Pressure Independent Valve Systems

ASHRAE Seminar

College of the North Atlantic, Doha, Qatar

20th April 2013

Agenda

- **Introduction**
- **Pressure independent Valves - mechanical**
  - PICCV
- **Pressure independent Valves - electronic**
  - EPIV
  - ENERGY VALVE

Introduction

The Evolution of the CCV (Characterised Control Valve)

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Functionality / customer benefit

CCV

Position

PICCV

Pressure-independence volumetric flow

EPIV

Flow measurement

- Pressure-independence
- Real-time information on flow rate

Energy Valve

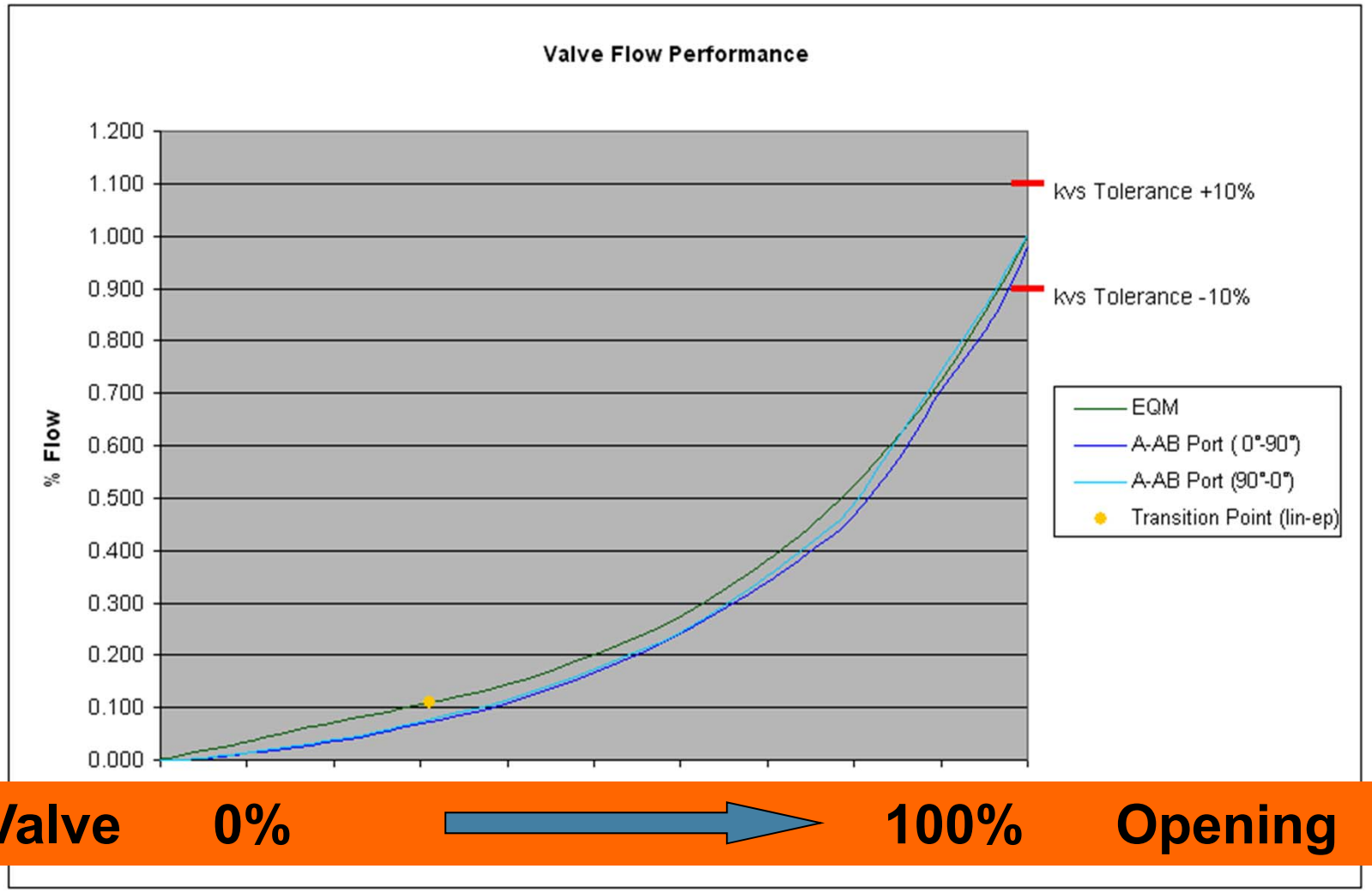
Flow measurement + Energy monitoring

- Pressure-independence
- Real-time information and recording system parameters

→ Provides energy transparency
→ Helps ensure an energy-optimised operation

1995 2003 2009 2011

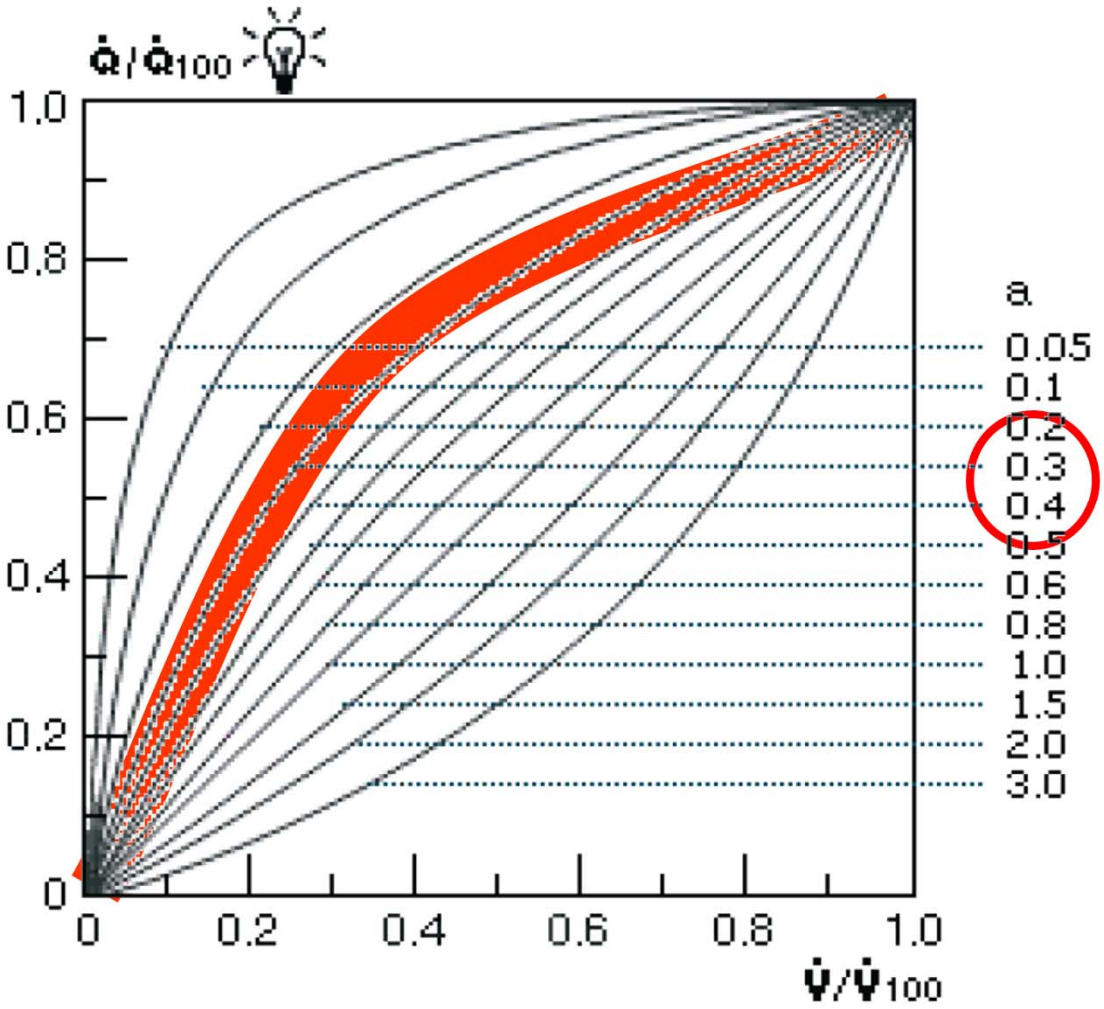
Control Valve - The Perfect Flow Curve !



ΔP across the control element = const !

HVAC Heat exchanger / Performance

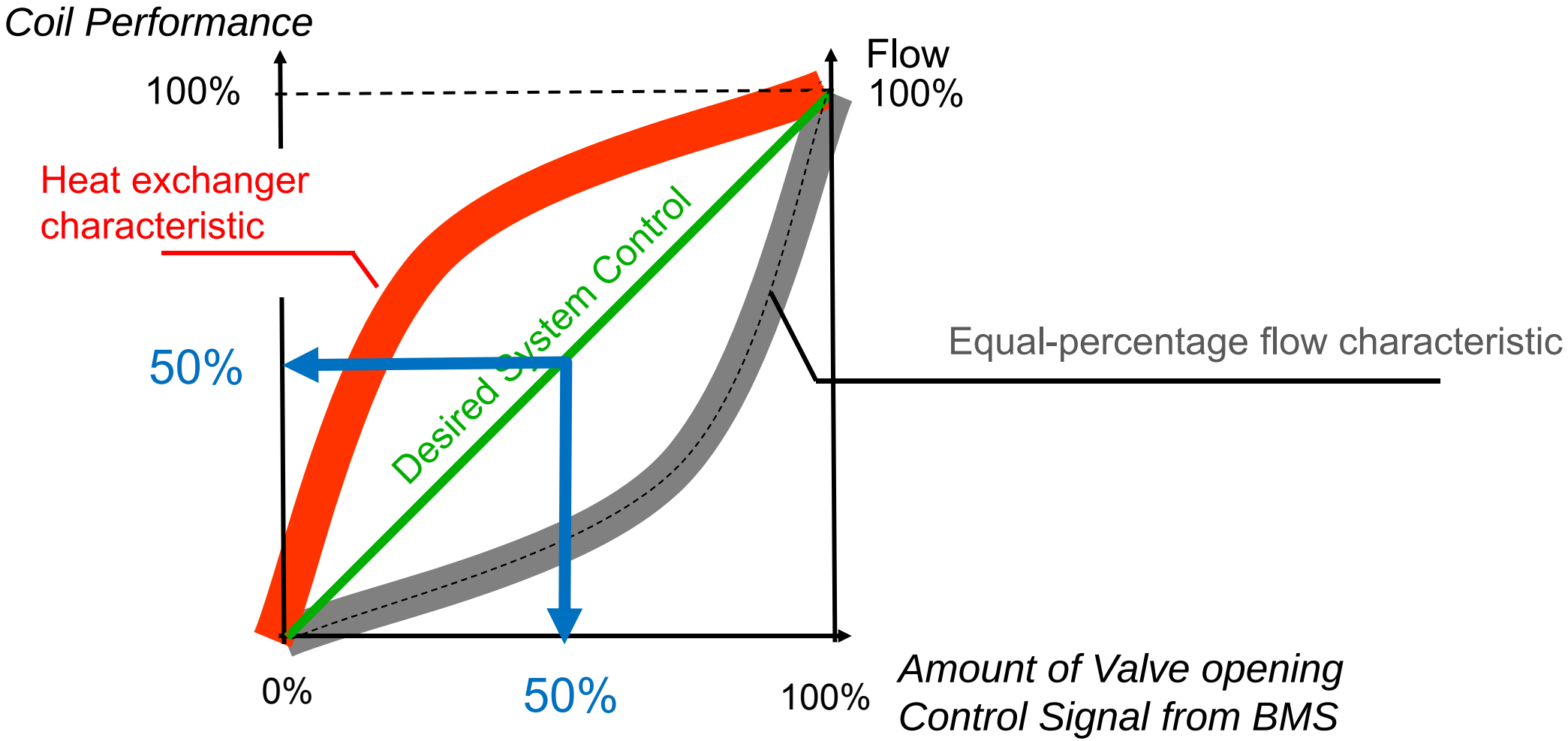
$$a = f \cdot \frac{(\vartheta 1_e - \vartheta 1_a)}{(\vartheta 1_e - \vartheta 2_a)}$$



The a-value (HVAC usually 0.2 – 0.6)

- **measure of non-linearity of a heat exchanger characteristic, calculated based on temperature conditions at the heat exchanger**

Typical HVAC Heat Exchanger Curve
+
Equal Percentage Valve Charactreristic



Control Valve – Pressure Dependence

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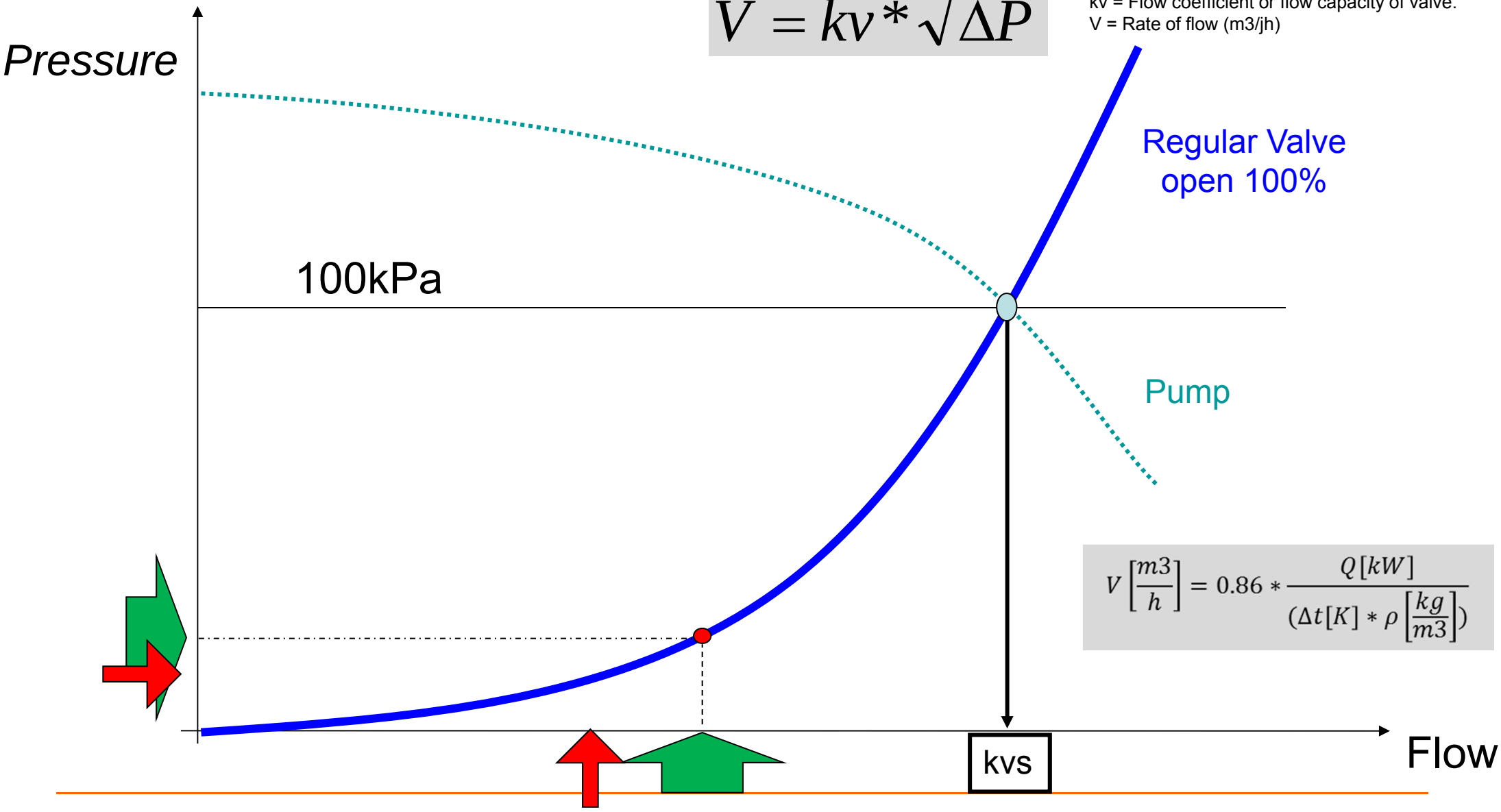
$$V = kv * \sqrt{\Delta P}$$

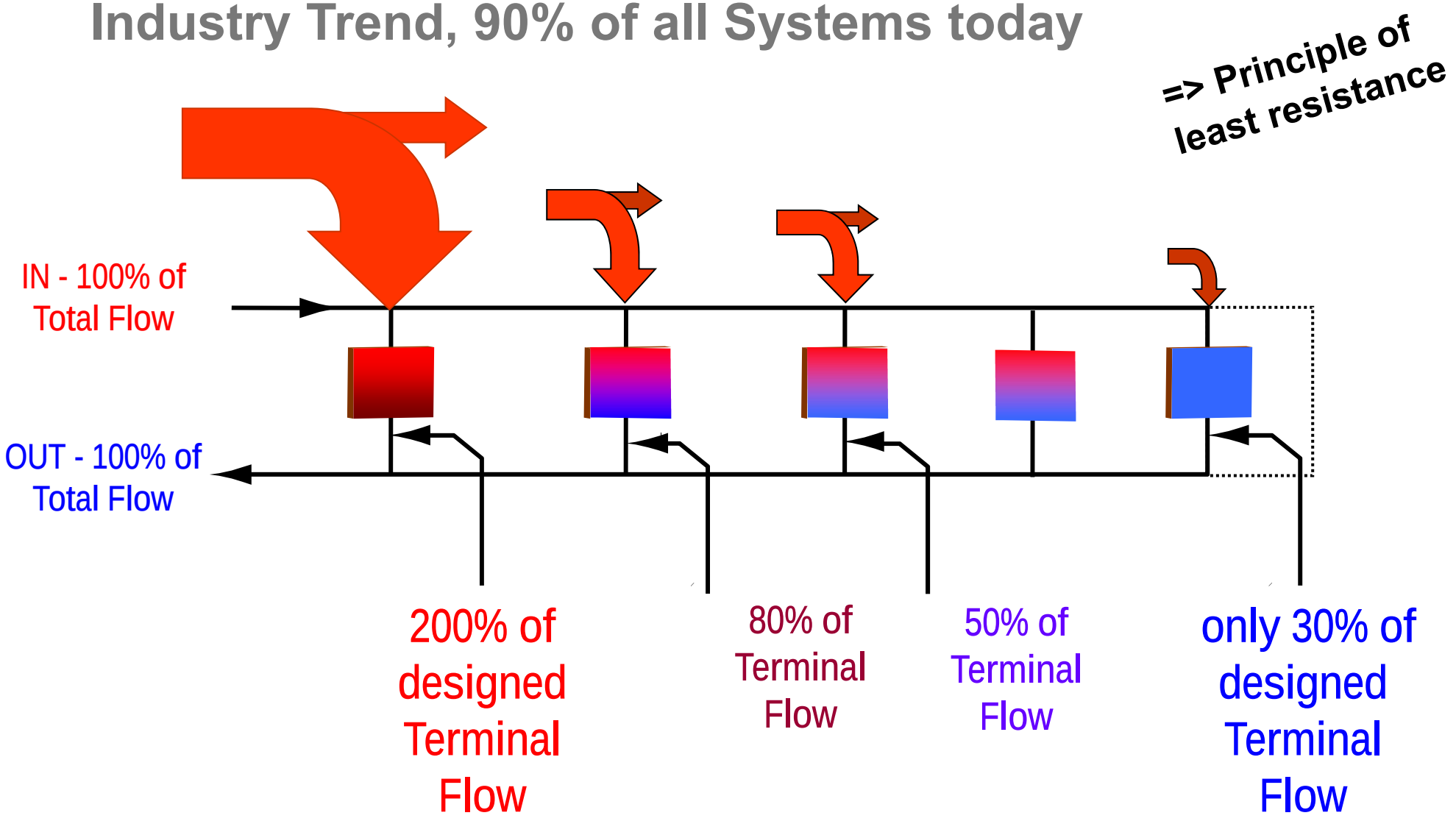
kv = Flow coefficient or flow capacity of valve.
V = Rate of flow (m3/jh)



$$V\left[\frac{m3}{h}\right] = 0.86 * \frac{Q[kW]}{(\Delta t[K] * \rho\left[\frac{kg}{m3}\right])}$$

Direct Return Systems

Industry Trend, 90% of all Systems today



Traditional Balancing Devices

Efforts for conventional hydraulic balancing

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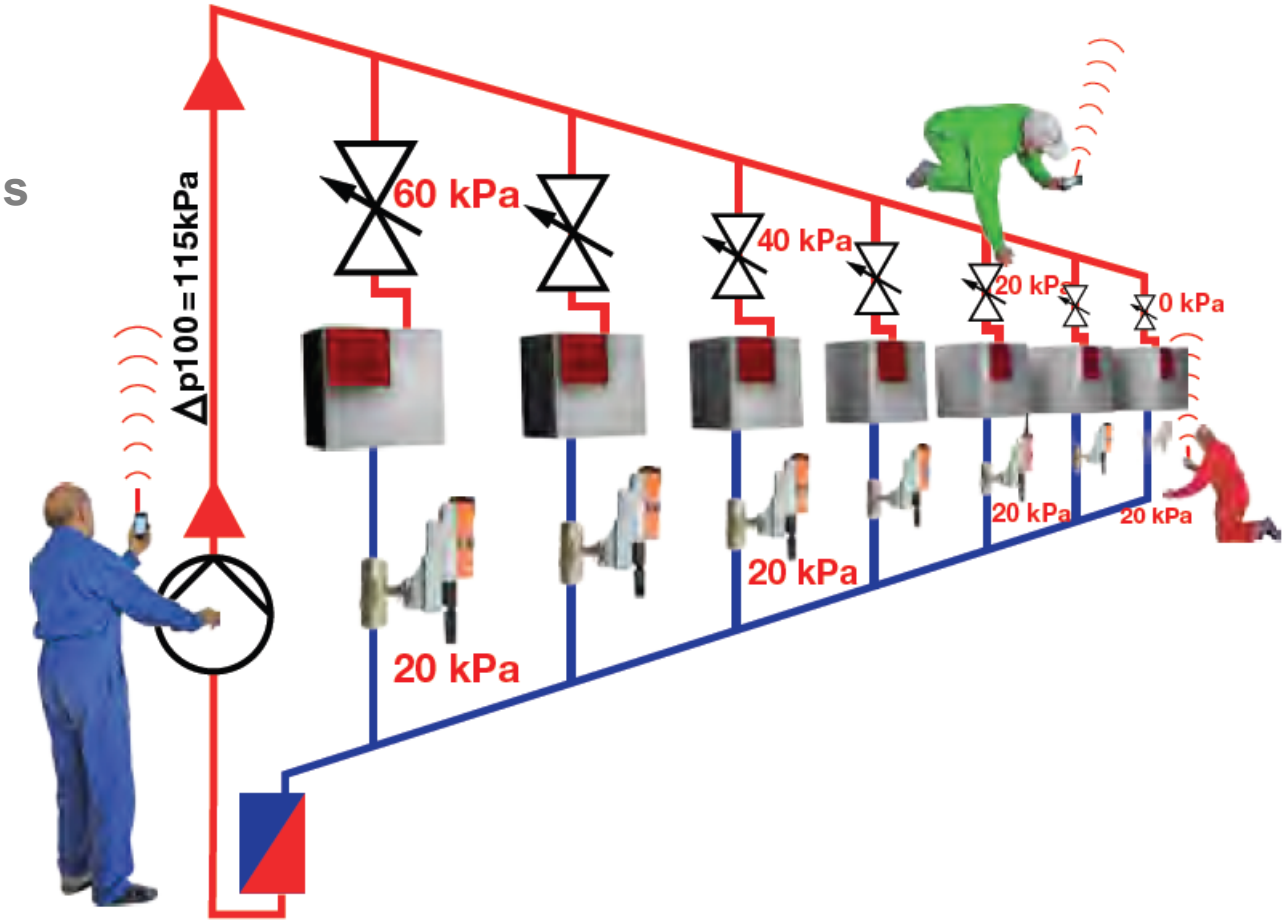
- **Very time-intensive**
  - 30 min per line (valve / coil)
- **Designed for full-load operation**
- **Additional Equipment:**
  - Measuring devices, Instructions
  - Laptop – for documentation
  - Communication devices
  - …

- **Requires at least 2 people in communication with one another**
  - Red continuously checks the last consumer
  - Blue varies the partial water flow with main pump
  - Green balancing of the repective consumer



PI-Valves General Benefits

- **Easier selection**
  - No kvs / Cv calculation required

$$V = kvs * \sqrt{\Delta P}$$

- **Easier installation**
  - Less components
  - Smaller setup than conventional
  - Minimized commissioning and balancing efforts

$$GPM = Cv * \sqrt{\Delta P}$$

- **Better control**
  - No influence from neighboring zones, areas, consumers
  - Dynamically balanced circuits at all load conditions
  - Only the temperature controls the valve, not pressure and temperature
  - Repeatability – specific flow is always bond to a specific signal

Pressure Independent Control Valve
Definition

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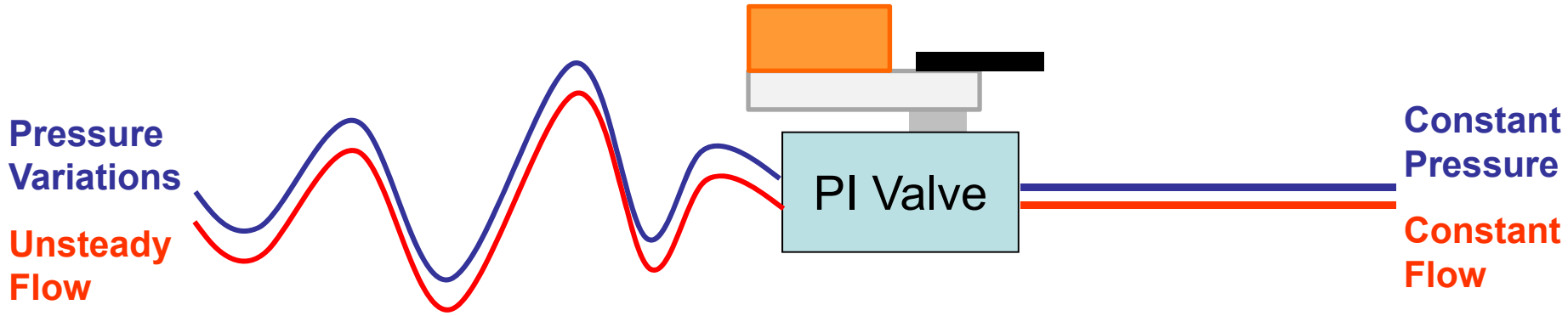
Pressure Independent Characterised Control Valve

is a 2-way Control Valve that supplies a specific flow for each value of the control signal

This specific requested flow @ a given setpoint will stay constant REGARDLESS of pressure variations in the system



PICCV

The Pressure Independent Characterised Control Valve

Three functions – One Unit

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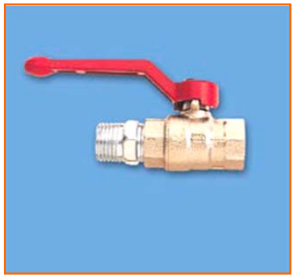
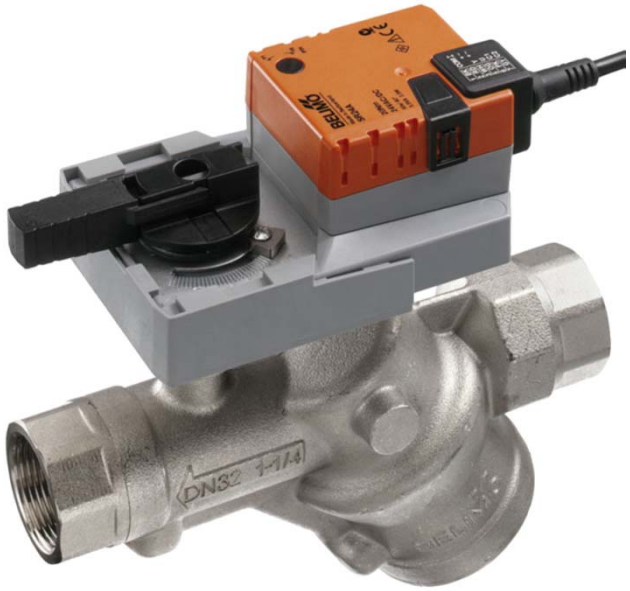
hydraulic balancing

temporary tight shut off



pressure independent control

PICCV



combined in one valve

Save time and money

PICCV – Function
"active“ between 30-350kPa

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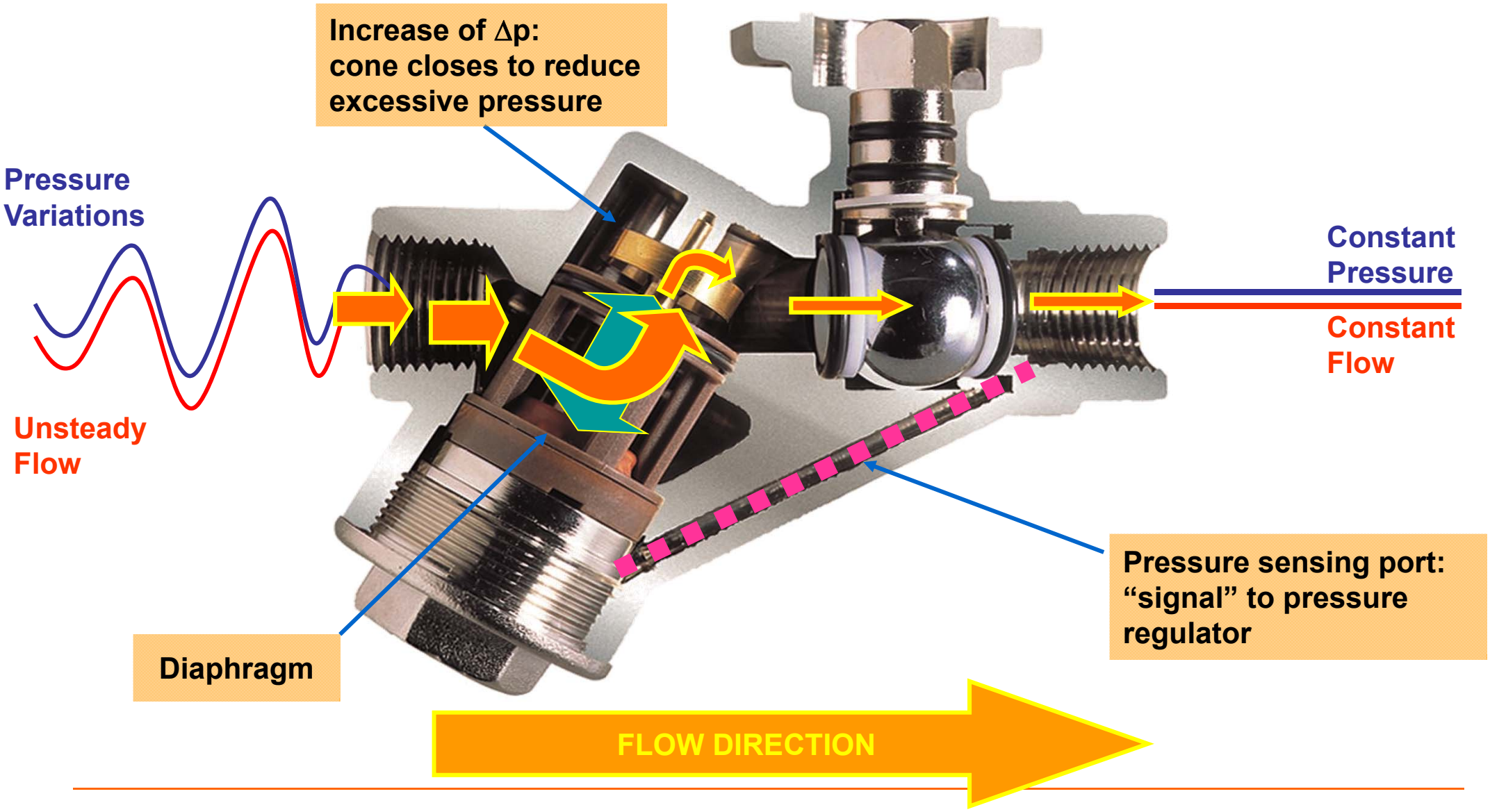
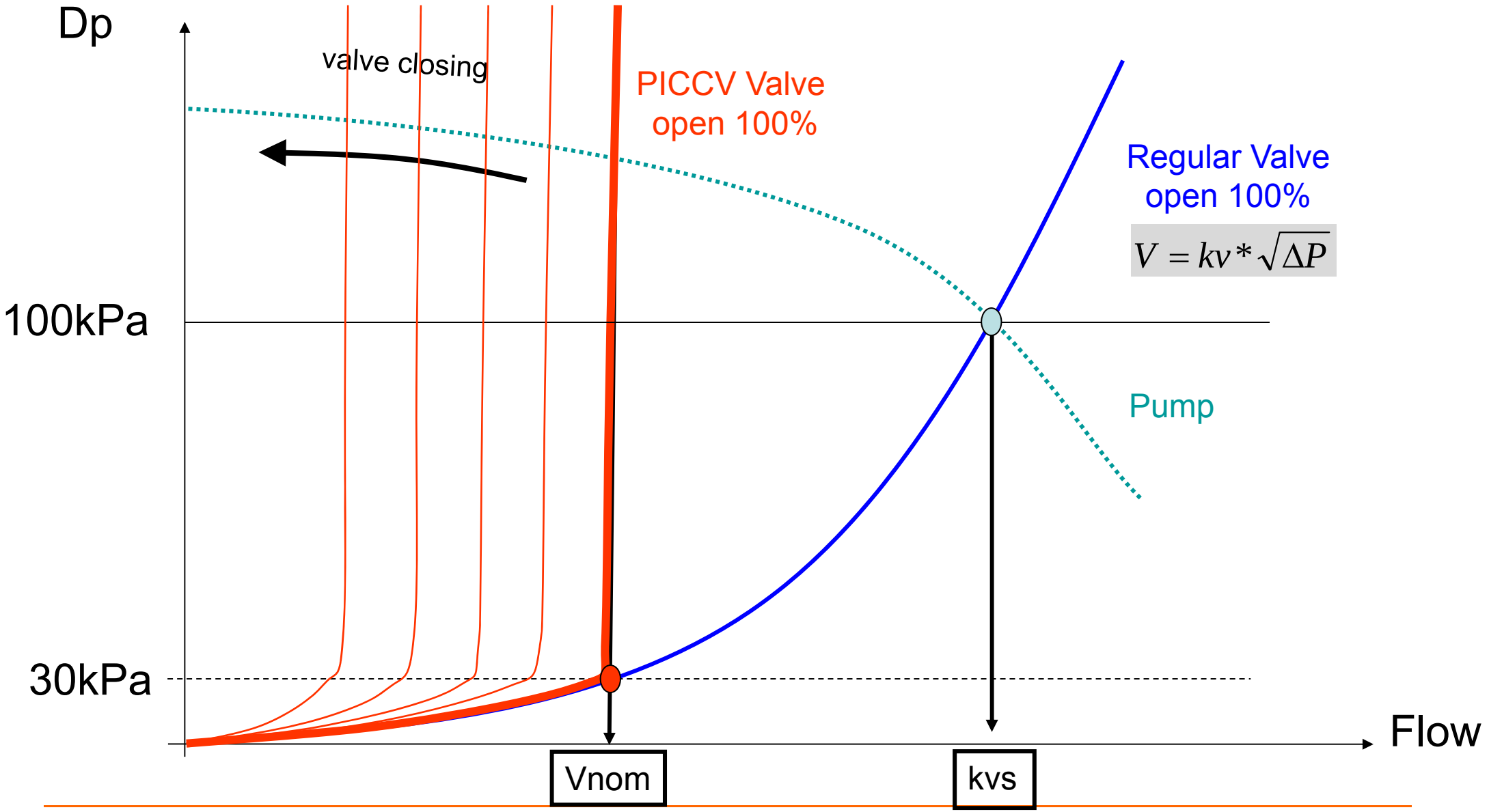
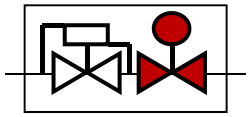


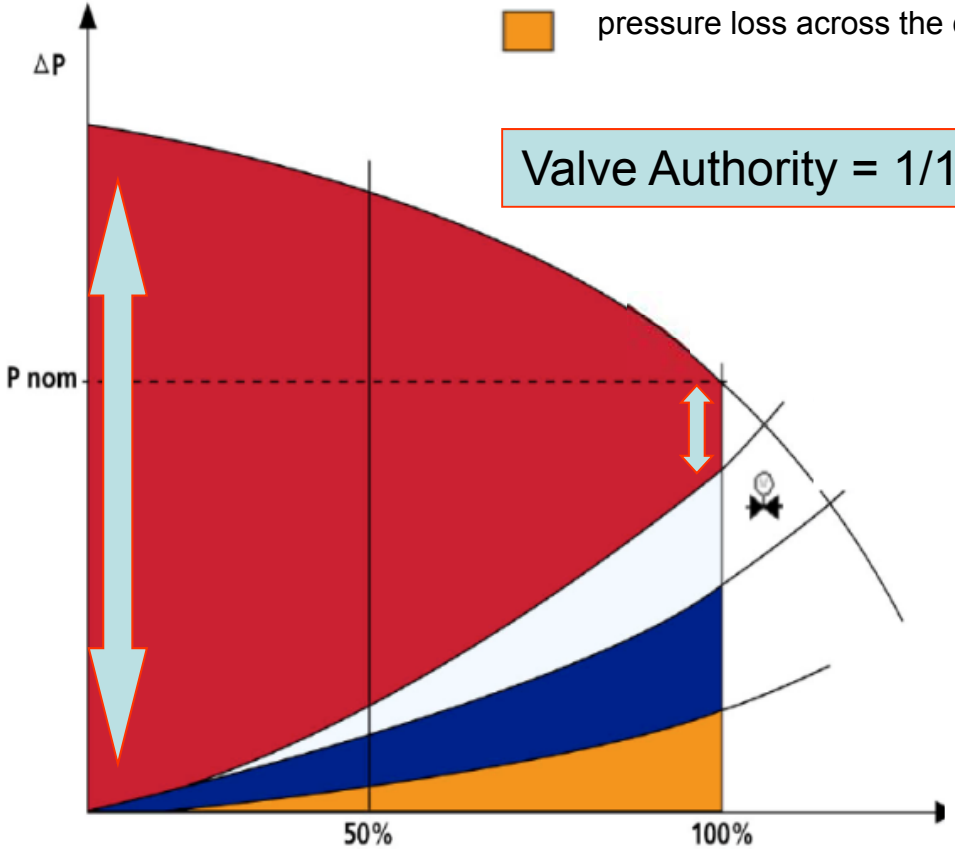
Control Valve – Pressure Independence



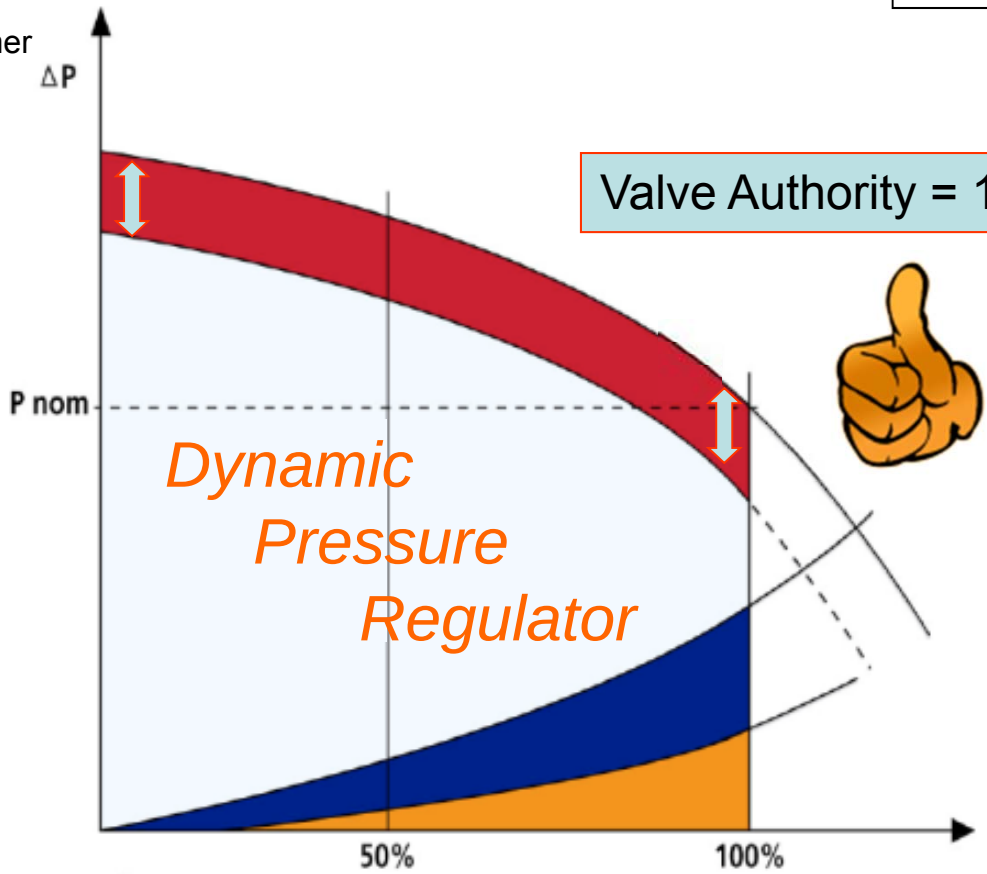
Characteristic Curves
Static vs. automatic balancing

- Pressure loss across the CV
- pressure loss across the static balancing valve
- Pressure loss across piping
- pressure loss across the consumer





Valve Authority = 1/10



Valve Authority = 1

Dynamic Pressure Regulator

PICCV – Function 30-350kPa

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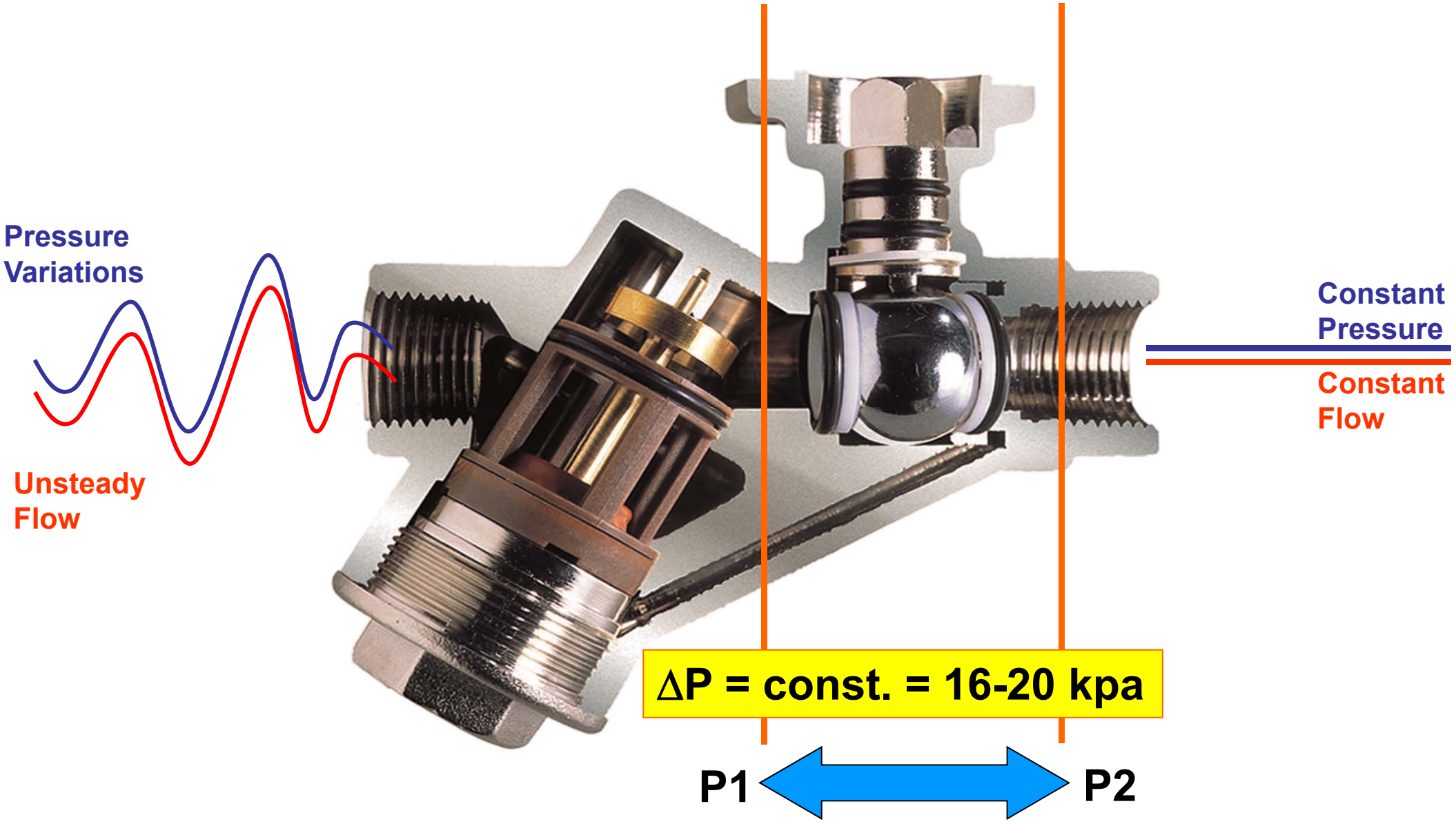

PICCV – SIZING and SELECTION
Required Information

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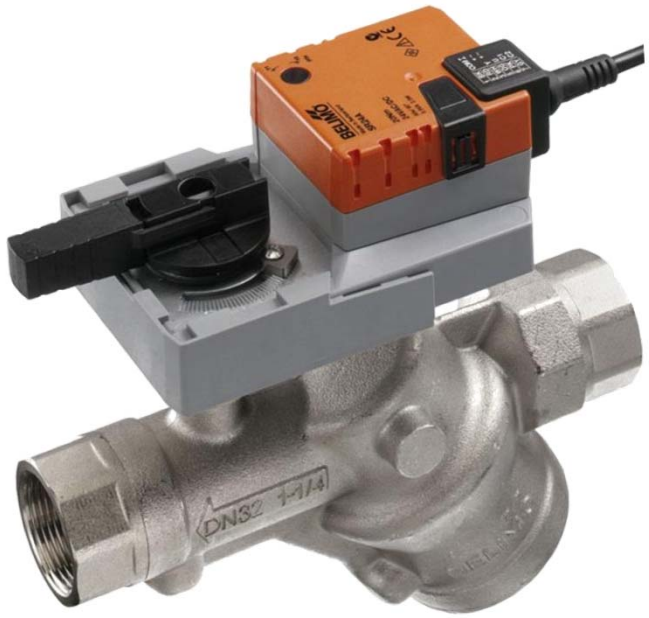
FOR SIZING:

- flow in l/s

FOR SELECTION:

- pipe size
- required (close-off) pressures



EQUATIONS USED

- No equations are required.
- Choose the PICCV that has the closest **Vnom** to the requirement and round up to next available flow.

PICCV - SIZING and SELECTION

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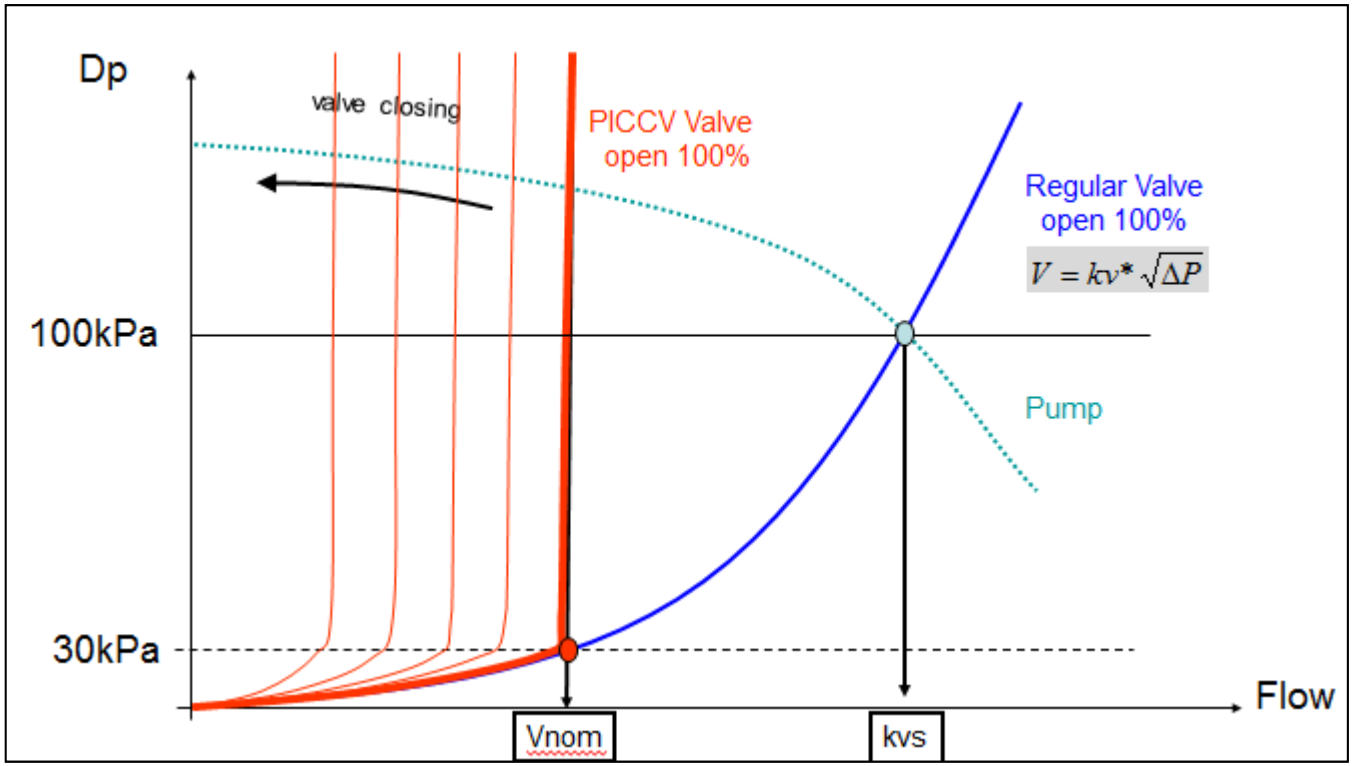


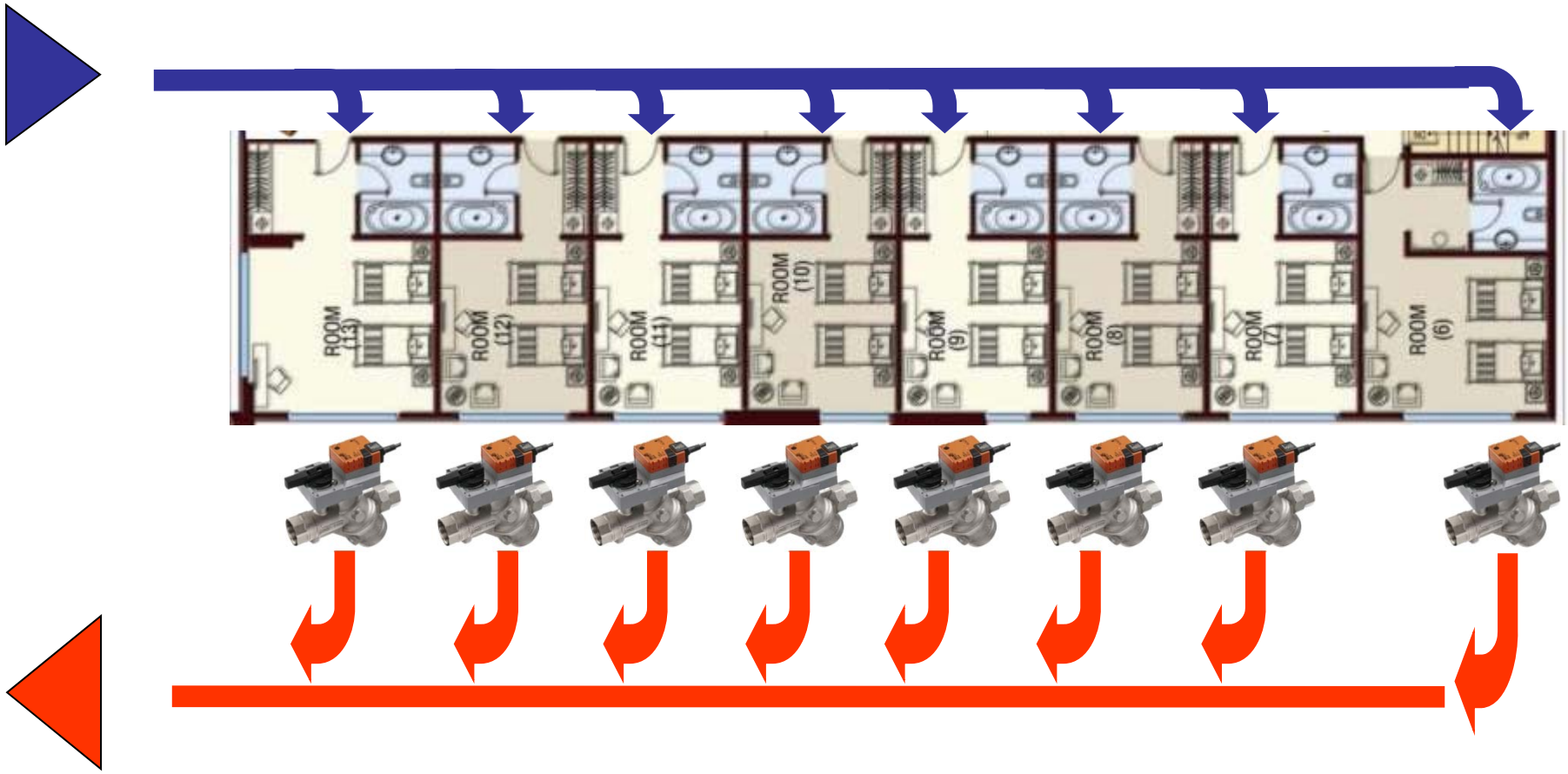
DN	Vnom [l/s]
15	0.1
15	0.4
20	0.4
20	0.6
25	0.7
25	1.1
32	1.2
32	1.6
40	1.8
40	2.2
50	2.7
50	5.5

Vnom:

- **100% Flow**
- **@ valve fully open**
- **@ 30-350 kPa**

E.g.
Required flow: 0.63l/s
Selected Vnom: 0.7l/s

APPLICATION Example
Hotel, Hospital, School



PICCV - Benefits

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Benefit	Remarks / Explanation
Simplest, safe valve design	No calculation of k_{vs} value required
No hydraulic balancing necessary	Pressure-independent operation
Correct flow rate values, even with partial-load operation	
Flexibility during the planning and construction phase	Simple adjustment V_{max} = 45 … 100% of V_{nom}
Flexible for future conversion	
«All-in-One» solution	3 functions: Control / Balance / Shut Off

EPIV

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The Electronic Pressure Independent Valve

Chiller Plant - PICCV / EPIV

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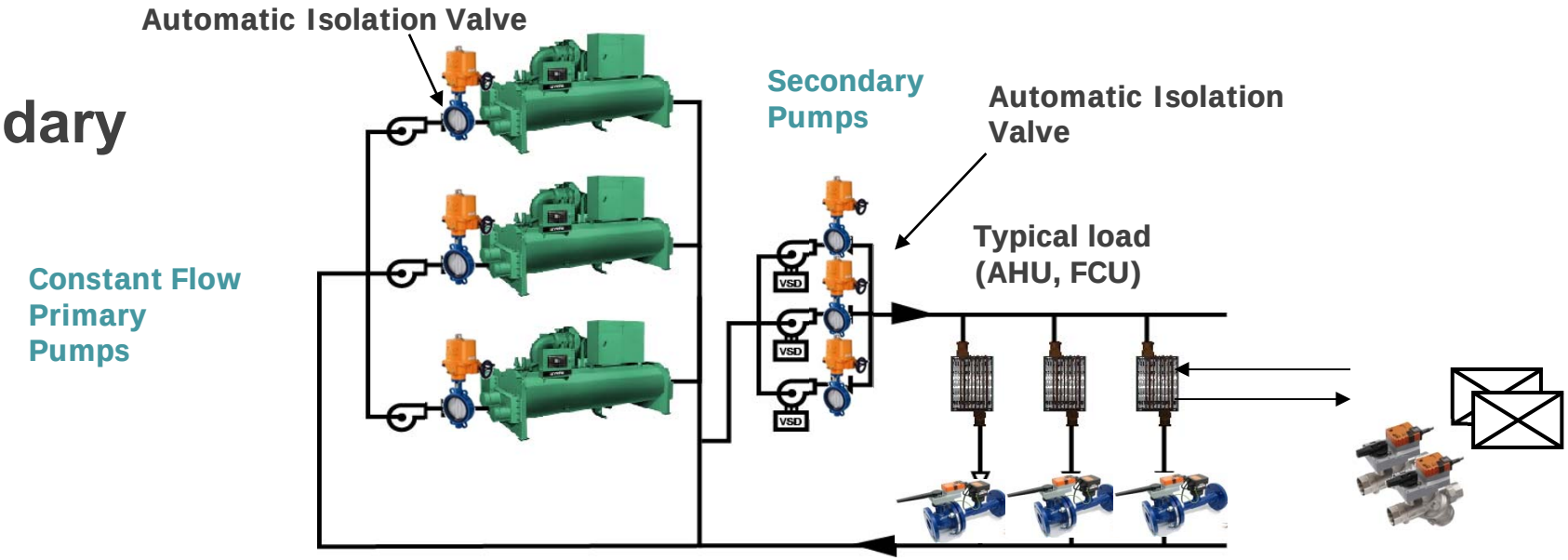
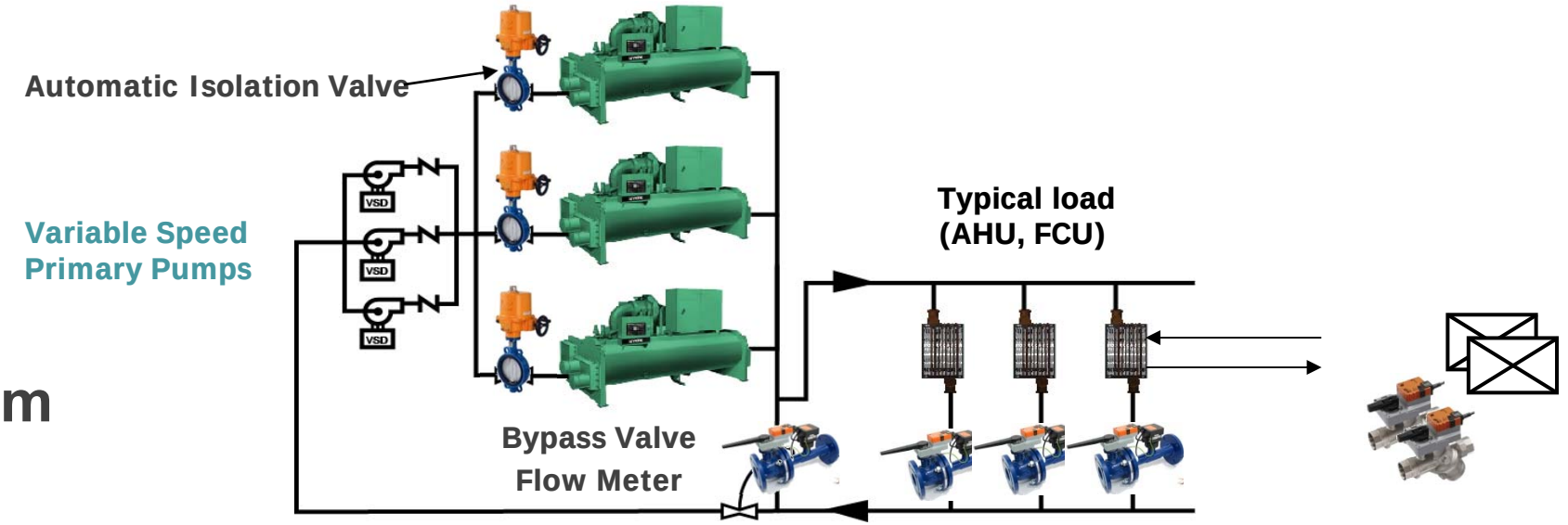
Primary/Secondary System



Variable Primary System



EPIV – 4 Functions – One Unit

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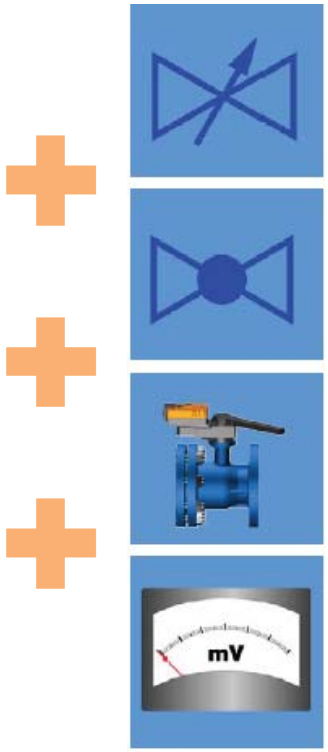
1. Hydraulic balancing
2. Air bubble-tight-shut-off
3. Pressure-independent flow control
4. Permanent volumetric flow measurement



With the EPIV, 4 functions are combined in one unit.

The EPIV
"VAV" for water applications

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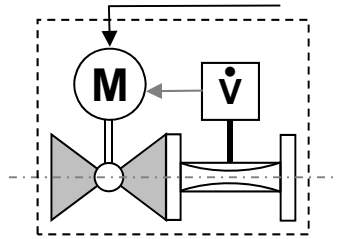
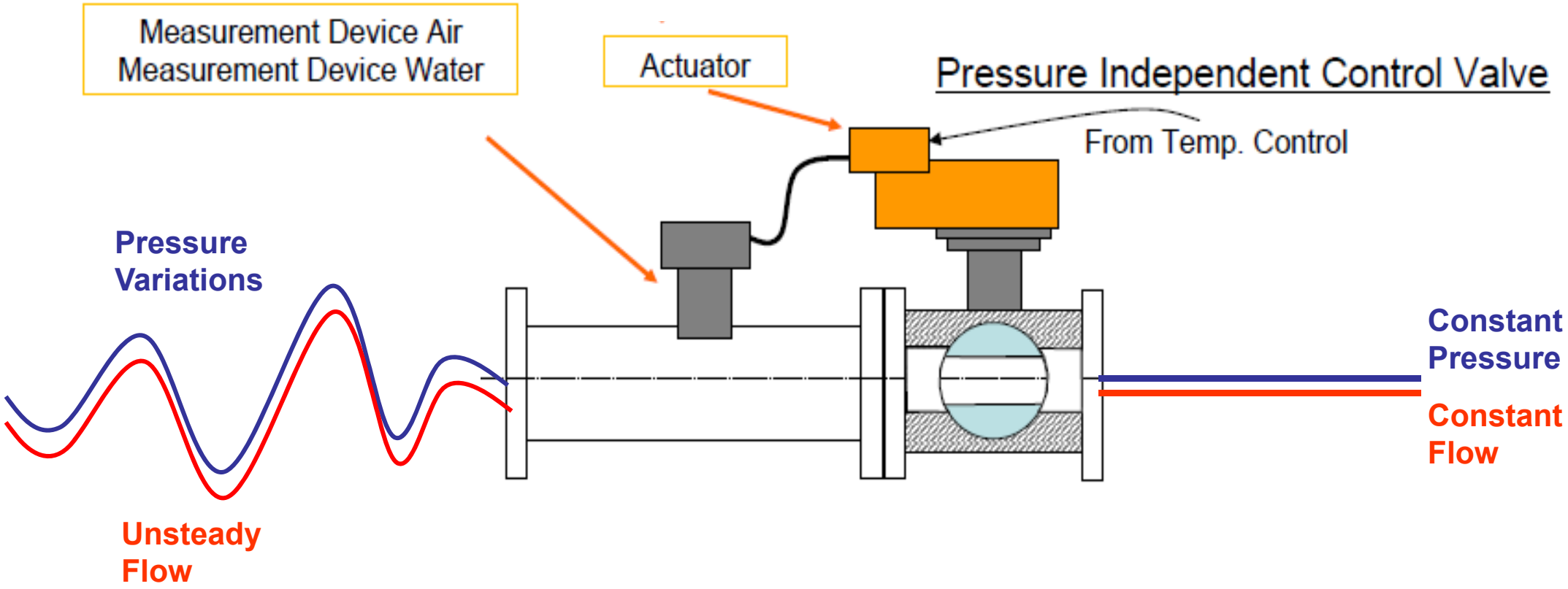
Y



- Measuring tube
- Flow sensor with control unit
- Intelligent Actuator with integrated control electronics
- Control valve (LG-CCV)

EPIV Operation



The Flow Sensor

Magnetic inductive flow metering

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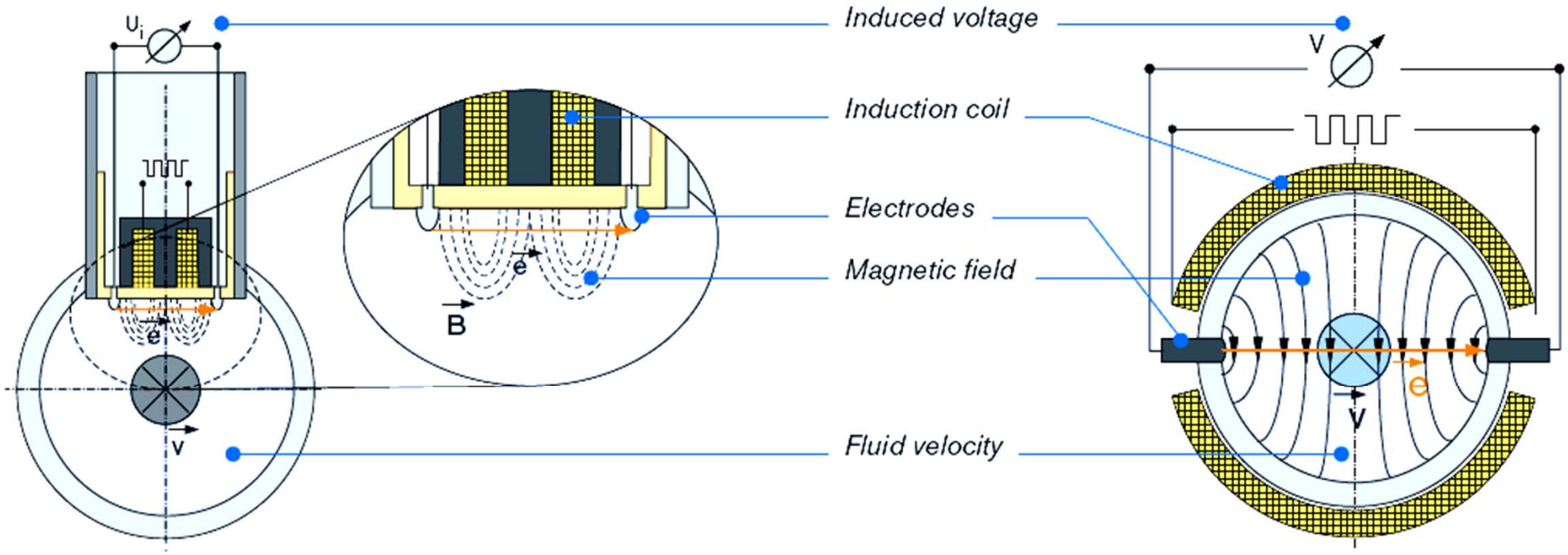

The Flow velocity is obtained by measuring the changes of induced voltage of the conductive fluid passing across a controlled magnetic field => Measured as 4-20mA

(Output to BMS: 0-10V with 10V=Vnom)

Accuracy of the EPIV
EPIV vs. calibrated Measuring Rig

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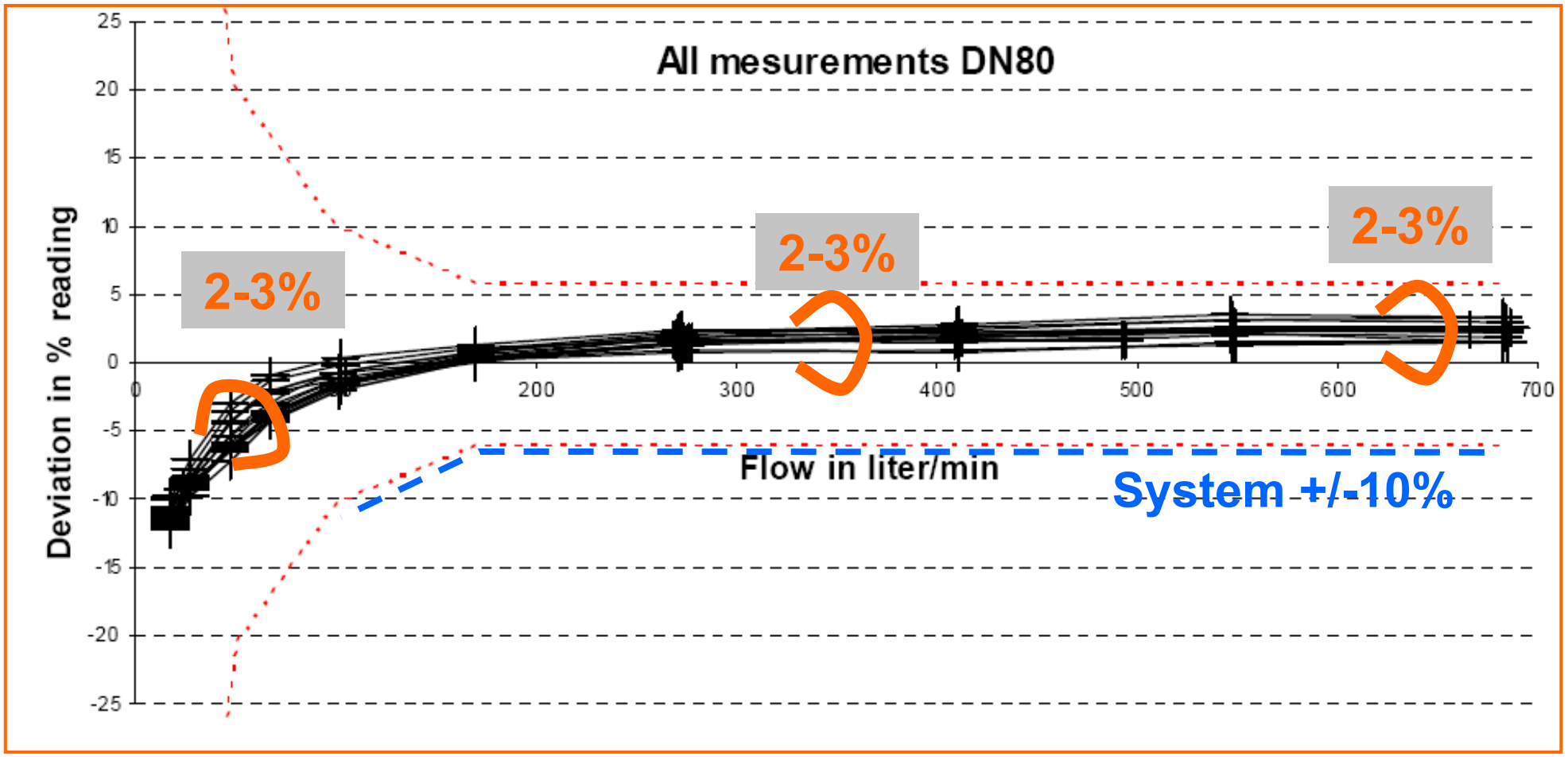
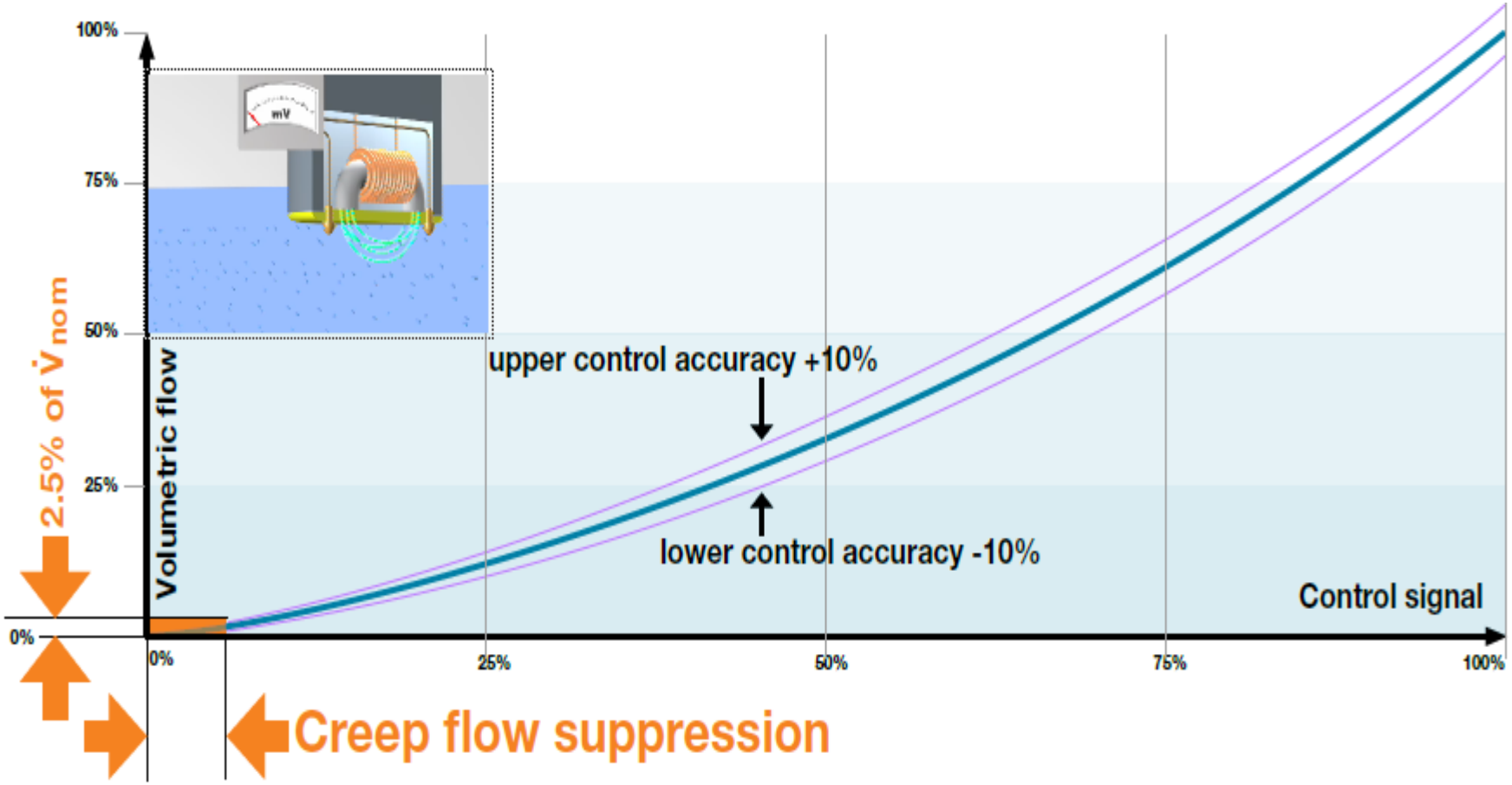


Flow 2.5% of Vnom = Vmin

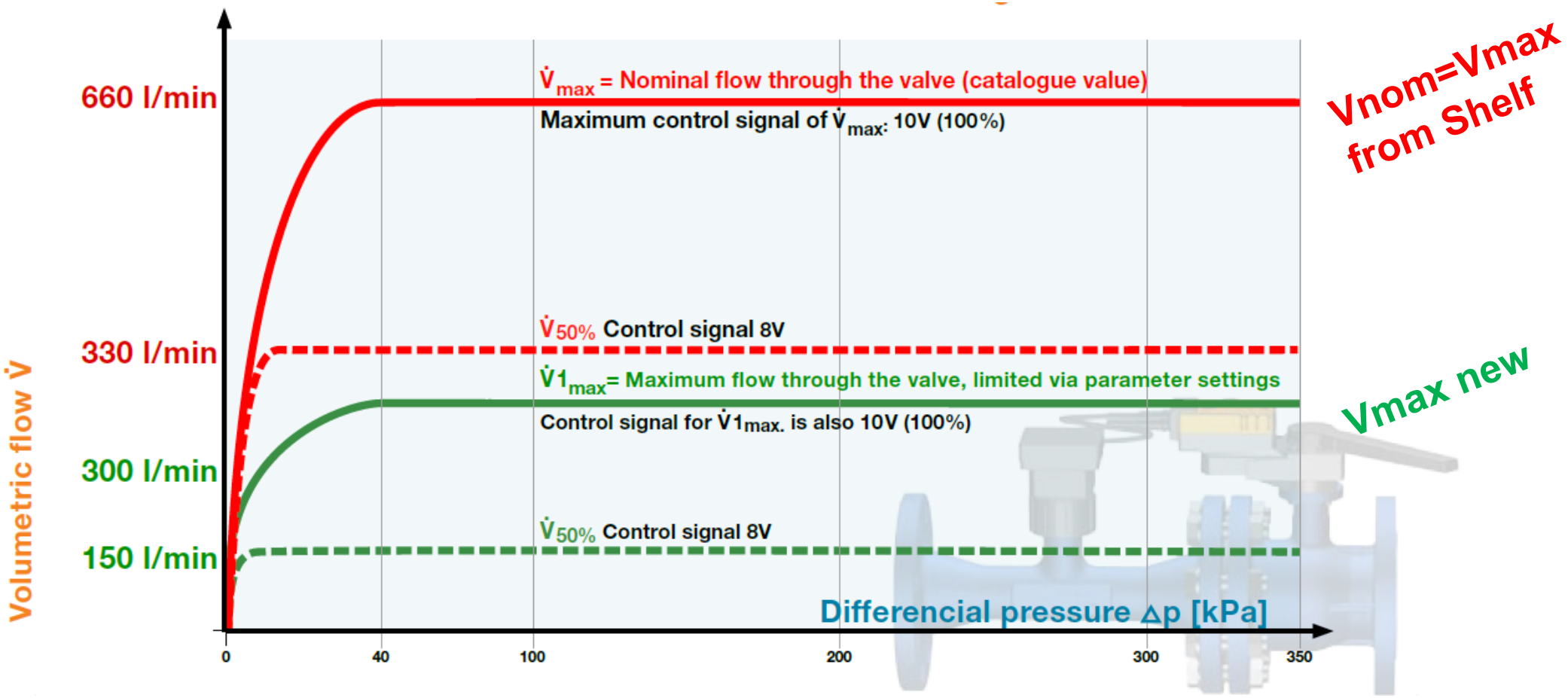
Flow 100% = Vnom

Creep Flow Suppresion

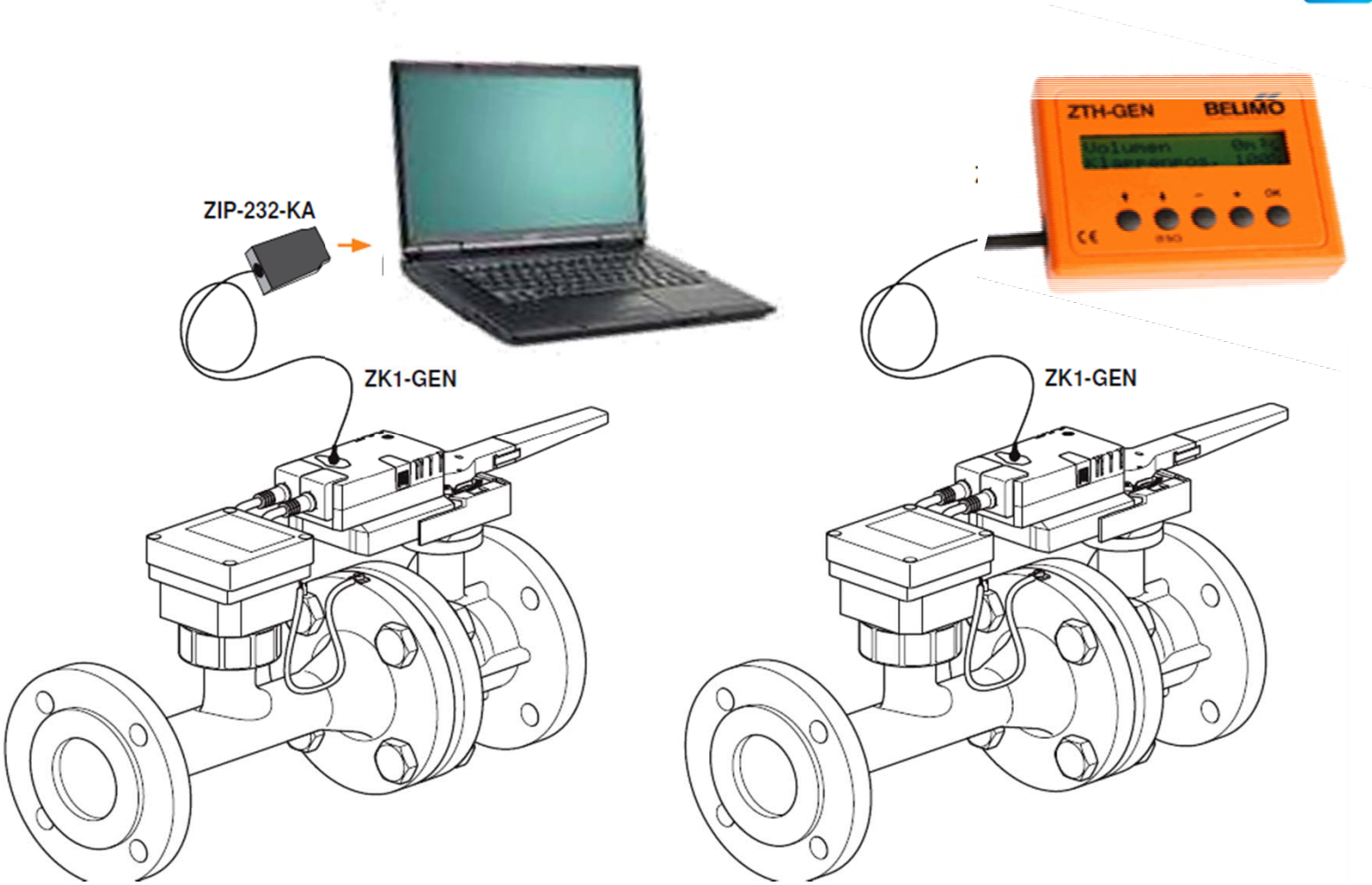


- **No precisely definable voltage arises when flow velocity is almost stationary**
- **This 2.5% range is suppressed electronically**

Programmable Flow Limitation
e.g. EPIV - P6080W1100E-MP



Service Devices



- ZTH-GEN manual “remote” control unit
- PC-Tool, (with ZIP-232-KA)
- BMS with MP-BUS

Old vs. "New" Hydraulic Balancing
Vmax setting withing seconds!

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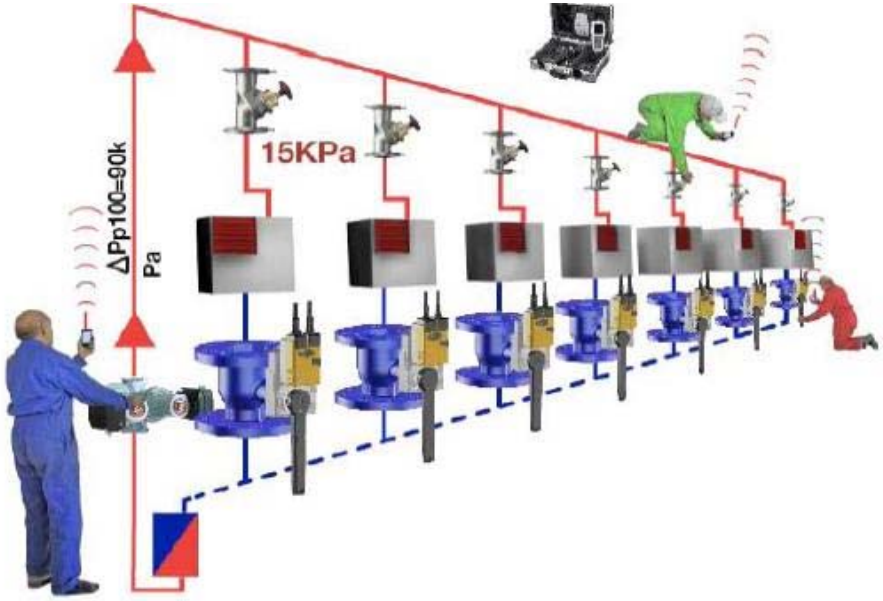

The old way of balancing

30 minutes per line
3 people
Equipment: • Laptop • Phone • Measuring device • Instructions
10 kg

The new way of balancing

10 seconds per line
1 person
Equipment: • Setting device ZTH-GEN
100 g

Balancing, directly form BMS

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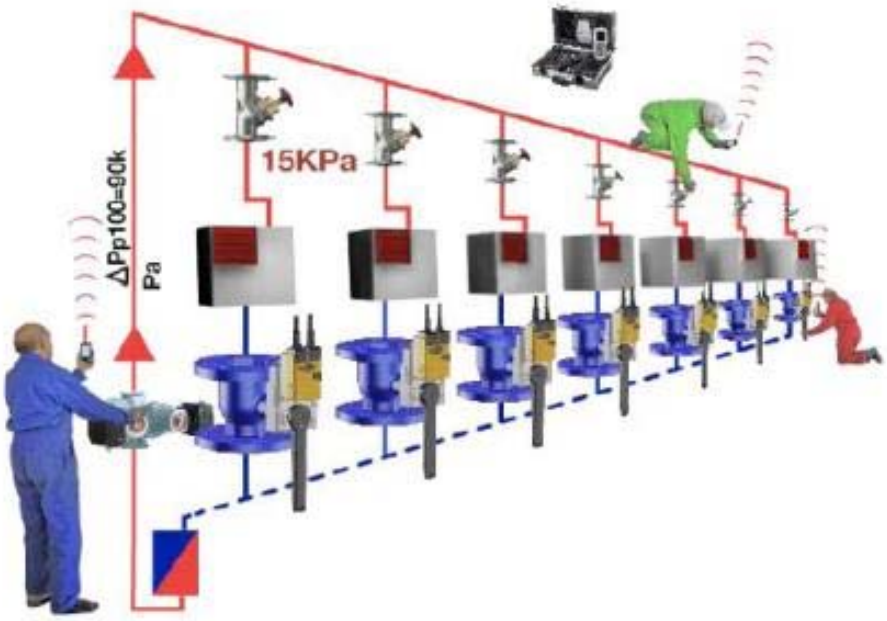

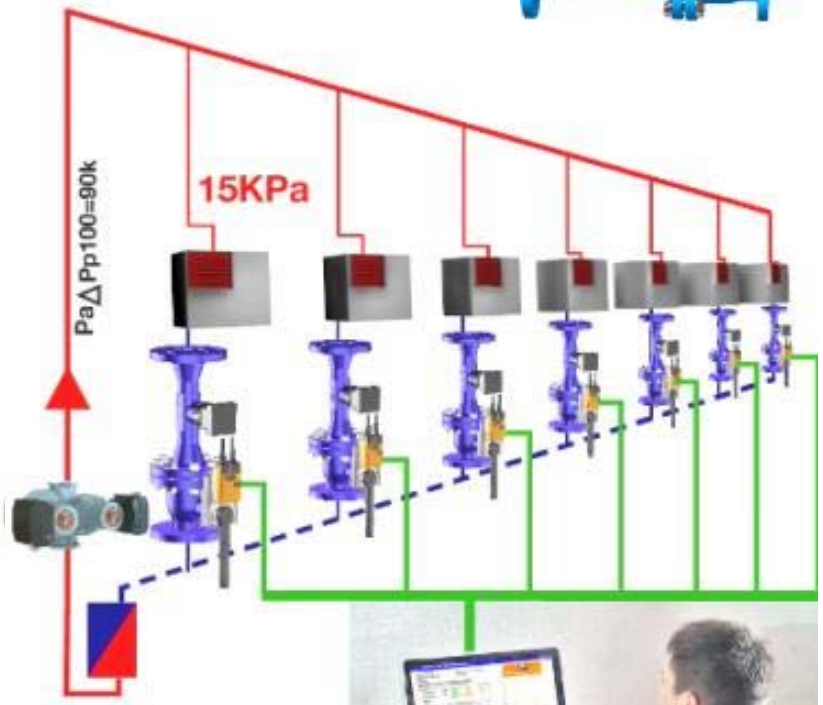

Conventional Balancing

- needs 3 people
- 30 min. for each line
- 210 min. for 7 lines

1 person, 10 sec. for 7 lines

PC-Tool Simulation

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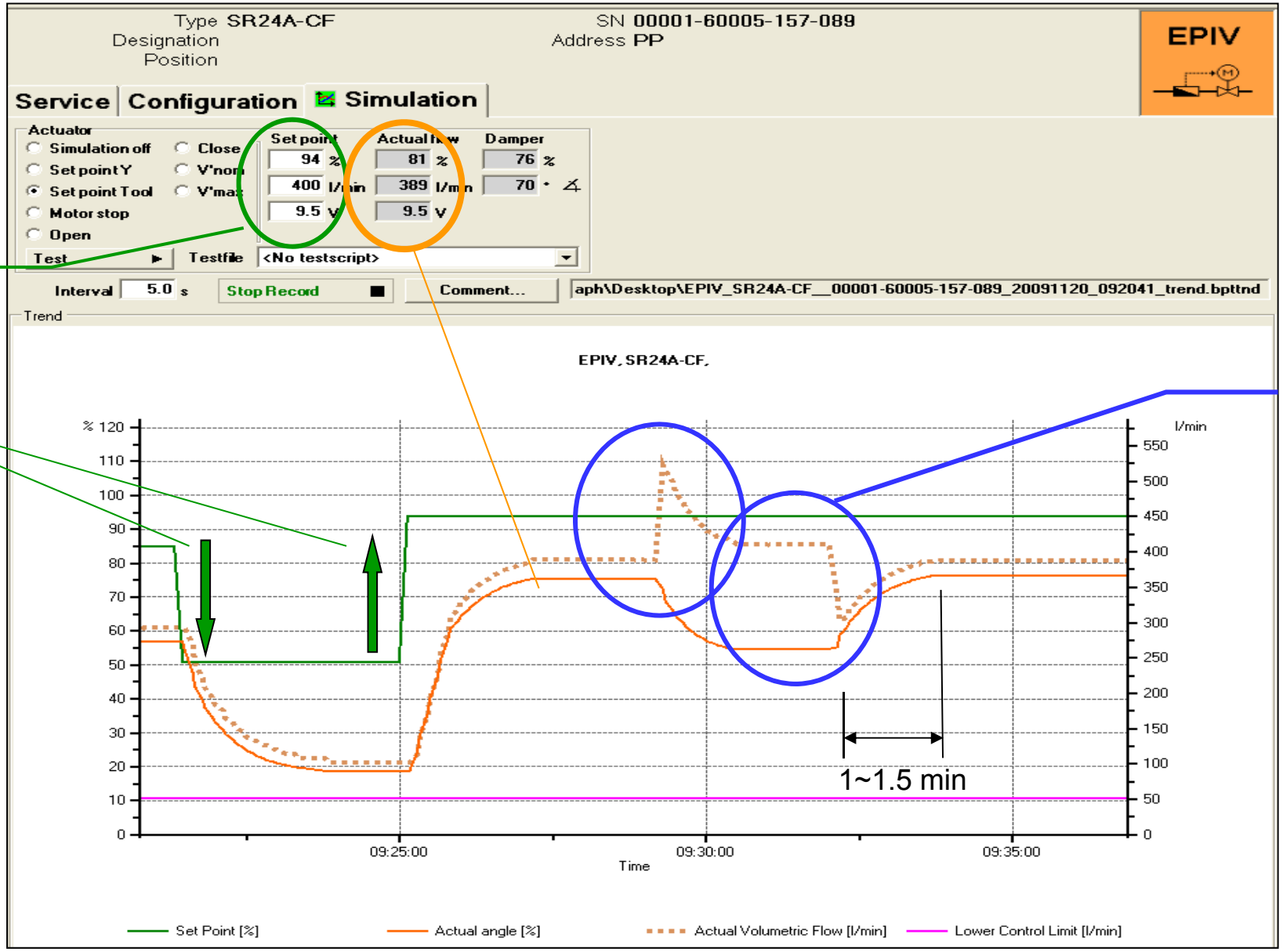

Changing Set values from controller => Set Flow

Set value = constant, Inlet pressure rises / drops

EPIV - Benefits

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Benefit	Remarks / explanation
Simplest, safe valve design	No calculation of k_{vs} value required
No hydraulic balancing necessary	Continuous monitoring / balancing of the volumetric flow Pressure-independent operation
Correct flow rate values, even with partial-load operation	
No energy loss with zero load	Leakage rate A (air bubble tight)
Flexibilty during the planning and construction phase	Simple adjustment V_{max} = 45 … 100% of V_{nom}
Flexible for future conversion	
«All-in-One» solution	4 functions: Control / Measure / Balance / Shut
Knowledge how much water flows through each consumer.	Displaying the measured current flow rate

ENERGY VALVE

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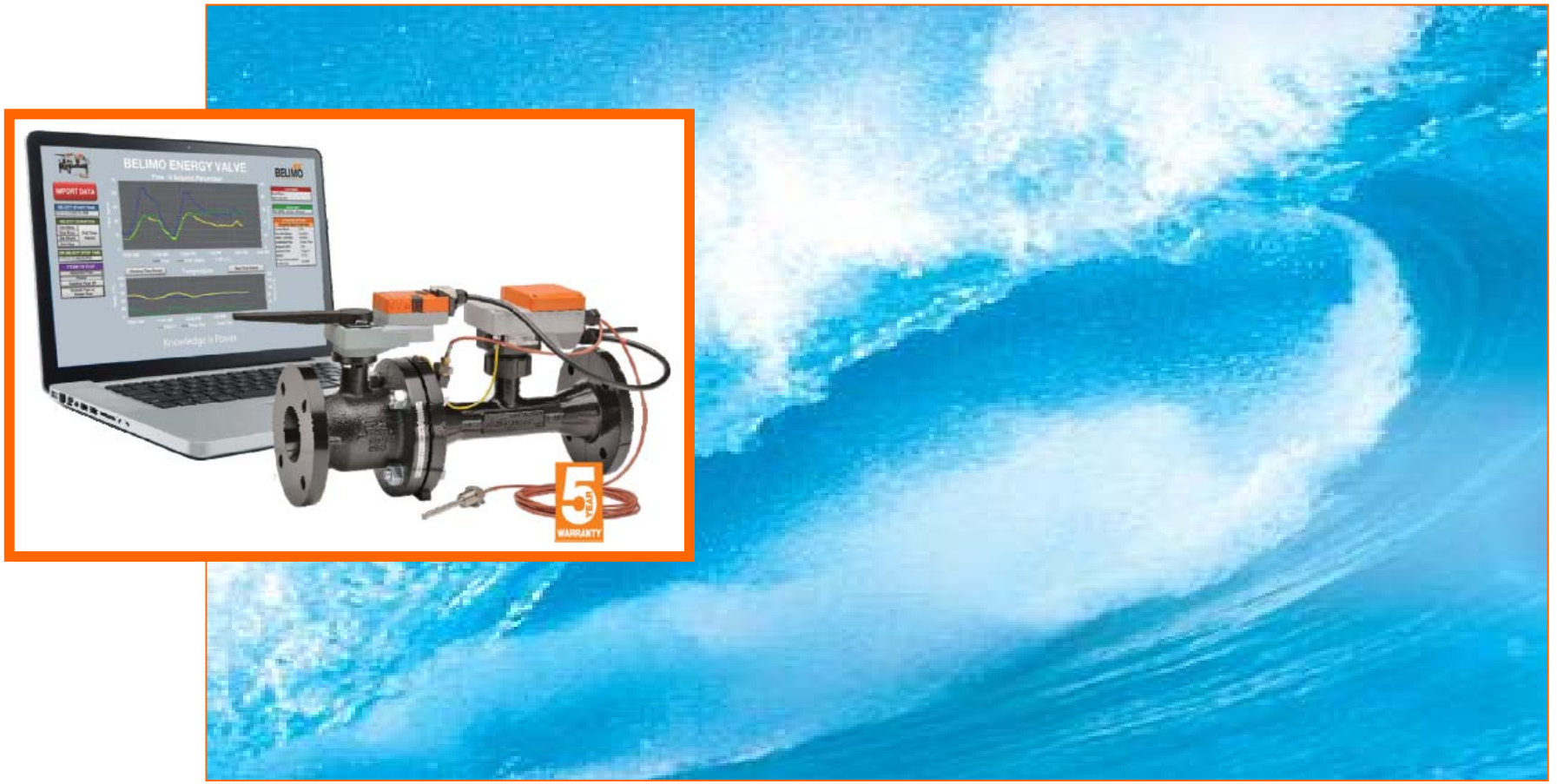

The Energy Valve - Knowledge is Power

APPLICATION Chiller Plant - PICCV / EV

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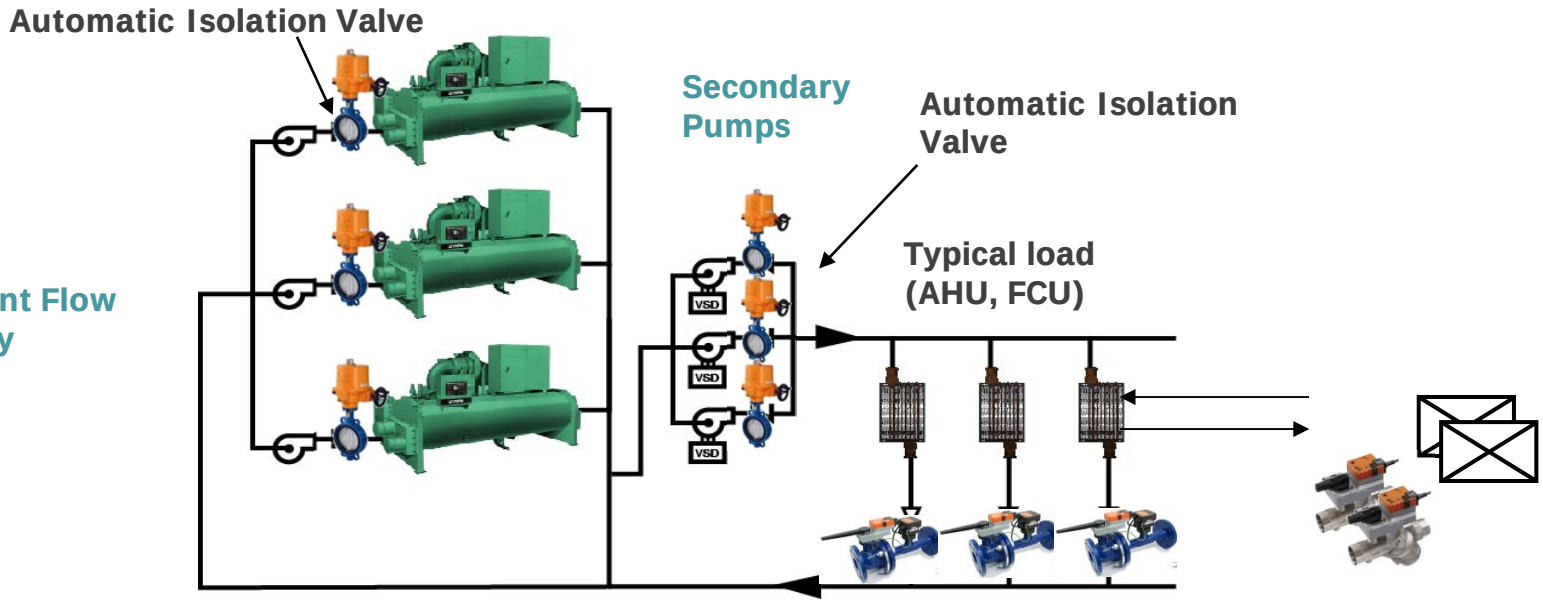
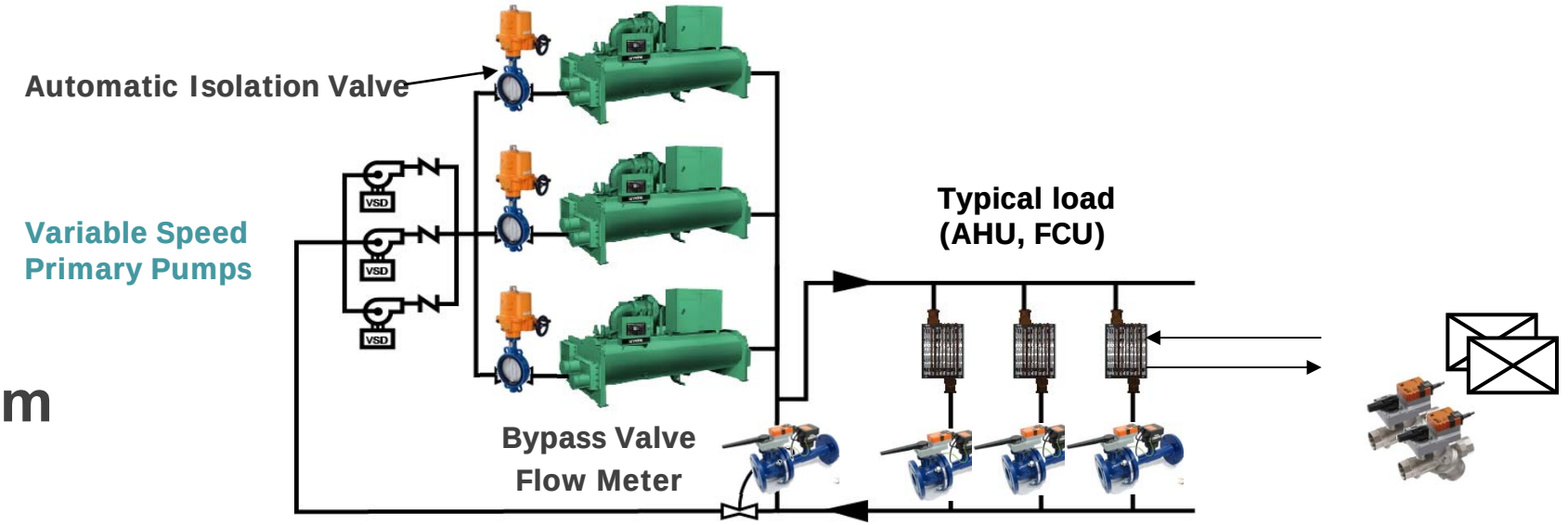
Primary/Secondary System



Variable Primary System



ENERGY VALVE – 5 Functions – One Unit

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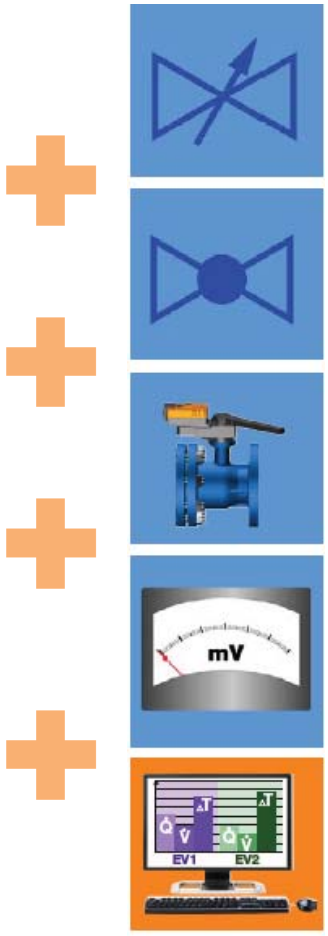
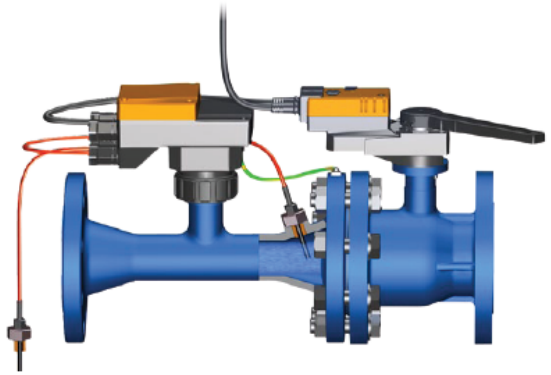
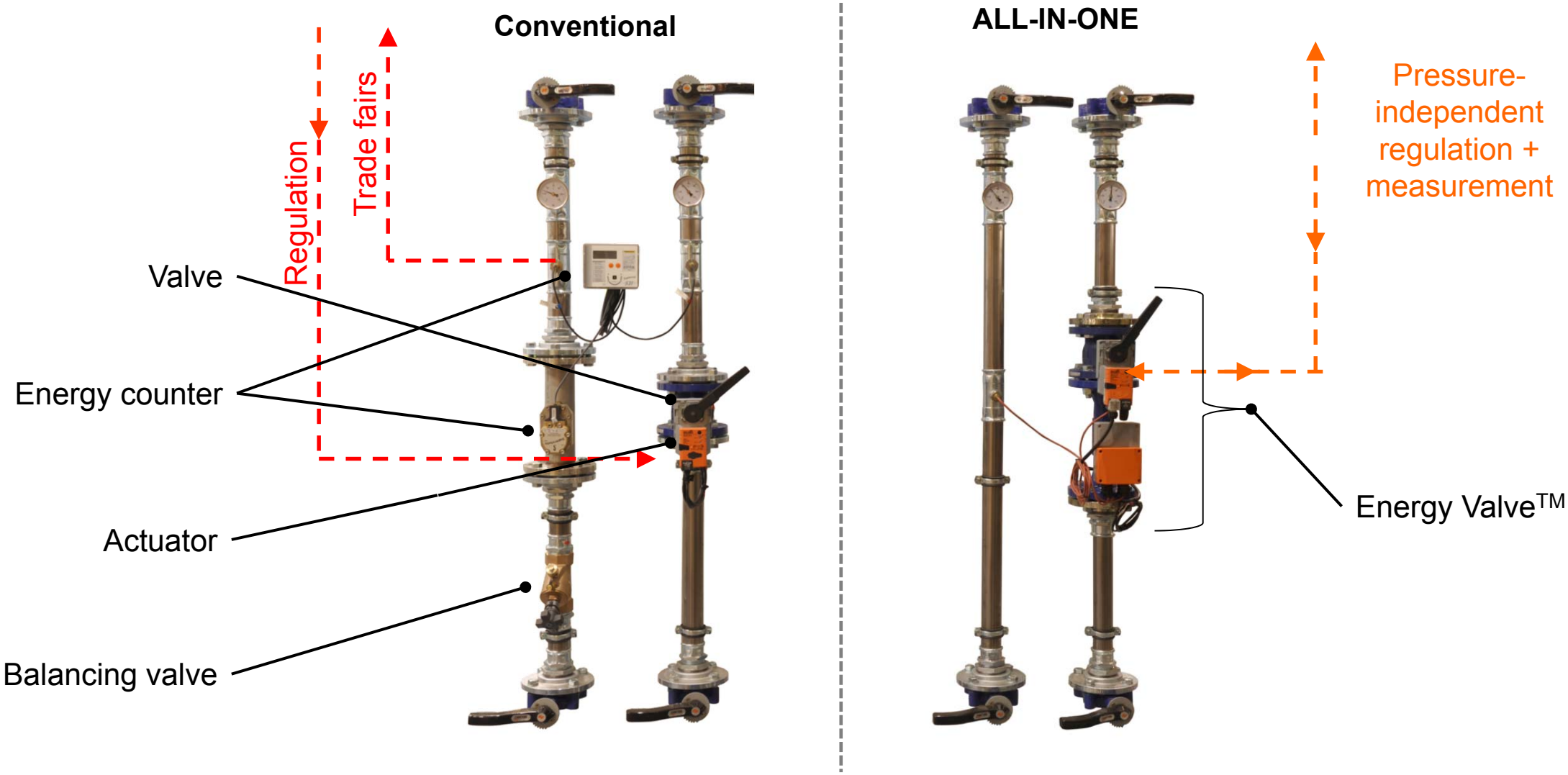
1. Hydraulic balancing
2. Air bubble-tight-shut-off
3. Pressure-independent flow control
4. Permanent volumetric flow measurement
5. Energy Monitoring



With the Energy Valve, all 5 functions are combined in one unit.



ALL-IN-ONE
Rapid installation, simple integration



The Energy Valve

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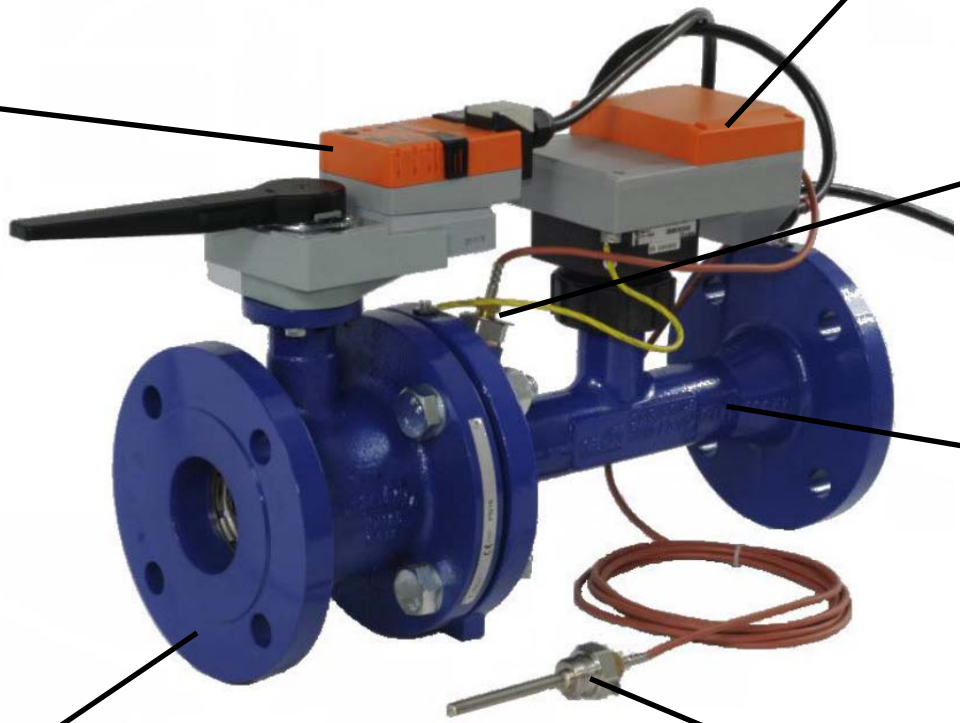

Velocity sensor
(Measurement principle: Magnetically inductive)

Intelligent Actuator with
- Integrated logic
- Integrated web server
- Data recording function

Temperature sensor T2
(installed)

Measuring pipe

Characterised control valve LG-CCV

Temperature sensor T1
(wired / length 10 m)

Power Calculation / Energy Consumption

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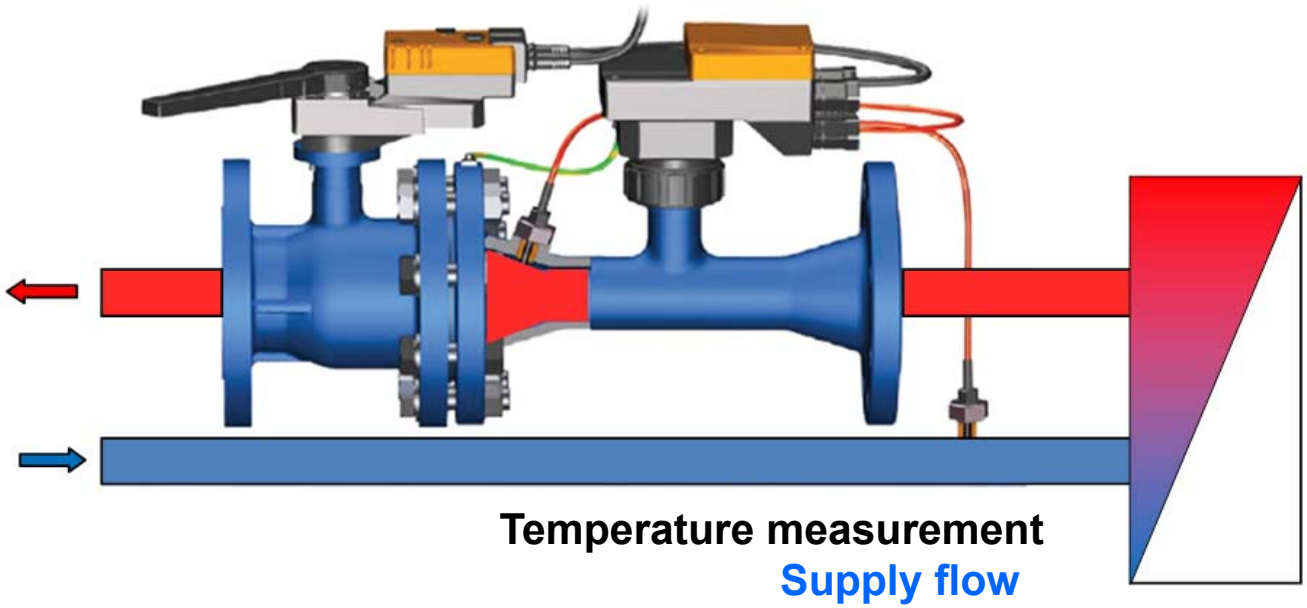
Energy consumption

$$Q = \int \dot{Q} \cdot \Delta t \quad \text{[kwh] [TonH]}$$

Temperature measurement
Return flow

flow measurement

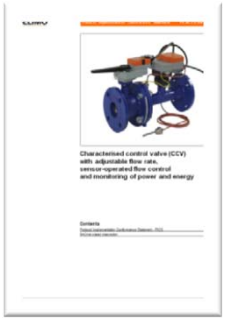


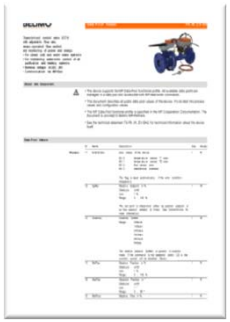
Temperature measurement
Supply flow

Power output

$$\dot{Q} = f\,(\dot{V}, \Delta T, \rho, c) \quad \text{[kw] [Ton]}$$

Energy Valve
Communication and Control





- **Conventional**
  - Positioning DDC signal Y (Volt) as **set point for flow rate**
  - Feedback U5 as information on **flow rate, power, T1, T2, ΔT or opening angle**

- **Always an integral part of the Energy Valve are:**
  - BACnet IP
  - BACnet MS/TP
    - Baud rates: 9600, 19,200, 38,400, 76,800, 115,200
  - MP bus (MP bus slave interface)

BACnet object description

Object Name	Object Type / Instance	Description	Values	Default
Device_Name	Device [x]			
SpRel	Analog Output [1]	Setpoint Relative in % The set point is interpreted either as position setpoint or as flow setpoint (related to Vmax). See ControlMode for more information.	0 … 100	0
RelPos	Analog Input [1]	Relative Position in %	0 … 100	-
AbsPos	Analog Input [2]	Absolute Position in °	0 … 90	-
RelFlow	Analog Input [10]	Relative Flow in %	0 … 100	-
AbsFlow_SI1	Analog Input [11]	Absolute Flow in l/min	0 … 100'000	-
AbsFlow_SI2	Analog Input [12]	Absolute Flow in m3/h	0 … 600	-
AbsFlow_US	Analog Input [13]	Absolute Flow in gpm	0 … 100'000	
T1_SI	Analog Input [20]	Temperature 1 (remote) in °C	-10 … +120	-
T1_US	Analog Input [25]	Temperature 1 (remote) in °F	14 … 248	
T2_SI	Analog Input [21]	Temperature 2 (embedded) in °C	-10 … +120	-
T2_US	Analog Input [26]	Temperature 2 (embedded) in °F	14 … 248	
DeltaT_SI	Analog Input [22]	Delta Temperature in °C	-500 … +500	-
DeltaT_US	Analog Input [27]	Delta Temperature in °F	-500 … +500	
P_SI	Analog Input [30]	Power in kW	0 … 2.147e+9	-
P_US	Analog Input [35]	Power in kBTU/h	0 … 2.147e+9	
E_Cooling_SI	Analog Input [31]	Cooling Energy in kWh	0 … 2.147e+9	-
E_Cooling_US	Analog Input [36]	Cooling Energy in kBTU	0 … 2.147e+9	
E_Heating_SI	Analog Input [32]	Heating Energy in kWh	0 … 2.147e+9	-
E_Heating_US	Analog Input [37]	Heating Energy in kBTU	0 … 2.147e+9	
Override	Multi-state Output [1]	Override Control	Auto Close Open Vnom Vmax Stop	Auto
Vmax	Analog Value [100]	Maximum Flow Limit in %	0 … 100	100
Vnom_SI	Analog Value [101]	Nominal volume flow in l/min (read-only)	0 … 100'000	-
Vnom_US	Analog Value [102]	Nominal volume flow in gpm (read-only)	0 … 100'000	-
ControlMode	Multi-state Value [100]	Control Mode The value defines the interpretation of the setpoint.	PosCtrl FlowCtrl	FlowCtrl
DeltaT_Limitation	Multi-state Value [101]	DeltaT Limitation	NoLimiting DeltaTLimiting	NoLimiting
SpDeltaT_SI	Analog Value [103]	Setpoint DeltaT in °C	4 … 20	0
SpDeltaT_US	Analog Value [104]	Setpoint DeltaT in °F	7 … 36	0

BACnet Objects to read from the ENERGY VALVE

See also

Data Recording

- **Integrated in the actuator**

- **Previous 7 days**
  - Measurement series every 30 seconds → 21’600 measurement series
- **Previous 13 months**
  - Measurement series every 2 hours
    → 4’750 measurement series
- **csv file → Excel**

Temperature T_2 at time X = ?
Value: 43.96
Unit: 0 = °C
→ **43.96 °C**

Default Datalog Configuration 18.01.2012 09:22

Timestamp	2.In0: Control	2.In1: Override	2.In12: DspS	2.In13: T1_re	2.In14: UnitTe	2.In15: T2_en	2.In16: UnitTe	2.In17: Delta	2.In18: UnitTe
10.02.2012 00:00:06	1	1	0	50.38	0	43.96	0	6.418	0
10.02.2012 00:00:37	1	1	0	50.52	0	43.96	0	6.558	0
10.02.2012 00:01:07	1	1	0	50.52	0	43.96	0	6.556	0
10.02.2012 00:01:37	1	1	0	50.49	0	43.93	0	6.553	0
10.02.2012 00:02:07	1	1	0	50.37	0	43.93	0	6.449	0
10.02.2012 00:02:37	1	1	0	50.36	0	43.88	0	6.482	0
10.02.2012 00:03:07	1	1	0	50.54	0	43.86	0	6.683	0
10.02.2012 00:03:37	1	1	0	50.5	0	43.86	0	6.644	0
10.02.2012 00:04:07	1	1	0	50.41	0	43.84	0	6.568	0

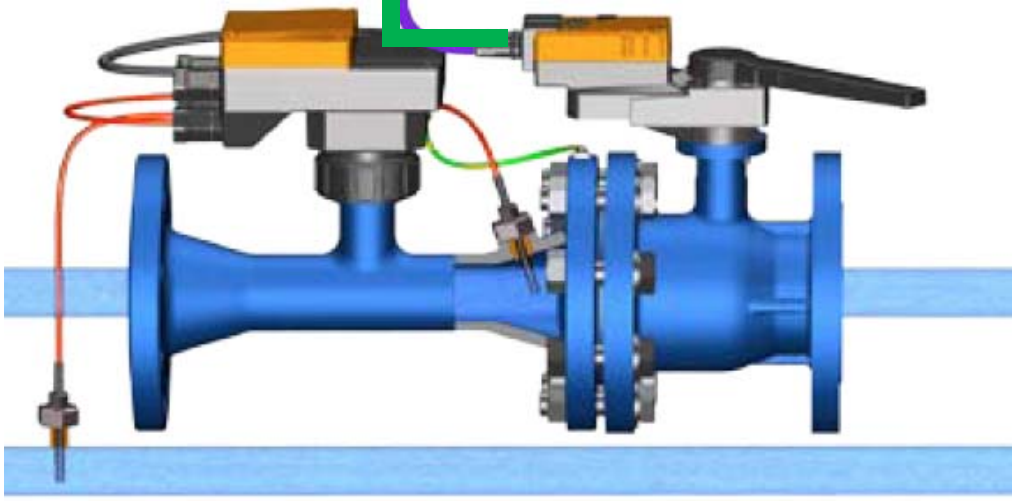
Integrated Web server…

…the unique added value

http://192.168.0.10:8080 (default) - to be changed individually

Web browser

Ethernet RJ45



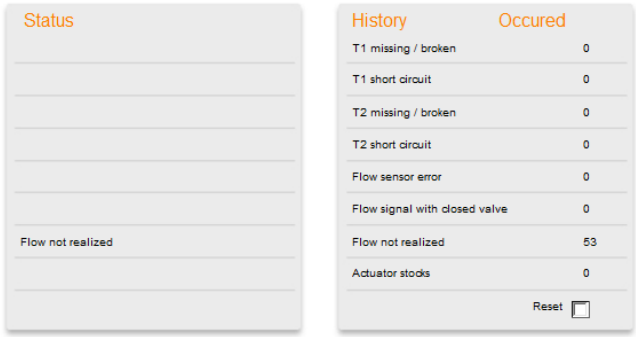
Web server

Integrated Web server

Example: EV50.belimo.ch

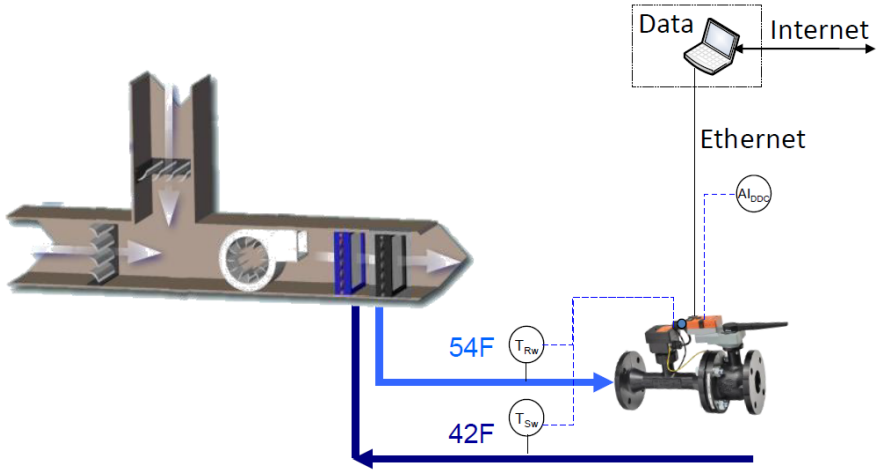
- **Real-time information**

- **Positioning signal**
- **Flow rate**
- **Temperatures T1 / T2 / ΔT**
- **Consumer power output**
- **Cumulated energy consumption heating/cooling**
- **Settings**
- **Status information**



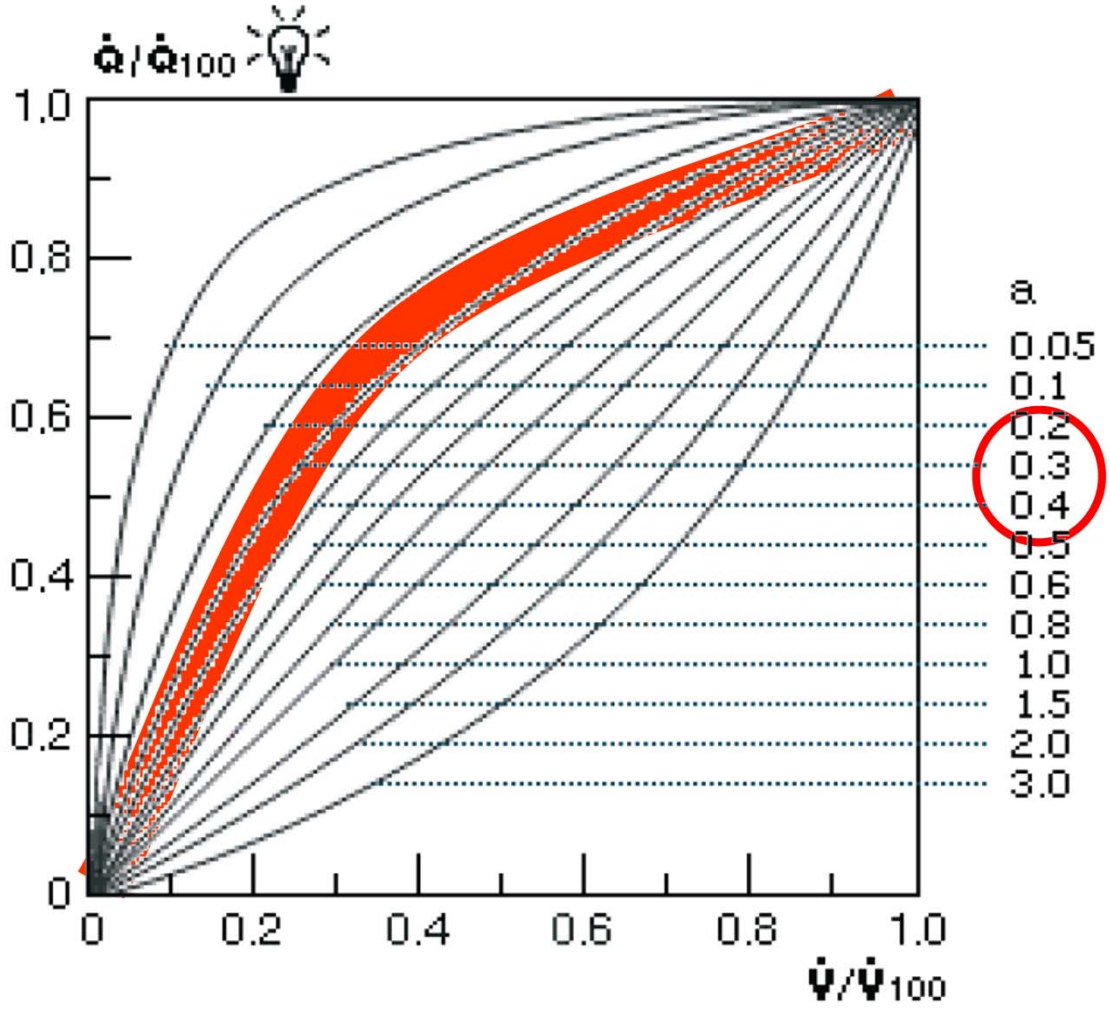
Field Test
Massachusetts Institute of Technology (MIT)

- **The Hayden Library (~ 14,000 m², built 1949)**

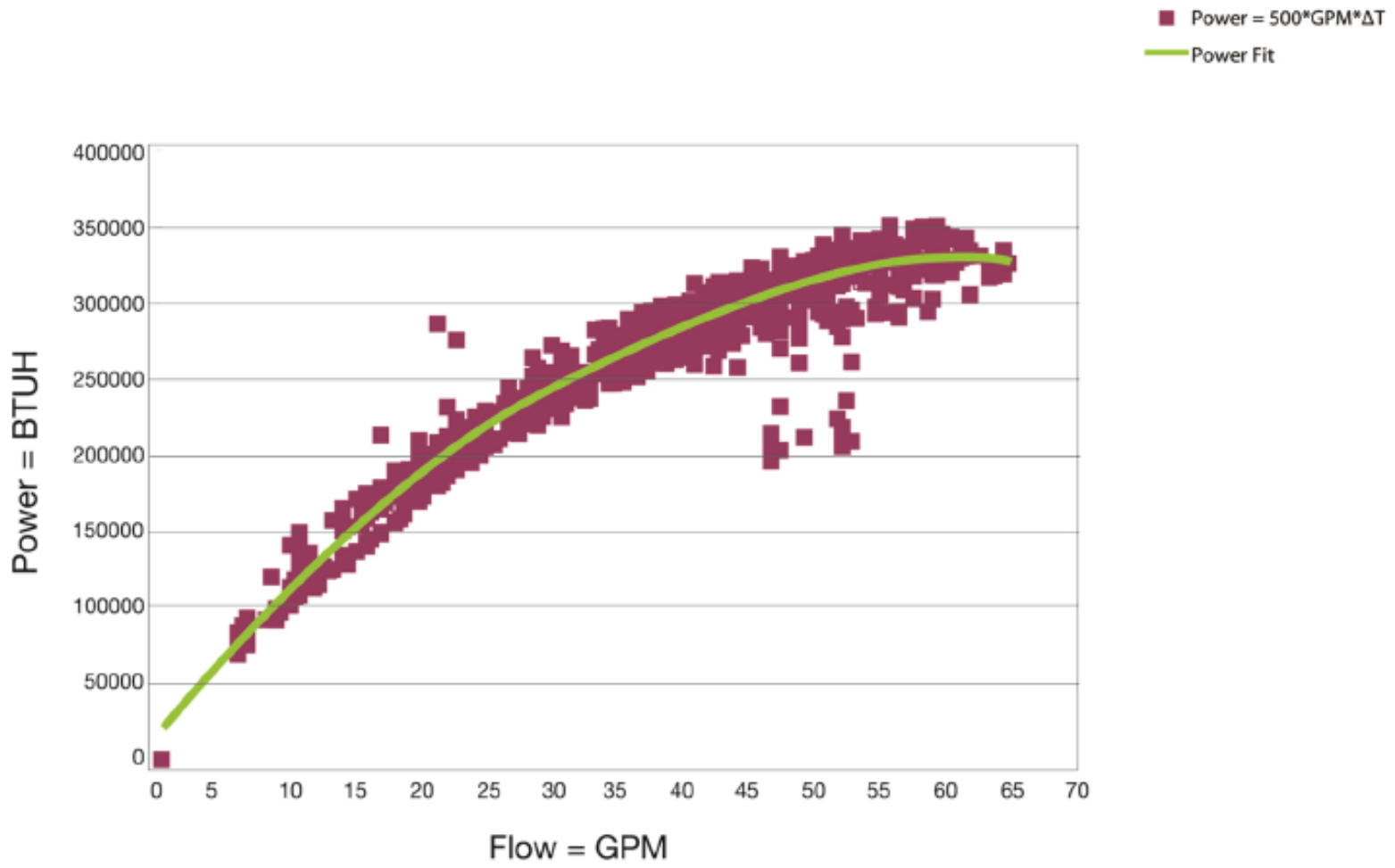


- **6 AHU / cooling**
- **Situation snapshot with the aid of the Energy Valve**
- **System optimisation**

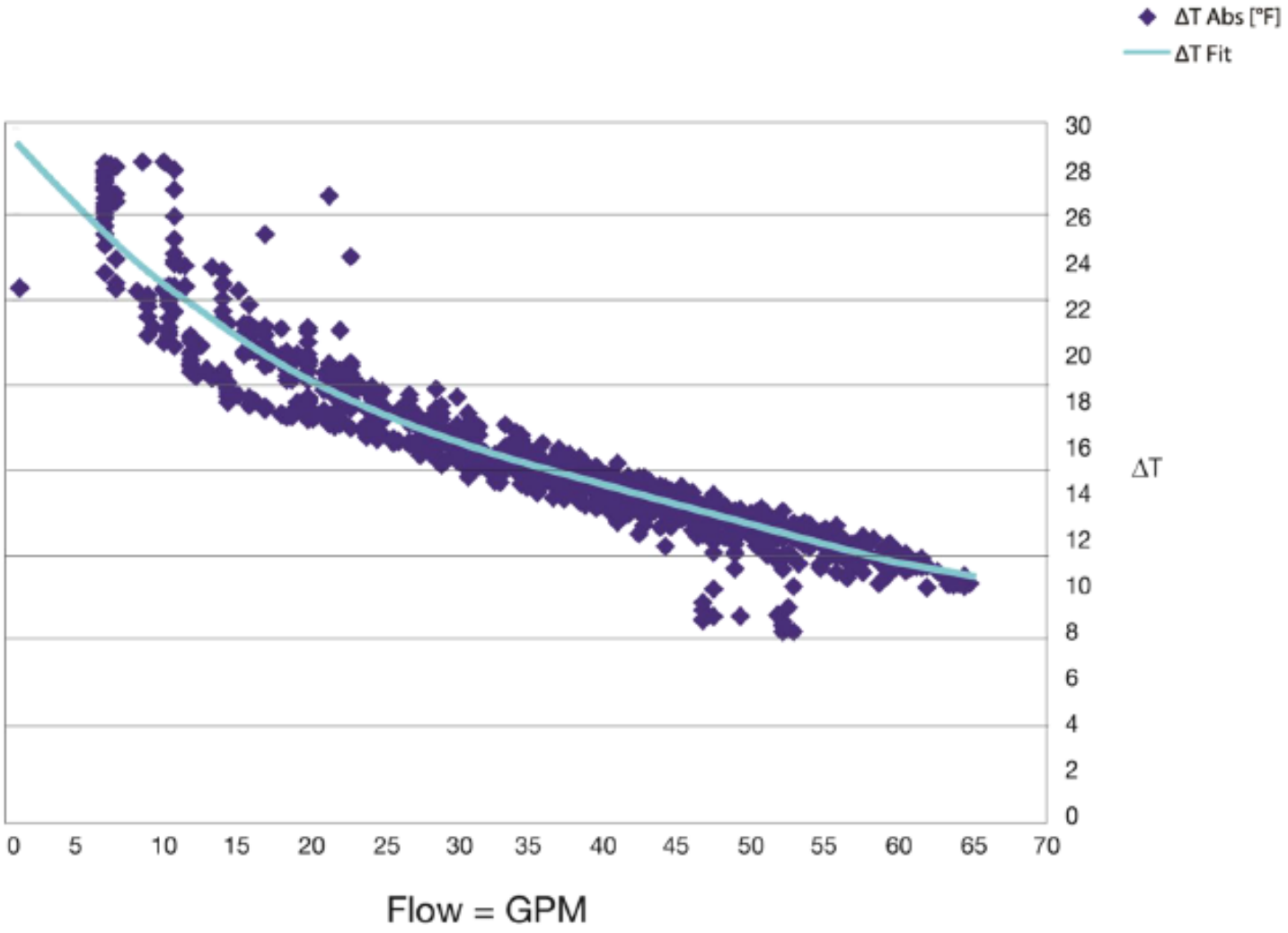
Coils / Heat exchangers



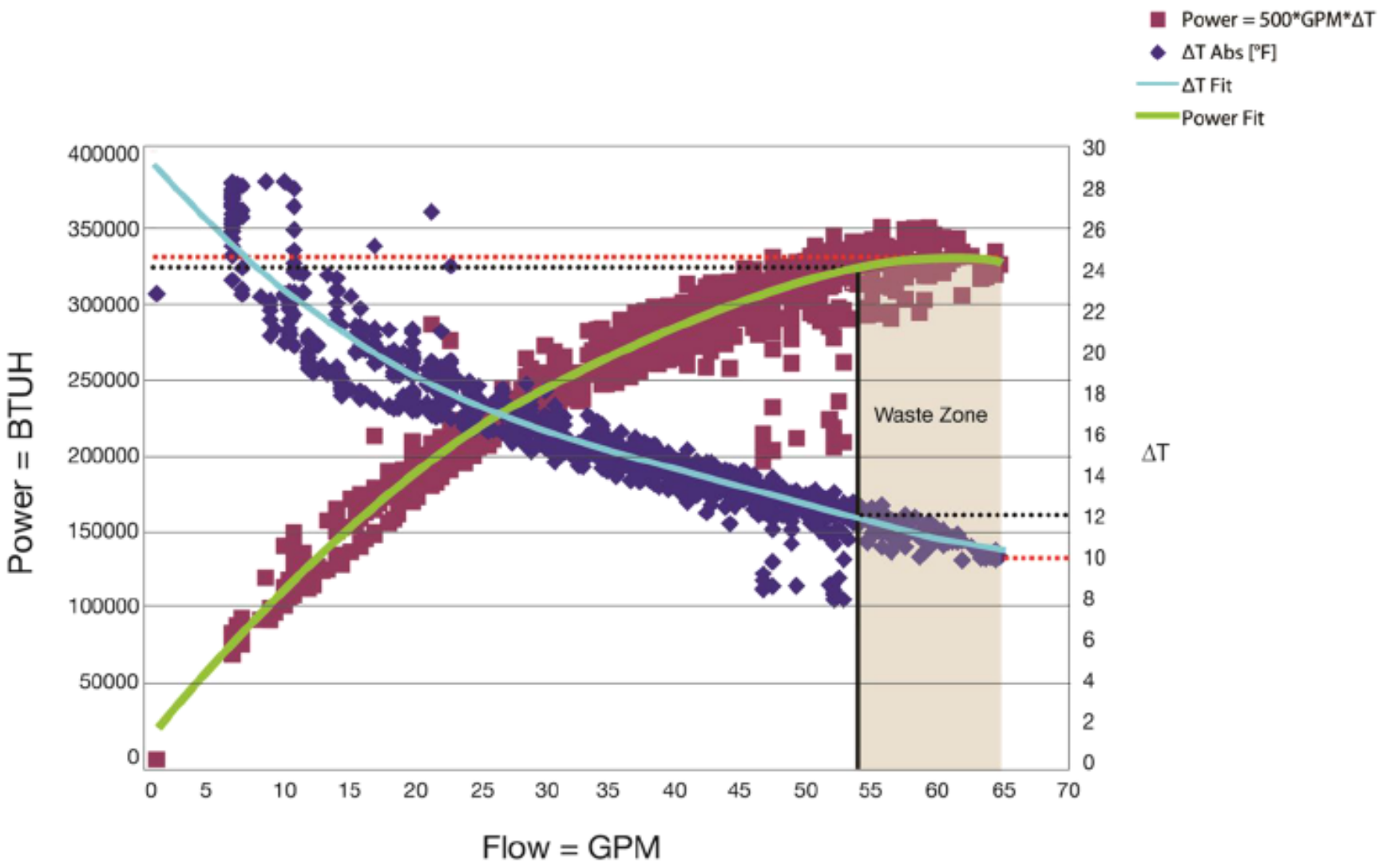
Application of the recorded Data
AHU-6 Power Curve



Application of the recorded Data
AHU-6 DT Curve



Power Saturation & Waste Zone



Coil Degradation

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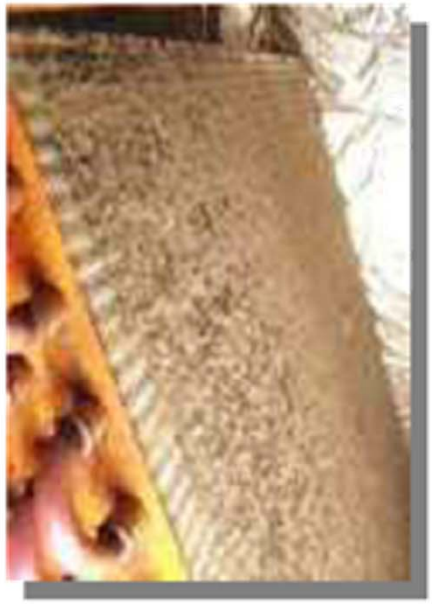
- Damaged Coils
- Air Side Fouling
- Water Side fouling

Damaged Coils



Air Side Dirt and Fouling

Water Side Fouling

Energy Valve - ΔT Limitation

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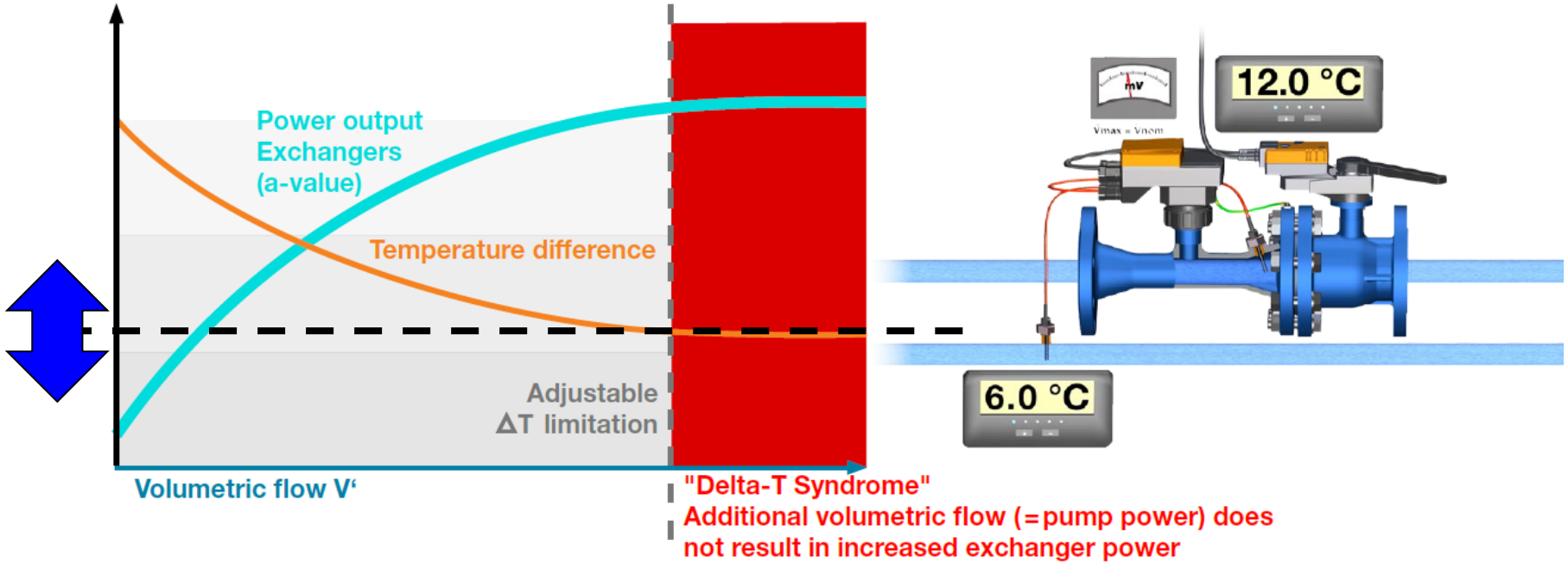
- **Adjustable minimal differential temperature**
- **Flow rate is limited automatically**



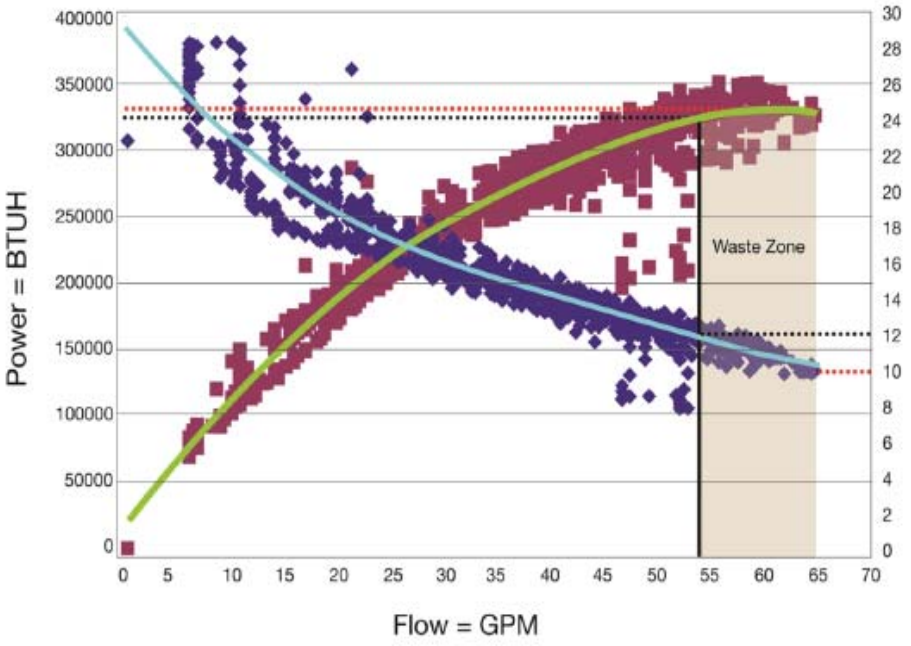
- **Adventages with added value**
  - Operation always in the optimum range of the exchanger
  - Reduced Pump operation, energy savings
  - Reduced and Improved Chiller operation
  - Reduction of operating costs

Field Test
Massachusetts Institute of Technology (MIT)

- **Field test results**

  - **System transparency** indicates large optimisation potential
  - Systems are operated with too much volumetric flow of water
  - Optimised water quantities can be defined

  - Significant reduction of pump energy
    - Typically, flow rate reduction **> 25%**
    - Previously, water quantity was too high by a factor of 2 on some days → pump energy reduction by **50%**



ENERGY VALVE - Benefits

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Benefit	Remarks / explanation
Simplest, safe valve design	No calculation of k_{vs} value required
No hydraulic balancing necessary	Continuous monitoring / balancing of the volumetric flow Pressure-independent operation
Correct flow rate values, even with partial-load operation	
No energy loss with zero load	Leakage rate A (air bubble tight)
Flexibility during the planning and construction phase	Simple adjustment V_{max} = 45 … 100% of V_{nom}
Flexible for future conversion	
«All-in-One» solution	5 functions: Control / Measure / Balance / Shut / Energy monitoring
Transparency provides the basis for the energy-efficient operation	It is not until becomes known where and how much energy is consumed that targeted optimisations can be undertaken. The EV makes all of the required information available.
Helps ensure preservation of value	Indicates worsening of performance
Ideal for retrofit applications	Reconstruction of the system's hydraulic data

ENERGY VALVE

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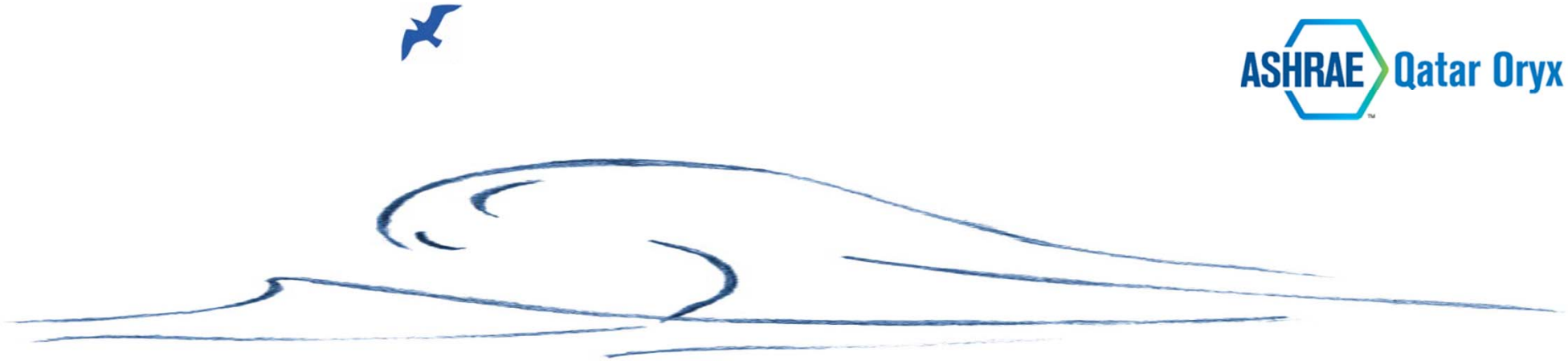
- ... includes all Benefits of a Control Ball Valve and an EPIV
- ... offers Transparency and Availability of Consumption and Operation Data (up to 13 months)
- ... is a powerfull Tool against Low DT
- ... will maximise Energy Efficiency of your Systems



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- ***Thank you for your attention!***

- It was a pleasure -