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The Little Red Schoolhouse

Large Chilled Water System Design Seminar

Courtesy of Oslin Nation Company

Presenter: Michael T. Licastro

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- Participate in class discussions where applicable
- Complete and Submit **Course Evaluation** using QR code received from **your local Bell & Gossett Representative**
- **This session is eligible for 0.6 CEU's (6 hours)**

- Proper Heat Transfer Coil selection, piping, and flow balance
- Basic Air Management for Closed Loop Systems
- One and Two Pipe Distribution Layout Strategies
- Pump Selection Fundamentals
- Parallel & Series Pumping
- Variable Speed Pumping – Design and Control Basics

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Hydronic System Fundamentals

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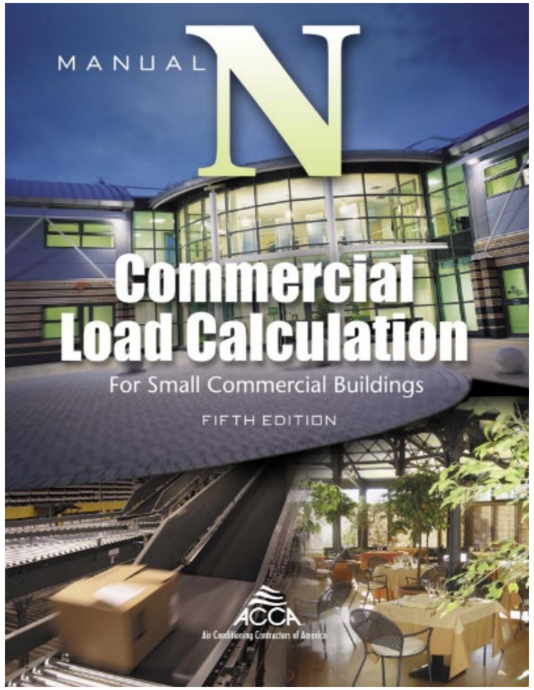
ASHRAE 90.1-2019 Section 6.4 – Mandatory Provisions

6.4.2.1 Load Calculations

Heating and Cooling *system* design loads for the purpose of sizing *systems* and *equipment* shall be determined in accordance with ASHRAE/ACCA Standard 183*



Available resources:

- **ASHRAE *Fundamentals Handbook* (Chapter 17 in the 2021 version)**
- **Air Conditioning Contractors of America (ACCA)**
  - **Manual J *(Residential Loads)***
  - **Manual N *(Commercial Loads)***
- **Third Party Manufacturers Software programs**

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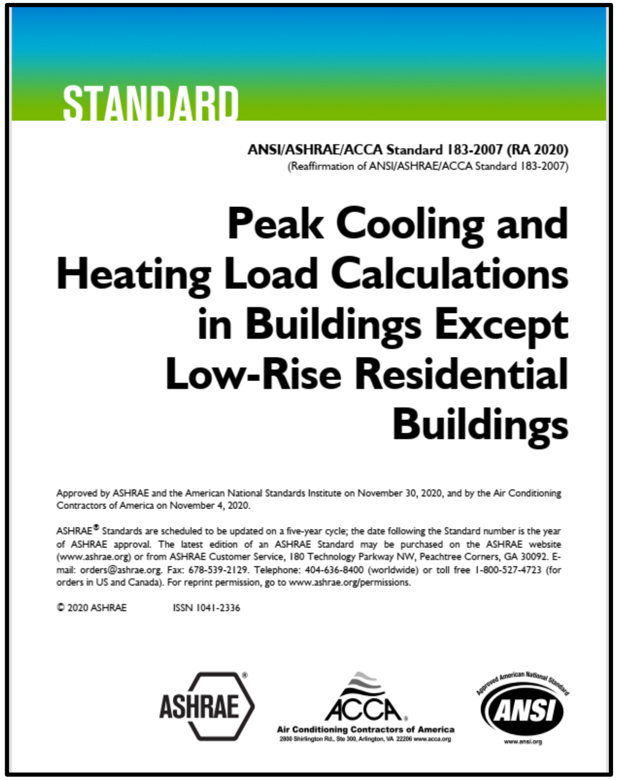
ANSI/ASHRAE Standard 183 2007 (RA 2020)

This standard establishes requirements for performing peak cooling and heating load calculations for buildings except low-rise residential buildings


STANDARD

ANSI/ASHRAE/ACCA Standard 183-2007 (RA 2020)
(Reaffirmation of ANSI/ASHRAE/ACCA Standard 183-2007)

Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings

Approved by ASHRAE and the American National Standards Institute on November 30, 2020, and by the Air Conditioning Contractors of America on November 4, 2020.

ASHRAE® Standards are scheduled to be updated on a five-year cycle; the date following the Standard number is the year of ASHRAE approval. The latest edition of an ASHRAE Standard may be purchased on the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 180 Technology Parkway NW, Peachtree Corners, GA 30092. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide) or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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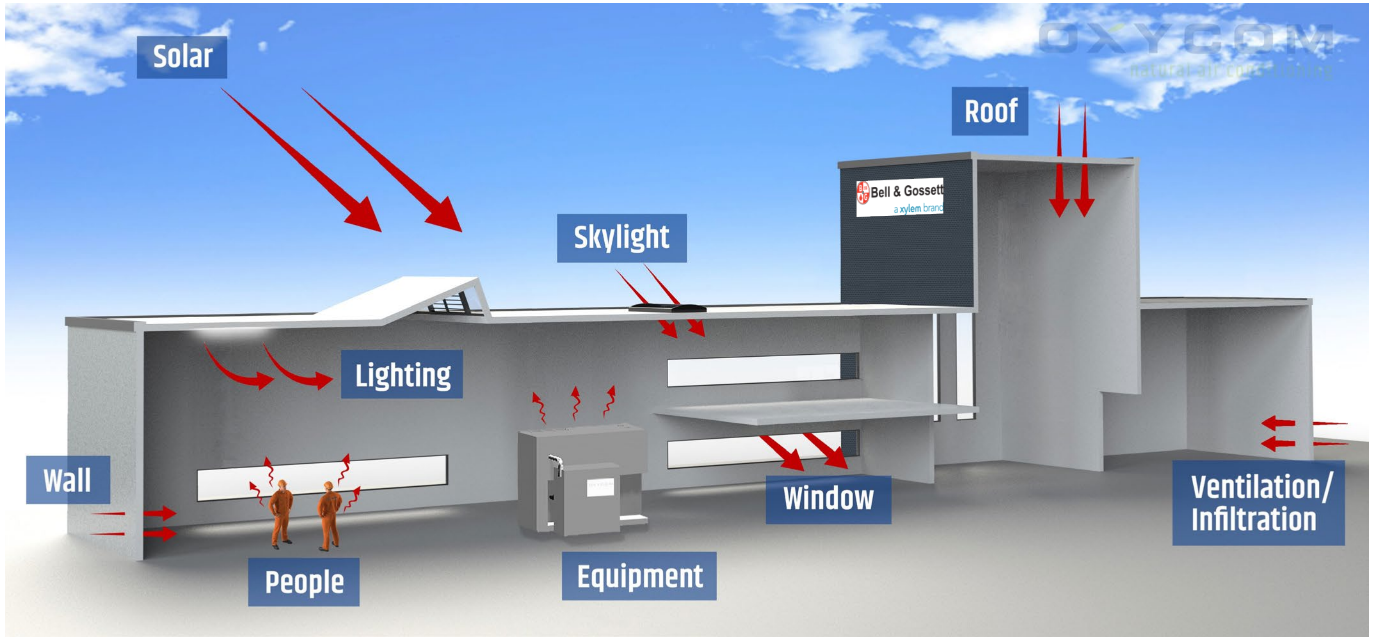
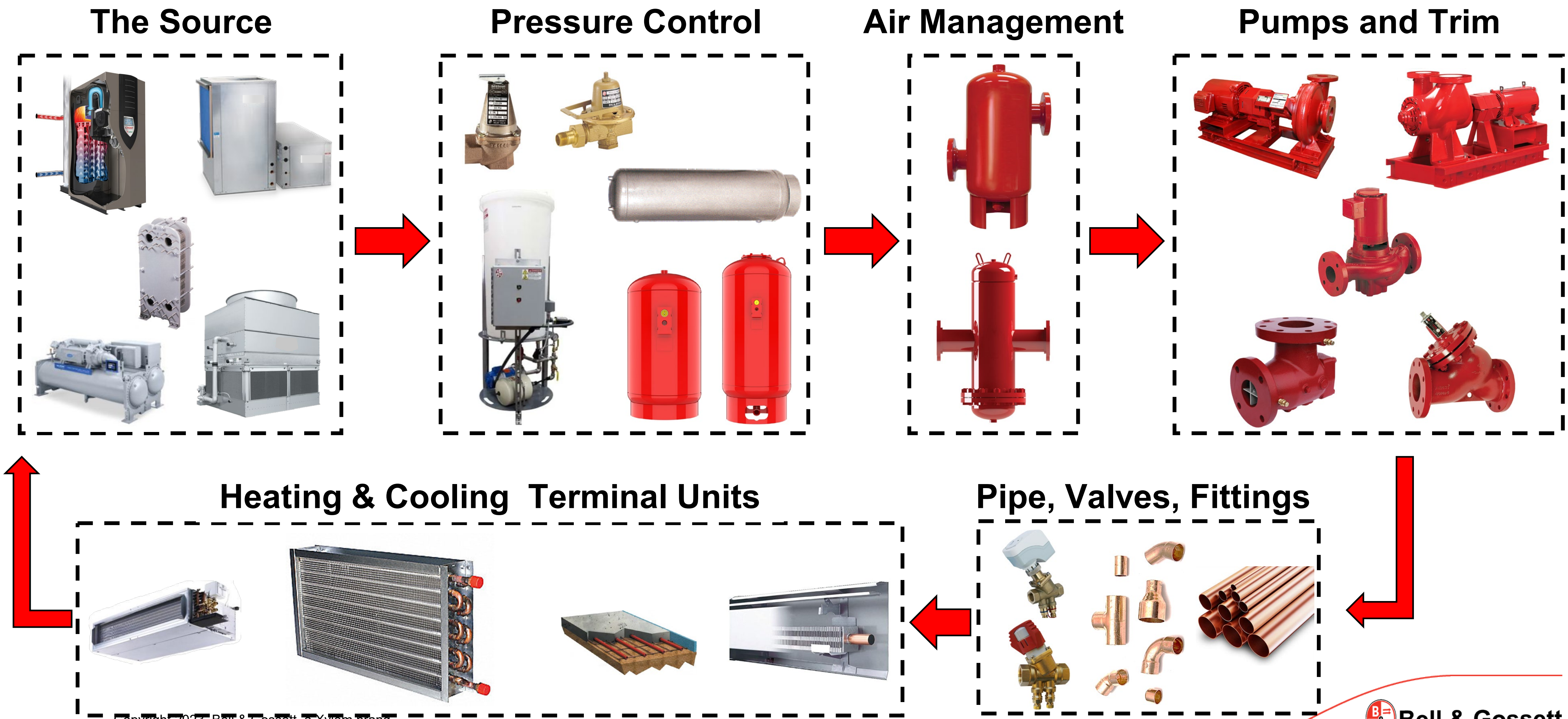
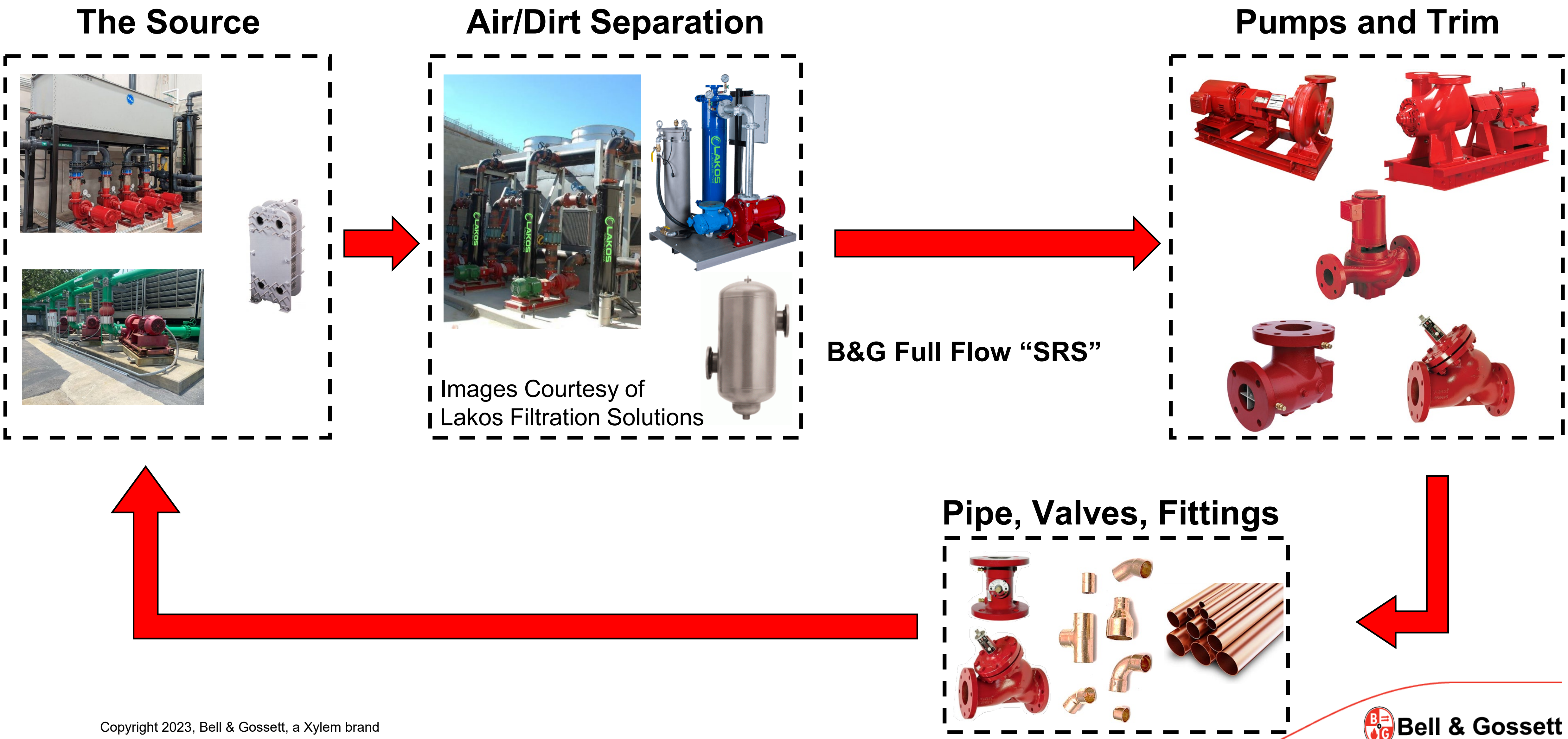
ASHRAE ACCA Air Conditioning Contractors of America ANSI





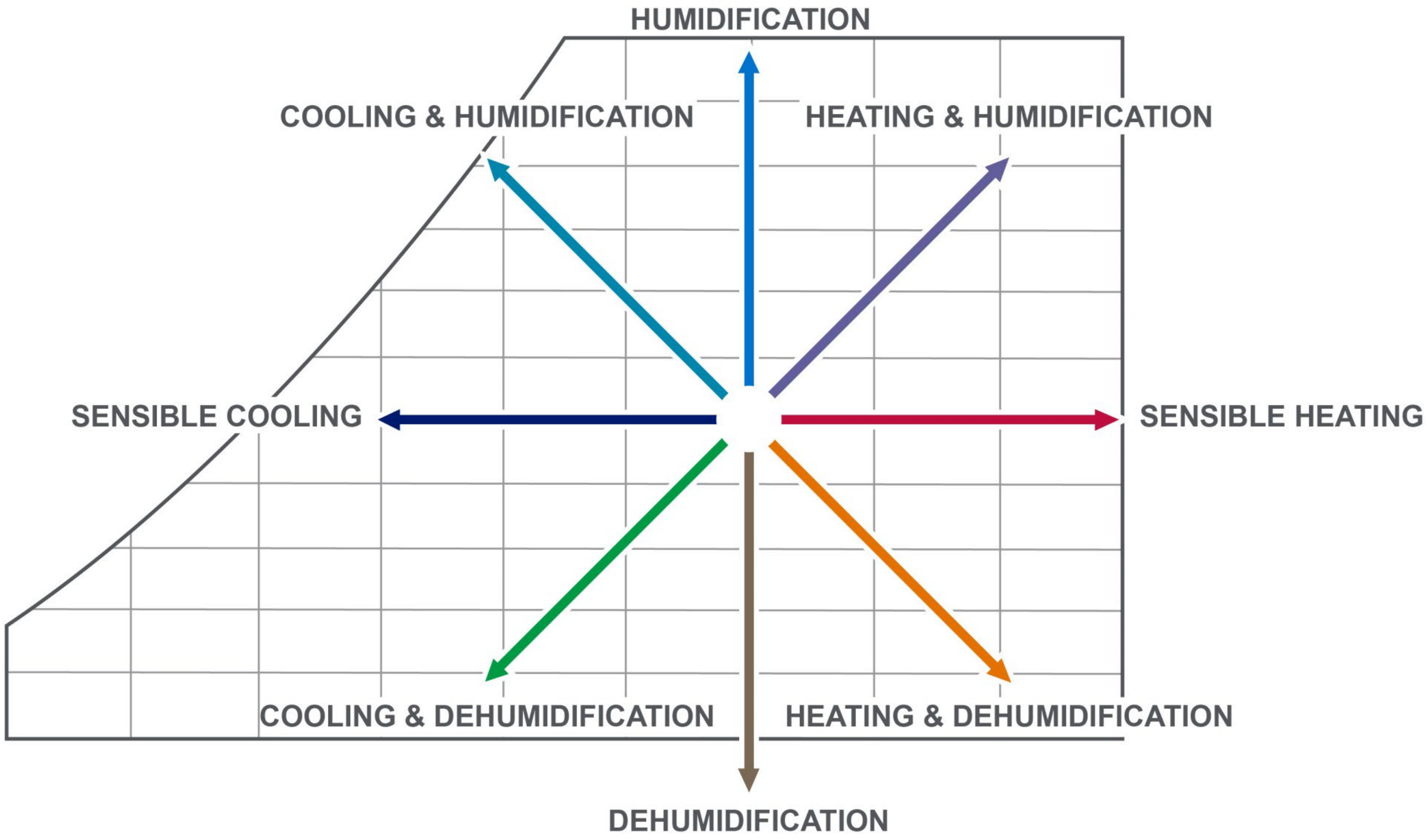
The Source
Pressure Control
Air Management
Pumps and Trim
Heating & Cooling Terminal Units
Pipe, Valves, Fittings


The Source
Air/Dirt Separation
Pumps and Trim
Images Courtesy of
Lakos Filtration Solutions
B&G Full Flow “SRS”
Pipe, Valves, Fittings

Design Method for Hydronic Systems

- **Step 1:** Size and Quantity of Heat Transfer Coils ***(Connected Load)***
- **Step 2:** Piping Layout Design ***(1 or 2 Pipe, Series or Parallel, Open or Closed?)***
- **Step 3:** Determine System Flow Rate ***(Btu/hr, ∆T, Fluid Specific Heat?)***
- **Step 4:** Size the piping ***(Friction Loss Rate, Velocity, Fluid Volume?)***
- **Step 5:** Size the boiler/chiller and components ***(Gross/Net Output, Tons of Cooling?)***
- **Step 6:** Select the Pump Type & Size ***(Flow, Head, Horsepower?)***

Chilled Water Coils *(The Load)*



Psychrometric Chart Data:

- Dry-Bulb Temperature
- Wet-Bulb Temperature
- Relative Humidity
- Dew Point Temperature
- Specific Volume of Humid Air
- Moisture Content/Humidity Ratio
- Enthalpy

** If 2 values are known, other 5 obtained from chart*

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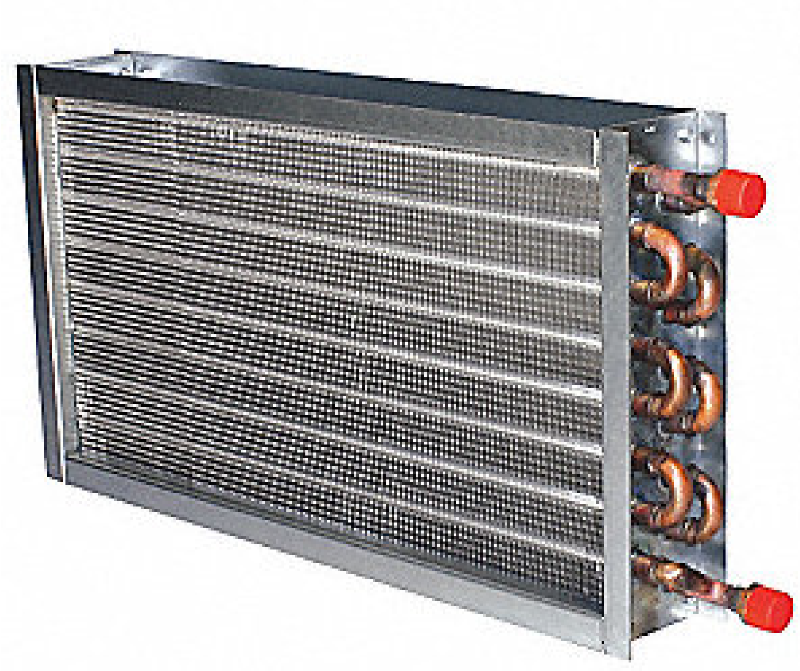


- Water Side Heat Transfer

$$q = mc_p(t_2 - t_1)$$

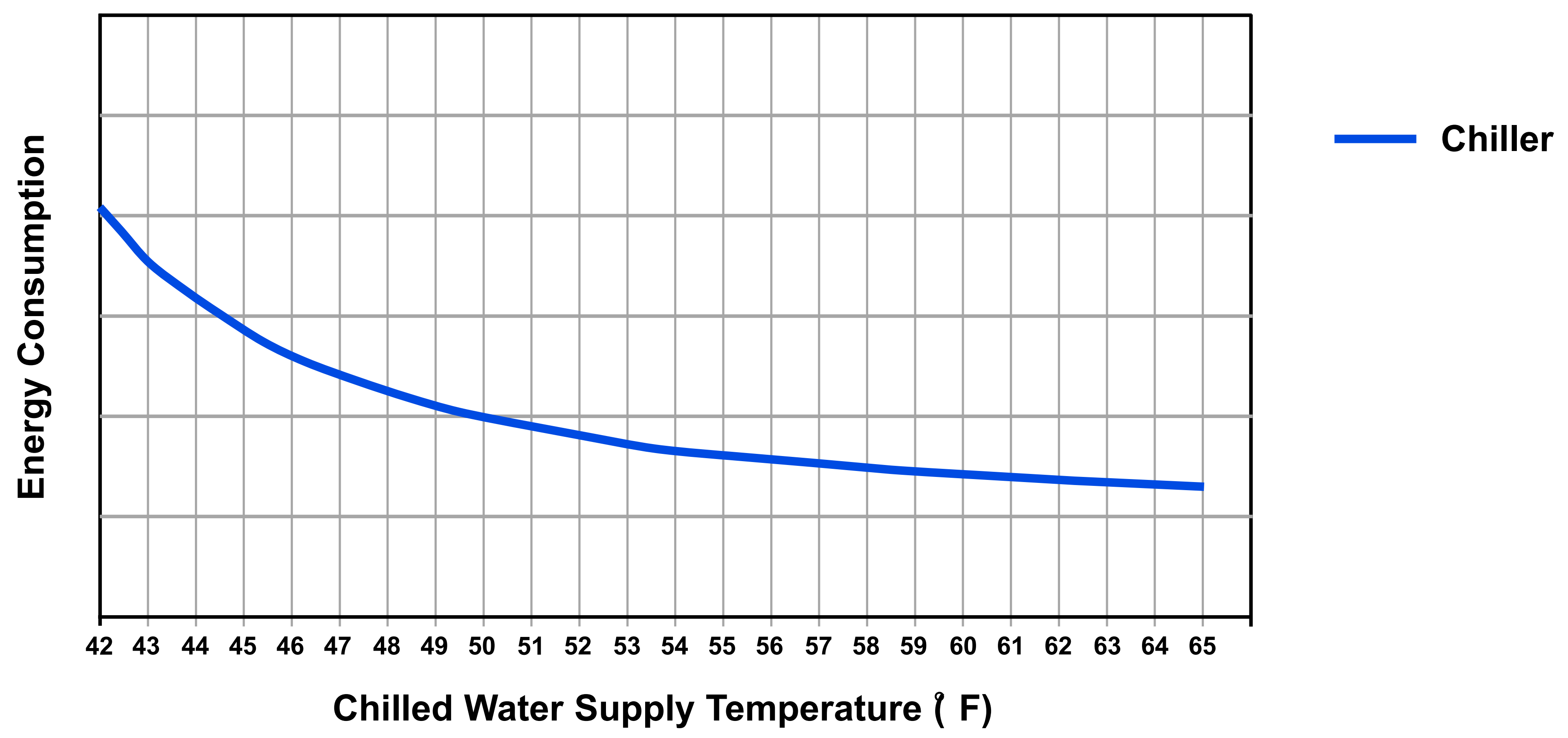
Where Δt is the water temperature change

- Coil Total Heat Transfer

$$q = UA(LMTD)$$

Where LMTD is the air-water
log mean temperature difference

Energy Consumption vs. Chilled Water Supply Temperature



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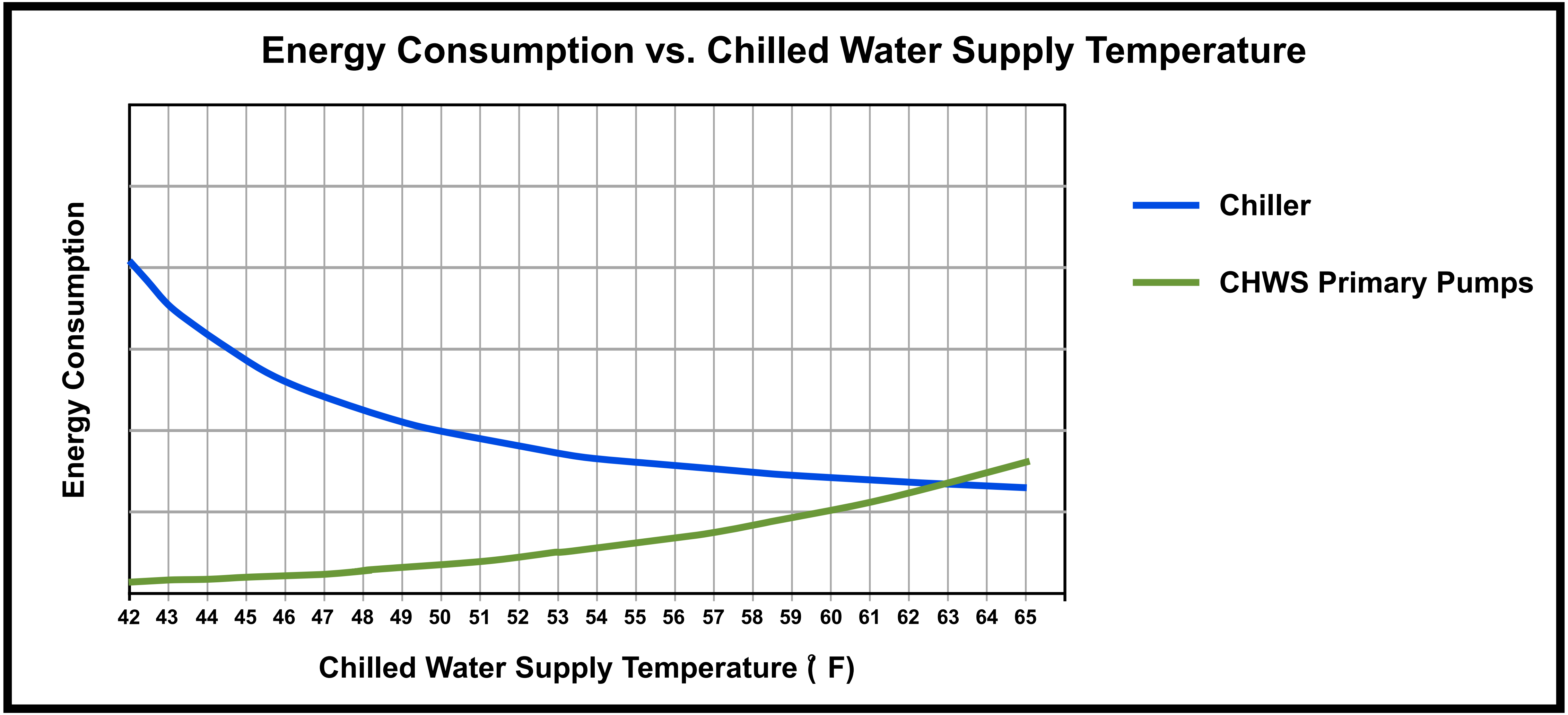
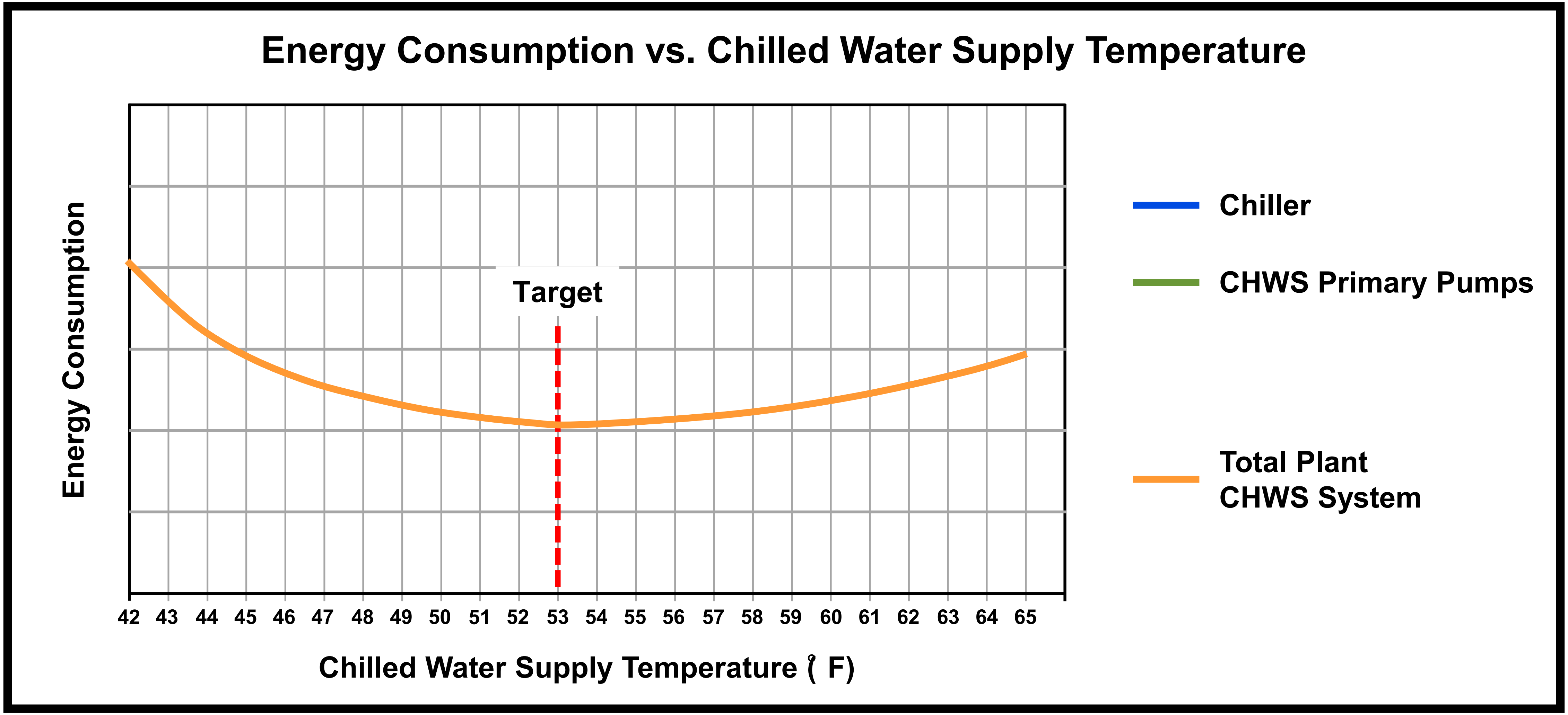
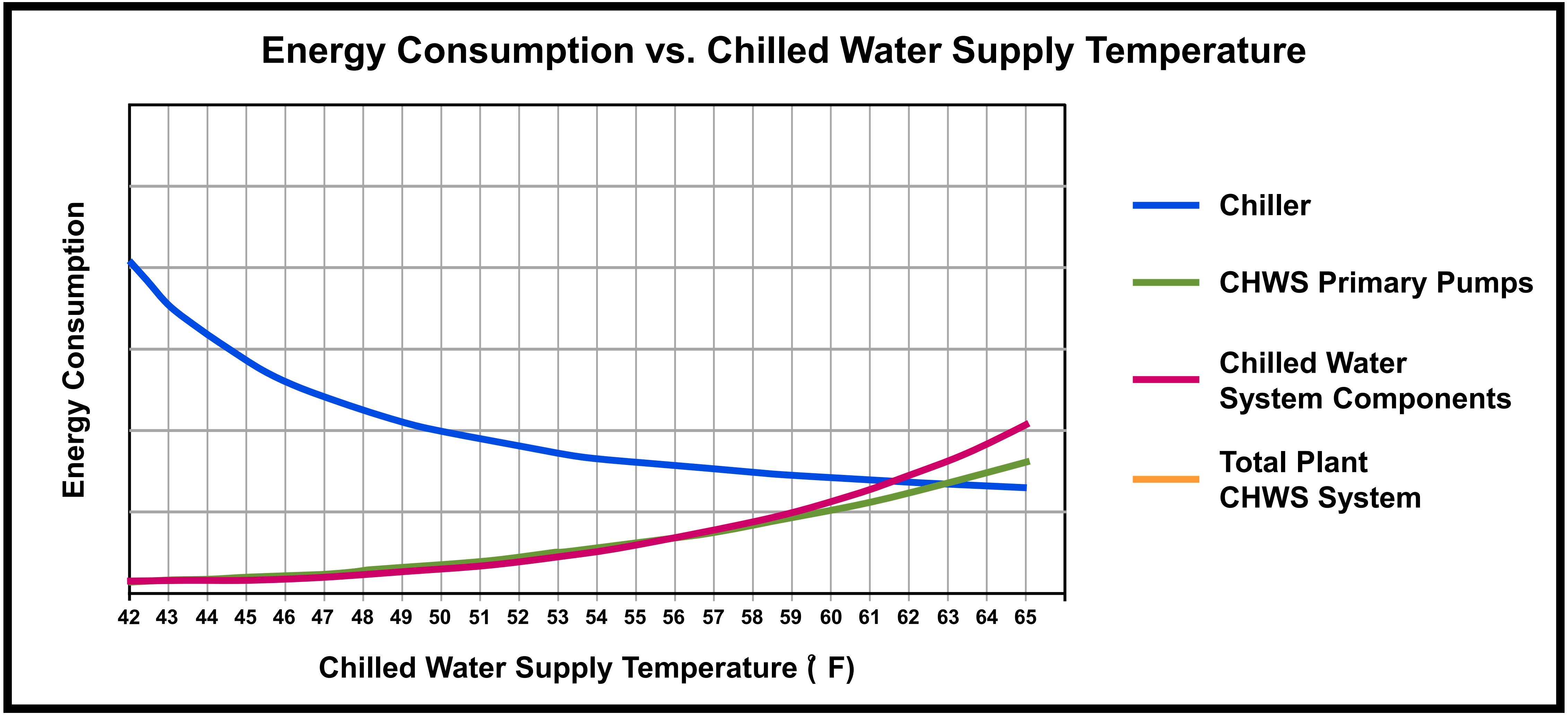


Energy Consumption vs. Chilled Water Supply Temperature
Energy Consumption
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
Chilled Water Supply Temperature (° F)
Chiller
CHWS Primary Pumps


Energy Consumption vs. Chilled Water Supply Temperature
Target
Chiller
CHWS Primary Pumps
Total Plant
CHWS System
Energy Consumption
42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65
Chilled Water Supply Temperature (° F)



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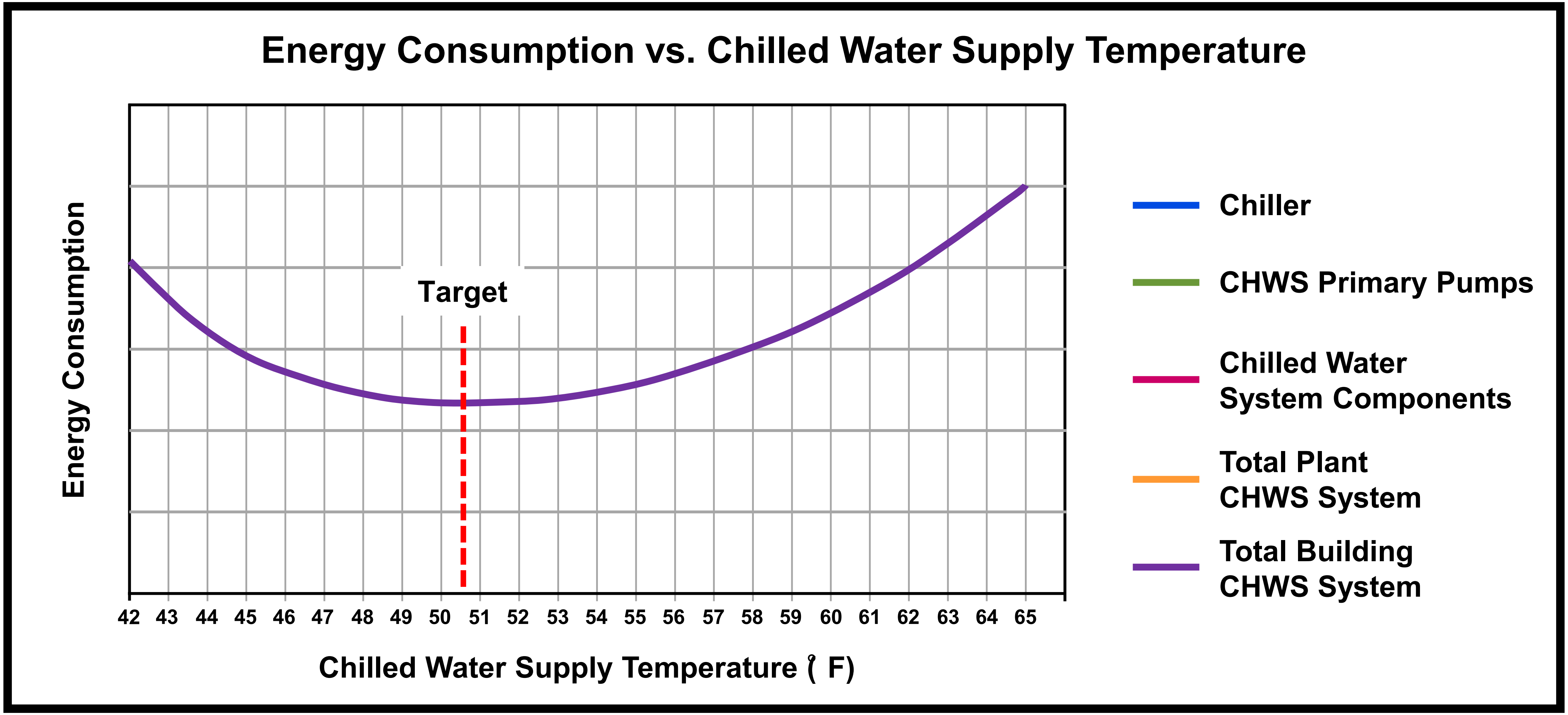
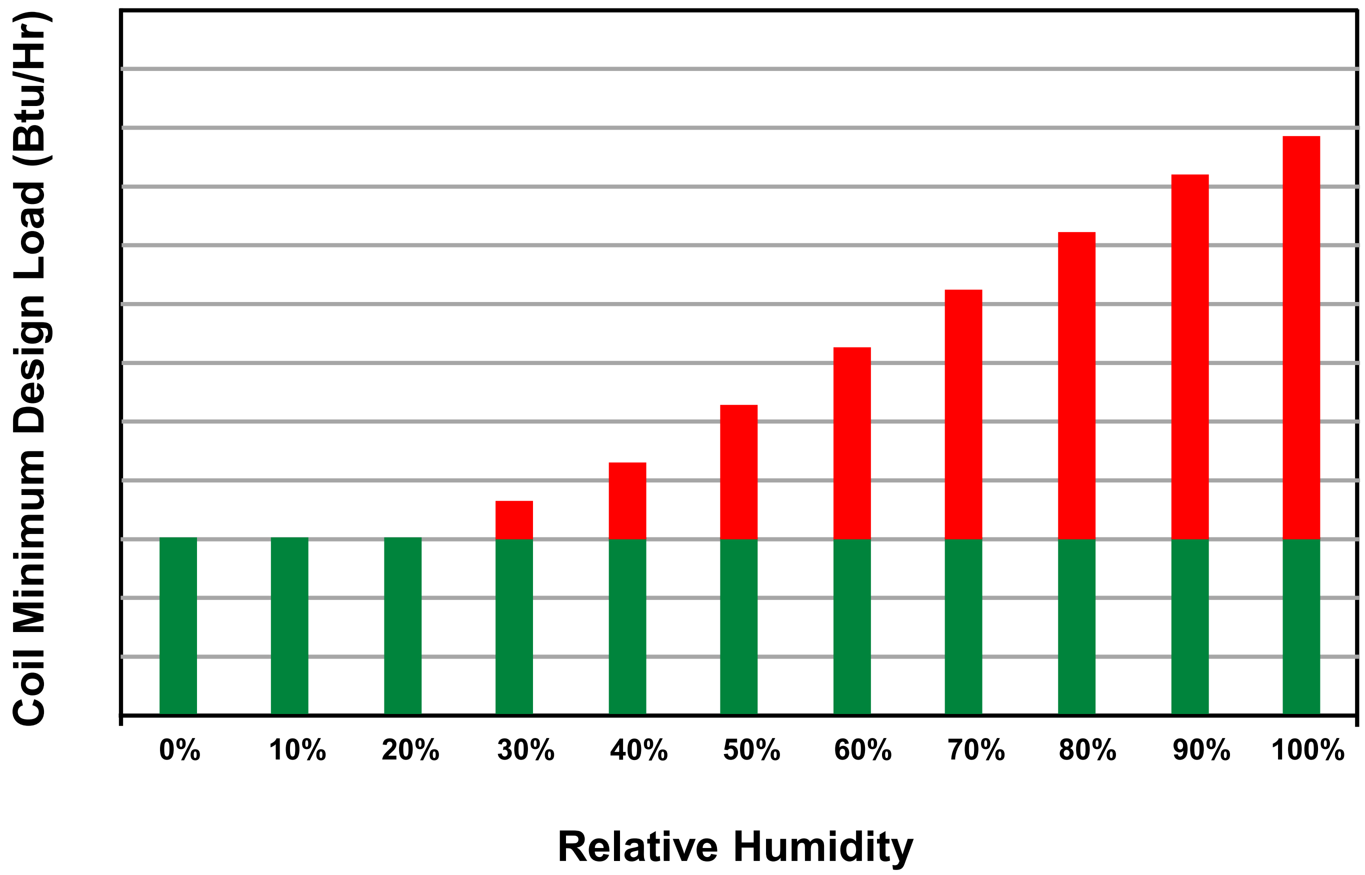

Energy Consumption vs. Chilled Water Supply Temperature
Energy Consumption
Target
42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65
Chilled Water Supply Temperature (°F)
Chiller
CHWS Primary Pumps
Chilled Water System Components
Total Plant CHWS System
Total Building CHWS System



Latent Load (Btu/Hr)*

$Q_L = 0.68 \times cfm \times \Delta W$

cfm = Volume of Air across coil (ft³/min.)

ΔW = Difference in moisture content (grains/lb.)
(Supply vs. Return Air)

Sensible Load (Btu/Hr)

$Q_S = 1.08 \times cfm \times \Delta T$

cfm = Volume of Air across coil (ft³/min.)

ΔT = Difference in Dry Bulb Temperature (°F)
(Supply vs. Return Air)

* ***Latent Loads:*** **require colder supply water temperature to reach air "dew point" for moisture extraction**

ASHRAE 90.1 Section 6.5 – Prescriptive Compliance Path

6.5.4.7 Chilled-Water Coil Selection

Chilled-water cooling coils shall be selected to provide a **15°F** or higher temperature difference between leaving and entering water temperatures and a minimum of **57°F** leaving water temperature at *design conditions.*

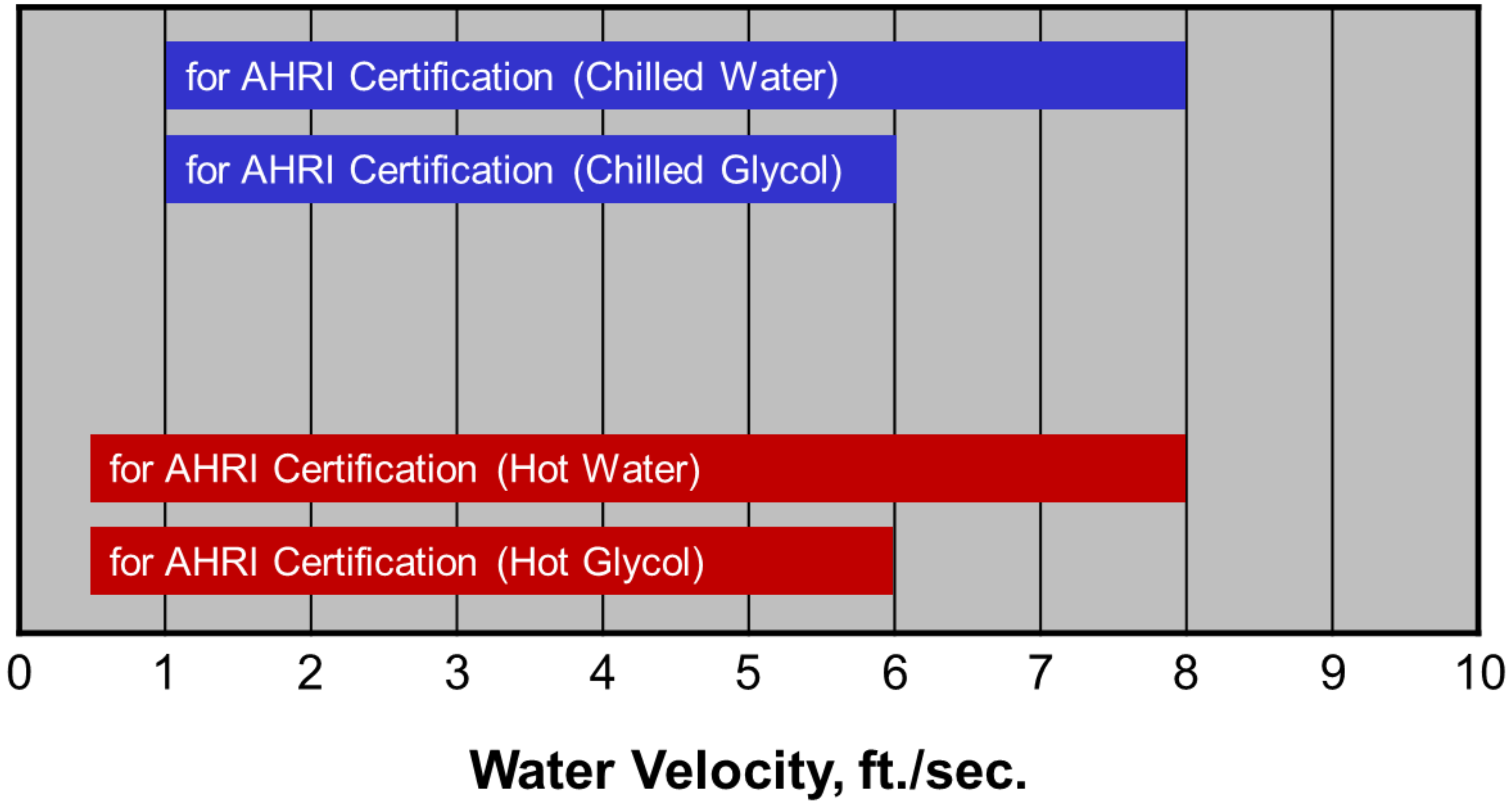
Life Cycle cost benefits

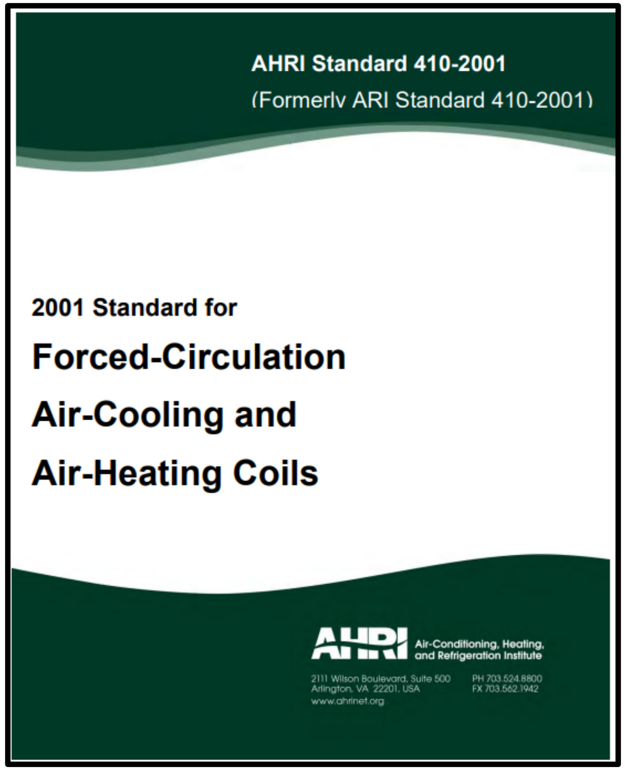
- Smaller pipes
- Smaller valves
- Smaller pump(s)
- Reduced system energy usage

Possible Concessions

- Increased coil surface area
- Higher air-side pressure drops
- Increased fan energy usage
- Lower supply water temperature
- Increased chiller energy usage

AHRI-410-2001 – Guidelines for Water Velocity





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Water Velocity Too Low

- Air trapped in coil
- Poor water distribution in coil(s)
- Tube fouling
- Risk of freezing

Water Velocity Too High

- High water pressure drop in coil
- Tube erosion
- Noise
- Vibration

THERMODYNAMIC

AIR SIDE			FLUID SIDE		
Face velocity (Standard)	[ft/min]	550	Fluid		Water
Air flow (Standard)	[cfm]	33,000	Fouling factor		0
Altitude	[ft]	0	Entering fluid temp.	[°F]	45.0
EAT db / wb	[°F]	80.0 / 67.0	Leaving fluid temp.	[°F]	60.0
Fin fouling factor		0			

RESULTS

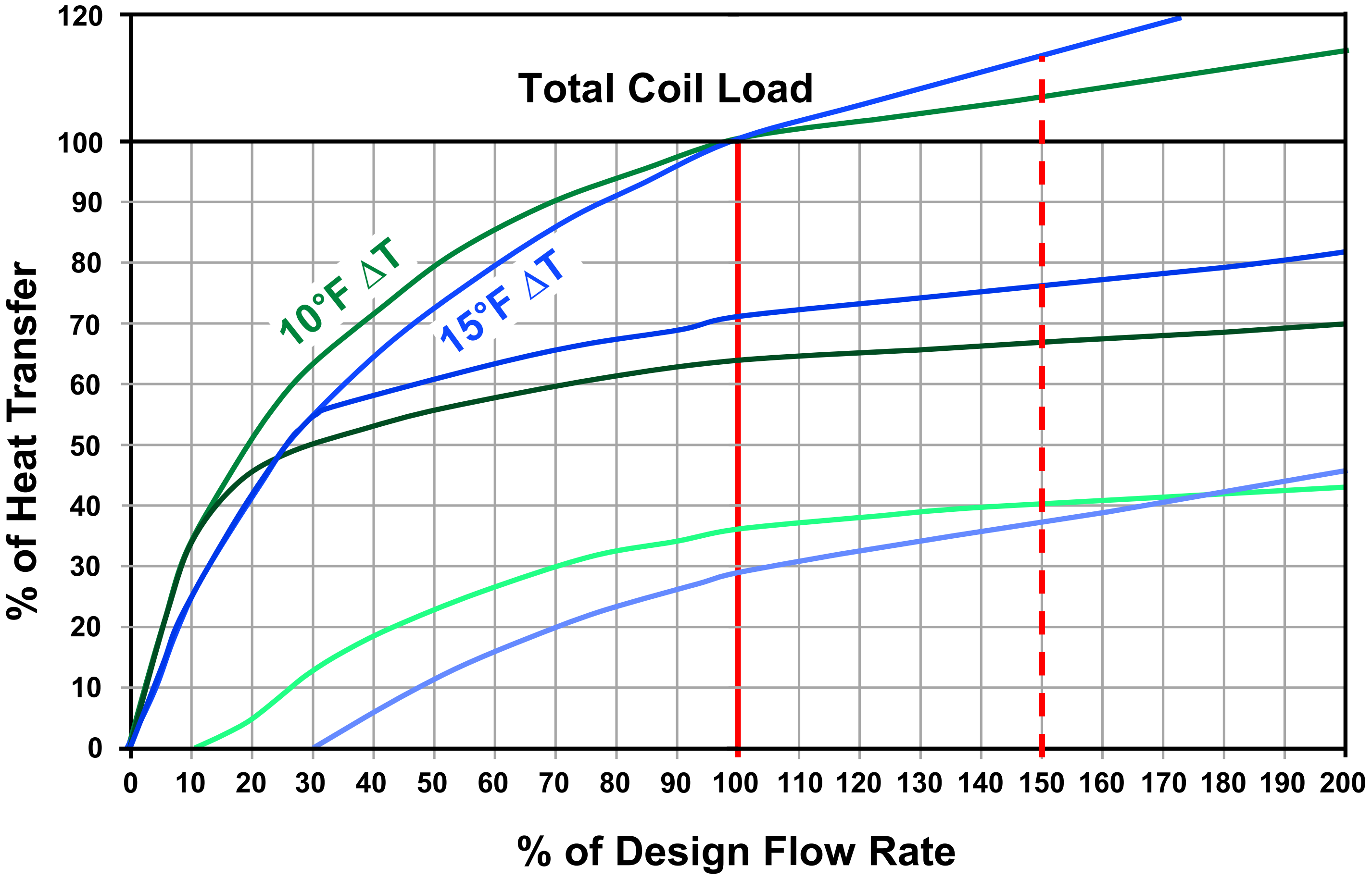
CONSTRUCTION			AIR SIDE		
Weight	[lbs]	2,282	Total / Sensible capacity	[Btu/hr]	1,470,170 / 996,522 473,648
Weight with fluid	[lbs]	3,144	LAT db / wb	[°F]	52.4 / 52.0
Face area	[ft²]	60.0	Air pressure drop (Standard)	[in wg]	1.23

FLUID SIDE

Fluid pressure drop	[ft H2O]	9.85
Fluid flow rate	[gpm]	195
Leaving fluid temp.	[°F]	60.0
Internal volume	[in³]	23,870
Tubeside velocity	[ft/s]	2.16

Typical Chilled Water Coil Performance

(Constant CFM, Constant Supply Water Temperature)



Sensible Load (Btu/Hr)

$Q_S = 1.08 \times cfm \times \Delta T$

Latent Load (Btu/Hr)

$Q_L = 0.68 \times cfm \times \Delta W$

Flow Rate more critical with higher ΔT

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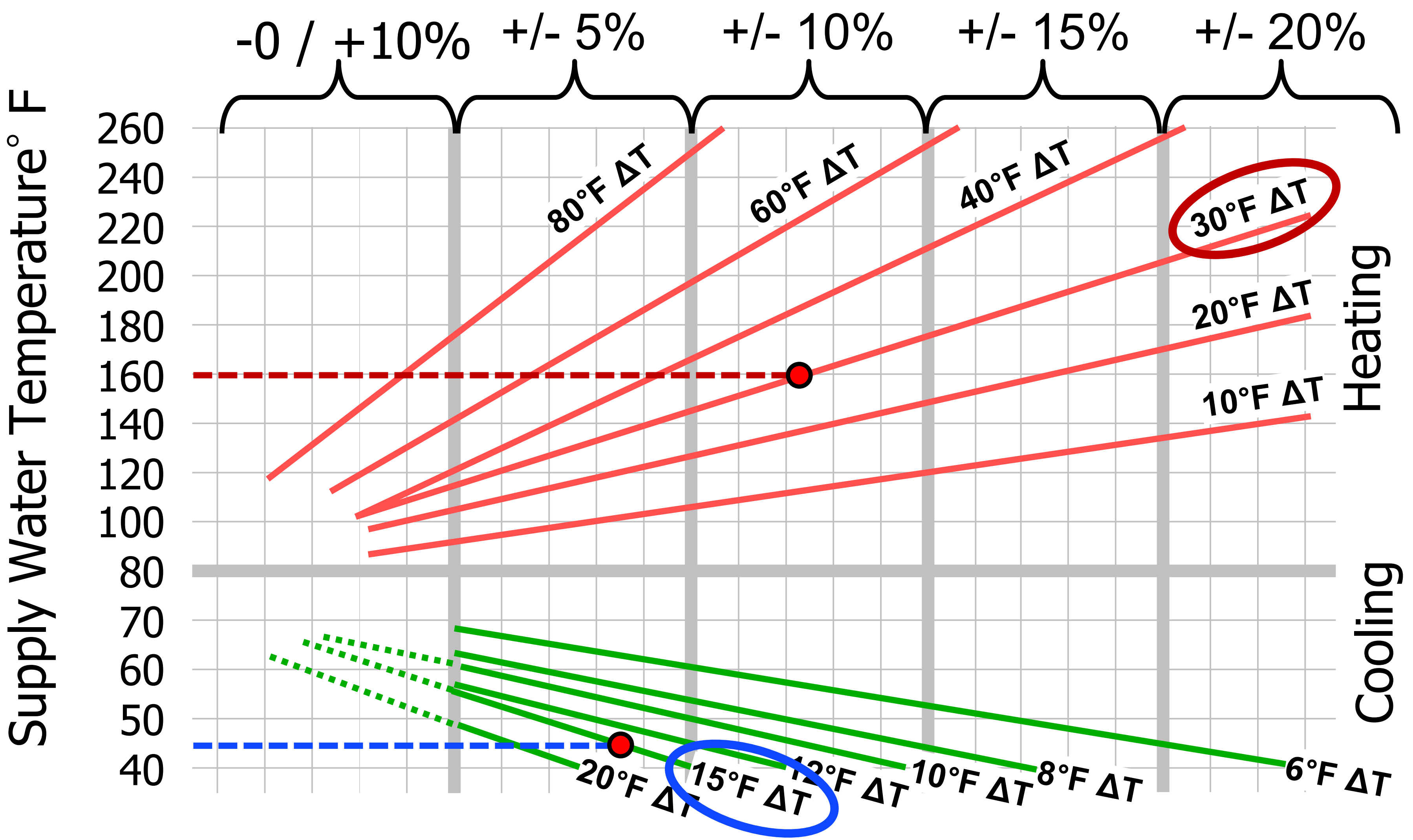
Suggested Flow Tolerance (%) For 97% Heat Transfer



* Reference ASHRAE Handbook – *"HVAC Applications"*, Chapter 35, Pg. 15, Fig. 2

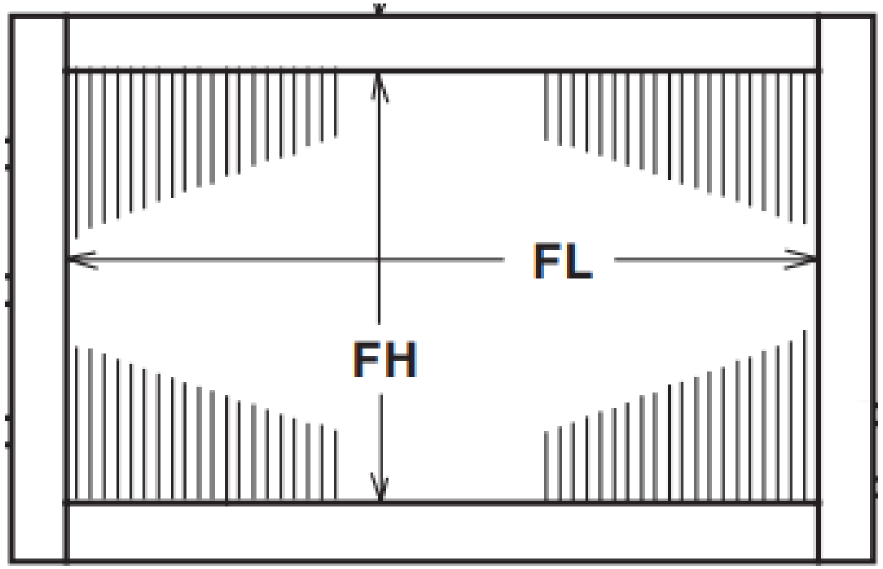
$$A = \frac{Q}{U \times LMTD}$$

A = Surface Area **(Ft²)**

Q = Heat Load **(Btuh)**

U = Heat Transfer Coefficient **(Btuh/Ft²/°F)**

LMTD = Log Mean Temperature Difference **(°F)**



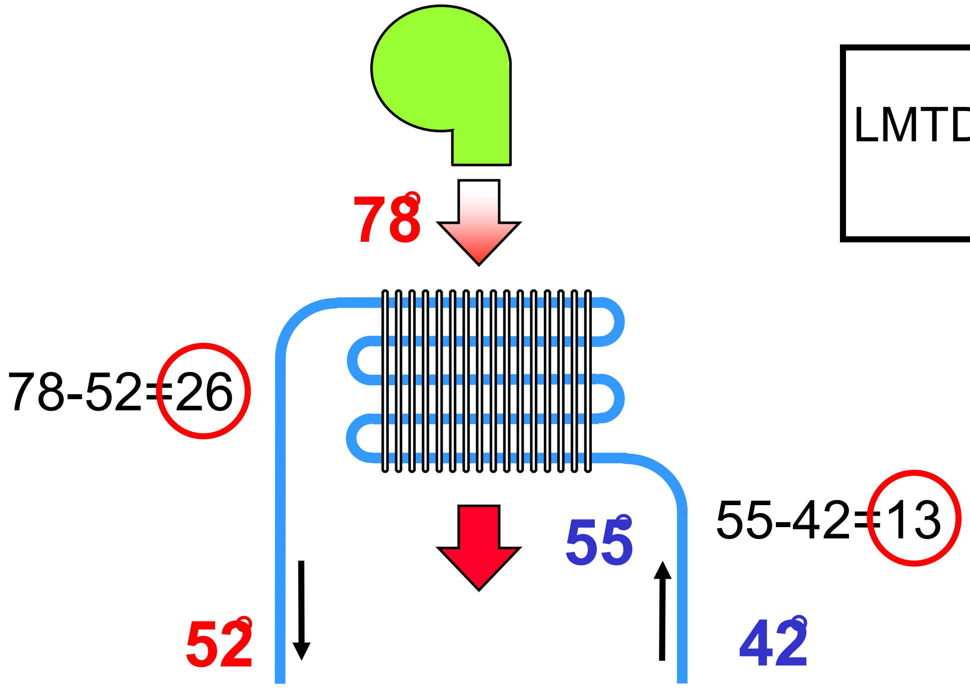
↑ U = ↓ A

↑ LTMD = ↓ A

$$\text{LMTD} = \frac{26 - 13}{\ln \frac{26}{13}}$$

$$= \frac{13}{\ln 2} = \frac{13}{0.693} = \underline{\mathbf{18.75}}$$

$$\text{LMTD} = \frac{\text{GTTD - LTTD}}{\ln \frac{\text{GTTD}}{\text{LTTD}}}$$

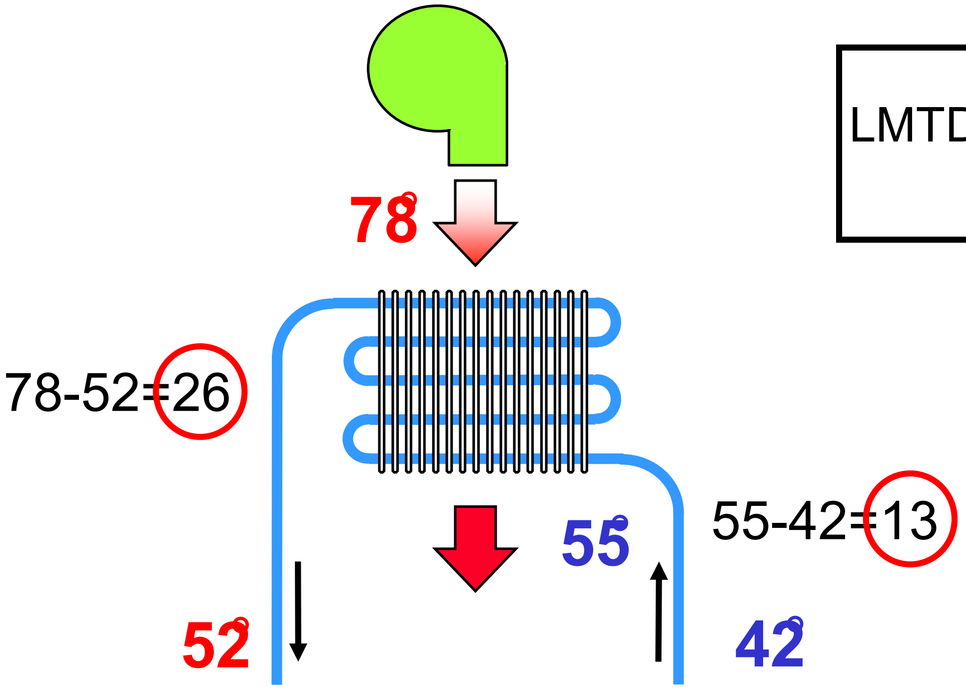


Piped Correctly

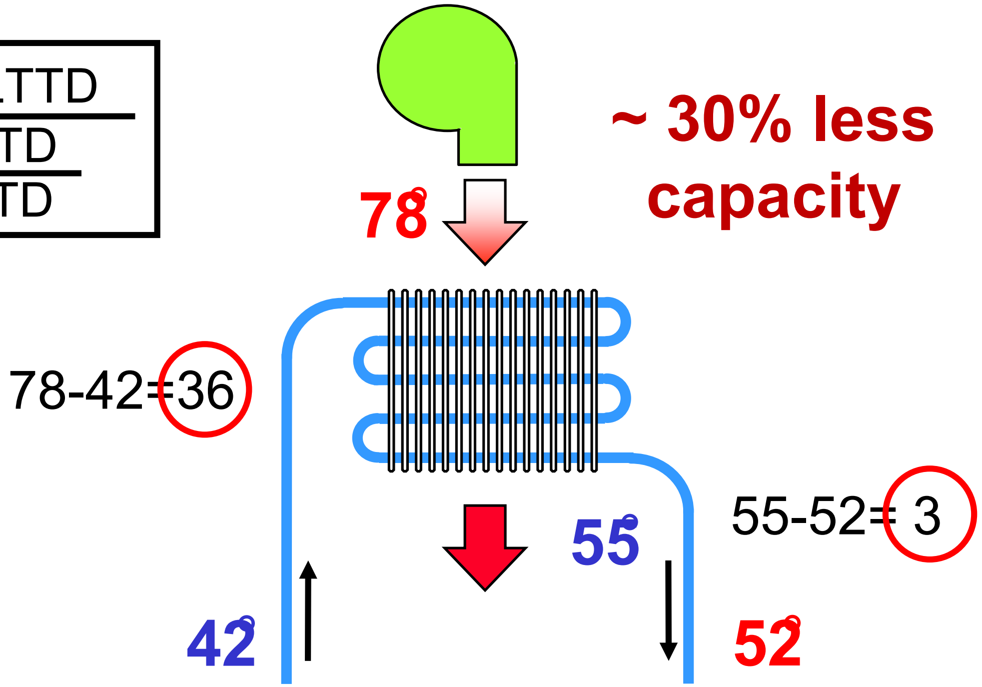
$$\text{LMTD} = \frac{26 - 13}{\ln \frac{26}{13}} = \frac{13}{\ln 2} = \frac{13}{0.693} = \underline{\mathbf{18.75}}$$

$$\text{LMTD} = \frac{36 - 3}{\ln \frac{36}{3}} = \frac{33}{\ln 12} = \frac{33}{2.485} = \underline{\mathbf{13.28}}$$

$$\text{LMTD} = \frac{\text{GTTD - LTTD}}{\ln \frac{\text{GTTD}}{\text{LTTD}}}$$



Piped Correctly



~ 30% less capacity

Piped Incorrectly

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Flow Control and Balance Valves for Heat Transfer Coils

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Flow Balancing Valves

ASHRAE 90.1 Section 6.7 – Submittals

6.7.3.3.3 Hydronic System Balancing

Hydronic systems shall be proportionally balanced in a manner to first minimize throttling losses; then the pump impeller shall be trimmed **or** pump speed shall be adjusted to meet design flow conditions.

Exceptions to 6.7.3.3.3

Impellers need not be trimmed, nor speed adjusted

1. for pumps with motors of 10hp or less **or**

2. when throttling results in no greater than 5% of the *nameplate horsepower* draw, or 3 hp, whichever is greater, above that required if impeller was trimmed.

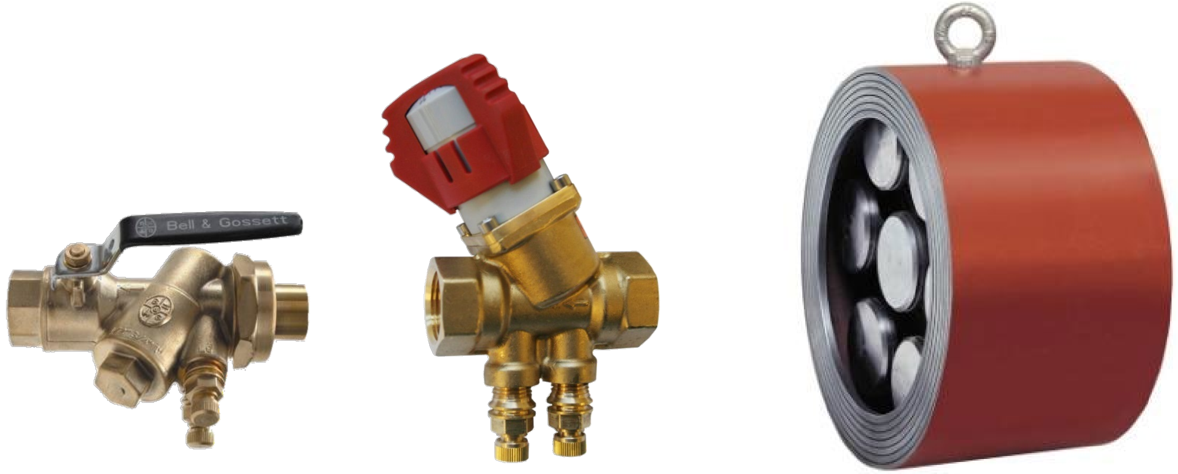
Chapter 46 - Valves

From Balancing Valves, Balancing Valve Selection, Page 46.11

Balancing Valves ***(Manual)*** should be selected with a **0.45 to 1 PSI (1’-3’)** pressure drop at the branch design flow

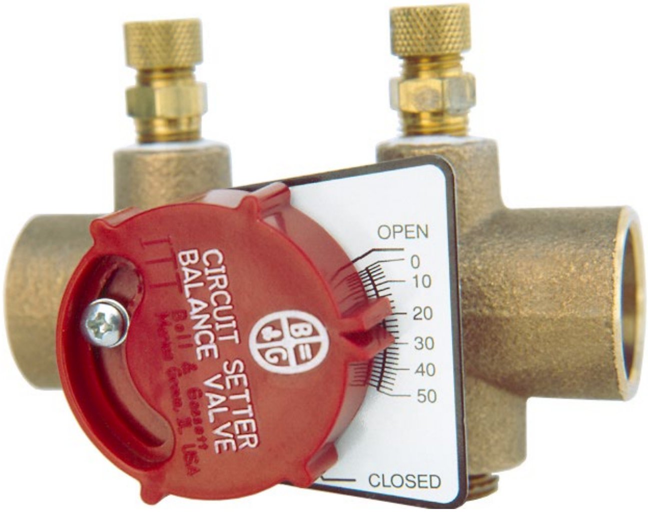
NOTE: Automatic Flow Limiting Valves will have **2-3 PSI (5’-7’)** *(under 4”)* **or 5-7 PSI (11’-16’)** *(4” and above)* at design flow.

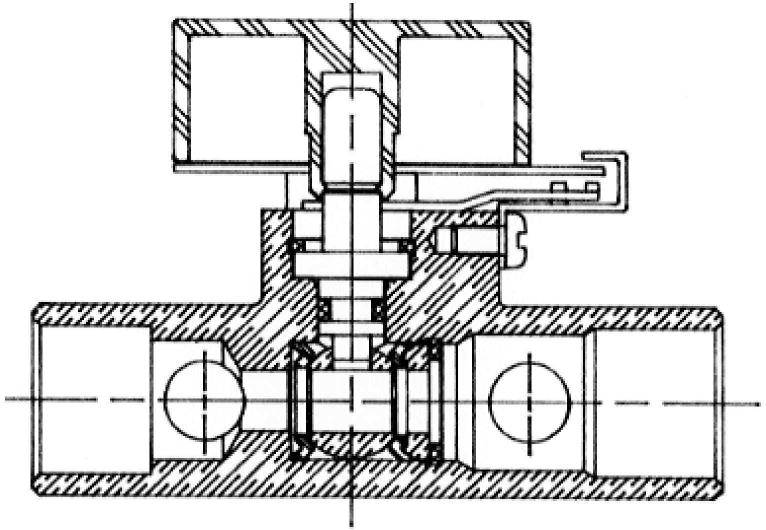
Manual Balance “Circuit Setter”



Automatic Flow Limiting “Circuit Sentry”

The "Circuit Setter": Pressure Dependent, Fixed Orifice

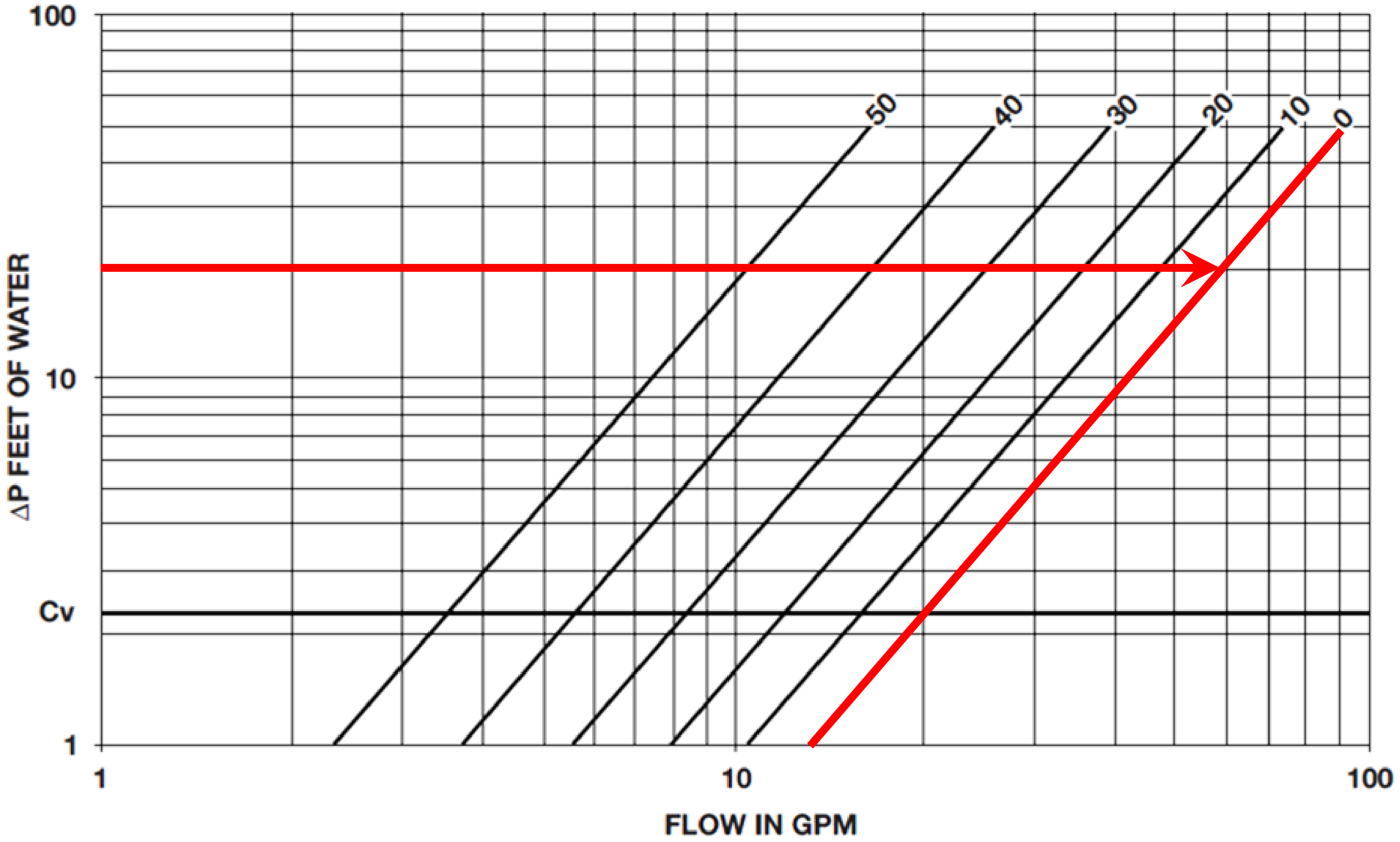




How do you determine the flow rate using a Circuit Setter?

Step 1:
Determine the valve setting

Step 2:
Measure the differential pressure and determine where it intersects with setting line.



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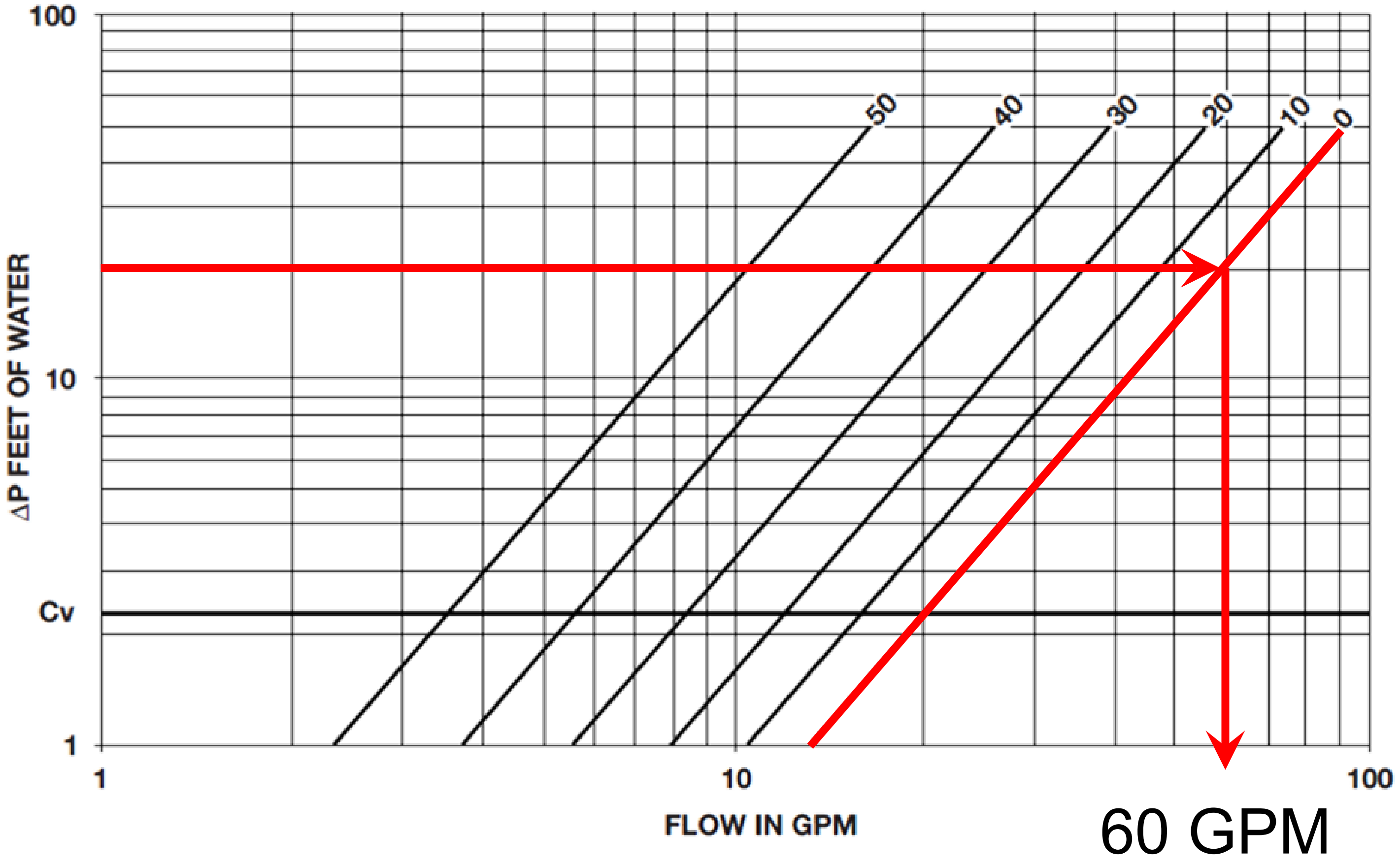
How do you determine the flow rate using a Circuit Setter?

Step 1:
Determine the valve setting

Step 2:
Measure the differential pressure and determine where it intersects with setting line.

Step 3:
Use chart to determine flow rate.



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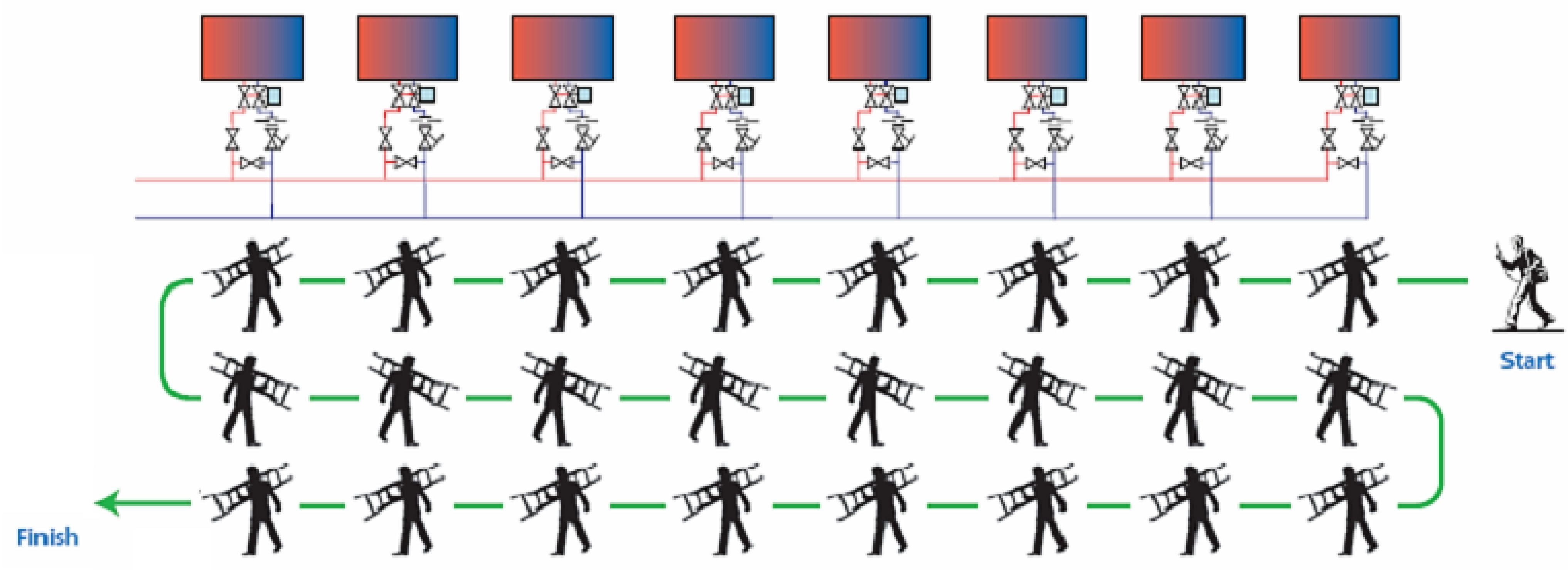
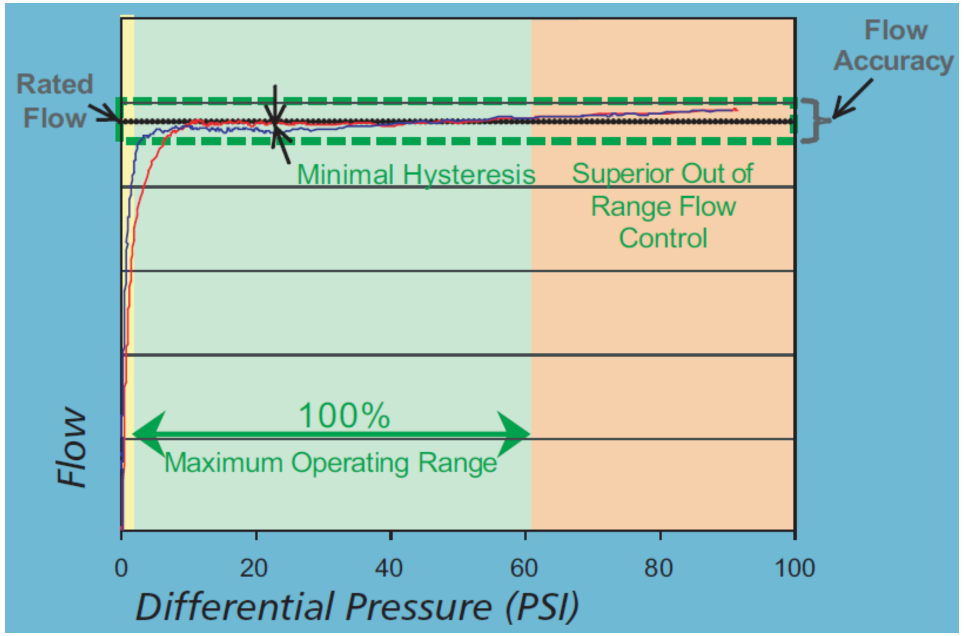
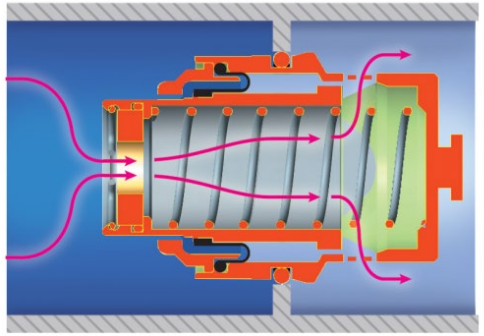

Start
Finish

- Maintains constant fluid flow ***(+/- 5%)*** by neutralizing pressure fluctuations
- Becomes *fixed orifice, variable flow* outside control range of **2-60 PSID**
- No limitations on before and after pipe lengths





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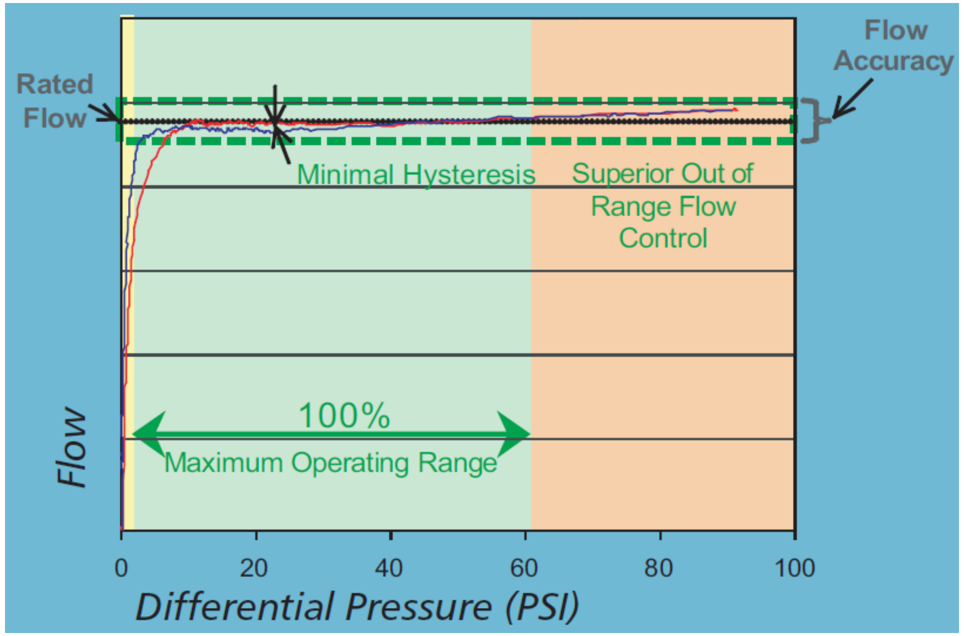
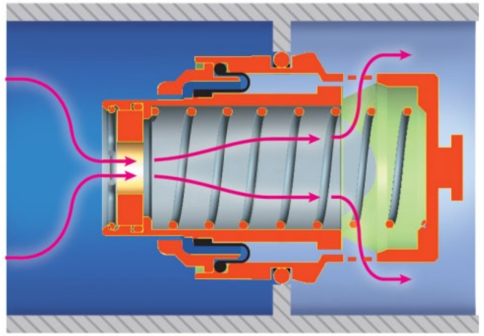
- Maintains constant fluid flow ***(+/- 5%)*** by neutralizing pressure fluctuations
- Becomes *fixed orifice, variable flow* outside control range of **2-60 PSID**
- No limitations on before and after pipe lengths





Non-Adjustable **Adjustable**

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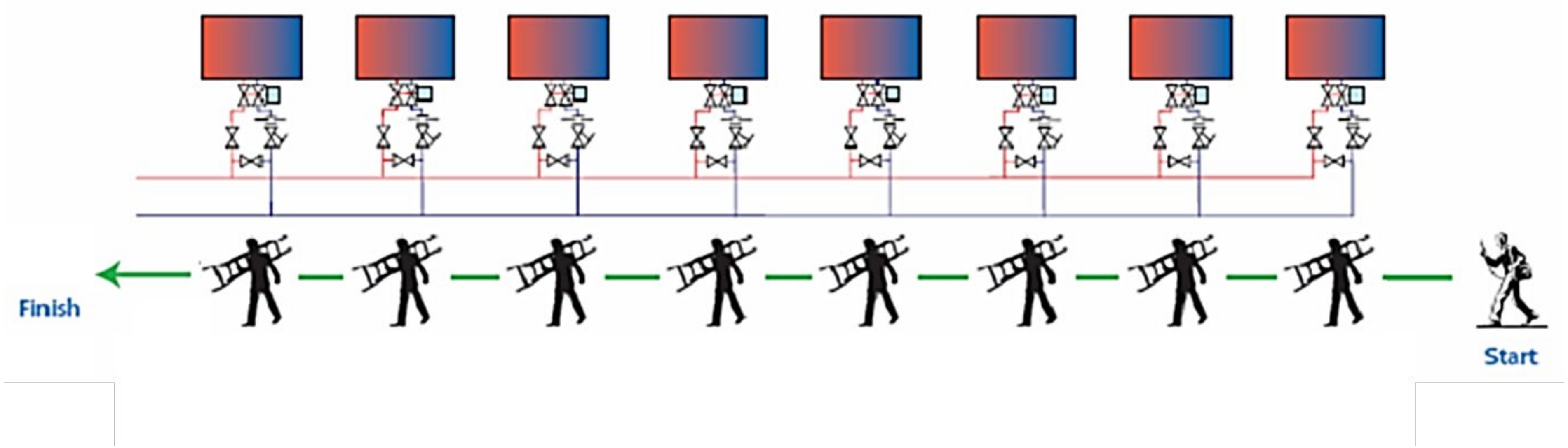
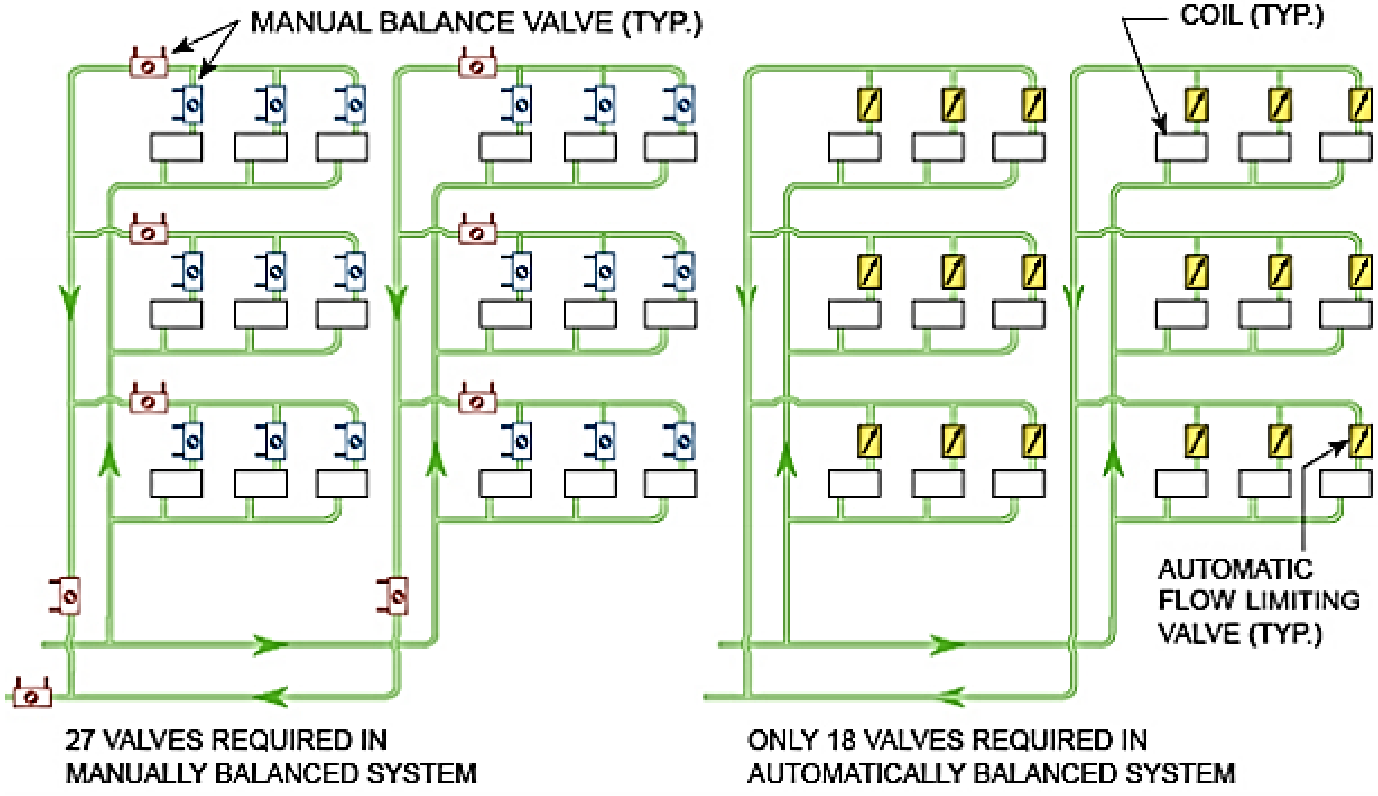

Finish
Start



- Primary branch return lines no longer requires balance
- No need to re-balance existing equipment when new added
- Limits the amount of overflow or control valve hunting

Flow Control Type Valves

Types

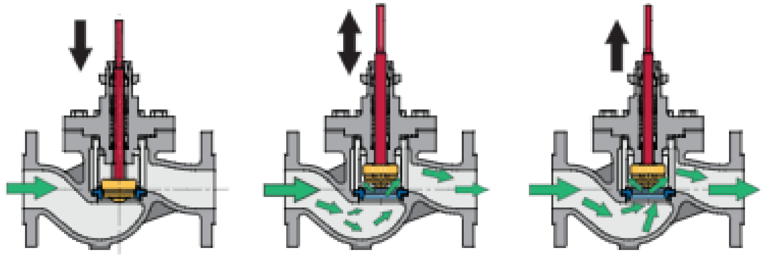
- Butterfly
- Globe
- Characterized Ball
- Solenoid or Safety Relief

Port Arrangements

- 2-Way: Isolation & Proportional
- 3-Way: Mixing & Diverting
- 6-Way: Dual Temperature Systems

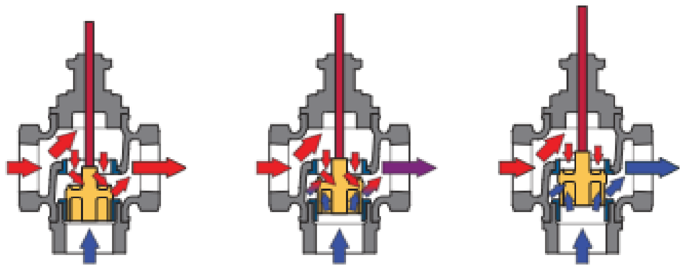
2-Way Modulating Valve

CLOSED	MODULATING	OPEN
(Stem Down)	(Stem Mid-Way)	(Stem Up)



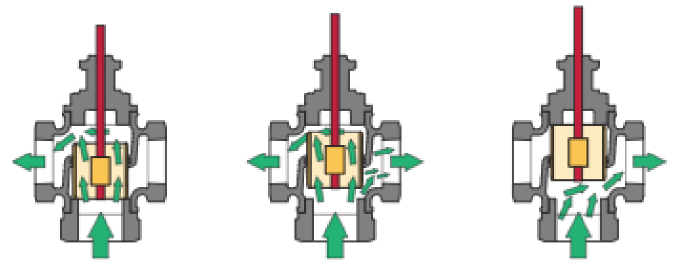
3-Way Mixing Valve

HOT	MIXING	COLD
(Stem Down)	(Stem Mid-Way)	(Stem Up)



3-Way Diverting Valve

OUTLET A	SPLITTING	OUTLET B
(Stem Down)	(Stem Mid-Way)	(Stem Up)



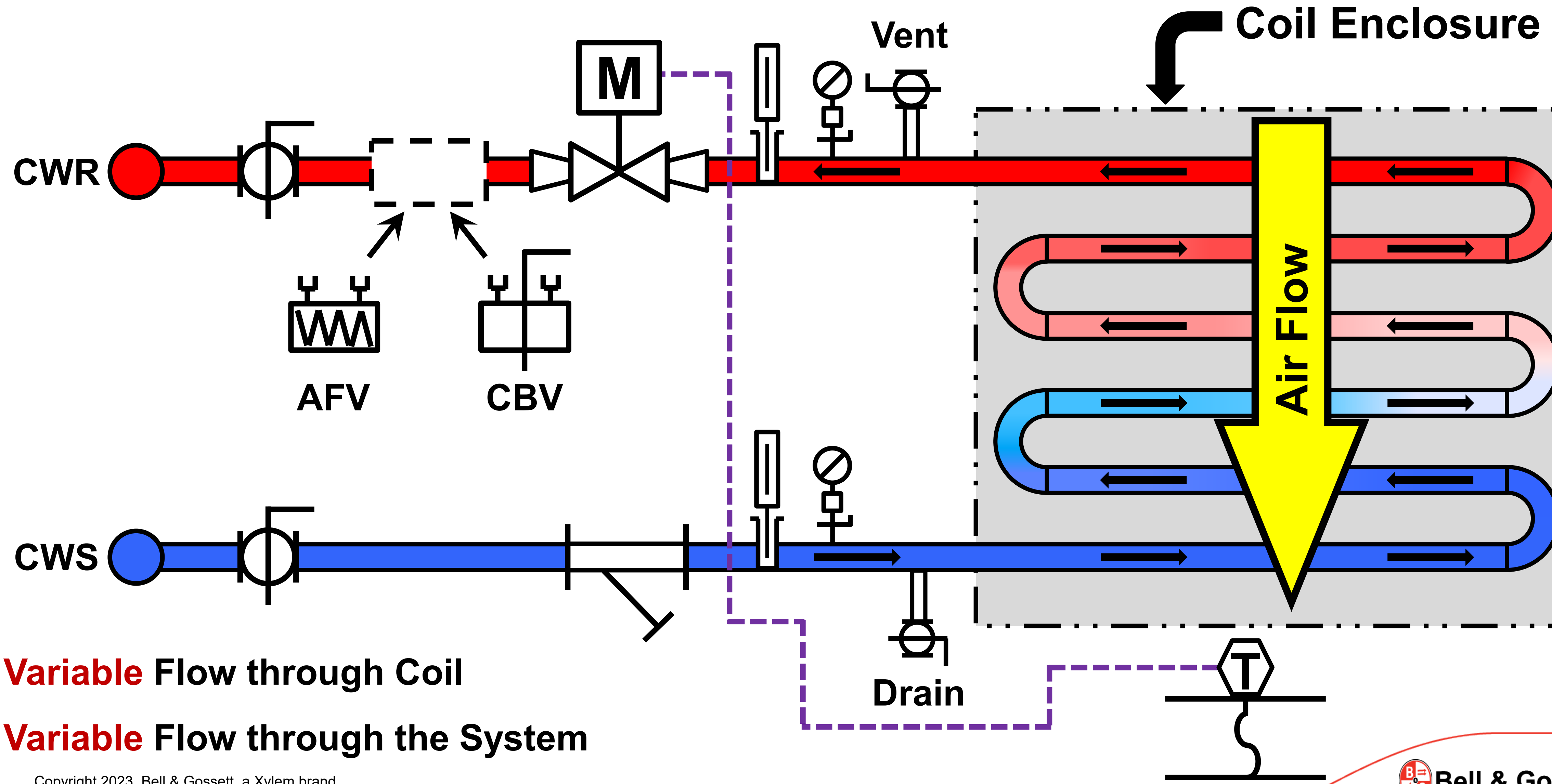
***Globe Type Valves shown**

Level 1

- Capacity
- Fluid Type
- Actuator Type
- Required level of accuracy
- Operating pressure and temperature
- Required performance characteristic to match process

Level 2

- Valve Type
- Valve Flow Coefficient
- Required Authority
- Rangeability
- Turn-Down
- Close-Off Pressure



- **Variable** **Flow through Coil**
- **Variable** **Flow through the System**

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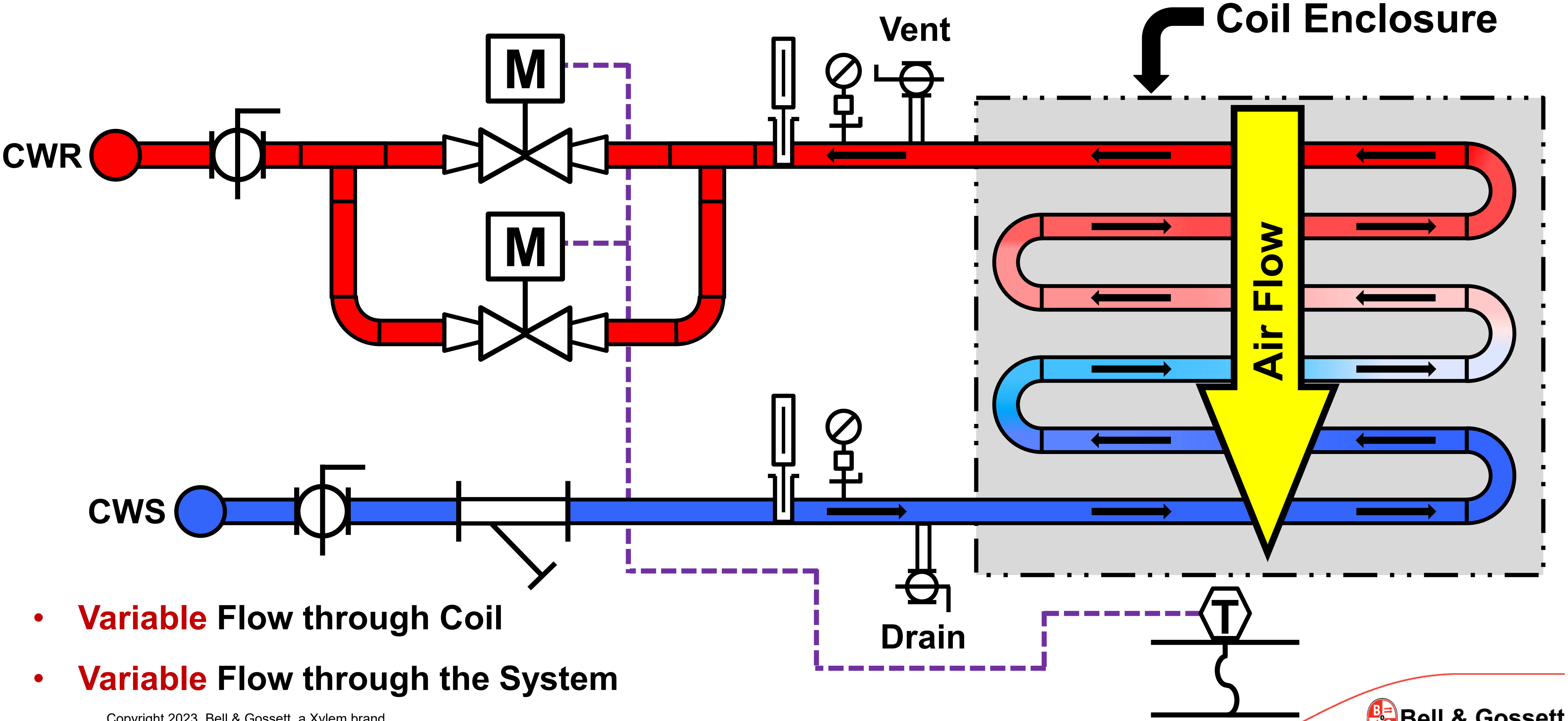
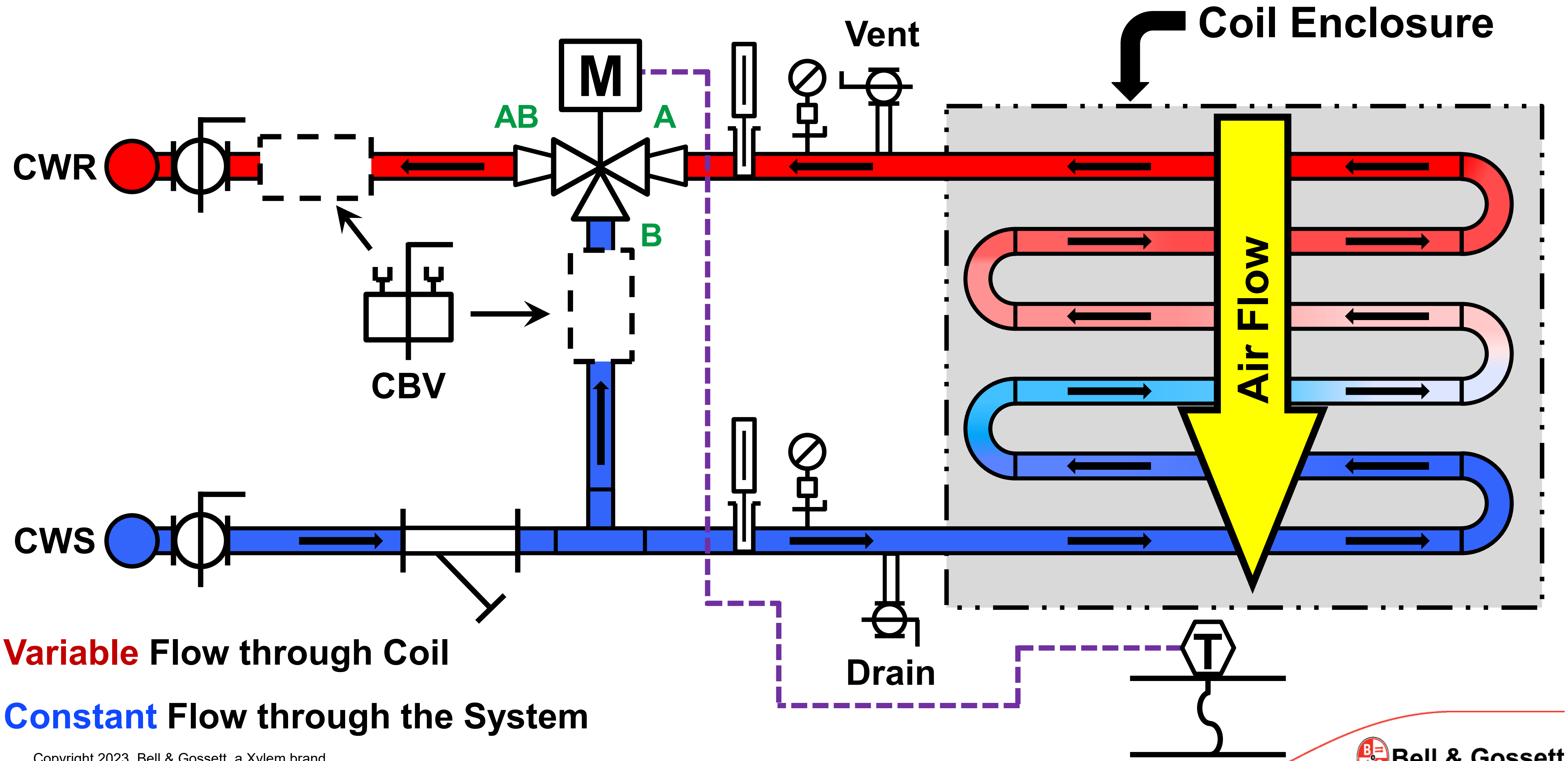
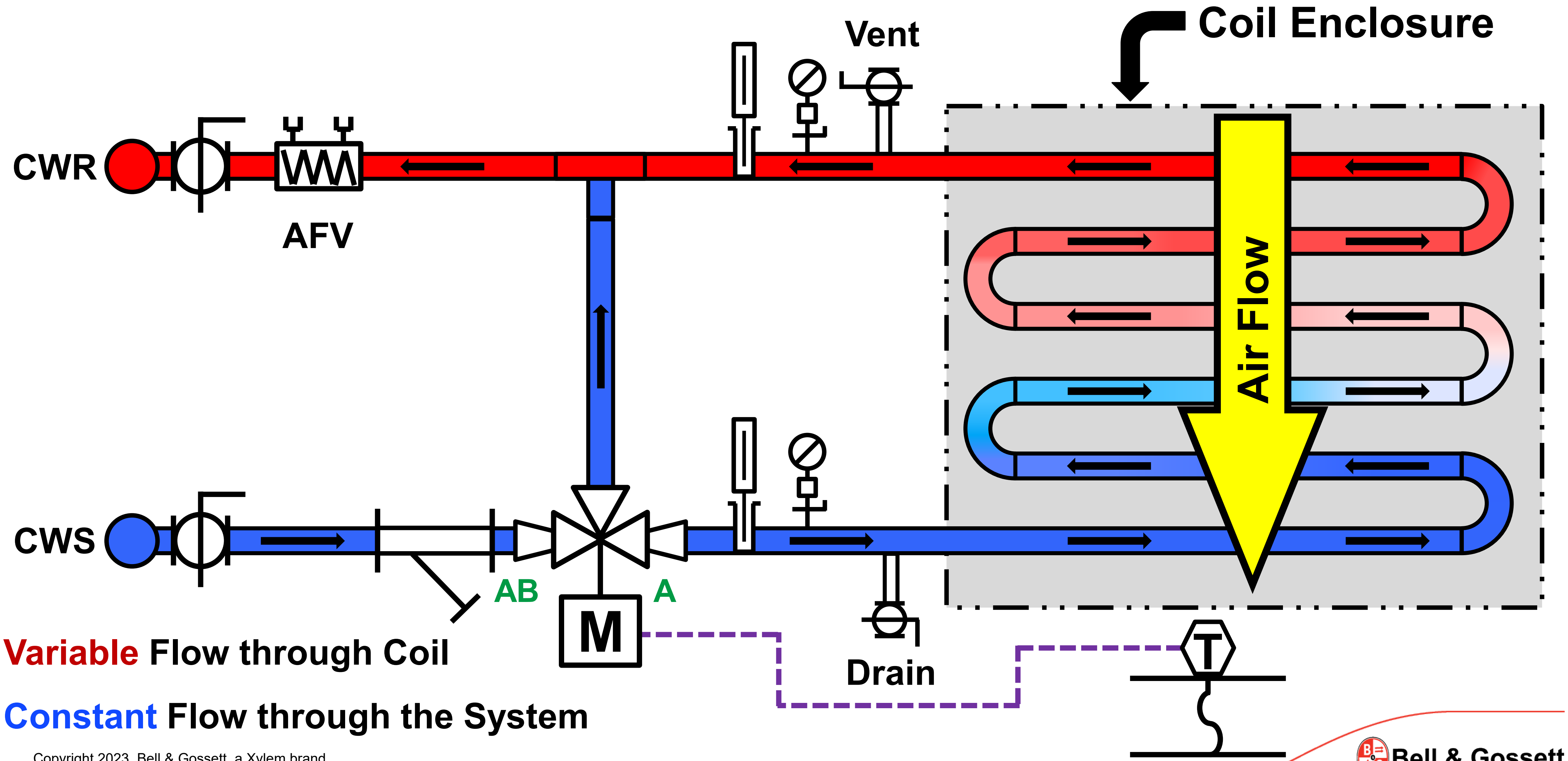
Higher Rangeability than single valve



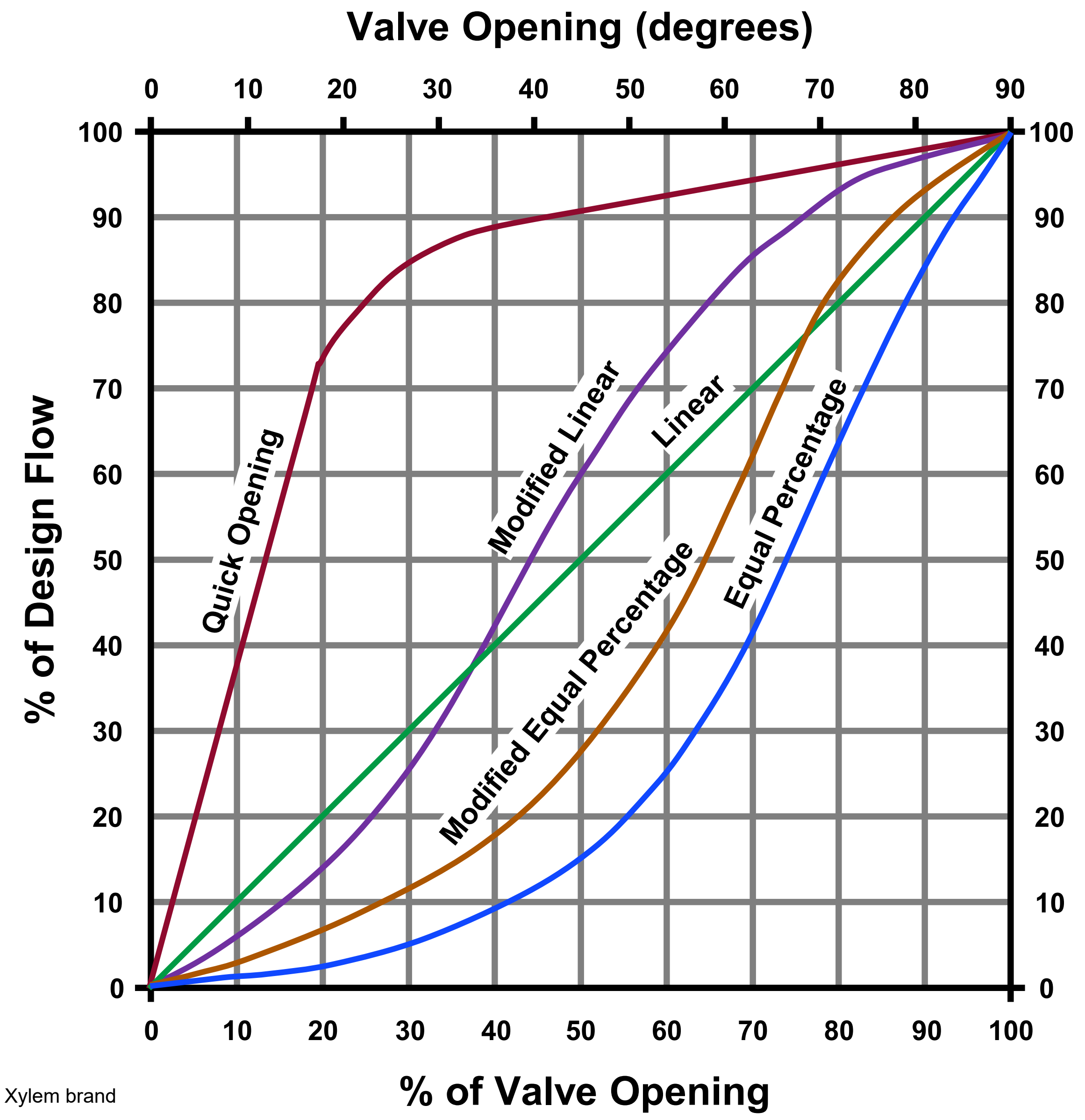
- **Variable** **Flow through Coil**
- **Variable** **Flow through the System**



- **Variable Flow through Coil**
- **Constant Flow through the System**



- **Variable Flow through Coil**
- **Constant Flow through the System**



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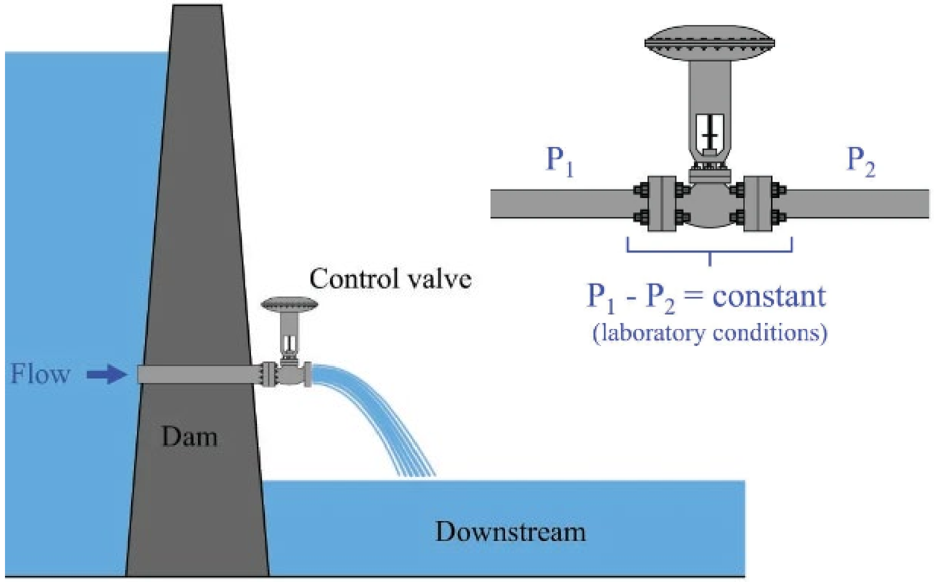
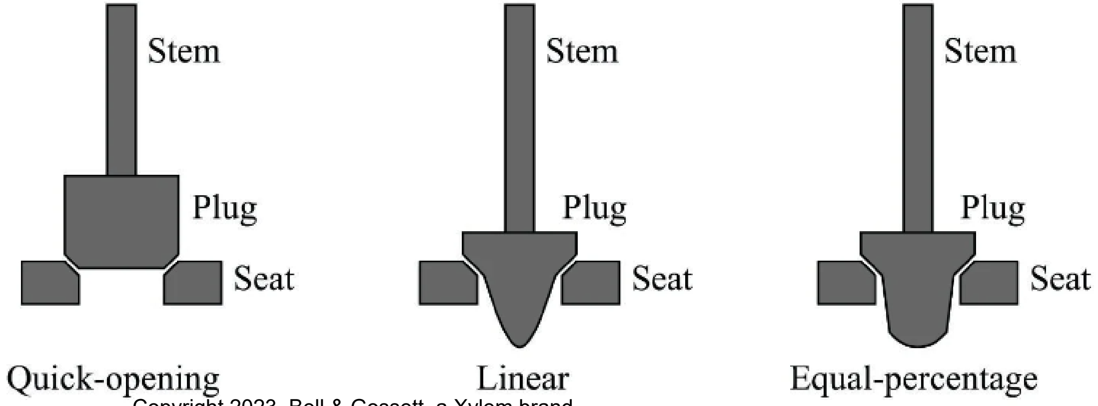
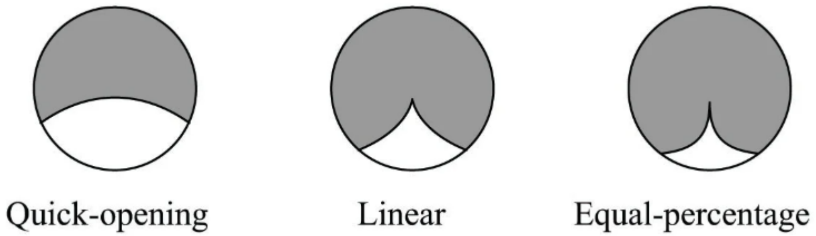
- Assumes control valve is only pressure drop
- “Theoretical” curve has Authority of 1.0
- Valve trim shape changes curve profile



Globe Type Valves



Ball Type Valves



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Chapter 46 - Valves

From Control Valve Flow Characteristics, Equal-Percentage, Page 46.9

The selection of the **control valve pressure drop** directly affects the **valve authority** and should be at least **25%-50%** of the **branch pressure drop.**
(i.e., the pressure drop from the branch connection from the supply main to the return main, including the piping, fittings, coil, balancing device and control valve).

Coil Performance + EPCV Performance = Linear Coil Output

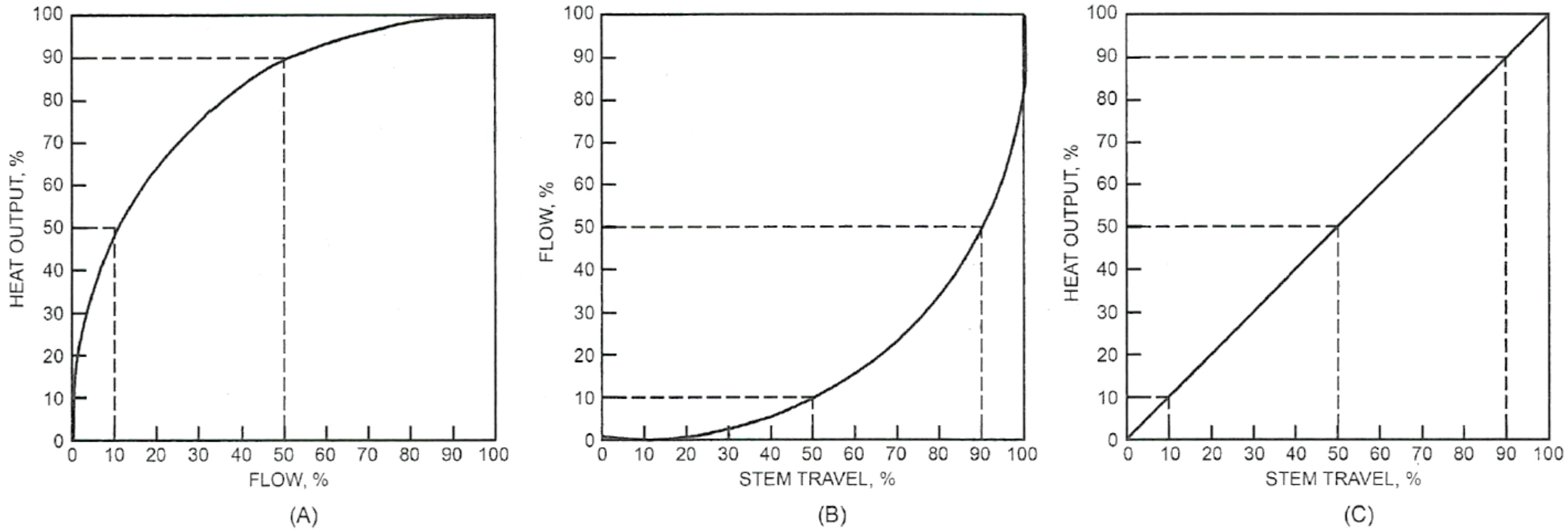


Fig. 17 Heat Output, Flow, and Stem Travel Characteristics of Equal-Percentage Valve

- **Flowrate in GPM** that produces a **1 PSI** pressure drop across the wide-open valve

$$\textbf{Valve Coefficient } (C_v) = Q\sqrt{\frac{(SG)}{\Delta P}}$$

For Water:

$$\textbf{Valve Coefficient } (C_v) = Q \div \sqrt{\Delta P}$$

NOTE: ΔP must be in PSI

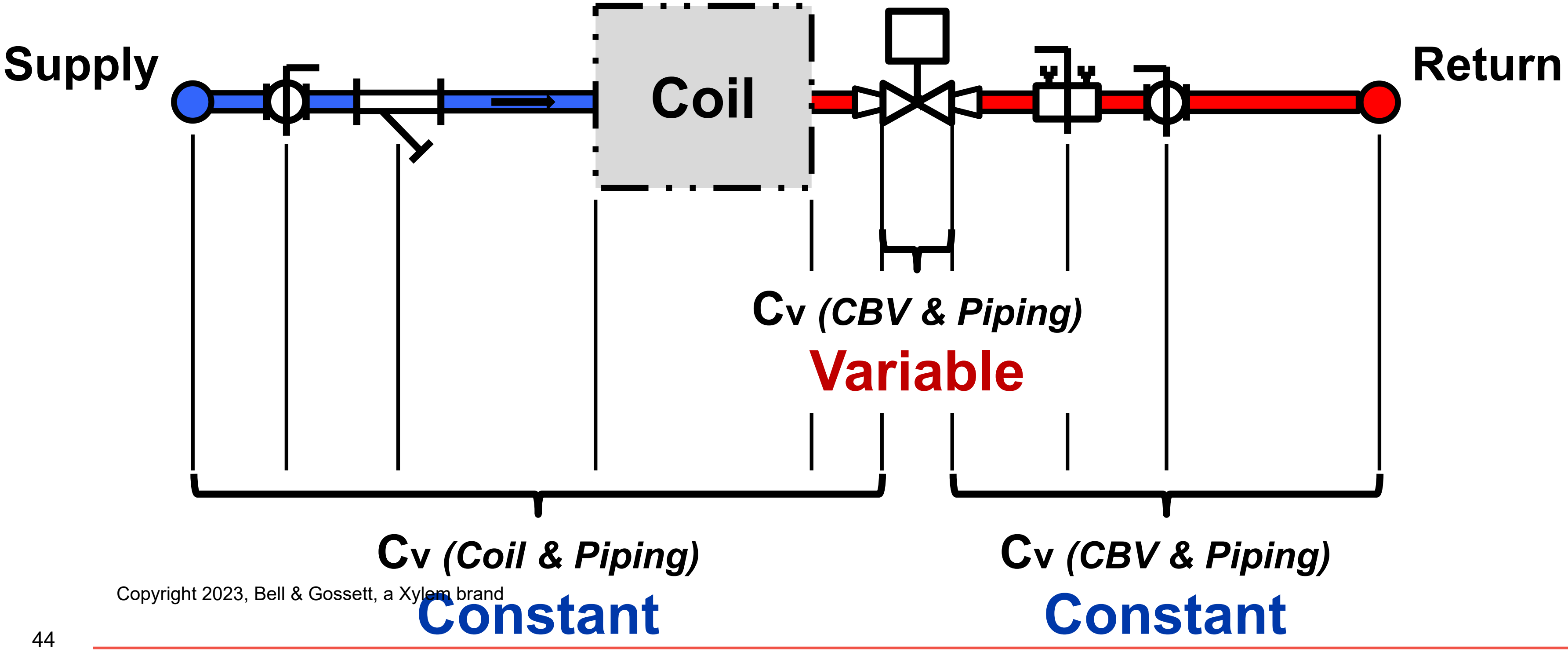
$$\text{Valve Coefficient } (C_v) = Q\sqrt{\frac{(SG)}{\Delta P}}$$

- **Flowrate in GPM** that produces a **1 PSI** pressure drop across the wide-open valve
- Selected to provide design flow at 25%-50% of the total available branch pressure drop

For Water:

$$\text{Valve Coefficient } (C_v) = Q \div \sqrt{\Delta P}$$

NOTE: ΔP must be in PSI



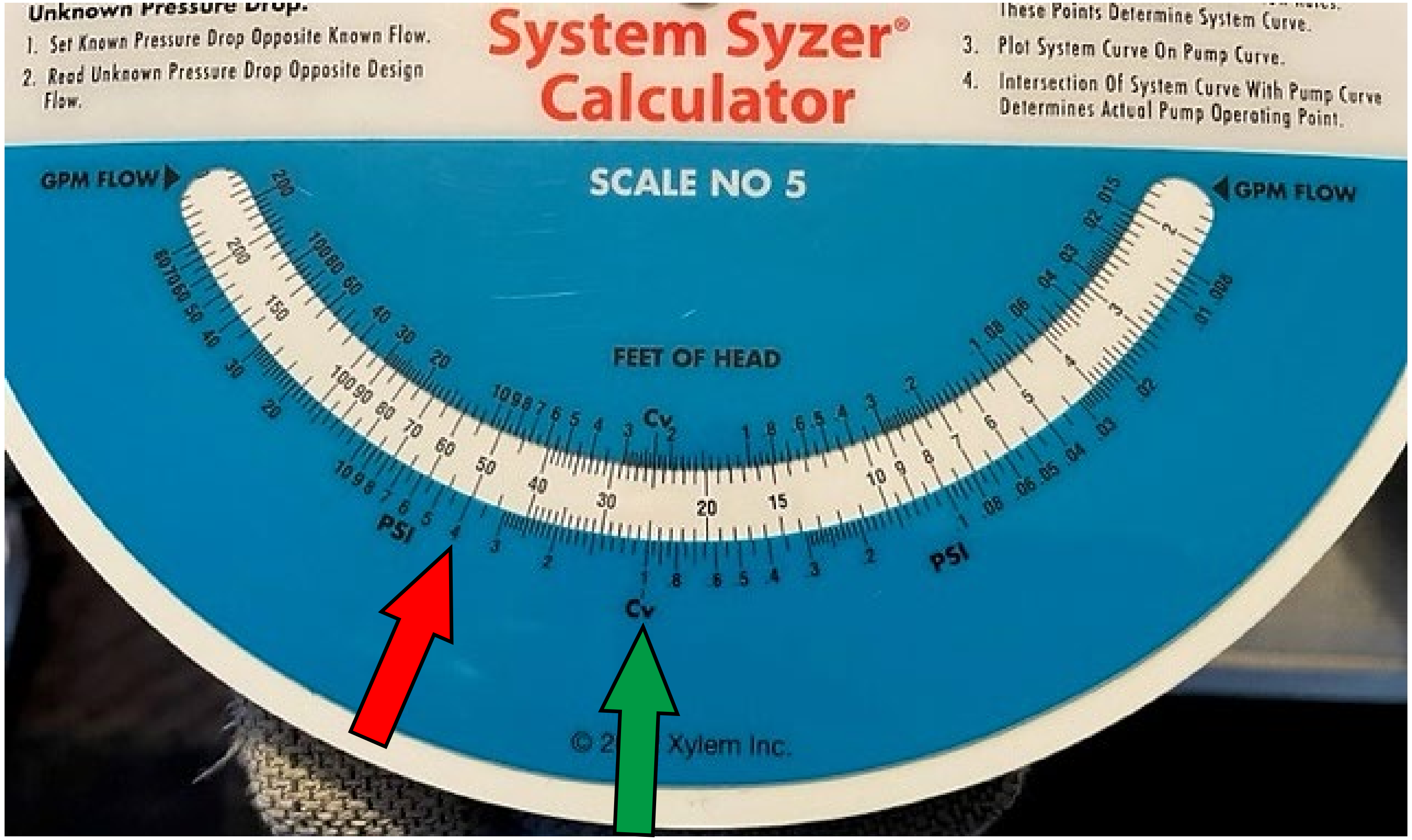
An equal percentage characterized ball valve is needed for a chilled water coil with a design flowrate of 50 GPM. Select the correct control valve size and required Cv.

RULE of THUMB:

Select valve C_v for pressure drop of 3-5 PSI (7'-11.5') at design flow for HVAC Applications

To select, water specific gravity is 1.0 and use 4.0 PSID as target.

$$(C_v) = 50 \div \sqrt{4.0} = 25$$



Step 1: Line up 50 GPM with 4 PSI

Step 2: Find the **Cv** designation under 1 PSI and read flowrate. **(Answer: 25)**

Example: Valve Flow Coefficient (Cv) & Selection

Typical selection for HVAC 2-position applications is 0.5 to 1.0 PSID. Typical selection for HVAC modulating applications is 3.0 to 5.0 PSID.

LINE SIZE	MODEL NO.	FULL PORT[1]	CLOSE OFFΔP[2]	FLOWRATE (GPM) @ DIFFERENTIAL PRESSURE (PSI) ACROSS VALVE											
				2-POSITION HVAC APPS					HVAC MODULATING APPS						
				Cv[3]											
				0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.0	10.0
1/2"	UR2A1_		130 PSI	0.3	0.38	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.8	1.0	1.2
	UR2A2_			0.5	0.68	0.8	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.8	2.2
	UR2A3_			0.9	1.3	1.6	1.8	2.1	2.3	2.4	2.6	2.8	2.9	3.4	4.1
	UR2A4_			1.8	2.6	3.2	3.7	4.1	4.5	4.9	5.2	5.5	5.8	6.9	8.2
	UR2A5_			3.3	4.7	5.8	6.6	7.4	8.1	8.8	9.4	10.0	10.5	12.4	14.9
	UR2A6_	•		8.3	11.7	14.3	16.5	18.5	20.3	21.9	23.4	24.8	26.2	31.0	37.0
	UR2A7_			5.7	8.0	9.8	11.3	12.6	13.9	15.0	16.0	17.0	17.9	21.2	25.3
3/4"	UR2B6_		130 PSI	0.2	0.31	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	1.0
	UR2B7_			0.4	0.63	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.7	2.0
	UR2B8_			0.8	1.2	1.5	1.7	1.9	2.1	2.2	2.4	2.5	2.7	3.2	3.8
	UR2B1_			1.8	2.5	3.1	3.5	4.0	4.3	4.7	5.0	5.3	5.6	6.6	7.9
	UR2B2_			3.0	4.3	5.3	6.1	6.8	7.4	8.0	8.6	9.1	9.6	11.4	13.6
	UR2B3_	•		10.4	14.7	18.0	20.8	23.2	25.5	27.5	29.4	31.2	32.9	38.9	46.5
	UR2B4_			7.1	10.1	12.4	14.3	16.0	17.5	18.9	20.2	21.4	22.6	26.7	31.9
	UR2B5_	•		20.2	28.6	35.0	40.4	45.2	49.5	53.5	57.2	60.7	64.0	75.7	90.4
1"	UR2C1_		100 PSI	6.4	9.0	11.0	12.7	14.2	15.6	16.8	18.0	19.1	20.1	23.8	28.5
	UR2C2_	•		20.1	28.4	34.8	40.2	44.9	49.2	53.1	56.8	60.2	63.5	75.1	89.8
	UR2C7_			3.1	4.4	5.4	6.2	7.0	7.6	8.2	8.8	9.3	9.8	11.6	13.9
	UR2C3_			10.8	15.3	18.7	21.6	24.2	26.5	28.6	30.6	32.5	34.2	40.5	48.4
	UR2C4_	•		38.3	54.2	66.4	76.7	85.7	93.9	101.4	108.4	115.0	121.2	143.4	171.4
	UR2C5_			18.5	26.1	32.0	36.9	41.3	45.2	48.8	52.2	55.4	58.4	69.1	82.5
	UR2C6_	•		31.0	43.9	53.8	62.1	69.4	76.0	82.1	87.8	93.1	98.2	116.1	138.8

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Example: Valve Flow Coefficient (Cv) & Selection

Typical selection for HVAC 2-position applications is 0.5 to 1.0 PSID. Typical selection for HVAC modulating applications is 3.0 to 5.0 PSID.

LINE SIZE	MODEL NO.	FULL PORT[1]	CLOSE OFF ΔP[2]	FLOWRATE (GPM) @ DIFFERENTIAL PRESSURE (PSI) ACROSS VALVE											
				2-POSITION HVAC APPS					HVAC MODULATING APPS						
					Cv[3]										
				0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.0	10.0
1/2"	UR2A1_		130 PSI	0.3	0.38	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.8	1.0	1.2
	UR2A2_			0.5	0.68	0.8	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.8	2.2
	UR2A3_			0.9	1.3	1.6	1.8	2.1	2.3	2.4	2.6	2.8	2.9	3.4	4.1
	UR2A4_			1.8	2.6	3.2	3.7	4.1	4.5	4.9	5.2	5.5	5.8	6.9	8.2
	UR2A5_			3.3	4.7	5.8	6.6	7.4	8.1	8.8	9.4	10.0	10.5	12.4	14.9
	UR2A6_	•		8.3	11.7	14.3	16.5	18.5	20.3	21.9	23.4	24.8	26.2	31.0	37.0
	UR2A7_			5.7	8.0	9.8	11.3	12.6	13.9	15.0	16.0	17.0	17.9	21.2	25.3
3/4"	UR2B6_		130 PSI	0.2	0.31	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	1.0
	UR2B7_			0.4	0.63	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.7	2.0
	UR2B8_			0.8	1.2	1.5	1.7	1.9	2.1	2.2	2.4	2.5	2.7	3.2	3.8
	UR2B1_			1.8	2.5	3.1	3.5	4.0	4.3	4.7	5.0	5.3	5.6	6.6	7.9
	UR2B2_			3.0	4.3	5.3	6.1	6.8	7.4	8.0	8.6	9.1	9.6	11.4	13.6
	UR2B3_	•		10.4	14.7	18.0	20.8	23.2	25.5	27.5	29.4	31.2	32.9	38.9	46.5
	UR2B4_			7.1	10.1	12.4	14.3	16.0	17.5	18.9	20.2	21.4	22.6	26.7	31.9
	UR2B5_	•		20.2	28.6	35.0	40.4	45.2	49.5	53.5	57.2	60.7	64.0	75.7	90.4
1"	UR2C1_		100 PSI	6.4	9.0	11.0	12.7	14.2	15.6	16.8	18.0	19.1	20.1	23.8	28.5
	UR2C2_	•		20.1	28.4	34.8	40.2	44.9	49.2	53.1	56.8	60.2	63.5	75.1	89.8
	UR2C7_			3.1	4.4	5.4	6.2	7.0	7.6	8.2	8.8	9.3	9.8	11.6	13.9
	UR2C3_			10.8	15.3	18.7	21.6	24.2	26.5	28.6	30.6	32.5	34.2	40.5	48.4
	UR2C4_	•		38.3	54.2	66.4	76.7	85.7	93.9	101.4	108.4	115.0	121.2	143.4	171.4
	UR2C5_			18.5	26.1	32.0	36.9	41.3	45.2	48.8	52.2	55.4	58.4	69.1	82.5
	UR2C6_	•		31.0	43.9	53.8	62.1	69.4	76.0	82.1	87.8	93.1	98.2	116.1	138.8

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Example: Valve Flow Coefficient (Cv) & Selection

Typical selection for HVAC 2-position applications is 0.5 to 1.0 PSID. Typical selection for HVAC modulating applications is 3.0 to 5.0 PSID.

LINE SIZE	MODEL NO.	FULL PORT[1]	CLOSE OFF ΔP[2]	FLOWRATE (GPM) @ DIFFERENTIAL PRESSURE (PSI) ACROSS VALVE											
				2-POSITION HVAC APPS					HVAC MODULATING APPS						
					Cv[3]										
				0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.0	10.0
1/2"	UR2A1_		130 PSI	0.3	0.38	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.8	1.0	1.2
	UR2A2_			0.5	0.68	0.8	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.8	2.2
	UR2A3_			0.9	1.3	1.6	1.8	2.1	2.3	2.4	2.6	2.8	2.9	3.4	4.1
	UR2A4_			1.8	2.6	3.2	3.7	4.1	4.5	4.9	5.2	5.5	5.8	6.9	8.2
	UR2A5_			3.3	4.7	5.8	6.6	7.4	8.1	8.8	9.4	10.0	10.5	12.4	14.9
	UR2A6_	•		8.3	11.7	14.3	16.5	18.5	20.3	21.9	23.4	24.8	26.2	31.0	37.0
	UR2A7_			5.7	8.0	9.8	11.3	12.6	13.9	15.0	16.0	17.0	17.9	21.2	25.3
3/4"	UR2B6_		130 PSI	0.2	0.31	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	1.0
	UR2B7_			0.4	0.63	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.7	2.0
	UR2B8_			0.8	1.2	1.5	1.7	1.9	2.1	2.2	2.4	2.5	2.7	3.2	3.8
	UR2B1_			1.8	2.5	3.1	3.5	4.0	4.3	4.7	5.0	5.3	5.6	6.6	7.9
	UR2B2_			3.0	4.3	5.3	6.1	6.8	7.4	8.0	8.6	9.1	9.6	11.4	13.6
	UR2B3_	•		10.4	14.7	18.0	20.8	23.2	25.5	27.5	29.4	31.2	32.9	38.9	46.5
	UR2B4_			7.1	10.1	12.4	14.3	16.0	17.5	18.9	20.2	21.4	22.6	26.7	31.9
	UR2B5_	•		20.2	28.6	35.0	40.4	45.2	49.5	53.5	57.2	60.7	64.0	75.7	90.4
1"	UR2C1_		100 PSI	6.4	9.0	11.0	12.7	14.2	15.6	16.8	18.0	19.1	20.1	23.8	28.5
	UR2C2_	•		20.1	28.4	34.8	40.2	44.9	49.2	53.1	56.8	60.2	63.5	75.1	89.8
	UR2C7_			3.1	4.4	5.4	6.2	7.0	7.6	8.2	8.8	9.3	9.8	11.6	13.9
	UR2C3_			10.8	15.3	18.7	21.6	24.2	26.5	28.6	30.6	32.5	34.2	40.5	48.4
	UR2C4_	•		38.3	54.2	66.4	76.7	85.7	93.9	101.4	108.4	115.0	121.2	143.4	171.4
	UR2C5_			18.5	26.1	32.0	36.9	41.3	45.2	48.8	52.2	55.4	58.4	69.1	82.5
	UR2C6_	•		31.0	43.9	53.8	62.1	69.4	76.0	82.1	87.8	93.1	98.2	116.1	138.8

Example: Valve Flow Coefficient (Cv) & Selection

Typical selection for HVAC 2-position applications is 0.5 to 1.0 PSID. Typical selection for HVAC modulating applications is 3.0 to 5.0 PSID.

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				2-POSITION HVAC APPS					HVAC MODULATING APPS						
					Cv[3]										
				0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.0	10.0
1/2"	UR2A1_		130 PSI	0.3	0.38	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.8	1.0	1.2
	UR2A2_			0.5	0.68	0.8	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.8	2.2
	UR2A3_			0.9	1.3	1.6	1.8	2.1	2.3	2.4	2.6	2.8	2.9	3.4	4.1
	UR2A4_			1.8	2.6	3.2	3.7	4.1	4.5	4.9	5.2	5.5	5.8	6.9	8.2
	UR2A5_			3.3	4.7	5.8	6.6	7.4	8.1	8.8	9.4	10.0	10.5	12.4	14.9
	UR2A6_	•		8.3	11.7	14.3	16.5	18.5	20.3	21.9	23.4	24.8	26.2	31.0	37.0
	UR2A7_			5.7	8.0	9.8	11.3	12.6	13.9	15.0	16.0	17.0	17.9	21.2	25.3
3/4"	UR2B6_		130 PSI	0.2	0.31	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	1.0
	UR2B7_			0.4	0.63	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.7	2.0
	UR2B8_			0.8	1.2	1.5	1.7	1.9	2.1	2.2	2.4	2.5	2.7	3.2	3.8
	UR2B1_			1.8	2.5	3.1	3.5	4.0	4.3	4.7	5.0	5.3	5.6	6.6	7.9
	UR2B2_			3.0	4.3	5.3	6.1	6.8	7.4	8.0	8.6	9.1	9.6	11.4	13.6
	UR2B3_	•		10.4	14.7	18.0	20.8	23.2	25.5	27.5	29.4	31.2	32.9	38.9	46.5
	UR2B4_			7.1	10.1	12.4	14.3	16.0	17.5	18.9	20.2	21.4	22.6	26.7	31.9
	UR2B5_	•		20.2	28.6	35.0	40.4	45.2	49.5	53.5	57.2	60.7	64.0	75.7	90.4
1"	UR2C1_		100 PSI	6.4	9.0	11.0	12.7	14.2	15.6	16.8	18.0	19.1	20.1	23.8	28.5
	UR2C2_	•		20.1	28.4	34.8	40.2	44.9	49.2	53.1	56.8	60.2	63.5	75.1	89.8
	UR2C7_			3.1	4.4	5.4	6.2	7.0	7.6	8.2	8.8	9.3	9.8	11.6	13.9
	UR2C3_			10.8	15.3	18.7	21.6	24.2	26.5	28.6	30.6	32.5	34.2	40.5	48.4
	UR2C4_	•		38.3	54.2	66.4	76.7	85.7	93.9	101.4	108.4	115.0	121.2	143.4	171.4
	UR2C5_			18.5	26.1	32.0	36.9	41.3	45.2	48.8	52.2	55.4	58.4	69.1	82.5
	UR2C6_	•		31.0	43.9	53.8	62.1	69.4	76.0	82.1	87.8	93.1	98.2	116.1	138.8

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Example: Valve Flow Coefficient (Cv) & Selection

Typical selection for HVAC 2-position applications is 0.5 to 1.0 PSID. Typical selection for HVAC modulating applications is 3.0 to 5.0 PSID.

LINE SIZE	MODEL NO.	FULL PORT[1]	CLOSE OFFΔP[2]	FLOWRATE (GPM) @ DIFFERENTIAL PRESSURE (PSI) ACROSS VALVE											
				2-POSITION HVAC APPS					HVAC MODULATING APPS						
					Cv[3]										
				0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.0	10.0
1/2"	UR2A1_		130 PSI	0.3	0.38	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.8	1.0	1.2
	UR2A2_			0.5	0.68	0.8	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.8	2.2
	UR2A3_			0.9	1.3	1.6	1.8	2.1	2.3	2.4	2.6	2.8	2.9	3.4	4.1
	UR2A4_			1.8	2.6	3.2	3.7	4.1	4.5	4.9	5.2	5.5	5.8	6.9	8.2
	UR2A5_			3.3	4.7	5.8	6.6	7.4	8.1	8.8	9.4	10.0	10.5	12.4	14.9
	UR2A6_	•		8.3	11.7	14.3	16.5	18.5	20.3	21.9	23.4	24.8	26.2	31.0	37.0
	UR2A7_			5.7	8.0	9.8	11.3	12.6	13.9	15.0	16.0	17.0	17.9	21.2	25.3
3/4"	UR2B6_		130 PSI	0.2	0.31	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	1.0
	UR2B7_			0.4	0.63	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.7	2.0
	UR2B8_			0.8	1.2	1.5	1.7	1.9	2.1	2.2	2.4	2.5	2.7	3.2	3.8
	UR2B1_			1.8	2.5	3.1	3.5	4.0	4.3	4.7	5.0	5.3	5.6	6.6	7.9
	UR2B2_			3.0	4.3	5.3	6.1	6.8	7.4	8.0	8.6	9.1	9.6	11.4	13.6
	UR2B3_	•		10.4	14.7	18.0	20.8	23.2	25.5	27.5	29.4	31.2	32.9	38.9	46.5
	UR2B4_			7.1	10.1	12.4	14.3	16.0	17.5	18.9	20.2	21.4	22.6	26.7	31.9
	UR2B5_	•		20.2	28.6	35.0	40.4	45.2	49.5	53.5	57.2	60.7	64.0	75.7	90.4
1"	UR2C1_		100 PSI	6.4	9.0	11.0	12.7	14.2	15.6	16.8	18.0	19.1	20.1	23.8	28.5
	UR2C2_	•		20.1	28.4	34.8	40.2	44.9	49.2	53.1	56.8	60.2	63.5	75.1	89.8
	UR2C7_			3.1	4.4	5.4	6.2	7.0	7.6	8.2	8.8	9.3	9.8	11.6	13.9
	UR2C3_			10.8	15.3	18.7	21.6	24.2	26.5	28.6	30.6	32.5	34.2	40.5	48.4
	UR2C4_	•		38.3	54.2	66.4	76.7	85.7	93.9	101.4	108.4	115.0	121.2	143.4	171.4
	UR2C5_			18.5	26.1	32.0	36.9	41.3	45.2	48.8	52.2	55.4	58.4	69.1	82.5
	UR2C6_	•		31.0	43.9	53.8	62.1	69.4	76.0	82.1	87.8	93.1	98.2	116.1	138.8

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Example: Valve Flow Coefficient (Cv) & Selection

Typical selection for HVAC 2-position applications is 0.5 to 1.0 PSID. Typical selection for HVAC modulating applications is 3.0 to 5.0 PSID.

LINE SIZE	MODEL NO.	FULL PORT[1]	CLOSE OFF ΔP[2]
	UR2A1_		
	UR2A2_		
	UR2A3_		
1/2"	UR2A4_		130 PSI
	UR2A5_		
	UR2A6_	•	
	UR2A7_		
	UR2B6_		
	UR2B7_		
	UR2B8_		
3/4"	UR2B1_		130 PSI
	UR2B2_		
	UR2B3_	•	
	UR2B4_		
	UR2B5_	•	
	UR2C1_		100 PSI
	UR2C2_	•	
	UR2C7_		
1"	UR2C3_		
	UR2C4_	•	
	UR2C5_		
	UR2C6_	•	

NOTE 2 The "Close Off Pressure" is the maximum allowable pressure drop across the valve body when the valve is fully closed, such that is can hold against the rated seat leakage

Chapter 46 - Valves

From Control Valve Flow Characteristics, Authority, Page 46.9

Low valve authority leads to unstable flow through the control valve during low-load conditions. An **authority of 1.0** will cause the valve to operate along its **theoretical curve**. …… In modulating applications, an **authority** between **0.25-0.50** usually provides the right balance between controllability and energy performance.

$$\textbf{Authority } (\beta) = \frac{\textbf{\textit{DP} of Valve}}{\textbf{\textit{DP} of Valve + \textit{DP} of branch}}$$

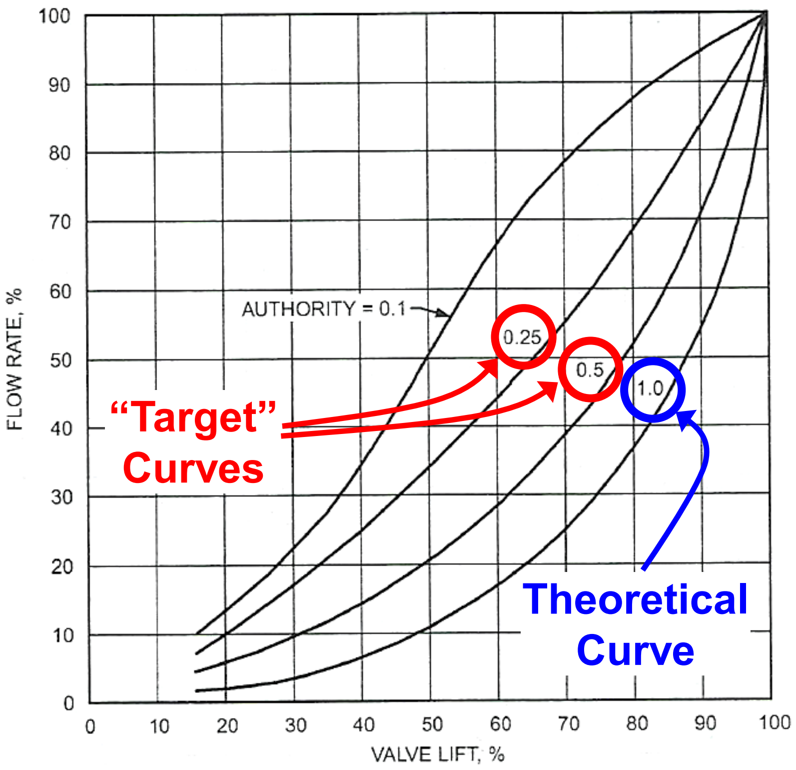
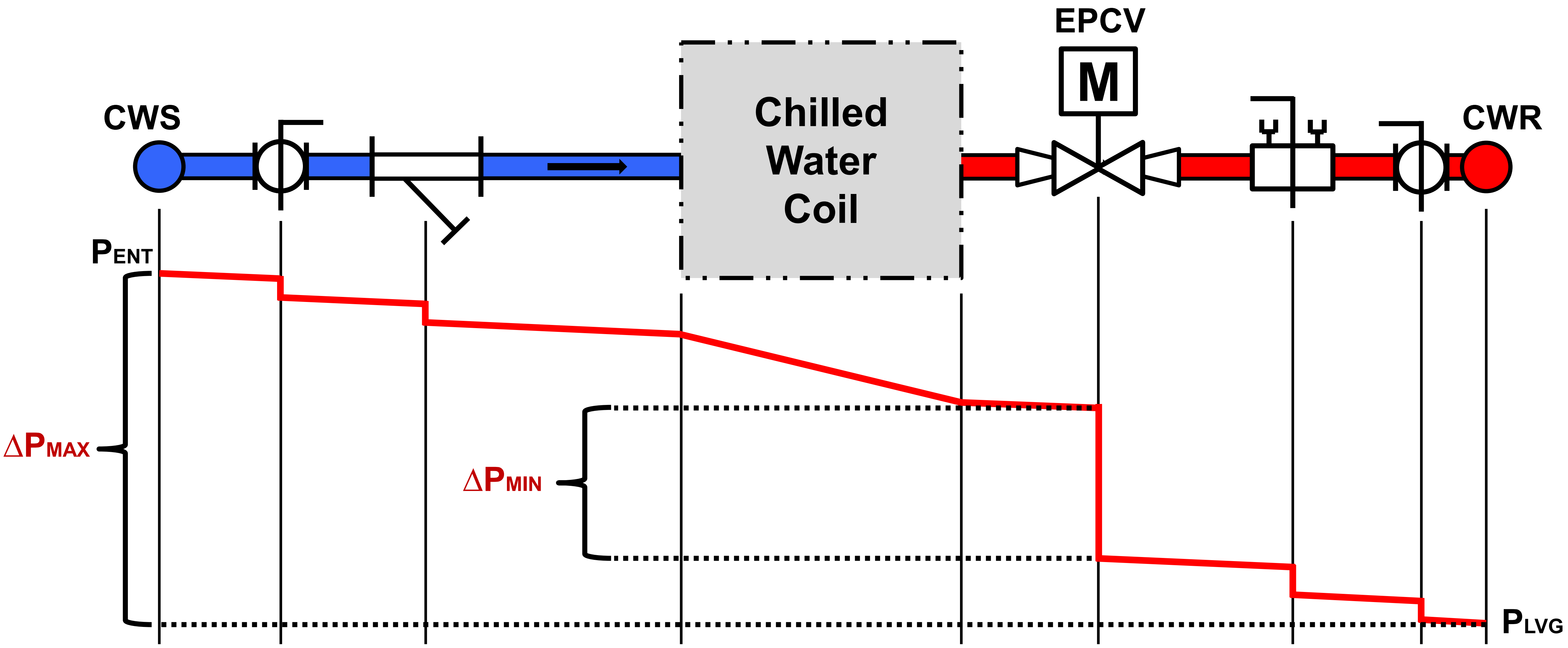
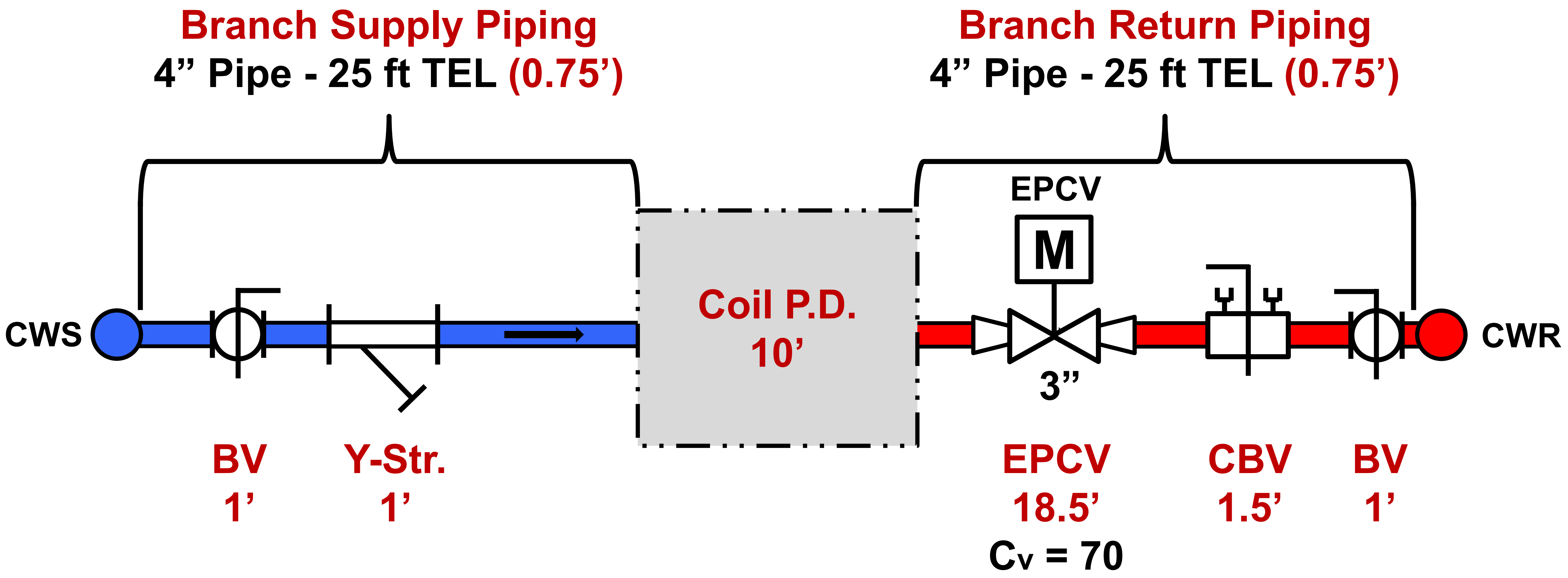


Fig. 19 Authority Distortion of Equal-Percentage Flow Characteristic



$$\text{Authority } (\beta) = \frac{\Delta P_{MIN}}{\Delta P_{MAX}}$$

Known Pressure Drop (KPD) Analysis w/EPCV & CBV

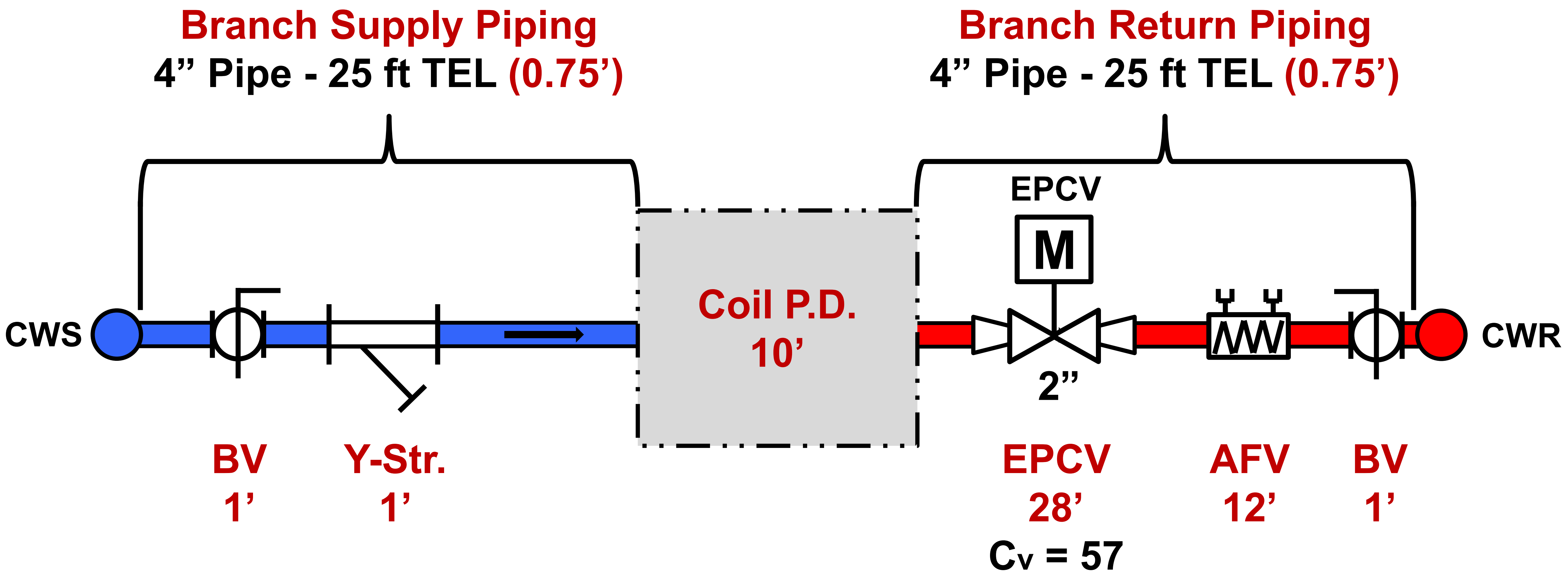


Branch KPD (less EPCV) = 16.0’ @ 195 GPM

Total Branch KPD = 34.5’ @ 195 GPM

$$(\beta) = \frac{18.5}{18.5 + 16.0} = 0.54$$

Known Pressure Drop (KPD) Analysis w/EPCV & AFV



Branch KPD (less EPCV) = 26.5’ @ 195 GPM

Total Branch KPD = 54.5’ @ 195 GPM

$$(\beta) = \frac{28.0}{28.0 + 26.5} = 0.51$$

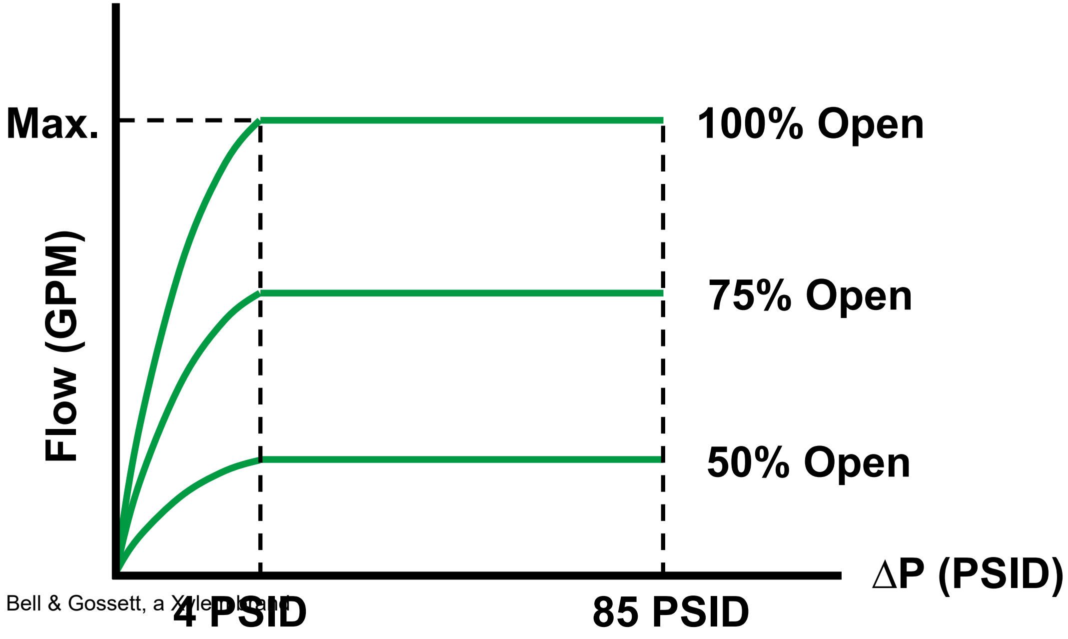
Stop the Madness!

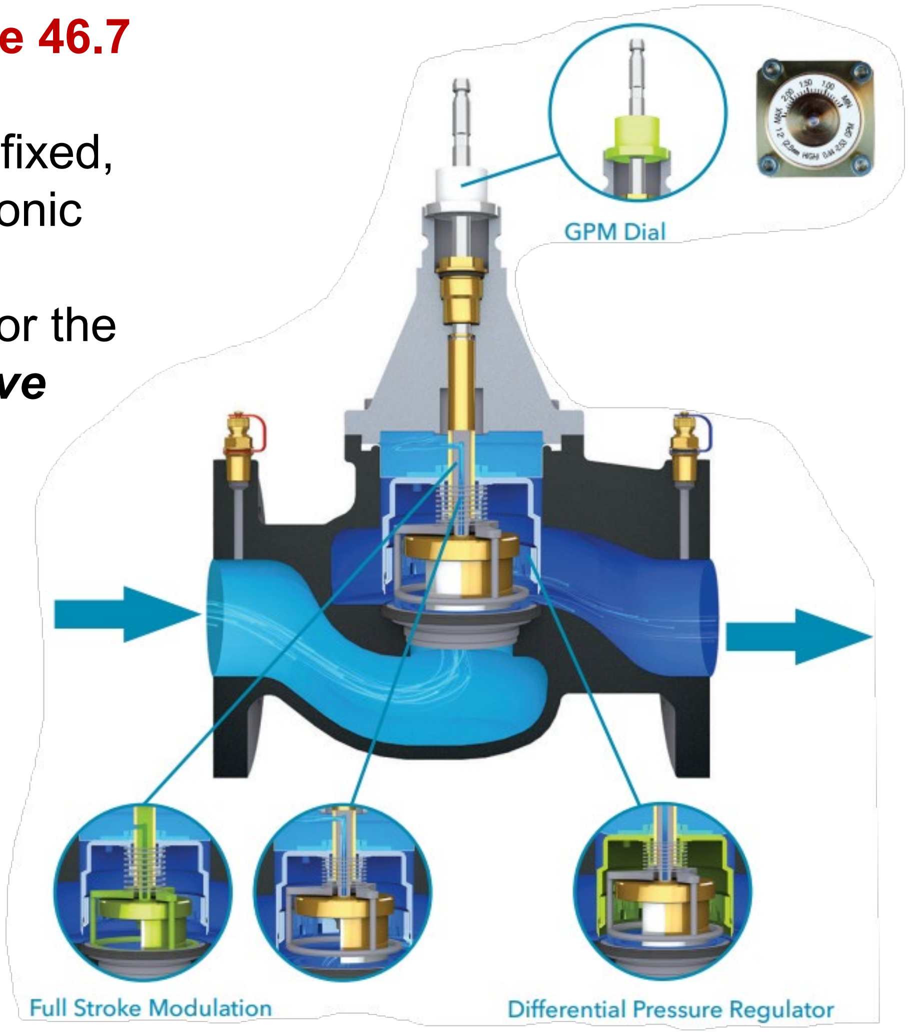
I can skip the Valve Coefficient calculations??

Chapter 46 - Valves

From Automatic Valves, Pressure-Independent Control Valves, Page 46.7

Advantages of PICV's include stable flow when the stem position is fixed, **regardless of pressure fluctuations**, and the elimination of a hydronic balancing device where the PICV is mounted. Sizing a PICV is straightforward because it is no longer necessary to calculate a **C_v** for the valve. …..Ultimately, PICV's operate as if they have the ***perfect valve authority (β = 1.0),*** all though mathematically impossible.





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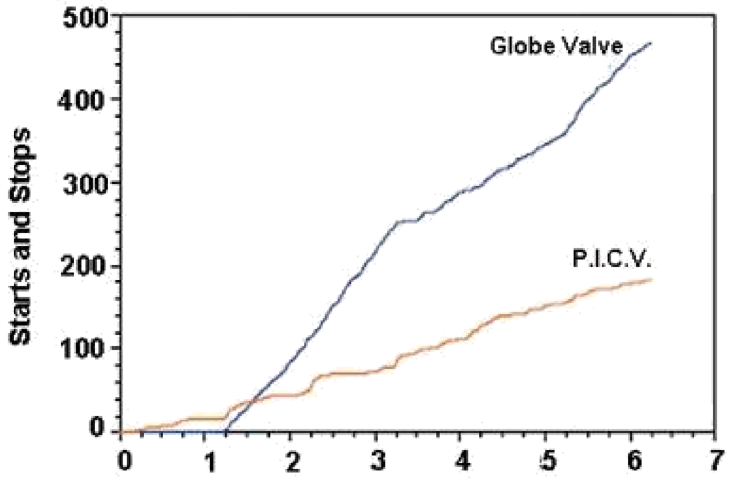
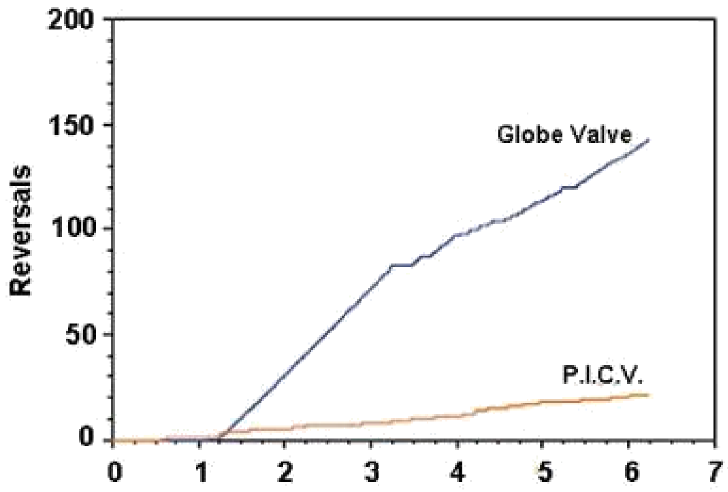
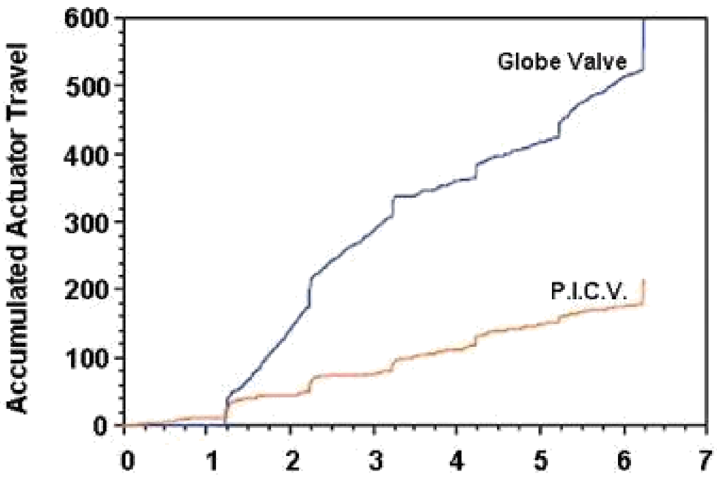


Accumulated Starts and Stops

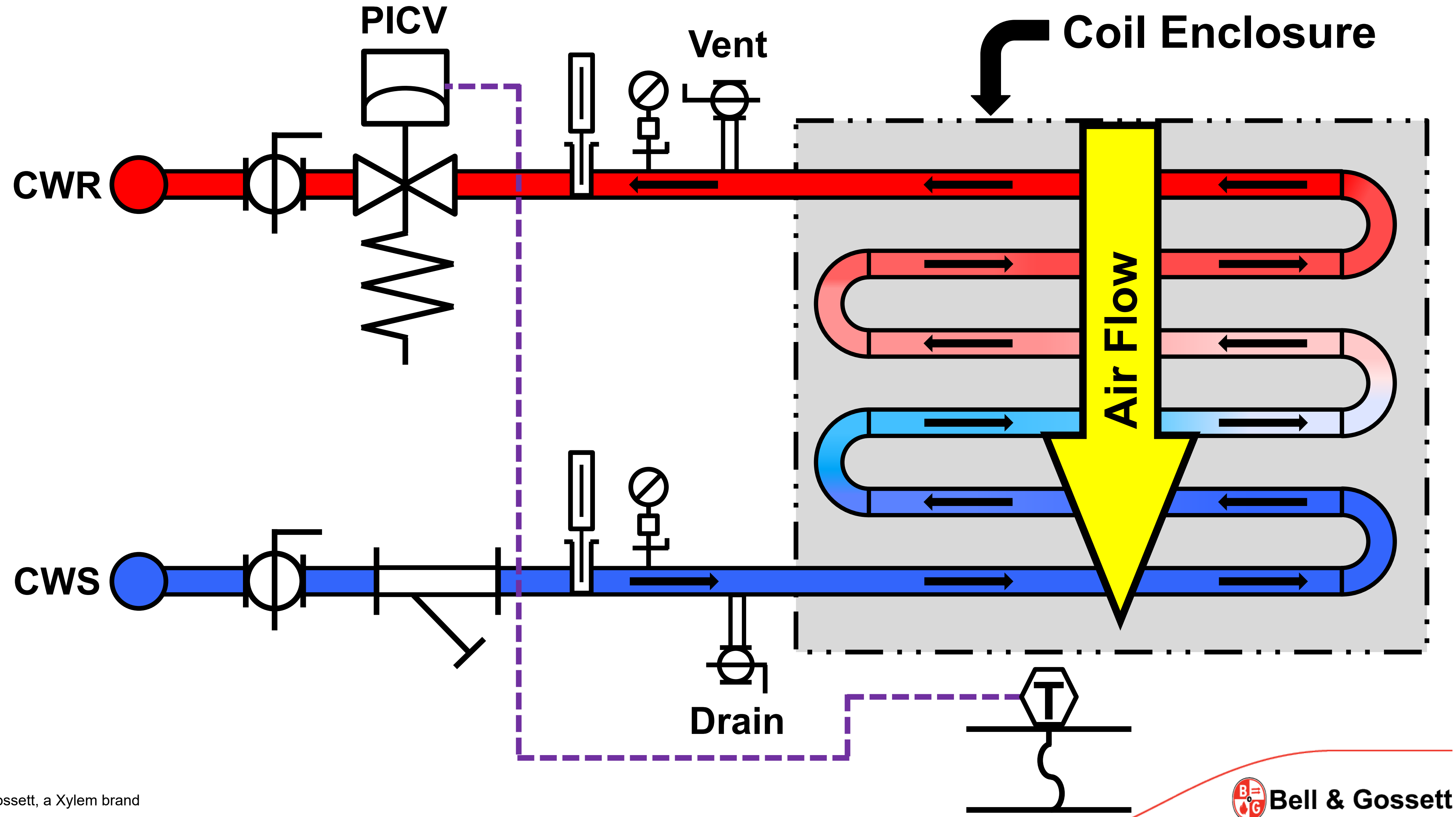


Accumulated Actuator Reversals

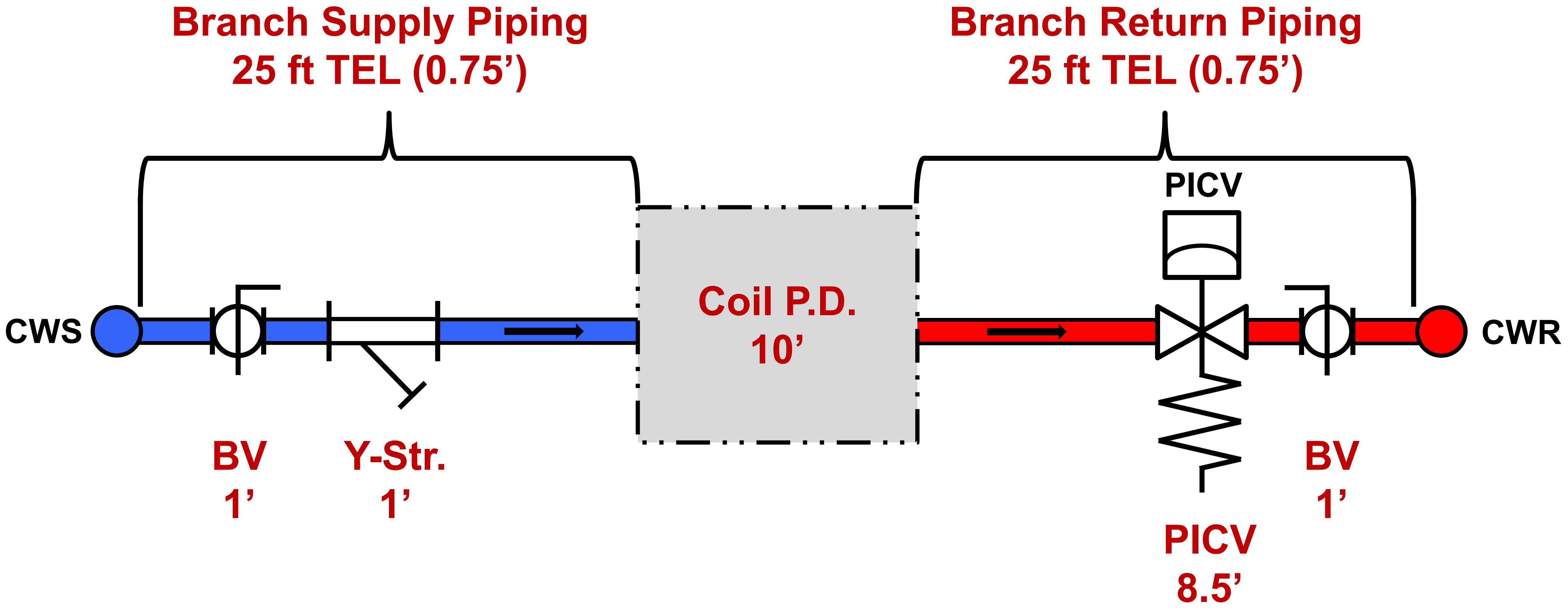


Accumulated Actuator Travel

- Stable Part Load Flow Control
- Valve position adjustment for load change only
- Improved Variable Speed Pump Control


PICV
Vent
Coil Enclosure
CWR
Air Flow
CWS
Drain
T

Known Pressure Drop (KPD) Analysis w/PICV



Total Branch KPD = 23.0' @ 195 GPM

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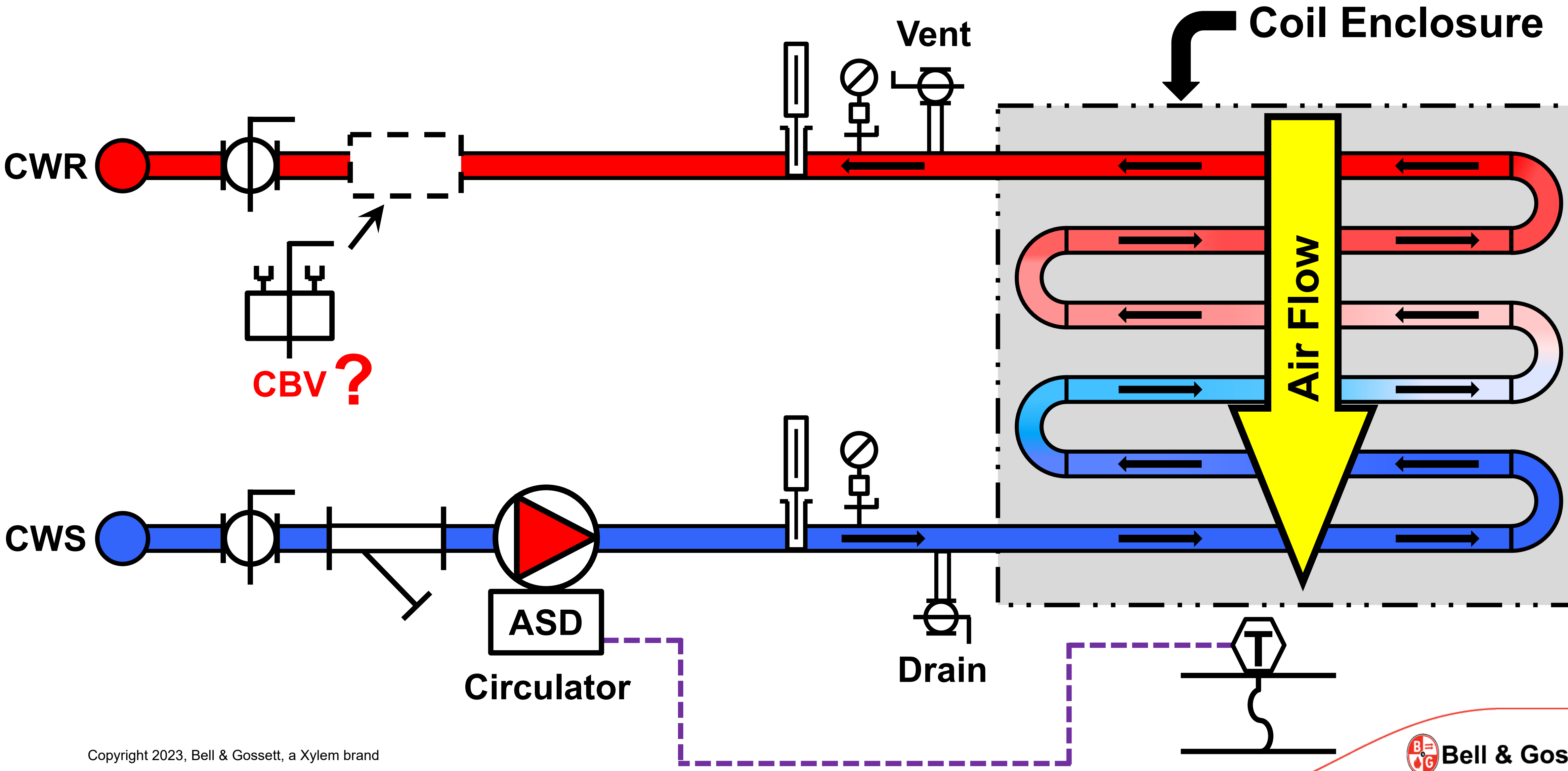
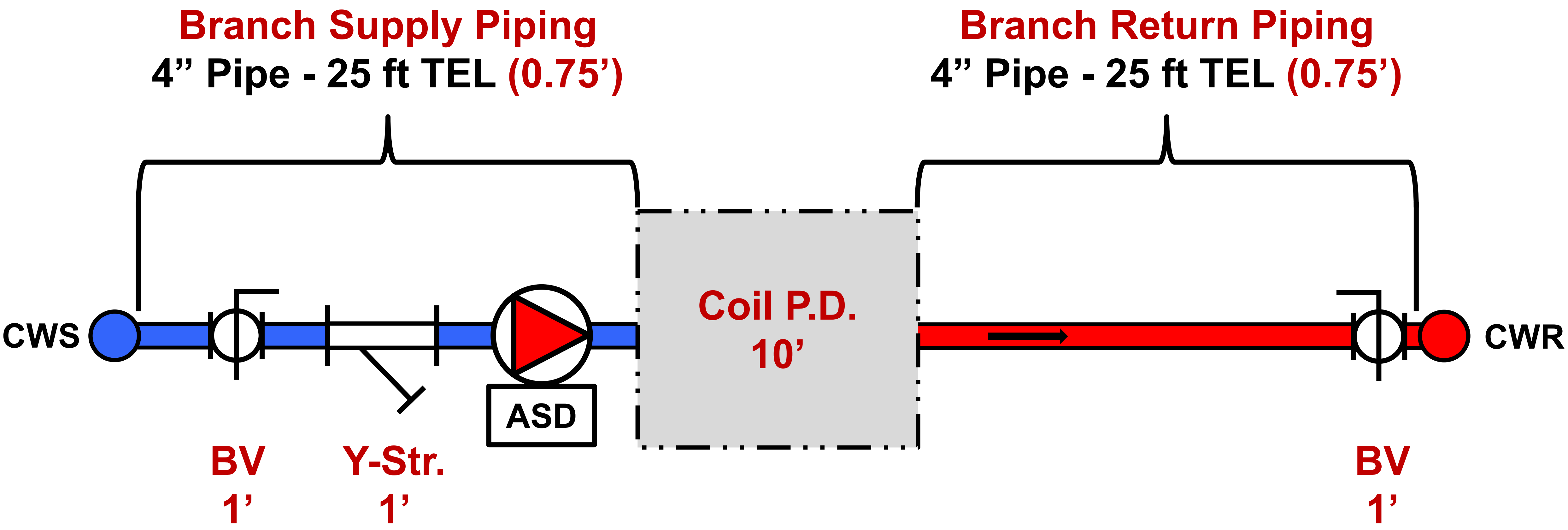


Vent
Coil Enclosure
CWR
Air Flow
CBV?
CWS
ASD
Circulator
Drain
T

Known Pressure Drop (KPD) Analysis w/VFD Pump



Total Branch KPD = 14.5' @ 195 GPM

Zone Pumping – Basic Flow Diagram

Primary-Secondary Zone Pumping