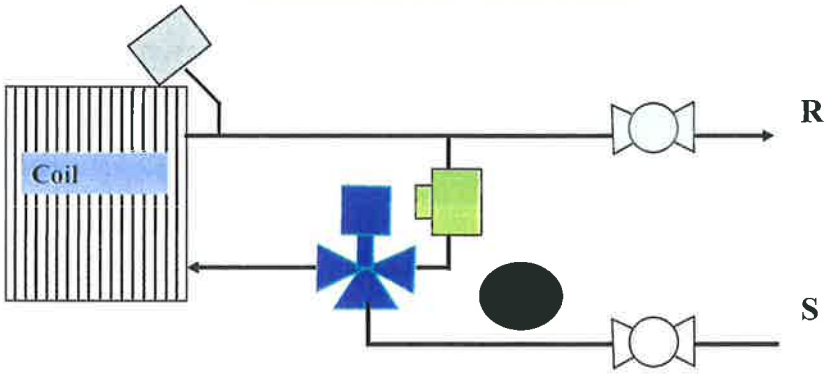
CONTROL VALVES



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DESIGN CHECKLIST STEPS

- Control Zoning Decisions
- Calculate peak zone cooling and heating loads
- Water terminal selections, flow rate and placement
  - Size room fan coil terminals
  - Select terminal control package
- Water piping system design
- Water system pressure loss estimate
- Pump selection
- Select chiller(s), boiler(s) and cooling tower(s)

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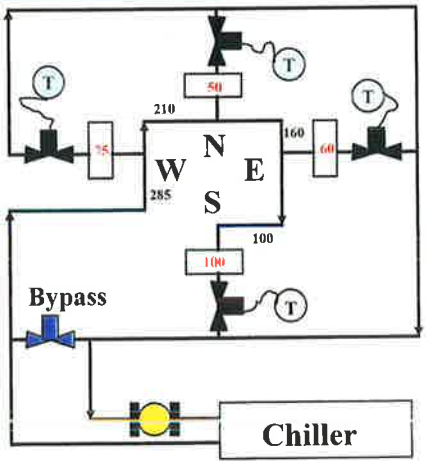
TWO-WAY MODULATING VALVE

- Throttle water flow through coils
  - Laminar flow at low load
- Variable circuit flow
- Variable water volume energy savings
- Chiller minimum flow
  - Laminar part load flow
- Pump minimum flow
  - Dead head pump
- Bypass protection needed
- Low cost control
- Can use "FLOW" diversity
  - Not all exposures peak at same time



Supply GPM's

Exposure	N	E	S	W	Tot
Peak GPM	210	160	100	285	285
Design GPM	153	131	100	191	191
Div. Mult.	.73	.82	1.0	.67	

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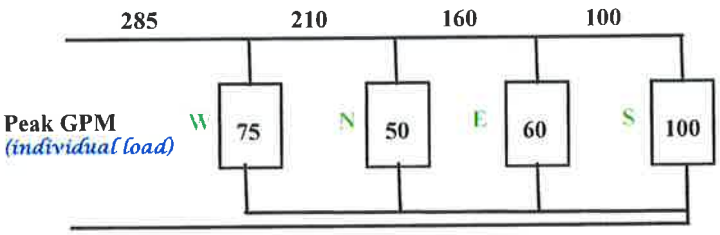

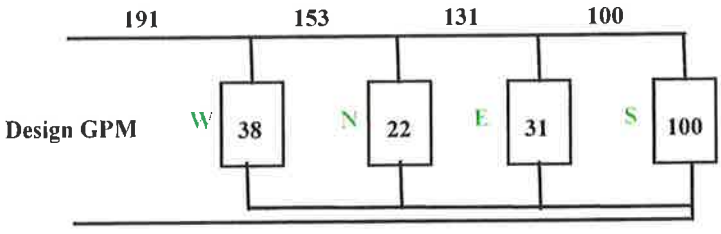

Diversity 0.76 0.73 0.82 1.00

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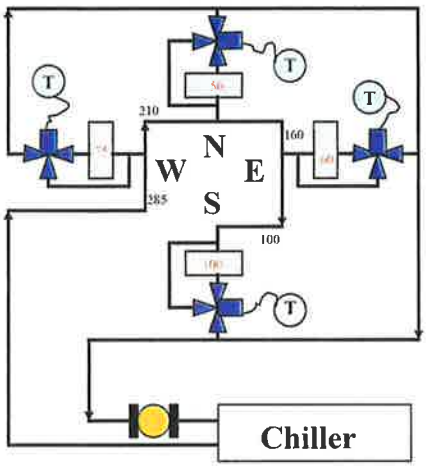
THREE-WAY VALVE

(ON-OFF OR MODULATING)

- Throttle water flow through coils
  - Laminar part load flow
- Constant circuit and main flow
- Chiller flow constant
- Pump flow constant
- No variable water flow energy savings
- No bypass needed
- More costly control package
- Cannot use GPM diversity
  - Peak flow at each exposure at all times



Exposure	N	E	S	W	Tot
Peak GPM	210	160	100	285	285
Design GPM	210	160	100	285	285

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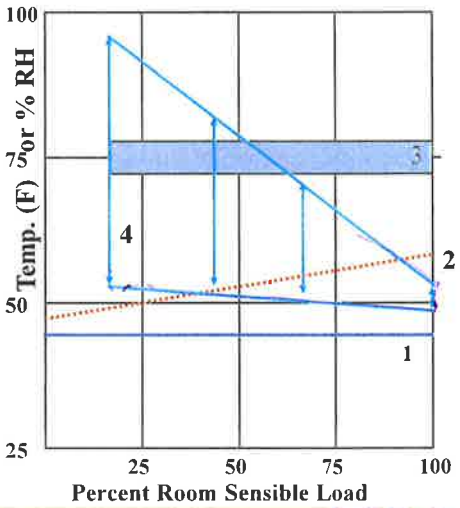
AUTOMATIC ON-OFF WATER

- Constant air flow
- Cycle water flow on-off
- Entering chilled water temp. 45F (1)
  - **Coil surface temp. F (2)**
  - **Room Dry Bulb Range - F (3)**
  - **Room Relative Humidity Range % (4)**
    - **Poor humidity mitigation at partial load**



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On off, humidity will increase.

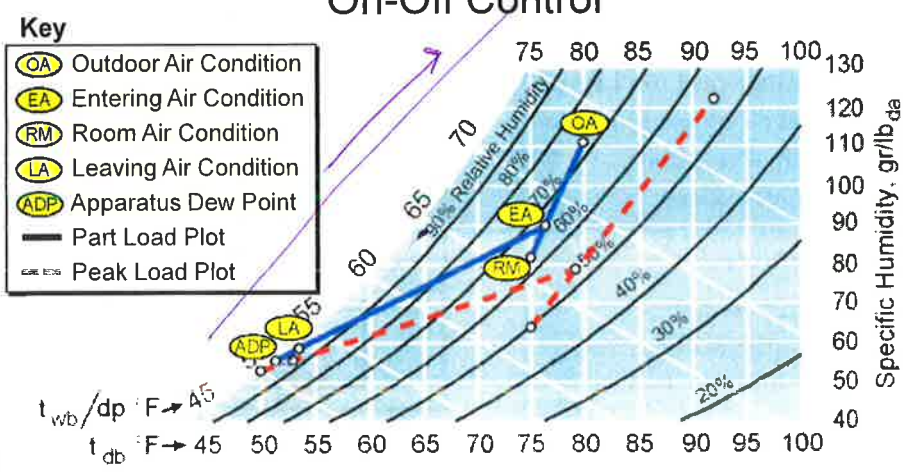
$\Delta h \uparrow$

$q = \dot{m}(h_1 - h_2)$

$\downarrow$

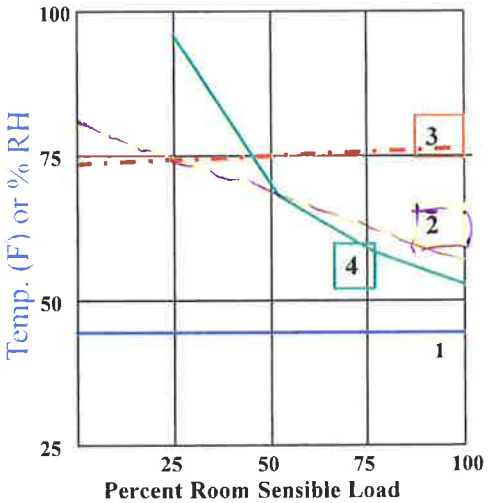
System Psychrometric Plots

On-Off Control



MODULATING WATER VALVE

- **Constant air flow**
- **Entering chilled water temp. 45F (1)**
- **Coil surface temp. F (2)**
- **Room Dry Bulb - F (3)**
- **Room Relative Humidity % (4)**
  - Poor humidity mitigation
  - Rising ADP at part load



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load high, valve open, off-coil lower

load low, valve less, off-coil high

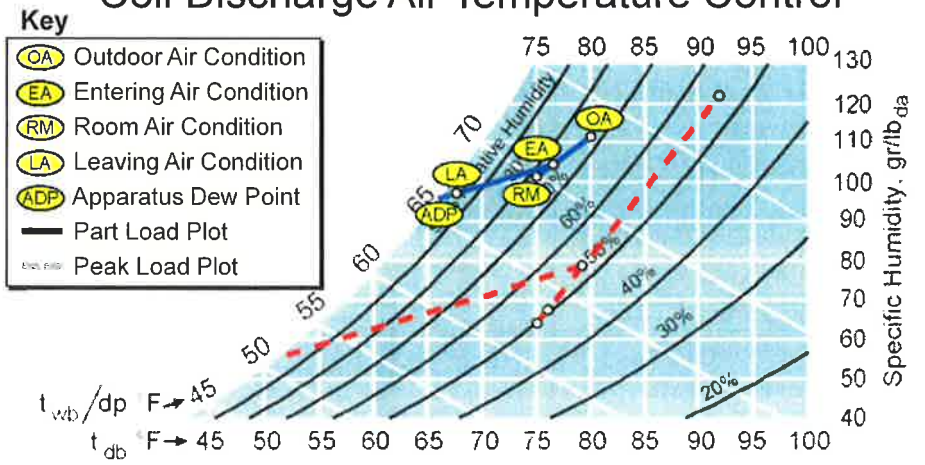
latent heat ↓ ∴ RH ↑

Reduce ΔT

$\Delta T \downarrow$ supply air $T \uparrow$

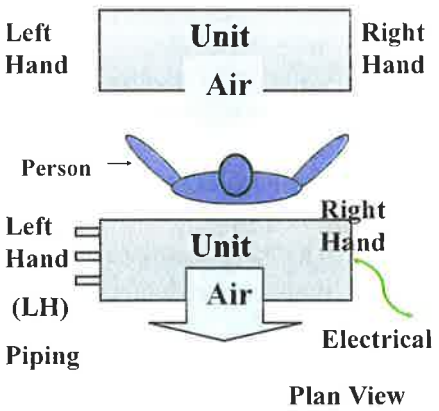
System Psychrometric Plots

Coil Discharge Air Temperature Control



FAN COIL VALVE DEFINITIONS

- Unit Hand - Fan Coils
  - When facing a unit with the supply air blowing in your face, your right and left hands match the unit right and left hand connections
  - Just the opposite of AHU
- Same End Connections
  - 2 or 4-pipe
  - All piping on one side
  - Electrical connections on the opposite side
- Opposite End Connections
  - For 4-pipe only
  - Hot water and electrical connections are on opposite end of chilled water connections



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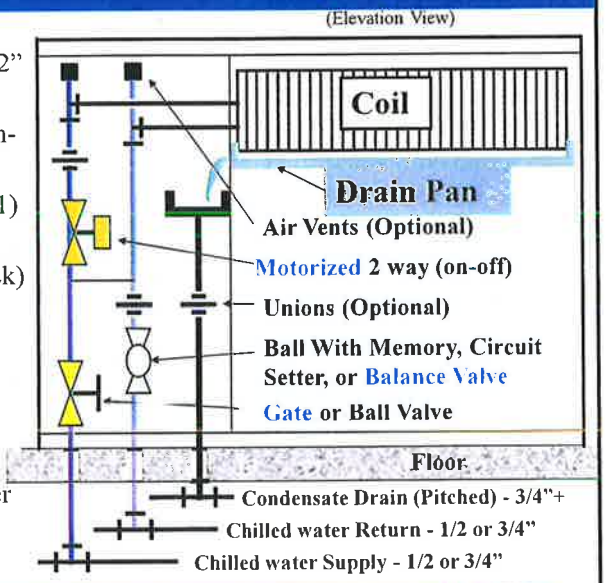
TYPICAL FAN COIL PIPING

- Supply and return lines are 1/2" or 3/4" copper
- Motorized control valve is (on-off) [2 or 3 way]
- Service of coil: (1) gate and (1) ball valve
- Ball or circuit setter (plug cock) also serves as balance
- Optional air vents
- Unions for coil removal
- All connections soldered (except for unions)
- Condensate - 3/4" min. copper and pitched ≥ 1/4" per foot
- 1/4" optional bleed line



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Valve Specifications Example

- **Pressure/Temperature Ratings**
  - Body Pressure
  - Close-Off Pressure
  - Close-Off Leakage
  - ΔP
  - Temp Ratings
- **Valve Flow**
  - Characterization Curve
  - Rangeability/Turndown
  - Valve Authority
- **Actuation**
  - Fail Safe
  - Normally Open/Normally Closed

BELIMO

Valve Specifications		
Service	chilled or hot water, 60% glycol	
Flow characteristic	A-port equal percentage B-port modified for constant common port flow	
Action	max 90° rotation	
Sizes	½" - 3"	
Type of end fitting ½" - 3"	NPT female ends	
Pressure rating 600 psi 400 psi	2-way ½" - 1¼" (B230) 1½" (B251) - 3"	3-way ½" - 1" 1¼" - 3"
Media temp range	0°F to 212°F [-18°C to +100°C]	
Close-off pressure 200 psi 100 psi	2-way ½" - 2" (B250) 2" (B251) - 3"	3-way ½" - 2"
Maximum differential pressure (ΔP)	30 psi	

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SELECTING FAN COIL CONTROL VALVES

- Fan coil units use two-position (not modulating) control valves in standard control packages (2-way or 3-way)
- Valves are sized to match coil connection size by the manufacturer:
  - 1/2 inch for 5/8 inch copper tubing
  - 3/4 inch for 7/8 inch copper tubing
- Only question: What is the valve pressure drop?
- C_v = Valve Flow Coefficient (GPM @ 1 PSI drop)
- **$P = (GPM / C_V)^2 \times 2.31$**
  Where P = Valve Pressure drop in ft. W.G.
- Standard fan coil valves have the following typical C_V characteristics:

FAN COIL VALVES - STANDARD		
MOTORIZED VALVE TYPE	VALVE C_V	
	1/2 INCH	3/4 INCH
2-WAY	2.3	2.3
3-WAY	5.0	5.0

$C_V = [GPM / (0.66 \times \sqrt{P})]$

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$P \propto \frac{1}{C_V}$

FAN COIL VALVE SIZING

ROOM FAN COIL SCHEDULE

NAME: Marvin Patnode | NOTE: 45 F CHILLED WATER 120 F HOT WATER | DATE: Mar 16, 2000 | JOB NAME: Casino Hotel Example (NW Top Room) | DESIGN TEAM NUMBER:

TAG NAME	UNIT MODEL	NO. OF UNITS	UNIT SIZE-ROWS	COOLING CAPACITY TOT BTUH	COOLING CAPACITY SEN BTUH	COOLING GPM	COOLING P.D.	HEATING COIL TYPE	HEATING COIL ROWS	HEATING CAPACITY BTUH	HEATING GPM	HEATING P.D.	FAN SPEED	FAN MOTOR VOLTAGE
1901NW TOP	42SJ	1	06-3	14700	9800	2.7	8.1	HW	3	16100	1.8	2.5	Med	277/1/60

- Cooling coil needs 2.7 GPM @ 8.1 ft wg drop
- Assume the use of a 2-way motorized 2-position valve
- What size valve should be used: [1/2 or 3/4 inch]
  - Both 1/2 and 3/4 inch valves have a C_V of 2.3
  - They both produce the same pressure drop for a given flow.
  - We are free to choose either valve from a pressure drop perspective
- Select 1/2 inch valve to match coil connection size.
  - Valve drop = $(GPM / C_V)^2 \times 2.31$
    = $(2.7 / 2.3)^2 \times 2.31 = 3.2$ ft. w.g.
  - Use field furnished valve if 3.2 ft wg is not acceptable
- **Higher valve loss makes system balancing easier.**

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VALVE SELECTION

- Fan coil control valves are factory sized based on coil connection size:
  - 1/2 inch or 3/4 inch
  - 2-way, 2-position control
  - Or field selected and installed
- Air handling unit control valves must be sized for C_v
  - They are modulating type, not 2-position
- Let's look at the principles behind selecting a modulating control valve
  - Typical coil piping
  - Control valve sizing

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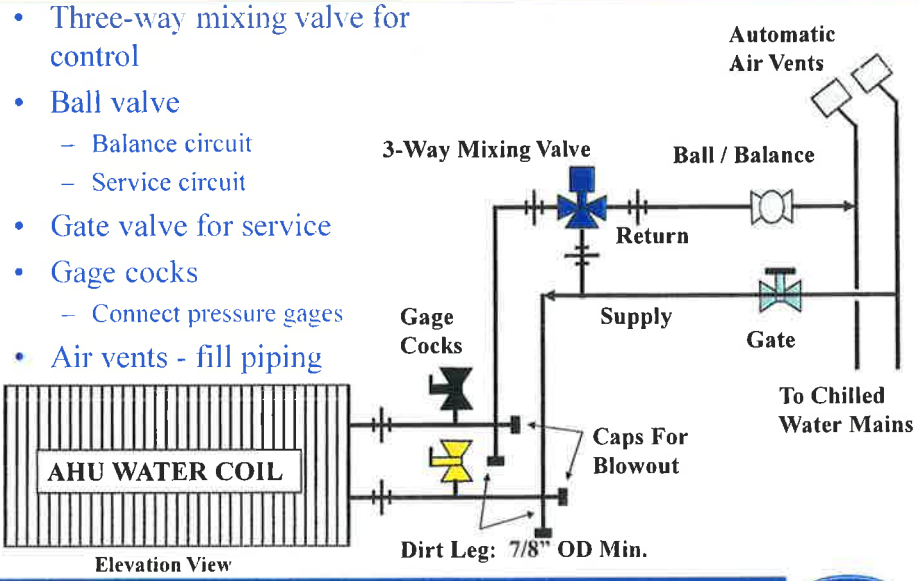
TYPICAL AHU PIPING

- Three-way mixing valve for control
- Ball valve
  - Balance circuit
  - Service circuit
- Gate valve for service
- Gage cocks
  - Connect pressure gages
- Air vents - fill piping



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CONTROL VALVE RANGEABILITY

- Valve Rangeability:
  - Definition: (max flow / min flow) @ constant pressure drop
  - Min flow is lowest controllable flow
  - Commercial valve rangeability range: (15:1 to 50:1)
  - 15:1 is pretty good on most commercial jobs
- Rangeability Example:
  - Valve designed for 150 gpm with 15:1 rangeability
  - Minimum flow = (150 / 15) = 10 gpm
  - Minimum % flow = (10 / 150) x 100 = 6.7%
  - Heating coil @ 6.7% flow results in a min controllable capacity of 35%
  - Cooling coil @ 6.7% flow results in a min controllable capacity of 20%
- Since valves are typically slightly oversized, it is reasonable to expect a valve to control down to no lower than 30 to 40% capacity - unless a high rangeability valve is chosen

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VALVE / ACTUATOR CLOSE OFF RATING

- FOR TWO WAY VALVES IT IS DEFINED AS :-
  - MAXIMUM DIFFERENTIAL PRESSURE THAT THE VALVE / ACTUATOR CAN WITHSTAND WITH OUT LEAKAGE WHILE IN THE FULLY CLOSED POSITION
- FOR THREE WAY VALVES IT IS DEFINED AS :-
  - MAXIMUM DIFFERENTIAL PRESSURE THAT IS APPLIED ACROSS EITHER OF THE TWO INLET PORTS AND THE COMMON OUTLET PORT AND WHICH THE ACTUATOR WILL STILL DRIVE THE VALVE PLUG CLOSED TO THE REQUIRED PORT

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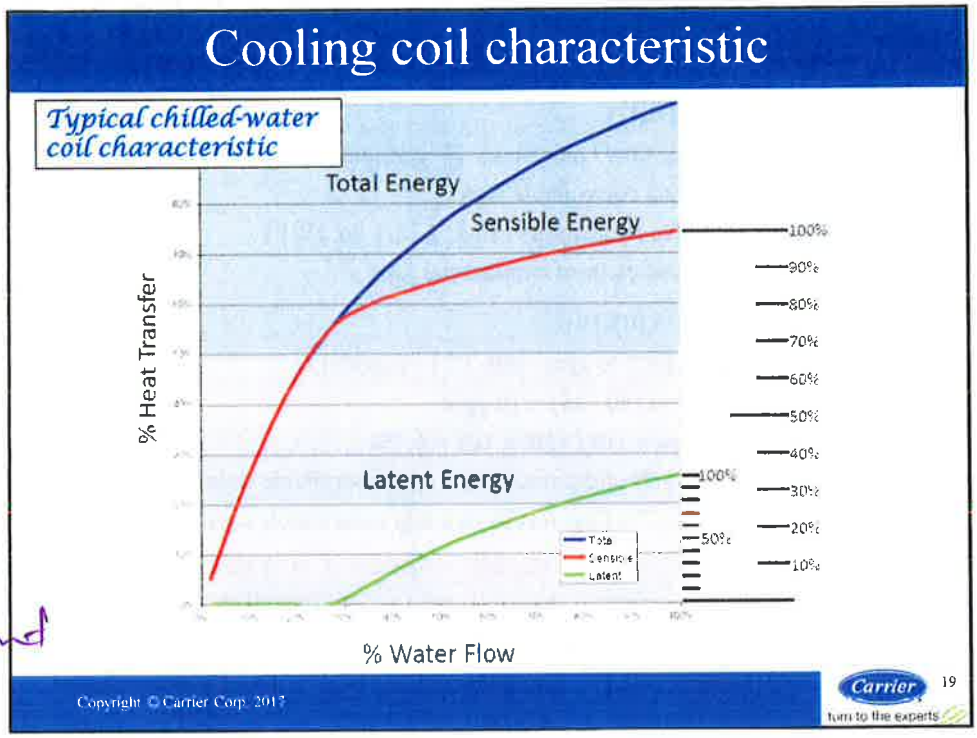
Cooling coil characteristic



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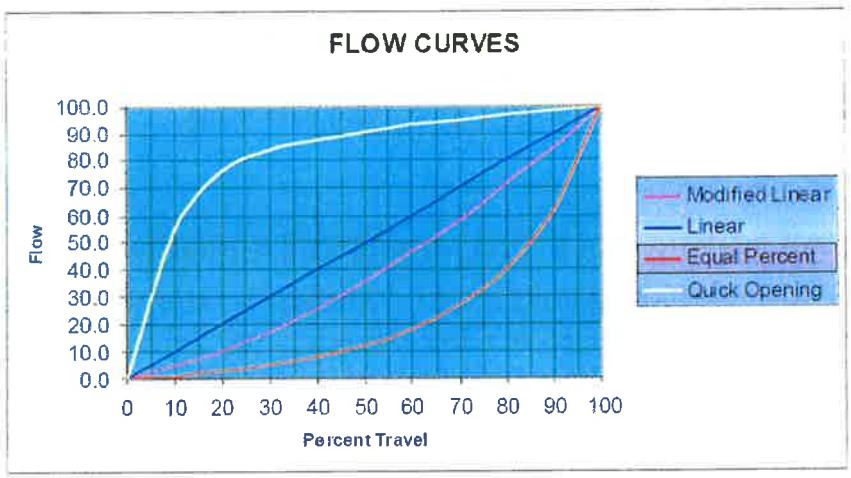
Coil temp at dew point
↳ Then latent can be removed.
↳ At low loads, only sensible.

Valve Flow Characteristic (Constant ΔP)



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Equal Percentage Valve Characteristic

Coil Characteristic | Valve Characteristic | Controlled Relationship

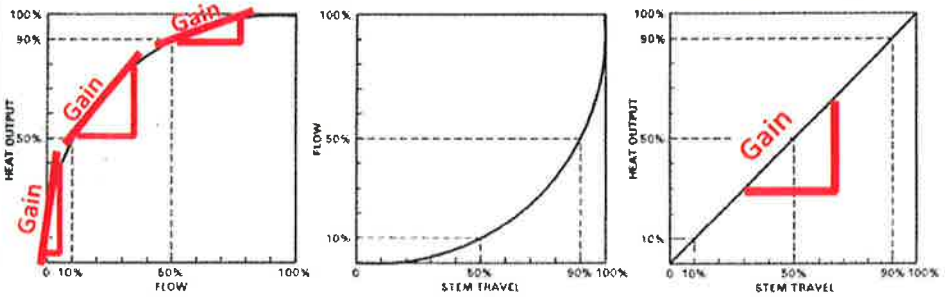

Fig. 17 Heat Output, Flow, and Stem Travel Characteristics of Equal Percentage Valve

Source: ASHRAE Handbook

Coil Characteristic Curve Combined with Valve Characteristic Curve Produces a Theoretically Linear Heat Output with Stem Travel

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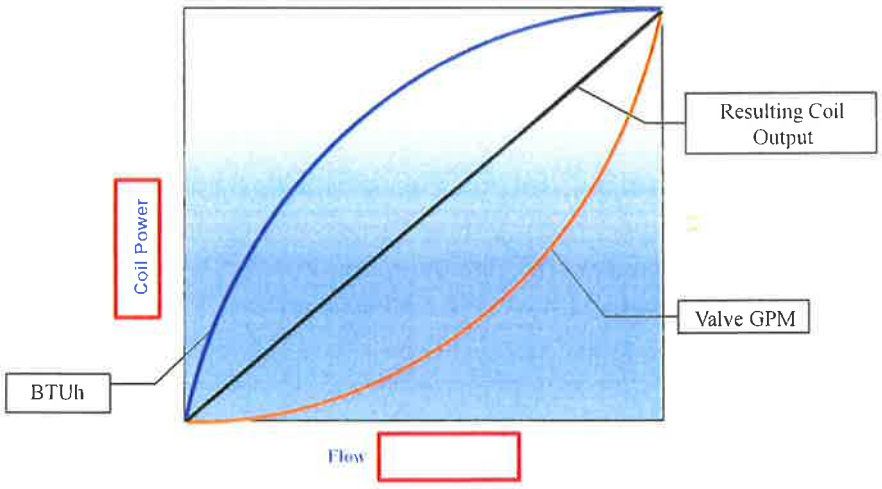
Understating Coil Behavior

Coil Performance



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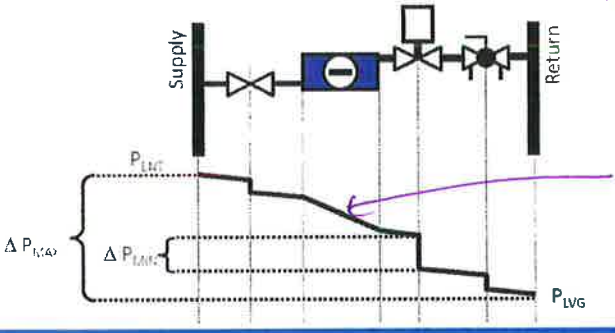
CONTROL VALVE AUTHORITY

System Hydraulic Effect; Valve Authority, β

- Valve authority affects controllability
- The Controller cannot control properly
- Simplified index value is β and is pressure drop of valve over "controlled" pressure drop

$$\beta = \Delta P_{MIN} / \Delta P_{MAX}$$

open valve, full flow



cooling coil drop

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CONTROL VALVE AUTHORITY

- **Valve Authority:**
  - **Definition:** (valve press. drop / loop press. drop) **x 100%**
  - **Valve authority must be** 25% to 50% of system loop pressure drop

- **Rule of Thumb Control Valve Sizing (Authority)**
  - **Size fan coils for a pressure drop of equal to or less than 10 ft. W.G.**
  - **Size central station AHU coils from 10 to 20 ft. W.G.**
  - **Size control valve at 1 to 2 times coil pressure drop**
  - **Select central station AHU valve for ΔP_w at leat 25% total loop ΔP_w**

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Rangeability & Turndown

Rangeability:

The ratio of maximum flow to minimum controllable flow of a valve body only under laboratory conditions with a constant differential pressure applied across the valve.

Turndown Ratio:

The ratio of maximum usable flow to minimum controllable flow of the valve assembly under installed conditions. It is always lower than the rangeability factor.

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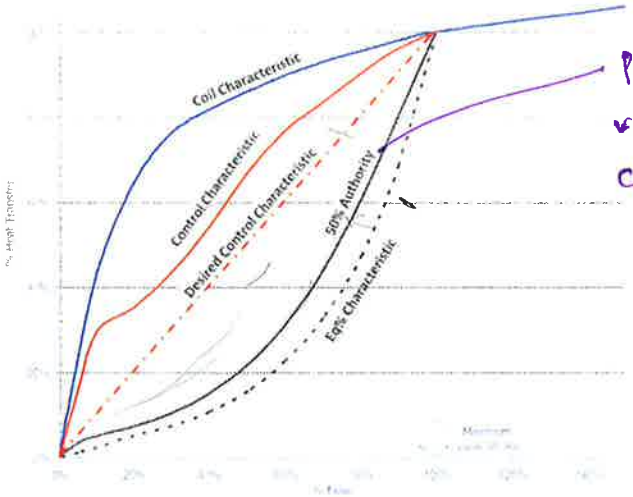
CONTROL VALVE AUTHORITY

The Goal; Make the red line straight and 100% to 100%



valve
Poor authority
results in poor
control characteristics.

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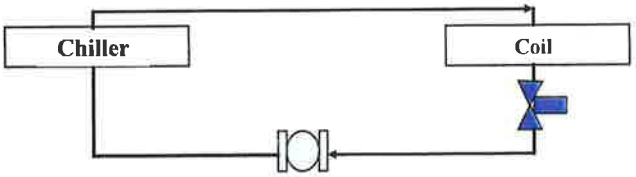
AUTHORITY EXAMPLE



• **Authority Example:**	1-times Coil ΔP	2-times Coil ΔP
– Chiller pressure drop	20 ft.	20 ft.
– Coil pressure drop	10 ft.	10 ft.
– Piping and fittings pressure drop	10 ft.	10 ft.
– Control valve pressure drop (1 - 2 times coil)	10 ft.	20 ft.
– Total loop pressure drop	50 ft	60 ft

- **Valve Authority**
  - @ 10 ft valve drop, (10 / 50) = 20%
  - @ 20 ft valve drop, (20 / 60) = 33%
  - Choose valve @ 20 ft drop (target authority = 25% to 50%)

High pressure drop
→ higher pumping energy

But control valve requires authority.

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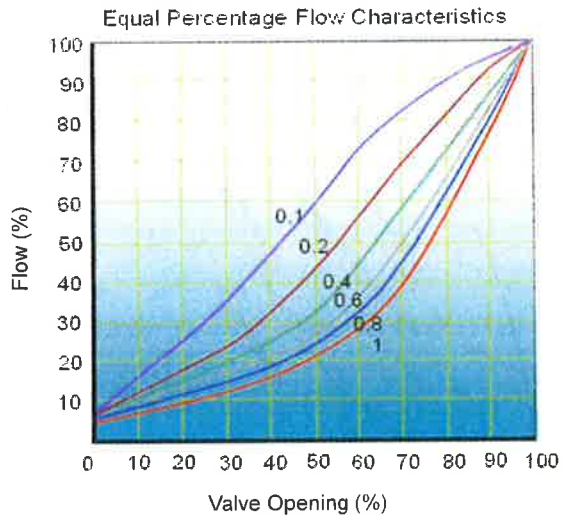
Equal Percentage Authority Distortion



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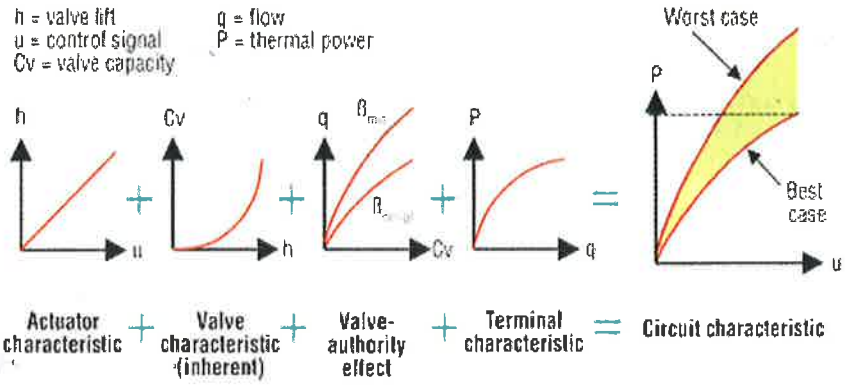
Valve Authority Effect

h = valve lift
u = control signal
Cv = valve capacity

q = flow
P = thermal power



Actuator characteristic + Valve characteristic (inherent) + Valve-authority effect + Terminal characteristic = Circuit characteristic

Impact of varying valve authority on circuit characteristic during operation.

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SIZING CONTROL VALVES - C_v

- Valves sized to produce "Authority"
  - 25 to 50% of loop pressure drop
  - 1 to 2 times coil pressure drop
- Valve sizing coefficient - C_V
  - $C_V = [GPM / (0.67 \times \sqrt{P})]$

  where

  GPM = gallons per minute

  P = pressure drop in ft. water gage

  C_V = GPM at 1 PSI pressure drop
- The higher the pressure drop (authority) the lower the C_V
- C_V values are published by the manufacturer
- Valve size usually one size less than line
- With C_V & GPM known, $\Delta P_v = (GPM / C_V)^2 \times 2.31$
- Use this table as typical for valve sizing in this course:

Modulating AHU Valve Sizes			
VALVE SIZE (IN)	MOTORIZED CONTROL VALVE VALVE C_V		
	TWO-WAY VALVE		
	A	B	C
1/2	0.4	1.3	2.3
3/4	5.0	6.2	8.0
1	9.0	10.0	11.0
1-1/4	12.0	14.0	16.0
1-1/2	19.0	22.0	26.0
2	30.0	35.0	40.0
2-1/2	44.0	50.0	56.0
3	61.0	72.0	85.0
4	90.0	95.0	100.0
SIZE (IN)	THREE-WAY VALVE		
	D	E	F
1/2	2.0	3.0	4.0
3/4	5.0	6.0	8.0
1	9.0	10.0	12.0
1-1/4	13.0	14.0	16.0
1-1/2	20.0	26.0	33.0
2	40.0	46.0	55.0
2-1/2	62.0	68.0	74.0
3	80.0	90.0	101.0
4	110.0	120.0	130.0

Example: Specify As: 1/2 - A

Note: $(1/2.31)^{1/2} = 0.658$, use 0.67 above)

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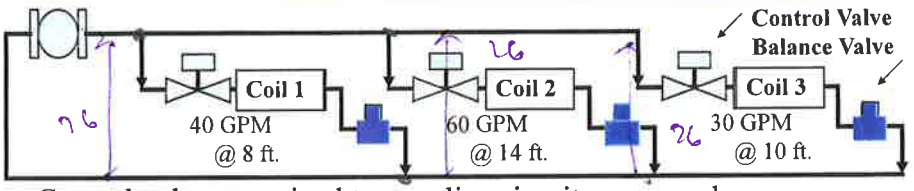
SIZING CONTROL VALVES - C_v



- Control valves are sized to equalize circuit pressure drop
- Circuit 2 has highest drop at 14 ft.
  - Select a control valve with a drop of 14 ft. (1 times coil drop is minimum)
  - $C_v = [60 / (0.67 \times \sqrt{14})] = 23.9$ select a 1 1/2 C valve @ 26 c_v PD = 12 ft
  - Circuit 2 pressure drop = [12 + 14] = 26 ft.
- Circuit 1 needs [26 - 8] = 18 ft valve drop to balance
  - $C_v = [40 / (0.67 \times \sqrt{18})] = 14$ select a 1 1/4 C valve @ 14 c_v PD = 19 ft
- Circuit 3 needs [26 - 10] = 16 ft valve drop to balance
  - $C_v = [30 / (0.67 \times \sqrt{16})] = 11.2$ select a 1 C valve @ 11 c_v PD = 17 ft

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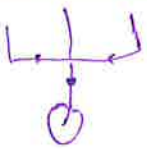
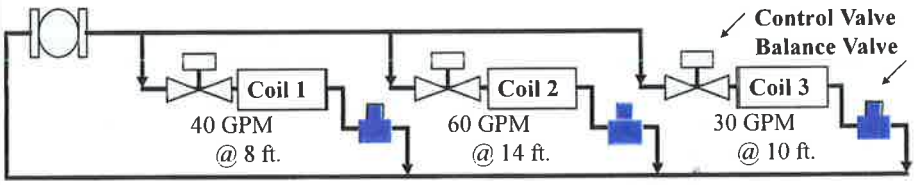


SIZING CONTROL VALVES - C_v



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  - Circuit 2 pressure drop = [12 + 14] = 26 ft.
- Circuit 1 needs [26 - 8] = 18 ft valve drop to balance
  - $C_v = [40 / (0.67 \times \sqrt{18})] = 14$ select a 11/4 C valve @ 14 c_v PD = 19 ft
- Circuit 3 needs [26 - 10] = 16 ft valve drop to balance
  - $C_v = [30 / (0.67 \times \sqrt{16})] = 11.2$ select a 1 C valve @ 11 c_v PD = 17 ft

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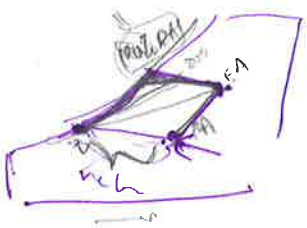
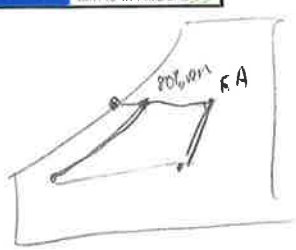




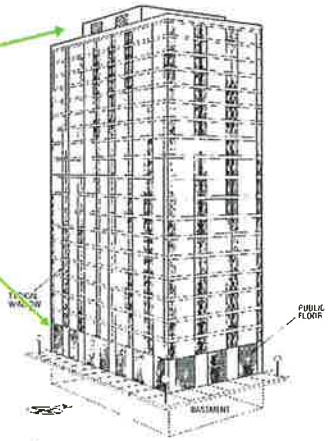
HIGH-RISE HOTEL AIR

- High-Rise Hotel has (3) air handling units
  - **(1) Ventilation unit in roof penthouse**
    Chilled water flow rate = 177.3 GPM
    Coil pressure drop = 13.6 ft wg
  - **(2) Units located in the ceiling of the first floor (casino & restaurant)**

Select control valve for ventilation unit (use 3-way valve)

Refer to next Page

HIGH-RISE HOTEL WITH CASINO



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EXAMPLE - 3-way valve

AHU VALVES			
VALVE	MOTORIZED CONTROL VALVE VALVE Cv		
SIZE (IN)	THREE-WAY VALVE		
	D	E	F
1/2	2.0	3.0	4.0
3/4	5.0	6.0	8.0
1	9.0	10.0	12.0
1-1/4	13.0	14.0	16.0
1-1/2	20.0	26.0	33.0
2	40.0	46.0	55.0
2-1/2	62.0	68.0	74.0
3	80.0	90.0	101.0
4	110.0	120.0	130.0

Example: Specify As: 1/2 - A

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EXAMPLE - VENT UNIT

- From Ventilation Unit selection output:
  - Chilled water flow rate 177.3 GPM
  - Coil pressure drop 13.6 ft wg
  - Required valve C_V rating 72
- Select a modulating 3-way mixing valve
- Locate valve selection table
  - Find a C_V of 72
  - **Choose a [2-1/2 - E] valve with a C_V of 68**
  - **Valve pressure drop**
    - **$(GPM / C_V)^2 \times 2.31$**
    - **$(177.3 / 68)^2 \times 2.31 =$ 15.7 ft. w.g.**

$$\frac{15.7}{13.6+15.7} = 53.6\%$$

AHU VALVES			
VALVE SIZE (IN)	MOTORIZED CONTROL VALVE VALVE Cv THREE-WAY VALVE D	E	F
1/2	2.0	3.0	4.0
3/4	5.0	6.0	8.0
1	9.0	10.0	12.0
1-1/4	13.0	14.0	16.0
1-1/2	20.0	26.0	33.0
2	40.0	46.0	55.0
2-1/2	62.0	68.0	74.0
3	80.0	90.0	101.0
4	110.0	120.0	130.0

Example: Specify As: 1/2 - A

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Flow coefficient of control valve

Cv-*imperial*

Cv is expressed as the flow rate of water in gpm (u.s.) for a pressure drop of 1 psi across a flow passage

Kv-*metric*

Kv is expressed as the flow rate of water in (m^3/h) for a pressure drop of (1 bar) across a flow passage

1 gpm = 0.227 m^3/h

1 psi = 0.069 bar

1 bar = 100 kPa

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VALVE RATINGS

- EACH VALVE HAS A SPECIFIC CAPACITY INDEX AND THIS IS DEFINED AS IT'S VOLUMETRIC CAPACITY AT A SPECIFIED PRESSURE DIFFERENCE
  - FOR IMPERIAL VALVES THIS IS EXPRESSED AS THE Cv RATING
  - FOR METRIC VALVES IT IS EXPRESSED AS THE Kv RATING

- THE CAPACITY INDICES FOR Cv AND Kv VALVES ARE NUMERICALLY RELATED
  - **Cv = Kv x 1.17**
  - **Kv = Cv x 0.86**

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