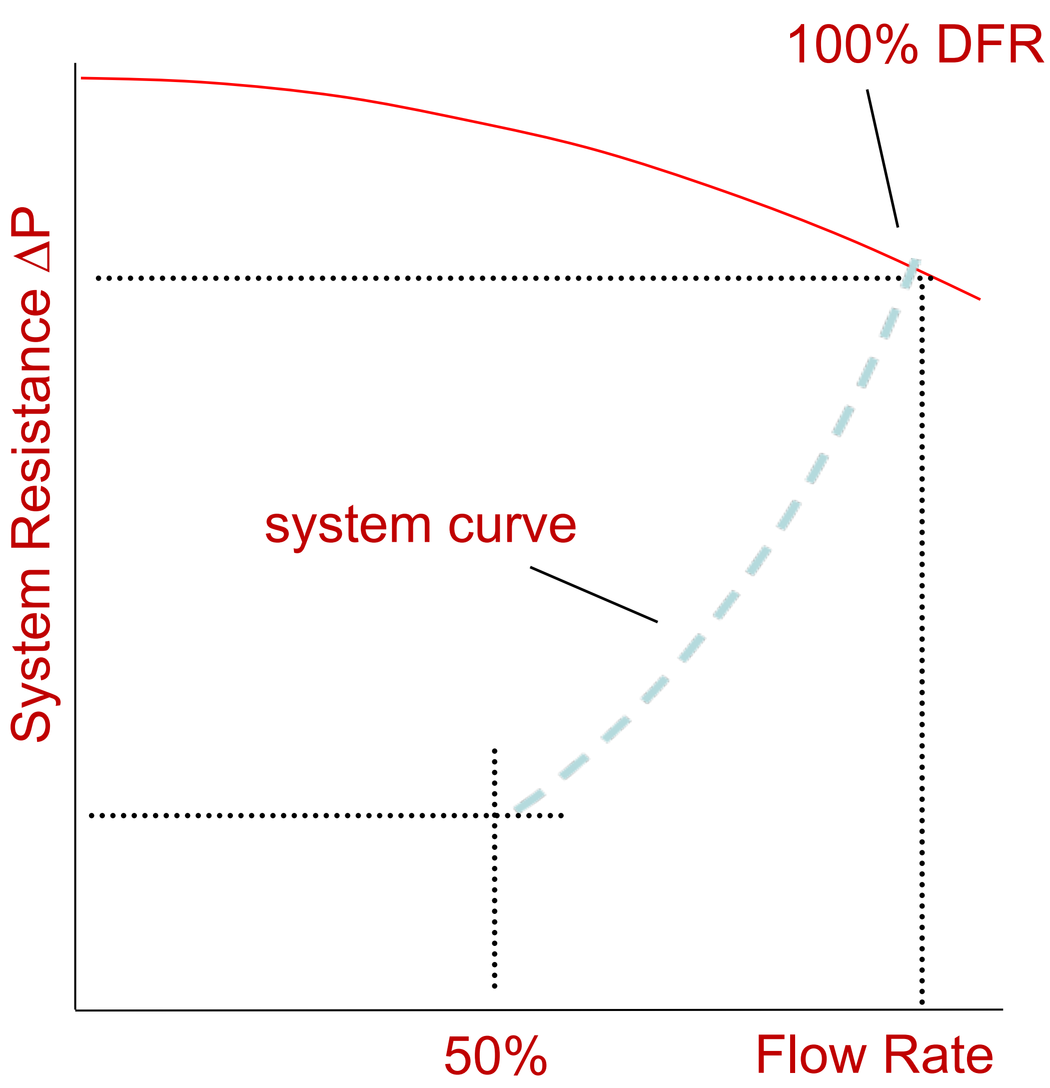
- Over 70% of cooling season
- Load is less than 50%



0933705533
Tinh.pham@Topflow.vn

Variable Volume Pump Energy Savings

- As system demand change, flow rate changes
- Direct relationship between pump speed and flow rate
- 50% pump speed = 50% flow rate



50% flow rate = 25% System Resistance

0933705533
Tinh.pham@Topflow.vn

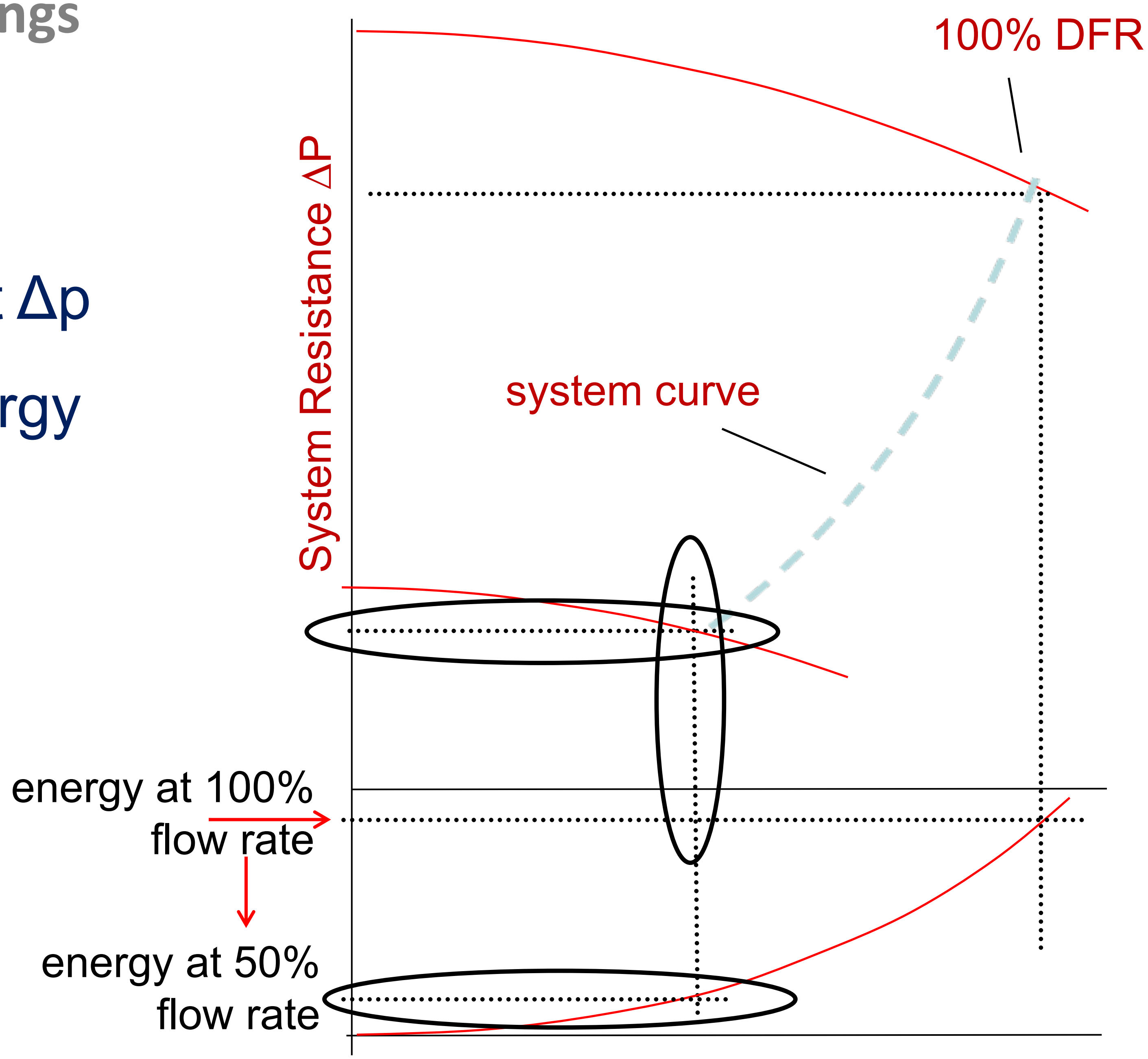
Top Solution, Top Choice
TOP FLOW

Variable Volume Pump Energy Savings

- 50% speed = 50% flow rate
- 50% flow rate = 25% circuit Δp
- 25% circuit Δp = 12.5% energy

50% flow rate = over 70% pump energy saving

Loses due to pump efficiency reducing



0933705533
Tinh.pham@Topflow.vn

What are Dynamic Balancing Valves?

Dynamic Balancing Valves

- **CFD**
  Constant Flow Device
  - constant flow areas
- **DPCV**
  Differential Pressure Control Valves
  - variable flow areas
    - radiators
    - chilled beams
    - radiant panels
    - underfloor heating
    - FCUs
    - AHUs
- **PICV**
  Pressure Independent Control Valves
  - variable flow areas
    - chilled beams
    - radiant panels
    - FCUs
    - AHUs

0933705533
Tinh.pham@Topflow.vn

What are Dynamic Balancing Valves?

Dynamic Balancing Valves

CFD
Constant Flow
Device

Constant flow
areas

0933705533
Tinh.pham@Topflow.vn

What are Dynamic Balancing Valves?

Dynamic Balancing Valves

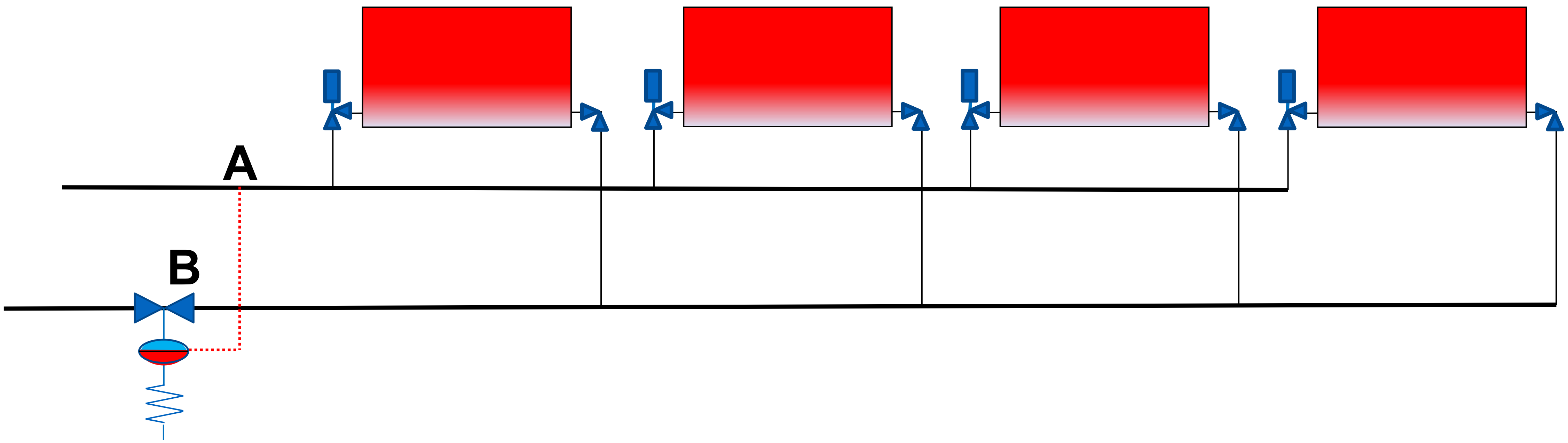
DPCV
Differential Pressure Control Valves

Variable flow areas
- Radiators
- Chilled beams
- Radiant panels
- Underfloor heating
- FCUs
- AHUs

0933705533
Tinh.pham@Topflow.vn

Why do we need Dynamic Balancing – radiator circuits

- To enable TRV (Thermostatic Radiator Valves) to correctly operate, a DPCV is installed to limit the radiator sub-circuit pressure differential
- The installation of DPCVs in sub-circuits with TRVs reduces the pressure that the TRV has to close against thus reducing the possibility of noisy valves

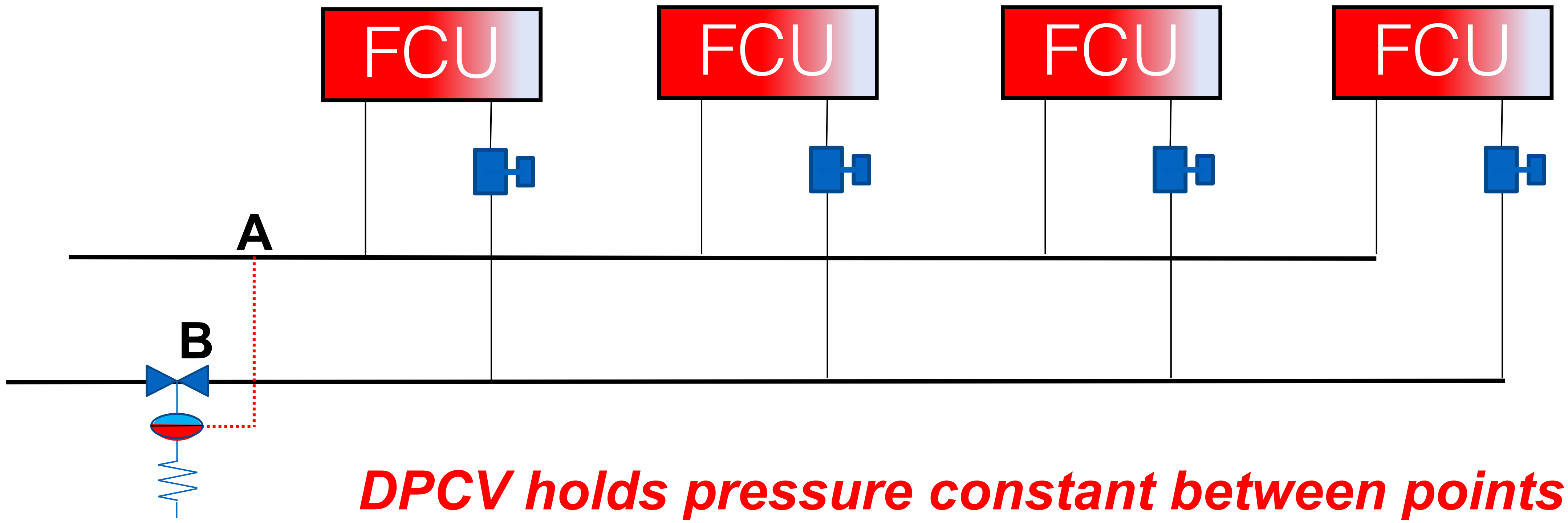


DPCV holds pressure constant between points A and B

0933705533
Tinh.pham@Topflow.vn

Why do we need Dynamic Balancing – DPCVs for FCU

- To enable modulating 2 port control valves to operate with an acceptable authority, a DPCV is installed to limit the circuit pressure differential
- The installation of DPCVs on sub-branches with 2 port control valves is therefore essential to achieve good control



DPCV holds pressure constant between points A and B

0933705533
Tinh.pham@Topflow.vn

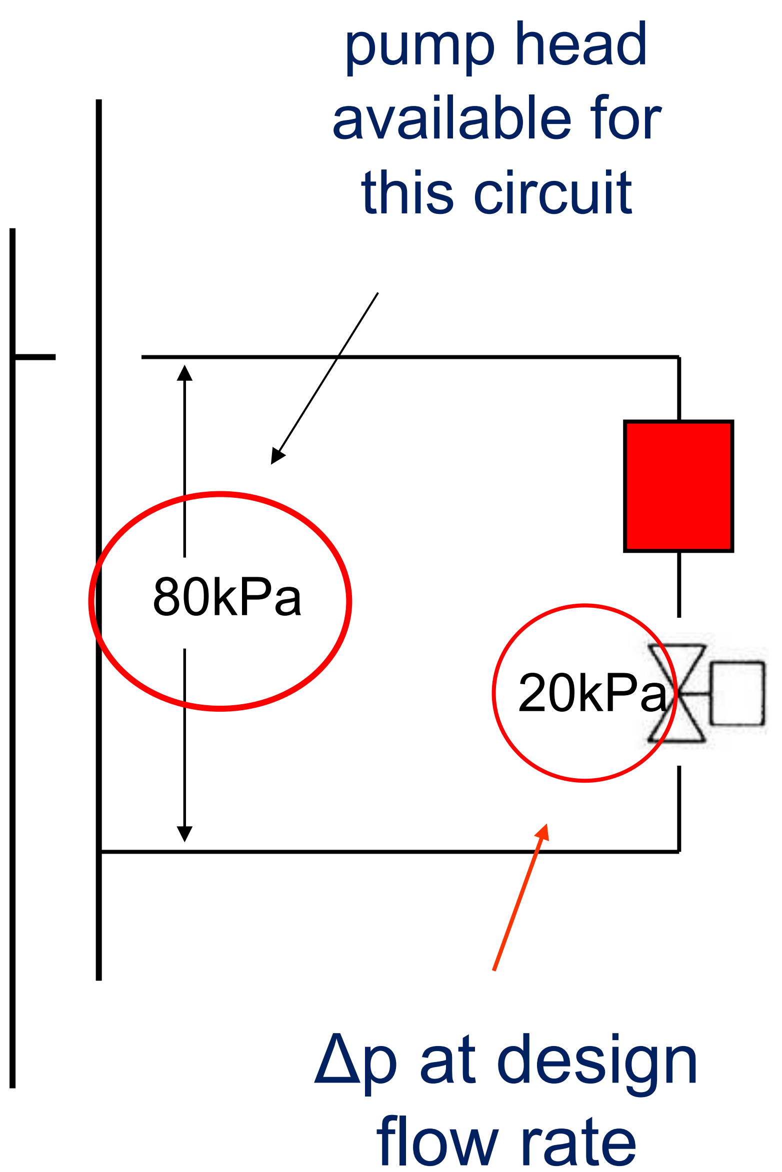
Why do we need DPCVs - control valve authority

Example without DPCV

$$\text{valve authority } ß = \frac{\Delta p \text{ across 2 port}}{\Delta p \text{ across circuit}}$$

$$ß = \frac{20 \text{ kPa}}{80 \text{ kPa}}$$

$$ß = 0.25$$



Too low - unacceptable

Why do we need DPCVs - control valve authority

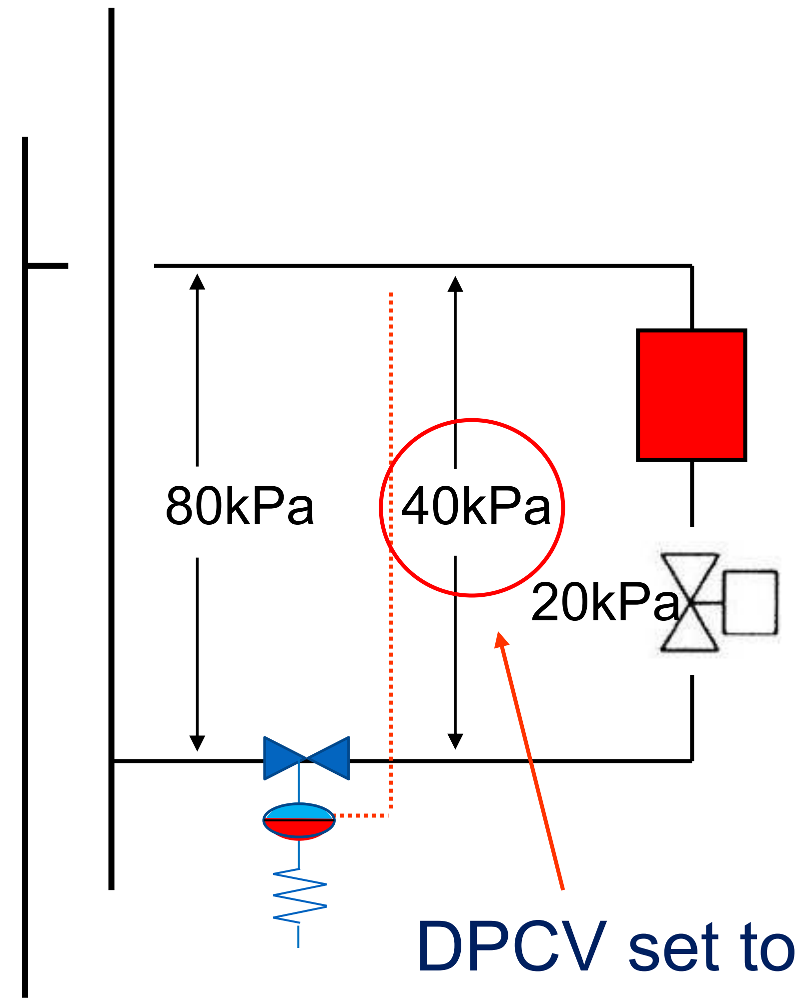
Example with DPCV fitted

$$\text{Valve authority } ß = \frac{\Delta p \text{ across 2 port}}{\Delta p \text{ across circuit}}$$

$$ß = \frac{20 \text{ kPa}}{40 \text{ kPa}}$$

$$ß = 0.5$$

Acceptable



DPCV set to control at design flow rate

0933705533
Tinh.pham@Topflow.vn

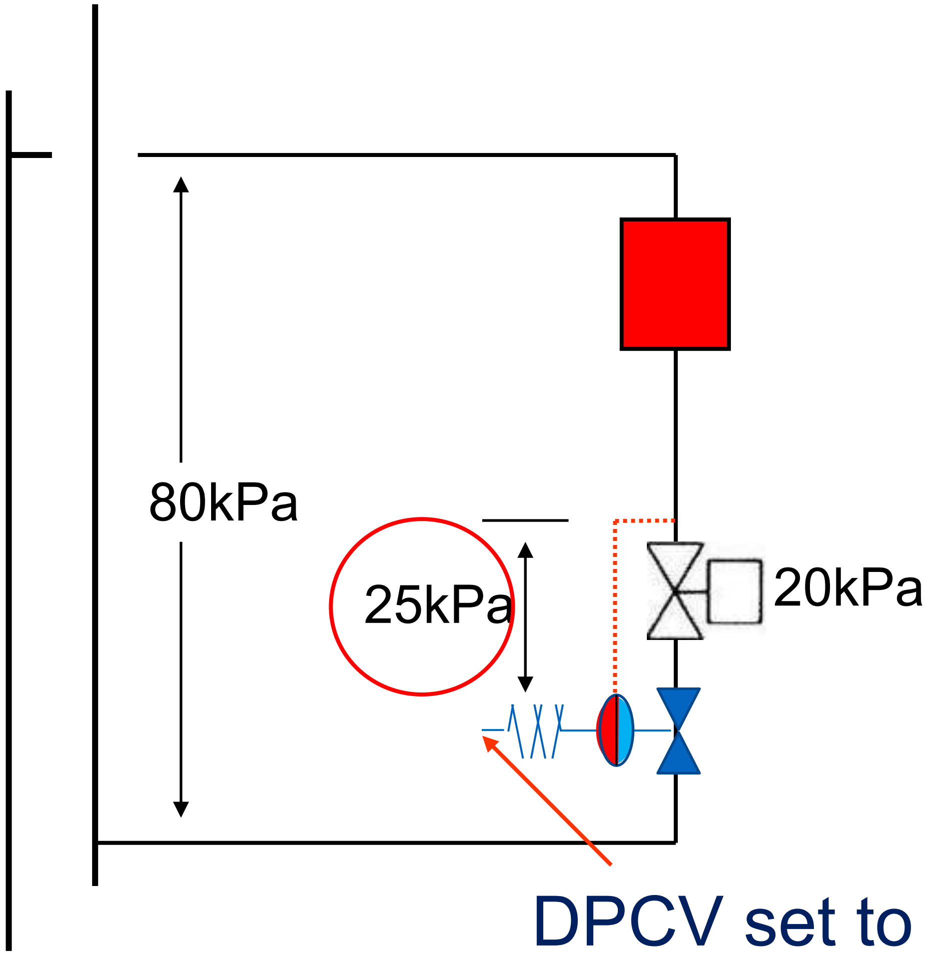
Why do we need DPCVs - control valve authority

Position of DPCV?

$$\text{valve authority } ß = \frac{\Delta p \text{ across 2 port}}{\Delta p \text{ across circuit}}$$

$$ß = \frac{20 \text{ kPa}}{25 \text{ kPa}}$$

$$ß = 0.8$$



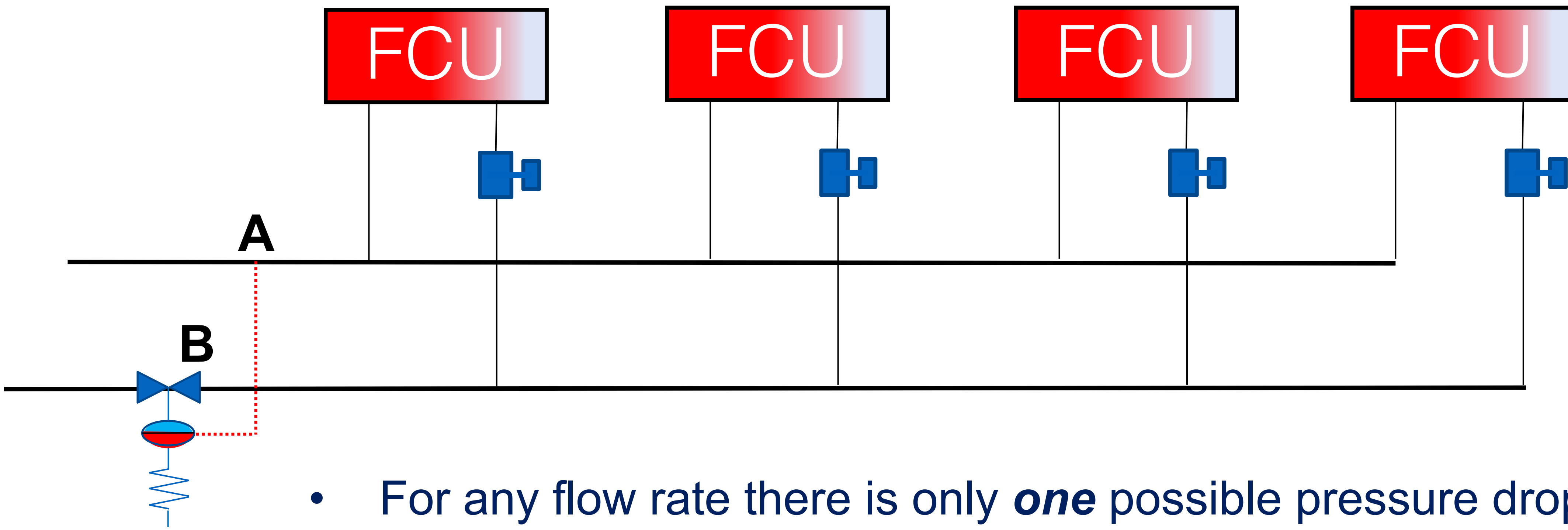
DPCV set to control at design flow rate

position can influence authority

on single terminal circuits – as closes as possible to control valves gives higher authority

0933705533
Tinh.pham@Topflow.vn

How do DPCVs work

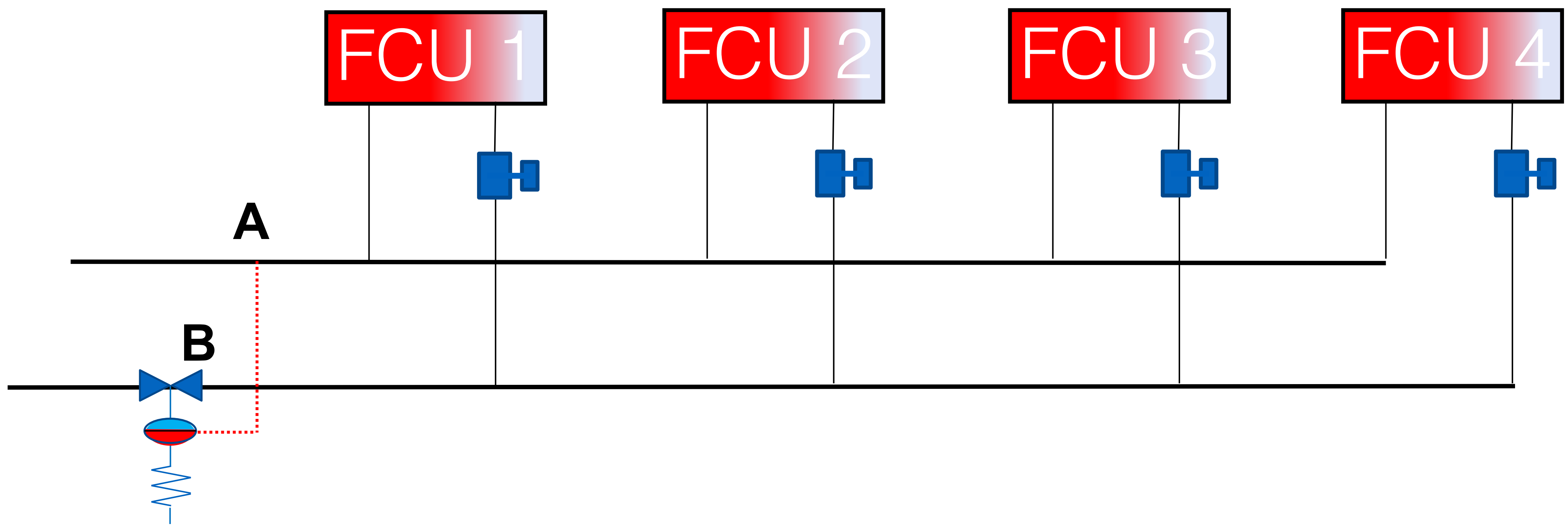


- For any flow rate there is only ***one*** possible pressure drop between any 2 points
- As flow rate changes Δp changes – squared change
  10% in flow = 21% in Δp

DPCV holds pressure constant between points A and B

0933705533
Tinh.pham@Topflow.vn

Why a DPCVs work

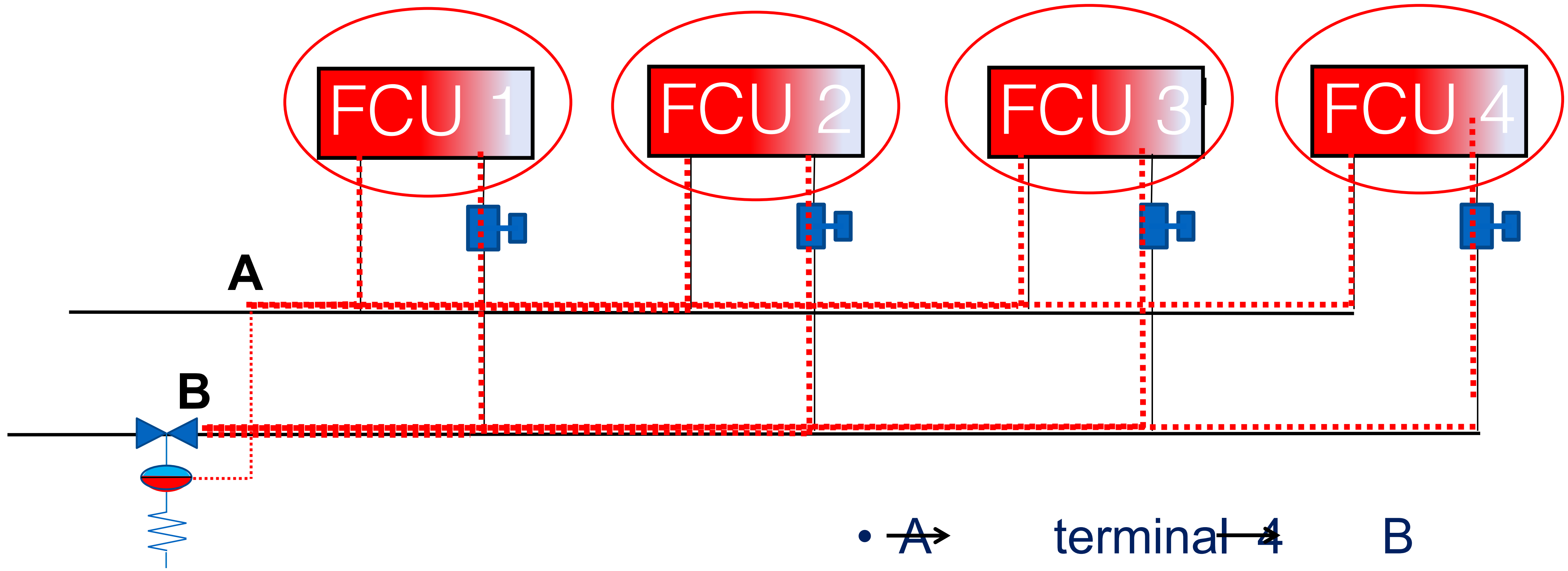


Kirchhoff's 2nd law states

'Head loss in parallel circuits must be equal'

0933705533
Tinh.pham@Topflow.vn

Why a DPCVs work



Applying Kirchhoff's law

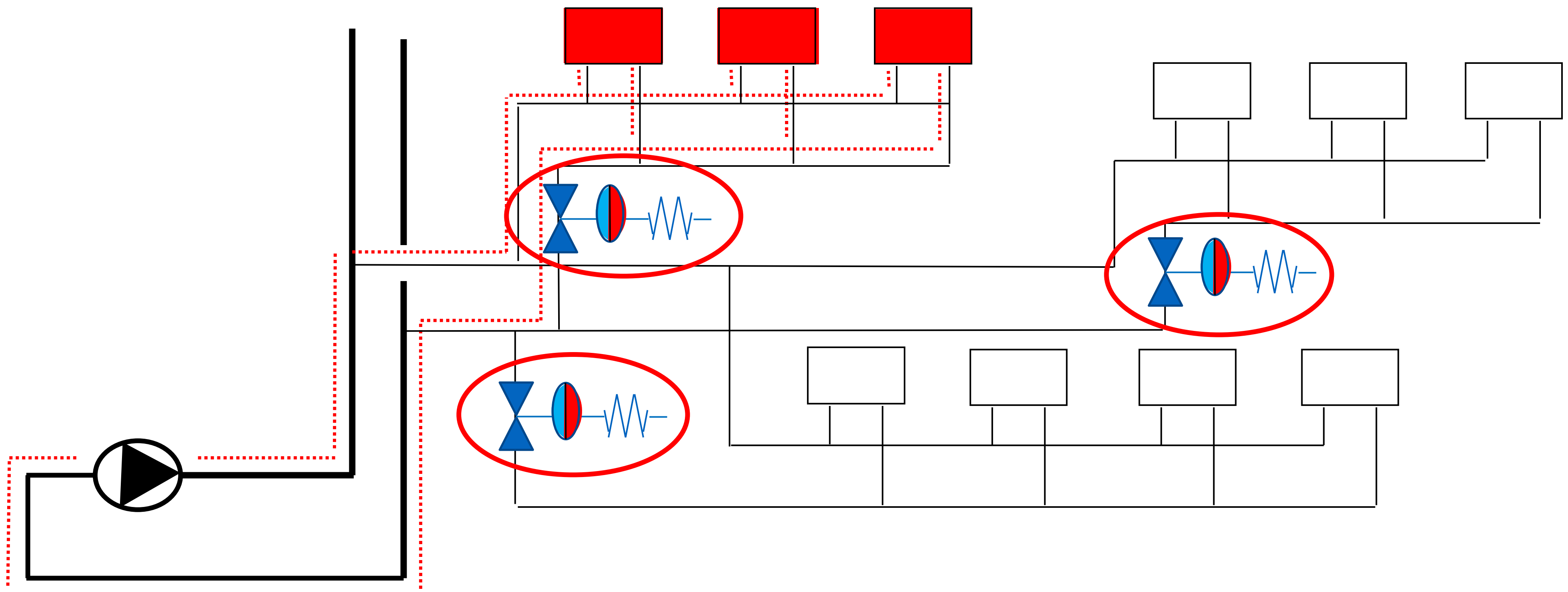
- A → terminal 4 → B
- A → terminal 3 → B
- A → terminal 2 → B
- A → terminal 1 → B

All have the same pressure drop irrespective of flow

0933705533
Tinh.pham@Topflow.vn
24

Where do DPCVs go

Branches are broken down into sub-circuits, each controlled by a DPCV

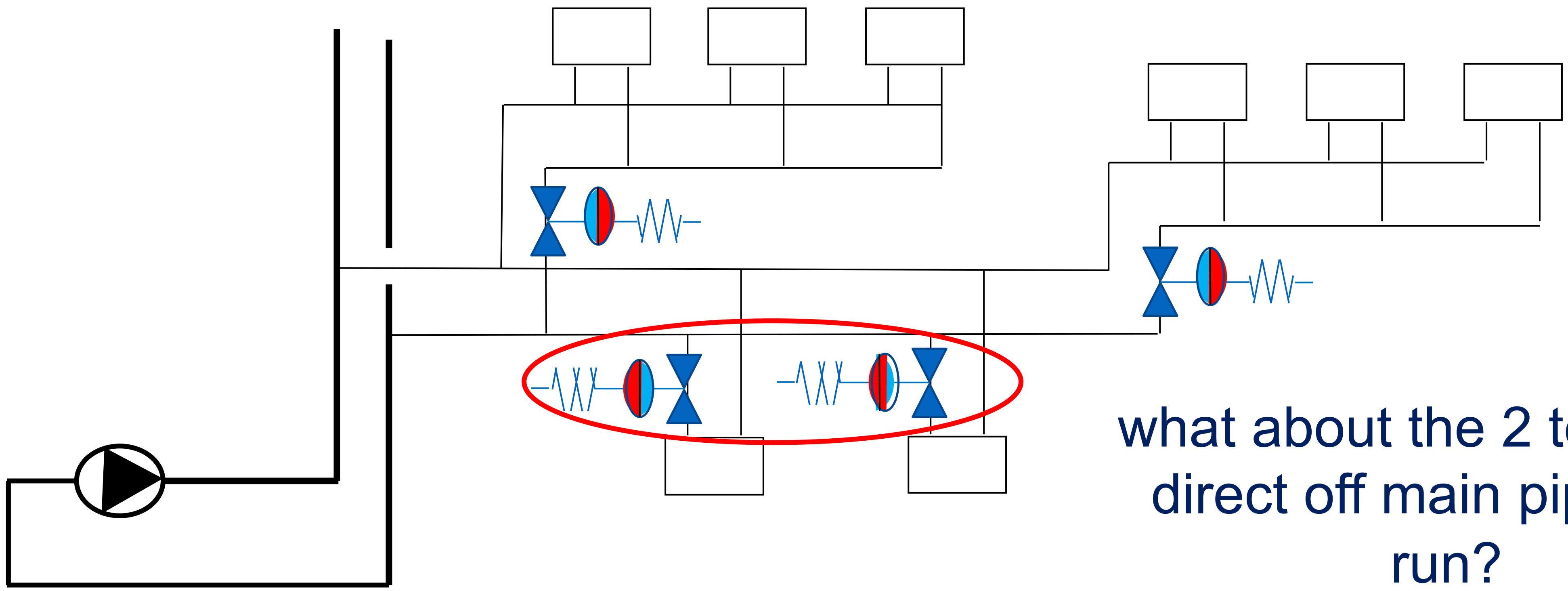


Each circuit must only flow through a single DPCV

0933705533
Tinh.pham@Topflow.vn

Where do DPCVs go

Branches are broken down into sub-circuits, each controlled by a DPCV



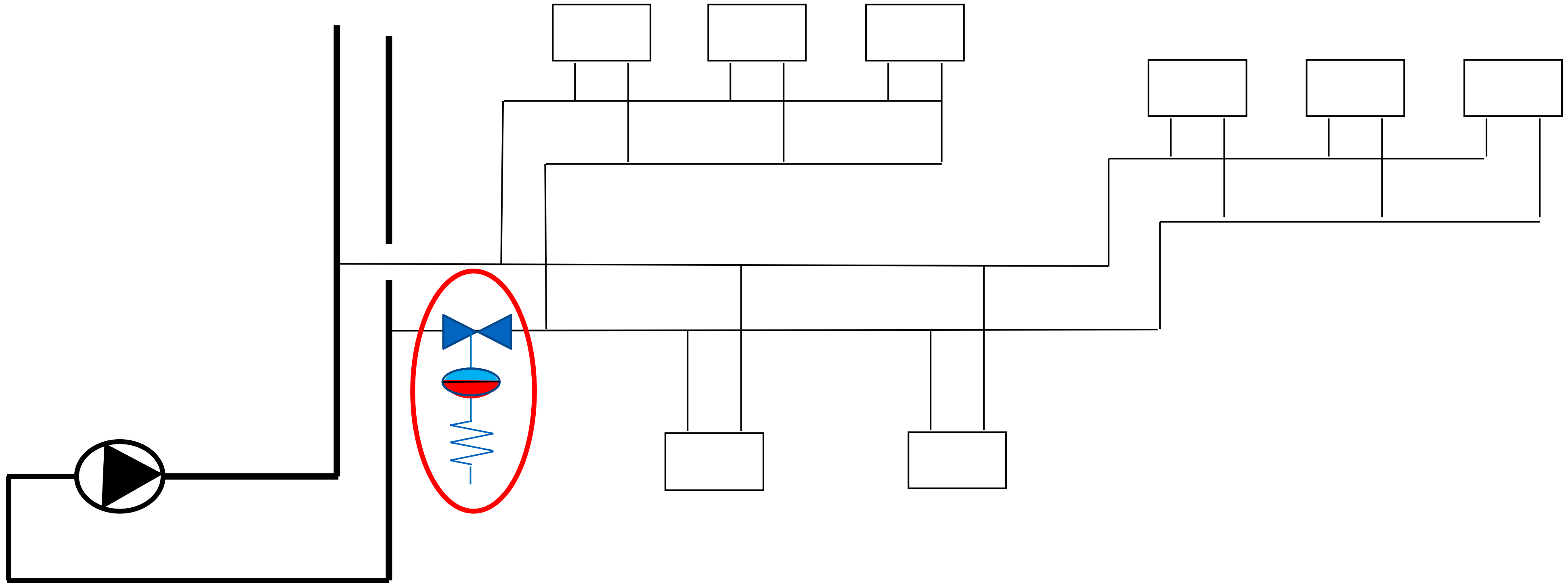
what about the 2 terminals direct off main pipework run?

Each circuit must have some protected from over flow

0933705533
Tinh.pham@Topflow.vn

Where do DPCVs go

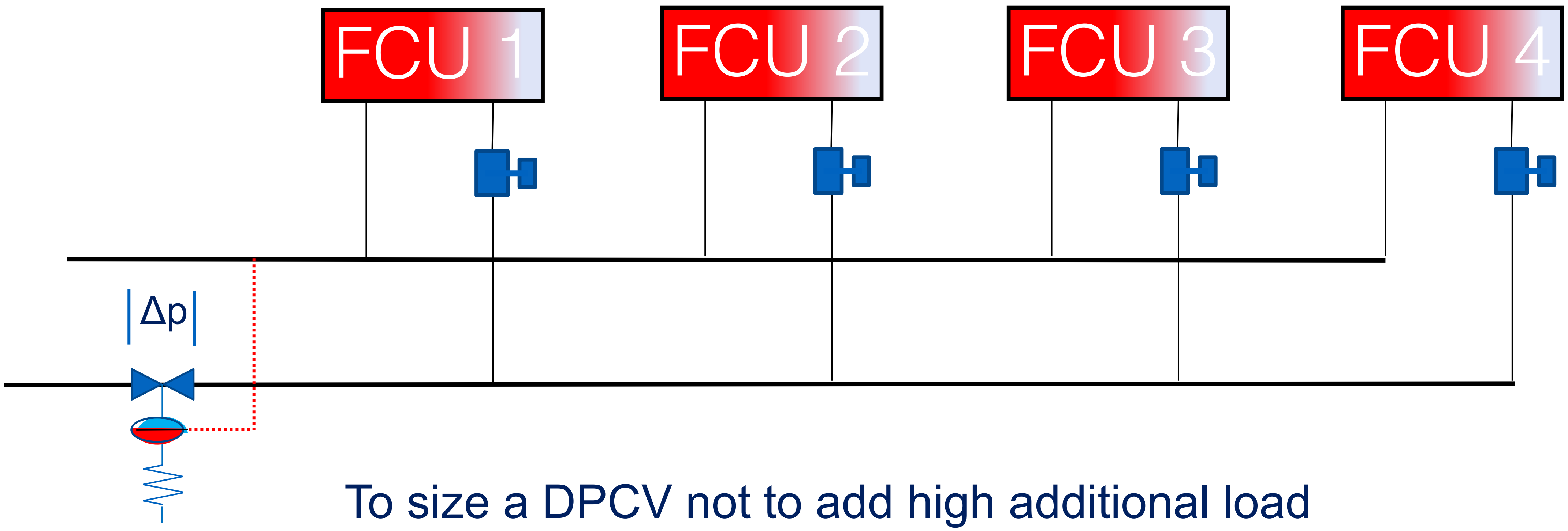
Alternative approach



Complete circuit protected by a single DPCV

0933705533
Tinh.pham@Topflow.vn

How are DPCVs selected



To size a DPCV not to add high additional load

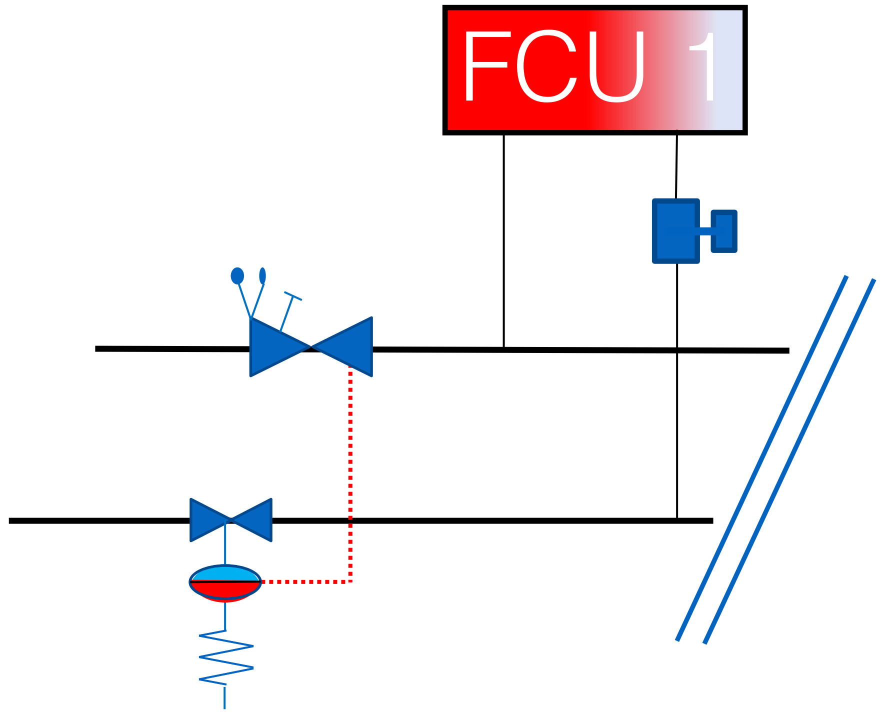
the Δp across the DPCV

is typically 10 - 20kPa

irrespective of the Δp through the circuit

0933705533
Tinh.pham@Topflow.vn

Other Valves associated with DPCVs - Companion Valve

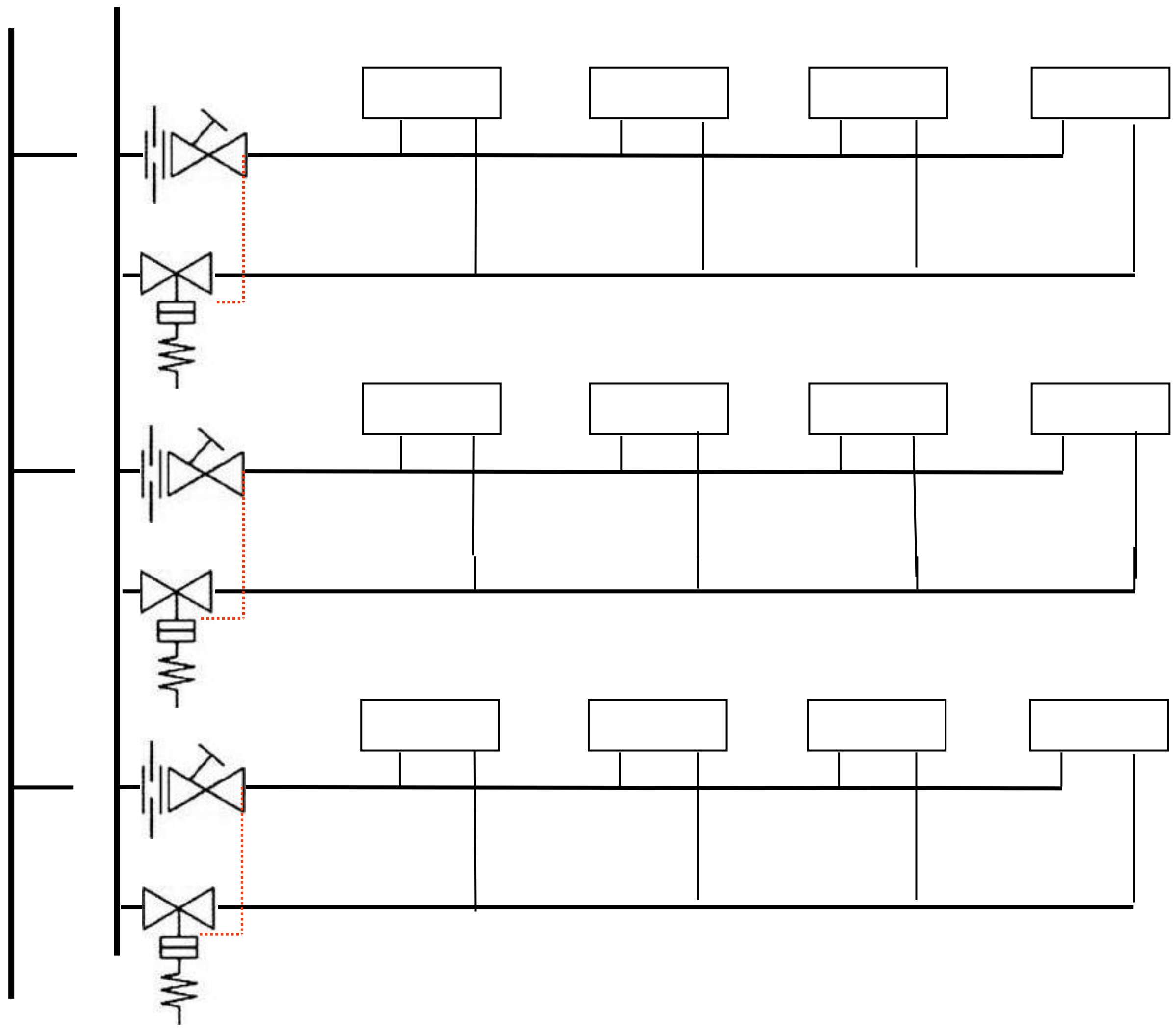


Companion Valve offers

- flow measurement
- isolation
- DPCV connection
- bosses for test points

Dynamic Balancing of the System

Because each sub-circuit is separated by a DPCV from fluctuating system pressure & therefore holds a constant pressure within the sub-circuit, commissioning sub-circuits can be carried out totally independently

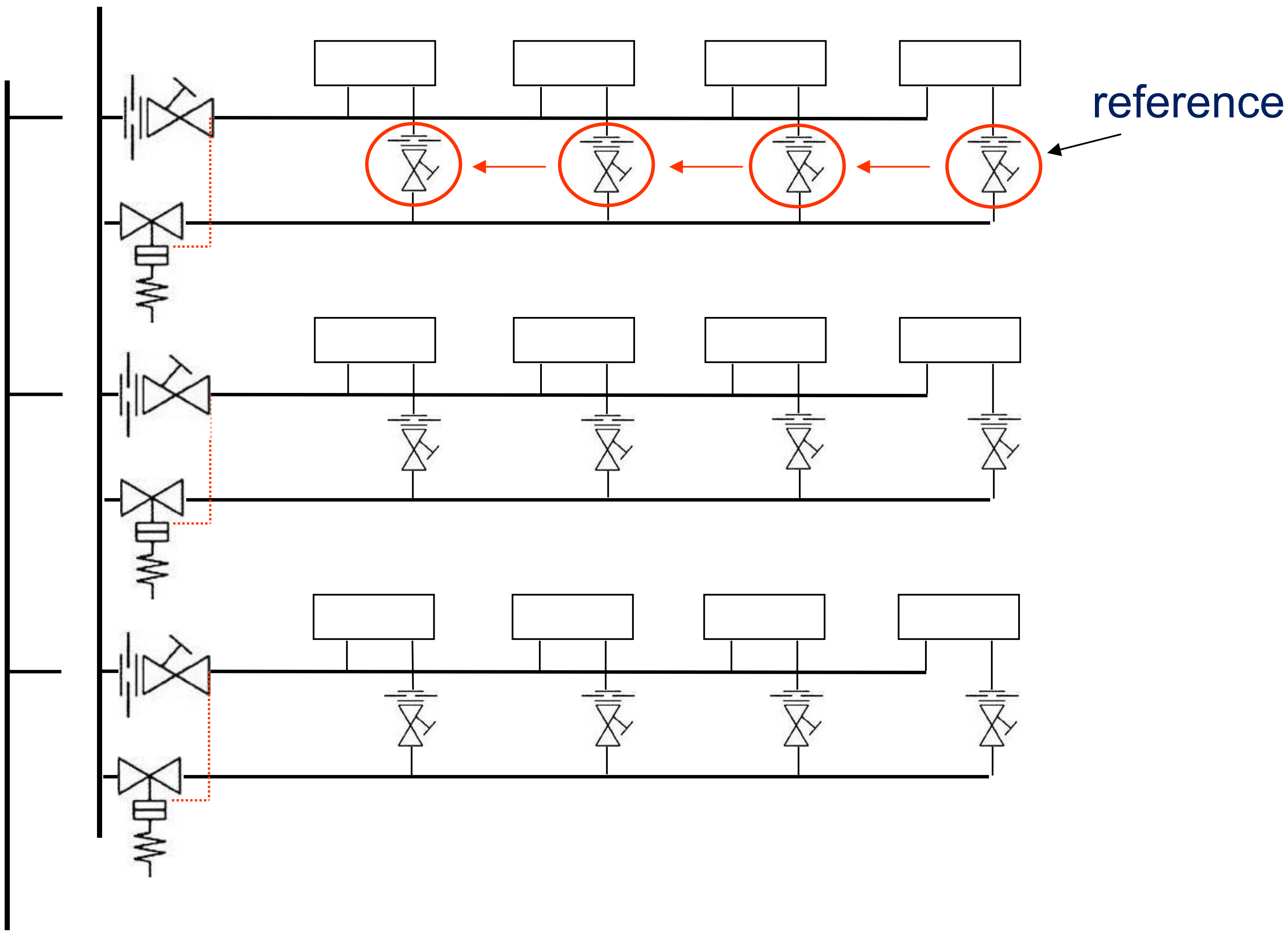


sub-circuits are independent of each other

0933705533
Tinh.pham@Topflow.vn

Dynamic Balancing of the System

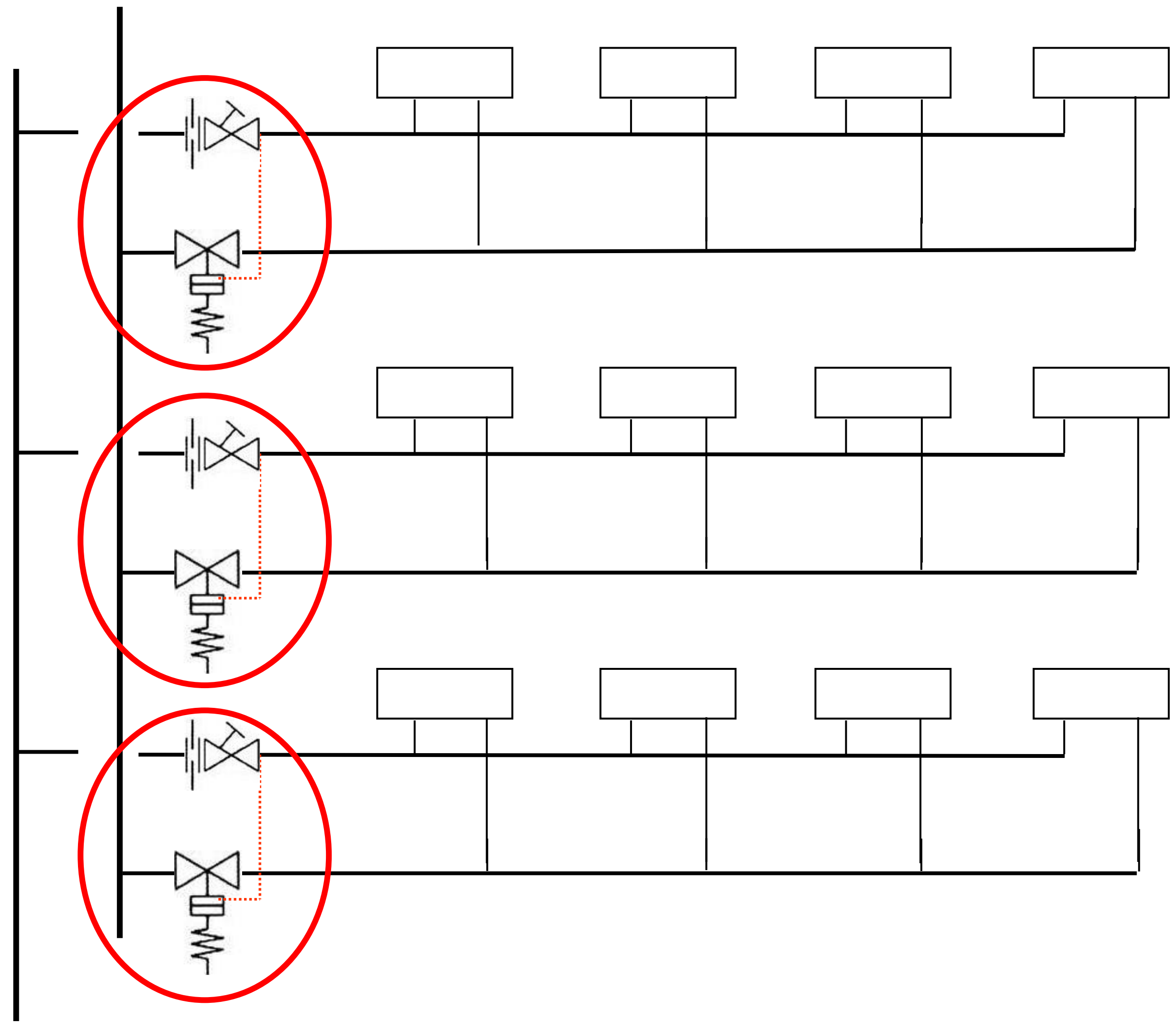
Commissioning within the sub-circuits is carried out by ‘proportional balancing’ in the conventional manner



0933705533
Tinh.pham@Topflow.vn

Dynamic Balancing of the System

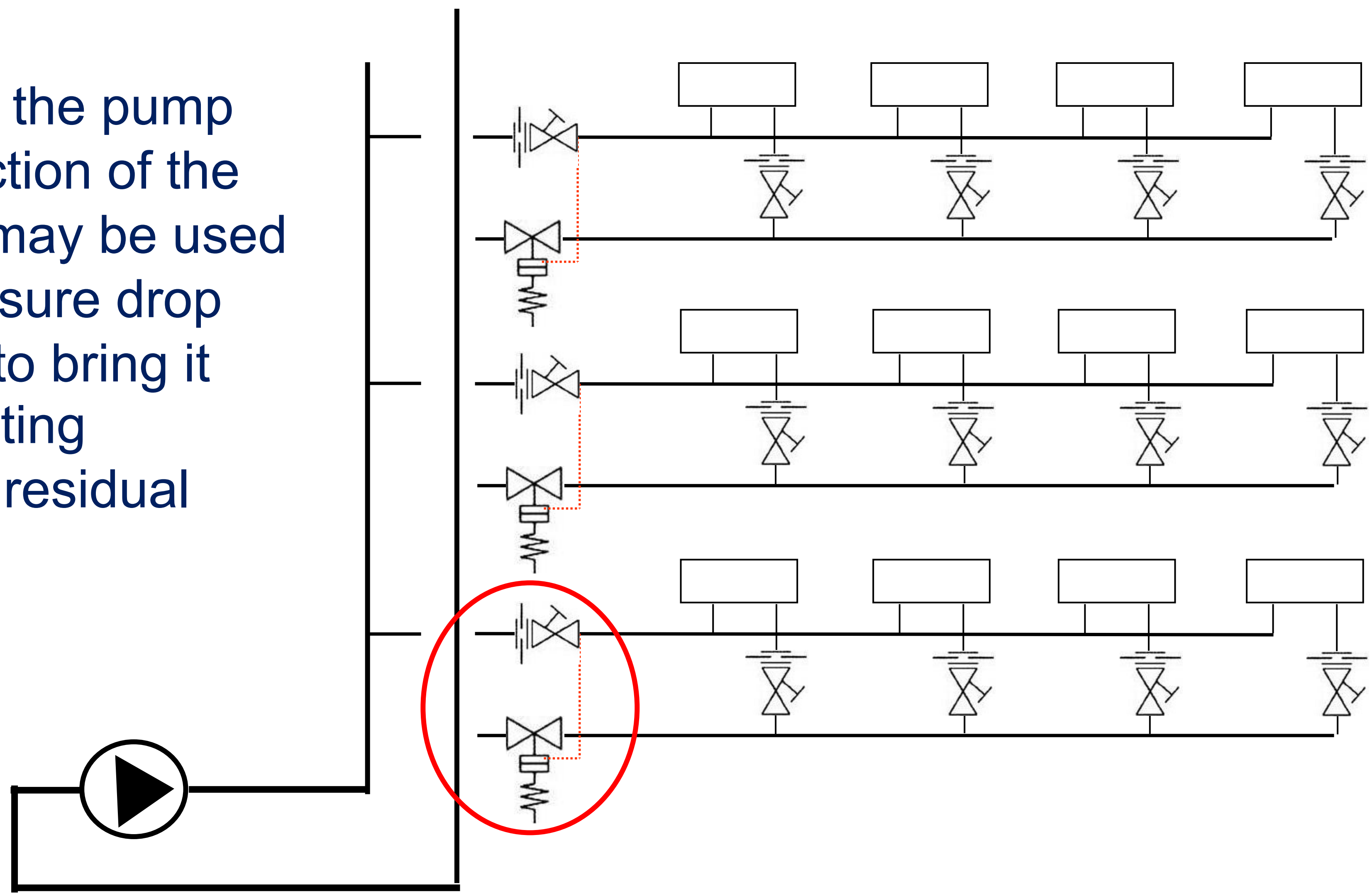
Each sub-circuit is balanced by measuring flow thro the ‘Companion Valve’ and adjusting DPCV to regulate flow



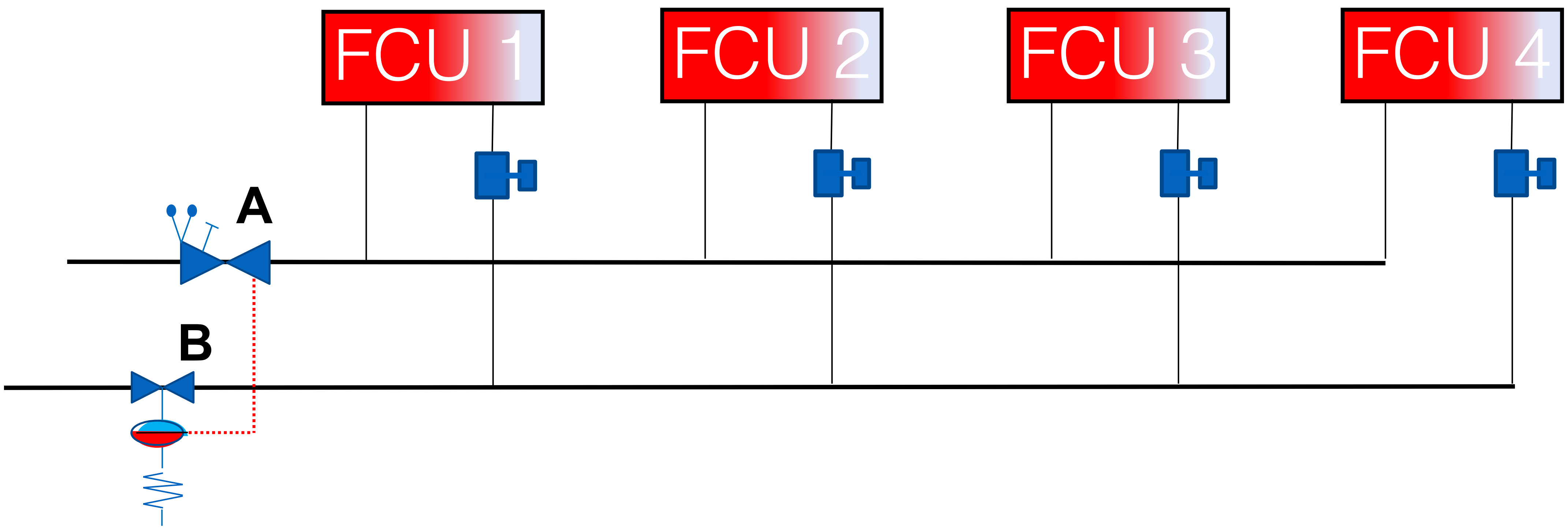
0933705533
Tinh.pham@Topflow.vn

Dynamic Balancing of the System

For circuits nearer the pump the regulating function of the companion valve may be used to reduce the pressure drop across the DPCV to bring it into a better operating position, i.e. splits residual pressure



Dynamic Balancing of the System



1. set DPCV to highest control range setting
   - highest pressure difference gives highest flow rates
2. measure flow rate at companion valve
3. adjust DPCV until design flow rate achieved

0933705533
Tinh.pham@Topflow.vn

Variable Volume System

At maximum pump turndown, typically 10 - 20%, consideration needs to be given to branches to ensure

- pump flow at minimum load
- circulation of water treatment
- ready supply of heating / chilled water

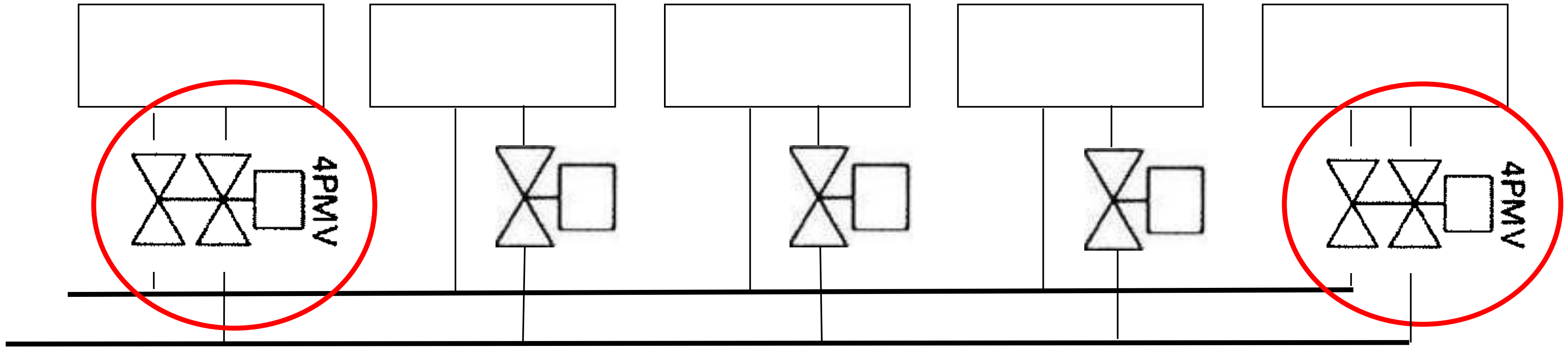
0933705533
Tinh.pham@Topflow.vn

Dynamic Balancing of the System

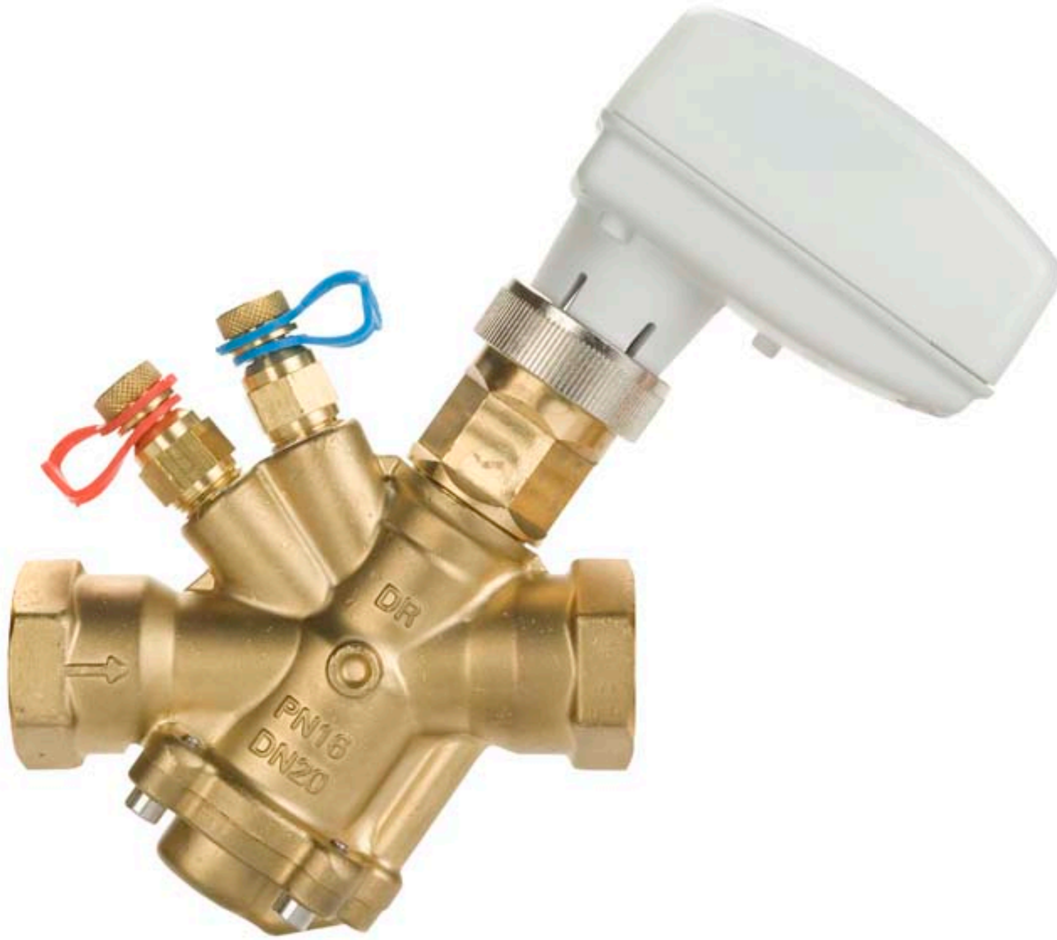
possible solution

end terminal could have a 3 or 4 port control valve

- on larger circuits additional 3 or 4 ports could be added



What are Dynamic Balancing Valves?



Dynamic Balancing Valves

PICV
Pressure Independent Control Valves

Variable Flow Areas
- chilled beams
- radiant panels
- FCUs
- AHUs

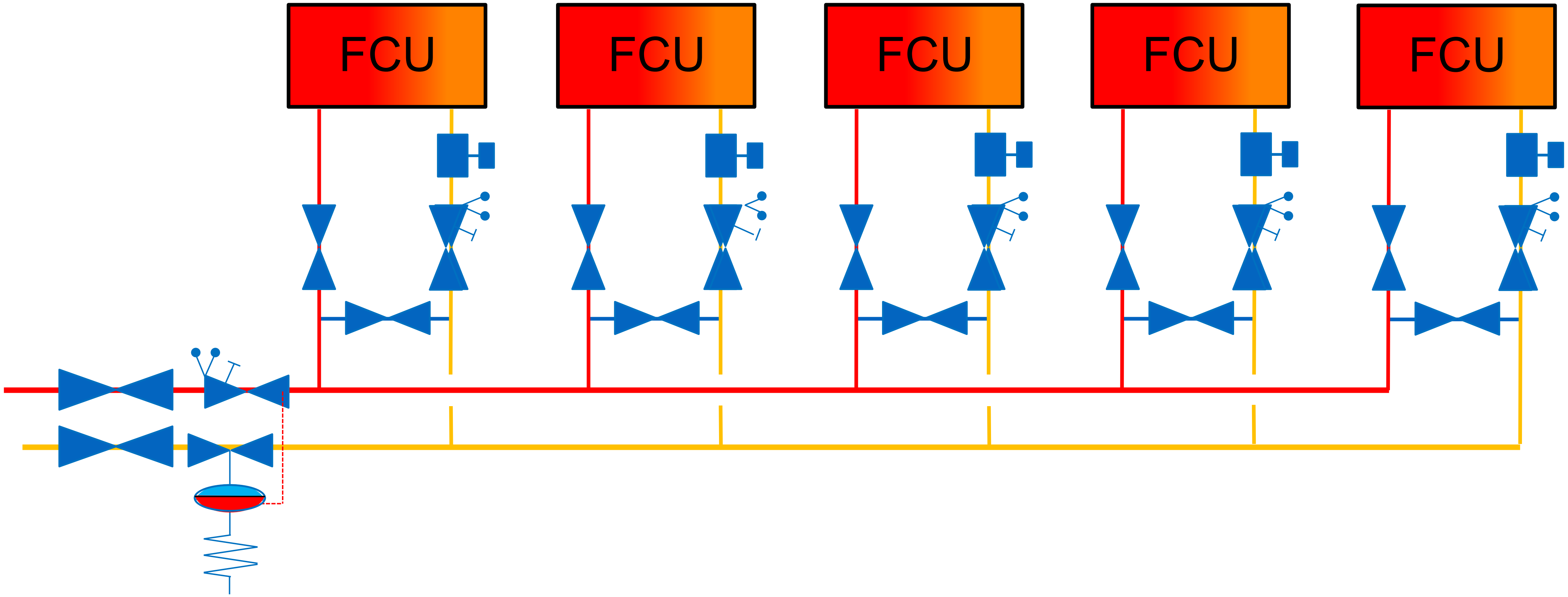
0933705533
Tinh.pham@Topflow.vn

Top Solution, Top Choice
TOP FLOW

Controlling Fluctuating System Pressures

Following the move to *variable volume* system design

- DPCVs were used to create areas with stable pressures

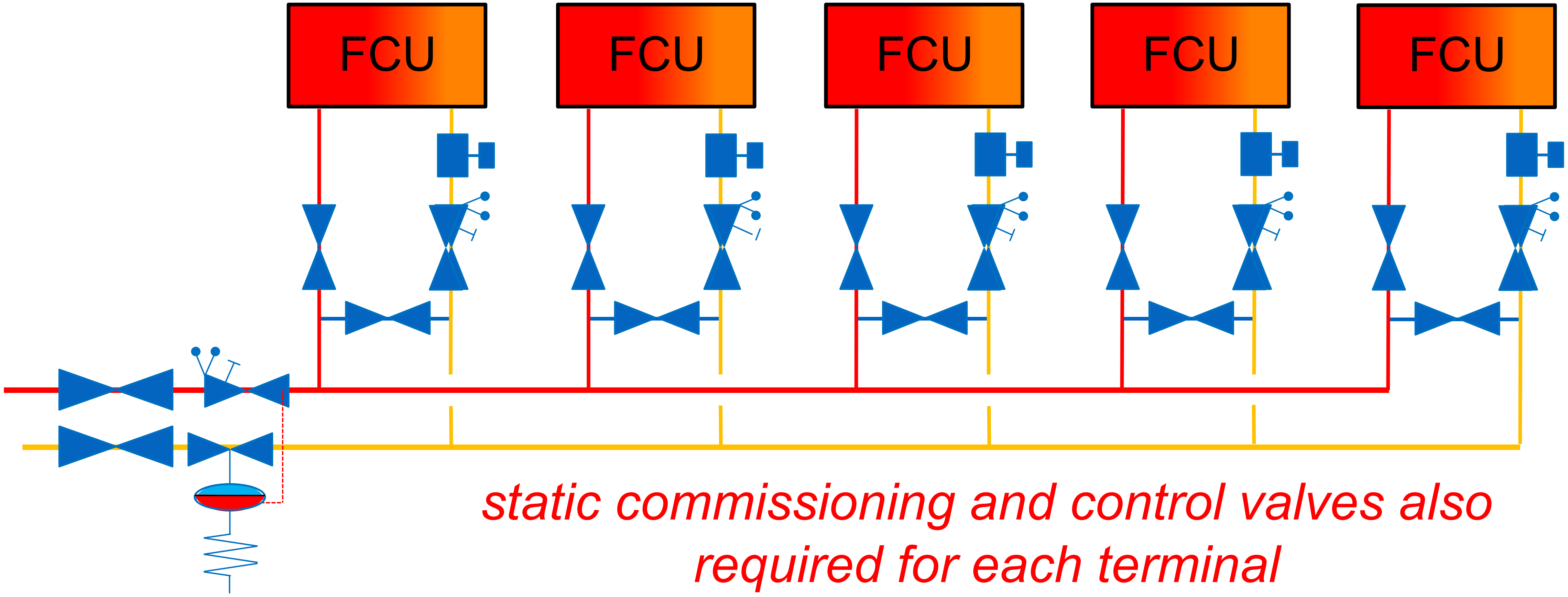


0933705533
Tinh.pham@Topflow.vn

Controlling Fluctuating System Pressures

DPCVs prove difficult to select correctly

- sizing relatively easy
- gathering required information difficult / impossible
    - number of terminals in protected zone / controlled Dp ?



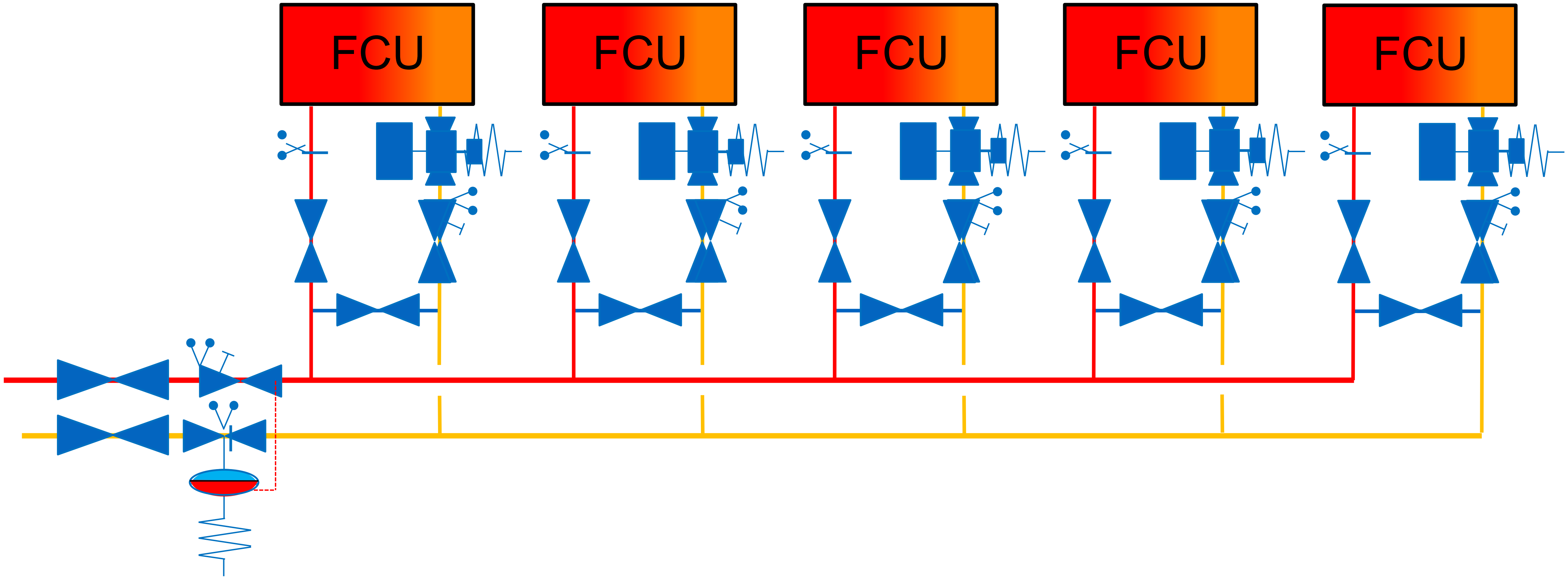
static commissioning and control valves also required for each terminal

0933705533
Tinh.pham@Topflow.vn

Controlling Fluctuating System Pressures

PICVs replacing DPCVs

other valves required?

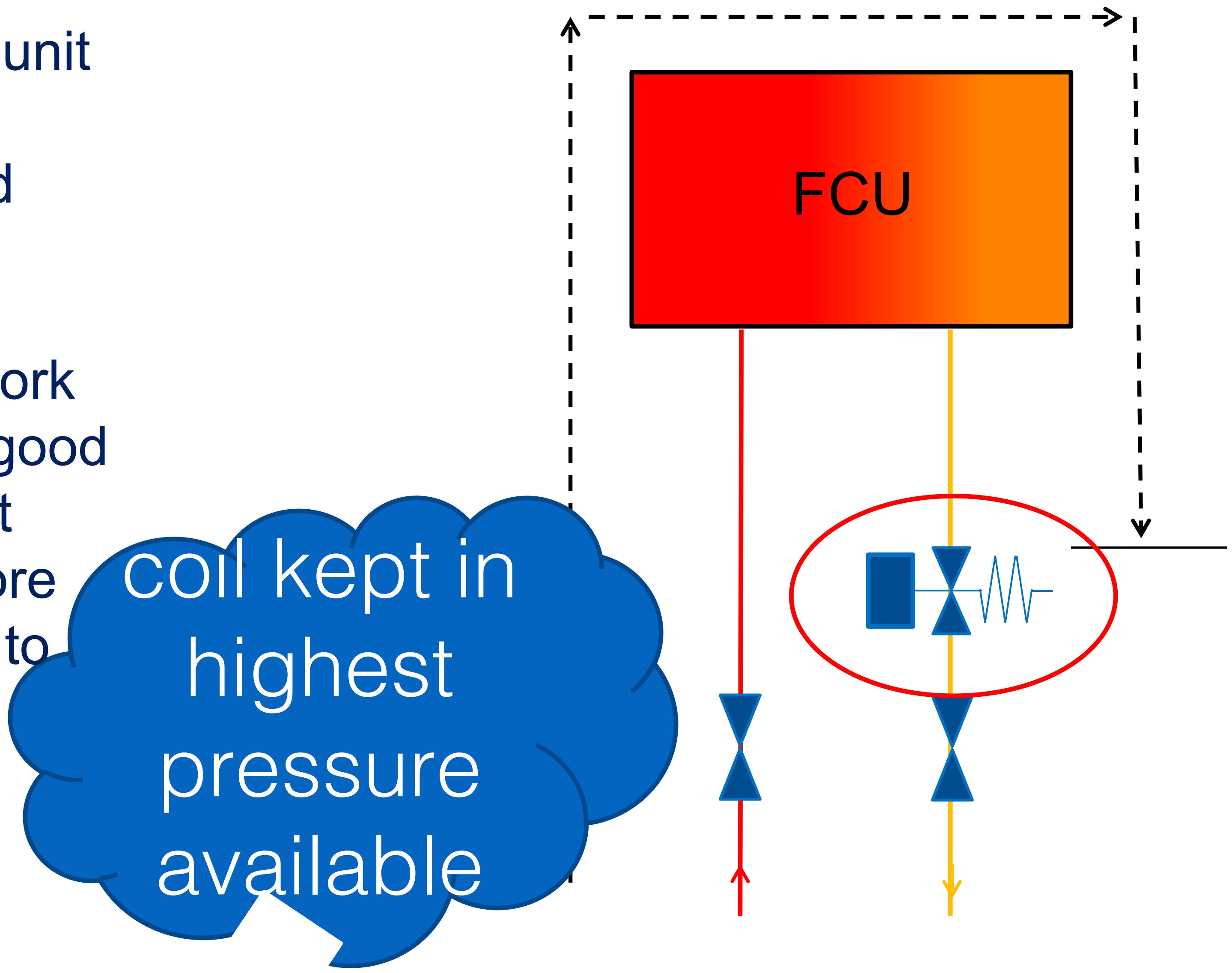


the PICV is fitted instead of – not as well as

0933705533
Tinh.pham@Topflow.vn

Controlling Fluctuating System Pressures

- Normally fitted to each terminal unit
- Return pipework is the preferred position
- Clear / straight lengths of pipework are *not* required for PICVs but ‘good practice’ suggests some straight lengths of pipework create a more stable flow pattern for the PICV to control

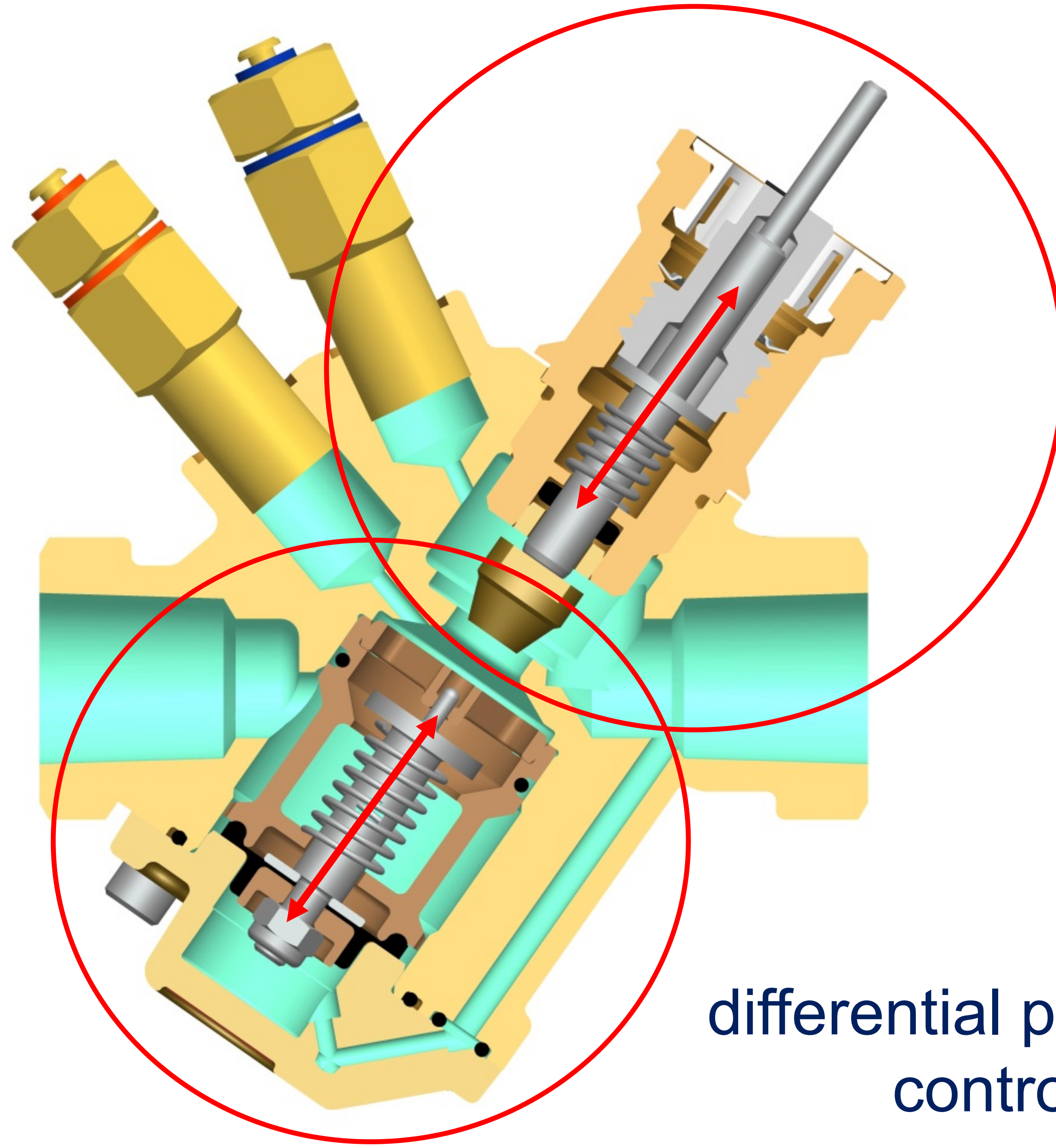


0933705533
Tinh.pham@Topflow.vn

Top Solution, Top Choice
TOP FLOW

What is a PICV?

Three functions in one



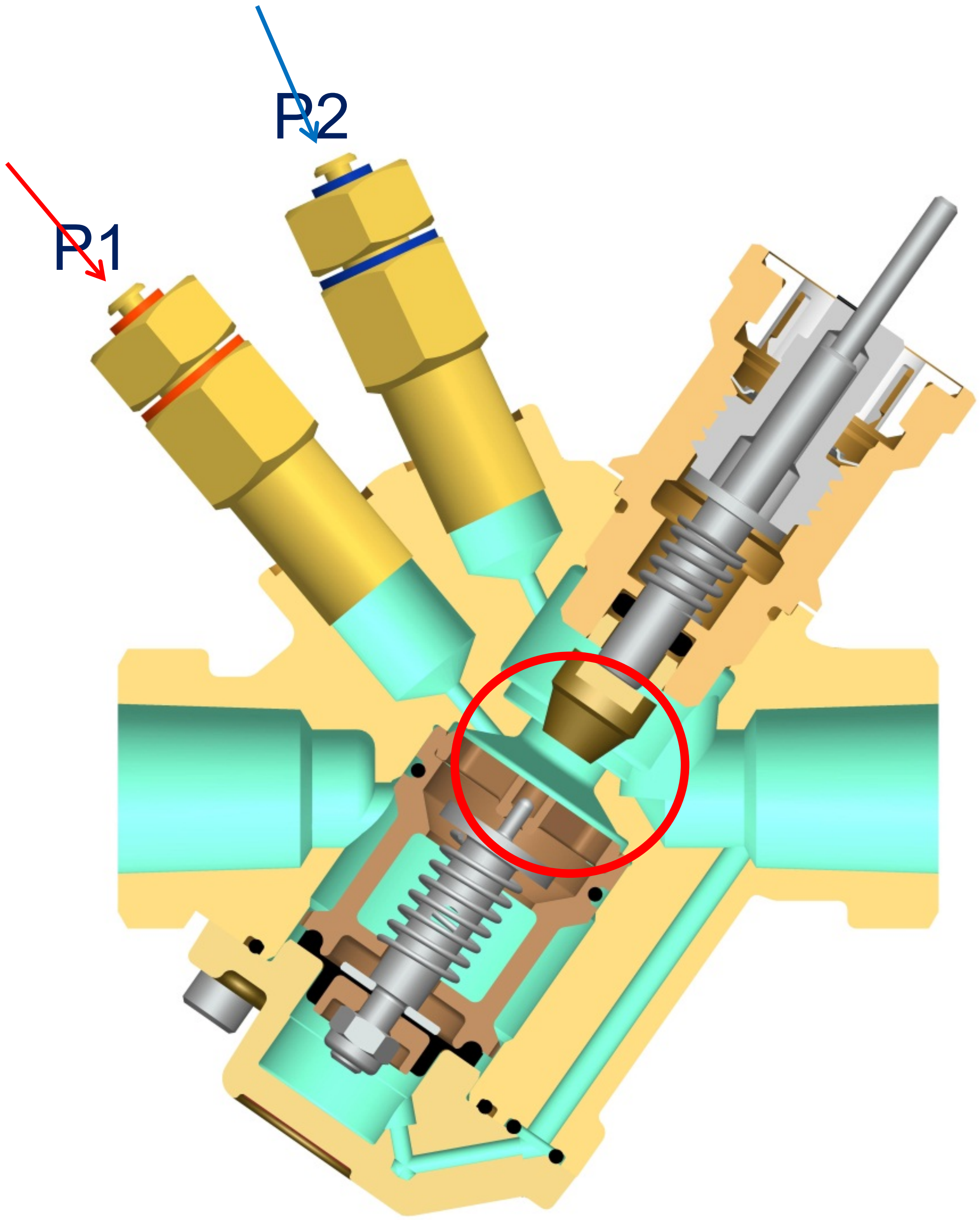
0933705533
Tinh.pham@Topflow.vn
47

Pressure Drops Across PICV

Differential pressure controller holds the Dp across the seat constant

Dp confirmed by test points

Often referred to as P1 – P2



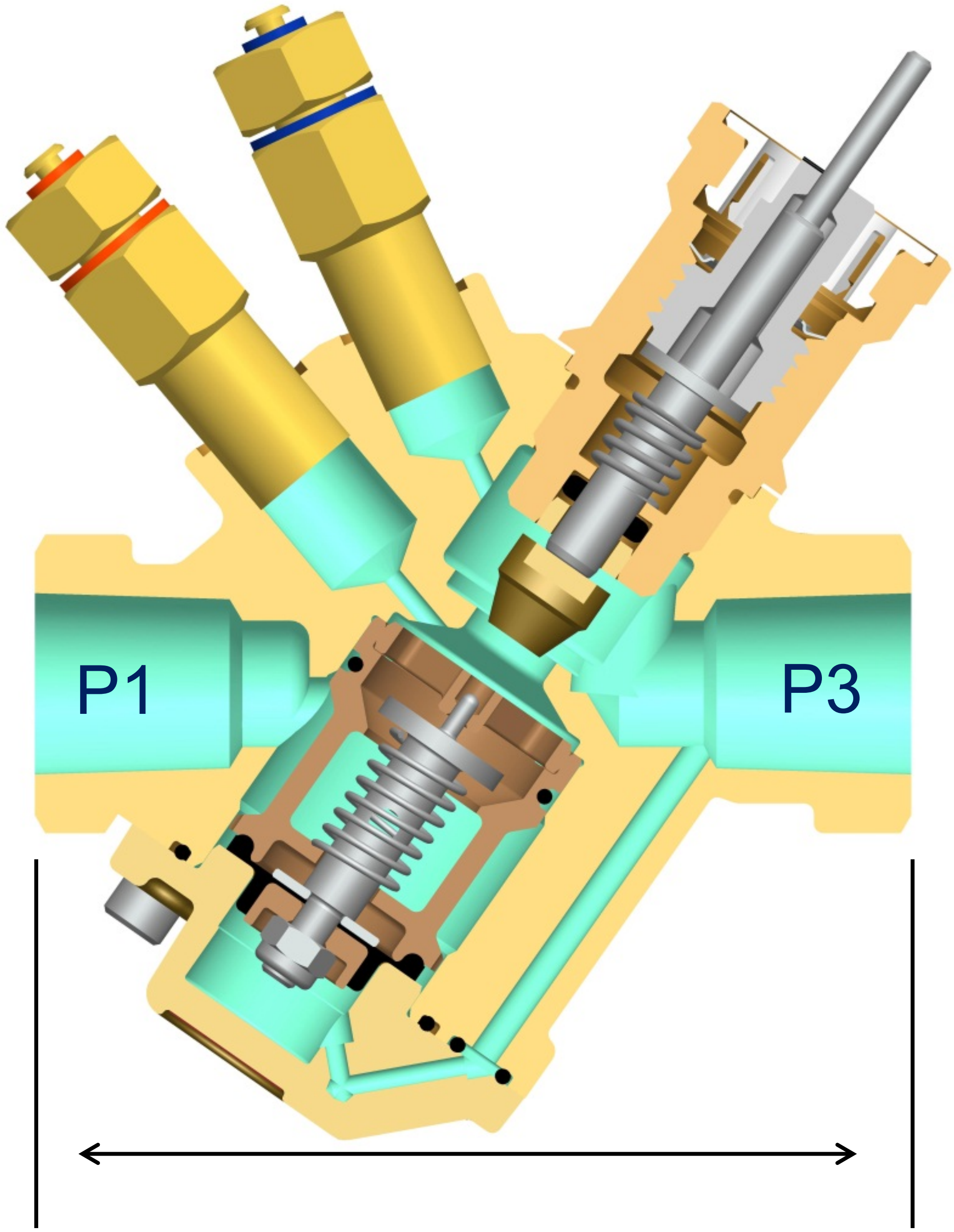
0933705533
Tinh.pham@Topflow.vn

Pressure Drops Across PICV

Differential pressure across the PICV varies

On smaller sizes total Dp *NOT* confirmed by test points

Often referred to as P1 – P3

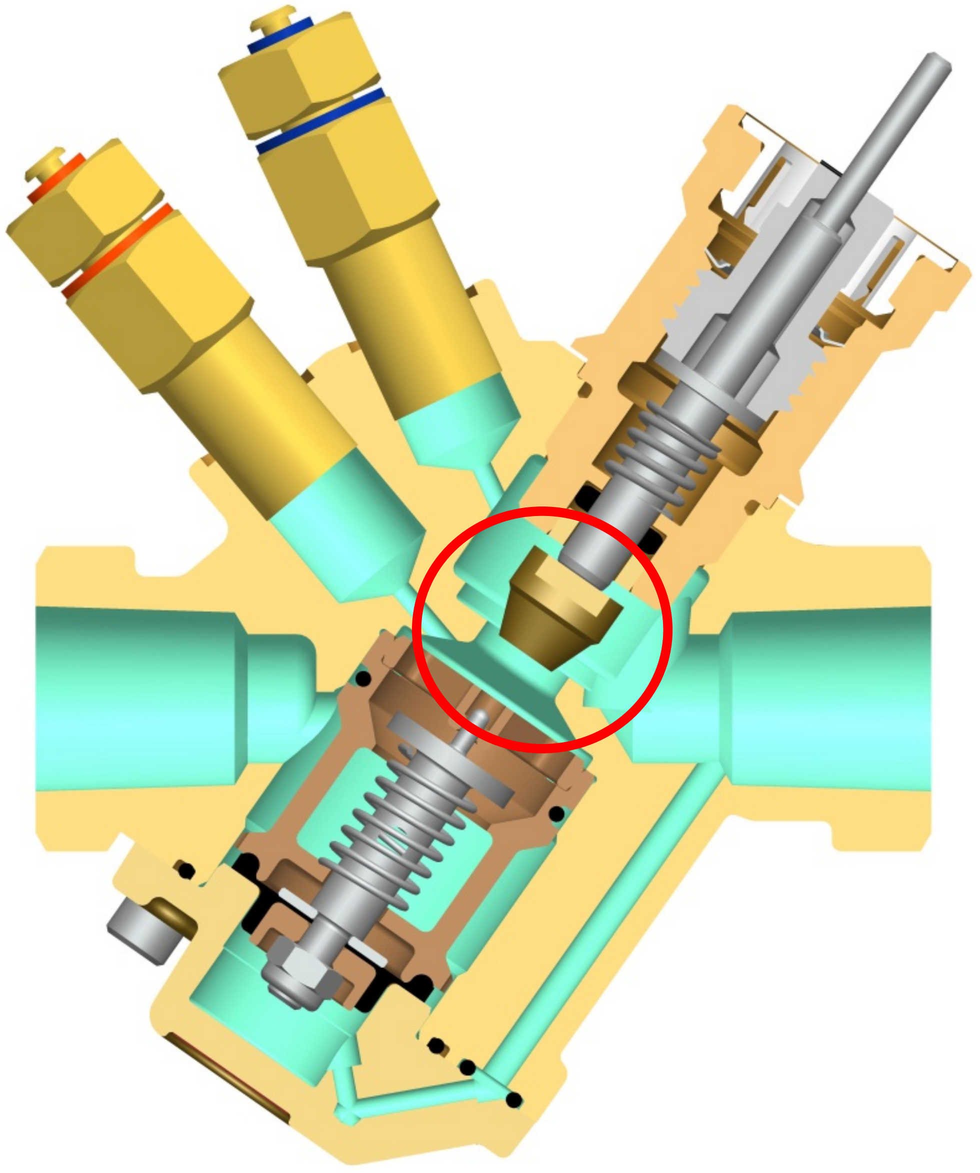


PICV Authority

$$\text{Authority } h = \frac{\text{Dp across control valve}}{\text{DP across circuit}}$$

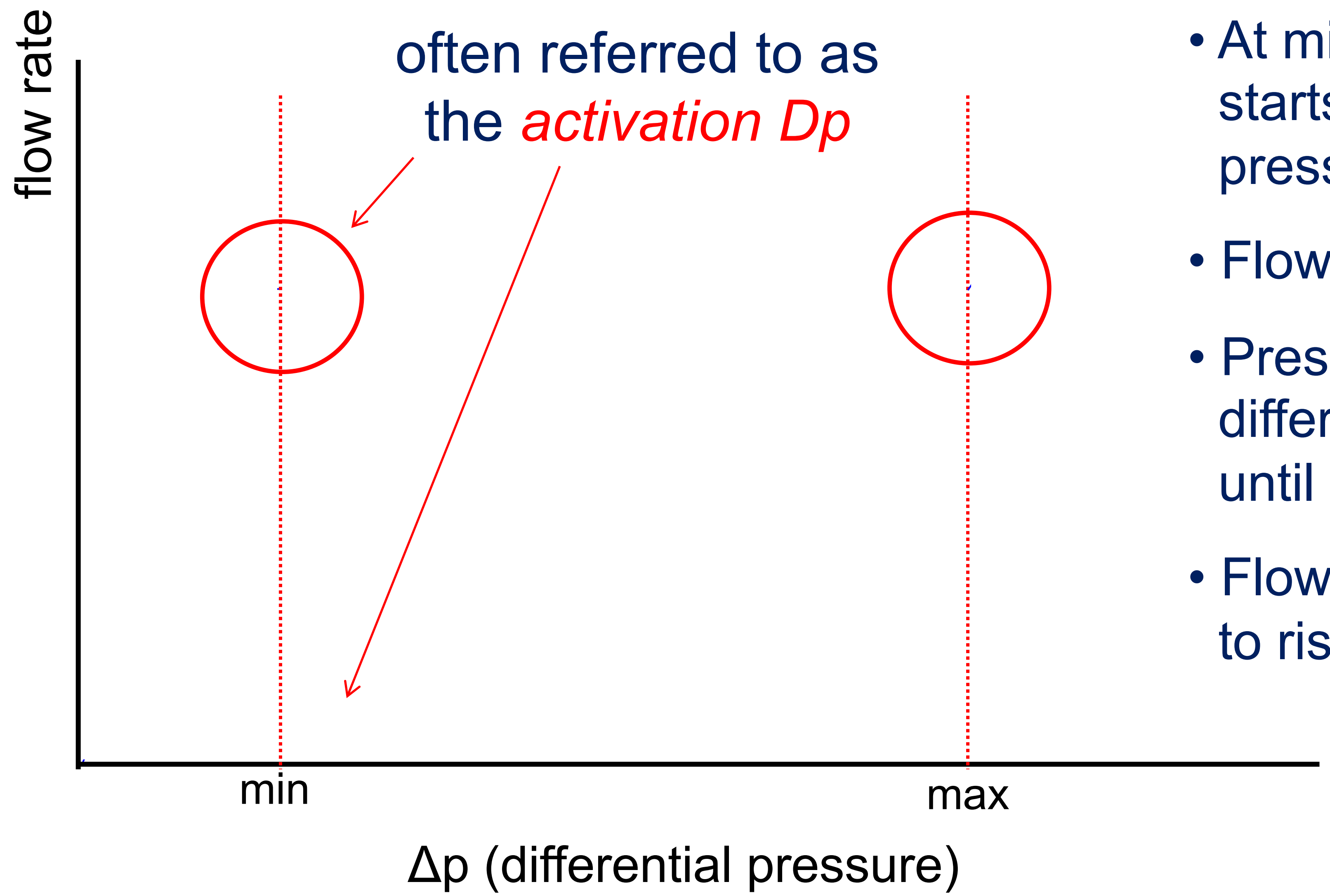
Dp control valve = DP circuit

Considered to be '1'



0933705533
Tinh.pham@Topflow.vn

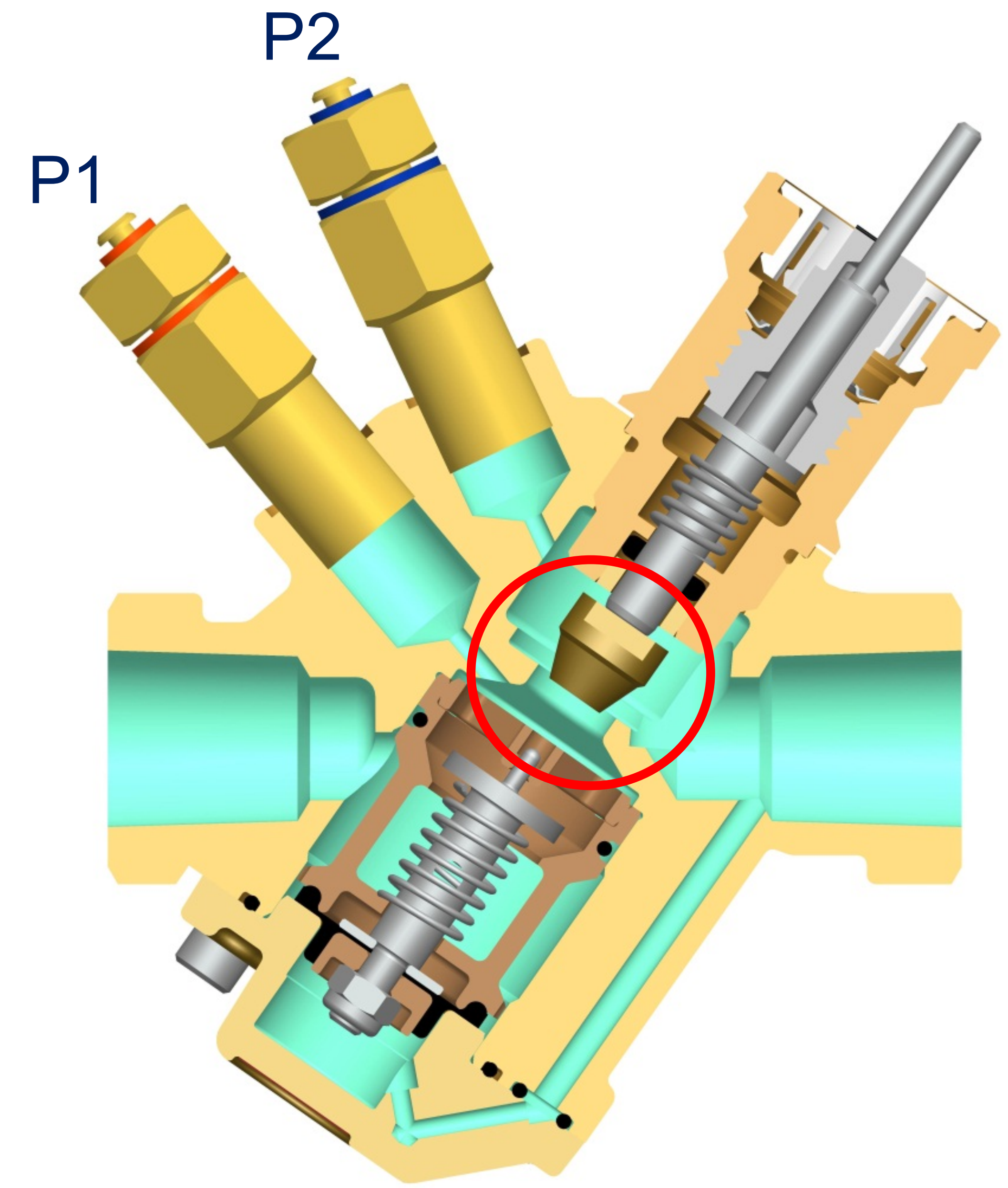
PICV Activation



- As flow increases Δp increases
- At min Δp, pressure controller starts to hold differential seat pressure constant
- Flow rate remains constant
- Pressure controller controls seat differential pressure at *min Δp* until max *total* Δp is reached
- Flow rate will rise as Δp continues to rise

0933705533
Tinh.pham@Topflow.vn

PICV Activation



P1 to P2
the activation Δp
always constant
measured by integral test points

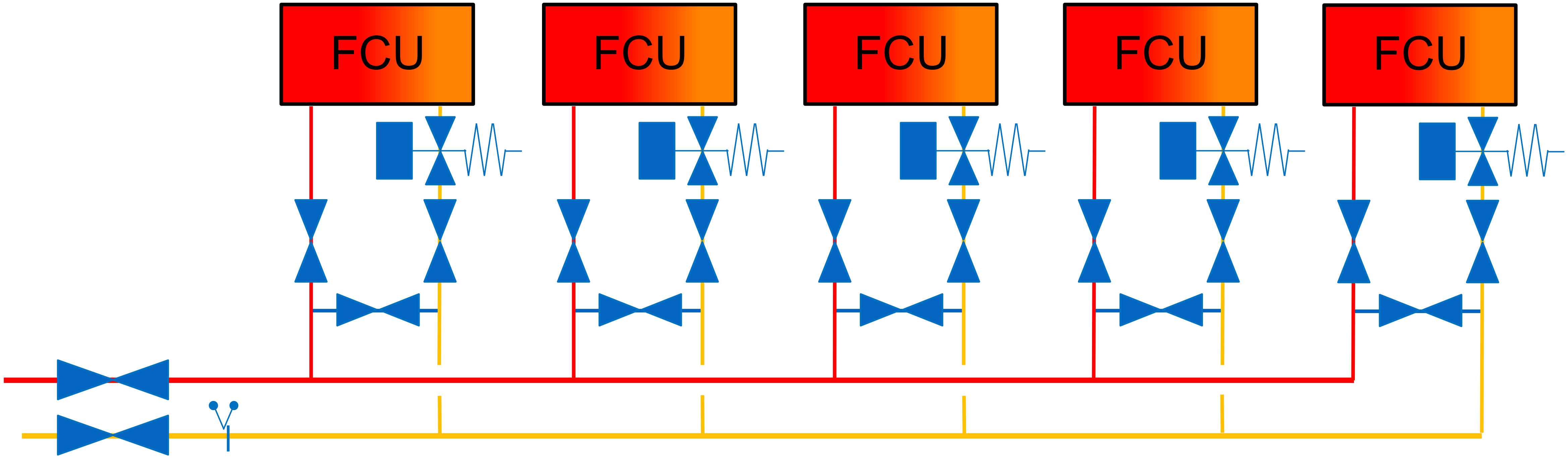
Where test points measure
P1 – P3
Δp will vary
between min & max

PICV Selection

Flow rate is the *main* selection criteria

Other considerations could be

- minimising pressure drop
- matching line sizes



Almost always it is flow rate that determines selection

0933705533
Tinh.pham@Topflow.vn

PICV Selection

DN15 Low Flow			DN15 Standard Flow		
setting position	flow rate l/s	total Δp kPa	setting position	flow rate l/s	total Δp kPa
2	0.008	15	2	0.04	15
3	0.010	15	3	0.060	15
4	0.020	15	4	0.080	20
5	0.030	15	5	0.105	20
6	0.040	20	6	0.120	20
7	0.050	20	7	0.140	20
8	0.060	20	8	0.155	25
9	0.070	20	9	0.175	25
10	0.080	20	10	0.200	25

selection charts are available

- flow rates
- set position
- minimum Δp (differential pressure) *total loss at activation*

0933705533
Tinh.pham@Topflow.vn

PICV Selection – activation point

- *activation* Δp lower than *total* Δp
- activation Δp constant
- total Δp varies

DN15 tandard Flow			
setting position	flow rate l/s	total Δp kPa	activation Δp kPa
2	0.040	15	12
3	0.060	15	12
4	0.080	20	12
5	0.100	20	12
6	0.120	20	12
7	0.140	20	12
8	0.160	25	12
9	0.180	25	12
10	0.200	25	12

0933705533
Tinh.pham@Topflow.vn

Top Solution, Top Choice

TOP FLOW

PICV Selection

DN15 Low Flow		
setting position	flow rate l/s	total Δp kPa
2	0.008	15
3	0.010	15
4	0.020	15
5	0.030	15
6	0.040	20
7	0.050	20
8	0.060	20
9	0.070	20
10	0.080	20

DN15 Standard Flow		
setting position	flow rate l/s	total Δp kPa
2	0.04	15
3	0.060	15
4	0.080	20
5	0.105	20
6	0.120	20
7	0.140	20
8	0.155	25
9	0.175	25
10	0.200	25

DN20 Standard Flow		
setting position	flow rate l/s	total Δp kPa
2	0.065	15
3	0.100	20
4	0.130	20
5	0.160	20
6	0.190	25
7	0.220	25
8	0.240	25
9	0.260	25
10	0.280	25

Example
required flow rate 0.160l/s

between setting 8 & 9
8.3ish

setting 5

0933705533
Tinh.pham@Topflow.vn

PICV Selection

DN15 Low Flow			DN15 Standard Flow			DN20 Standard Flow		
setting position	flow rate l/s	total Δp kPa	setting position	flow rate l/s	total Δp kPa	setting position	flow rate l/s	total Δp kPa
2	0.008	15	2	0.04	15	2	0.065	15
3	0.010	15	3	0.060	15	3	0.100	20
4	0.020	15	4	0.080	20	4	0.130	20
5	0.030	15	5	0.105	20	5	0.160	20
6	0.040	20	6	0.120	20	6	0.190	25
7	0.050	20	7	0.140	20	7	0.220	25
8	0.060	20	8	0.155	25	8	0.240	25
9	0.070	20	9	0.175	25	9	0.260	25
10	0.080	20	10	0.200	25	10	0.280	25

example
required flow rate 0.160l/s

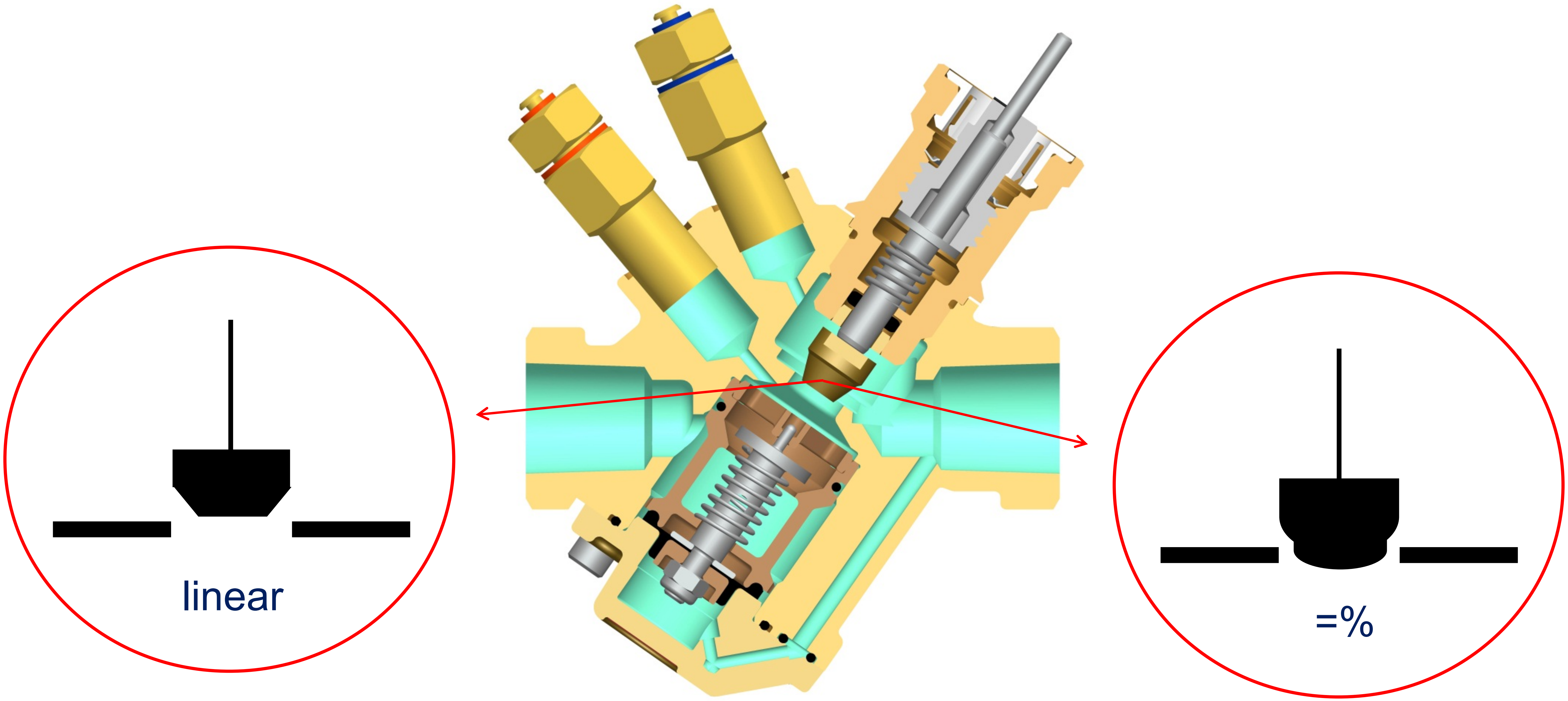
total Δp (P1 – P3)
25 kPa

total Δp (P1 – P3)
20 kPa

Total Δp could rise to max Δp – 350 kPa

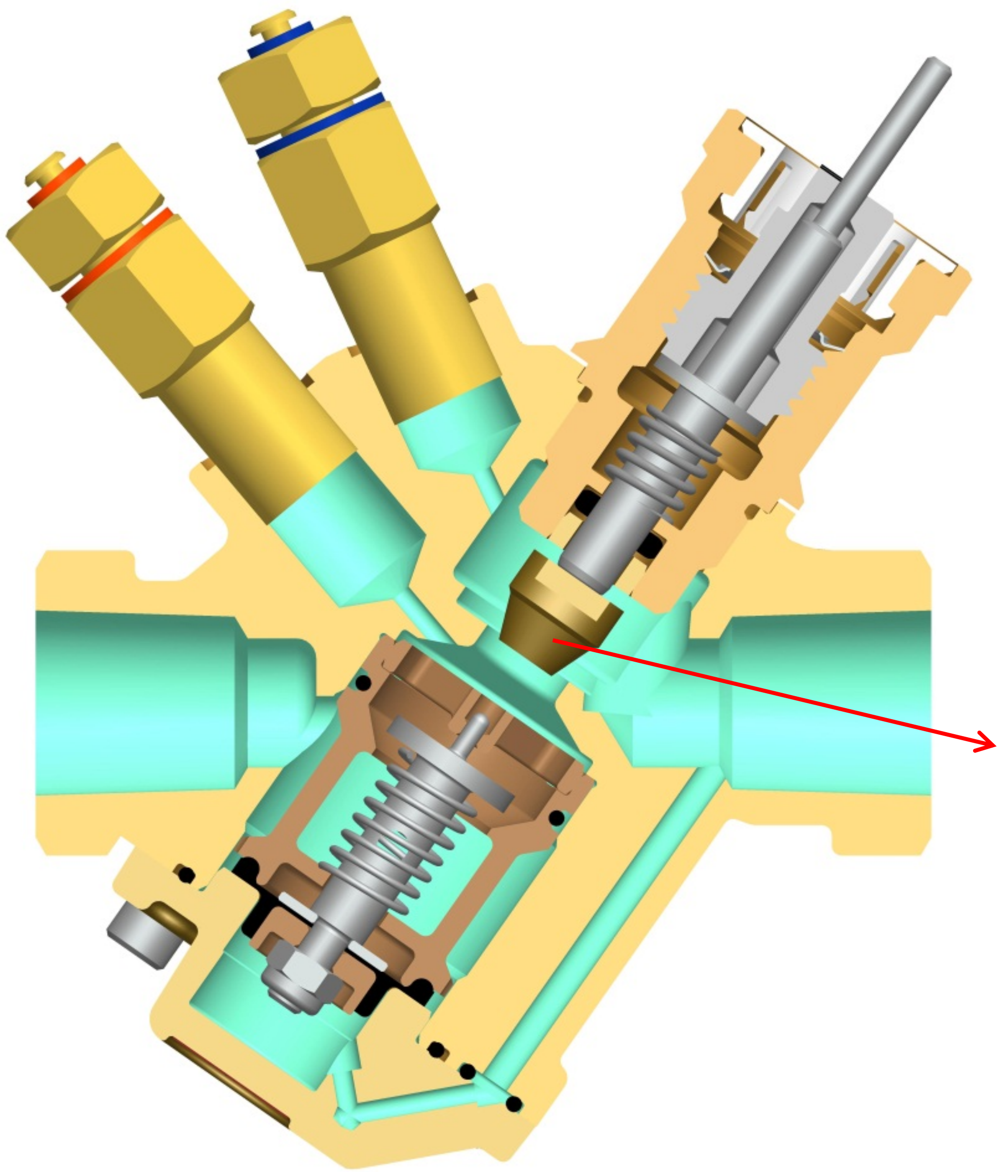
0933705533
Tinh.pham@Topflow.vn

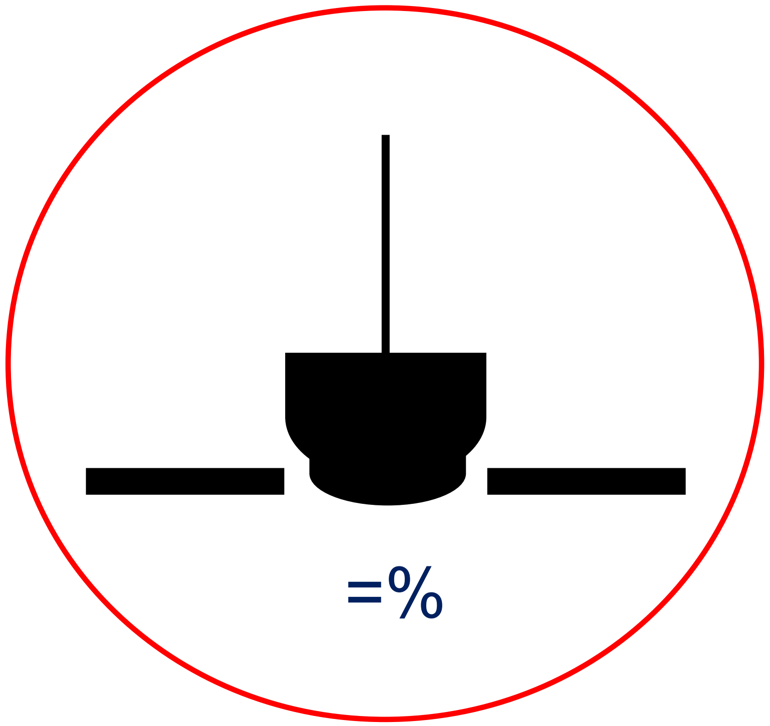
PICV Control Characteristic



PICV Control Characteristic - =%

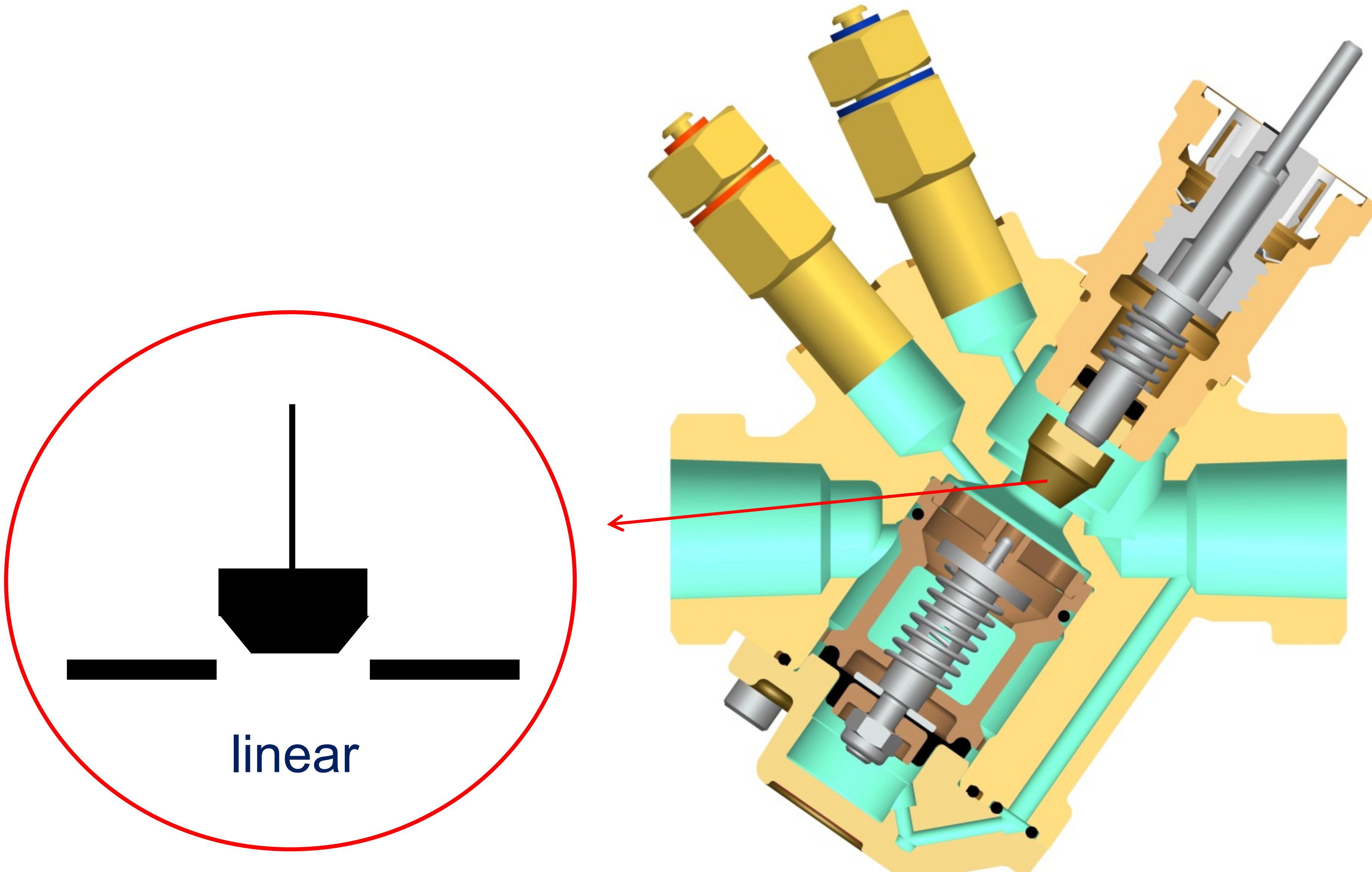
if stem it used to regulate flow rate Control Characteristic is changed at lower settings





0933705533
Tinh.pham@Topflow.vn

PICV Control Characteristic - linear



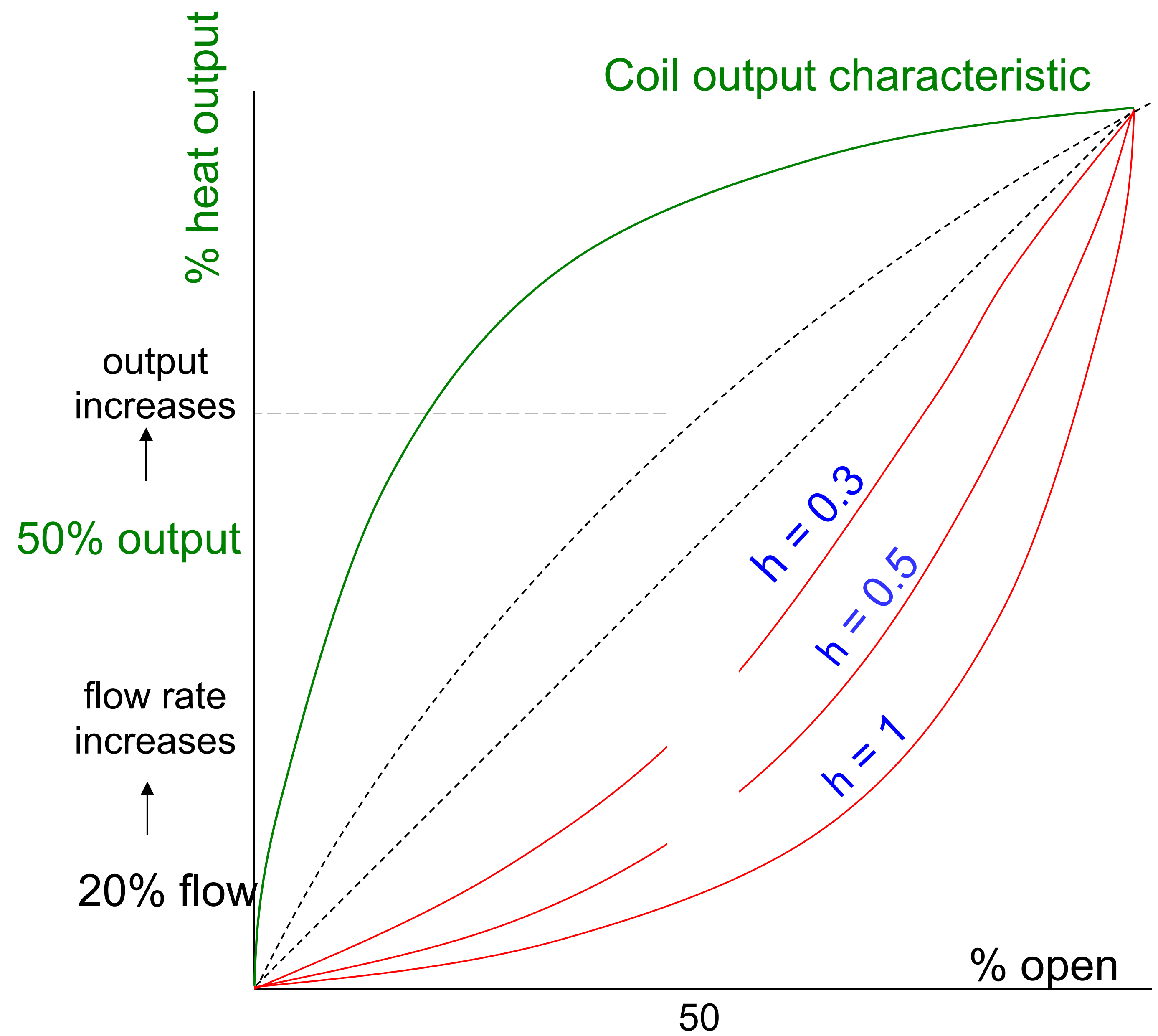
If stem it used to regulate flow rate Control Characteristic is *NOT* changed at lower settings

PICV Control Characteristic

Equal percentage control valves are designed with a

h = 1

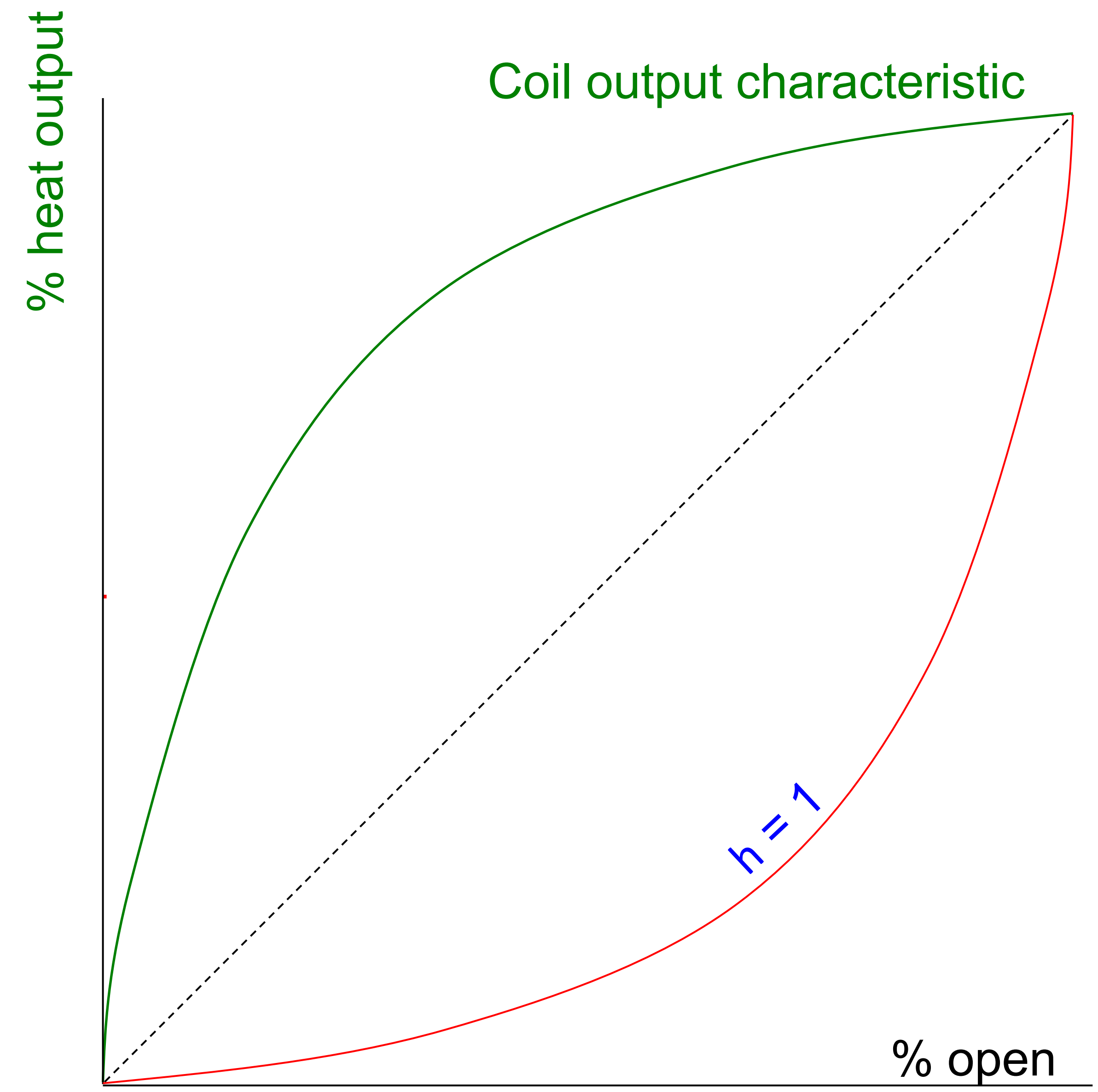
Mirror image of coil characteristic



0933705533
Tinh.pham@Topflow.vn

PICV Control Characteristic - =%

- Establish a direct relationship between open position & *heat output*
- 50% valve opening = 50% heat output

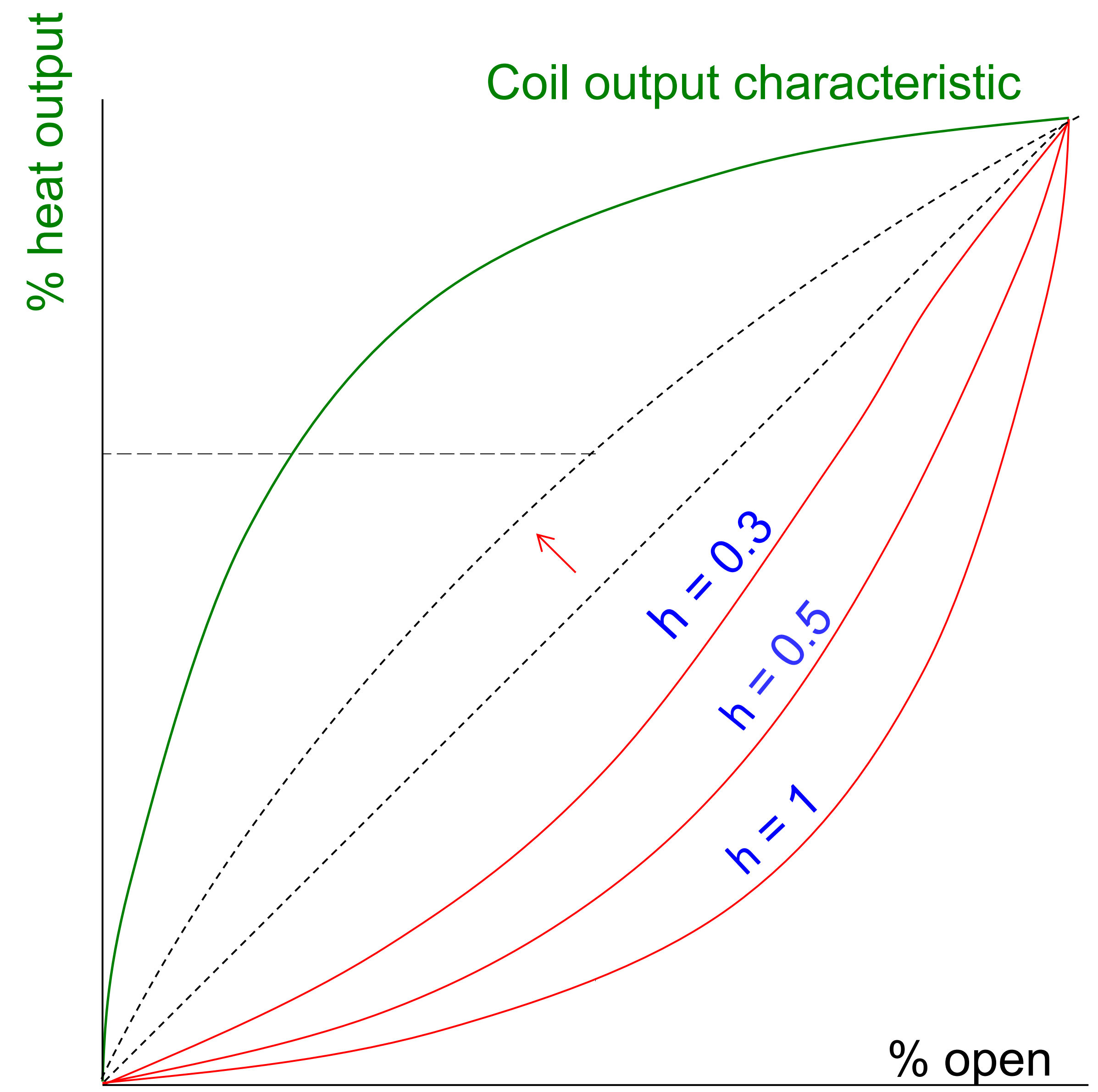


0933705533
Tinh.pham@Topflow.vn

PICV Control Characteristic - =%

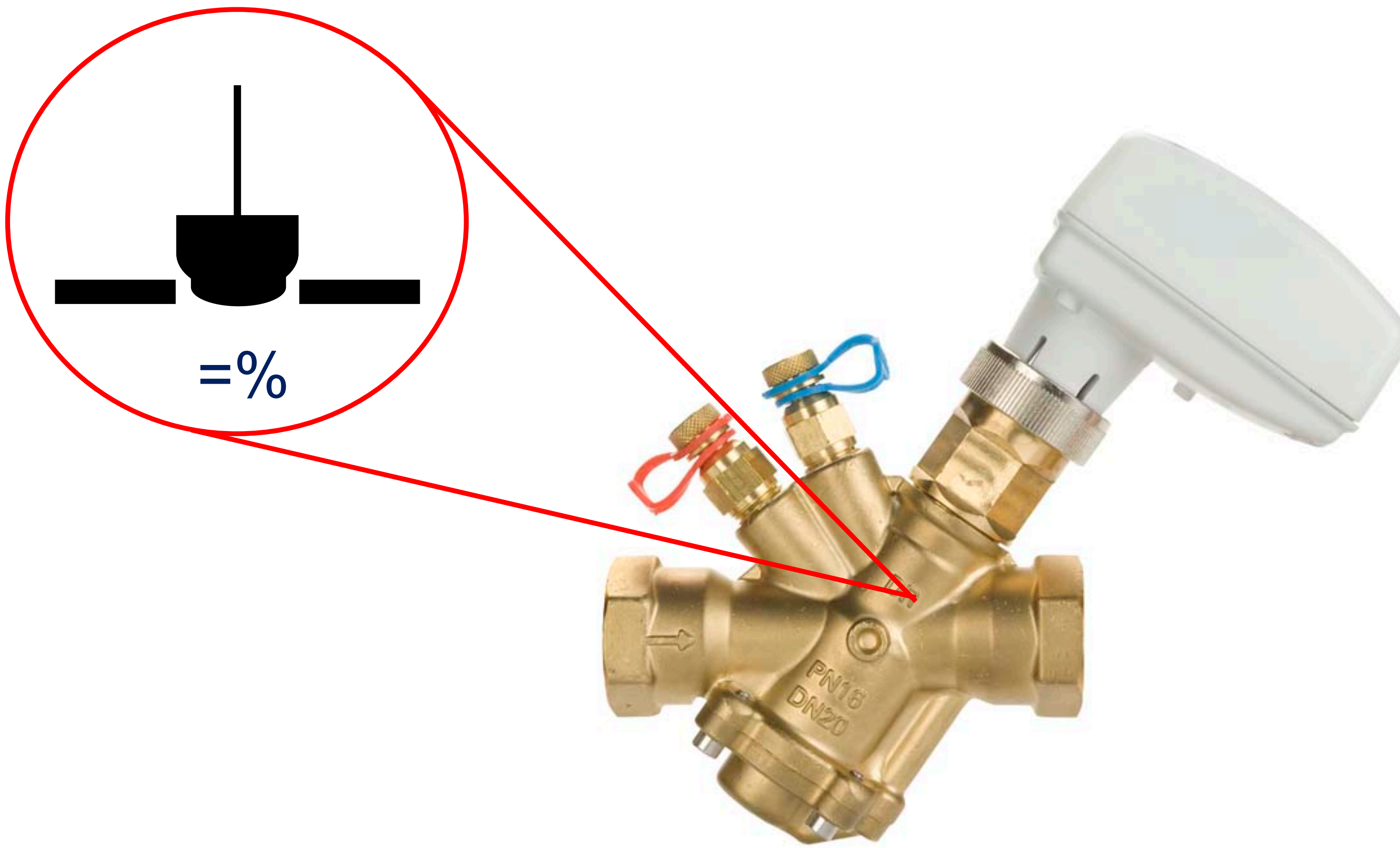
- Where stem used to regulate flow rate
- Changes control characteristic

combined 'linear' position moves due to effect of valve characteristic

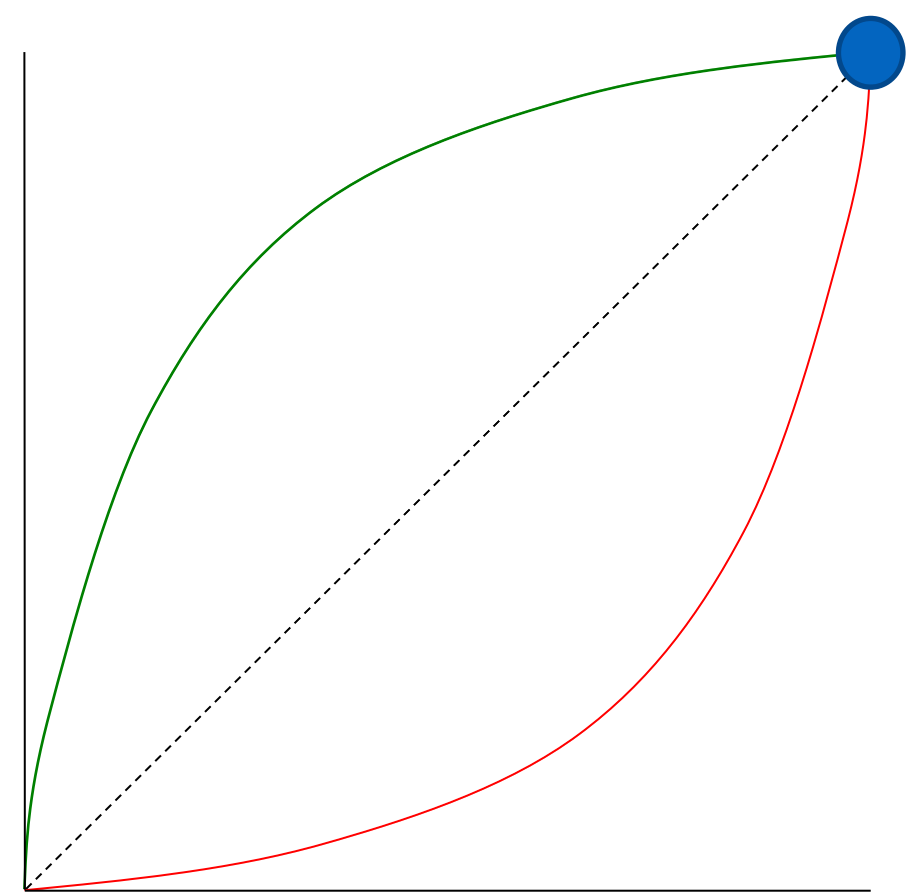


0933705533
Tinh.pham@Topflow.vn

PICV Control Characteristic - =%



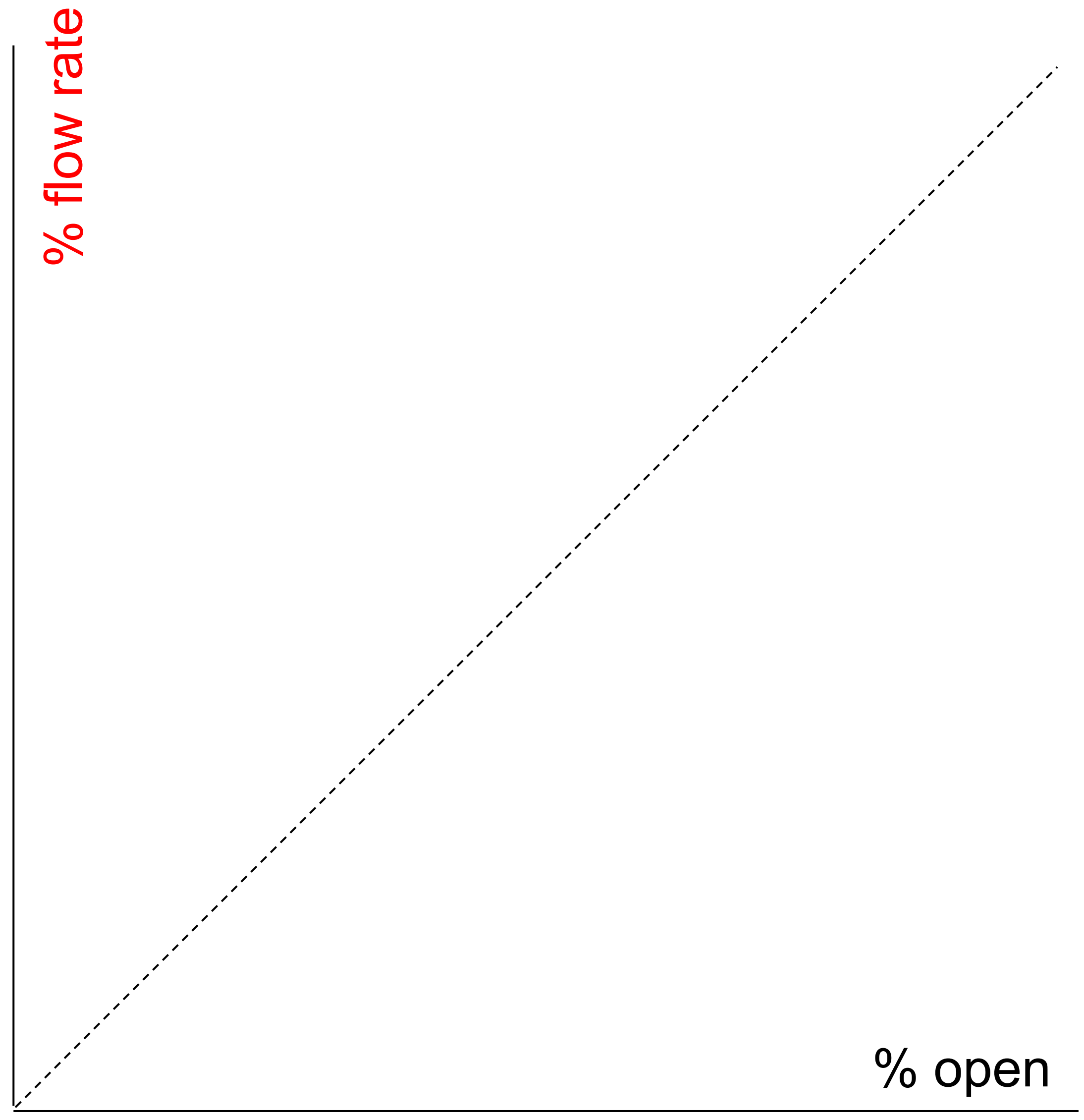
'Linear' control actuator giving equal percentage characteristic



0933705533
Tinh.pham@Topflow.vn

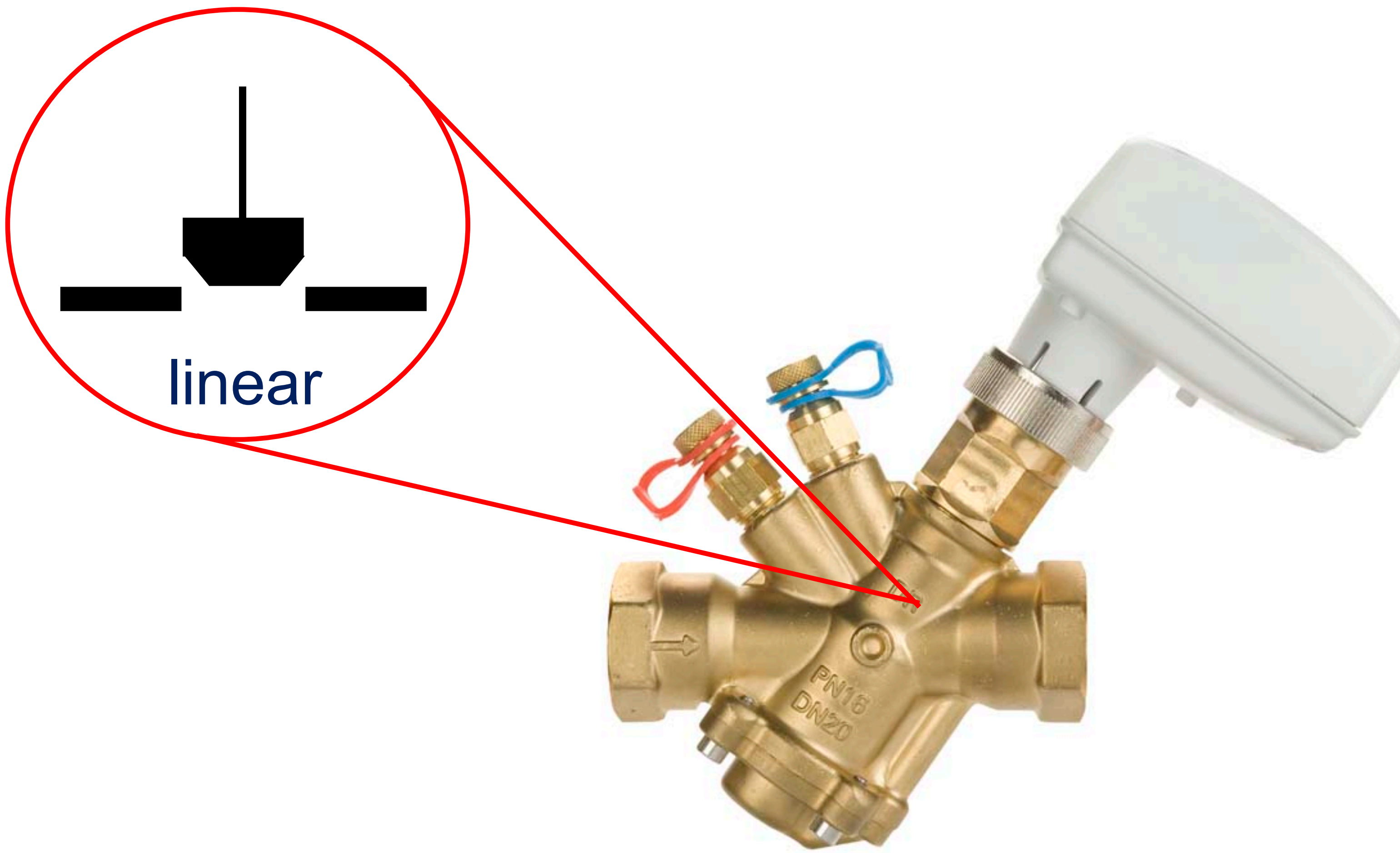
PICV Control Characteristic - linear

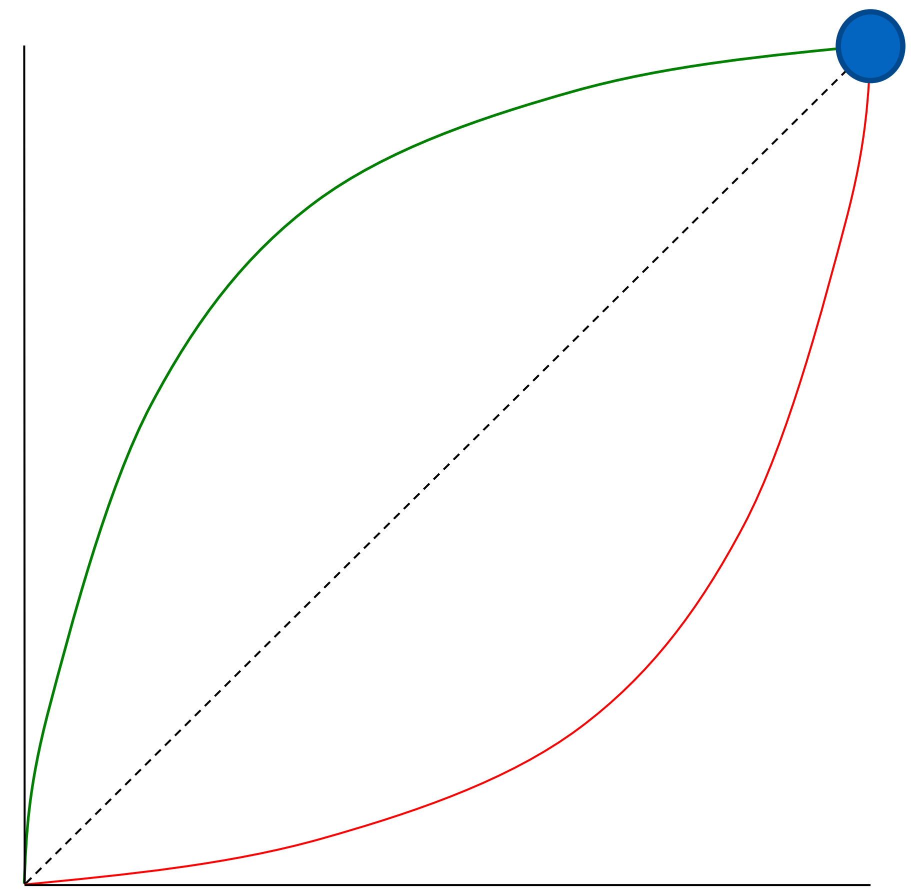
- Establish a direct relationship between open position & *flow rate*
- 50% valve opening = 50% flow rate
- Not effected by flow regulation



0933705533
Tinh.pham@Topflow.vn

PICV Control Characteristic - linear





‘Equal Percentage’ control actuator giving equal percentage characteristic

0933705533
Tinh.pham@Topflow.vn

Variable Volume System

At maximum pump turndown, typically 10 - 20%, consideration needs to be given to branches to ensure

- pump flow at minimum load
- circulation of water treatment
- ready supply of heating / chilled water

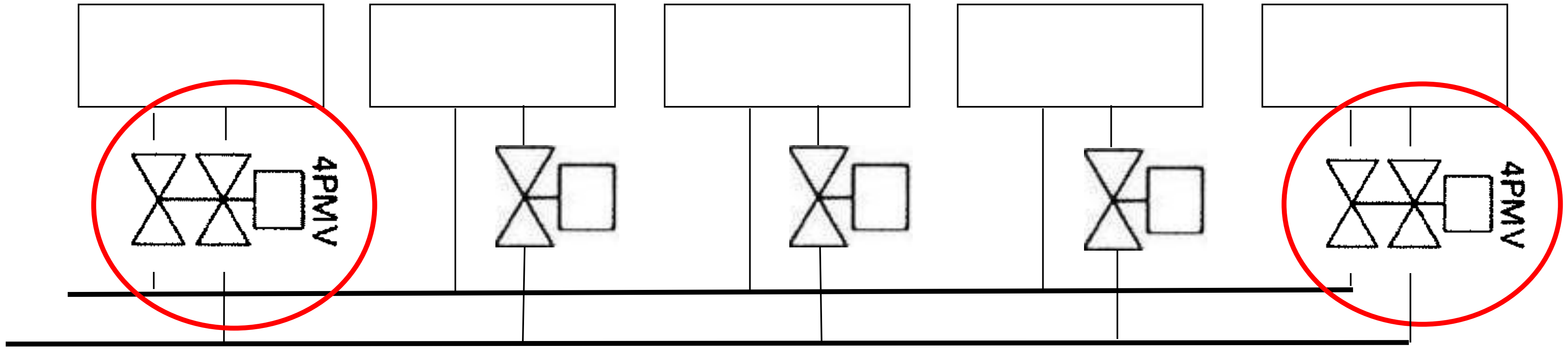
0933705533
Tinh.pham@Topflow.vn

Dynamic Balancing of the System

Possible solution

End terminal could have a 3 or 4 port control valve

- on larger circuits additional 3 or 4 ports could be added



0933705533
Tinh.pham@Topflow.vn

Flow Accuracy

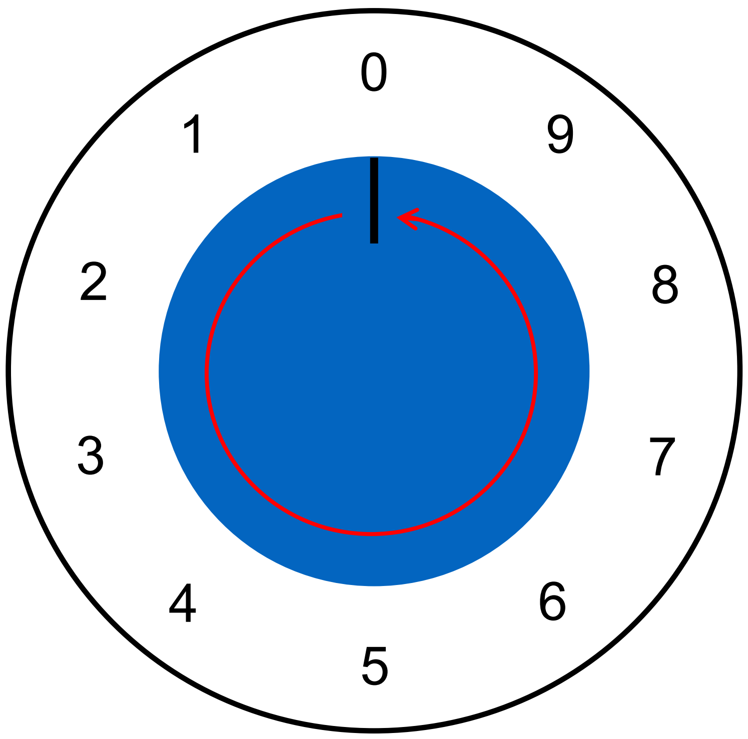
Different factors affect accuracy

- pre-set position
- available pump pressure
- actuator control

Accuracy is a combination of all factors

0933705533
Tinh.pham@Topflow.vn

Flow Accuracy – Pre-set Position

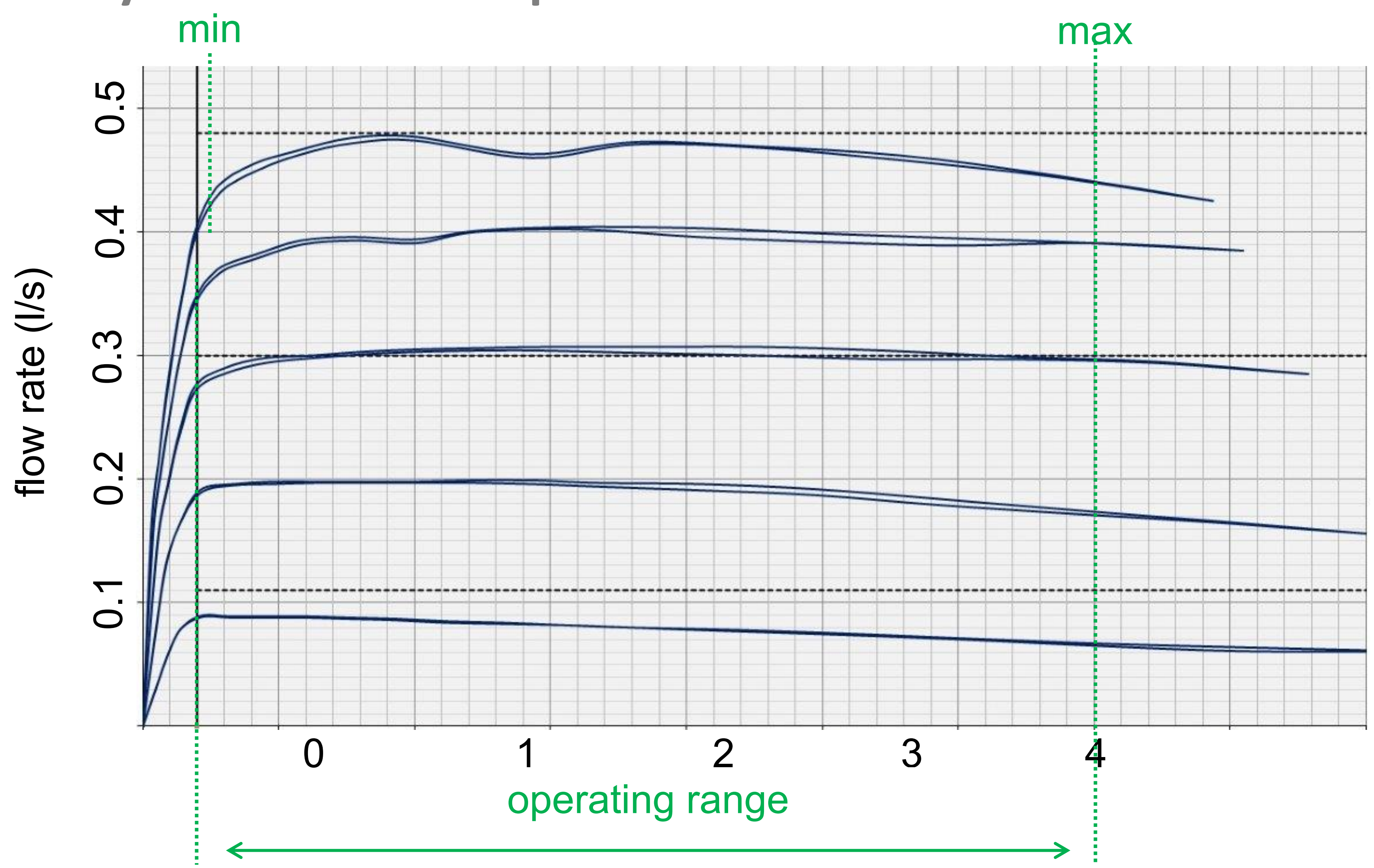


Aligning dial with scale

Pre-set position accuracy can be improved by the installation of a FMD

0933705533
Tinh.pham@Topflow.vn

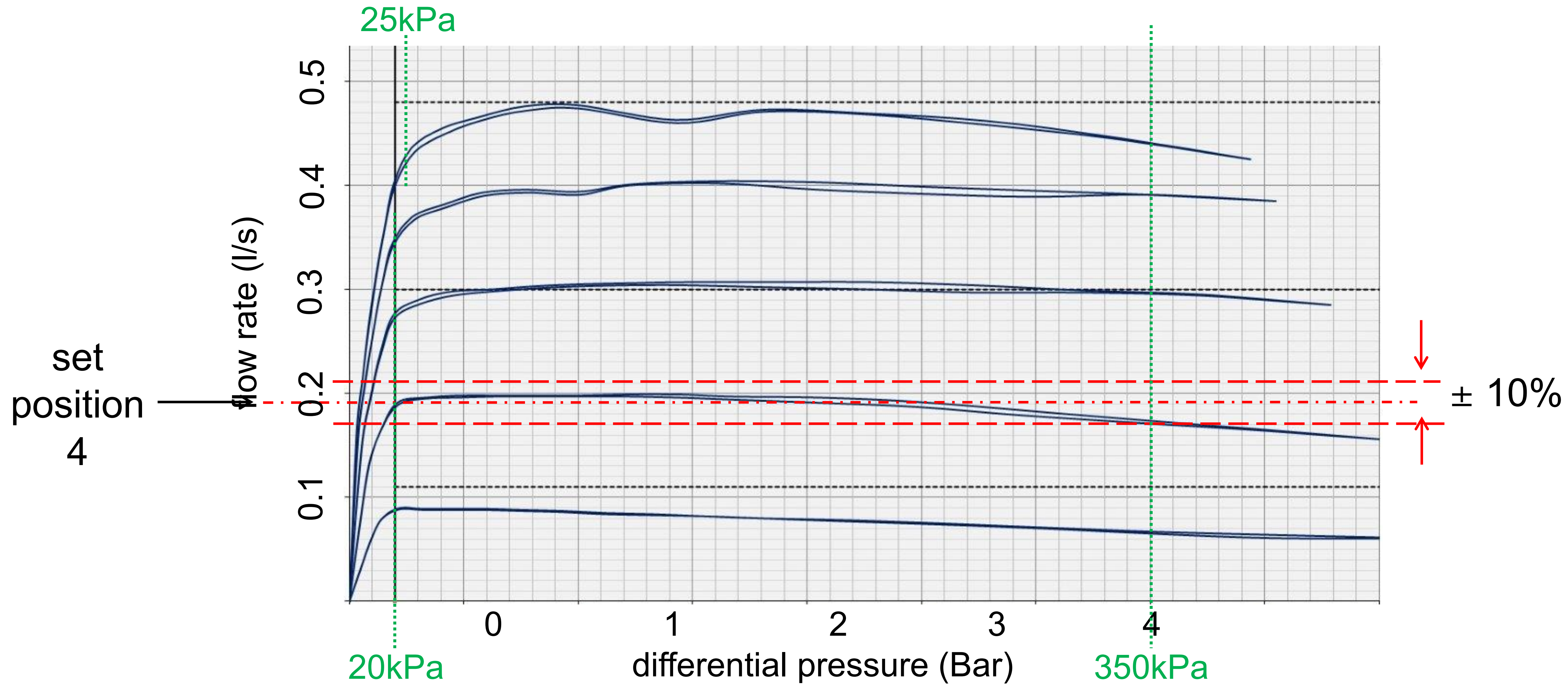
Flow Accuracy – Available Pump Pressure



As pump pressure varies flow rate varies

0933705533
Tinh.pham@Topflow.vn

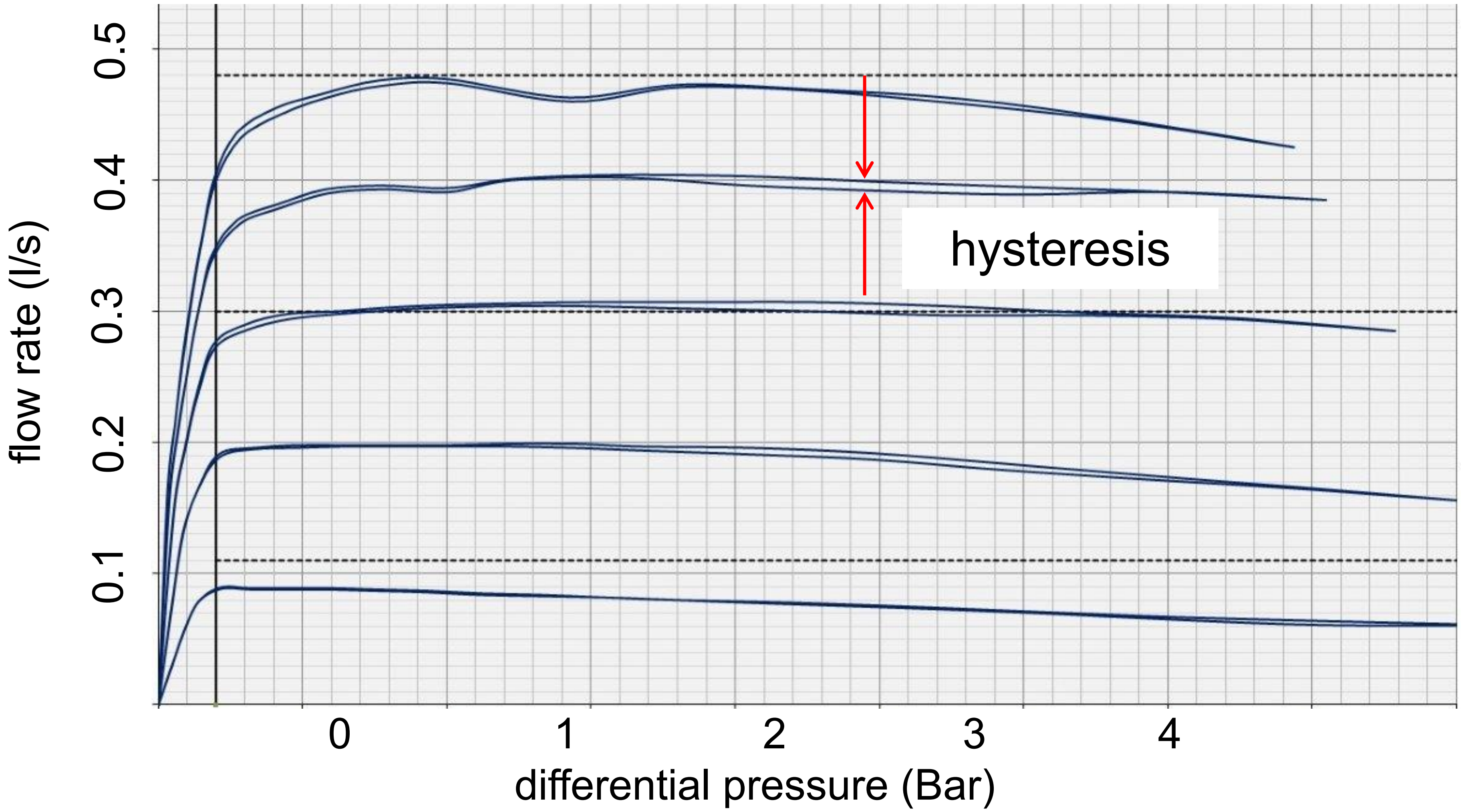
Flow Accuracy – Available Pump Pressure



As pump pressure varies flow rate varies

0933705533
Tinh.pham@Topflow.vn

Flow Accuracy – Rising / Falling Pressure



Hysteresis is relatively low but need to be considered and understood

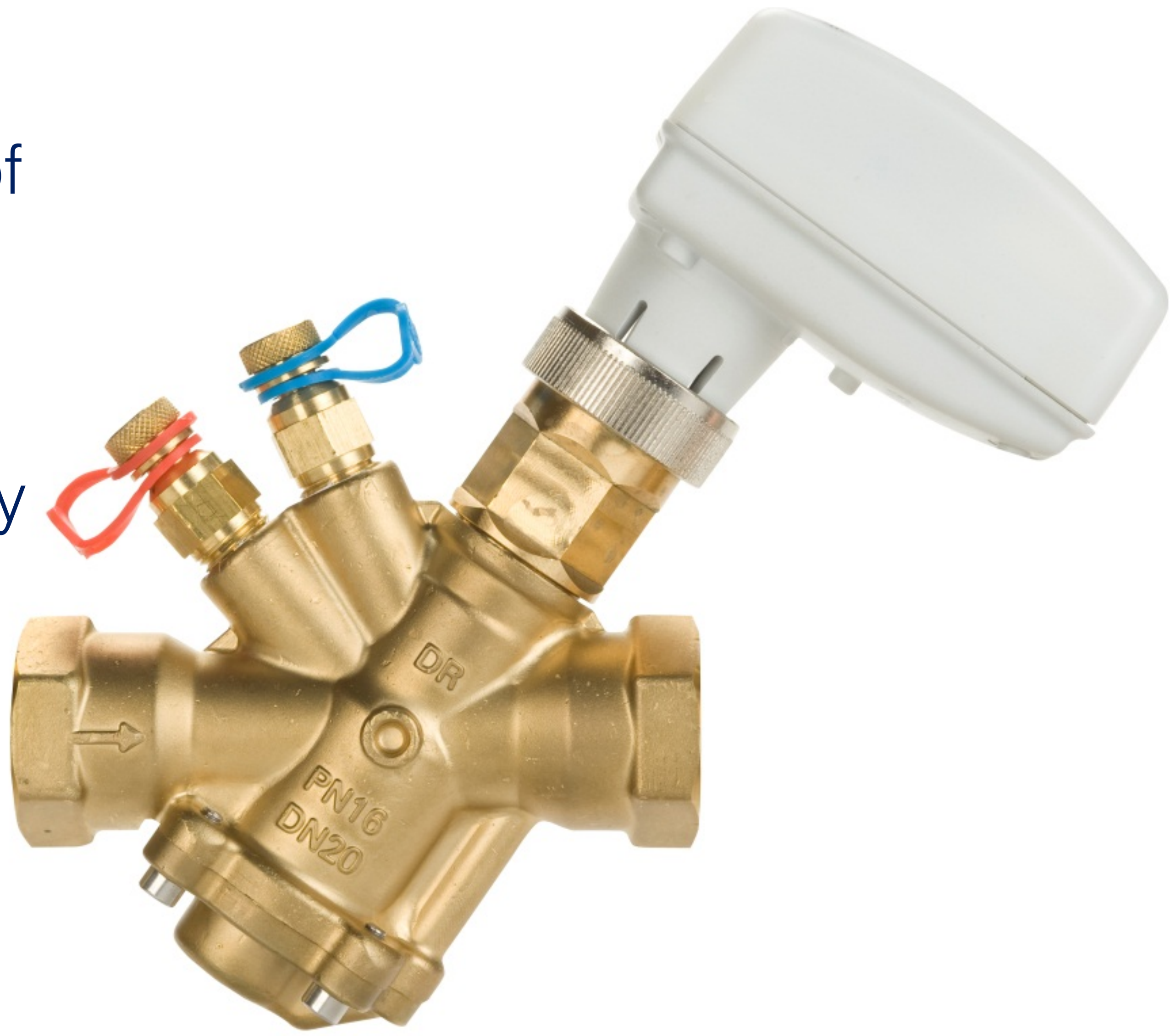
0933705533
Tinh.pham@Topflow.vn

Flow Accuracy – Actuator

Installed PICVs are a combination of

- PICV
- Actuator

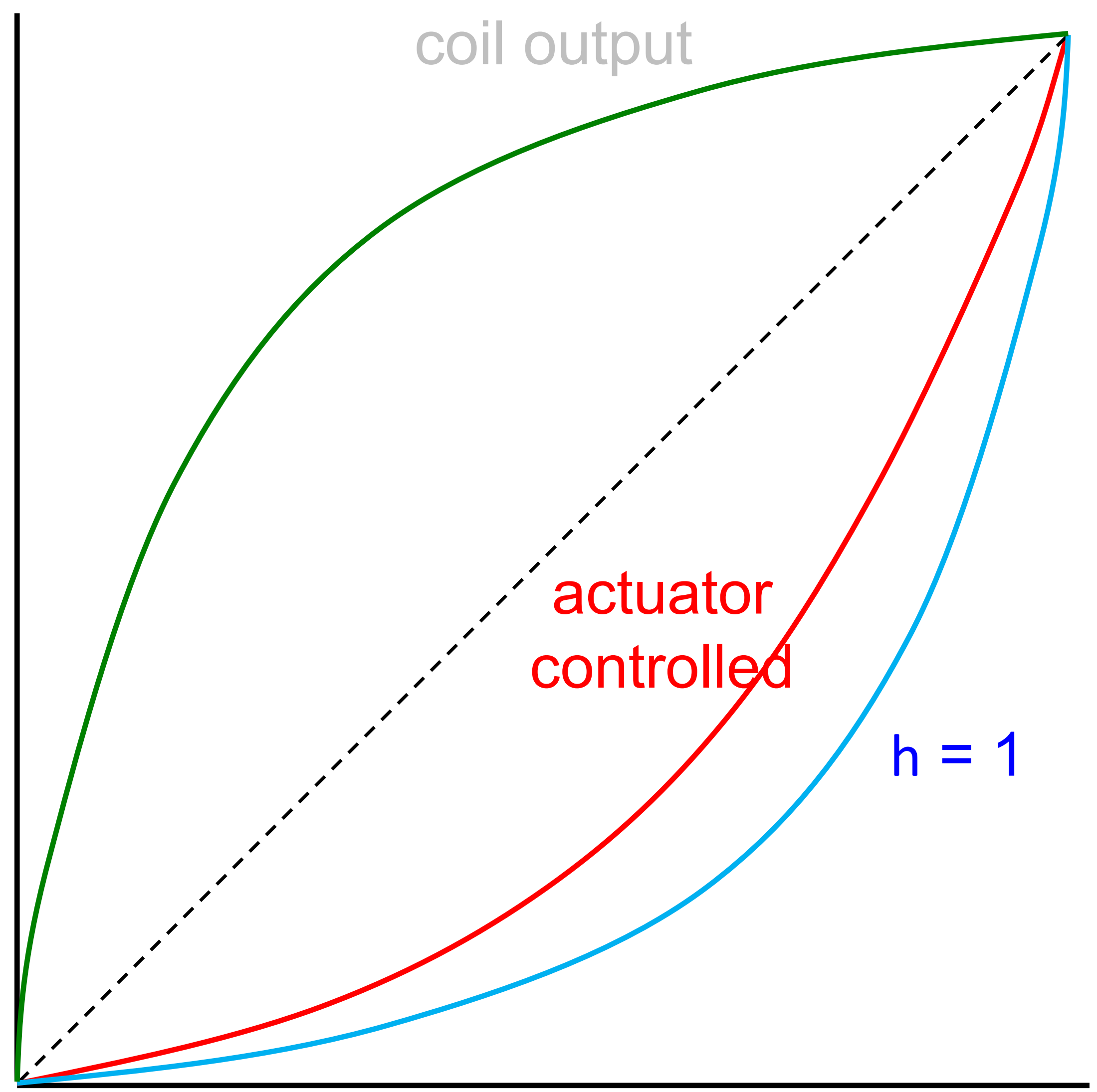
so we should consider the assembly and not the standalone PICV



Consider as a 'matched' pair

Flow Accuracy – Actuator

- PICV can perform well as a stand alone valve
- But when actuator is fitted performance of valve can be undermined



0933705533
Tinh.pham@Topflow.vn

Actuators

Actuators are divided into 2 types

- Thermal
- Electro-mechanical

And then by control characteristic

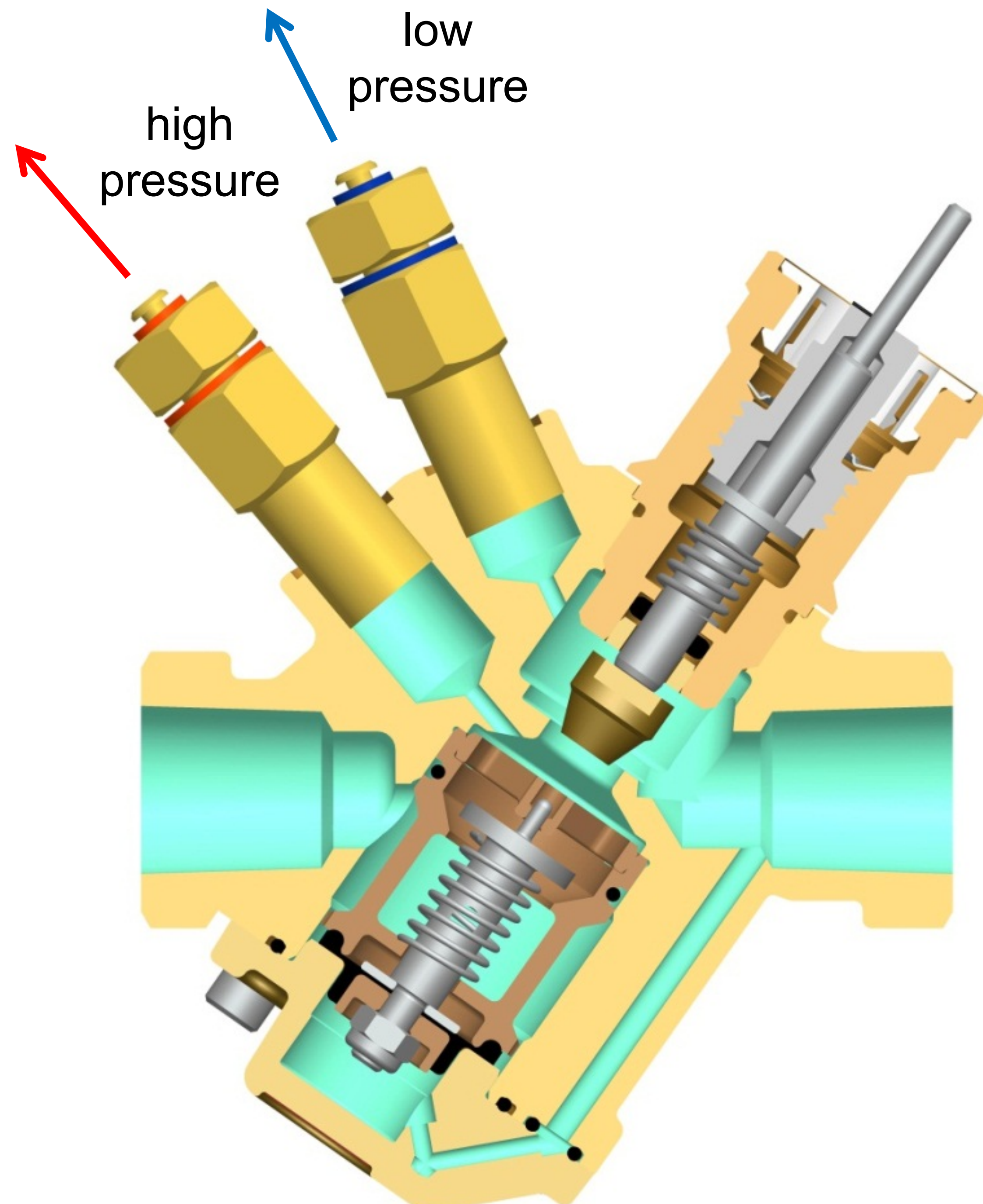
- On / Off
- Modulating

PICV Commissioning

PICVs are set to give the required flow rate, there is no commissioning required for the PICV

Commissioning Engineers are required to set the pump speed to ensure that the *'least favoured'* (index) PICV generates at least the minimum required differential pressure

if the least favoured PICV has sufficient different pressure, all other PICVs must have greater differential pressure



0933705533
Tinh.pham@Topflow.vn

Summary

- Change in system design to variable flow controlled by 2 port control valve resulting in pump energy saving
- Fluctuation in system pressure undermines control valve authority
- DPCV installed into sub-circuits to 'protect' control valves from fluctuating pressure to maintain control valve authority
    - terminal units commissioned by conventional proportional method
    - branches commissioned by use of 'Companion' Valve & DPCV
    - branches commissioned independently of each other
- PICVs installed on terminal unit
    - replacing static commissioning valves / 2 port control valve / DPCV

0933705533
Tinh.pham@Topflow.vn