Fundamentals of Hydronic Design

Healthy HEATING

Comforting your mind, body and *soles*

Radiant Based HVAC Systems

Fundamentals of Hydronic Design

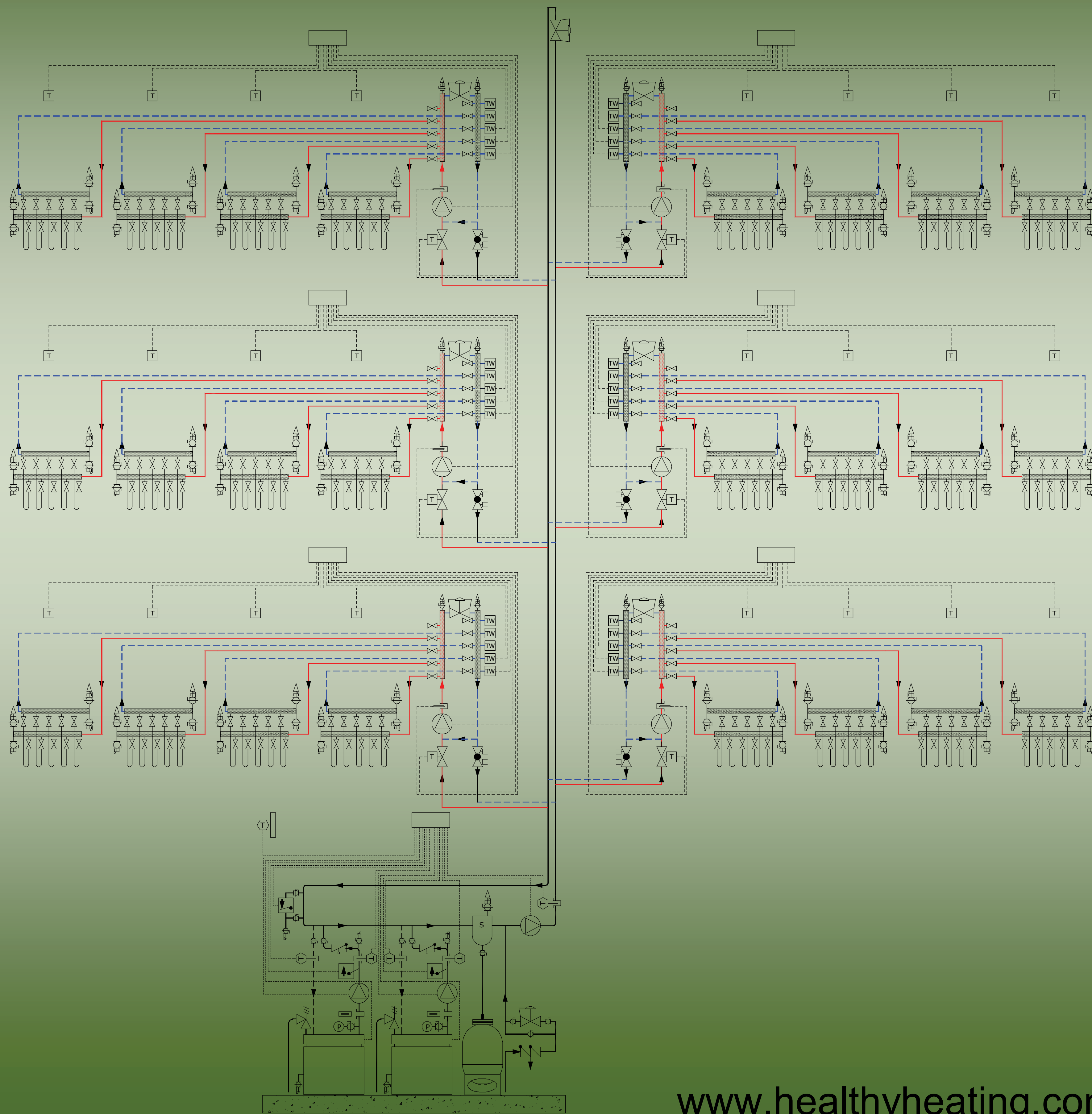
Healthy HEATING

Comforting your mind, body and soles

Selecting Control Valves

Fundamentals of Hydronic Design

- Radiant based HVAC
- IAQ + ICQ = IEQ
- Efficient & Effective
- Constant flow, variable temp
- Variable flow, constant temp
- Large Δ*t*'s on distribution
- Larger Δ*t*'s on boilers
- Modulating injection valves
- Differential press. controls
- Exp tank sized on low temp
- Multi Story – use HEX/floor



Fundamentals of Hydronic Design

Some slides contained animations in the original .ppt format which have been eliminated in the conversions to Adobe's .pdf format.

Fundamentals of Hydronic Design

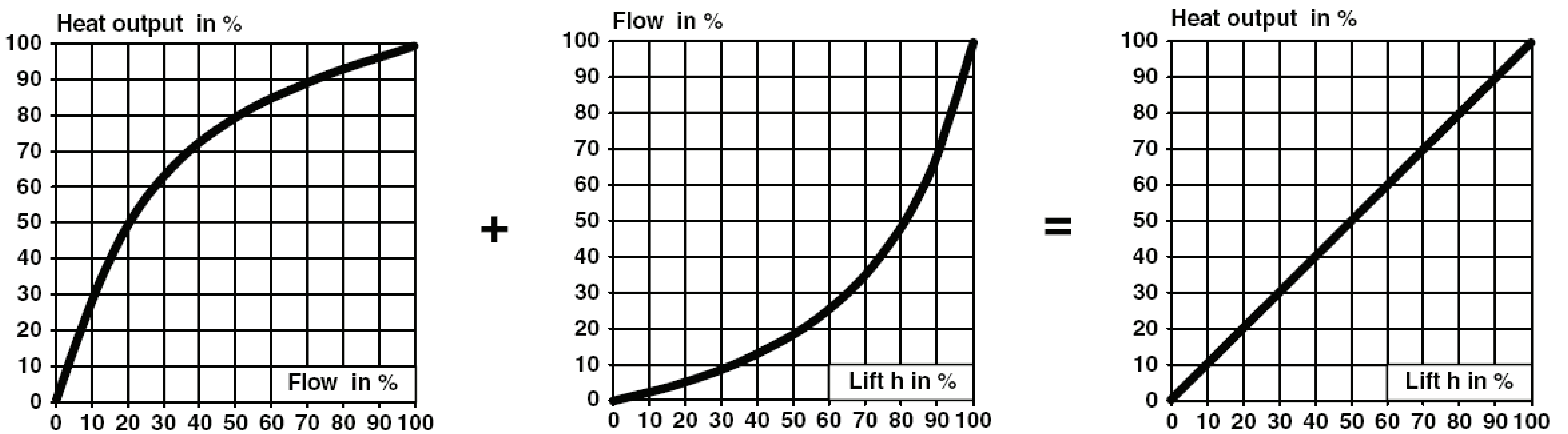
There is no point calculating zone flow unless one is prepared to control it properly…zone flow is regulated by controlling differential pressure which is done with control valves and or circulators.

Fundamentals of Hydronic Design

- Three Conditions for System Authority – “Control”
  - The design flow (determined by Δp) must be available at all terminals.
  - The differential pressure (Δp) across control valves must not vary too much.
  - Flows must be compatible at system interfaces.
    - Ex. 1, Primary/secondary
    - Ex. 2, Series flow when control valves are located between two circulators

Fundamentals of Hydronic Design

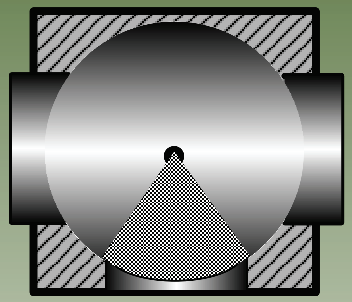
- Selecting Control Valves
  - Ball, gate, fast acting ‘zone’ valves are NOT control valves.
  - Control valves have ‘engineered shaped plugs’ which produce a flow/lift curve specific to each shape and are connected to modulating actuators.
  - An inverse characteristic shaped plug is selected against the shape of the heat terminal unit to generate linear performance…that’s why its called “control”.

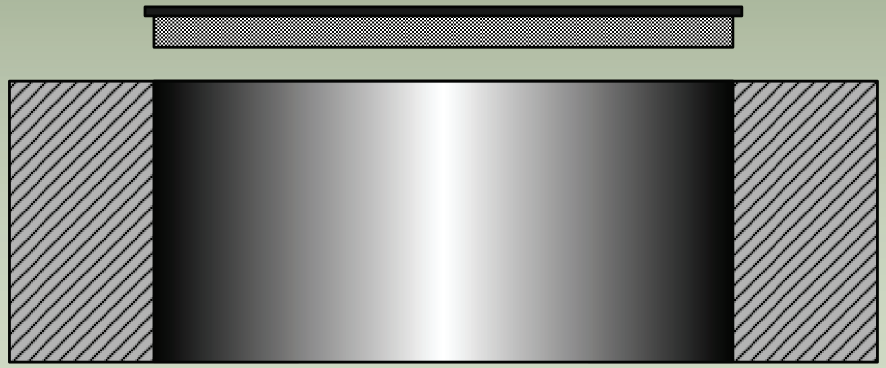


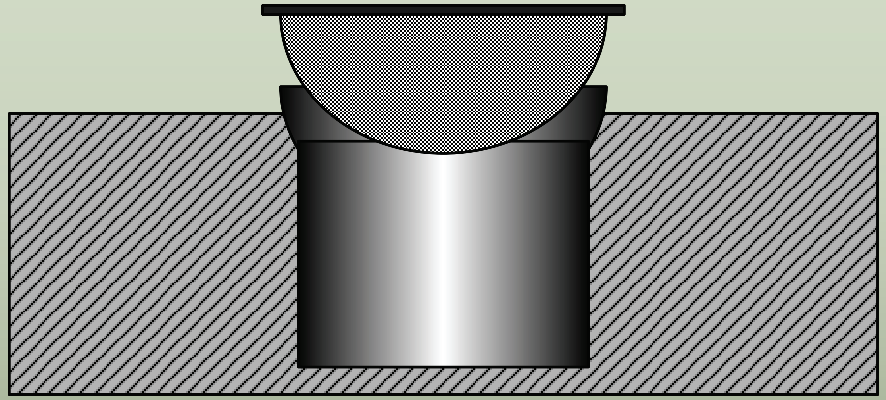
a- Typical coil characteristics | b- EQM valve characteristic | c- Combination of both characteristics

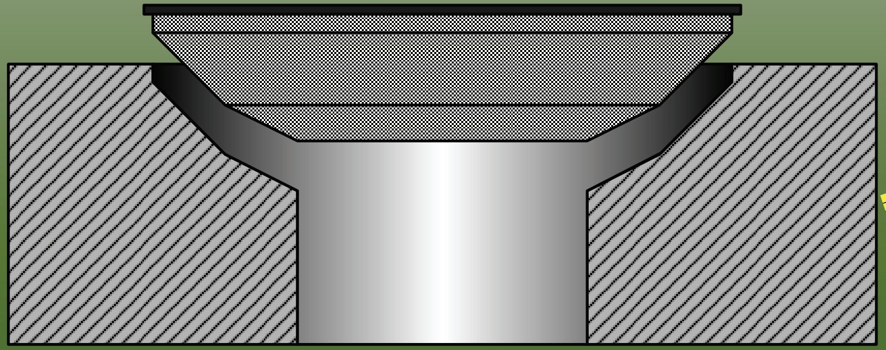
Fundamentals of Hydronic Design

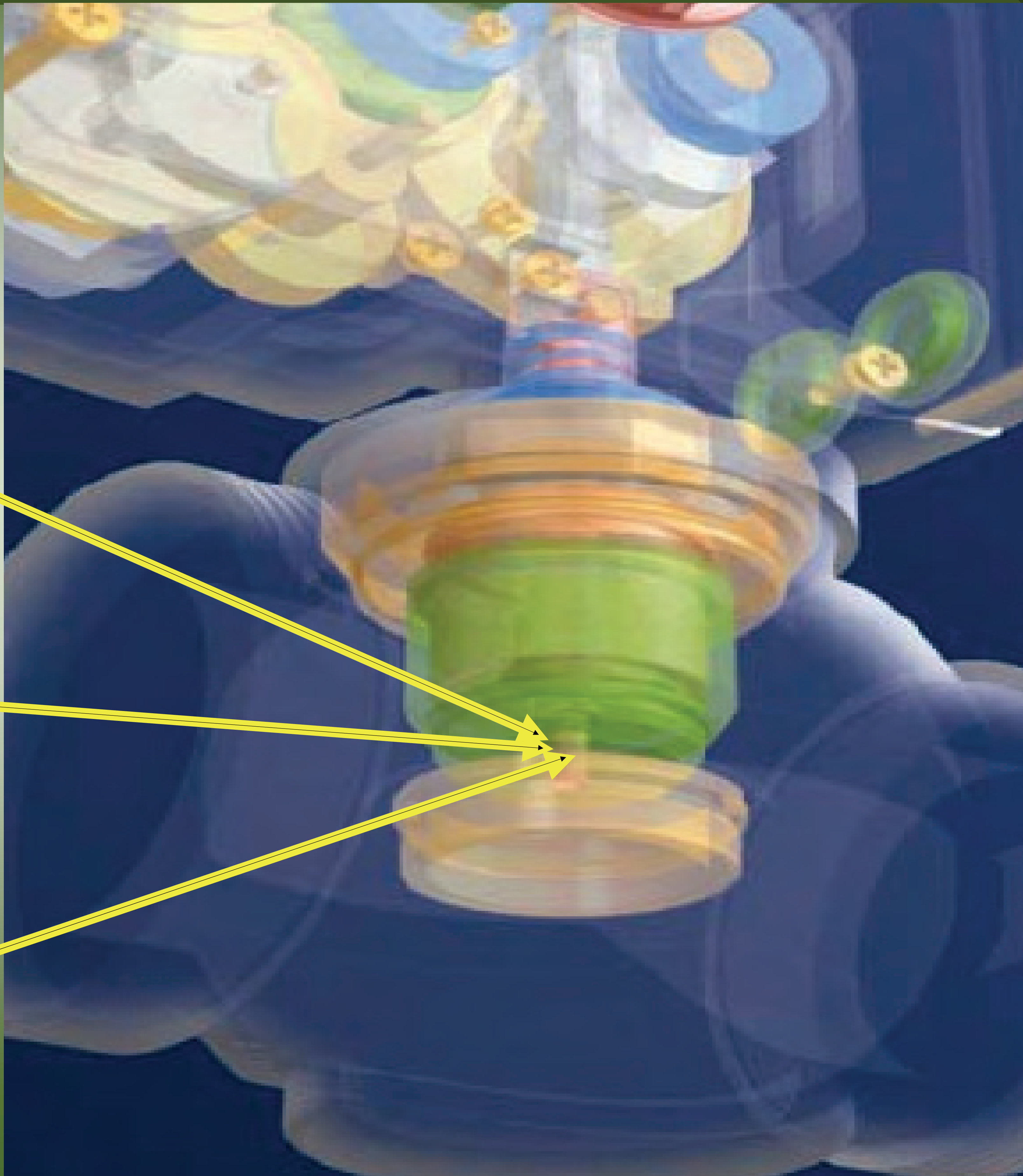
- Plug Shapes





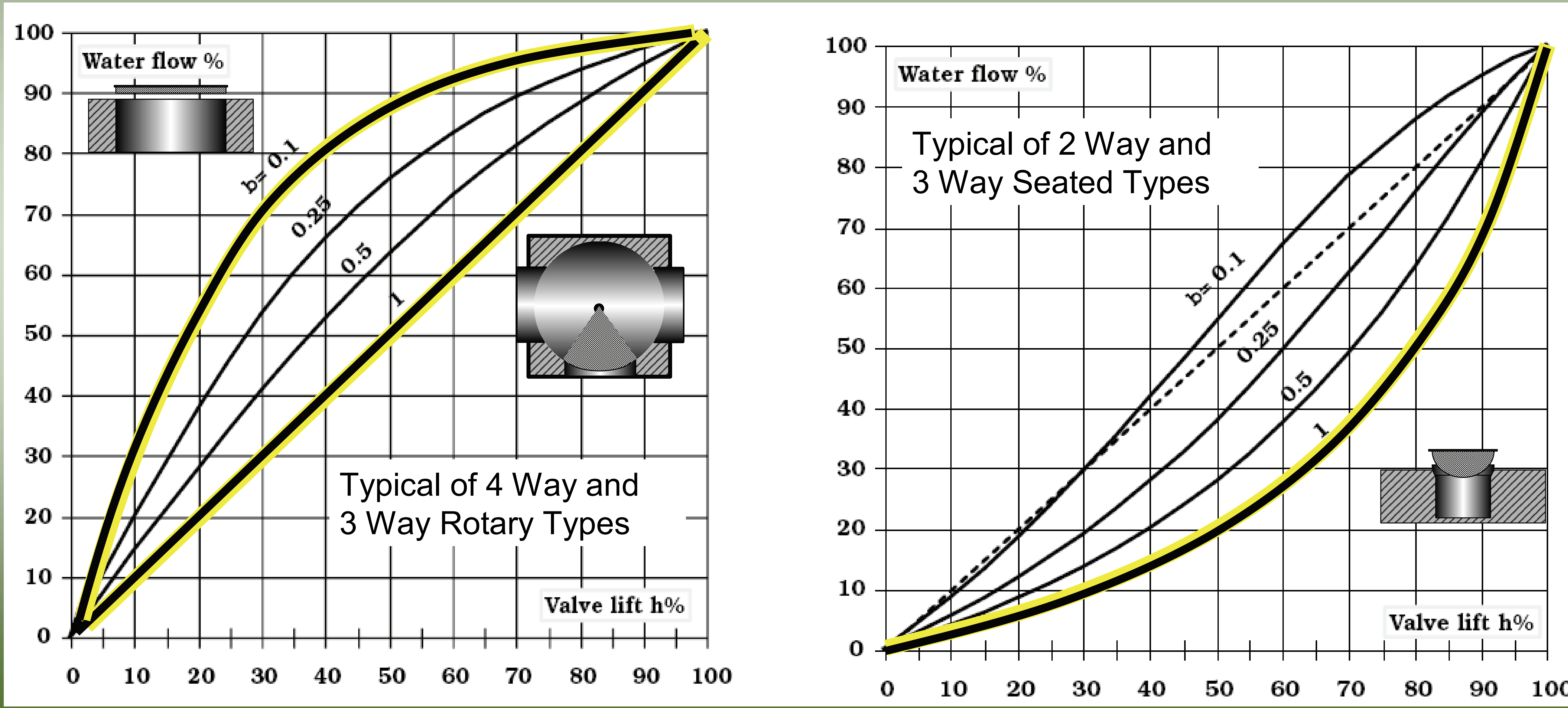






Fundamentals of Hydronic Design

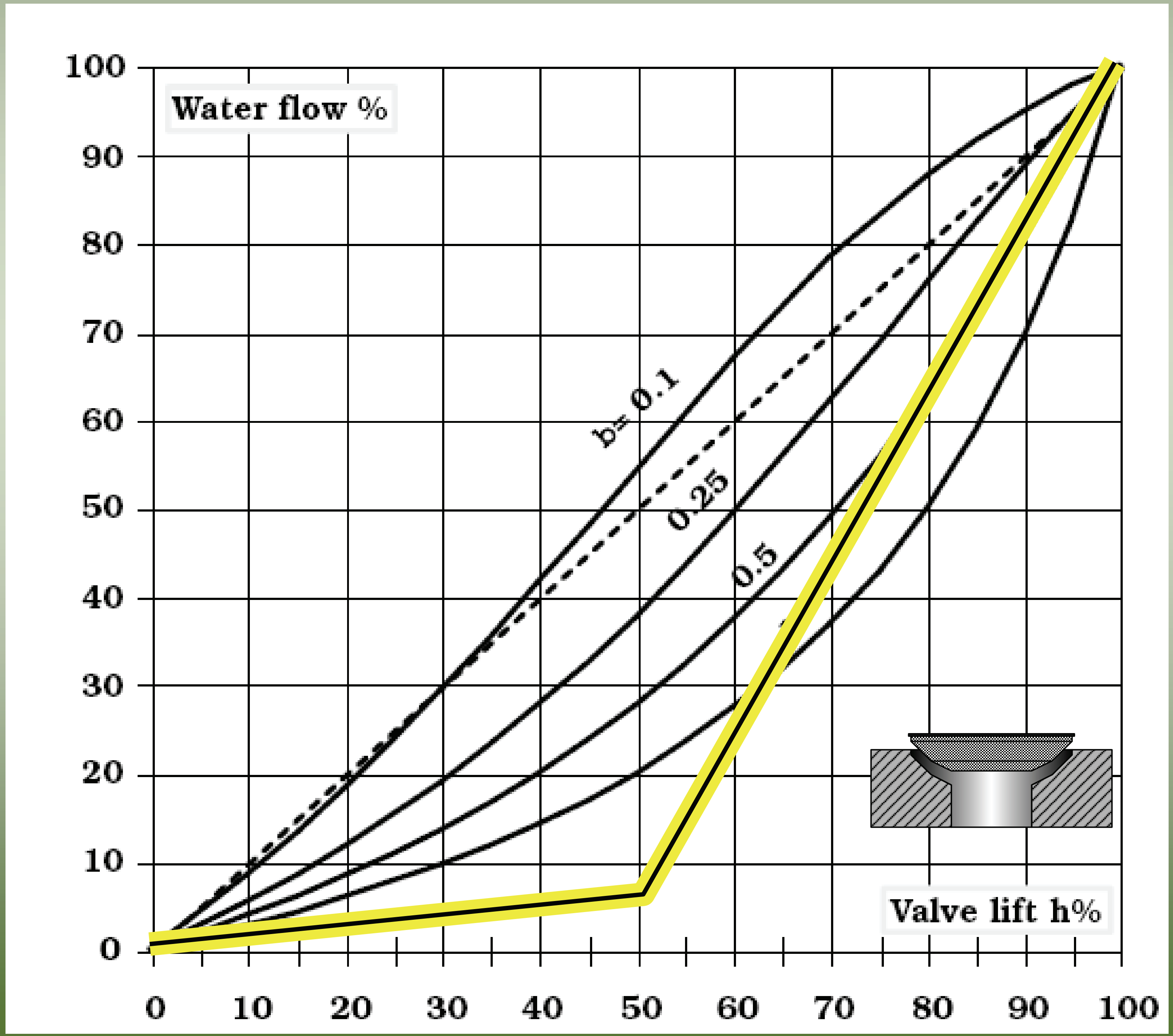
- Two Typical Types of Characteristics and Authority Distortion
  - Linear shown left, Logarithmic (Equal Percentage) shown right



The quick opening valve has a characteristic of the linear valve with an authority = 0.1 (poor)

Fundamentals of Hydronic Design

- Modified Characteristics
  - Split Type
  - Recognizes low loads
  - Refer to Manufacturers Data



The quick opening valve has a characteristic of the linear valve with an authority = 0.1 (poor)

Fundamentals of Hydronic Design

Avoid marrying control valves with heat terminal units which have similar characteristics. i.e.: Fan/coils, baseboard, panel radiator with fast acting low cost zone valves!

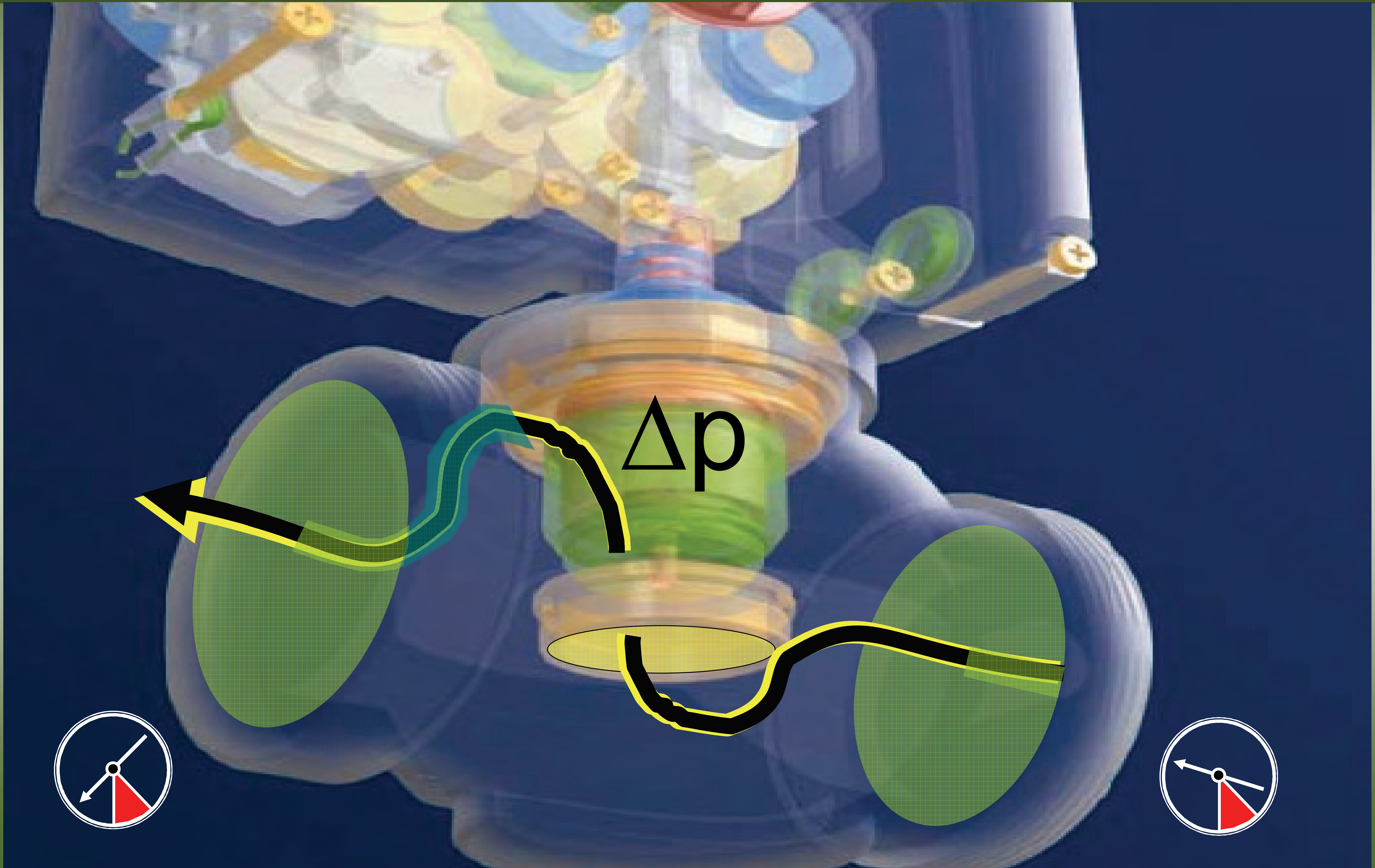
Fundamentals of Hydronic Design

- Selecting Control Valve Characteristics
  - Quick opening valves can be used on heat terminal unit with slow responsiveness such as:
    - Swimming pools
    - High mass radiant heated concrete slabs
    - Non critical bulk storage tanks
    - Valve authority does not apply to quick opening valves
  - All other applications should use modulating linear, logarithmic or split characteristics types

Fundamentals of Hydronic Design

- Selecting Control Valves
  - With controlled differential pressure (Δp) there is controlled flow.
  - With controlled flow and temperature there is authority over the system.
  - Excessive pressure drops across a valve means:
    - Small C_v ,large flow rate, no Δp control (or all of the above).
  - Insufficient pressure drops across a valve means:
    - Large C_v ,small flow rate, insufficient circulator power.
  - What is the correct amount?

Fundamentals of Hydronic Design



Valve C_v

Flow Coefficient

Fundamentals of Hydronic Design

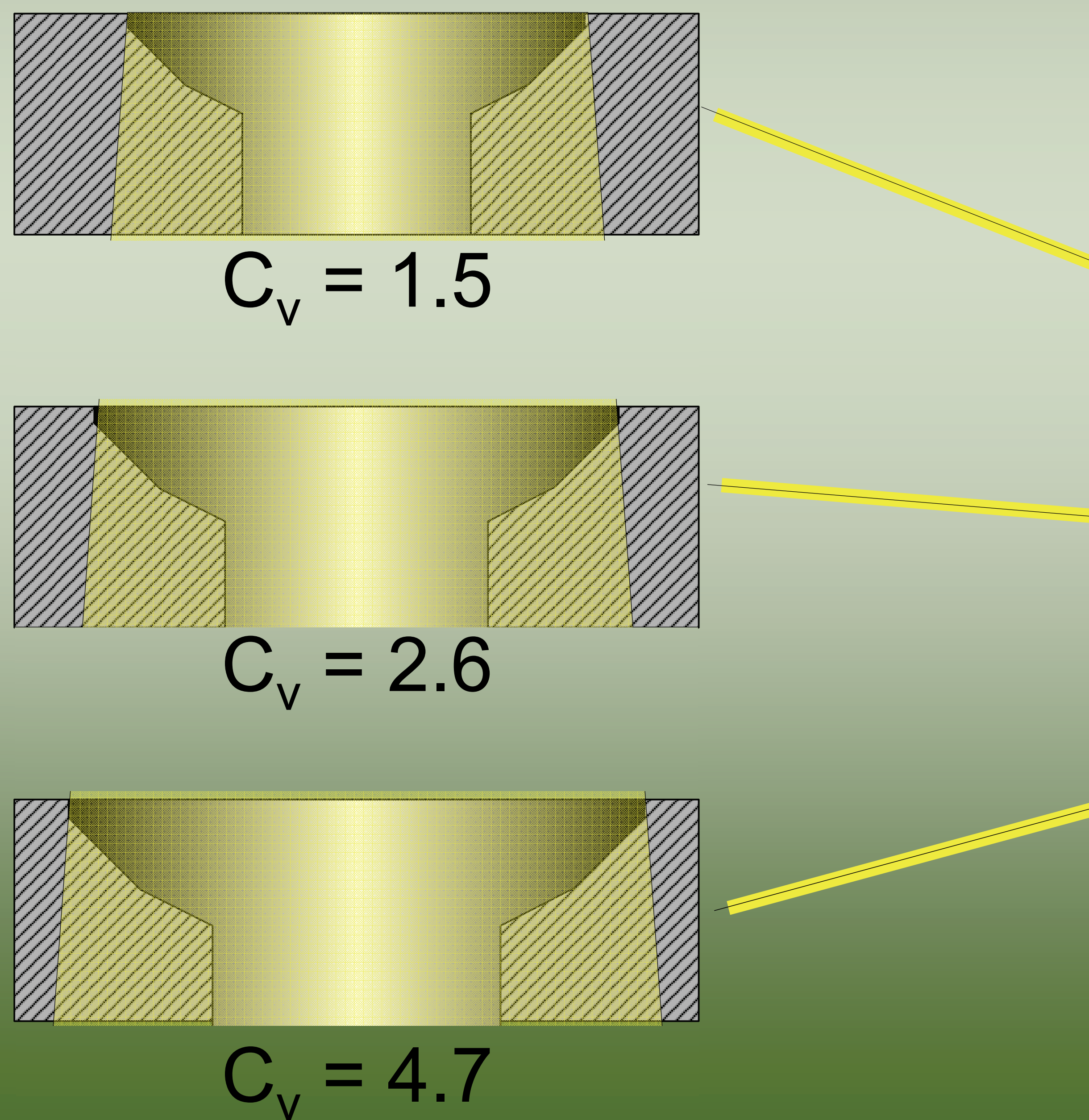
- Definition of C_v
  - The C_v value published by the manufacturer corresponds to the water flow expressed in USgpm for a differential pressure of 1 psi.
  - C_v values increase in a geometric progression, called a Reynard series:
  - C_v: 1.0, 1.6, 2.5, 4.0, 6.3, 10, 16 .....
  - Each value is about 60% greater than the previous value.

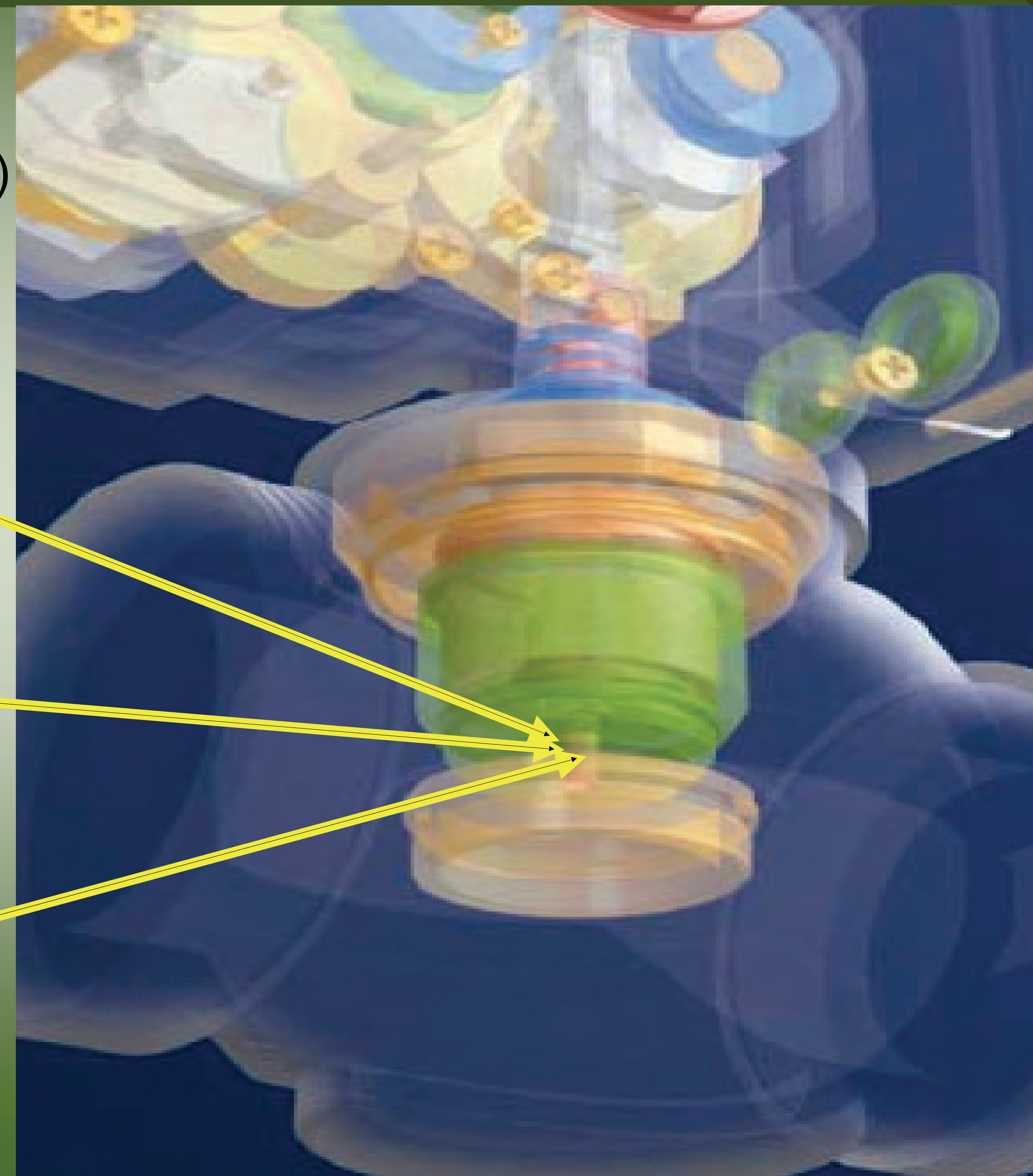
Fundamentals of Hydronic Design

ΔP, psi		Common Valve C_v's														
		1	1.6	2.1	2.5	2.7	4	4.7	6.3	10	11.7	14	16	18.7	23.4	29.3
US gallons per minute	1	1.00	0.39	0.23	0.16	0.14	0.06	0.05	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	2	4.00	1.56	0.91	0.64	0.55	0.25	0.18	0.10	0.04	0.03	0.02	0.02	0.01	0.01	0.00
	3	9.00	3.52	2.04	1.44	1.23	0.56	0.41	0.23	0.09	0.07	0.05	0.04	0.03	0.02	0.01
	4	16.00	6.25	3.63	2.56	2.19	1.00	0.72	0.40	0.16	0.12	0.08	0.06	0.05	0.03	0.02
	5	25.00	9.77	5.67	4.00	3.43	1.56	1.13	0.63	0.25	0.18	0.13	0.10	0.07	0.05	0.03
	6	36.00	14.06	8.16	5.76	4.94	2.25	1.63	0.91	0.36	0.26	0.18	0.14	0.10	0.07	0.04
	7	49.00	19.14	11.11	7.84	6.72	3.06	2.22	1.23	0.49	0.36	0.25	0.19	0.14	0.09	0.06
	8	64.00	25.00	14.51	10.24	8.78	4.00	2.90	1.61	0.64	0.47	0.33	0.25	0.18	0.12	0.07
	9	81.00	31.64	18.37	12.96	11.11	5.06	3.67	2.04	0.81	0.59	0.41	0.32	0.23	0.15	0.09
	10	100.00	39.06	22.68	16.00	13.72	6.25	4.53	2.52	1.00	0.73	0.51	0.39	0.29	0.18	0.12
	11	121.00	47.27	27.44	19.36	16.60	7.56	5.48	3.05	1.21	0.88	0.62	0.47	0.35	0.22	0.14
	12	144.00	56.25	32.65	23.04	19.75	9.00	6.52	3.63	1.44	1.05	0.73	0.56	0.41	0.26	0.17
	13	169.00	66.02	38.32	27.04	23.18	10.56	7.65	4.26	1.69	1.23	0.86	0.66	0.48	0.31	0.20
	14	196.00	76.56	44.44	31.36	26.89	12.25	8.87	4.94	1.96	1.43	1.00	0.77	0.56	0.36	0.23
	15	225.00	87.89	51.02	36.00	30.86	14.06	10.19	5.67	2.25	1.64	1.15	0.88	0.64	0.41	0.26
	16	256.00	100.00	58.05	40.96	35.12	16.00	11.59	6.45	2.56	1.87	1.31	1.00	0.73	0.47	0.30
	17	289.00	112.89	65.53	46.24	39.64	18.06	13.08	7.28	2.89	2.11	1.47	1.13	0.83	0.53	0.34
	18	324.00	126.56	73.47	51.84	44.44	20.25	14.67	8.16	3.24	2.37	1.65	1.27	0.93	0.59	0.38
	19	361.00	141.02	81.86	57.76	49.52	22.56	16.34	9.10	3.61	2.64	1.84	1.41	1.03	0.66	0.42
	20	400.00	156.25	90.70	64.00	54.87	25.00	18.11	10.08	4.00	2.92	2.04	1.56	1.14	0.73	0.47
	21	441.00	172.27	100.00	70.56	60.49	27.56	19.96	11.11	4.41	3.22	2.25	1.72	1.26	0.81	0.51
	22	484.00	189.06	109.75	77.44	66.39	30.25	21.91	12.19	4.84	3.54	2.47	1.89	1.38	0.88	0.56
	23	529.00	206.64	119.95	84.64	72.57	33.06	23.95	13.33	5.29	3.86	2.70	2.07	1.51	0.97	0.62
	24	576.00	225.00	130.61	92.16	79.01	36.00	26.08	14.51	5.76	4.21	2.94	2.25	1.65	1.05	0.67
	25	625.00	244.14	141.72	100.00	85.73	39.06	28.29	15.75	6.25	4.57	3.19	2.44	1.79	1.14	0.73

Fundamentals of Hydronic Design

- Selecting Control Valves
  - One Single Valve Size (thread)
  - Multiple C_v Options



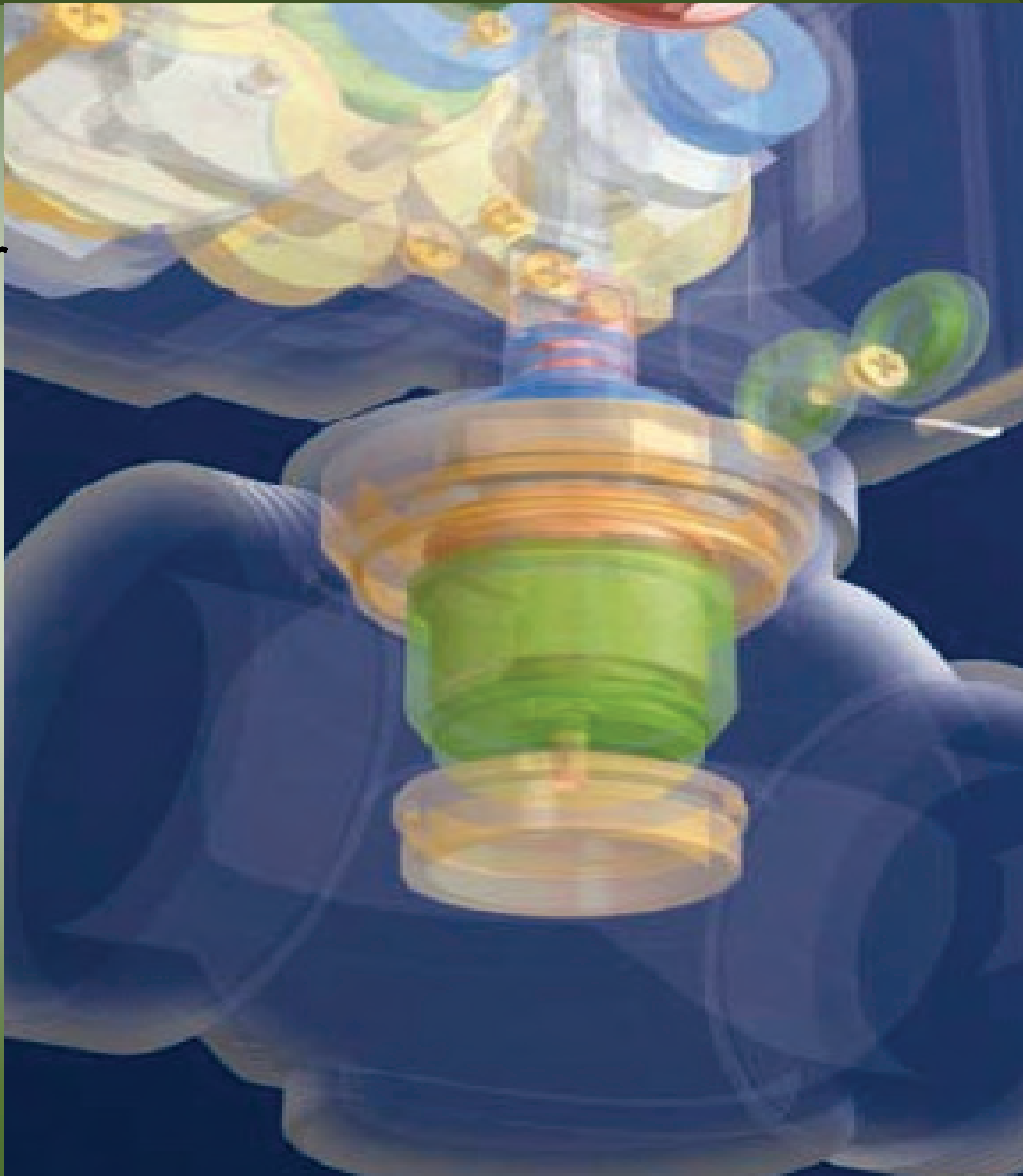


Fundamentals of Hydronic Design

- Selecting Control Valves
  - Convert Heat Loss to Flow
  - Select C_v from Manufacturer
  - Example:

$$\left[\frac{q_w,\ \text{USgpm}}{C_v}\right]^2 = \Delta p,\ \text{psi}$$

$$\left[\frac{8\ \text{USgpm}}{6.3}\right]^2 = 1.61\ \text{psi}$$



  - It will take 1.61 psi Δp to move 8 USgpm through a C_v = 6.3

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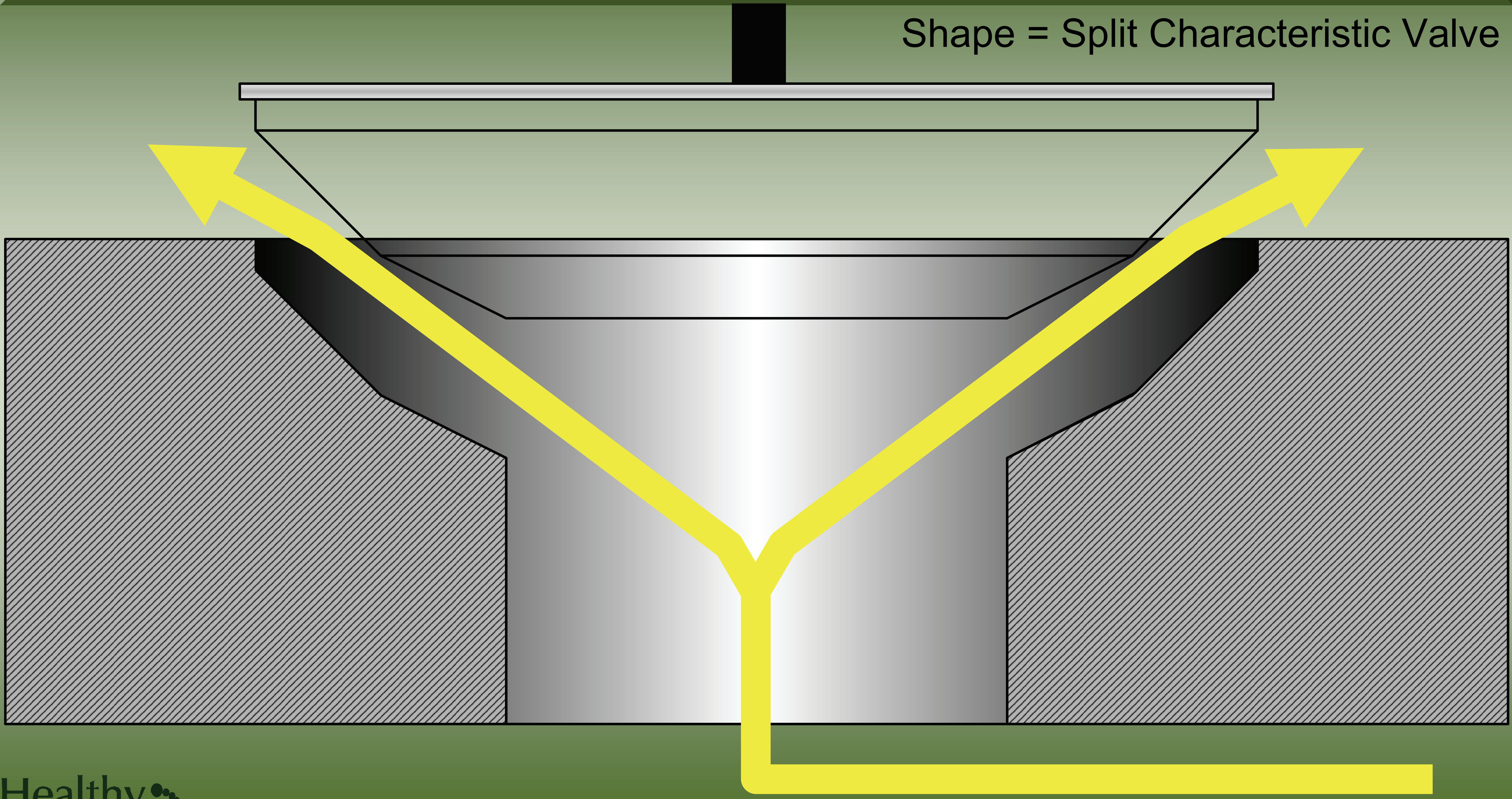
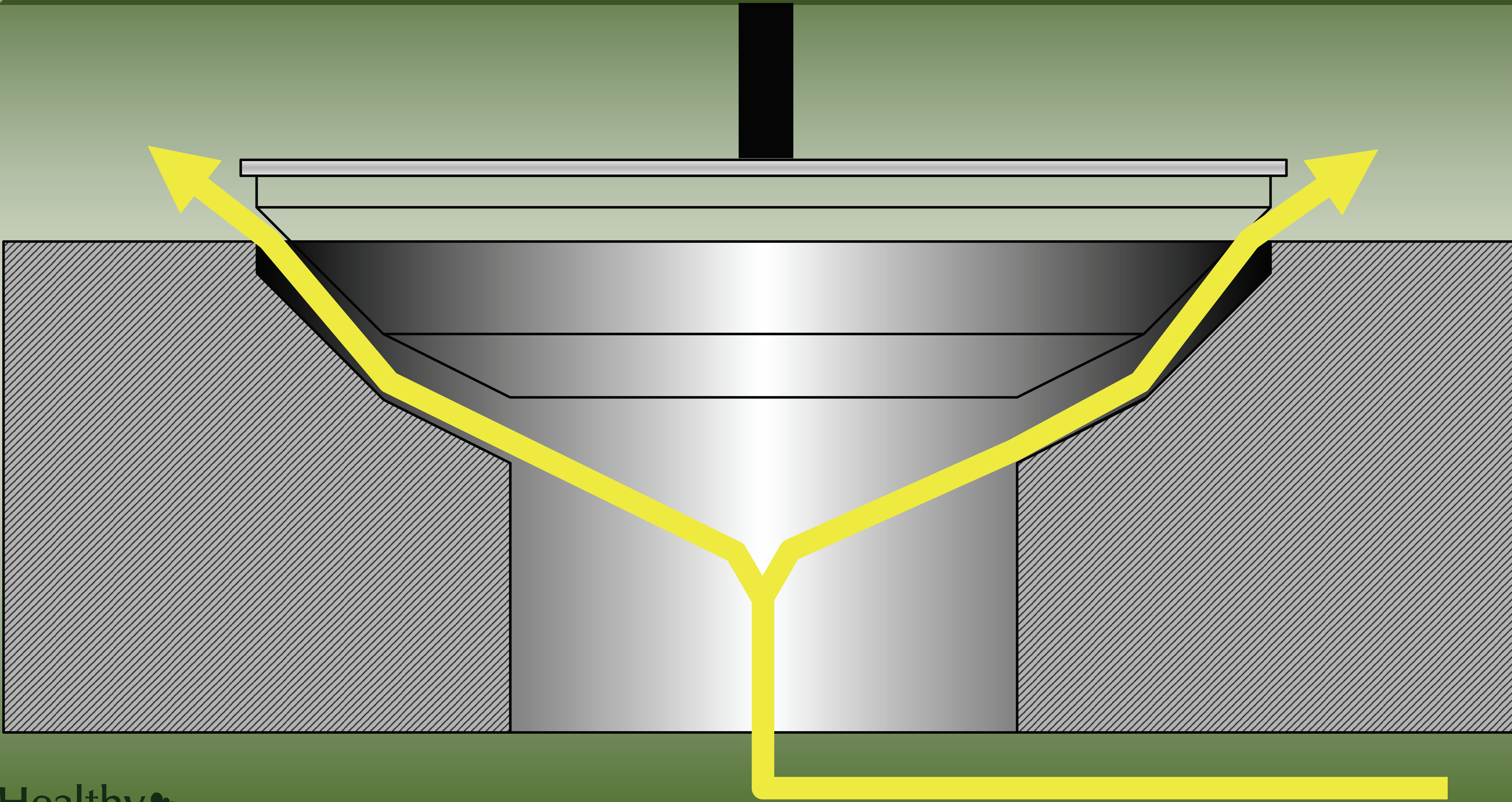
Fundamentals of Hydronic Design

Shape = Split Characteristic Valve



Fundamentals of Hydronic Design



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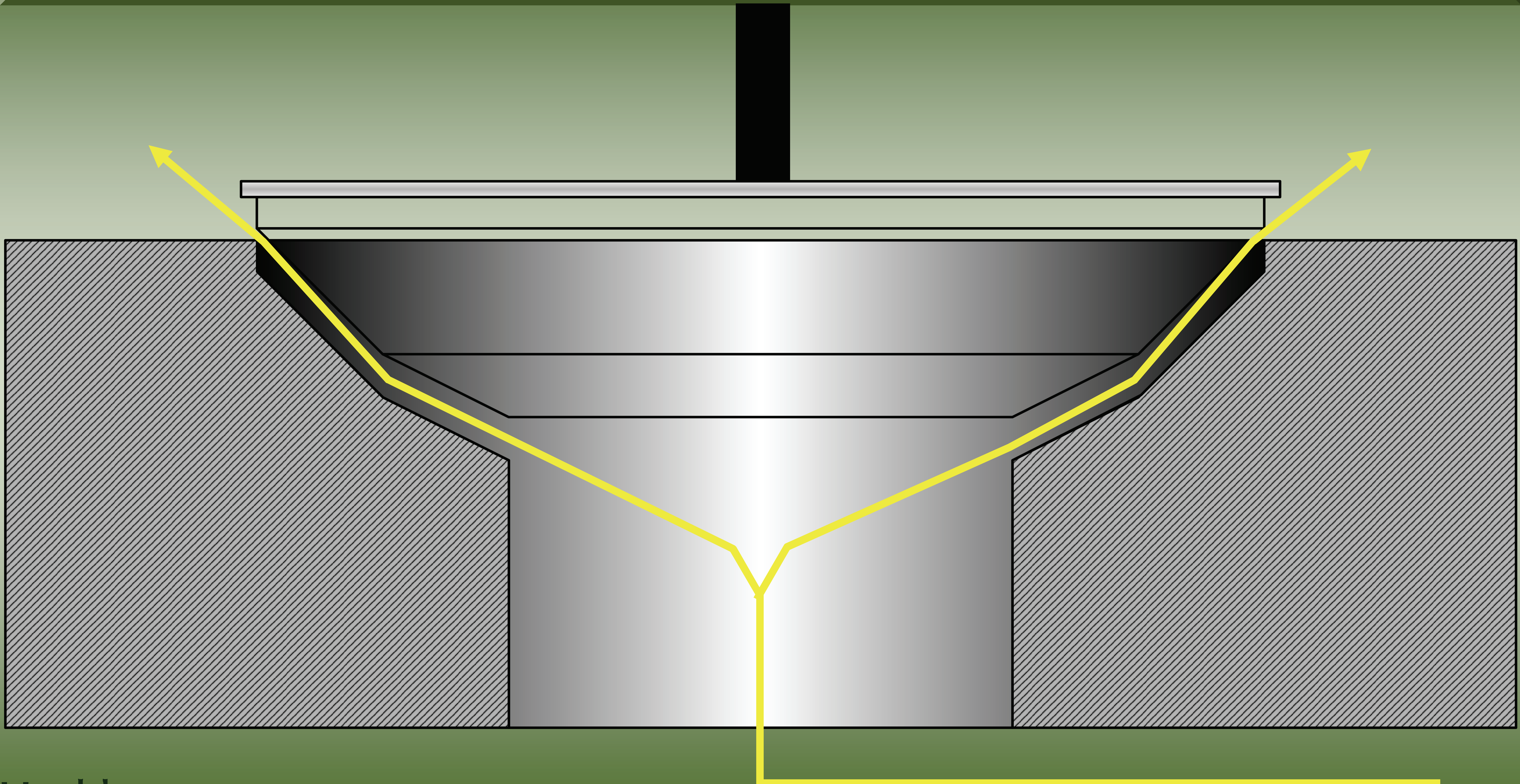

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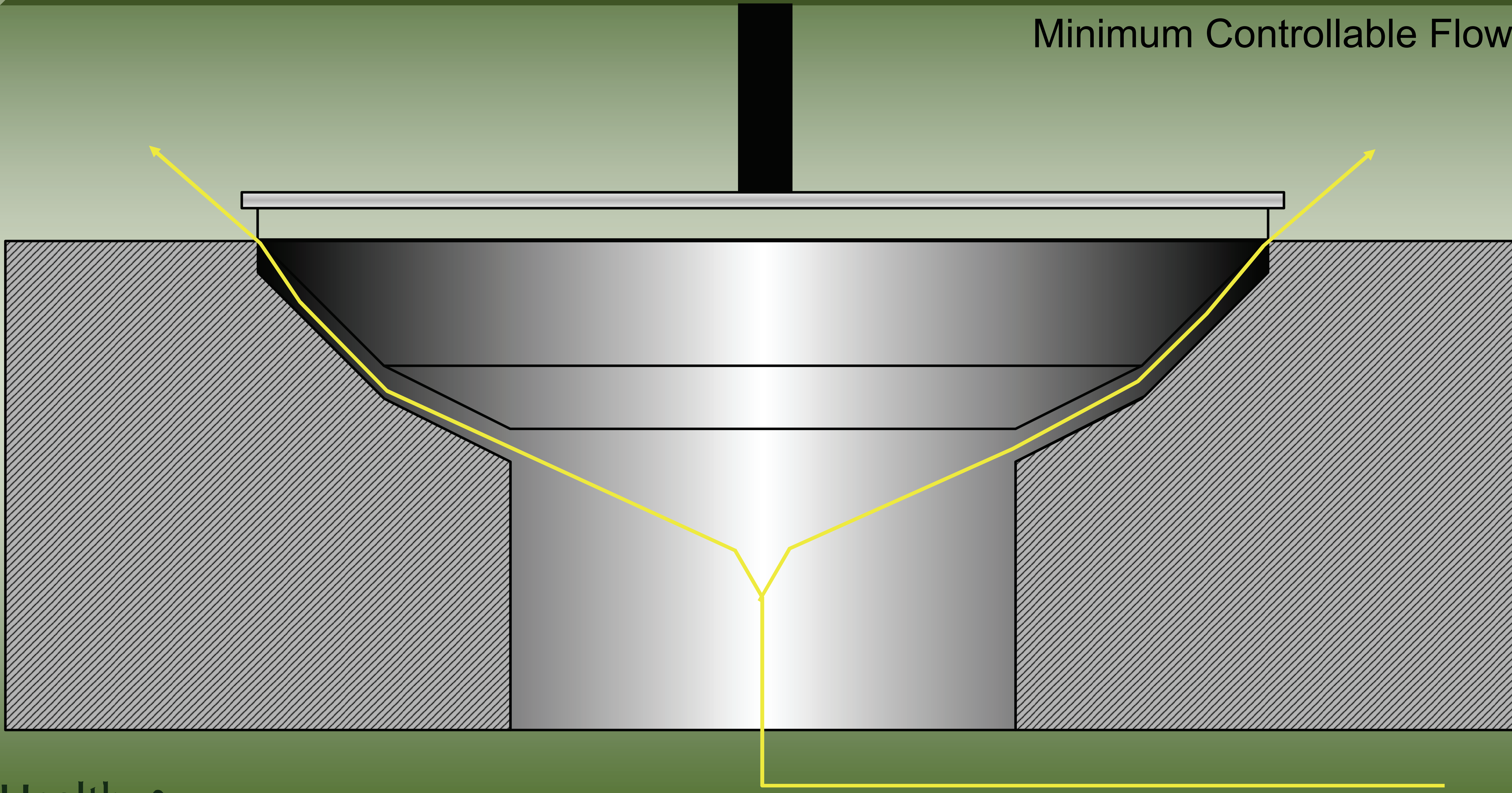
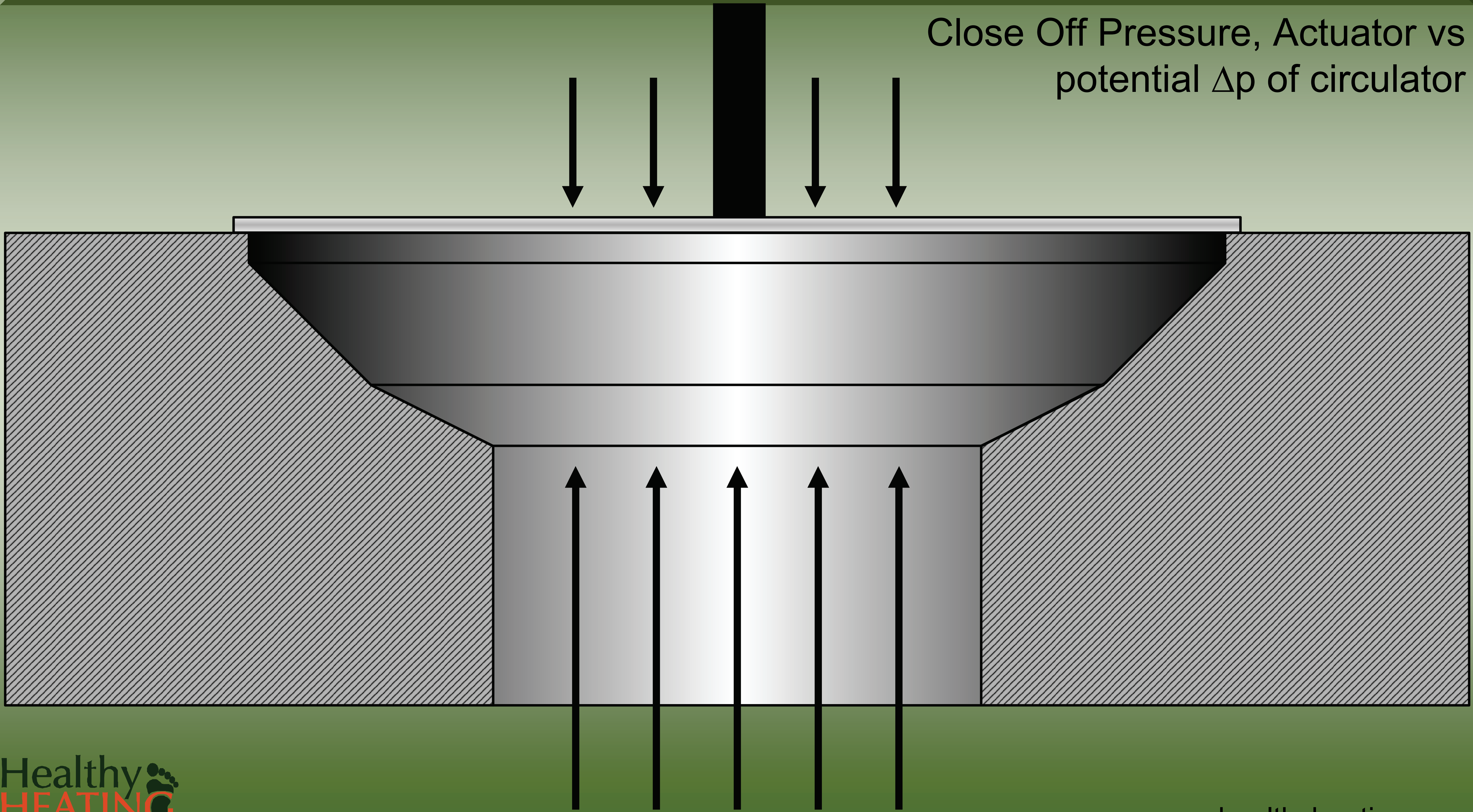
Fundamentals of Hydronic Design

Minimum Controllable Flow



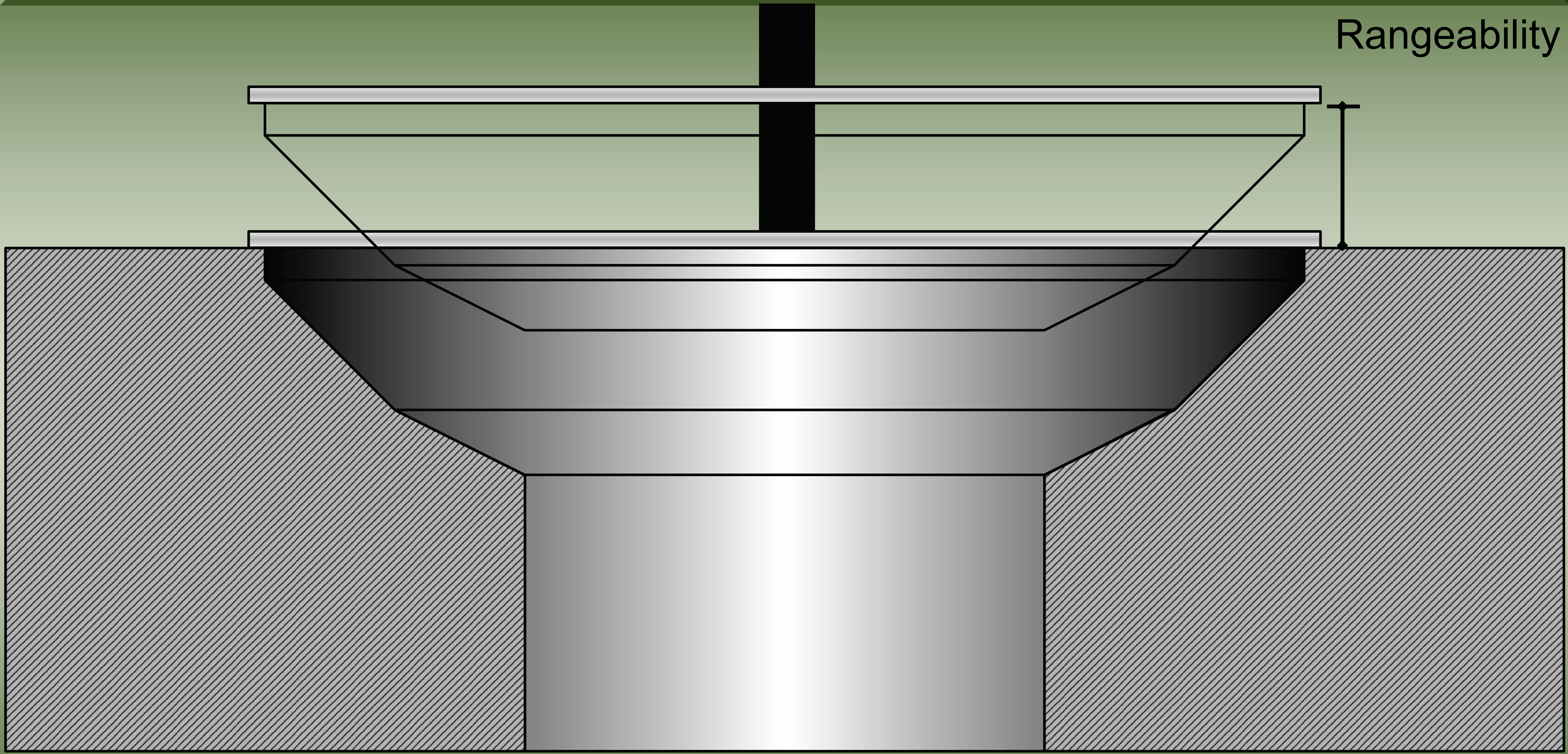
Fundamentals of Hydronic Design

Close Off Pressure, Actuator vs potential Δp of circulator



Fundamentals of Hydronic Design

Rangeability



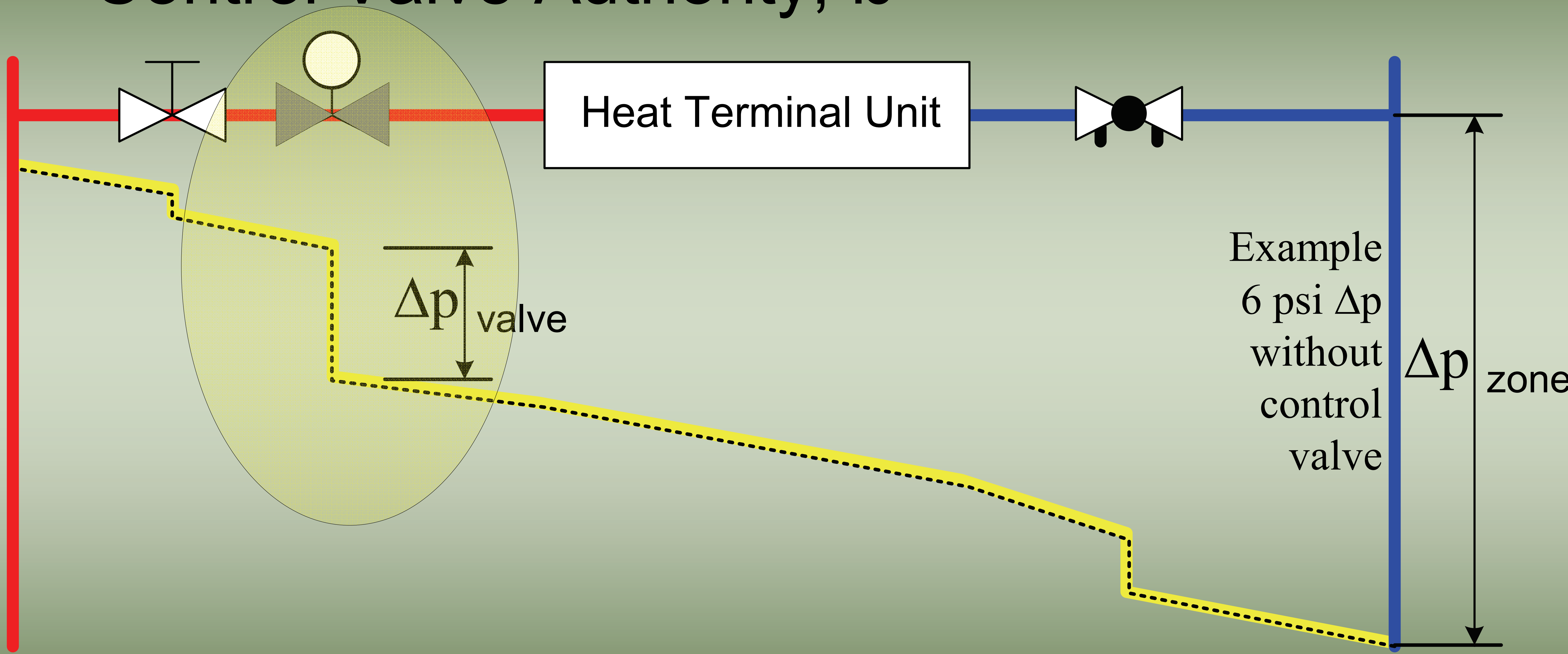
- Selecting Control Valves
  - Control Valves Used in The Regulation of:
    - Space Temperature
      - Typically Two Way Valves
      - Ideally Operative Based
      - MRT, AUST, Dry Bulb
    - Fluid Temperature
      - 2, 3 or 4 Way Valves
      - Supply & Return

Regulation of Room Temperature
Control Valve Authority, ß

why control valve manufacturers do what they do

Fundamentals of Hydronic Design

- Control Valve Authority, ß



$$ß = \frac{\Delta p_{\text{fully open valve and design flow}}}{\Delta p_{\text{fully closed valve}}} \geq 30\% < 50\%$$

Fundamentals of Hydronic Design

- Control Valve Authority, ß
  - Calculate Heat Loss
  - Convert to Flow
  - Design Piping Network
  - Calculate the ΔP_{Zone}.
  - Select Authority Multiplier.
  - Multiply X $\Delta P_{Zone} = \Delta P_{Valve}$
  - Search For C_v Which Generates ΔP_{Valve} at Design Flow.

Valve Authority Multiplier	
Authority	Multiplier
50%	1
40%	.66
30%	.43

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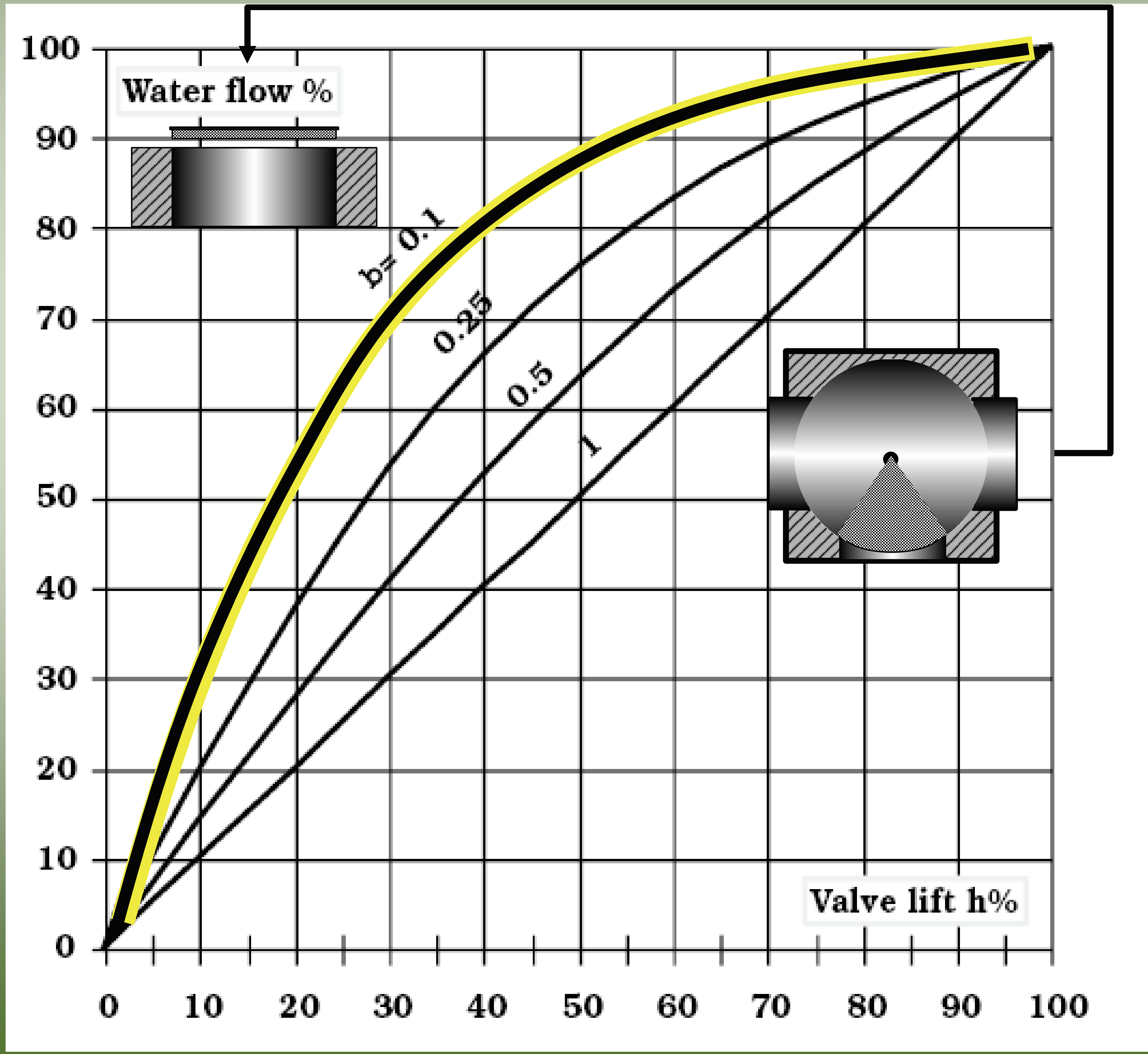
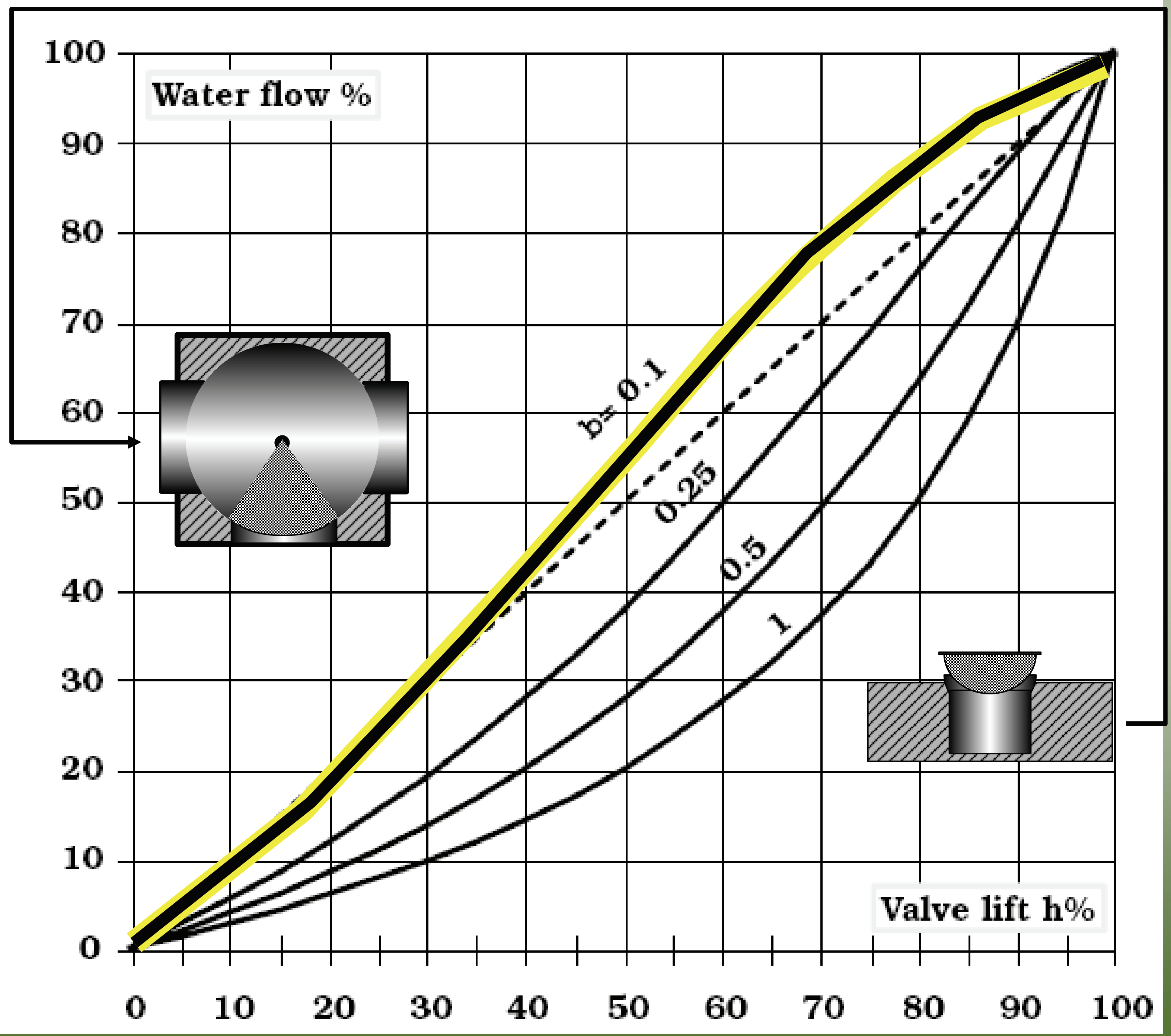
Fundamentals of Hydronic Design

- When Valves Are Oversized
  - They lose their identity and start behaving like someone else

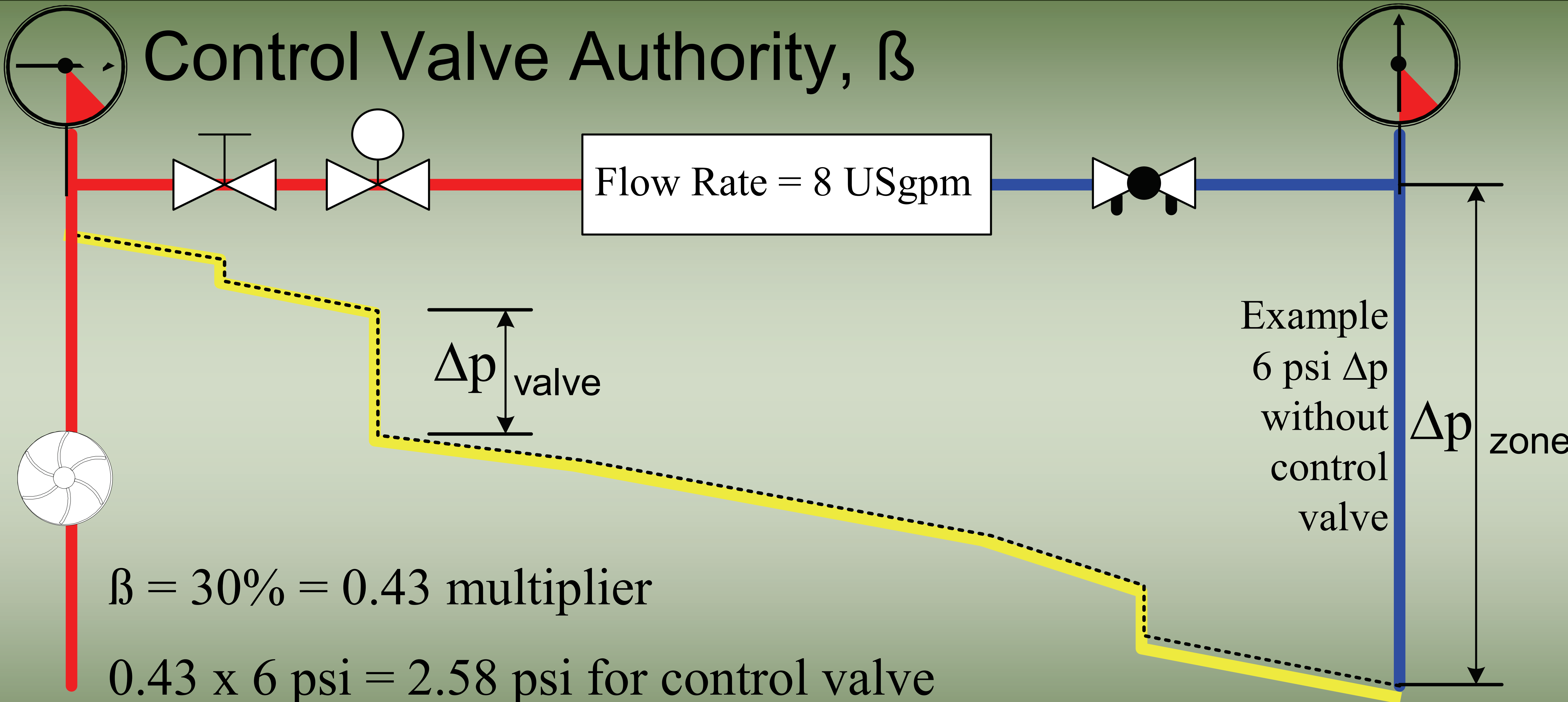




The quick opening valve has a characteristic of the linear valve with an authority = 0.1 (poor)

Fundamentals of Hydronic Design

Control Valve Authority, ß



ß = 30% = 0.43 multiplier

0.43 x 6 psi = 2.58 psi for control valve

6 psi + 2.58 psi = 8.58 psi total Δp

2.58 psi min / 8.58 psi max = .30 or 30% authority confirmation

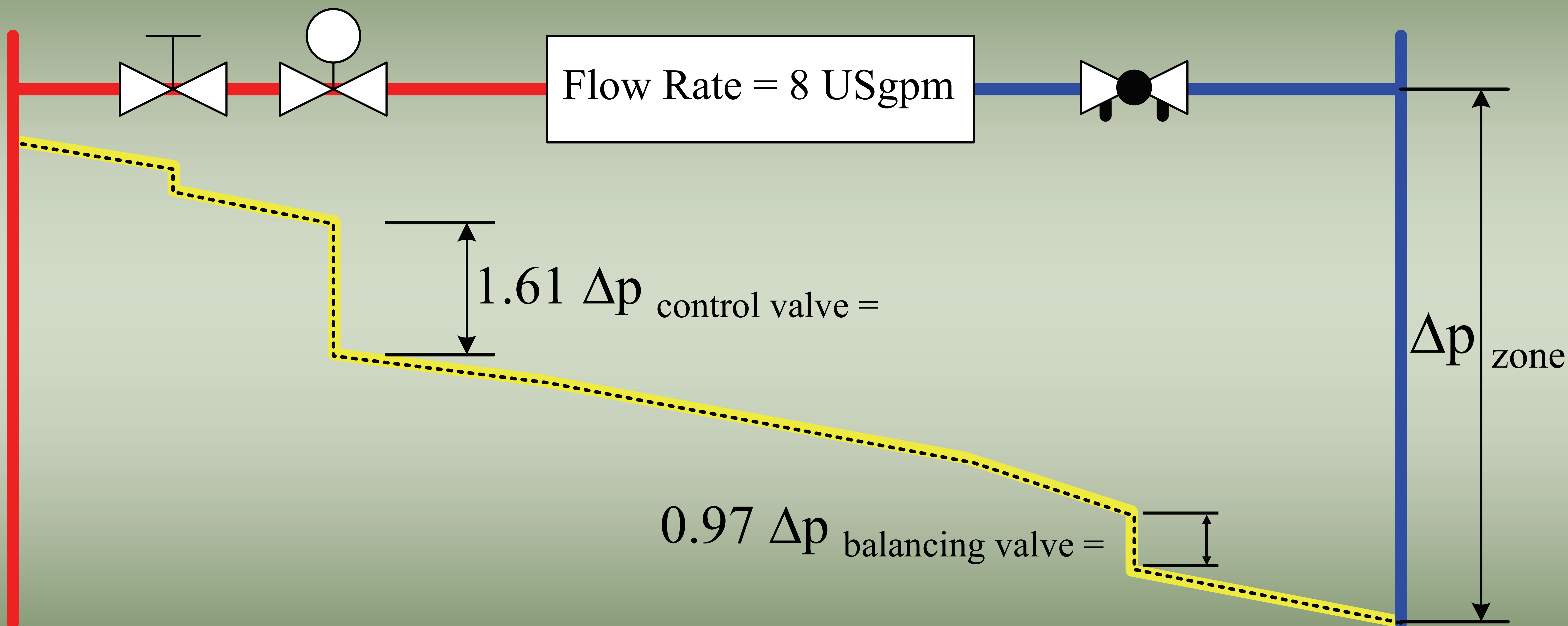
Fundamentals of Hydronic Design

- Find $C_v \approx$ 2.58 psi at 8 US gpm design flow
  - One Solution: Pick C_v = 6.3 with a 1.61 psi Δp
  - 2.58 psi – 1.61 psi = 0.97 psi short…what to do?

ΔP, psi		Valve C_v							
		1	1.6	2.1	2.5	2.7	4	4.7	6.3
Design Flow, USgpm	1	1.00	0.39	0.23	0.16	0.14	0.06	0.05	0.03
	2	4.00	1.56	0.91	0.64	0.55	0.25	0.18	0.10
	3	9.00	3.52	2.04	1.44	1.23	0.56	0.41	0.23
	4	16.00	6.25	3.63	2.56	2.19	1.00	0.72	0.40
	5	25.00	9.77	5.67	4.00	3.43	1.56	1.13	0.63
	6	36.00	14.06	8.16	5.76	4.94	2.25	1.63	0.91
	7	49.00	19.14	11.11	7.84	6.72	3.06	2.22	1.23
	8	64.00	25.00	14.51	10.24	8.78	4.00	2.90	1.61
	9	81.00	31.64	18.37	12.96	11.11	5.06	3.67	2.04
	10	100.00	39.06	22.68	16.00	13.72	6.25	4.53	2.52
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fundamentals of Hydronic Design

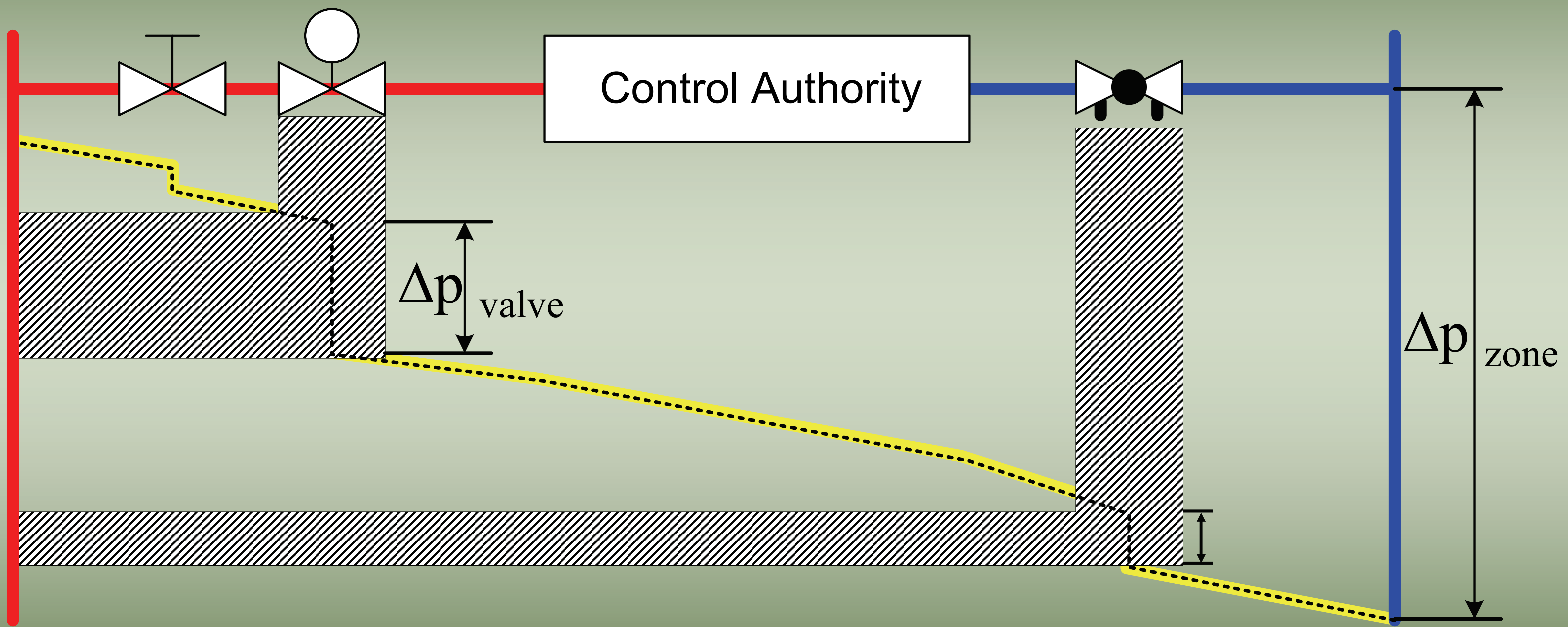
- Control Valve Authority, ß with Balancing Valve



$1.61 \text{ psi } \Delta p_{\text{control valve}} + 0.97 \text{ psi } \Delta p_{\text{balancing valve}} = 2.58 \text{ psi } \Delta p$

Fundamentals of Hydronic Design

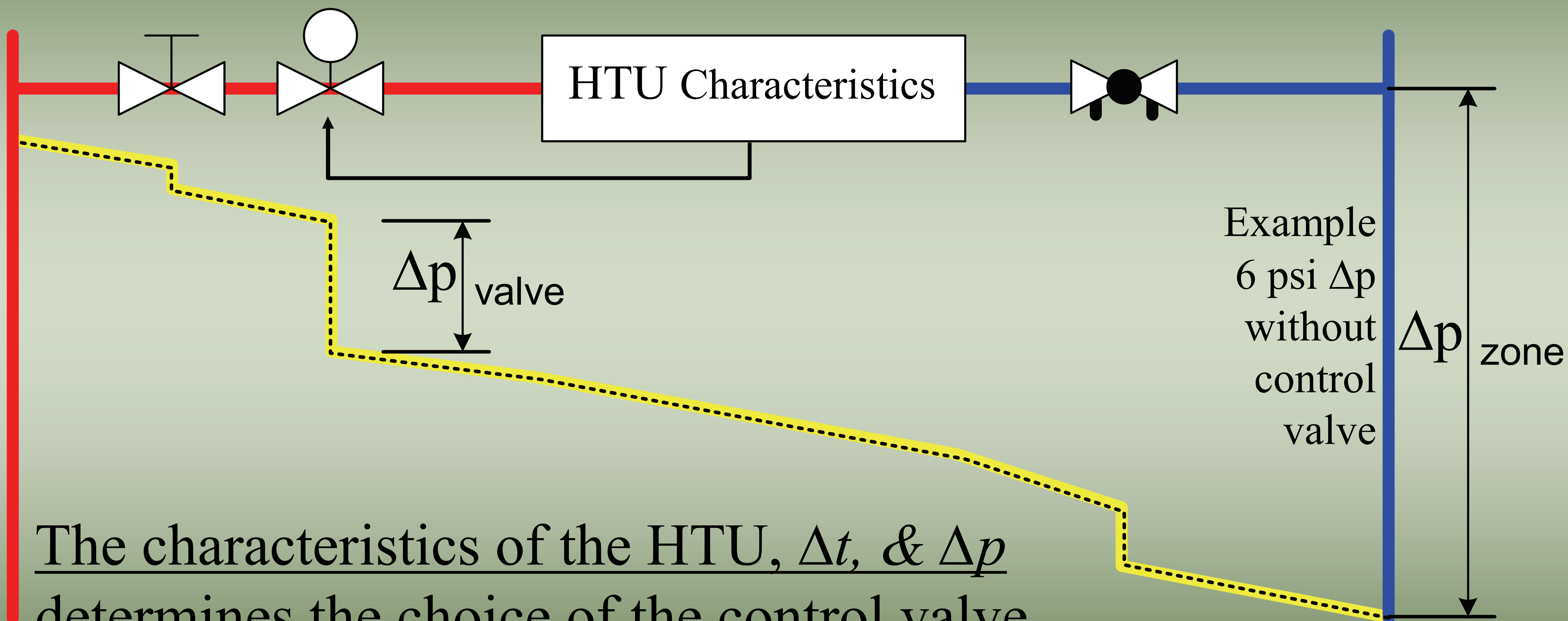
- Control Valve Authority, ß with Balancing Valve



$$(\Delta p_{\text{control valve}} + \Delta p_{\text{balancing valve}}) \,/\, \Delta p_{\text{zone}} = ß_{\text{authority}}$$

Fundamentals of Hydronic Design

- Control Valve Authority, ß



<u>The characteristics of the HTU, Δ*t*, & Δ*p* determines the choice of the control valve characteristics.</u>

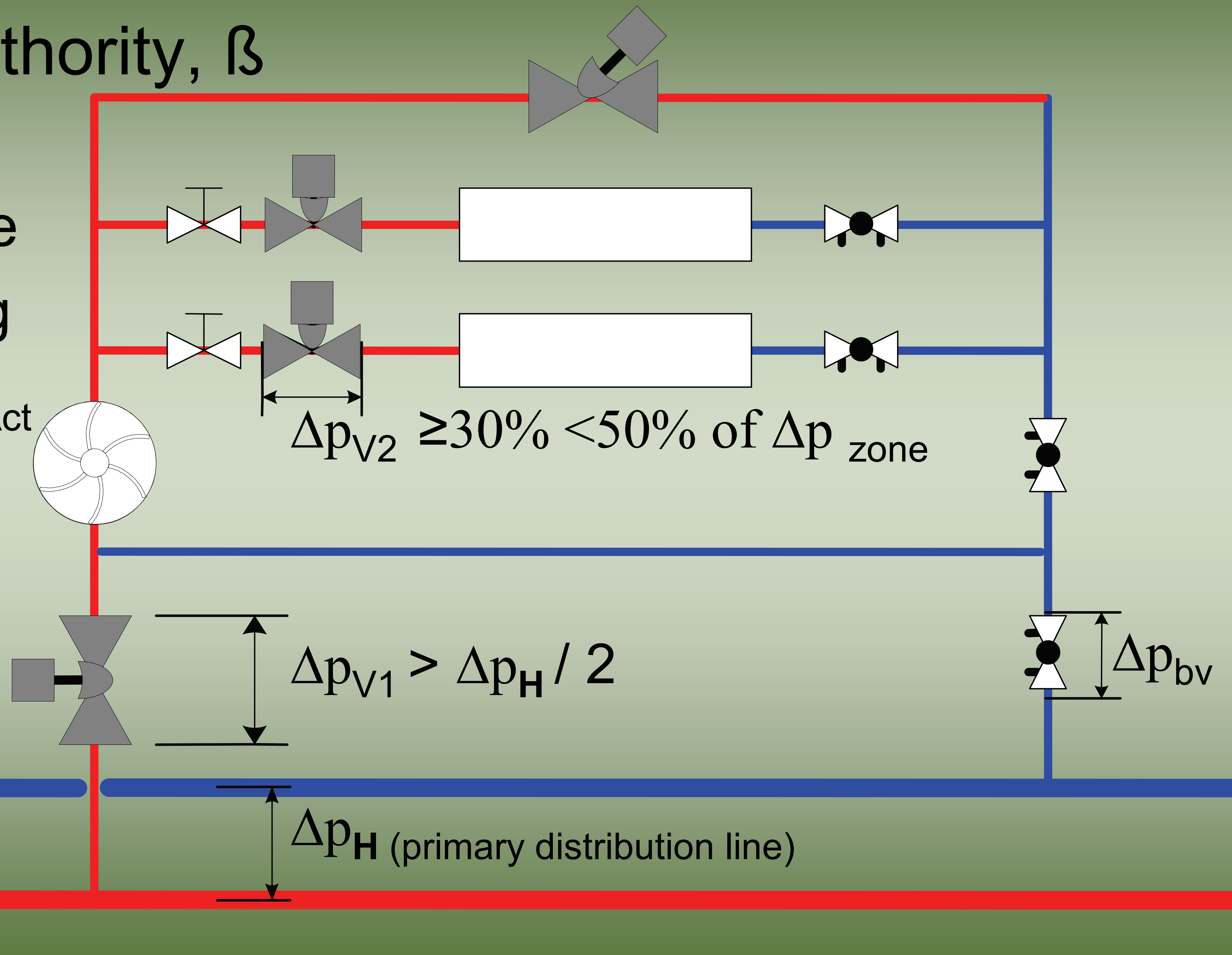
How many choose valves based on price?

Regulation of Fluid Temperature
Control Valve Authority, ß

why control valve manufacturers do what they do

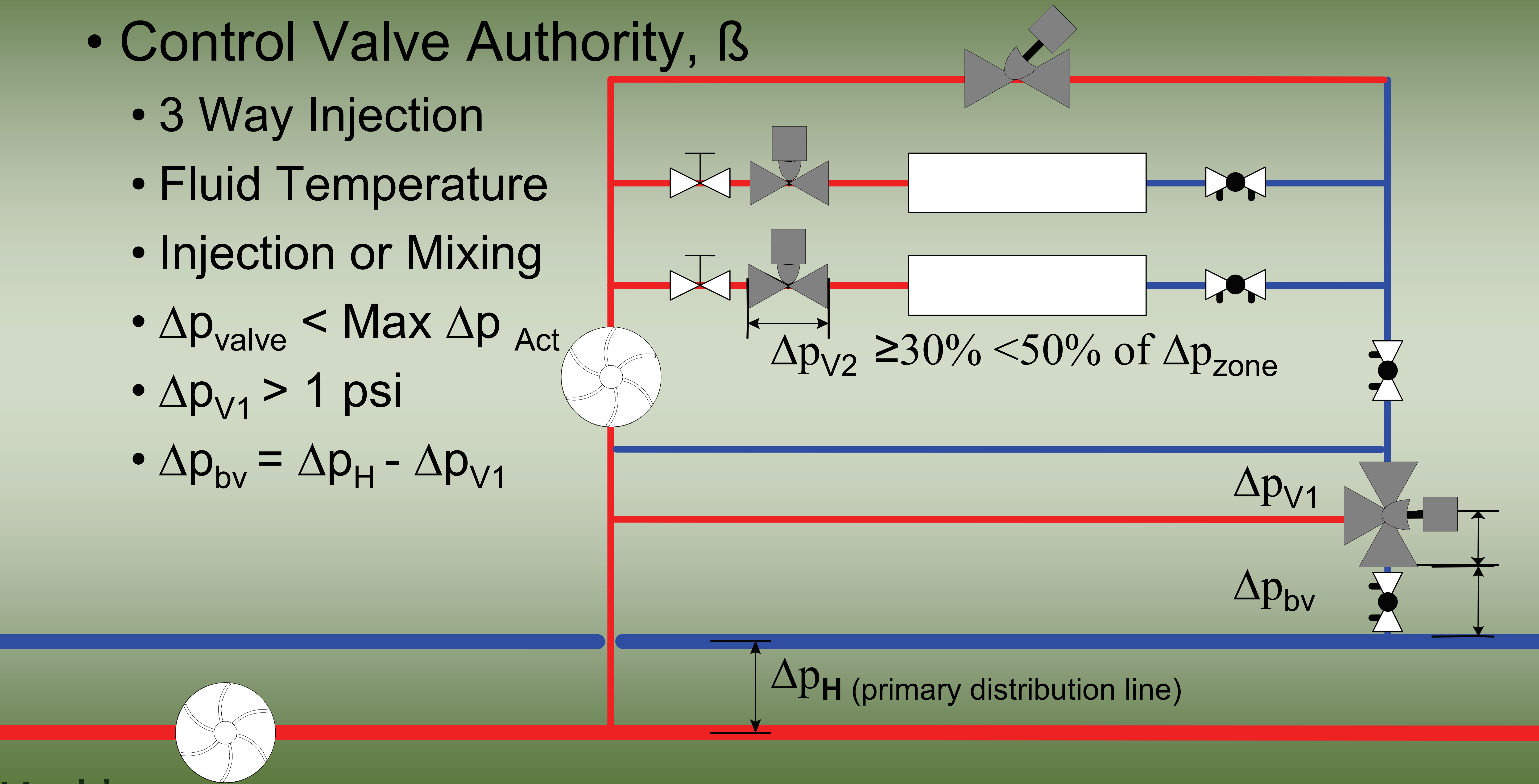
Fundamentals of Hydronic Design

- Control Valve Authority, ß
  - 2 Way Injection
  - Fluid Temperature
  - Injection or Mixing
  - $\Delta p_{valve} < \text{Max } \Delta p_{Act}$
  - $\Delta p_{bv} = \Delta p_H - \Delta p_{V1}$



Fundamentals of Hydronic Design

- Control Valve Authority, ß
  - 3 Way Injection
  - Fluid Temperature
  - Injection or Mixing
  - $\Delta p_{valve} < \text{Max } \Delta p_{Act}$
  - $\Delta p_{V1} > 1$ psi
  - $\Delta p_{bv} = \Delta p_H - \Delta p_{V1}$



Fundamentals of Hydronic Design

- Selecting Control Valves
  - On/Off Valves, Quick Opening Zone Valves
    - Have no controllability unless applied to slow mellow systems like high mass applications.
      - Think = “postal”, “confused”, “unstable”
    - Therefore the concept of valve authority is meaningless
    - The authority is then given by the balancing valve.
    - As a solution for unstable systems use a combination of balancing valves, differential pressure control and weather compensation which will reduce the cycling of the zone valves.
    - Otherwise use modulating control valves

Fundamentals of Hydronic Design

- Selecting Control Valves
  - Summary
    - The shape of the control valve plug determines valve characteristics.
    - Oversized valves have no authority over controllability
    - Undersized valves create unnecessary head losses.
    - A C_v representing between 30% to 50% of the total Δp_{zone} provides controllability.
    - A balancing valve is required to create the conditions for authority.
    - For fluid temperature control, injection and mixing valves connected in a direct return system pick:
      - $Cv = \Delta p_{valve} > \Delta_{primary\ distribution} / 2$

Valve cycling and valve hunting are not sporting events for hydronic systems.

Fundamentals of Hydronic Design

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