System Diagram Workshop

Basic Concepts

Tools and Techniques for Developing your System Diagrams

Instructor:

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Senior Engineer

Facility Dynamics Engineering

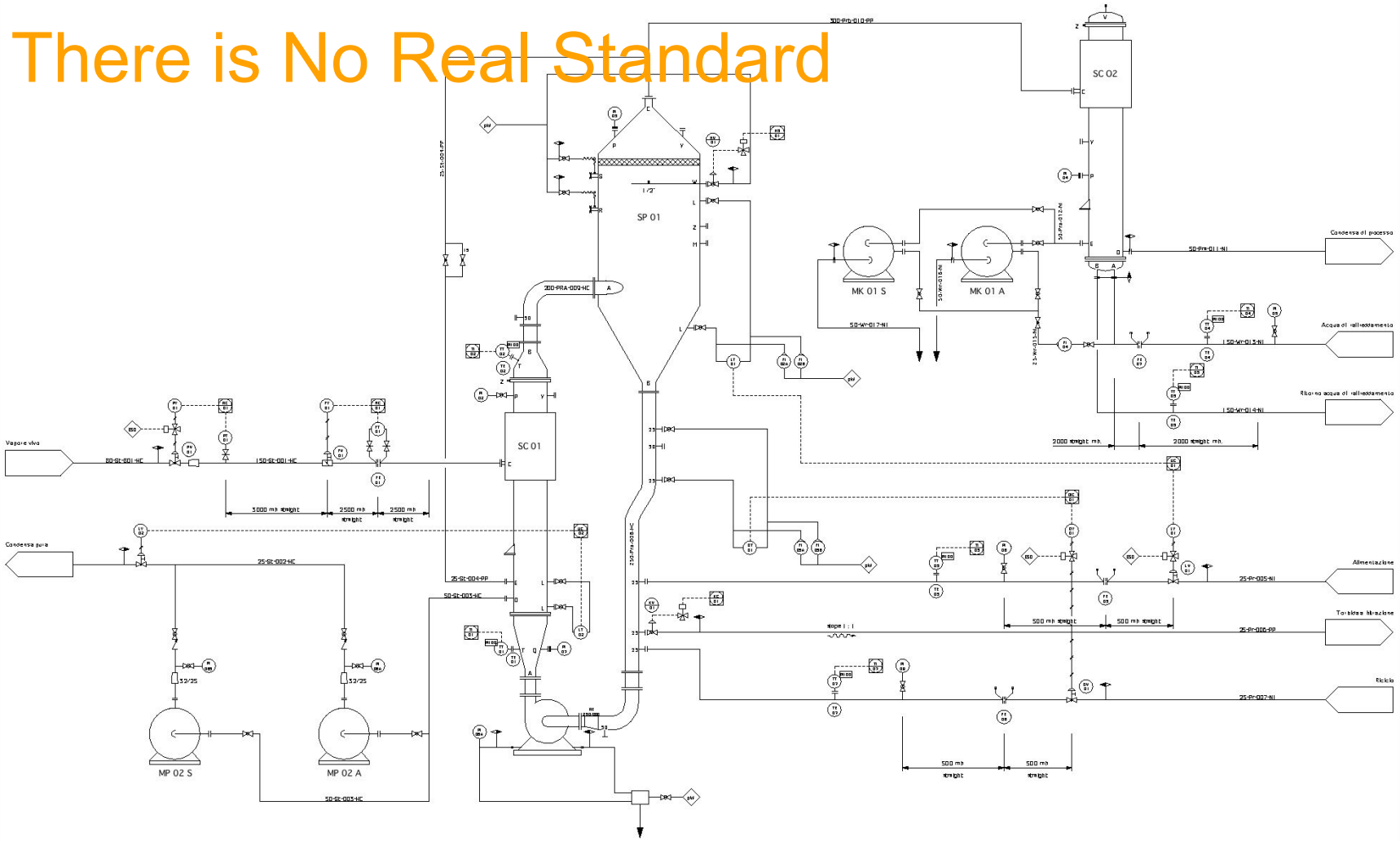
September 17, 2017

Resource for Details Behind this Content

www.Av8rdas.Wordpress.com

Posts with the heading “System Diagrams: …”

There is No Real Standard

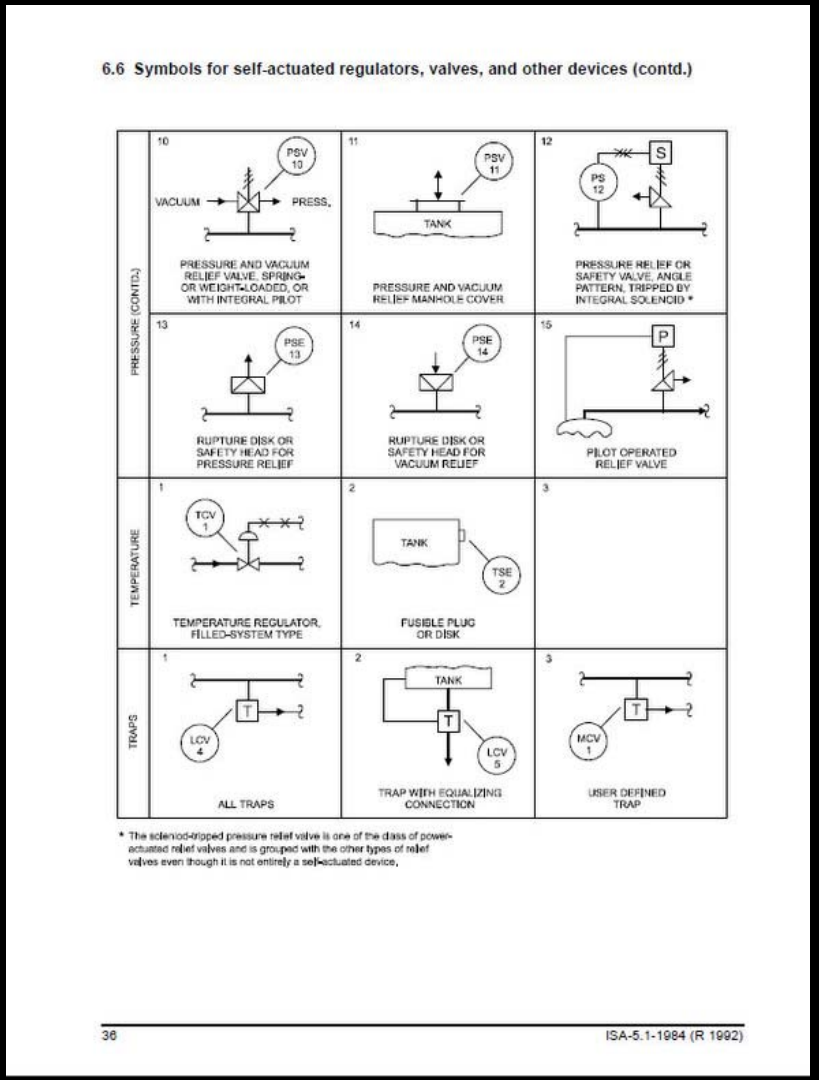


P&ID (Process and Instrumentation Diagrams) are a similar concept as is a PFD (Process Flow Diagram)

http://en.wikipedia.org/wiki/Piping_and_instrumentation_diagram - From the author's own work - Creative Commons Share Alike

Starting Points for Symbols

ISA-5.1-1984 Instrumentation Symbols and Identification



6.6 Symbols for self-actuated regulators, valves, and other devices (contd.)

PRESSURE (CONTD.)

10 — PSV 10 — VACUUM — PRESS. — PRESSURE AND VACUUM RELIEF VALVE, SPRING- OR WEIGHT-LOADED, OR WITH INTEGRAL PILOT

11 — PSV 11 — TANK — PRESSURE AND VACUUM RELIEF MANHOLE COVER

12 — S — PS 12 — PRESSURE RELIEF OR SAFETY VALVE, ANGLE PATTERN, TRIPPED BY INTEGRAL SOLENOID *

13 — PSE 13 — RUPTURE DISK OR SAFETY HEAD FOR PRESSURE RELIEF

14 — PSE 14 — RUPTURE DISK OR SAFETY HEAD FOR VACUUM RELIEF

15 — P — PILOT OPERATED RELIEF VALVE

TEMPERATURE

1 — TCV 1 — TEMPERATURE REGULATOR, FILLED-SYSTEM TYPE

2 — TANK — TSE 2 — FUSIBLE PLUG OR DISK

3

TRAPS

1 — T — LCV 4 — ALL TRAPS

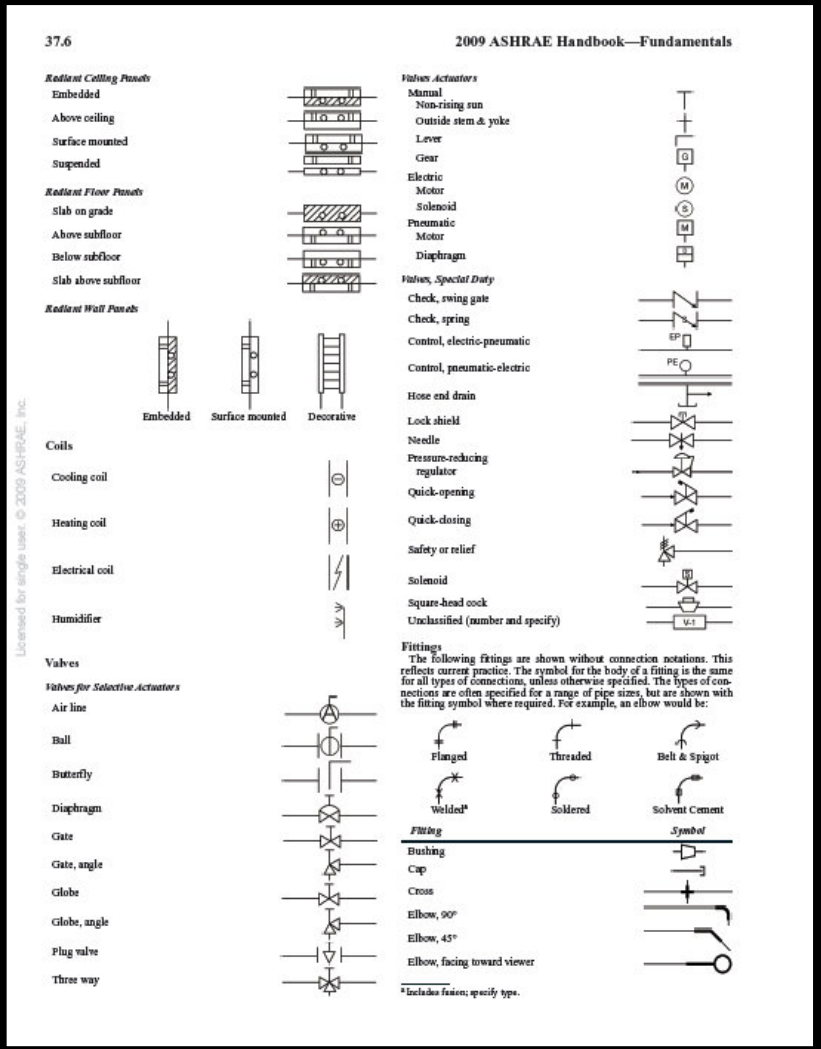
2 — TANK — T — LCV 5 — TRAP WITH EQUALIZING CONNECTION

3 — T — MCV 1 — USER DEFINED TRAP

* The solenoid-tripped pressure relief valve is one of the class of power-actuated relief valves and is grouped with the other types of relief valves even though it is not entirely a self-actuated device.

Starting Points for Symbols

2009 (or earlier) ASHRAE Handbook of Fundamentals, Chapter 37



37.6 2009 ASHRAE Handbook—Fundamentals

Radiant Ceiling Panels
Embedded
Above ceiling
Surface mounted
Suspended

Radiant Floor Panels
Slab on grade
Above subfloor
Below subfloor
Slab above subfloor

Radiant Wall Panels
Embedded
Surface mounted
Decorative

Coils
Cooling coil
Heating coil
Electrical coil
Humidifier

Valves
Valves for Selective Actuators
Air line
Ball
Butterfly
Diaphragm
Gate
Gate, angle
Globe
Globe, angle
Plug valve
Three way

Valves Actuators
Manual
Non-rising sun
Outside stem & yoke
Lever
Gear
Electric
Motor
Solenoid
Pneumatic
Motor
Diaphragm

Valves, Special Duty
Check, swing gate
Check, spring
Control, electric-pneumatic
Control, pneumatic-electric
Hose end drain
Lock shield
Needle
Pressure-reducing regulator
Quick-opening
Quick-closing
Safety or relief
Solenoid
Square-head cock
Unclassified (number and specify)

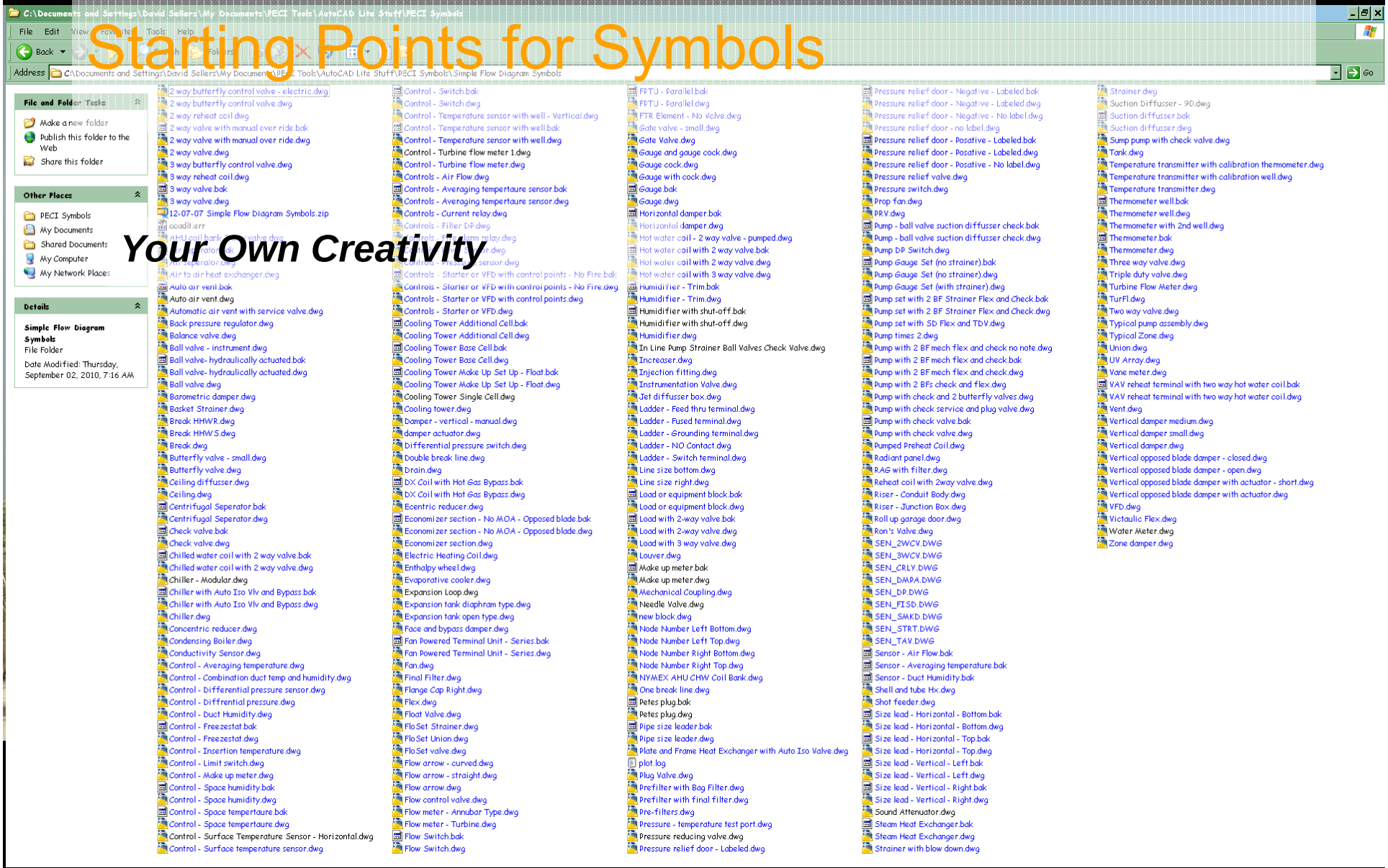
Fittings
The following fittings are shown without connection notations. This reflects current practice. The symbol for the body of a fitting is the same for all types of connections, unless otherwise specified. The types of connections are often specified for a range of pipe sizes, but are shown with the fitting symbol where required. For example, an elbow would be:

Flanged
Threaded
Belt & Spigot
Welded[a]
Soldered
Solvent Cement

Fitting	*Symbol*
Bushing	
Cap	
Cross	
Elbow, 90°	
Elbow, 45°	
Elbow, facing toward viewer	

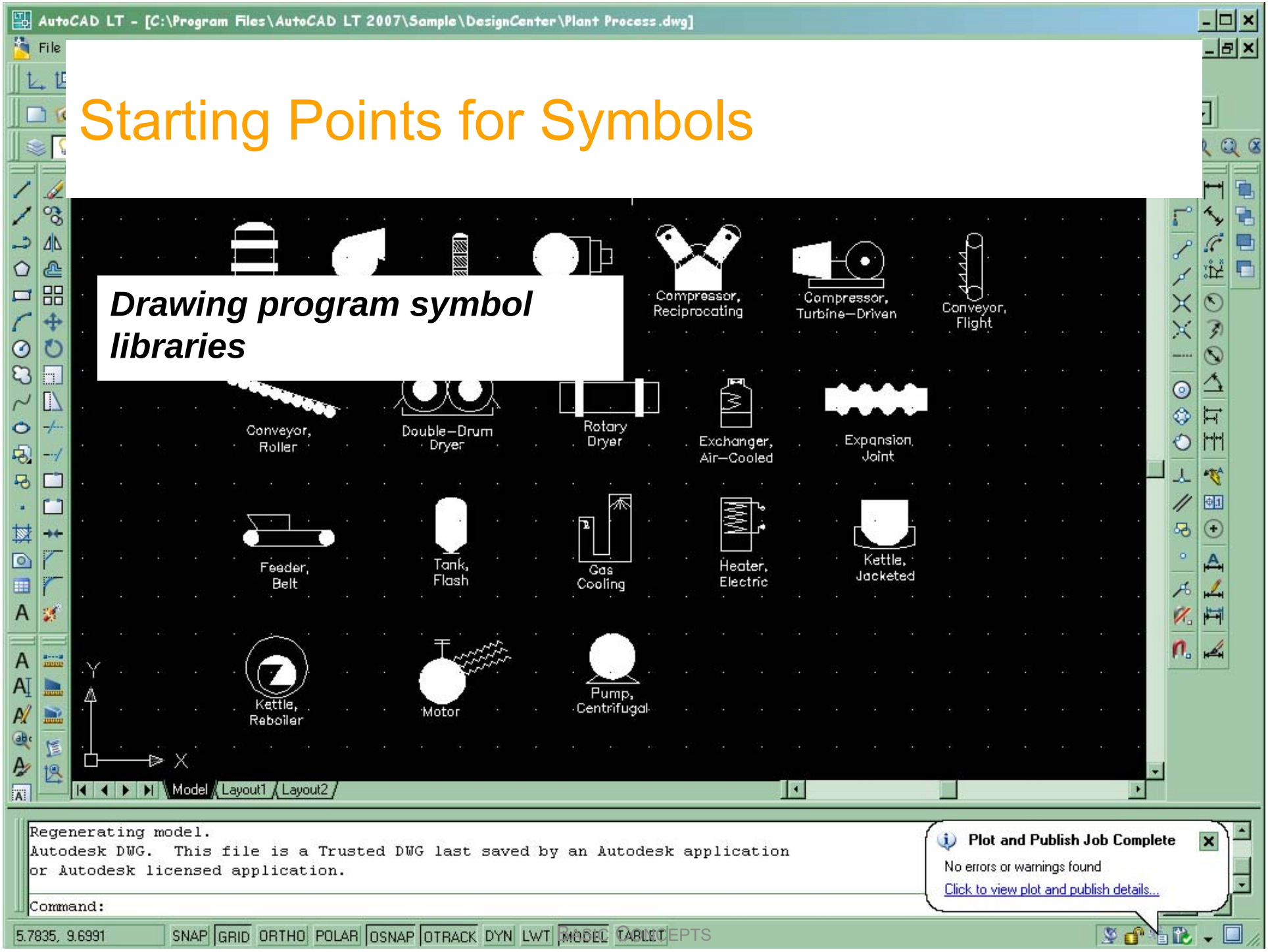
[a] Includes fusion; specify type.

Starting Points for Symbols

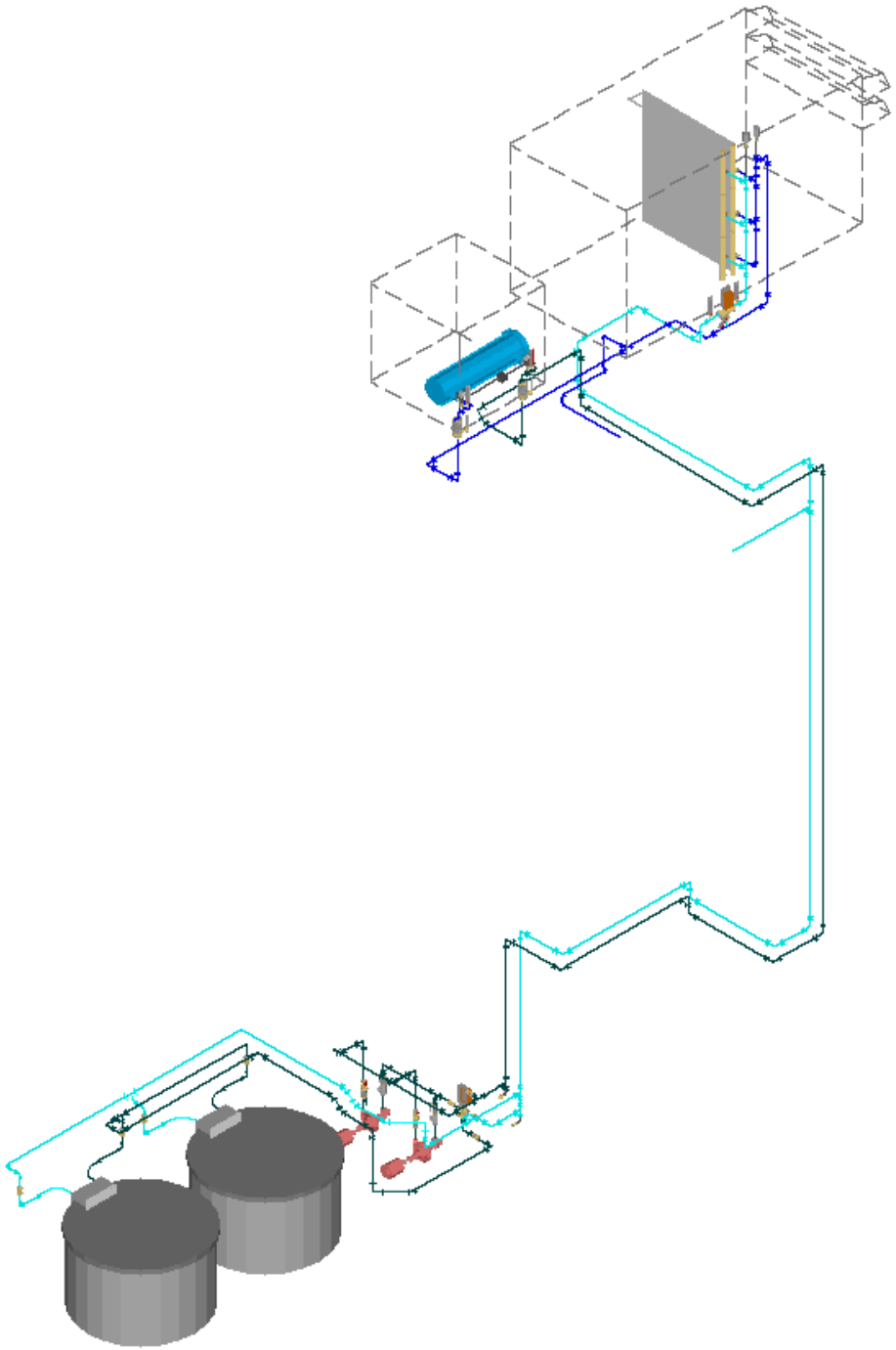


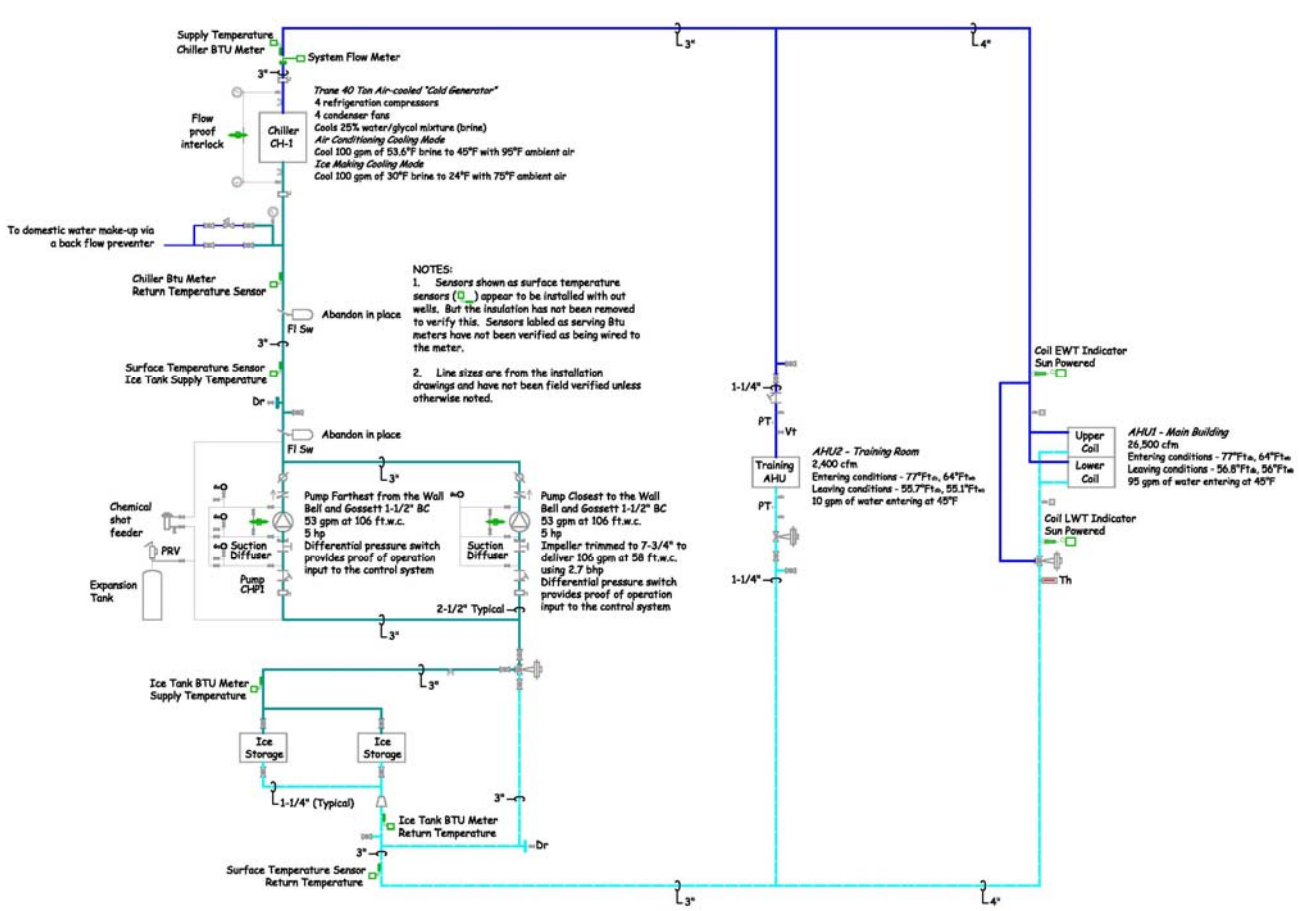
Your Own Creativity

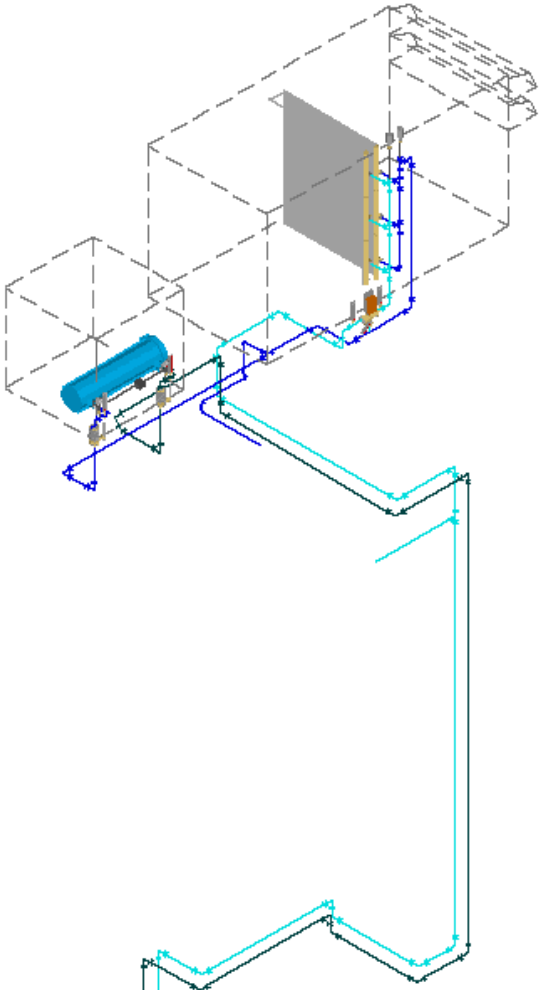
Starting Points for Symbols

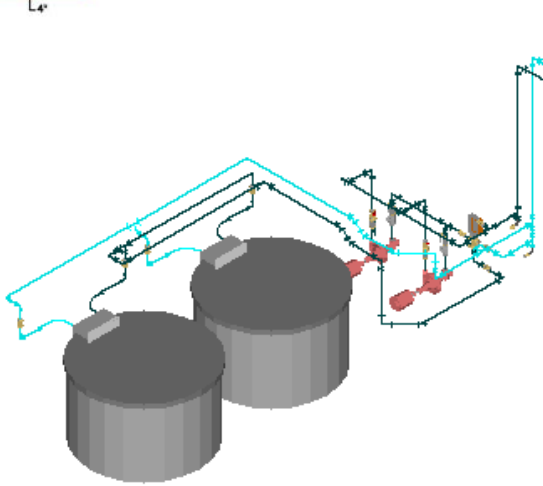


Physically Complex,

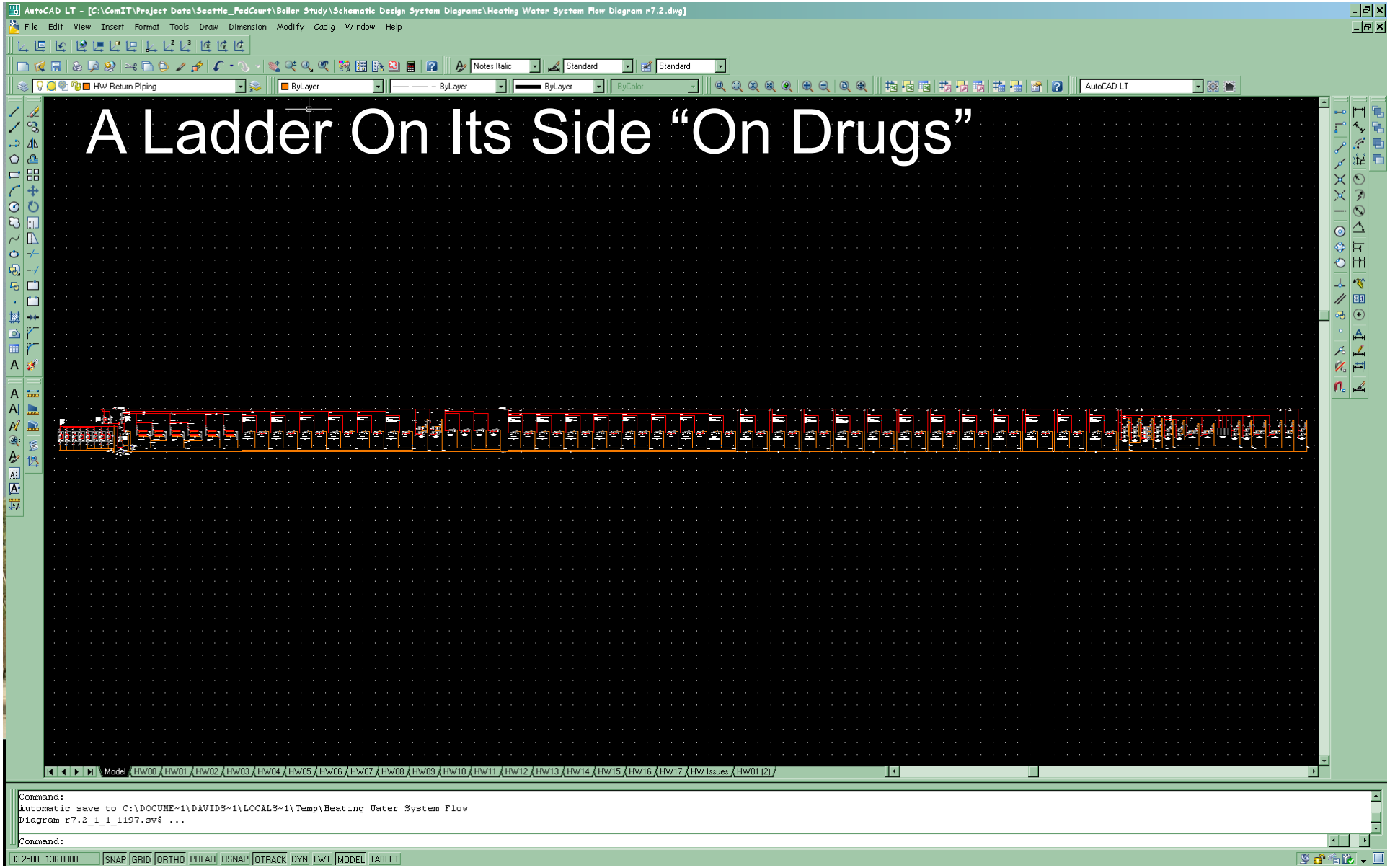




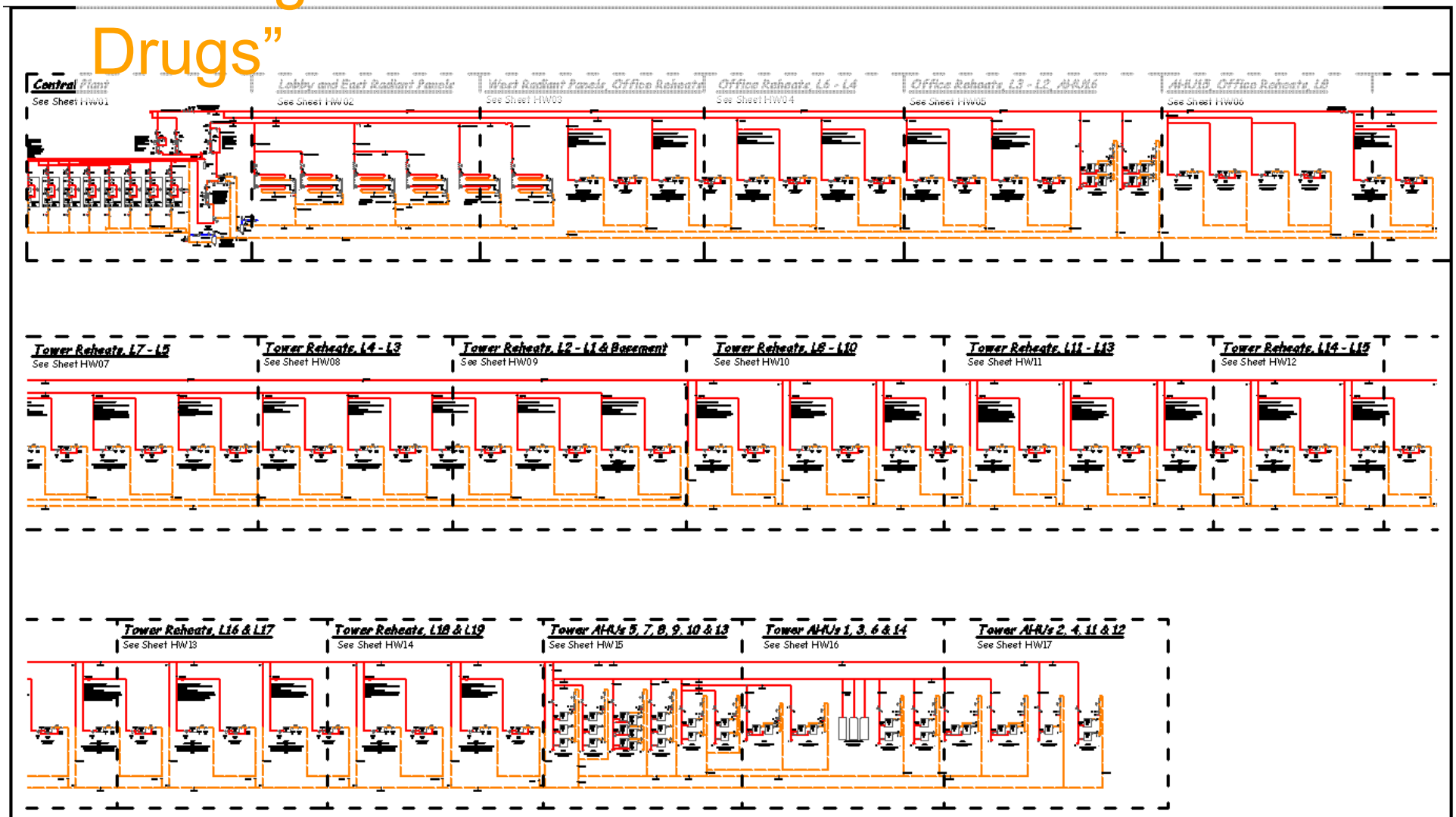




Physically Complex,


AutoCAD LT - [C:\ComIT\Project Data\Seattle_FedCourt\Boiler Study\Schematic Design System Diagrams\Heating Water System Flow Diagram r7.2.dwg]
File Edit View Insert Format Tools Draw Dimension Modify Cadig Window Help
HW Return Piping
ByLayer
ByLayer
ByLayer
ByColor
AutoCAD LT
A Ladder On Its Side "On Drugs"
Model HW00 HW01 HW02 HW03 HW04 HW05 HW06 HW07 HW08 HW09 HW10 HW11 HW12 HW13 HW14 HW15 HW16 HW17 HW Issues HW01 (2)
Command:
Automatic save to C:\DOCUME~1\DAVIDS~1\LOCALS~1\Temp\Heating Water System Flow
Diagram r7.2_1_1_1197.sv$ ...
Command:
93.2500, 136.0000
SNAP GRID ORTHO POLAR OSNAP OTRACK DYN LWT MODEL TABLET

Dealing With a Ladder On Its Side "On Drugs"

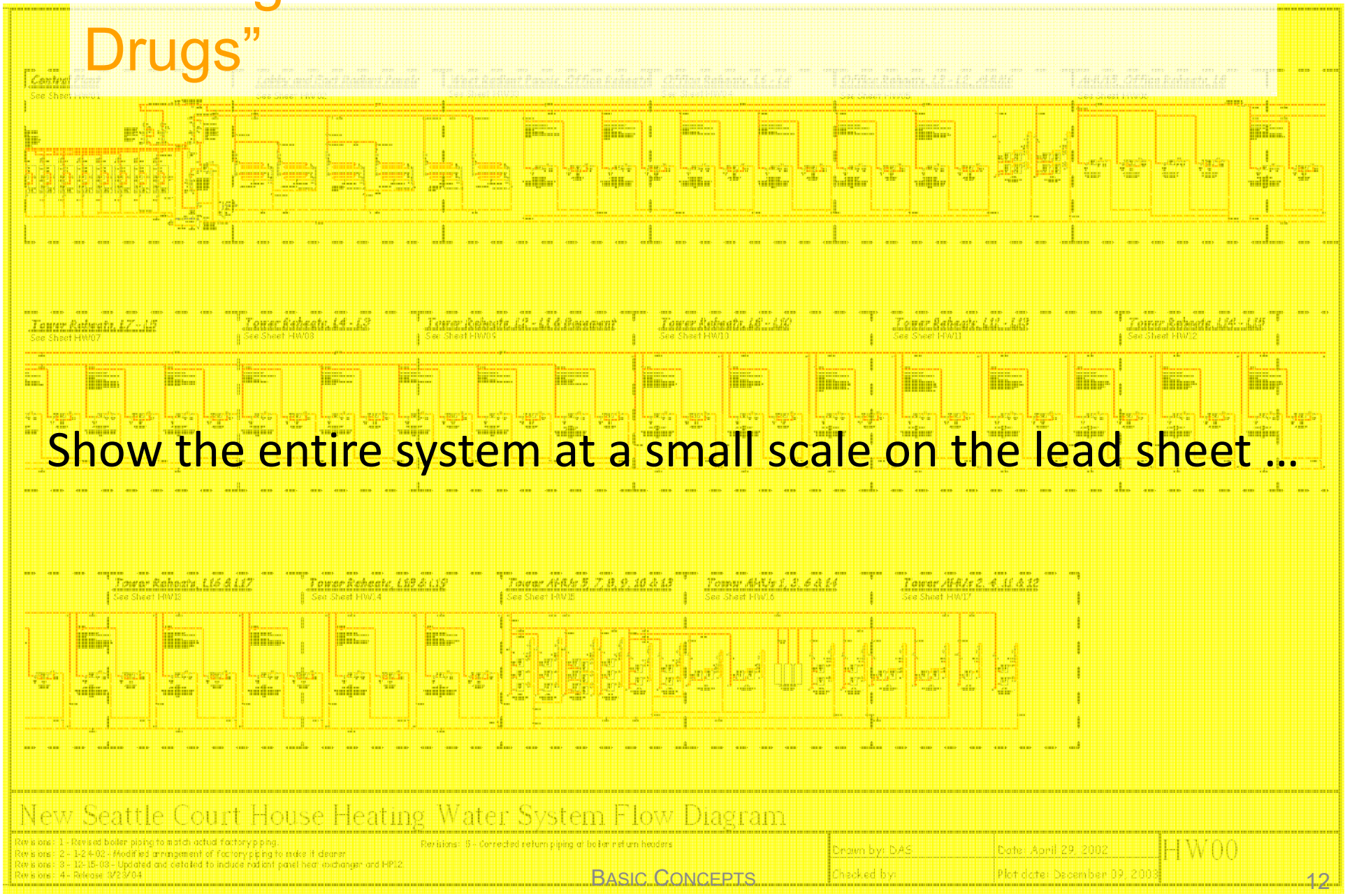


New Seattle Court House Heating Water System Flow Diagram

Revisions: 1 - Revised boiler piping to match actual factory piping.
Revisions: 2 - 1-24-02 - Modified arrangement of factory piping to make it clearer
Revisions: 3 - 12-15-03 - Updated and detailed to include radiant panel heat exchanger and HP12.
Revisions: 4 - Release 3/23/04
Revisions: 5 - Corrected return piping at boiler return headers

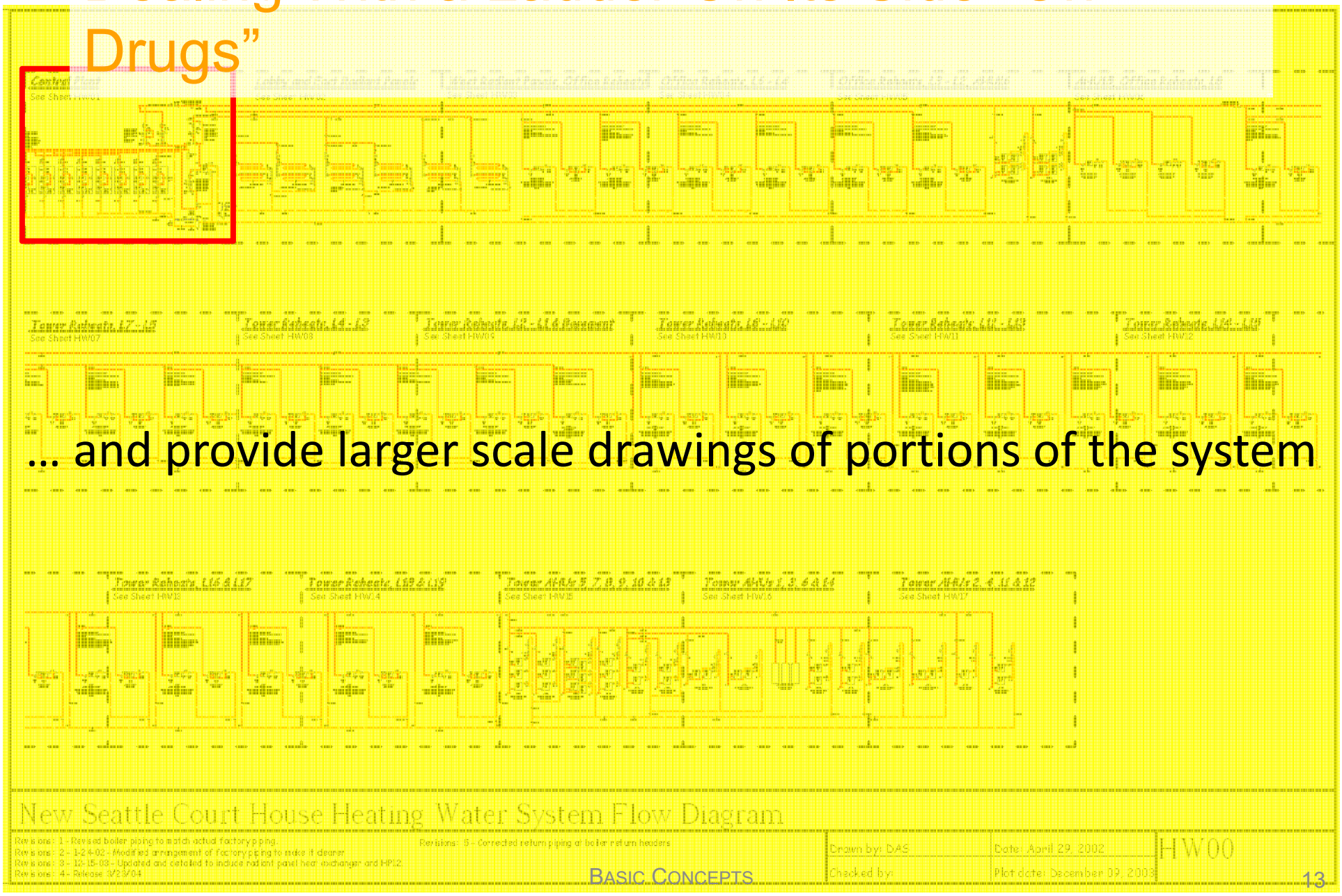
Drawn by: DAS	Date: April 29, 2002	HW00
Checked by:	Plot date: December 09, 2003	

Dealing With a Ladder On Its Side "On Drugs"

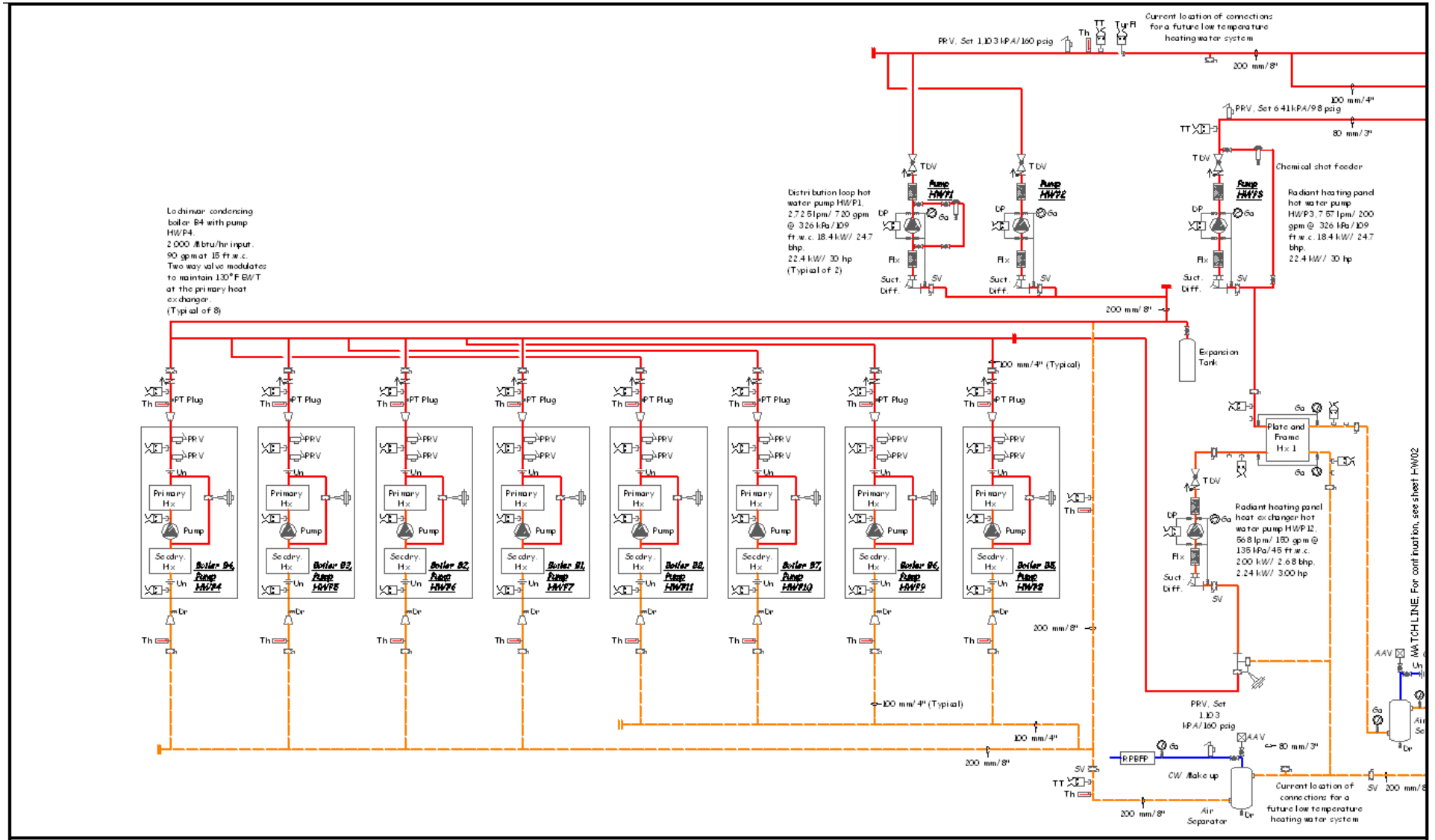


Show the entire system at a small scale on the lead sheet …

Dealing With a Ladder On Its Side "On Drugs"



… and provide larger scale drawings of portions of the system



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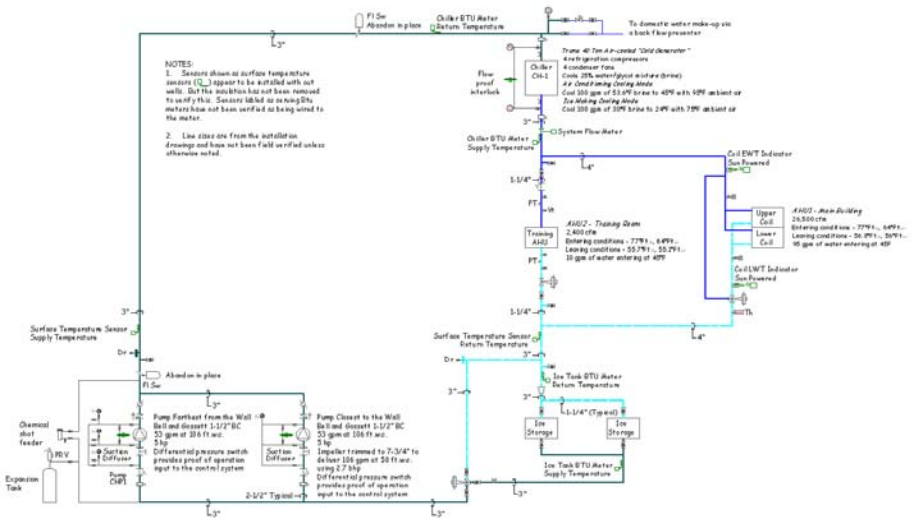
Revisions: 4 - Release 3/23/04
Revisions: 5 - 7-6-04 - Revised radiant panel pump connections.
Revisions: 5.1 - 7-7-04 - Revised radiant panel connection to the boiler header.

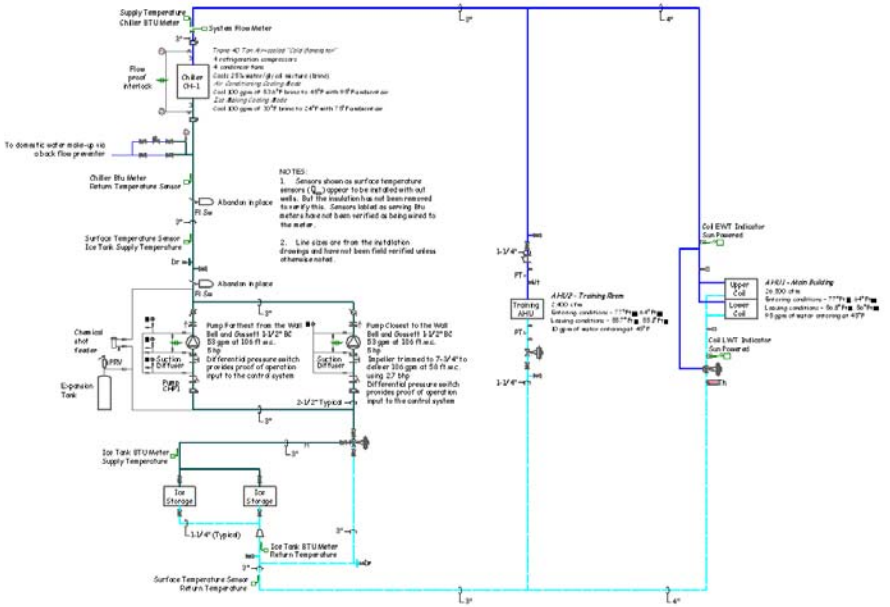
Drawn by: DAS	Date: April 29, 2002	HW01
Checked by:	Plot date: December 16, 2003	

What's on the Ladder Rungs and What's on the Ladder Rails Can Vary

"What's using up the pump head?" focus



"What's making and using cold glycol?" focus



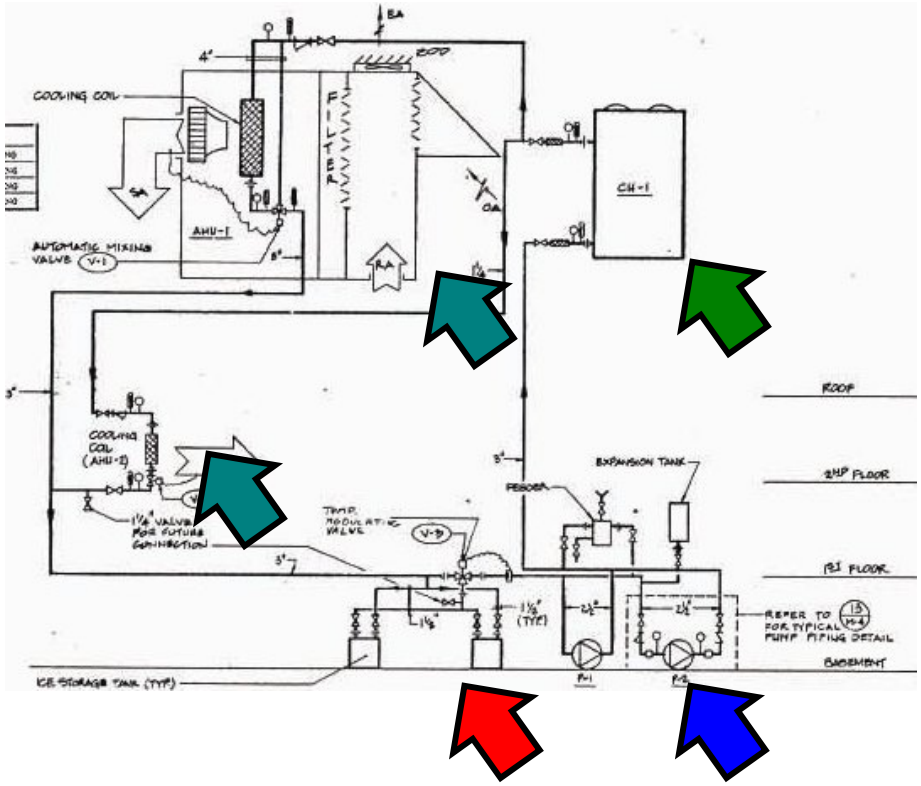
“Untangled” versus “Tangled”

tangled *adj*

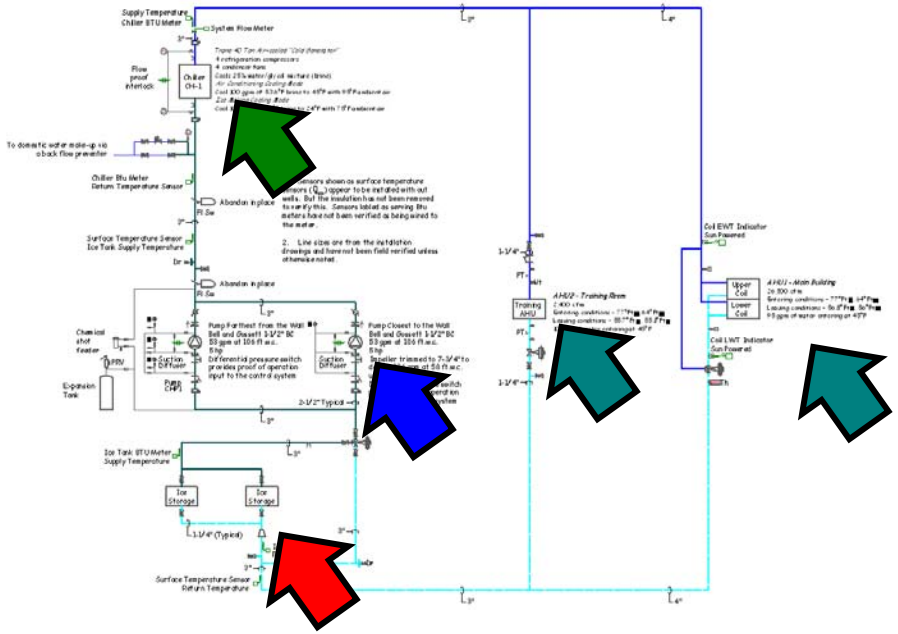
1. existing in or giving the appearance of a state of utter disorder
2. very involved : exceedingly complex

“Untangled” versus “Tangled”

Tangled



Untangled



Sutardja Dia Hall

Applying a system diagram to analyze a system

Tangled vs. Untangled – An Exercise

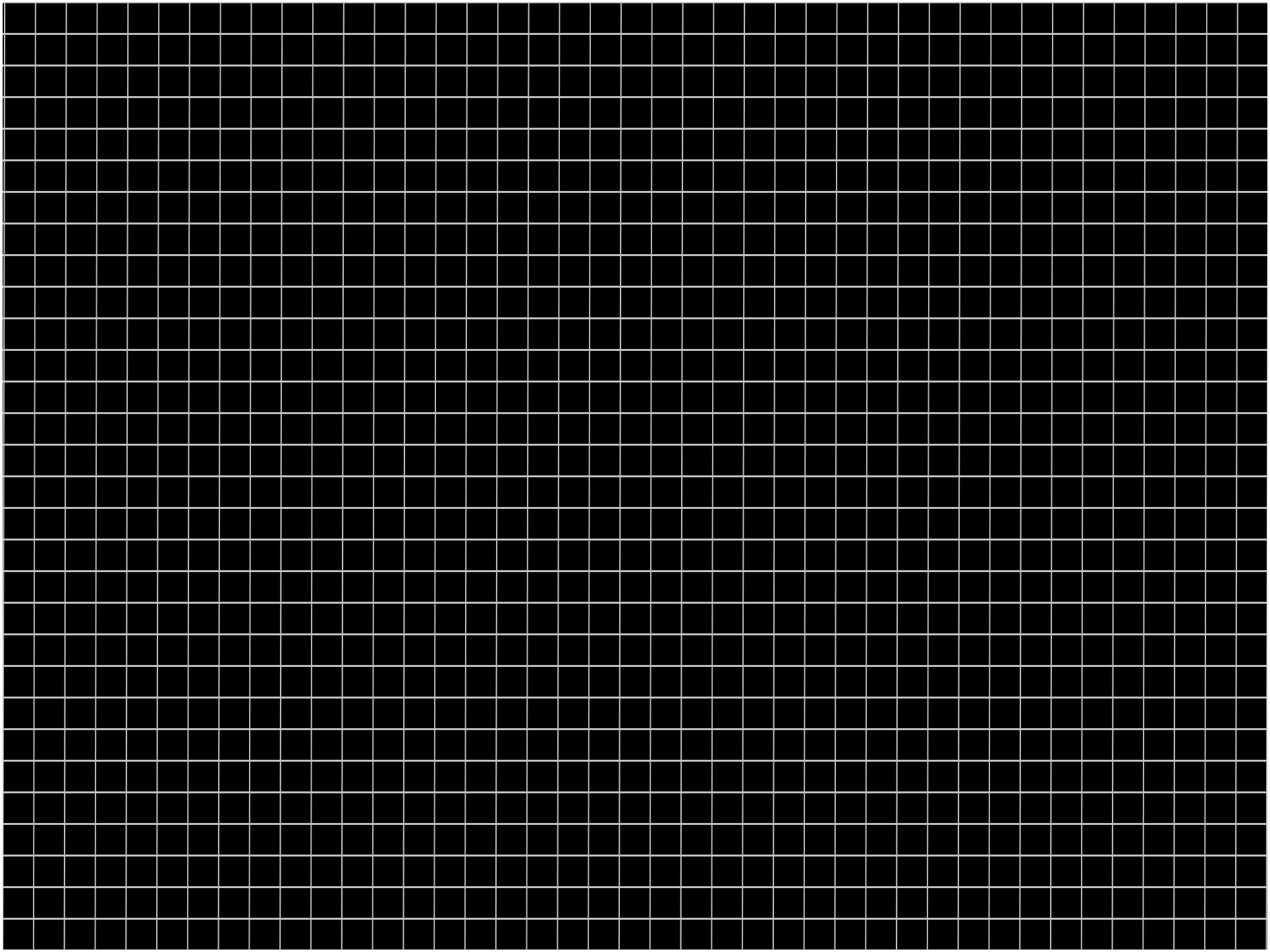
Left Side of the Room

- Locate the file named *Main Mechanical Room Plan.pdf* in the 02 - Exercise Materials\CW System directory, but don't open it, just get ready to

Right Side of the Room

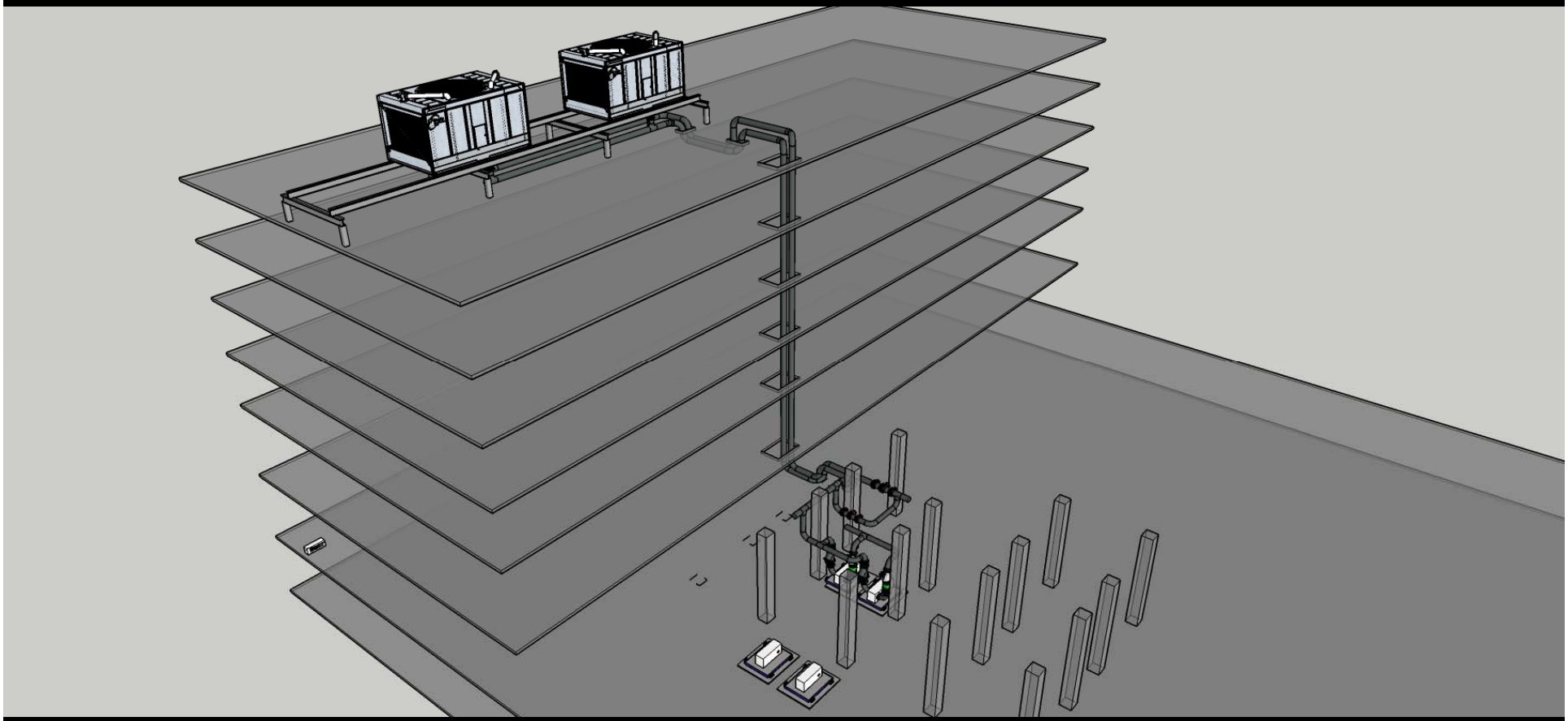
- Locate the file named *02-16-10 Condenser Water v3 - Teaching Example.pdf* in the 02 - Exercise Materials\CW System directory, but don't open it, just get ready to

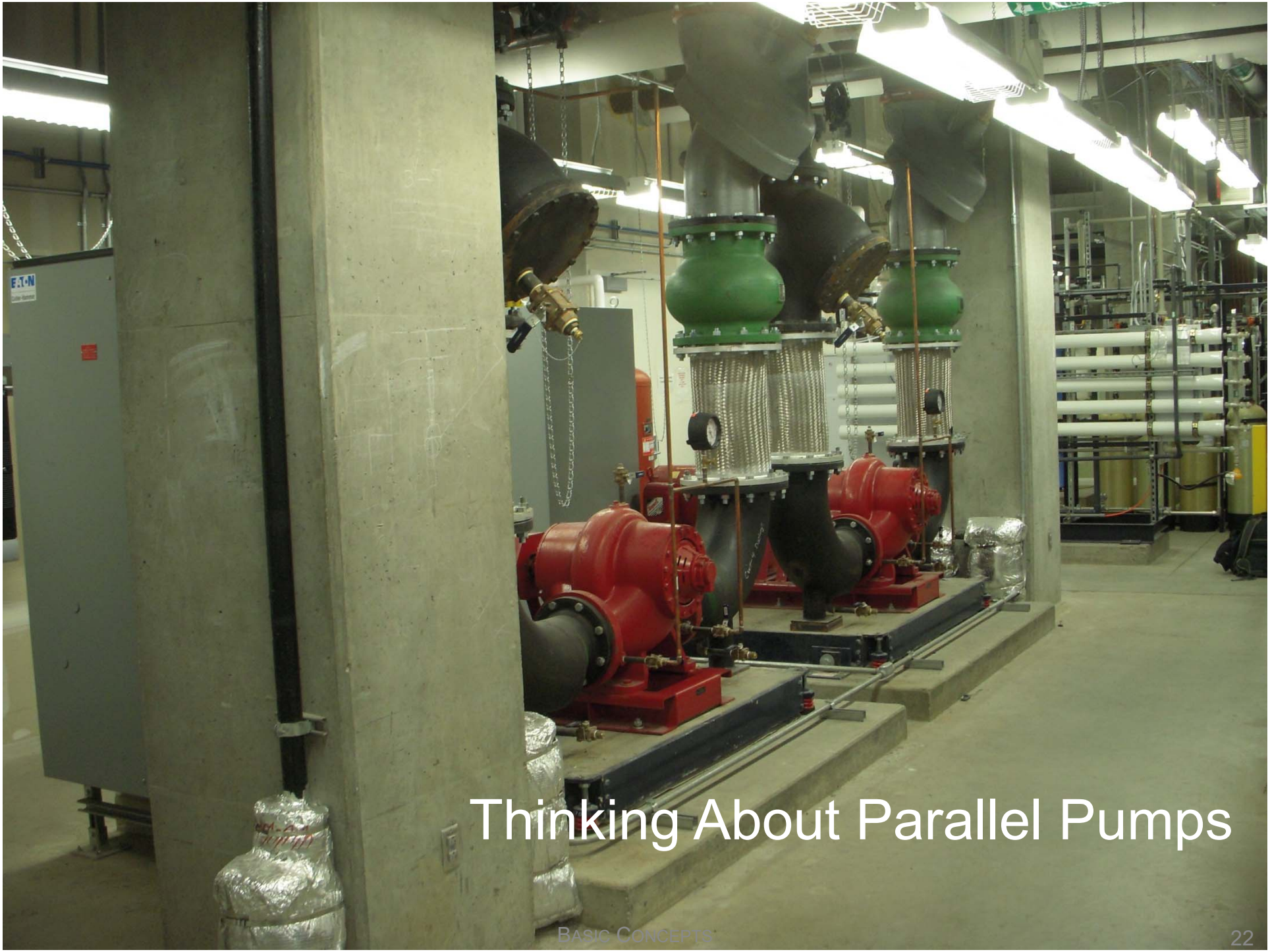
- When I say "Go" open the file you are associated with and try to understand if the Centrifugal Chiller condenser water pumps, the Absorption chiller condenser water pumps, and the Multistack chiller condenser water pumps are in parallel with each other through their loads
- Raise your hand when you think you know the answer

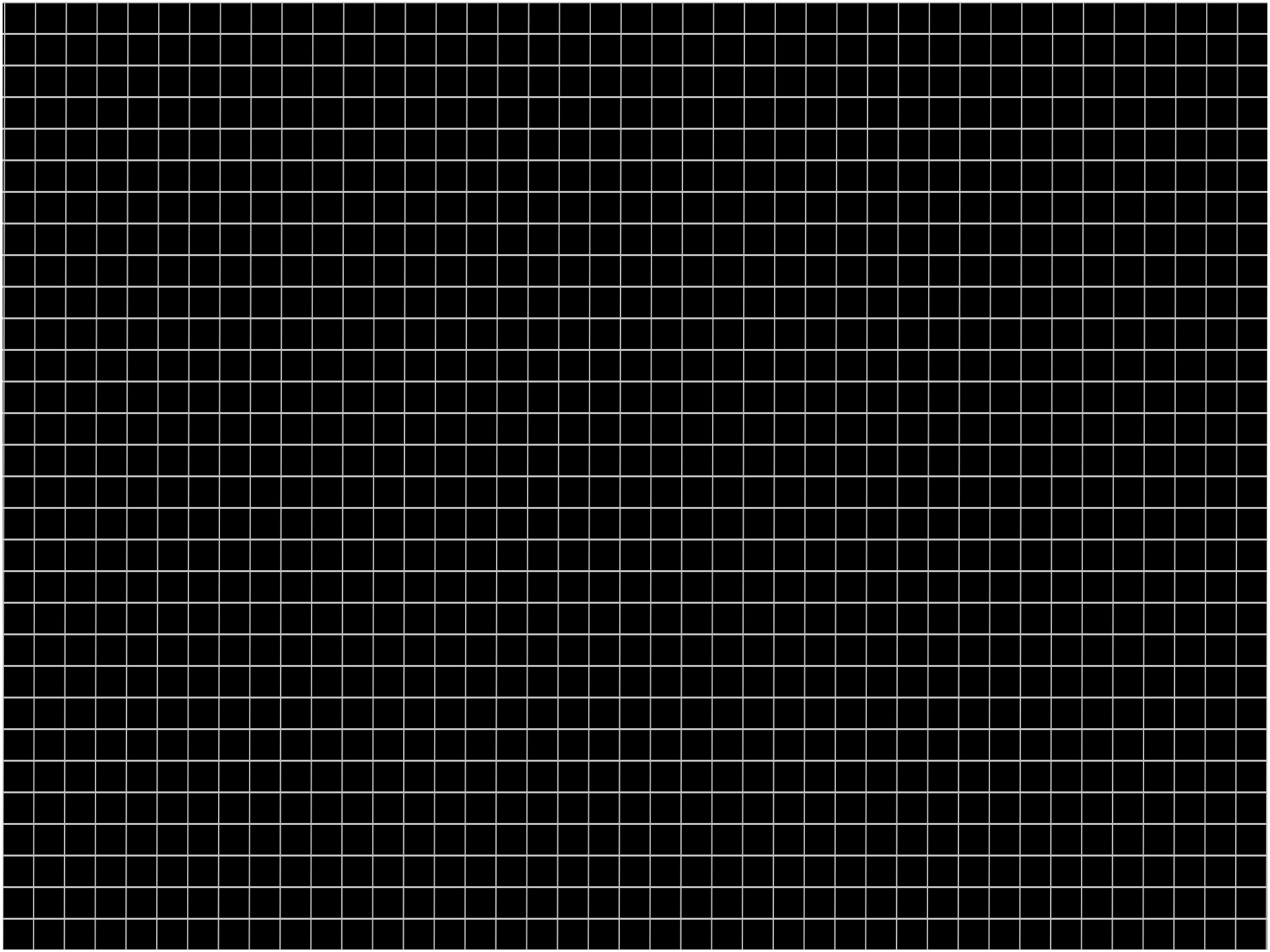


Sutardja Dia Hall

Why This Matters

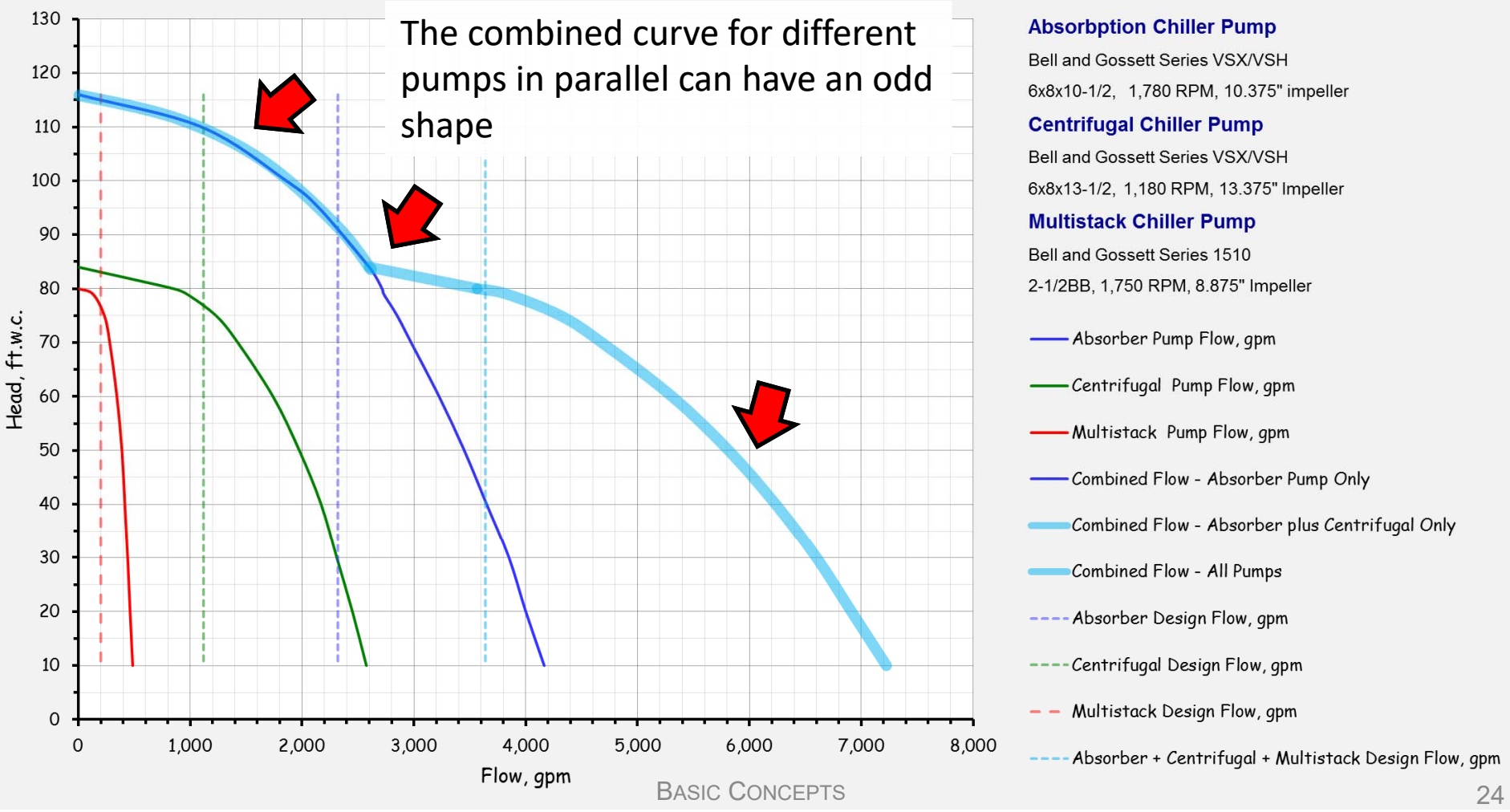



Thinking About Parallel Pumps



Incremental Volume

System Dynamics can be Complex as Pumps Interact

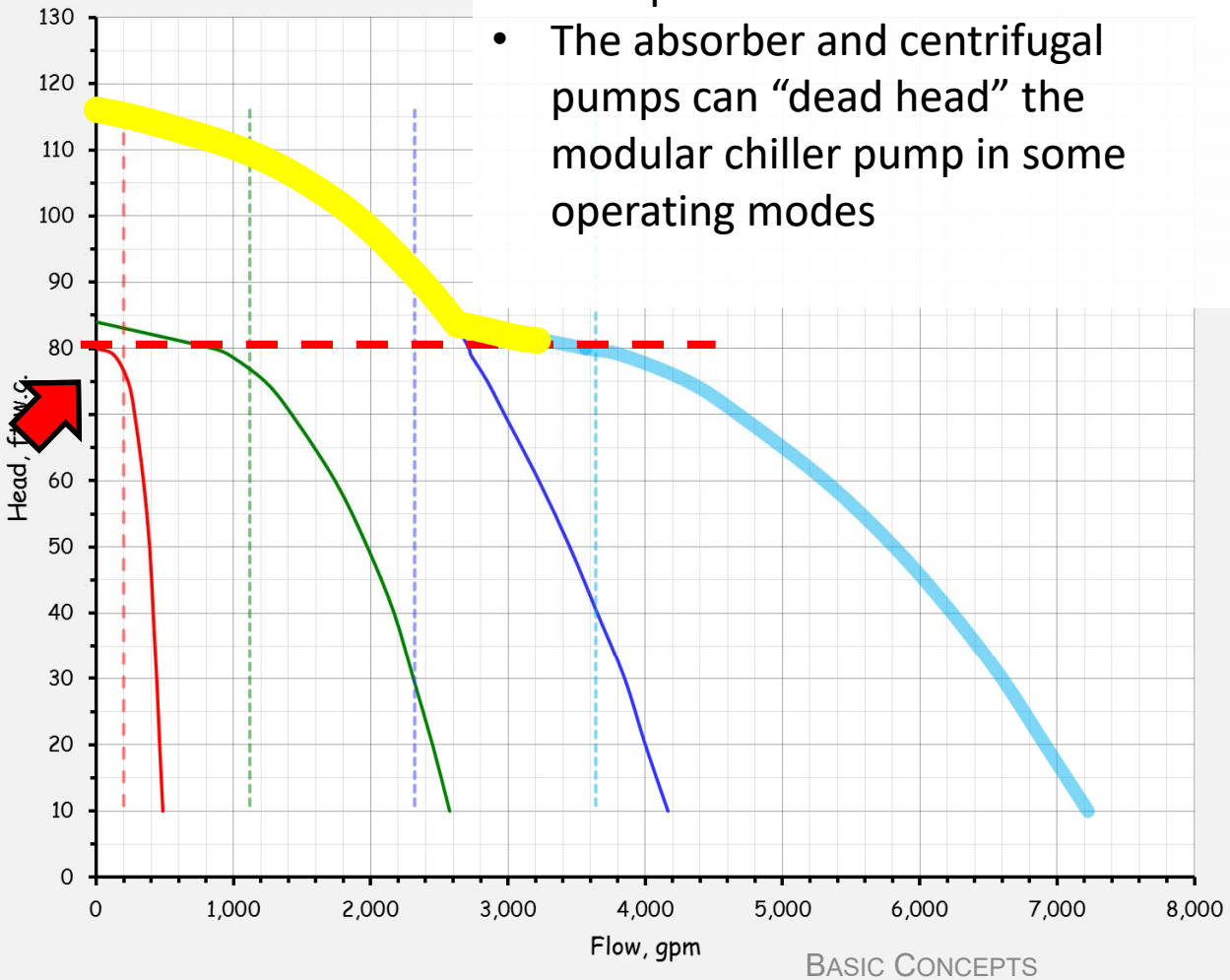


Incremental Volume

System Dynamics can be Complex as Pumps Interact

Odd shapes can lead to odd events

- The absorber and centrifugal pumps can “dead head” the modular chiller pump in some operating modes



Absorbption Chiller Pump

Bell and Gossett Series VSX/VSH

6x8x10-1/2, 1,780 RPM, 10.375" impeller

Centrifugal Chiller Pump

Bell and Gossett Series VSX/VSH

6x8x13-1/2, 1,180 RPM, 13.375" Impeller

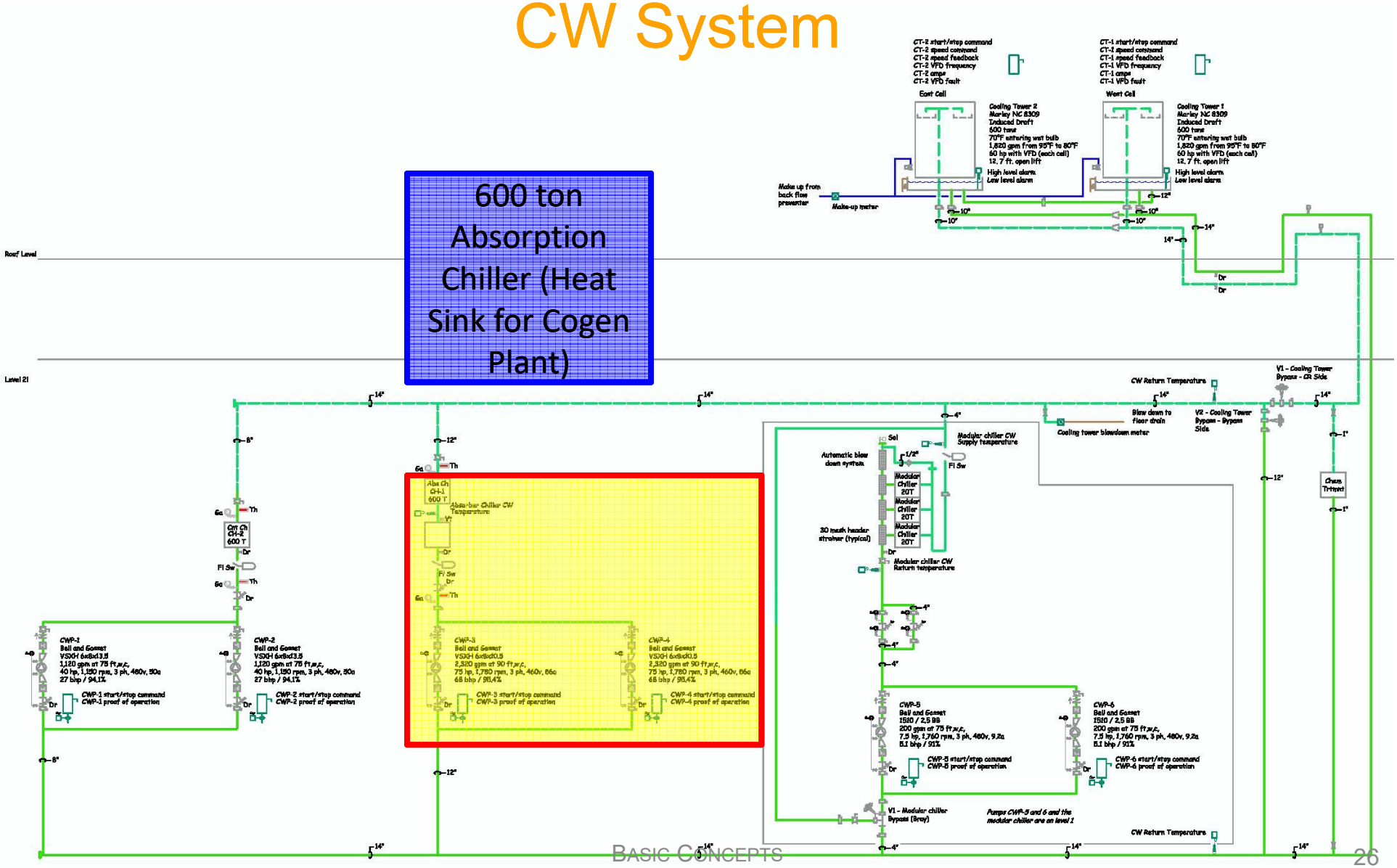
Multistack Chiller Pump

Bell and Gossett Series 1510

2-1/2BB, 1,750 RPM, 8.875" Impeller

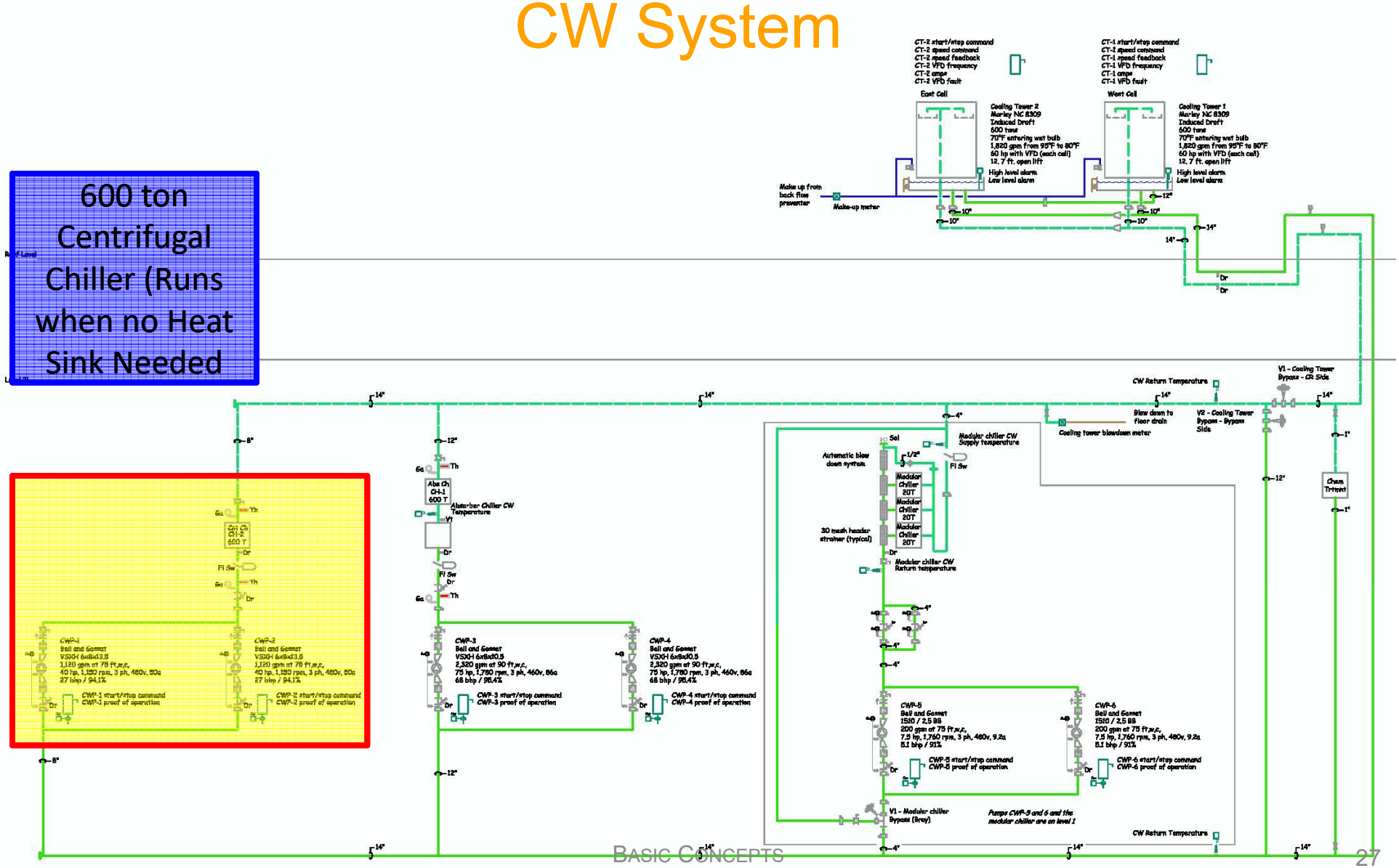
- Absorber Pump Flow, gpm
- Centrifugal Pump Flow, gpm
- Multistack Pump Flow, gpm
- Combined Flow - Absorber Pump Only
- Combined Flow - Absorber plus Centrifugal Only
- Combined Flow - All Pumps
- Absorber Design Flow, gpm
- Centrifugal Design Flow, gpm
- Multistack Design Flow, gpm
- Absorber + Centrifugal + Multistack Design Flow, gpm

Constant Volume CW System

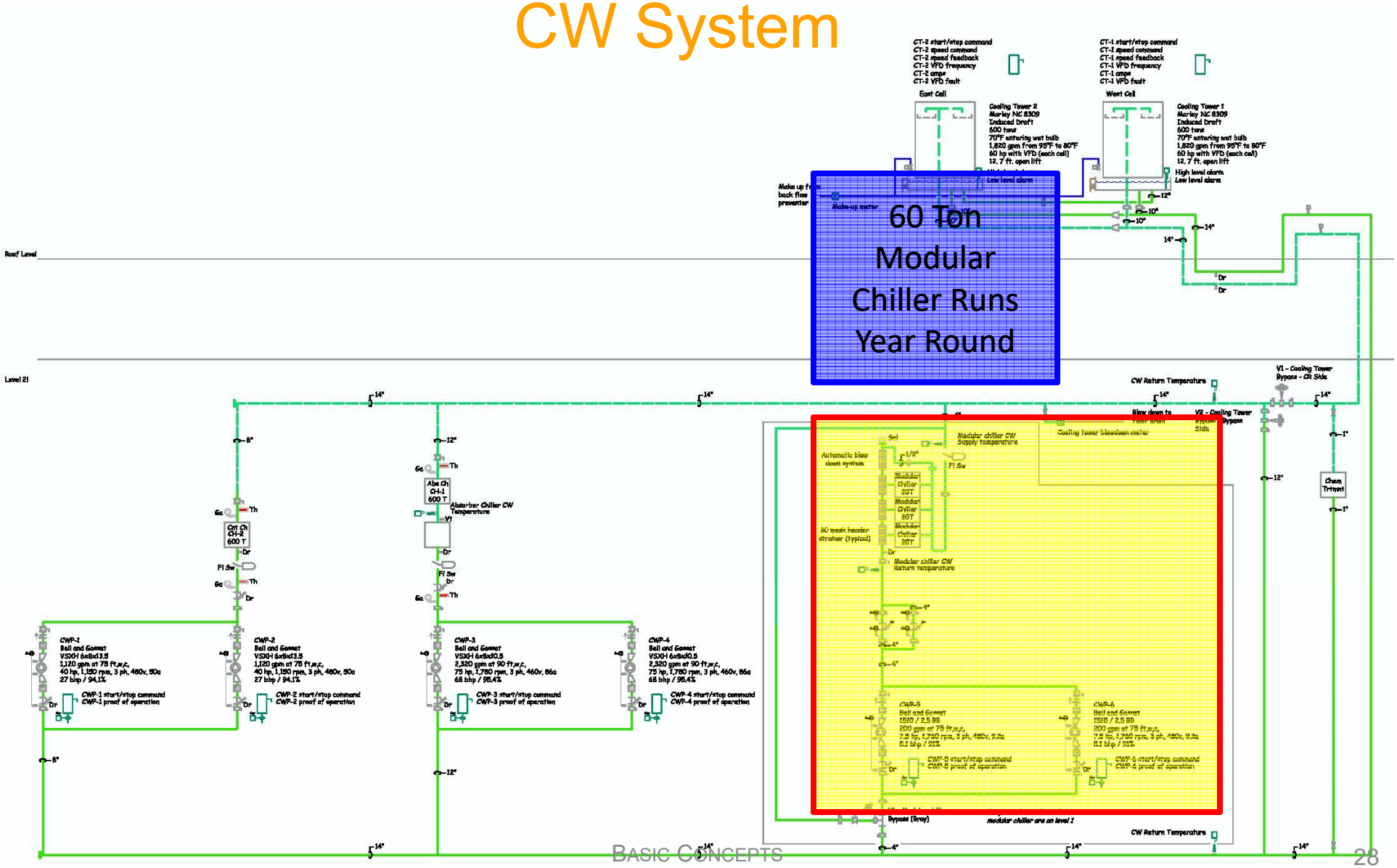


Constant Volume CW System

600 ton Centrifugal Chiller (Runs when no Heat Sink Needed



Constant Volume CW System



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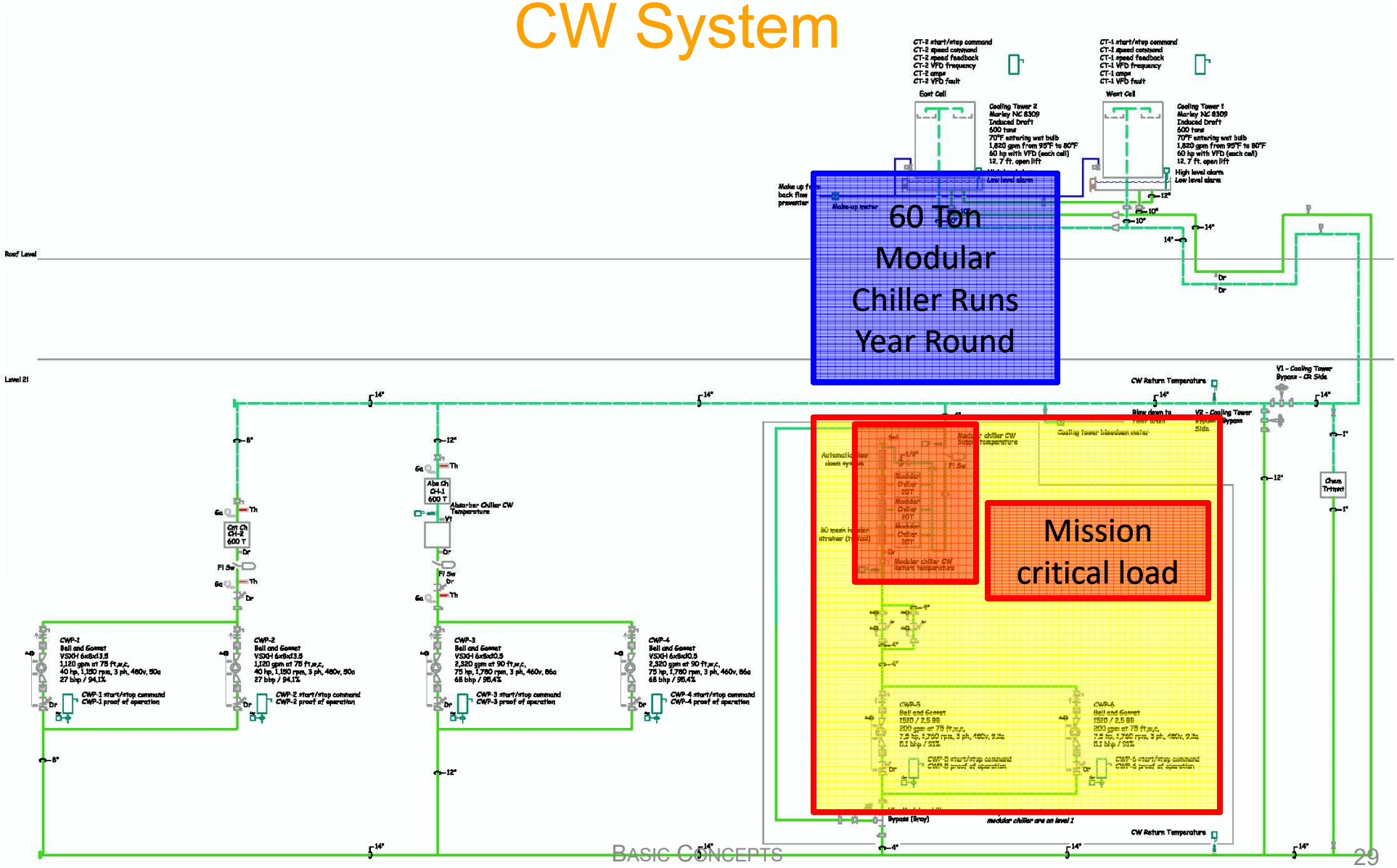
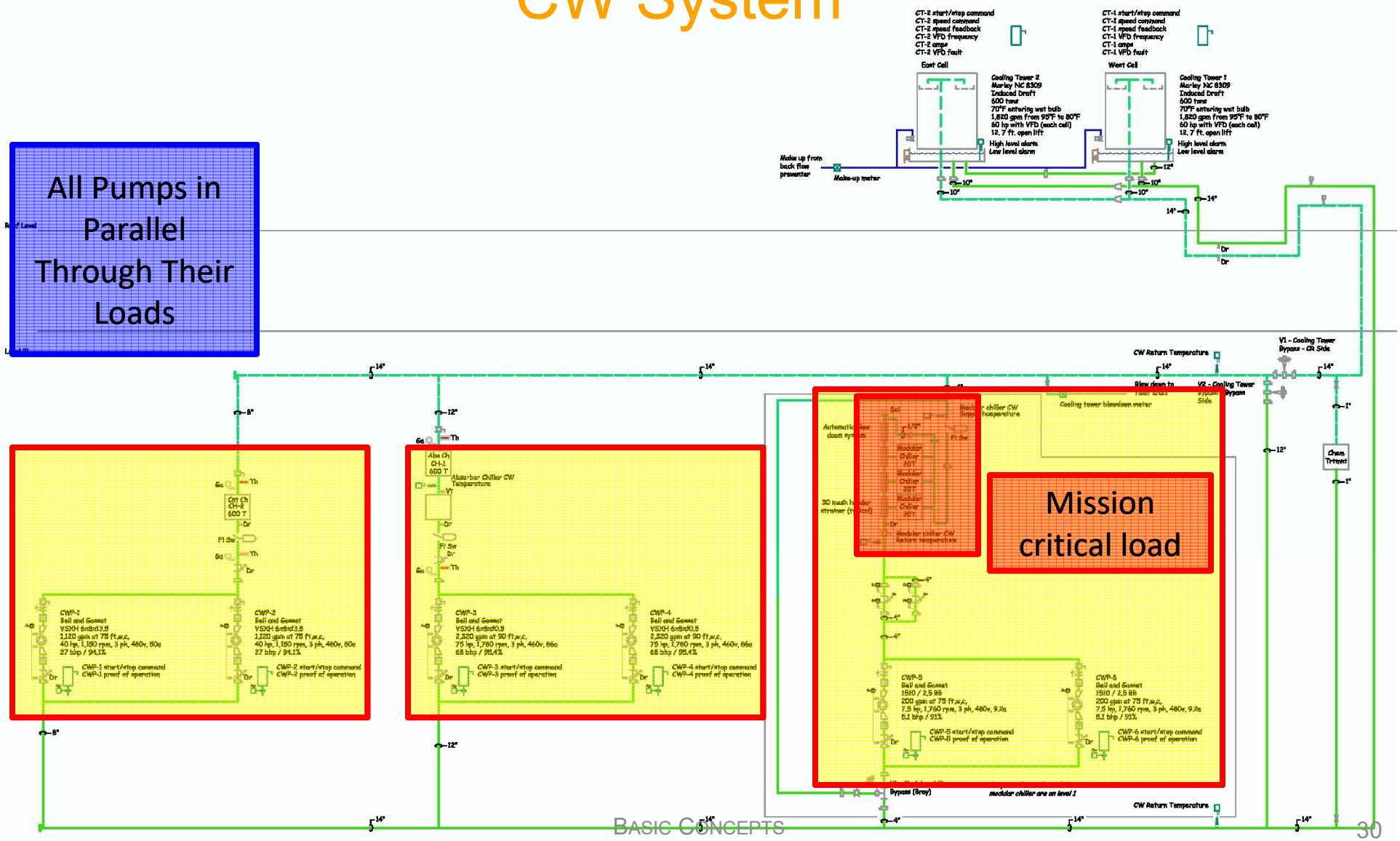


Constant Volume CW System

All Pumps in Parallel Through Their Loads



Constant Volume CW System

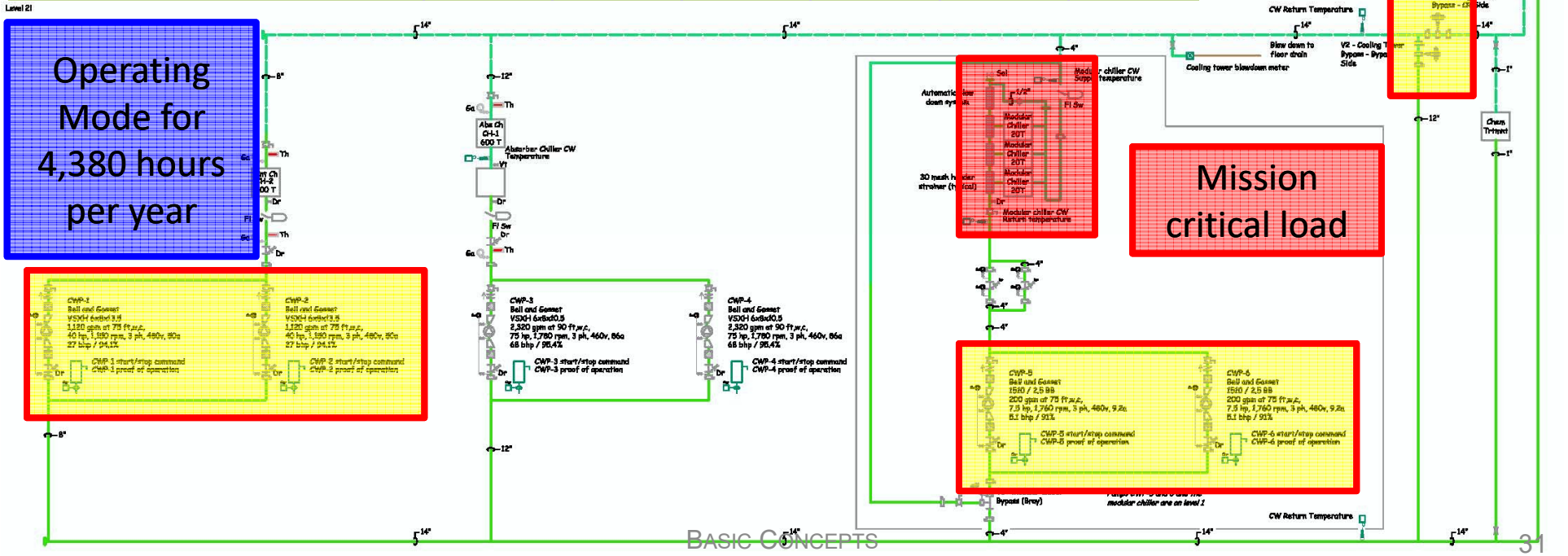
Test Data Summary

Design Targets	Total Flow, gpm
Centrifugal Chiller	1120
Absorption Chiller	2320
Modular Chiller	200
Absorber plus Centrifugal Chiller	3440
Absorber plus Modular Chiller	2520
Centrifugal plus Modular Chiller	1320
All Chillers	3640

Test Mode (V2 at 100% = Full Cooling Tower Bypass)	Total Flow, gpm	Target	% of Target	Centrifugal % Design Flow	Absorber % Design Flow	Modular % Design Flow
Testing Mode: M.S. Stand-Alone (V-2 0%)	205	200	103%			103%
Testing Mode: M.S. (V-2 100%)	235	200	118%			118%
Testing Mode: M.S. & Abs (V-2 0%)	2,510	2,520	100%		101%	80%
Testing Mode: M.S. & Abs (V-2 100%)	2,740	2,520	109%		112%	70%
Testing Mode: M.S. & Cent (V-2 0%)	1,475	1,320	112%	116%		88%
Testing Mode: M.S. & Cent (V-2 100%)	1,625	1,320	123%	132%		88%
Testing Mode: M.S, Abs & Cent (V-2 0%)	3,183	3,640	87%	92%	93%	0%
Testing Mode: M.S, Abs & Cent (V-2 100%)	4,045	3,640	111%	118%	110%	85%

Operating Mode for 4,380 hours per year

Mission critical load



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~~Constant Volume~~ CW System

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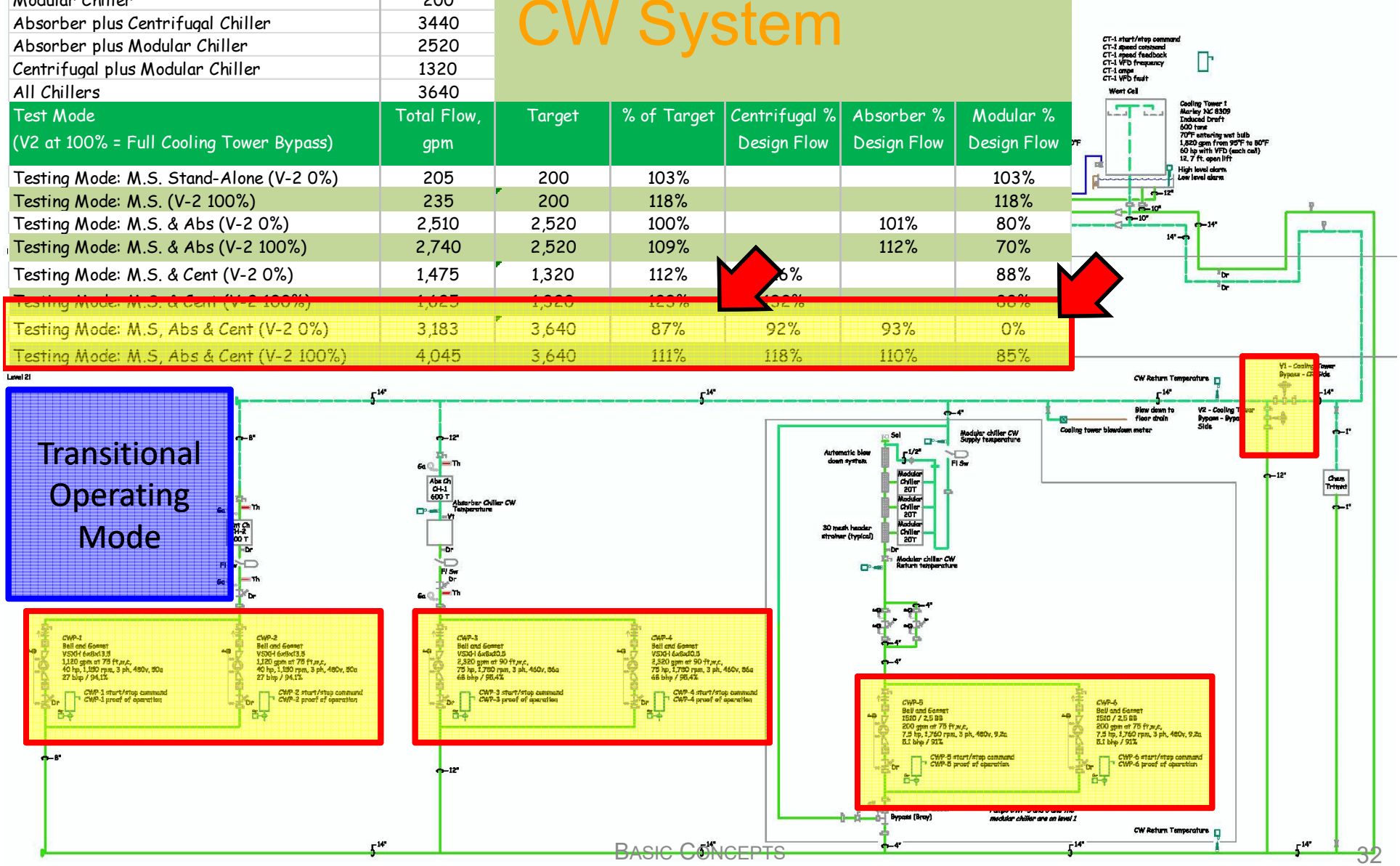
Testing Mode: M.S. & Cent (V-2 0%)	1,475	1,320	112%	[illegible]%		88%
~~Testing Mode: M.S. & Cent (V-2 100%)~~	~~1,625~~	~~1,320~~	~~123%~~	~~[illegible]%~~		~~88%~~
Testing Mode: M.S, Abs & Cent (V-2 0%)	3,183	3,640	87%	92%	93%	0%
Testing Mode: M.S, Abs & Cent (V-2 100%)	4,045	3,640	111%	118%	110%	85%



It All Depends on the Lags

David W. St. Clair

$$P_N \cong 4 \times L$$

Where :

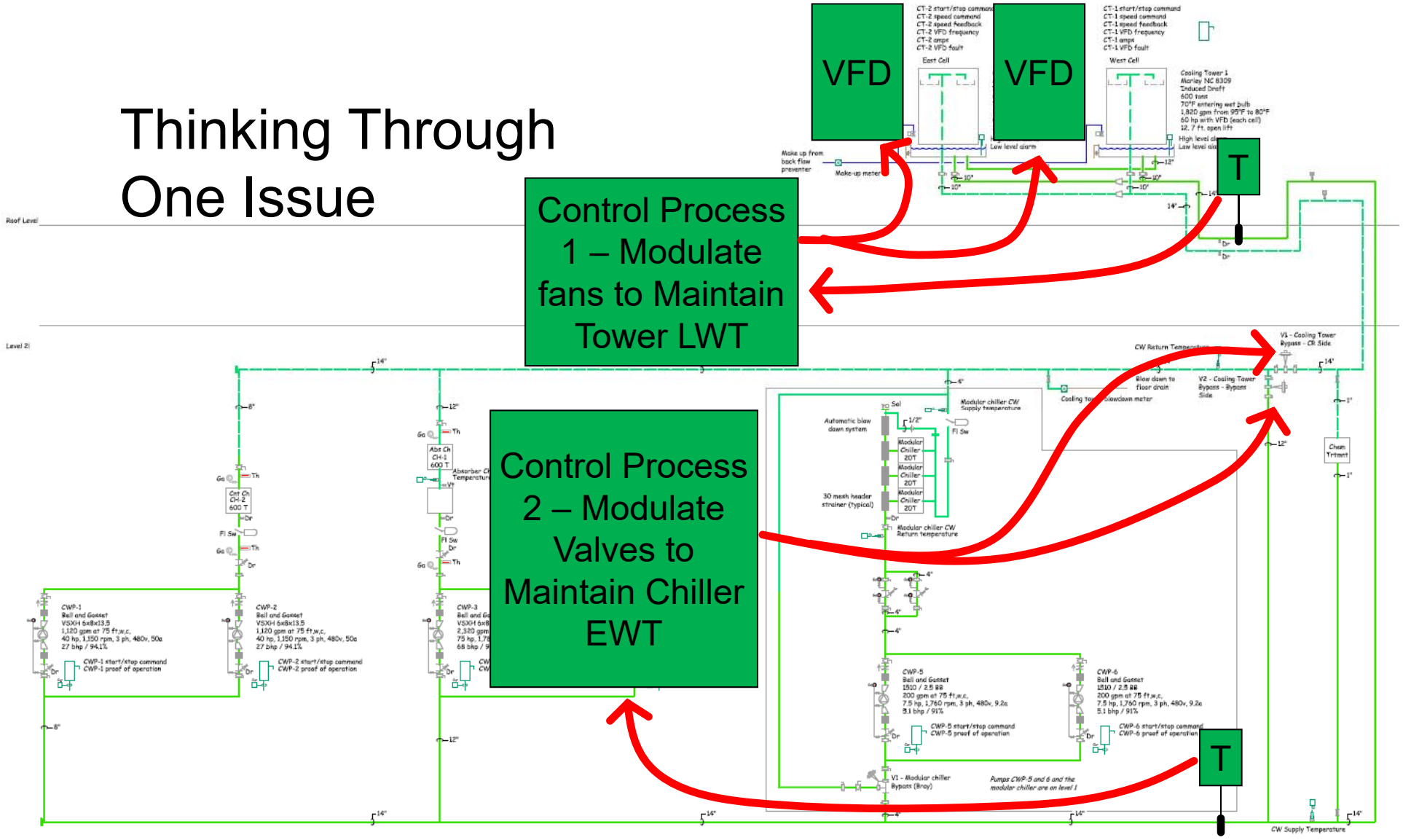
P_N = Natural period

L = Apparent dead time

If you understand the lags, you understand the potential for precision; i.e. what's the best result you can hope for

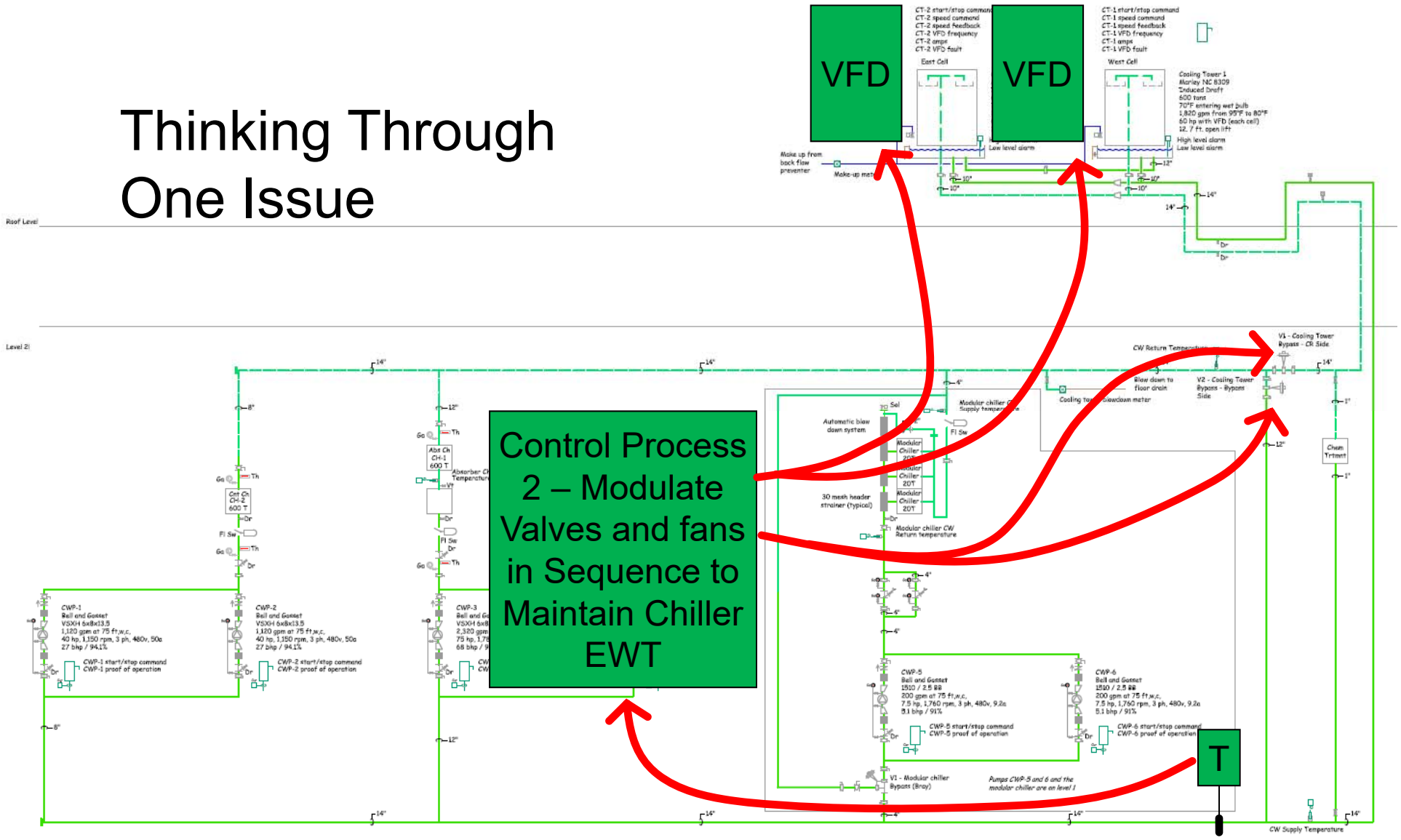
- In the best of all worlds, how far will things get out of hand before the control system will limit the deviation after an upset
- In the best of all worlds how fast will you be able to recover after an upset

Thinking Through One Issue



Given the information that follows what are the pros and cons of controlling the tower fans and bypass valve based on two independent loops …

Thinking Through One Issue



… or one loop?

Thinking Through a Control Process

- Minimum flow rate is 200 gpm (Modular chiller only; when below 50°F OAT in Berkeley CA)
- Maximum flow rate is 3,640 gpm (transitioning from absorber to centrifugal or vice versa)
- Typical flow rate is 1,320 – 2,520 gpm (centrifugal or absorber plus modular chiller)

Black Iron Pipe Data

Source - ASHRAE 2012 Systems and Equipment Handbook, Chapter 46, Pipe, Tubes, and Fittings, Table 2

Nominal Size, inches	Pipe OD, inches	Schedule Number or Weight[a]	Wall Thickness, inches	Inside Diameter, inches	Surface Area, square feet		Cross Section, square inches		Weight, pounds/foot		Working Pressure, ASTM A53 B to 400°F[c]		
					Outside, sq.ft.	Inside, sq.ft.	Metal Area	Flow Area	Pipe	Water	Mfg. Process	Joint Type[b]	Rating, psig
1/4	0.54	40 ST	0.088	0.364	0.141	0.095	0.125	0.104	0.424	0.045	CW	T	188
		80 XS	0.119	0.302	0.141	0.079	0.157	0.072	0.535	0.031	CW	T	871
3/8	0.675	40 ST	0.091	0.493	0.177	0.129	0.167	0.191	0.567	0.083	CW	T	203
		80 XS	0.423	0.177	0.111	0.217	0.141	0.738	0.061	CW	T	820	
1/2	0.84	40 ST	0.109	0.622	0.22	0.163	0.25	0.304	0.85	0.131	CW	T	214
		80 XS	0.546	0.22	0.143	0.32	0.234	1.087	0.101	CW	T	753	
3/4	1.05	40 ST	0.113	0.824	0.275	0.216	0.333	0.533	1.13	0.231	CW	T	217
		80 XS	0.742	0.275	0.194	0.433	0.432	1.47	0.187	CW	T	681	
1	1.315	40 ST	0.133	1.049	0.344	0.275	0.494	0.864	1.68	0.374	CW	T	226
		80 XS	0.957	0.344	0.251	0.639	0.719	2.17	0.311	CW	T	642	
1-1/4	1.66	40 ST	0.14	1.38	0.435	0.361	0.669	1.5	2.27	0.647	CW	T	229
		80 XS	1.278	0.435	0.335	0.881	1.28	2.99	0.555	CW	T	594	
1-1/2	1.9	40 ST	0.145	1.61	0.497	0.421	0.799	2.04	2.72	0.881	CW	T	231
		80 XS	1.5	0.497	0.393	1.068	1.77	3.63	0.765	CW	T	576	
2	2.375	40 ST	0.154	2.067	0.622	0.541	1.07	3.36	3.65	1.45	CW	T	230
		80 XS	1.939	0.622	0.508	1.48	2.95	5.02	1.28	CW	T	551	
2-1/2	2.875	40 ST	0.203	2.469	0.753	0.646	1.7	4.79	5.79	2.07	CW	W	533
		80 XS	2.323	0.753	0.608	2.25	4.24	7.66	1.83	CW	W	835	
3	3.5	40 ST	0.216	3.068	0.916	0.803	2.23	7.39	7.57	3.2	CW	W	482
		80 XS	2.9	0.916	0.759	3.02	6.6	10.25	2.86	CW	W	767	
4	4.5	40 ST	0.237	4.026	1.178	1.054	3.17	12.73	10.78	5.51	CW	W	430
		80 XS	3.826	1.178	1.002	4.41	11.5	14.97	4.98	CW	W	695	
6	6.625	40 ST	0.28	6.065	1.734	1.588	5.58	28.89	18.96	12.5	ERW	W	696
		80 XS	5.761	1.734	1.508	8.4	26.07	28.55	11.28	ERW	W	1209	
8	8.625	30	0.277	8.071	2.258	2.113	7.26	51.16	24.68	22.14	ERW	W	526
		40 ST	0.322	7.981	2.258	2.089	8.4	50.03	28.53	21.65	ERW	W	643
		80 XS	0.5	7.625	2.258	1.996	12.76	45.66	43.35	19.76	ERW	W	1106
10	10.75	30	0.307	10.136	2.814	2.654	10.07	80.69	34.21	34.92	ERW	W	485
		40 ST	0.365	10.02	2.814	2.623	11.91	78.85	40.45	34.12	ERW	W	606
		XS	0.5	9.75	2.814	2.552	16.1	74.66	54.69	32.31	ERW	W	887
		80	0.593	9.564	2.814	2.504	18.92	71.84	64.28	31.09	ERW	W	1081
12	12.75	30	0.33	12.09	3.338	3.165	12.88	114.8	43.74	49.68	ERW	W	449
		ST	0.375	12	3.338	3.141	14.58	113.1	49.52	48.94	ERW	W	528
		40	0.406	11.938	3.338	3.125	15.74	111.9	53.48	48.44	ERW	W	583
		XS	0.5	11.75	3.338	3.076	19.24	108.4	65.37	46.92	ERW	W	748
		80	0.687	11.376	3.338	2.978	26.03	101.6	88.44	43.98	ERW	W	1076
14	14	30 ST	0.375	13.25	3.665	3.469	16.05	137.9	54.53	59.67	ERW	W	481
		40	0.437	13.126	3.665	3.436	18.62	135.3	63.25	58.56	ERW	W	580
		XS	0.5	13	3.665	3.403	21.21	132.7	72.04	57.44	ERW	W	681
		80	0.75	12.5	3.665	3.272	31.22	122.7	106.05	53.11	ERW	W	1081
16	16	30 ST	0.375	15.25	4.189	3.992	18.41	182.6	62.53	79.04	ERW	W	421
		40 XS	0.5	15	4.189	3.927	24.35	176.7	82.71	76.47	ERW	W	596
18	18	ST	0.375	17.25	4.712	4.516	20.76	233.7	70.54	101.13	ERW	W	374
		30	0.437	17.126	4.712	4.483	24.11	230.3	81.91	99.68	ERW	W	451
		XS	0.5	17	4.712	4.45	27.49	227	93.38	98.22	ERW	W	530
		40	0.562	16.876	4.712	4.418	30.79	223.7	104.59	96.8	ERW	W	607
20	20	20 ST	0.375	19.25	5.236	5.039	23.12	291	78.54	125.94	ERW	W	337
		30 XS	0.5	19	5.236	4.974	30.63	283.5	104.05	122.69	ERW	W	477
		40	0.593	18.814	5.236	4.925	36.15	278	122.82	120.3	ERW	W	581

a. Numbers are schedule numbers per ASME Standard B36.10M; ST = Standard Weight; XS = Extra Strong.

b. T = Thread; W = Weld

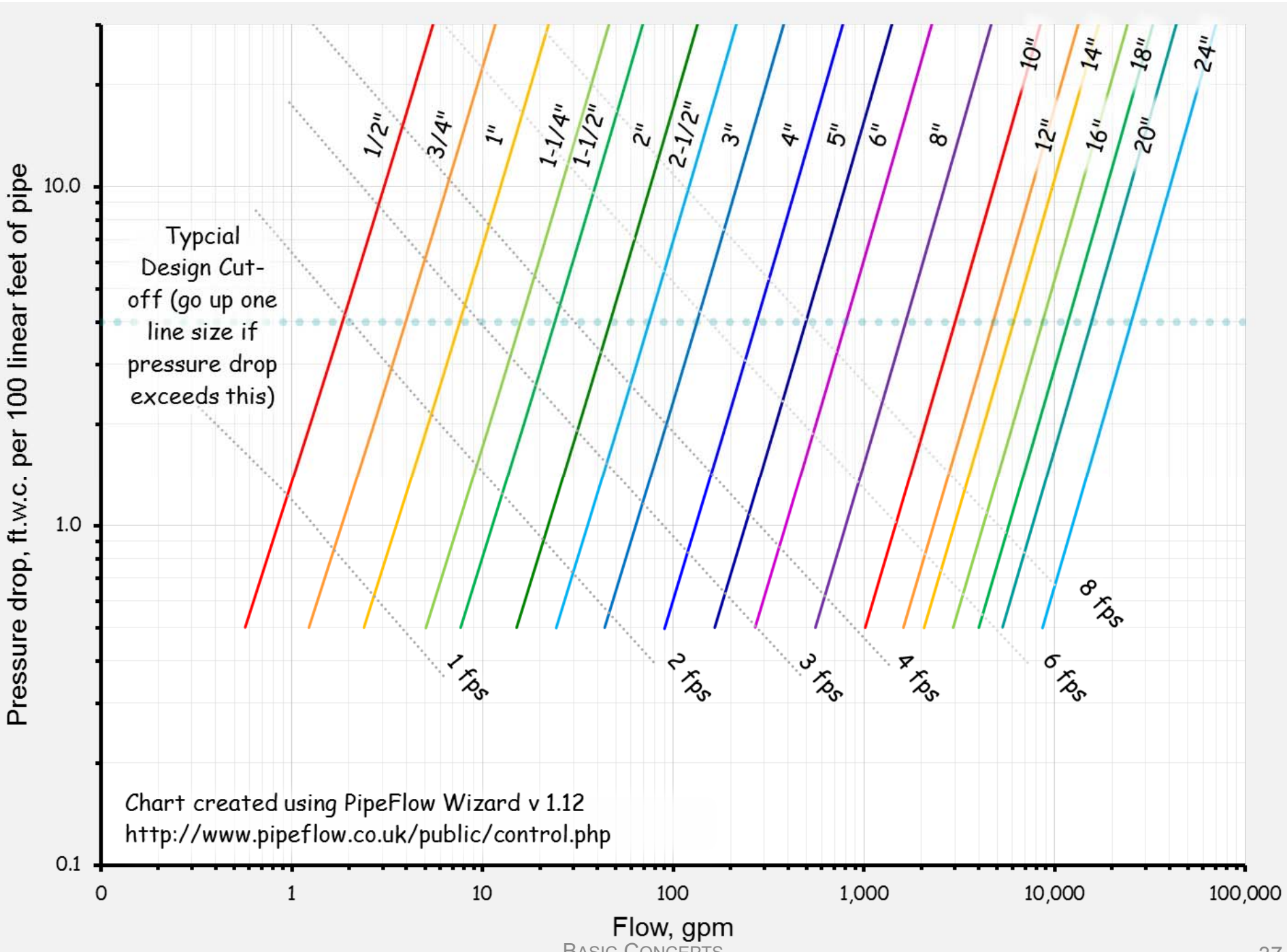
c. Working pressures were calculated per ASME B31.9 using furnace butt-weld (continuous weld, CW) pipe through 4 in. and electric resistance weld (ERW) thereafter. The allowance A has been taken as:

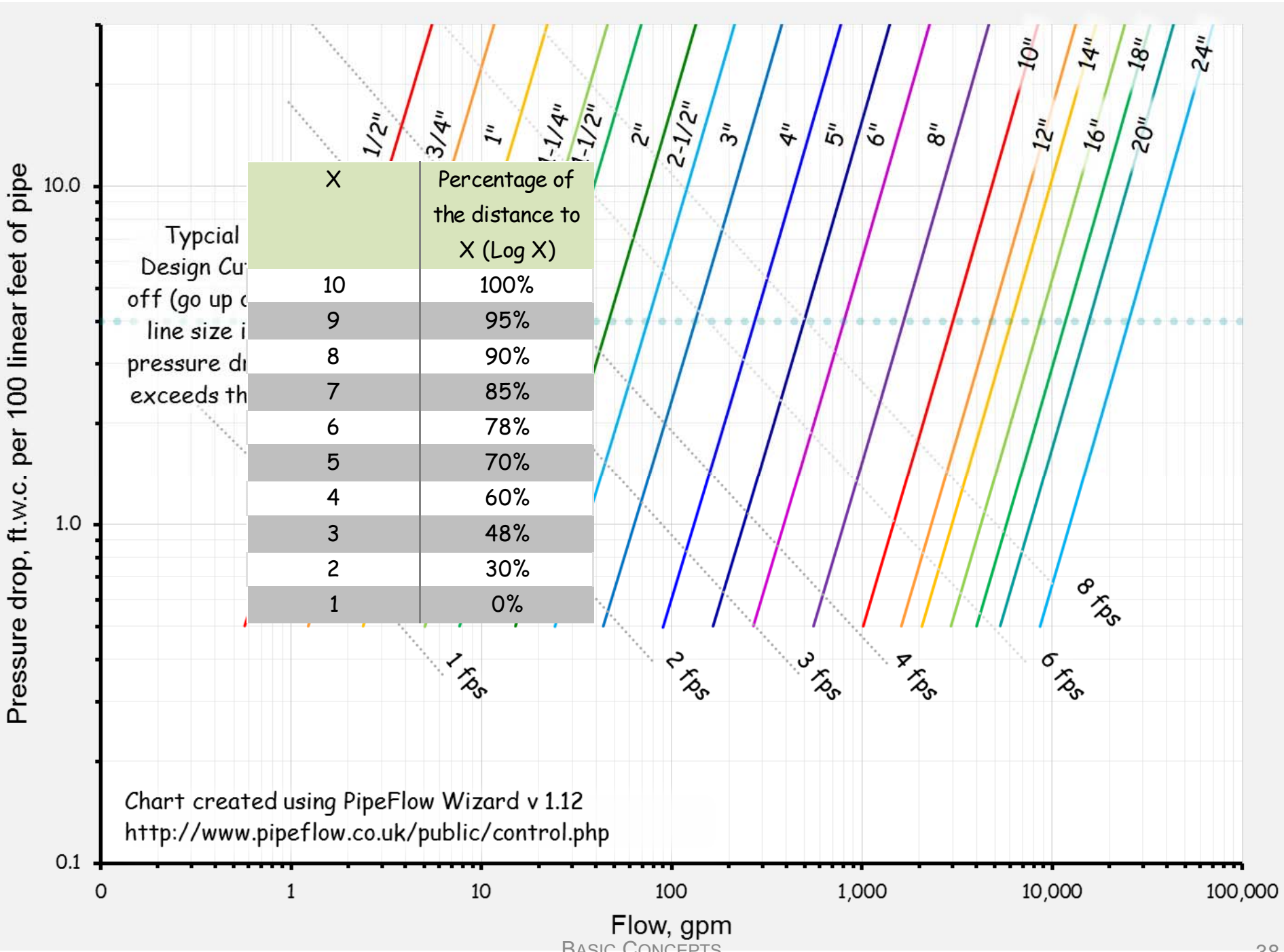
(1) 12.5% of t for mill tolerance on pipe wall thickness, plus

(2) An arbitrary corrosion allowance of 0.025 in. for pipe sizes through NPS 2 and

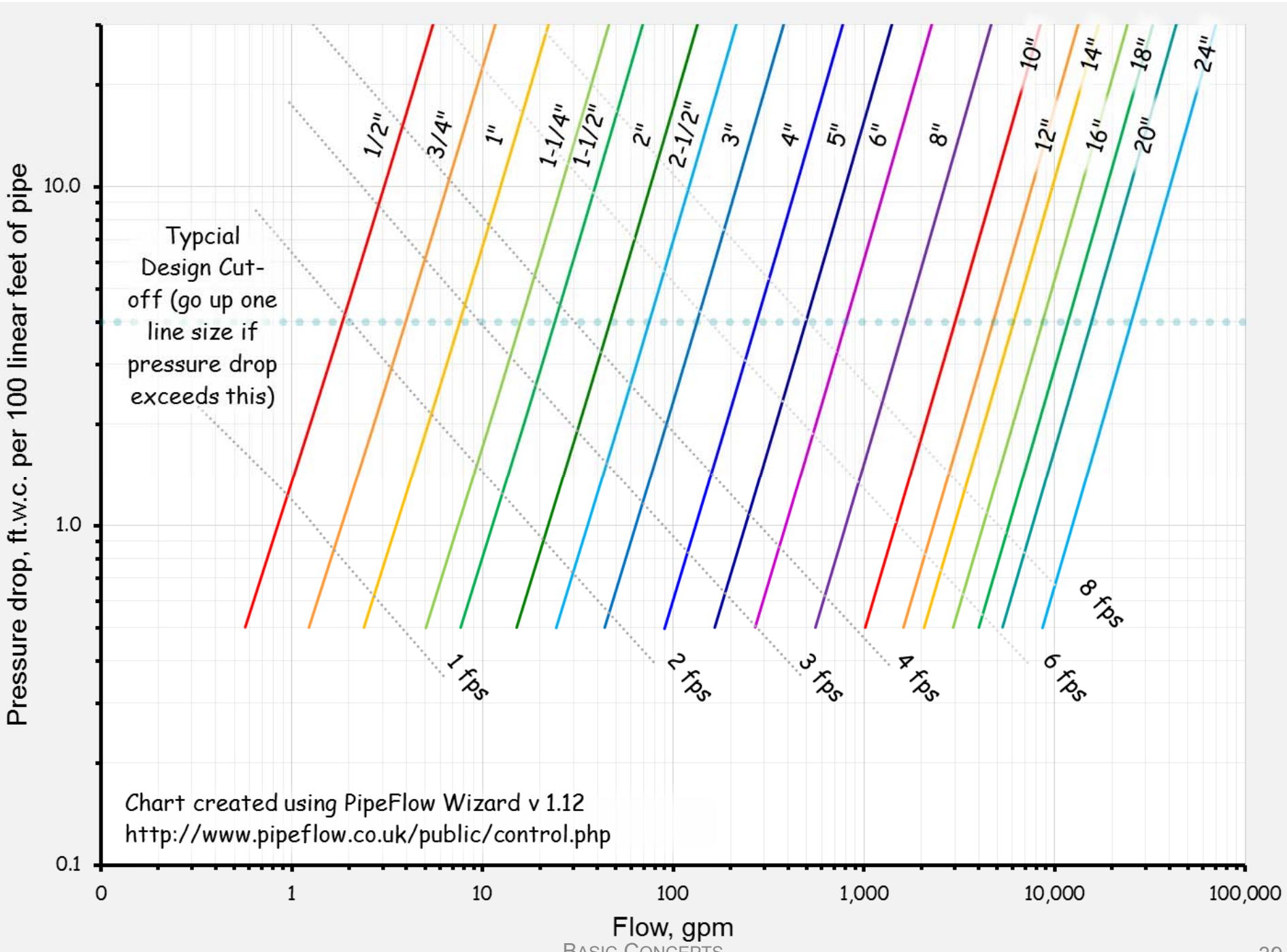
(3) A thread cutting allowance for sizes through NPS 2.

Because the pipe wall thickness of threaded standard pipe is so small after deducting allowance A, the mechanical strength of the pipe is impaired. It is good practice to limit standard weight threaded pipe pressure to 90 psig for steam and 125 psig for water.


Pressure drop, ft.w.c. per 100 linear feet of pipe
10.0
1.0
0.1
0
1
10
100
1,000
10,000
100,000
Flow, gpm
Typcial Design Cut-off (go up one line size if pressure drop exceeds this)
1/2"
3/4"
1"
1-1/4"
1-1/2"
2"
2-1/2"
3"
4"
5"
6"
8"
10"
12"
14"
16"
18"
20"
24"
1 fps
2 fps
3 fps
4 fps
6 fps
8 fps
Chart created using PipeFlow Wizard v 1.12
http://www.pipeflow.co.uk/public/control.php



X	Percentage of the distance to X (Log X)
10	100%
9	95%
8	90%
7	85%
6	78%
5	70%
4	60%
3	48%
2	30%
1	0%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16"
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1 fps
2 fps
3 fps
4 fps
6 fps
8 fps
Chart created using PipeFlow Wizard v 1.12
http://www.pipeflow.co.uk/public/control.php

“Untangled” versus “Tangled”

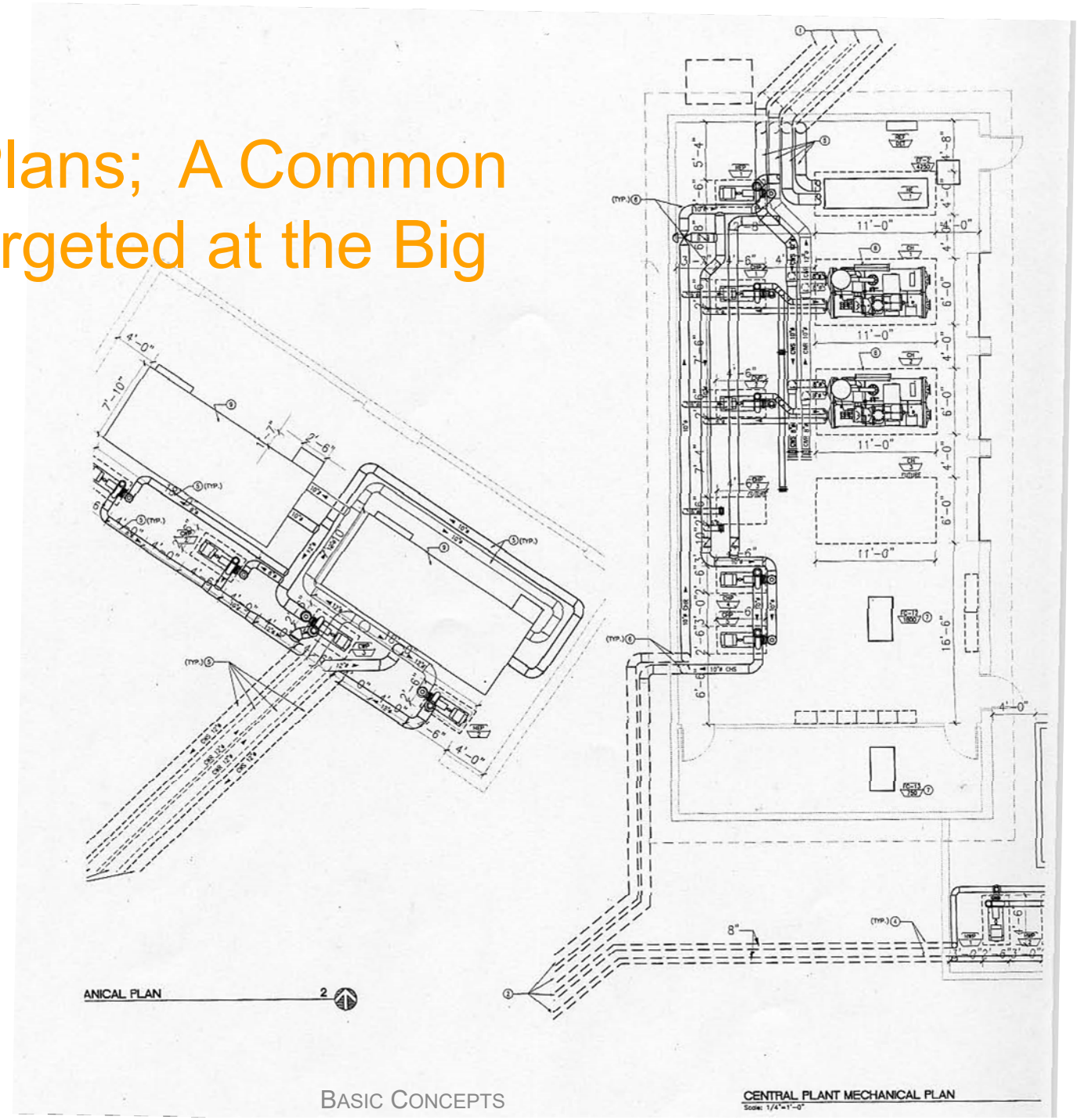
Keep simplifying things to minimize line crossings and head towards a “ladder on its side”

But remember:

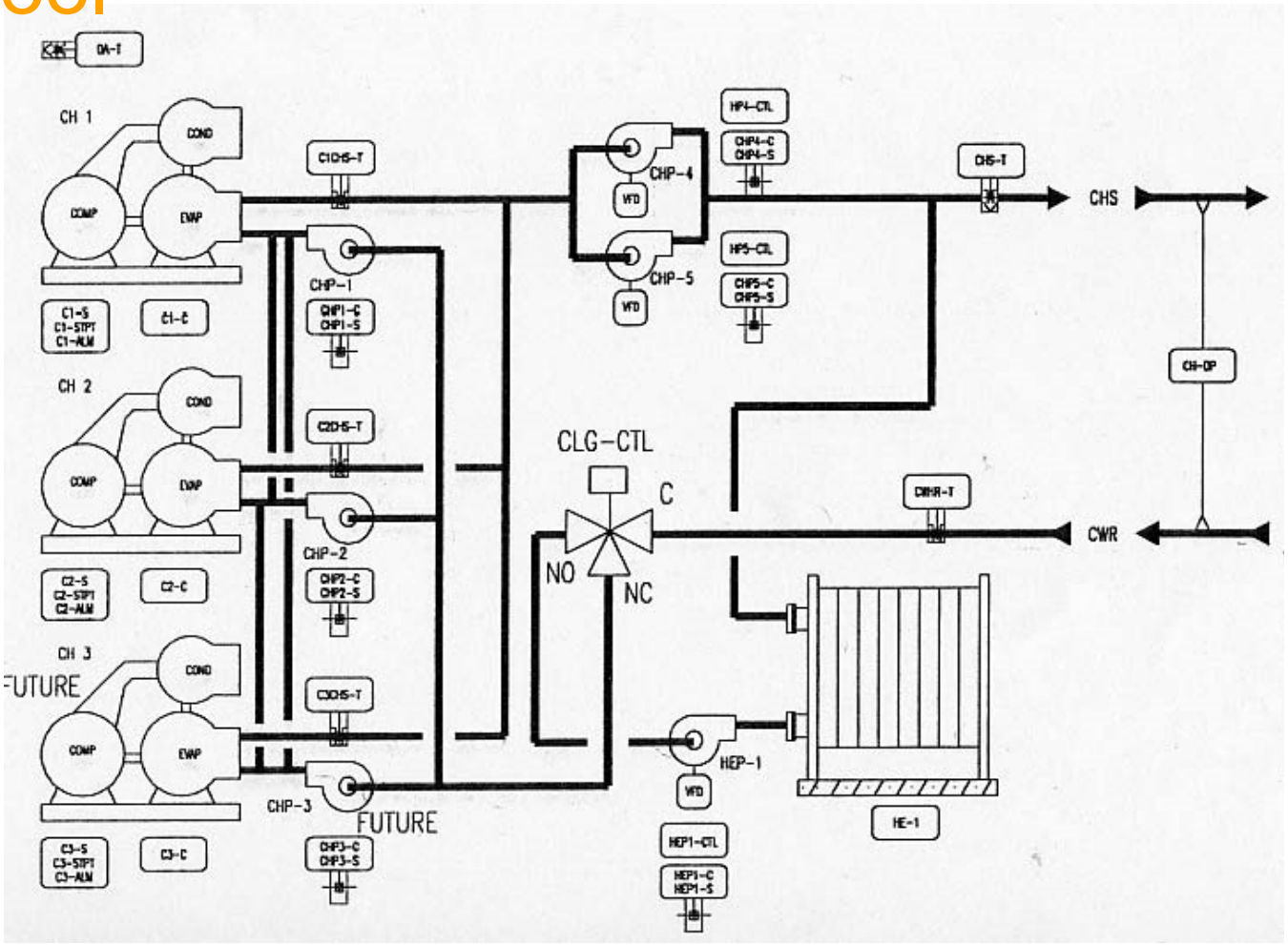
> *Things should be made as simple as possible, but not any simpler.*
>
> *Albert Einstein*

That means for a system diagram, order of connection “trumps” untangled

Floor Plans; A Common Tool Targeted at the Big Picture

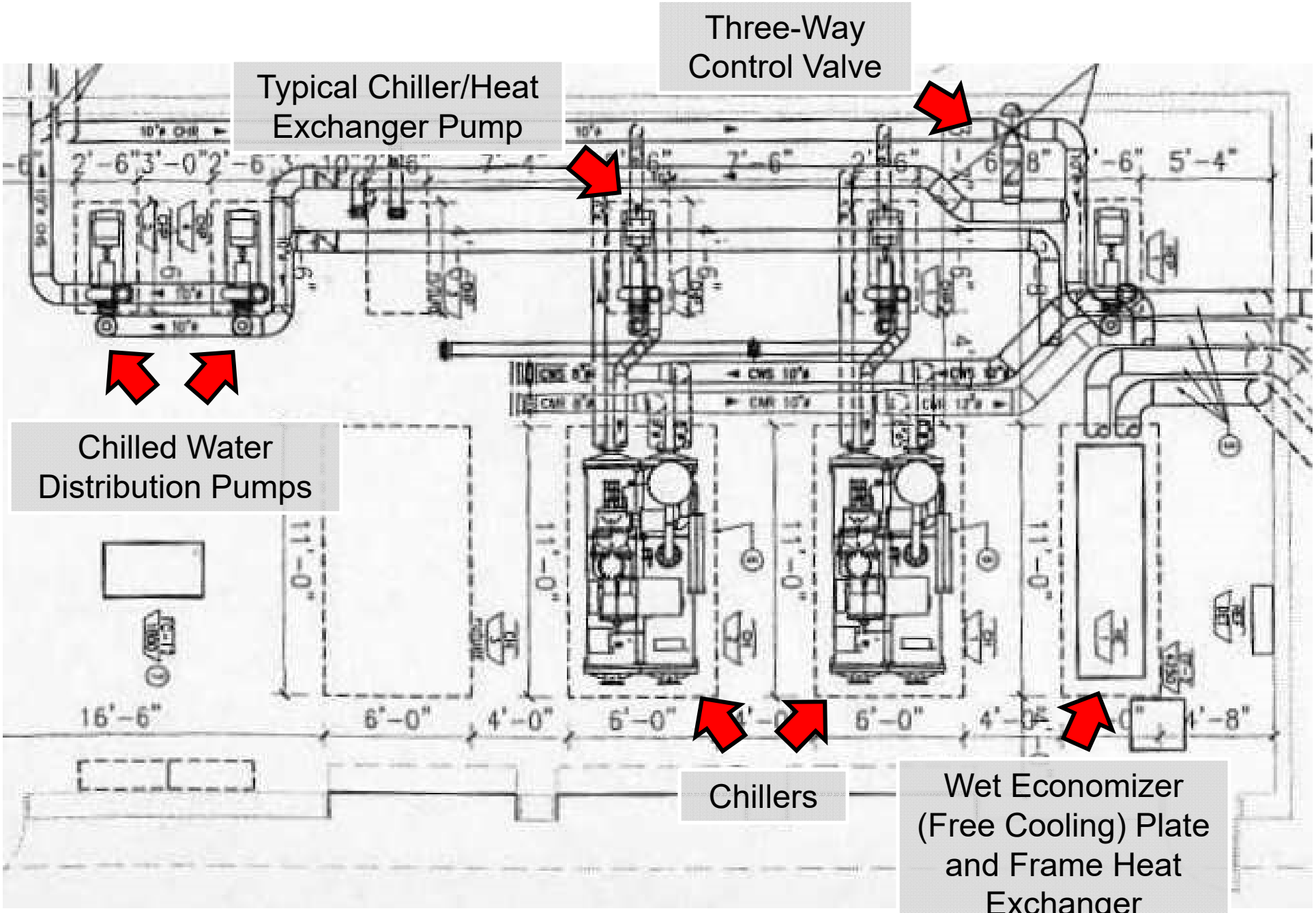


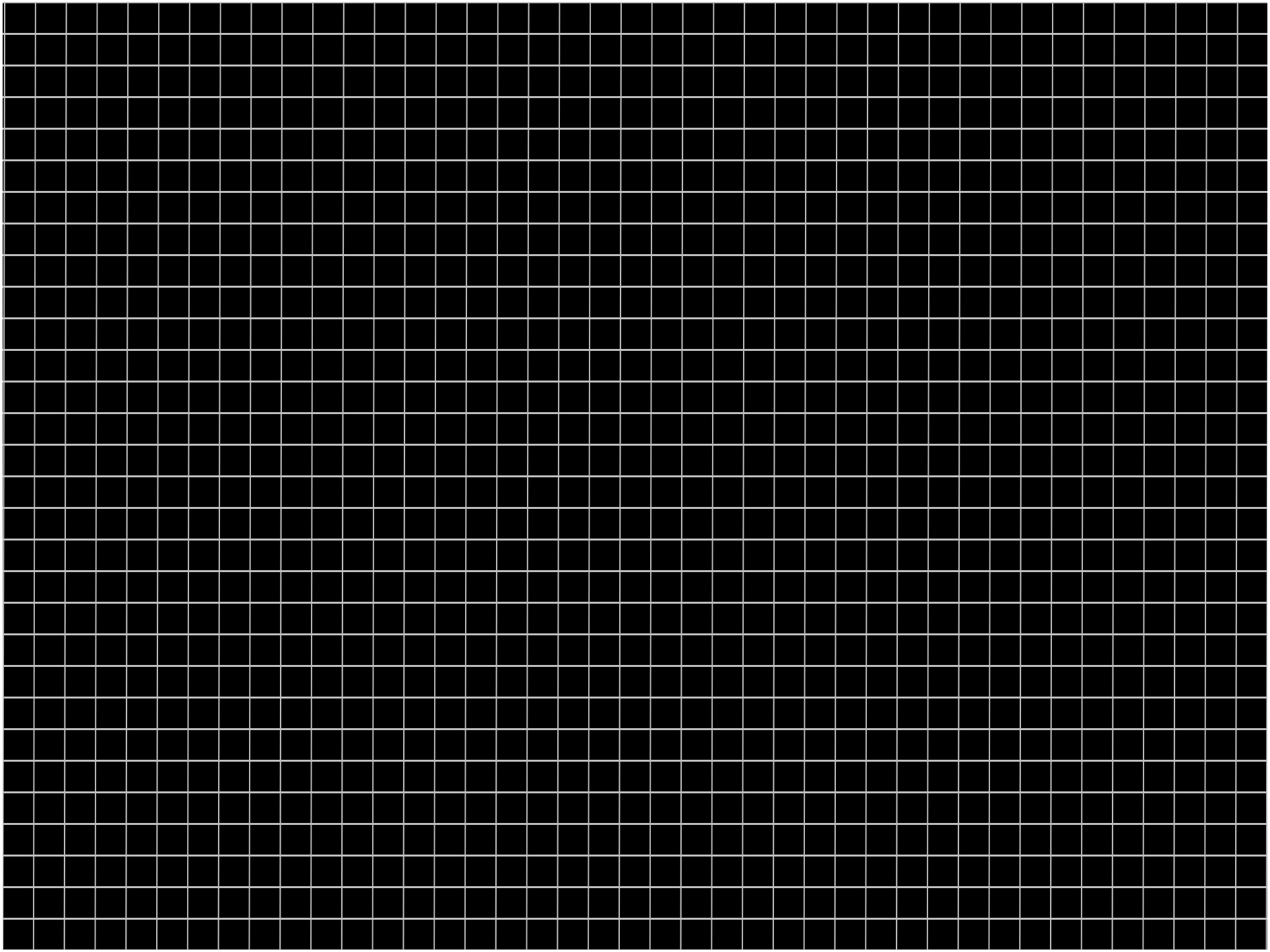
Schematics; Another Common Tool



An Exercise Applying What You've Learned So Far

- *Half the class take the piping plan in the next slide and make a system diagram from it*
- *The other half of the class take the schematic in the previous slide and make a system diagram from it*
- *See if there are any problems that jump out at you from your system diagrams*
- *Did you recognize/understand them before you did the system diagram?*


Three-Way Control Valve
Typical Chiller/Heat Exchanger Pump
Chilled Water Distribution Pumps
Chillers
Wet Economizer (Free Cooling) Plate and Frame Heat Exchanger



Order of Connection Matters

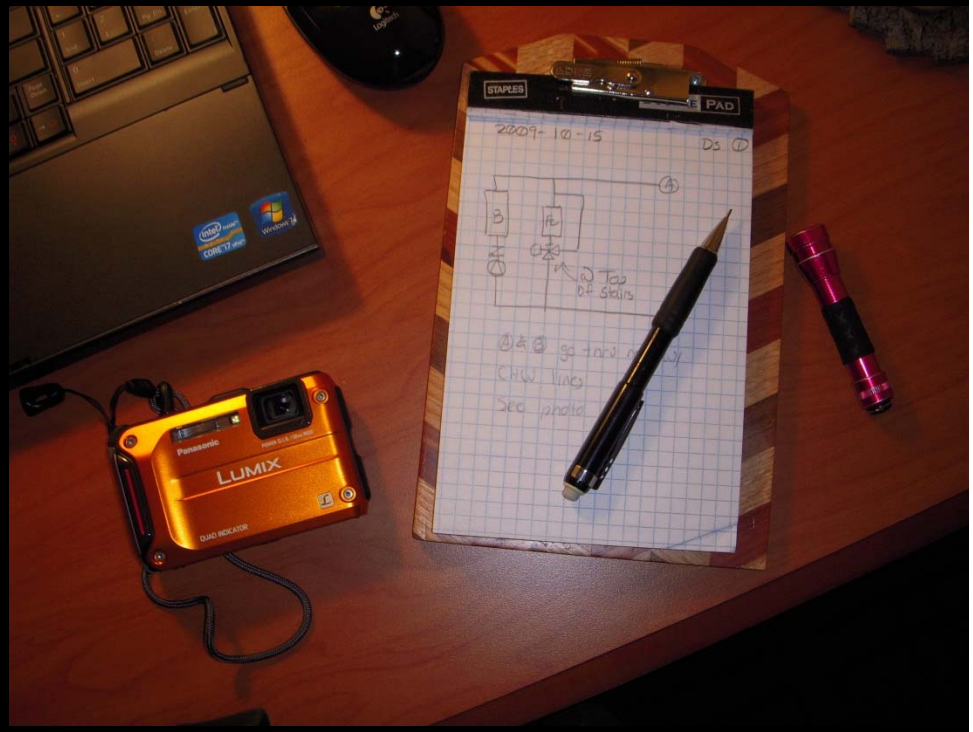
Getting Ready to Go Out in the Field

Study existing drawings if they exist

- May include a schematic
- May reveal issues
- Provides a first draft

Be ready for reality

- Clipboard
- Paper
- Flashlight
- Camera



Getting Started

Find something you can identify

- Nameplate data
- Labels
- Past experience

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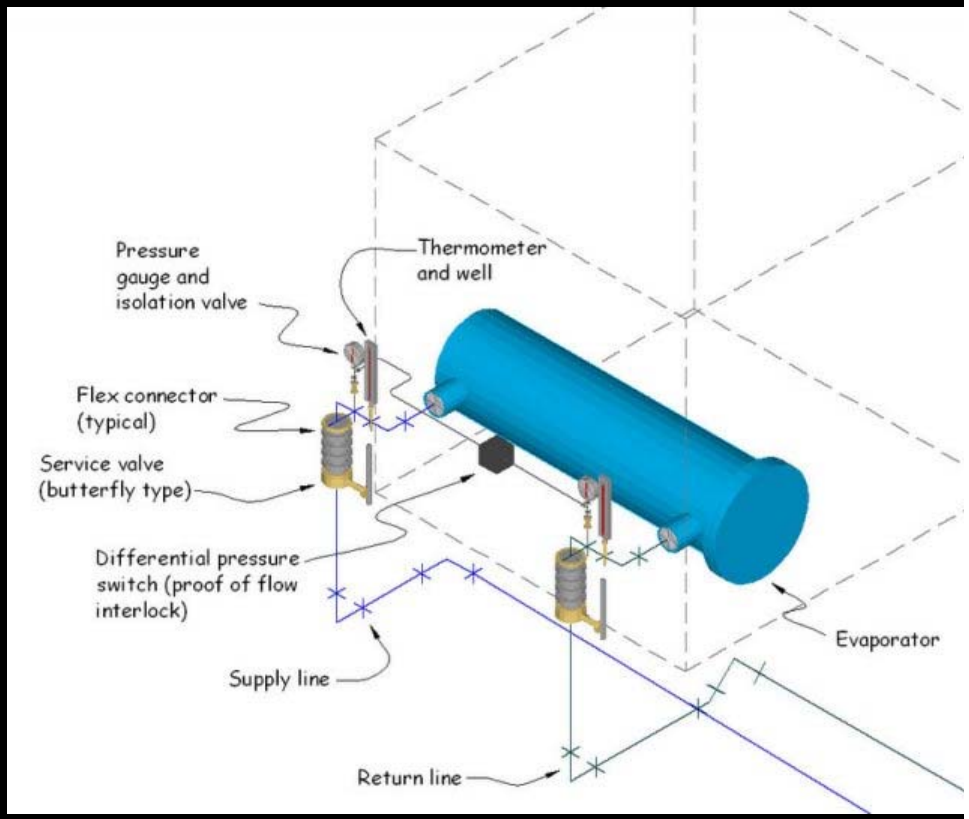

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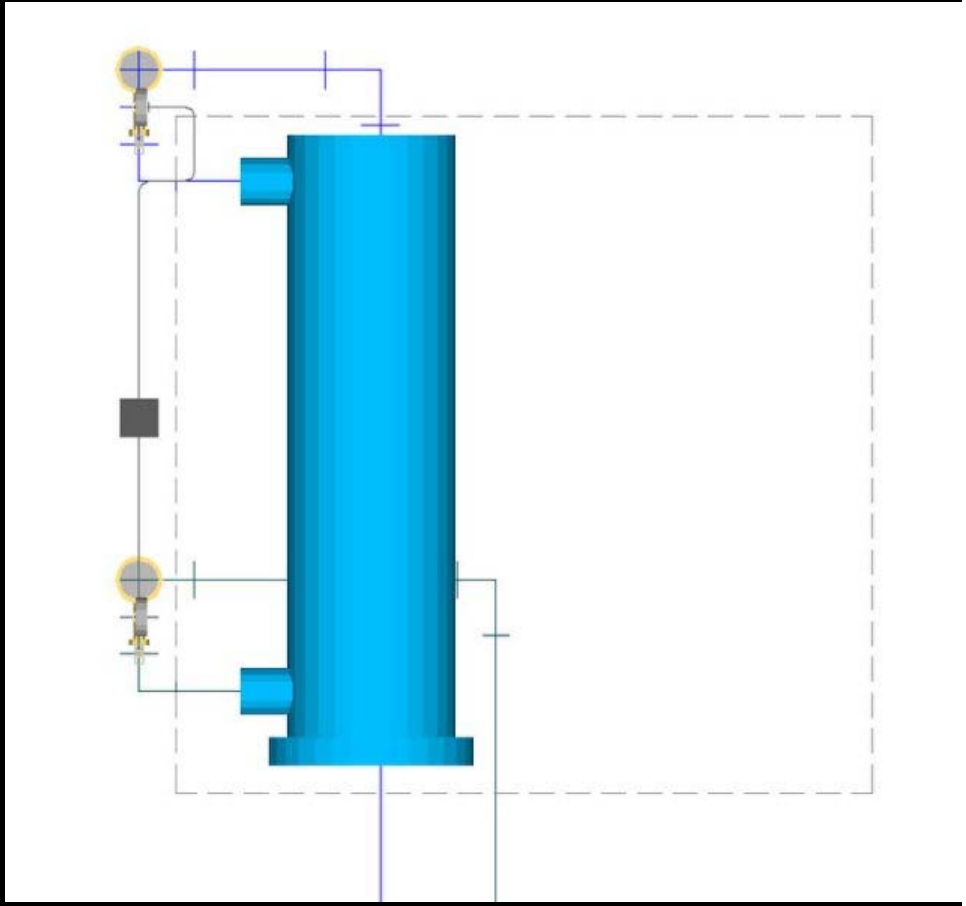

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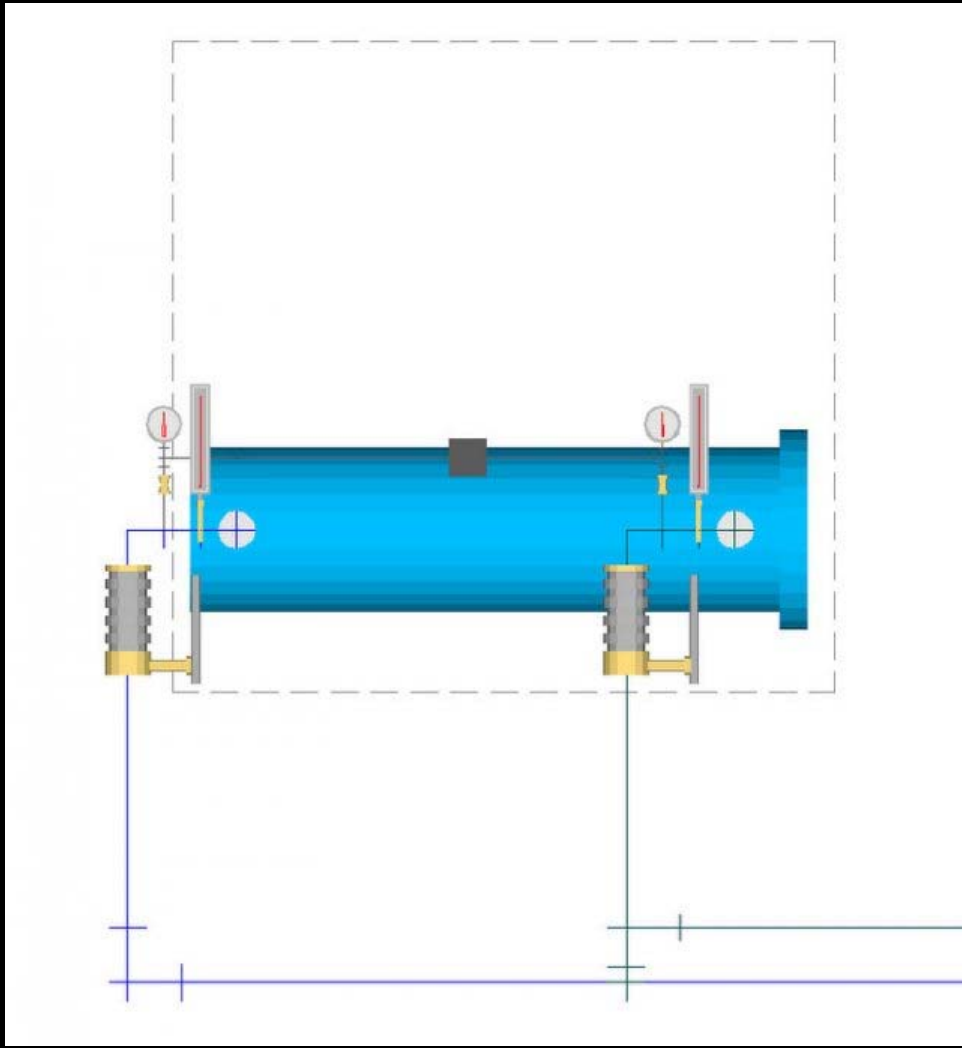

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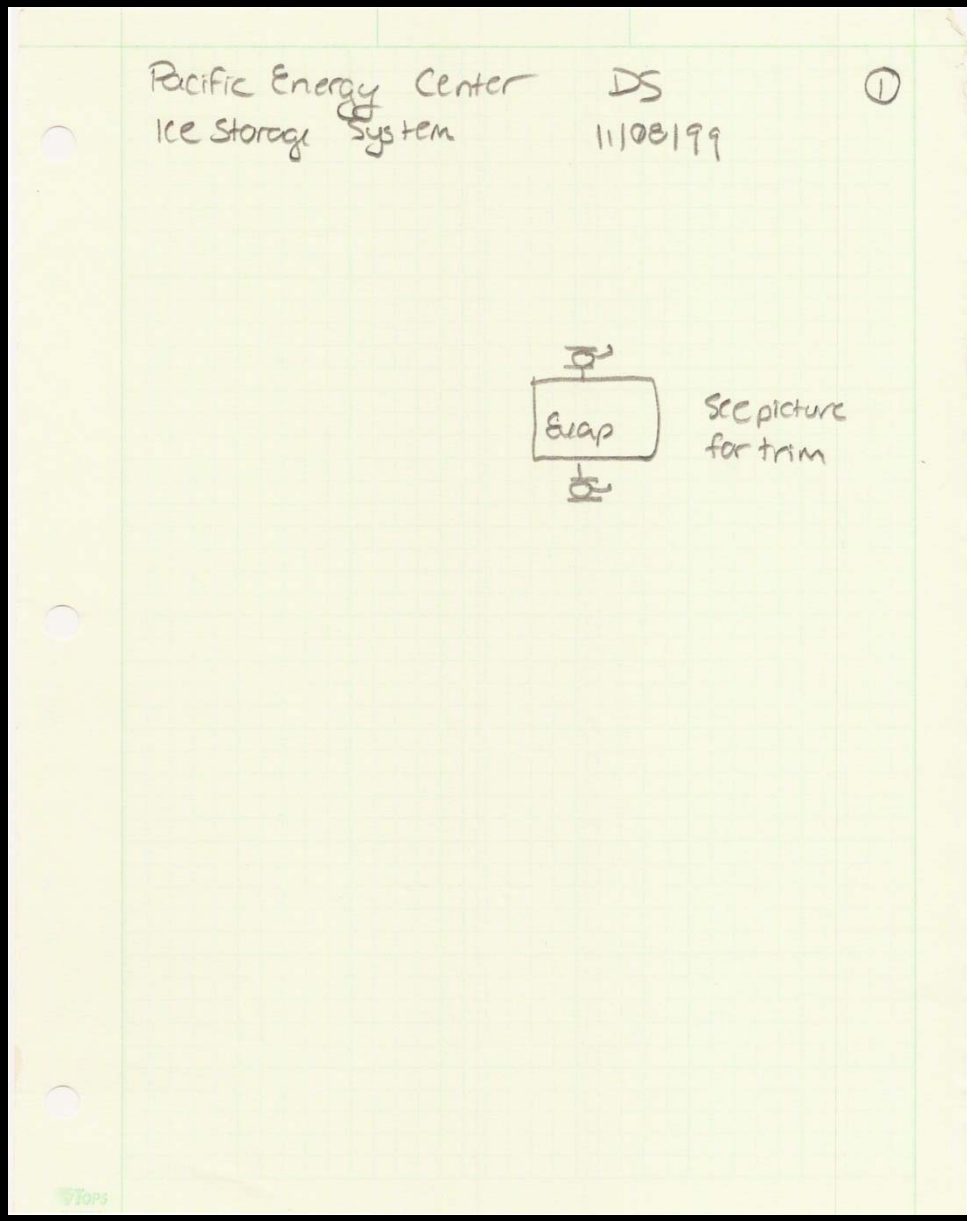
Start following the system of interest

- Your first effort will likely not be your last effort



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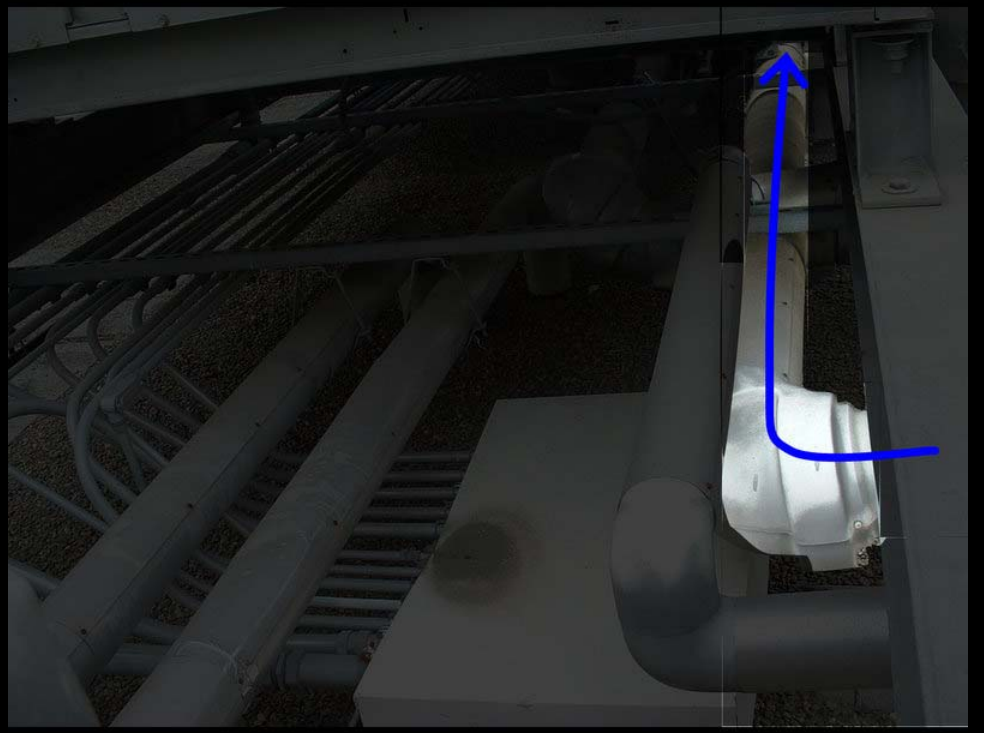

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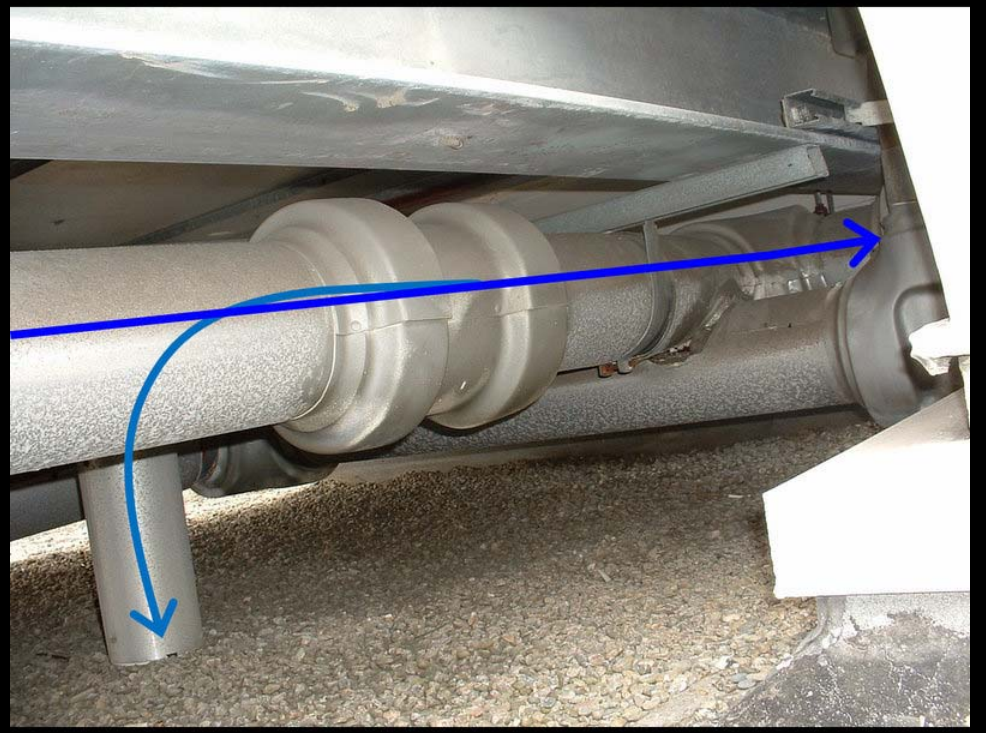
- Make decisions at tees



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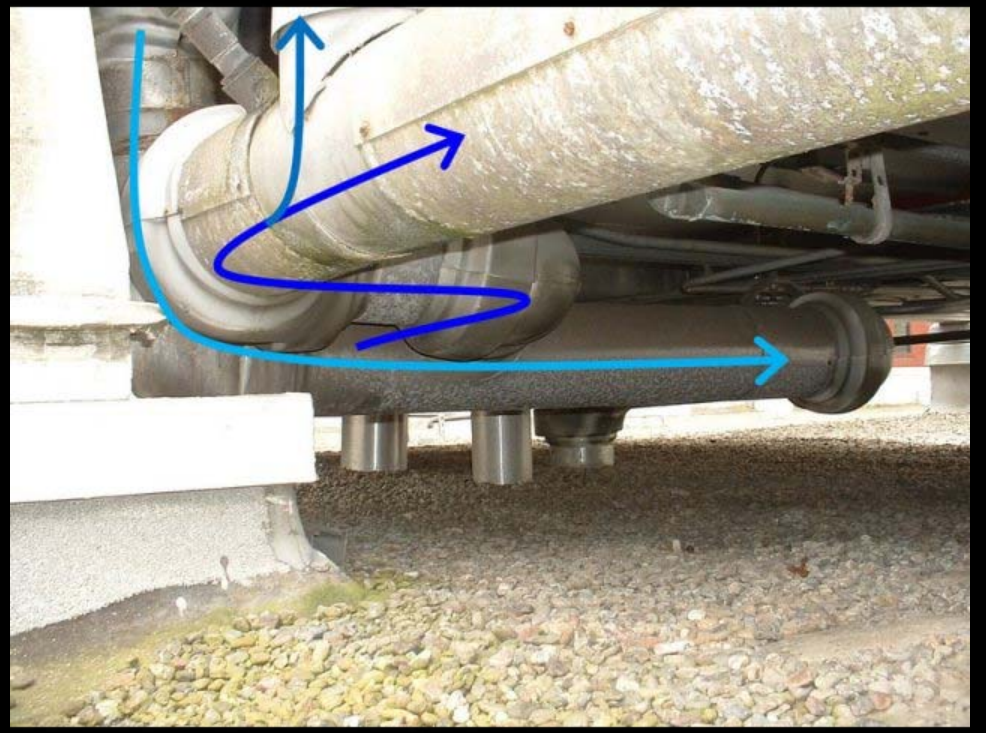

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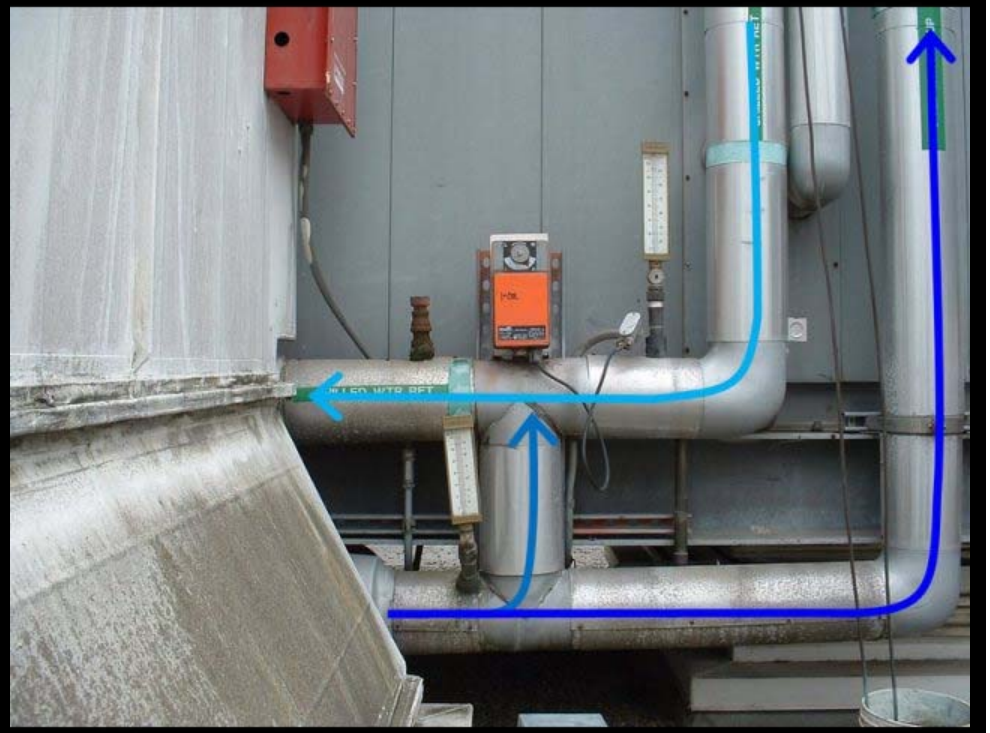

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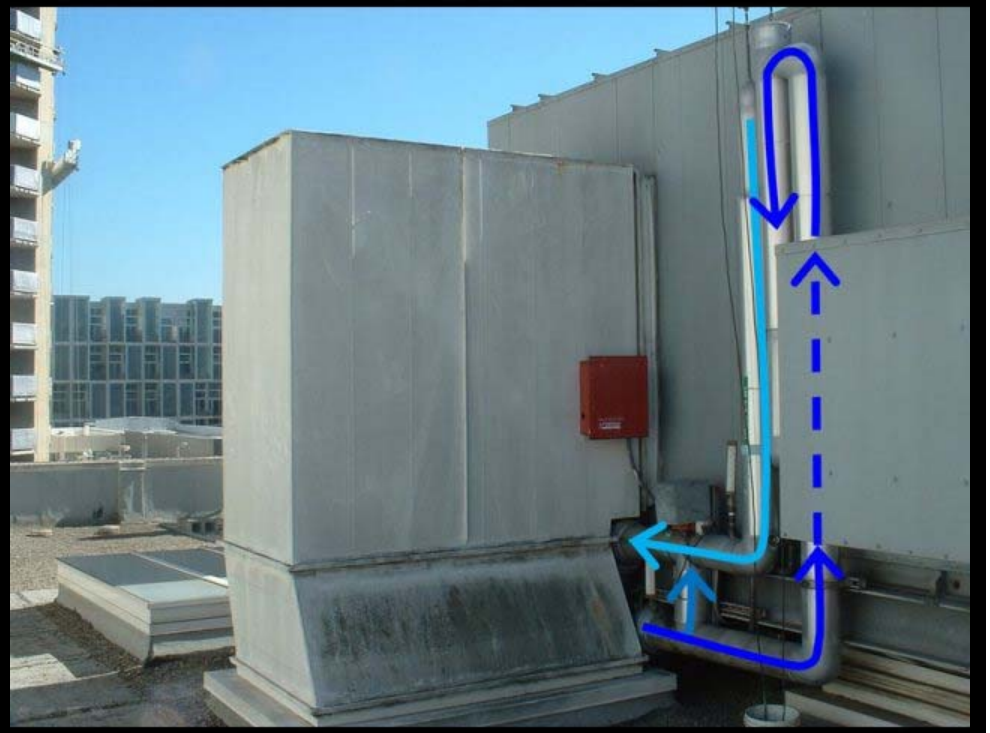

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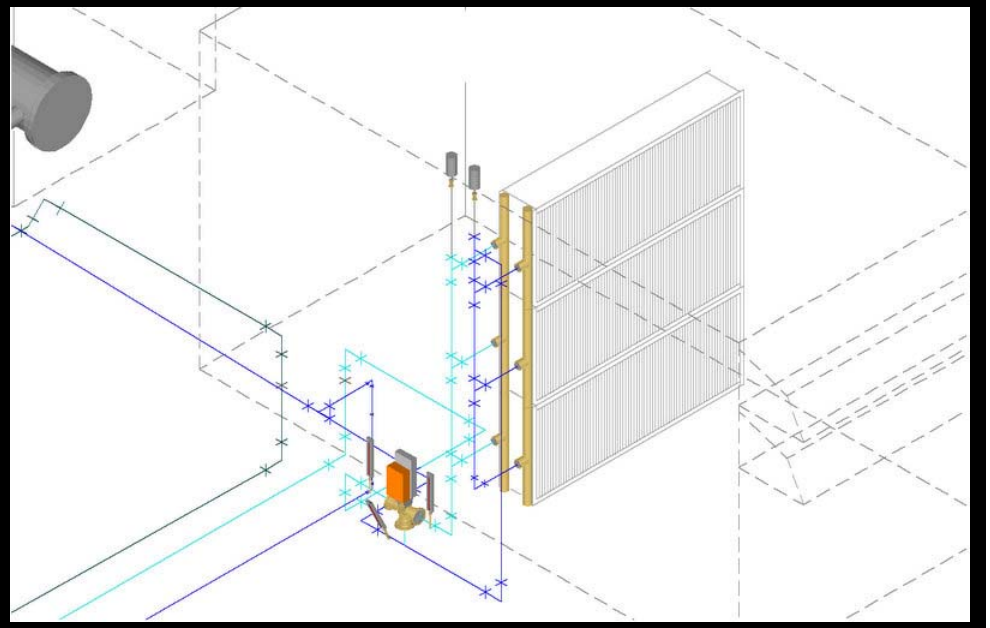

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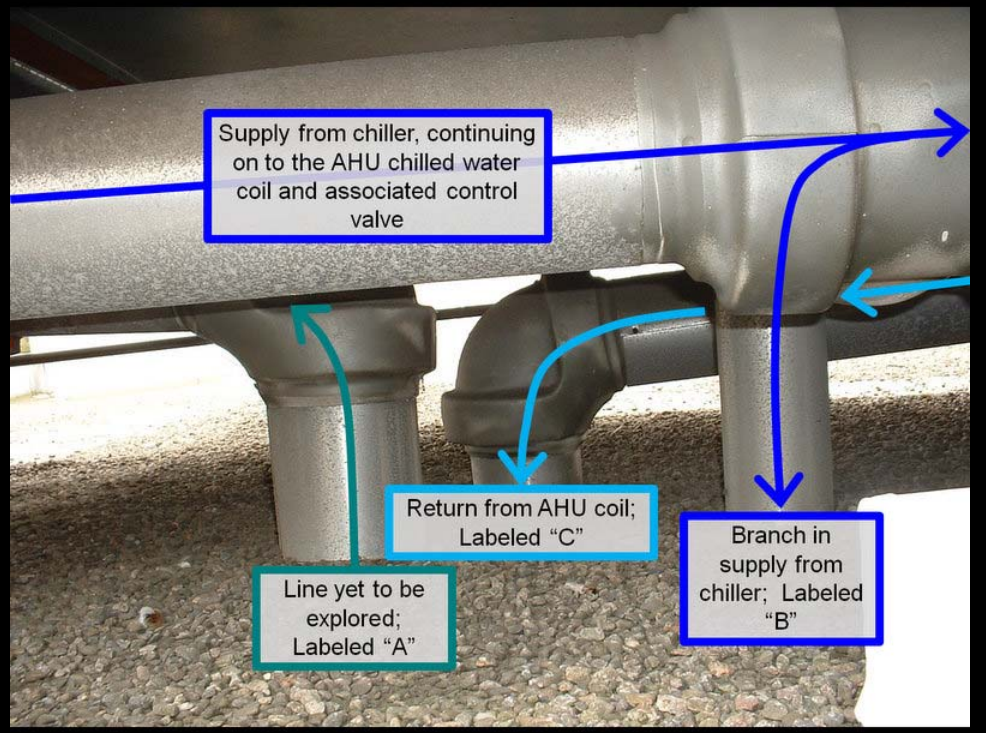

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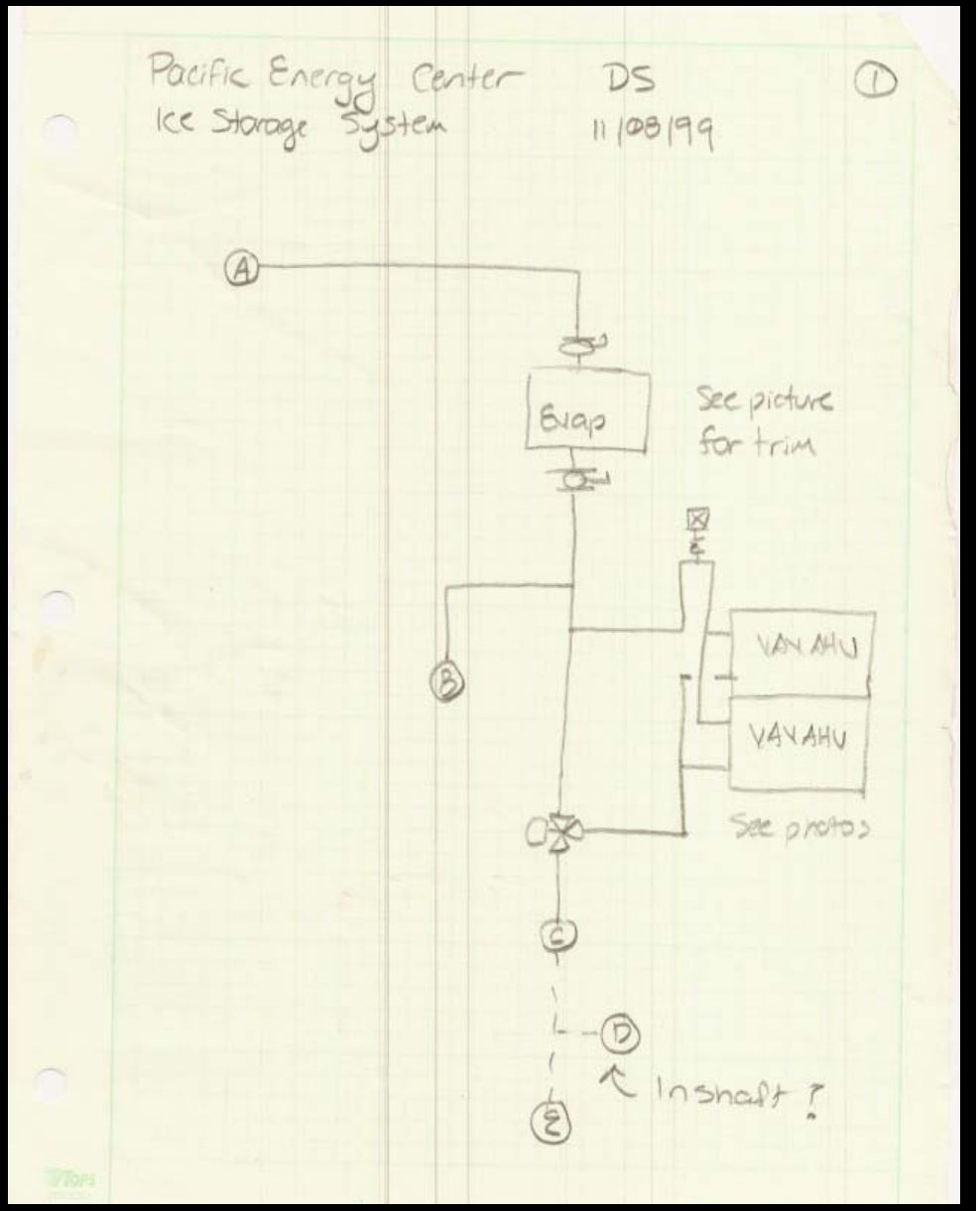

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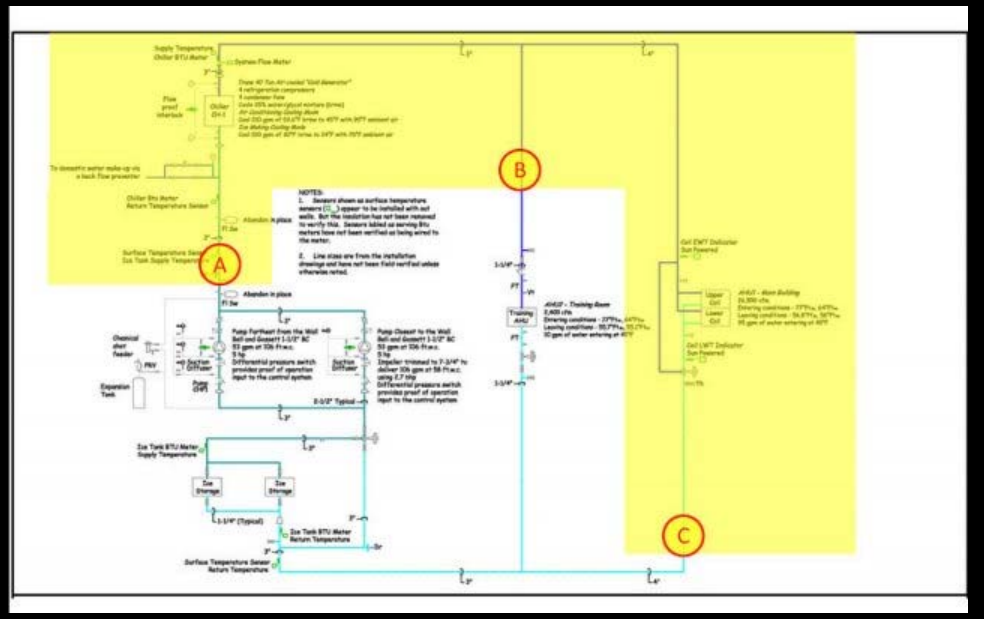
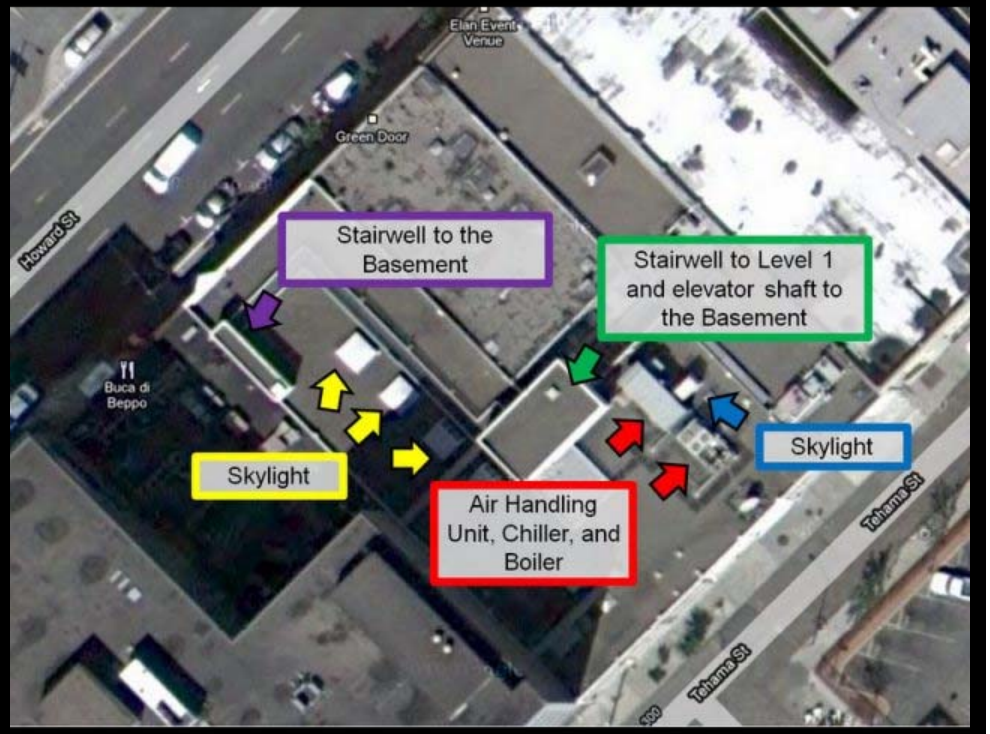


Getting Off the Roof

- Identify a Point of Reference



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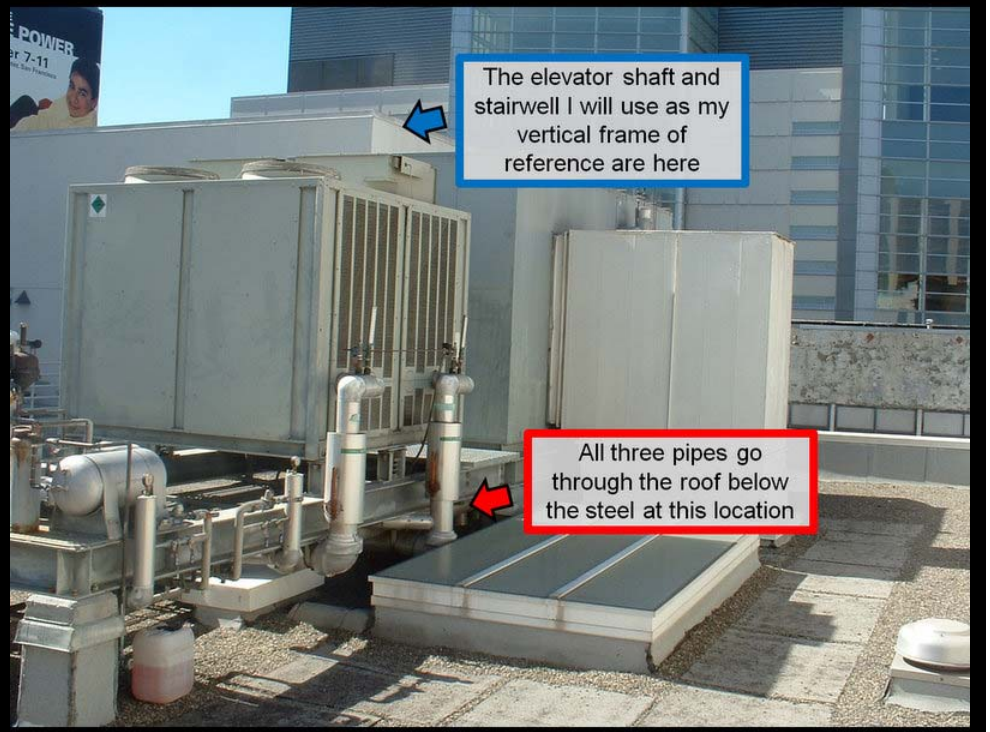
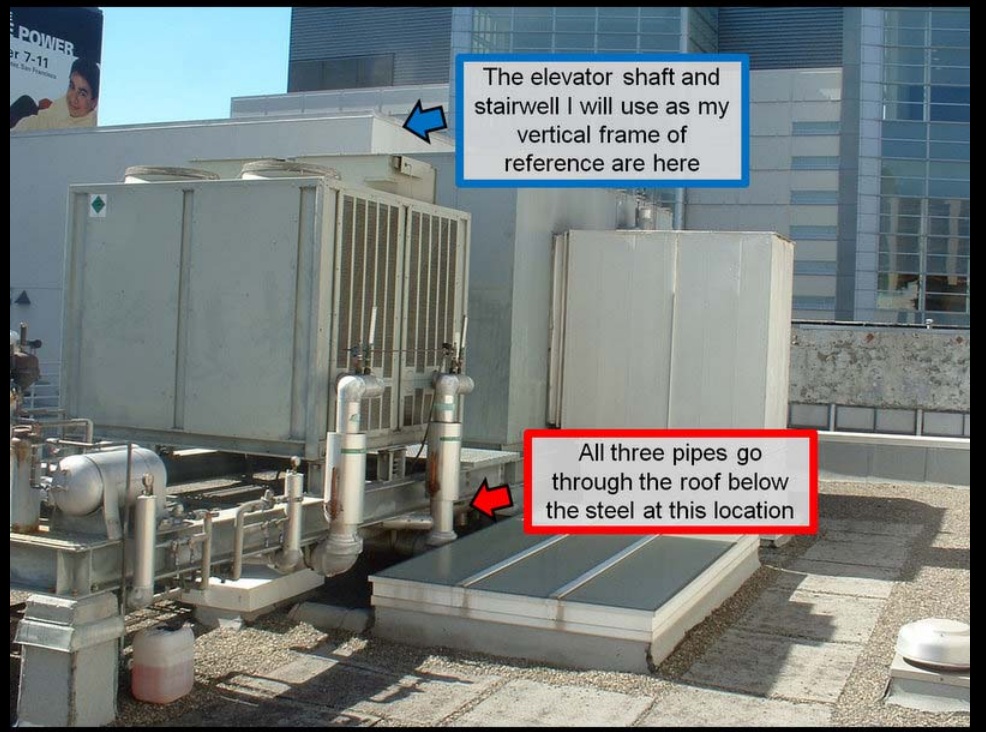


Getting Off the Roof

- Identify a Point of Reference
- Identify Your “Pace”
- Use Your “Pace” to Develop Coordinates Relative to the Point of Reference



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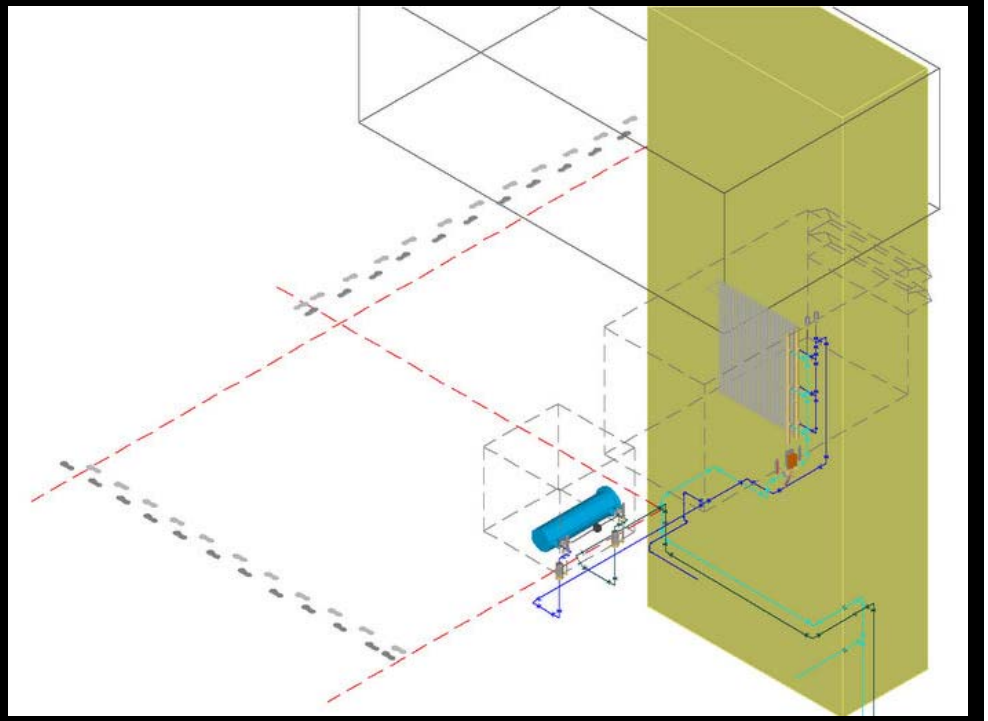

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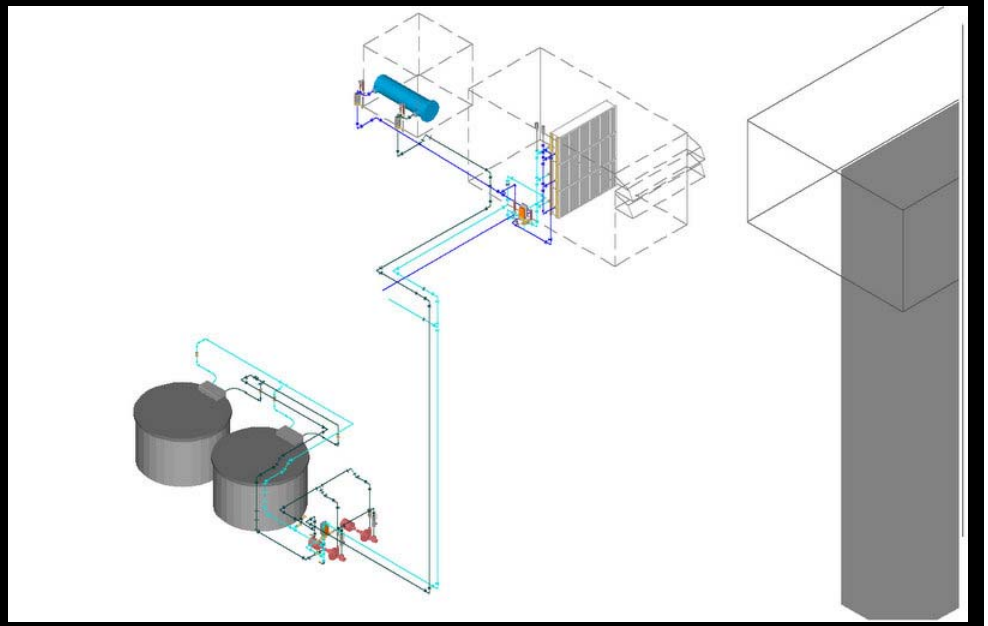


Getting Off the Roof

- Identify a Point of Reference
- Identify Your “Pace”
- Use Your “Pace” to Develop Coordinates Relative to the Point of Reference
- Apply Your Coordinates on a Different Floor
- Leverage Existing Labels (Maybe)
  - Cutting a hole in the wall or pipe may or may not be warranted
  - Leverage other clues
  - Some of them may be misleading

What About Drawing Programs?

AutoCAD and AutoCAD LT

- Quasi-standard in the industry
- Full version $3 – $4K
- Factor of 4 price difference between full and LT version
- LT probably sufficient for most Cx providers
- Steep learning curve
- Can do more than diagrams
  - Drafting
  - Some 3-D
  - Automation

Visio

- Microsoft family
- Full version about $1K
- Factor of 4 price difference between low end and high end versions
- Geared toward diagrams
  - Not as universally applicable
  - Faster to pick up
- Basic wire-frame capabilities in higher end products
- Interfaces with other Microsoft products directly

What About Drawing Programs?

Draw – OpenOffice.org

- Free
- Limited page size (about 12” x 12”)
- Basic diagramming features
- 3D capabilities

Word/PowerPoint Drawing Utilities

- Part of the Office package
- Difficult to use for complex drawings
- Relatively easy to pick up for basic shapes
- Some issues with alignment in 2007 versions

What About Drawing Programs?

Sketch-up

- Google/Trimble
- Free
- Using 3D model to convey 2D information

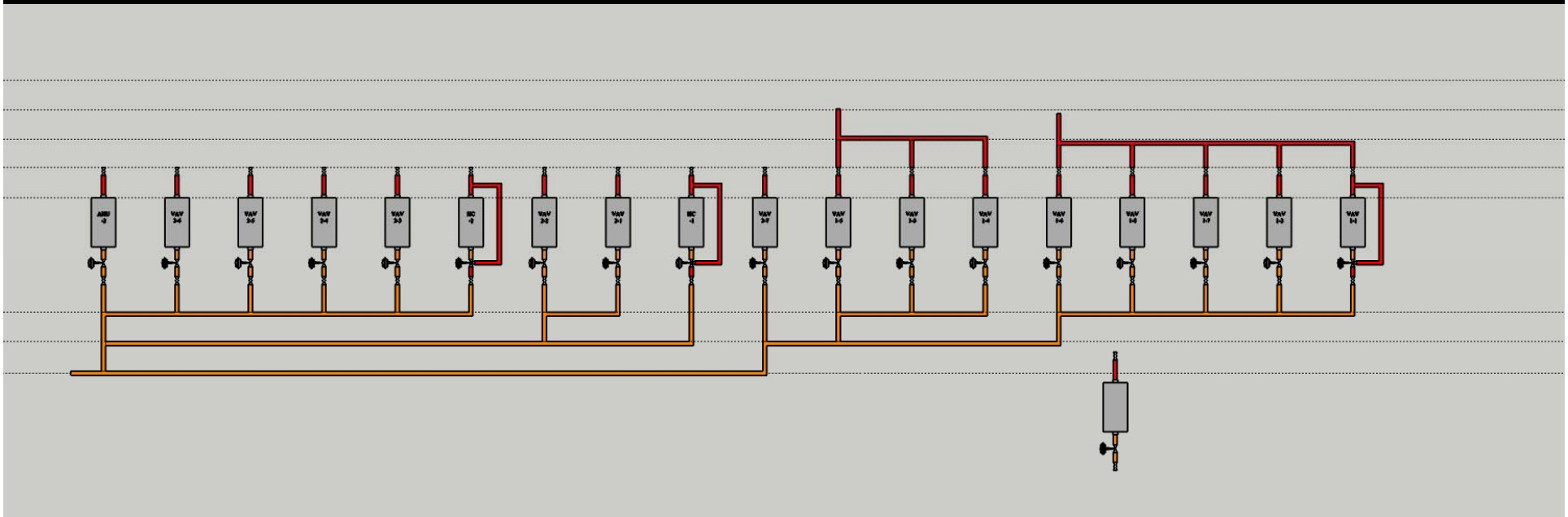


Diagram Drawing 101

Get in the habit of drawing on a grid

- "Electronic graph paper"
- Orderly drawings
- Alignment is easier
- Can be "on" or "off" for printing

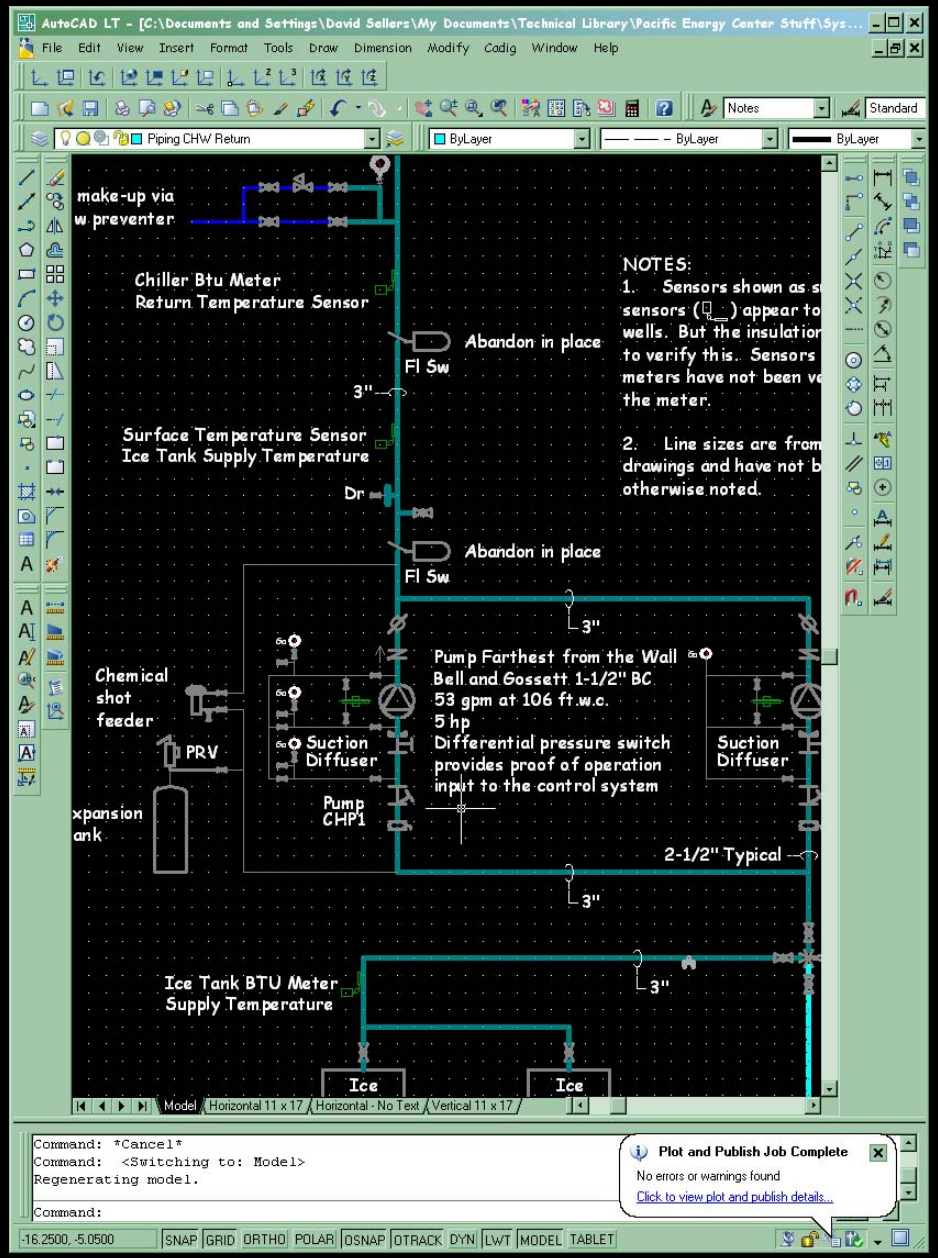


Diagram Drawing 101

Colors can be used to advantage

- Distinguish different types of fluids (chilled water, hot water, condenser water)
- Distinguish hot from cold, warmer from cooler, supply from return

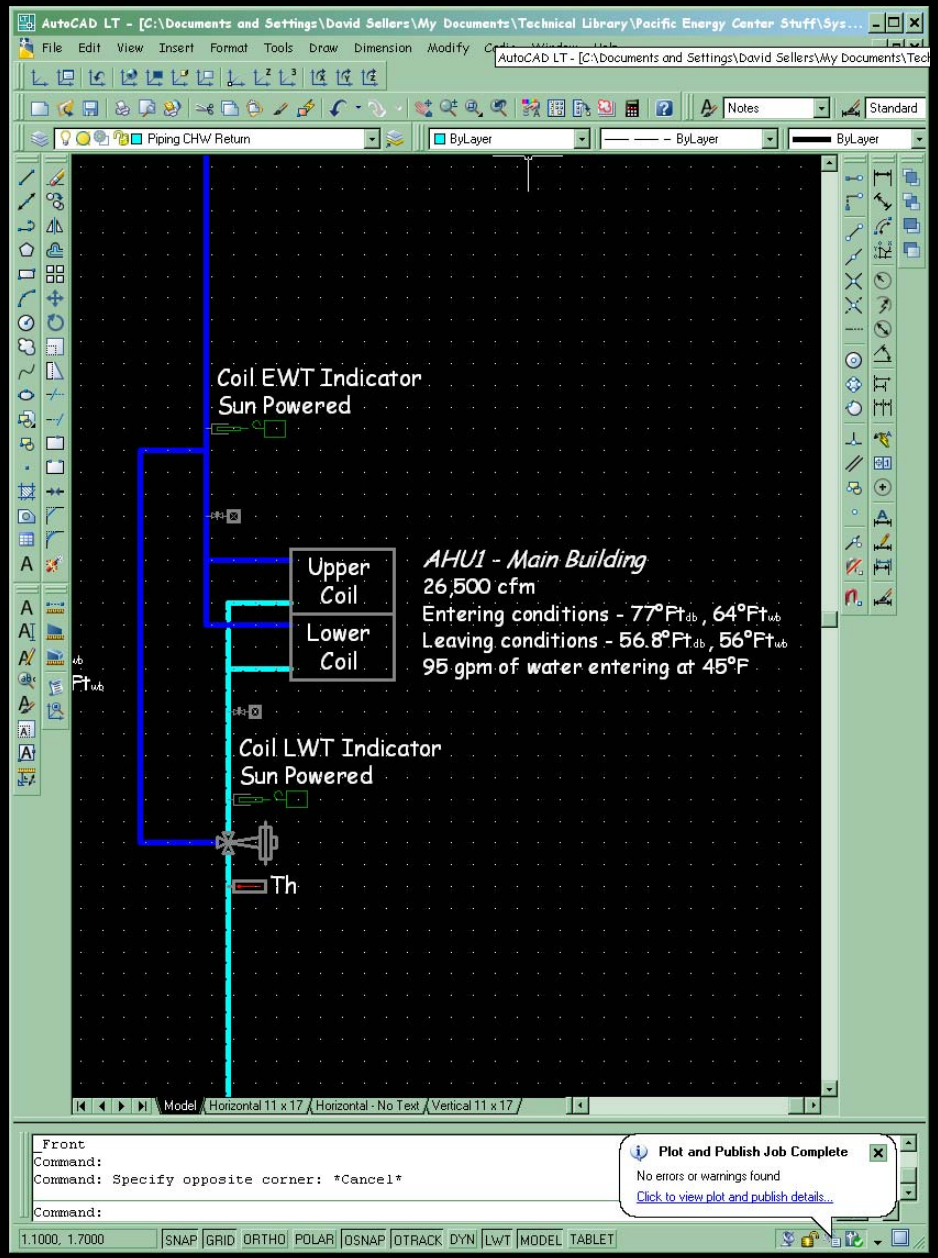


Diagram Drawing 101

Colors can be used to advantage

- Distinguish different types of fluids (chilled water, hot water, condenser water)
- Distinguish hot from cold, warmer from cooler, supply from return
- Enhance understanding

  Outside Air mixing with Return Air makes Mixed Air

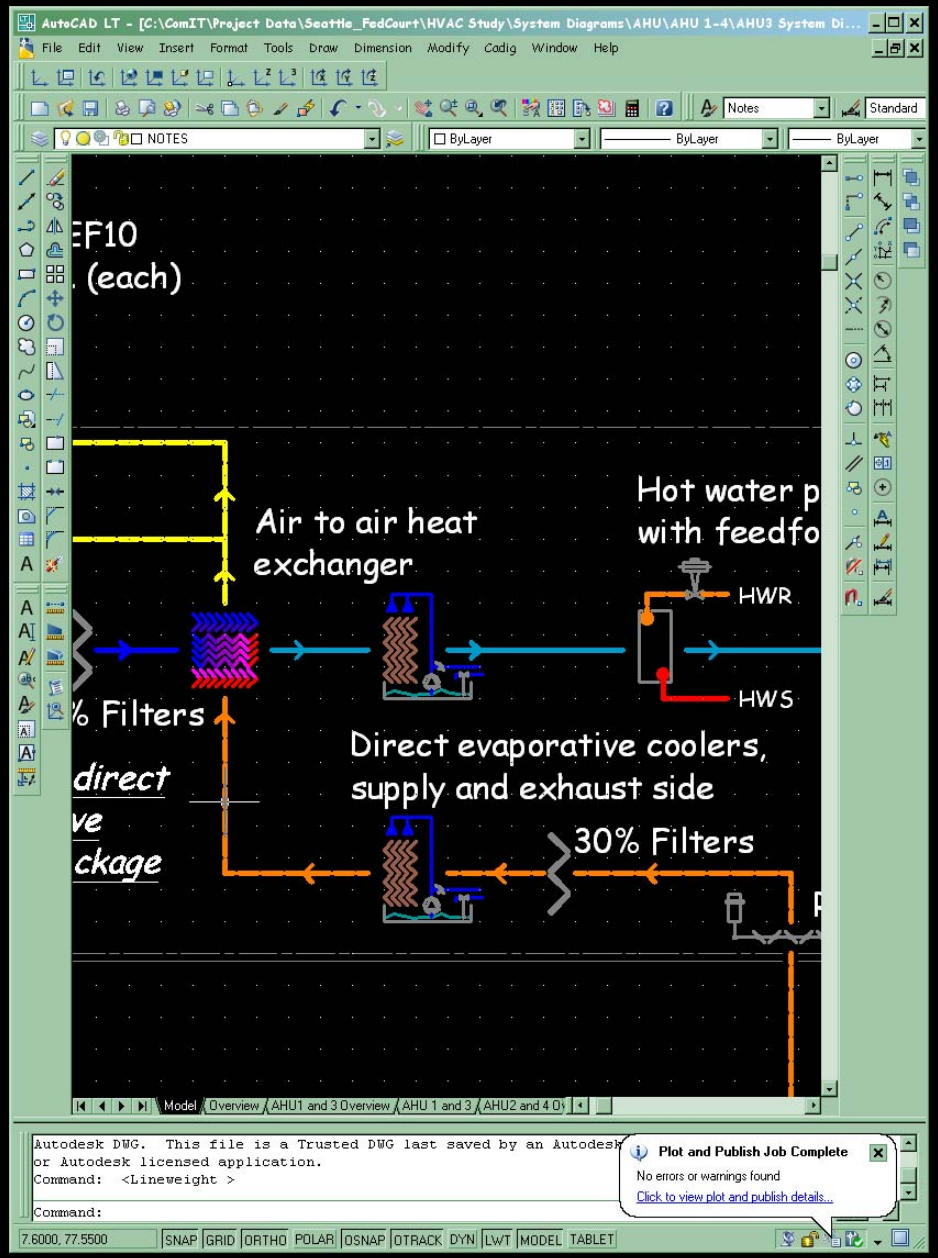
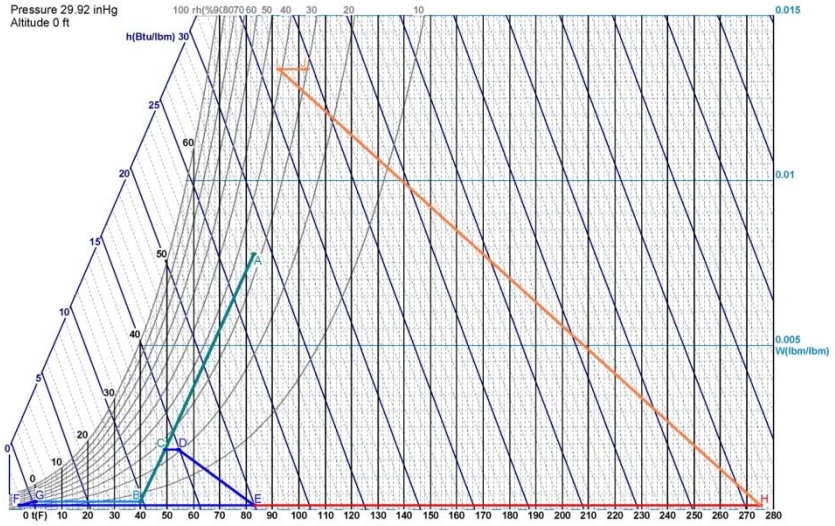


Diagram Drawing 101



90 cfm
A
Outdoor air intake at 1st floor roof level serving AH-C, DH2, and DH-3. 90 cfm taken in for DH-1 reactivation air

Colors can be used to advantage

Outdoor air to AH-C and DH-2

90 cfm
J

Open shaft to roof level provides relief path for AH-C as well as DH-2 and DH-3 reactivation air exhaust. DH-3 exhausts 90 cfm

Freezer Room Cooling and Dehumidification System DH-3

Thermocouple
M
SWSI supply fan with current switch
90 cfm at 2.85 in. w.c.
1.86 in.w.c external static pressure
1 hp, 0.4 bhp, 3,450 rpm
I
Thermocouple
H
Electric reactivation heater 8.7 kW
Metal mesh filter
Temperature switch, set -6°F
Temperature switch, set -15°F
Duct temperature and relative humidity monitor
F
C
M
D
E
30% Prefilter and 95% final filter with differential pressure switch
Variable speed, SWSI supply fan with air flow switch
400 cfm at 4.24 in. w.c.
1.12 in.w.c external static pressure
1 hp, 0.7 bhp, 3,450 rpm
Titanium silica gel (TiGel) type dessicant wheel
11 revolutions per hour
0.29 in.w.c. process air pressure drop
0.26 in.w.c. reactivation air pressure drop
Carbon filter with differential pressure switch
65% final filter with differential pressure switch
Direct expansion cooling coil with 5 hp water cooled condensing unit and hot gas bypass
Refrigerant 404
6 row, 30,848 btu/hr
83°F entering air temperature
-6°F leaving air temperature
-15° saturated suction temperature

– *Color code a process*

Freezer Room
310 cfm total flow
0°F plus or minus 1°F
30-35% relative humidity
G
310 cfm

Reheat coil RC-1
Maintains a 40°F discharge temperature to prevent snow when the freezer return air mixes with the outdoor air brought in for reactivation
B
HWR
HWS
310 cfm

Diagram Drawing 101

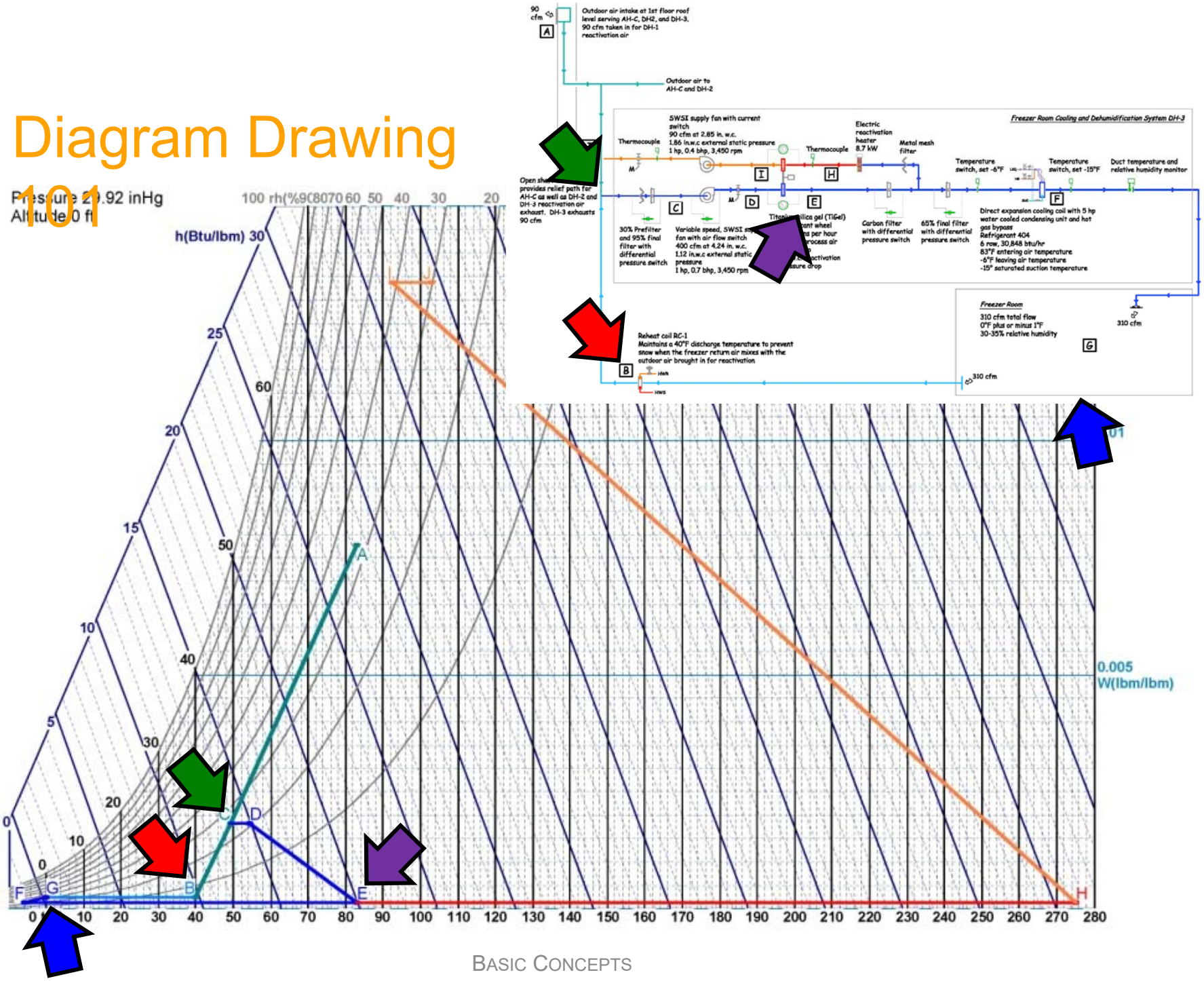


Diagram Drawing 101

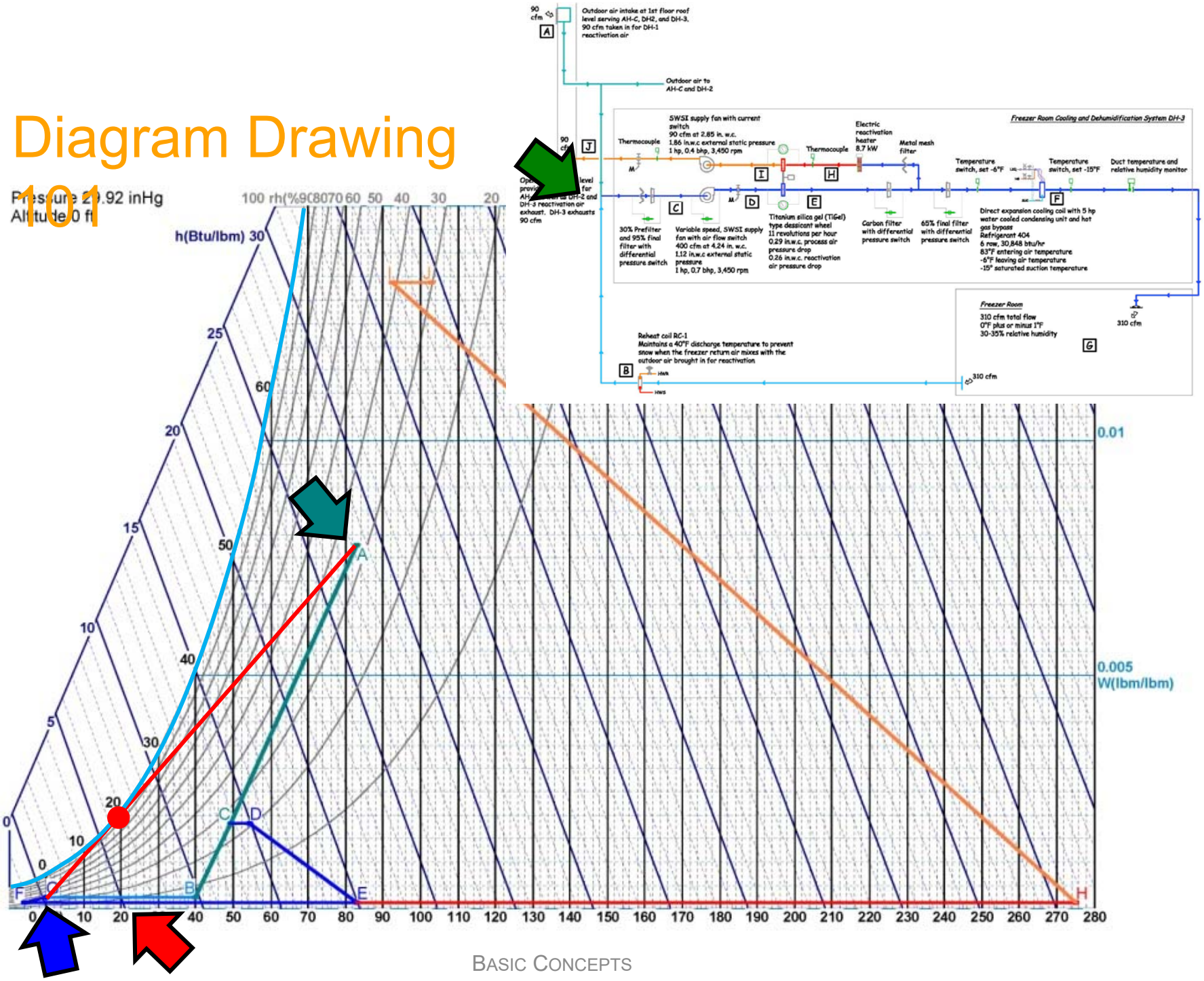


Diagram Drawing 101

Line weights can be important

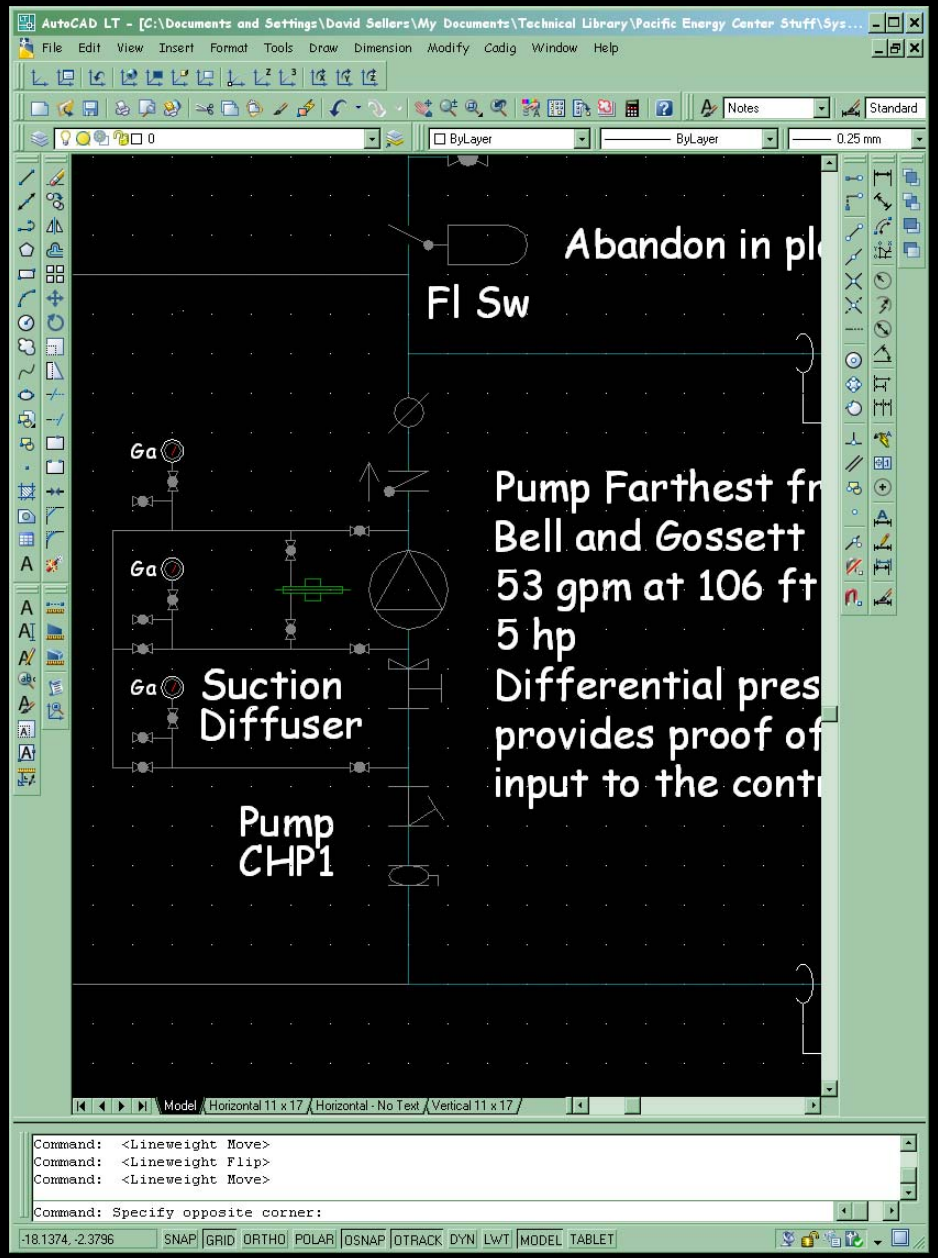


Diagram Drawing 101

Line weights can be important

- Heavier lines draw the eye towards the major system elements
- Lighter line weights show related equipment that is auxiliary to the main system elements

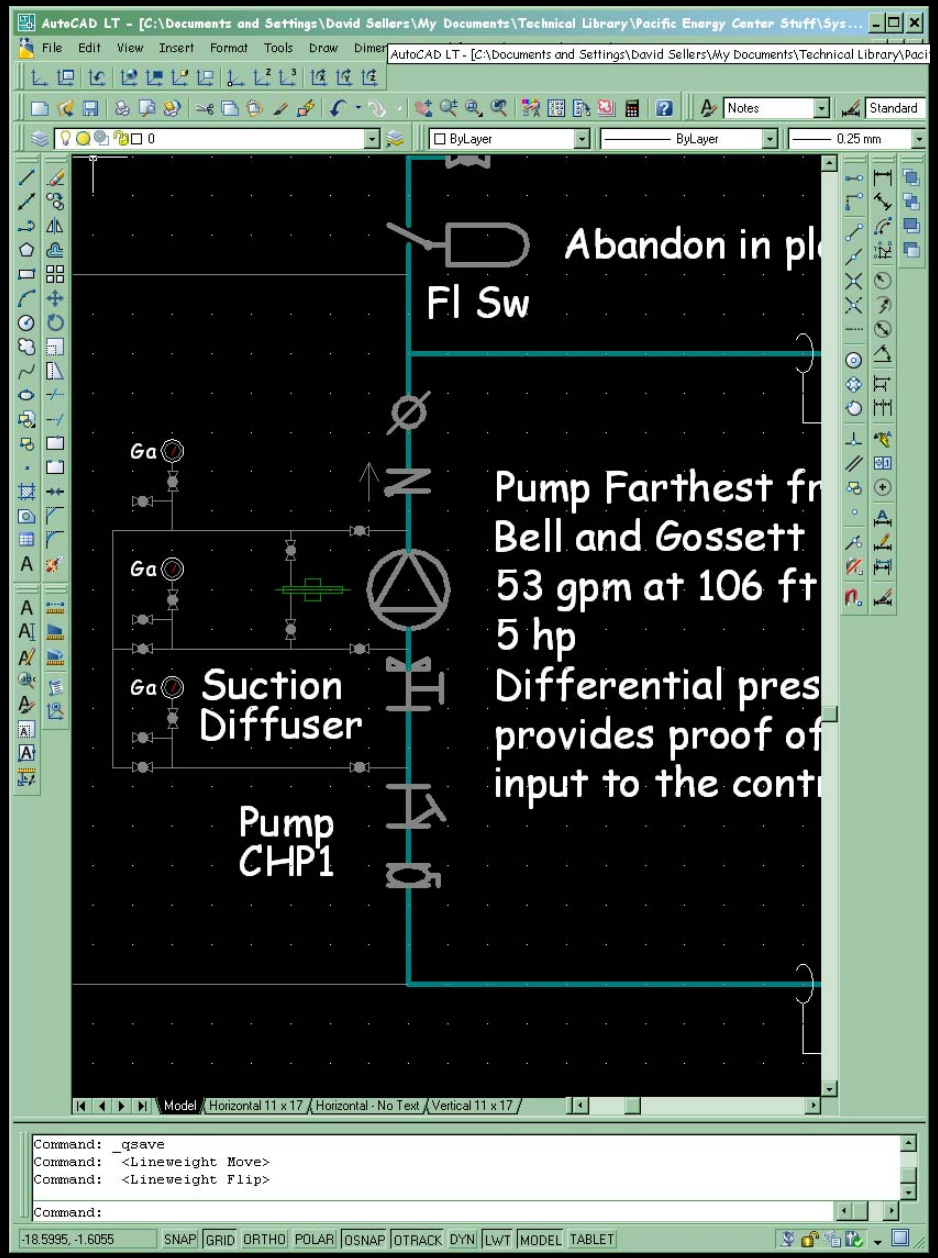


Diagram Drawing 101

Points where lines cross vs. connect should be clear

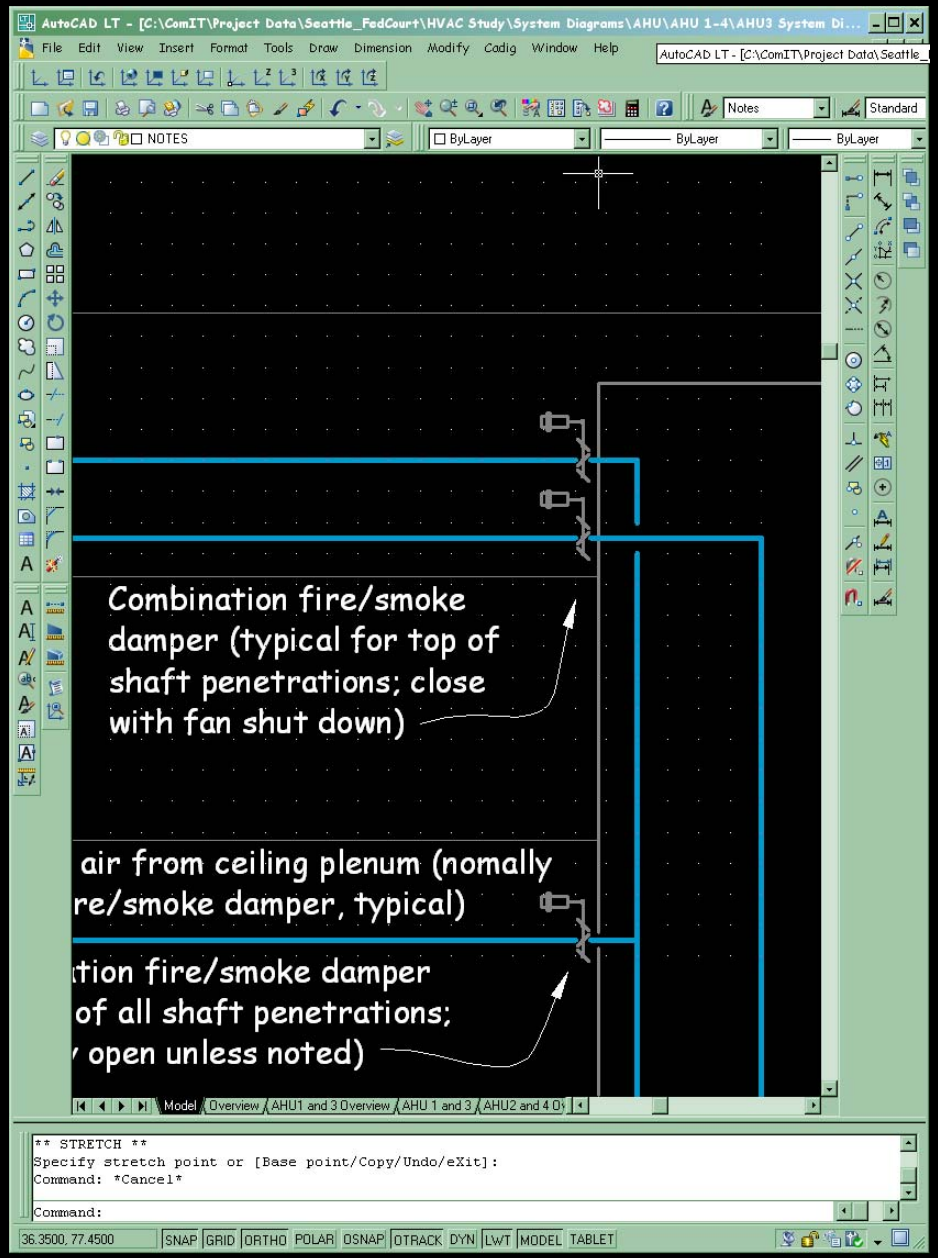


Diagram Drawing 101

Points where lines cross vs. connect should be clear

- Gaps where lines cross need to consider the plot scale relative to the line weight

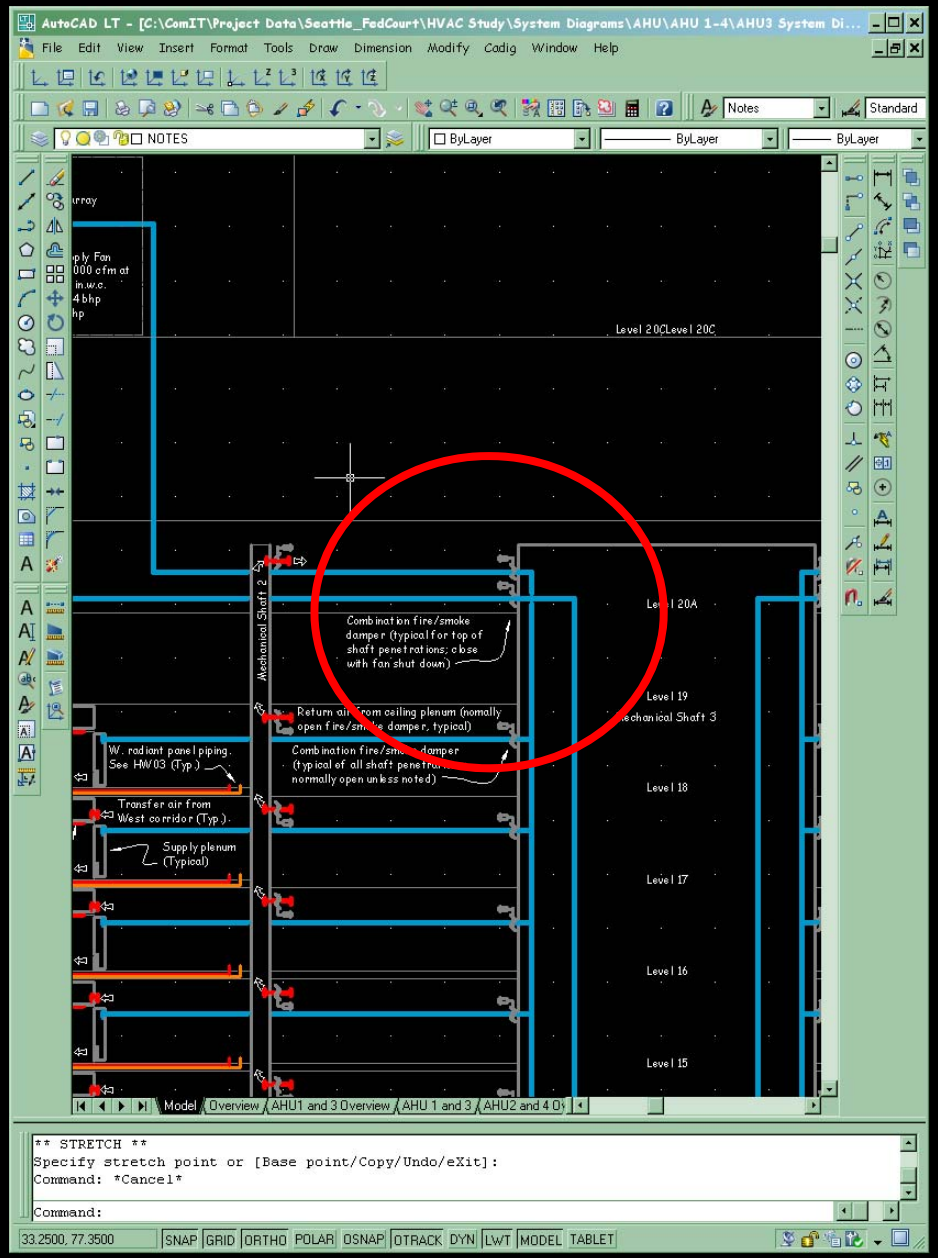


Diagram Drawing 101

Points where lines cross vs. connect should be clear

- Gaps where lines cross need to consider the plot scale relative to the line weight
- “Bumps” can be used to clarify line crossings but can become tedious to draw

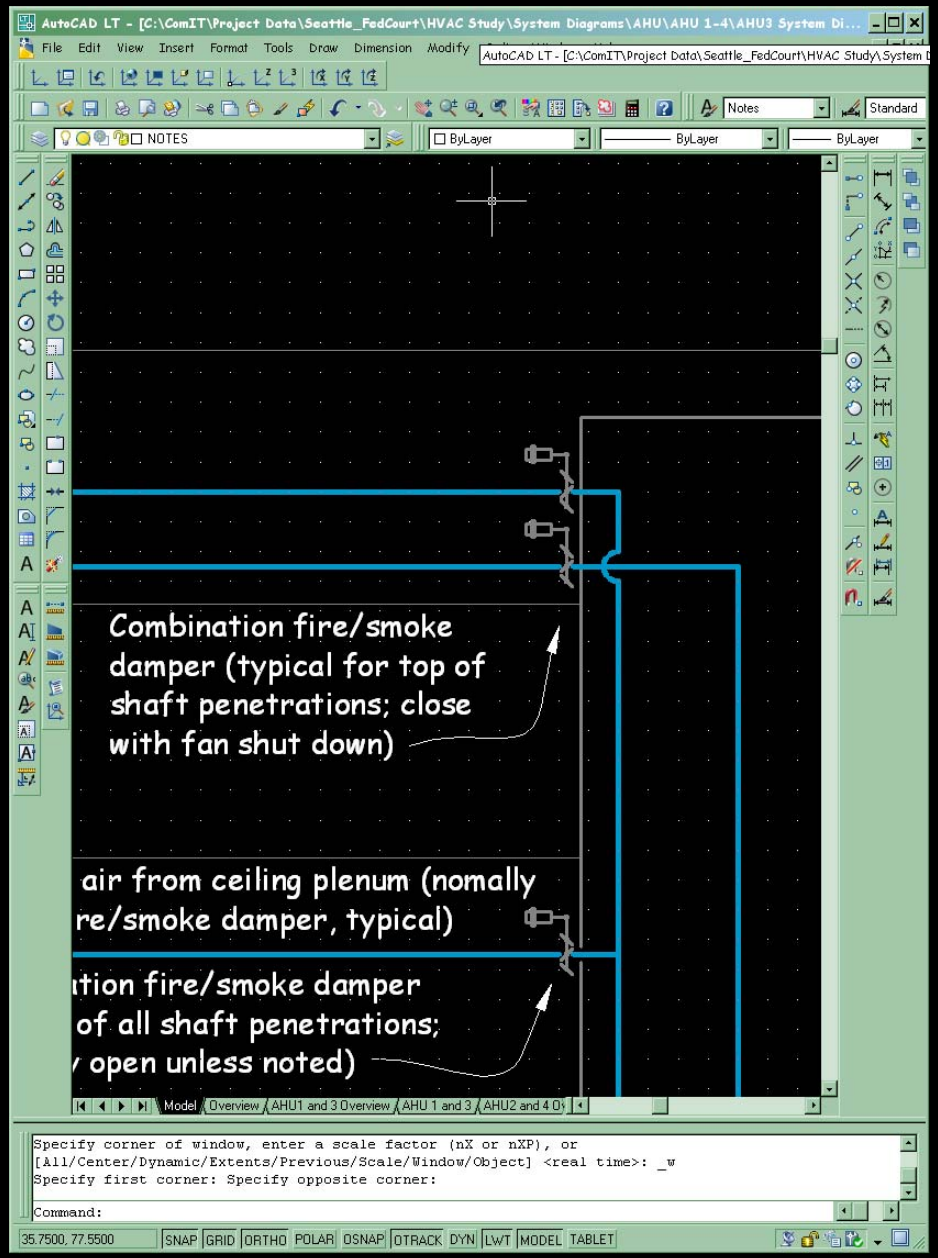


Diagram Drawing 101

Create symbols

- Most programs allow you to take collections of objects, given them a name, and save them as a more complex object
- AutoCAD blocks are an example

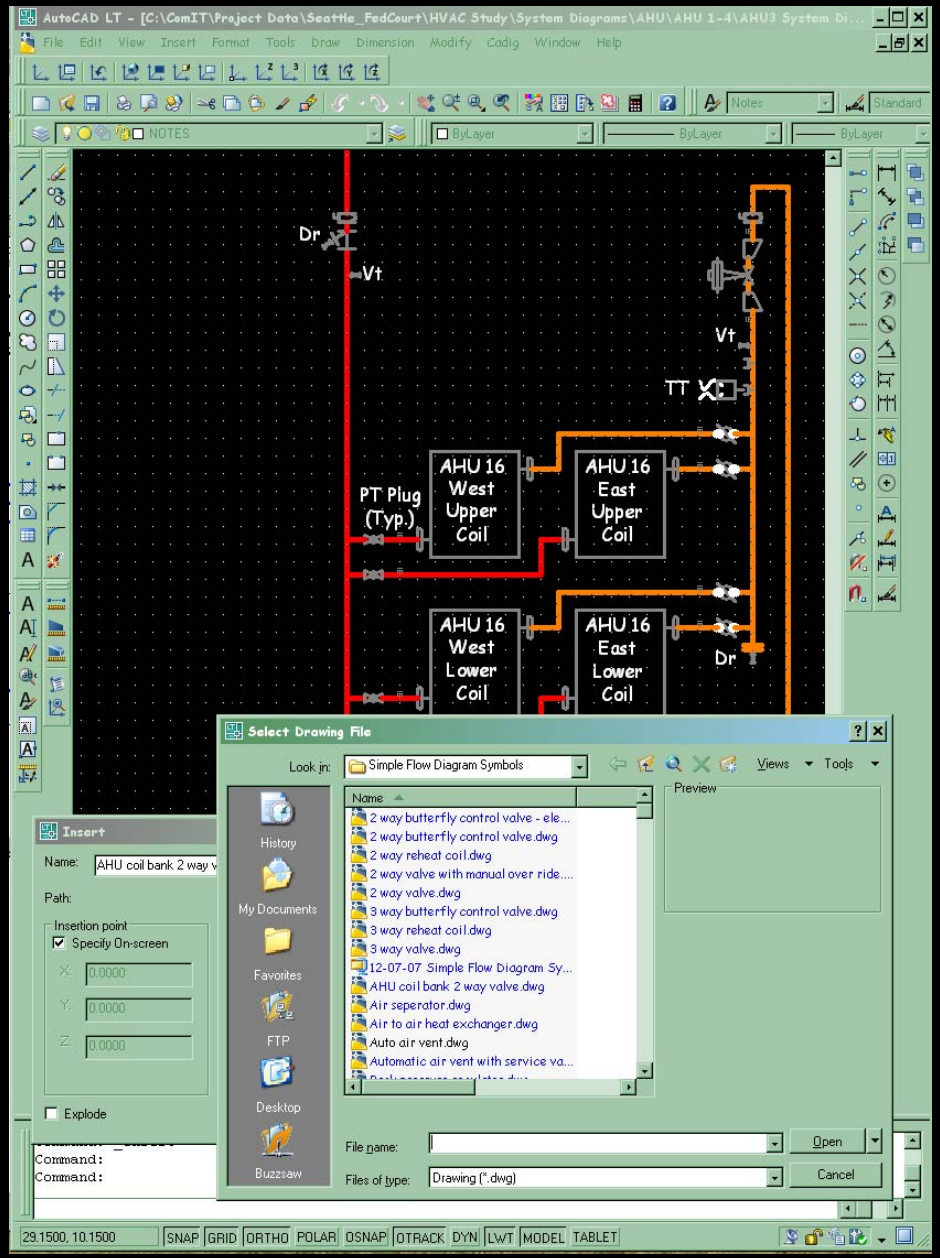


Diagram Drawing 101

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- AutoCAD blocks are an example
- AutoCAD allows you to assign “fill in the blank” field for data associated with the block
- This data can then be extrapolated to generate equipment schedules, point lists, etc.

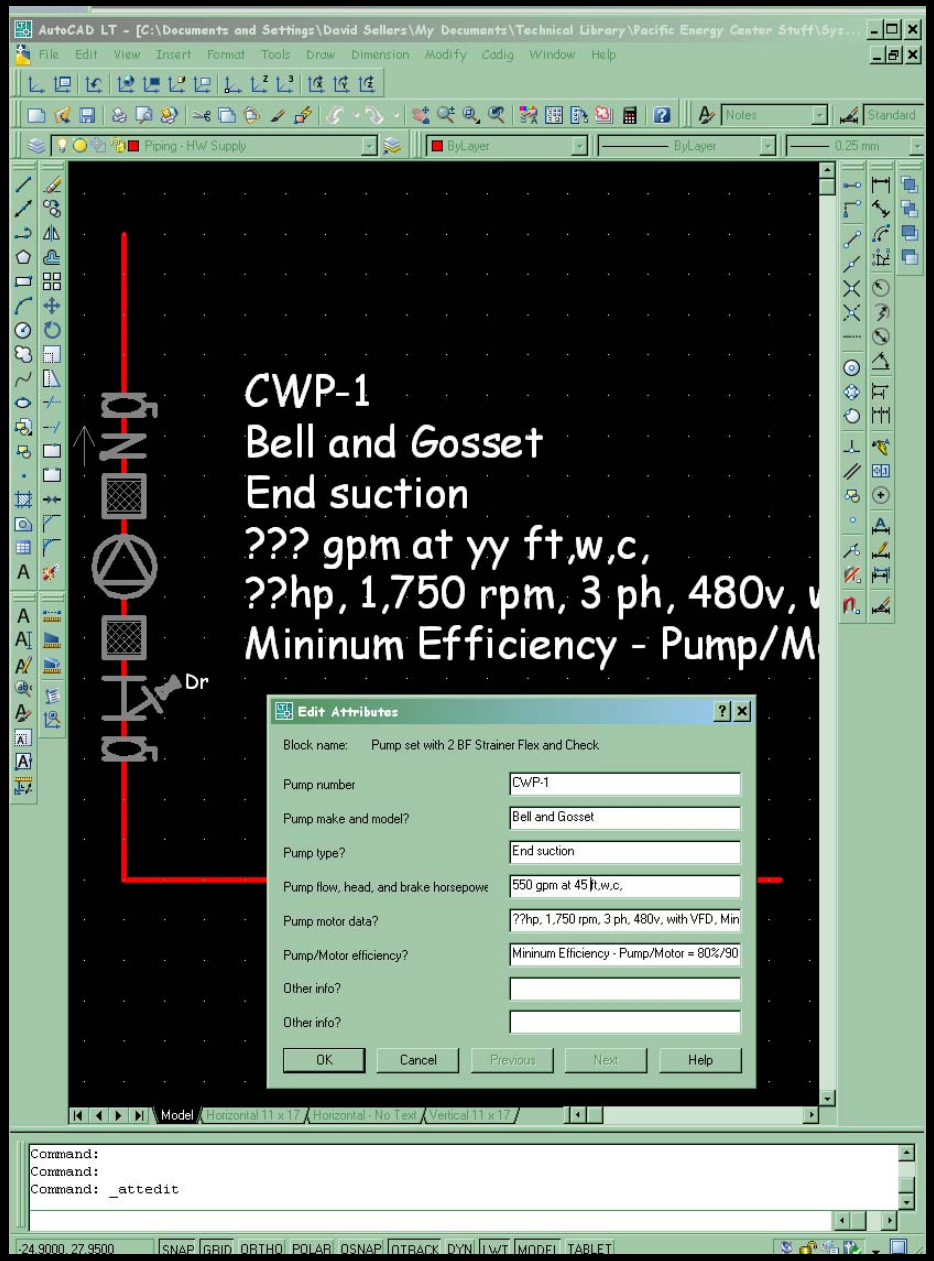


Diagram Drawing 101

Create symbols

- Most programs allow you to take collections of objects, given them a name, and save them as a more complex object
- AutoCAD blocks are an example
- AutoCAD allows you to assign “fill in the blank” field for data associated with the block
- This data can then be extrapolated to generate equipment schedules, point lists, etc.
- You can also edit blocks after they are inserted

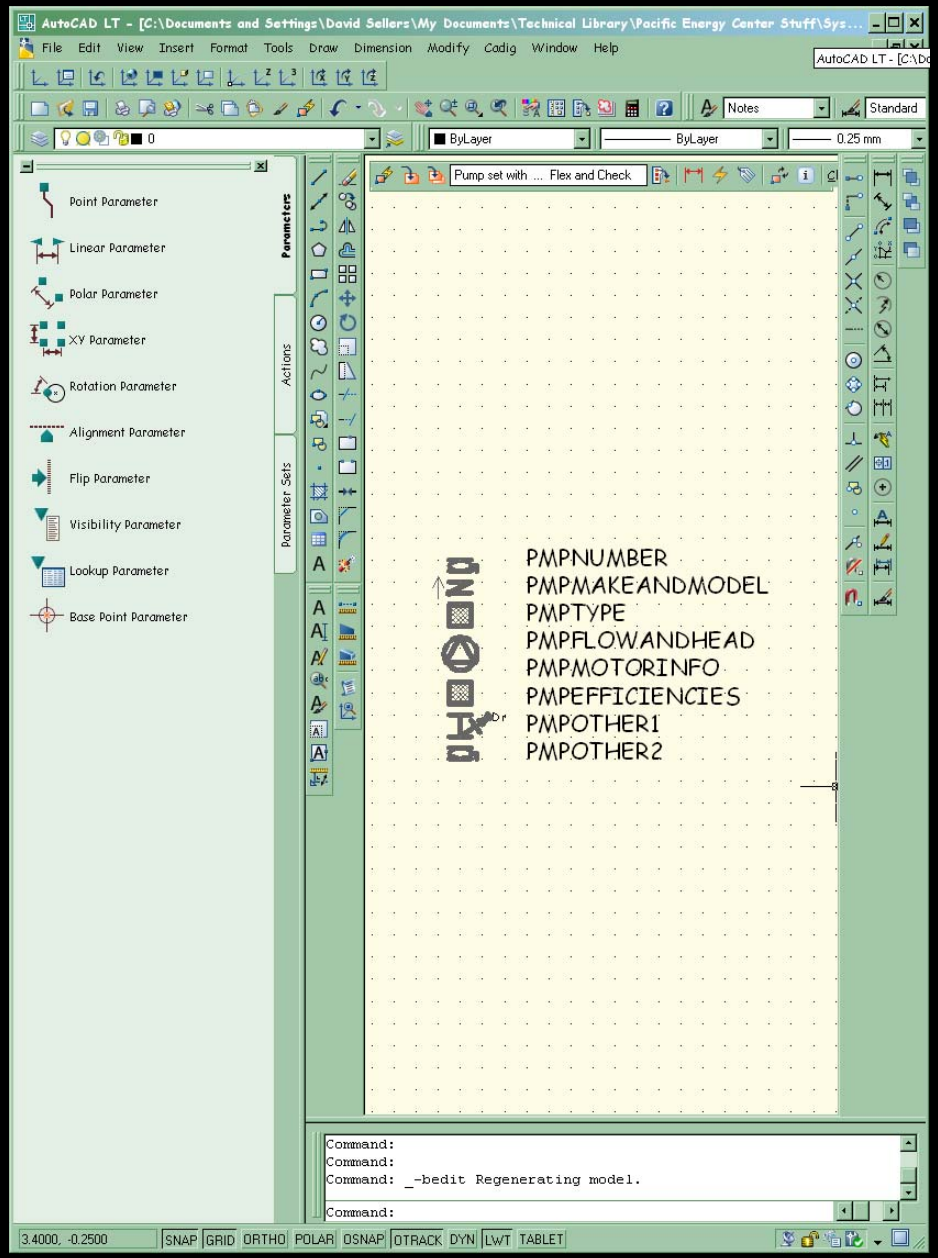
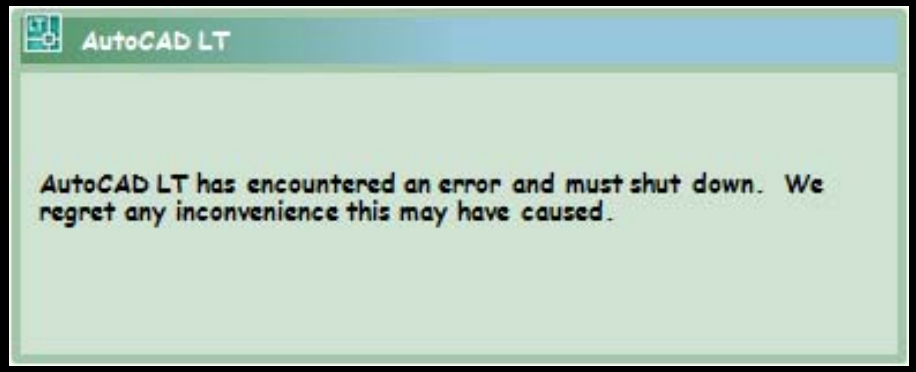


Diagram Drawing 101

Desirable habits/features

- Frequent “saves”
- Enable “auto-save”
- Regular back-ups



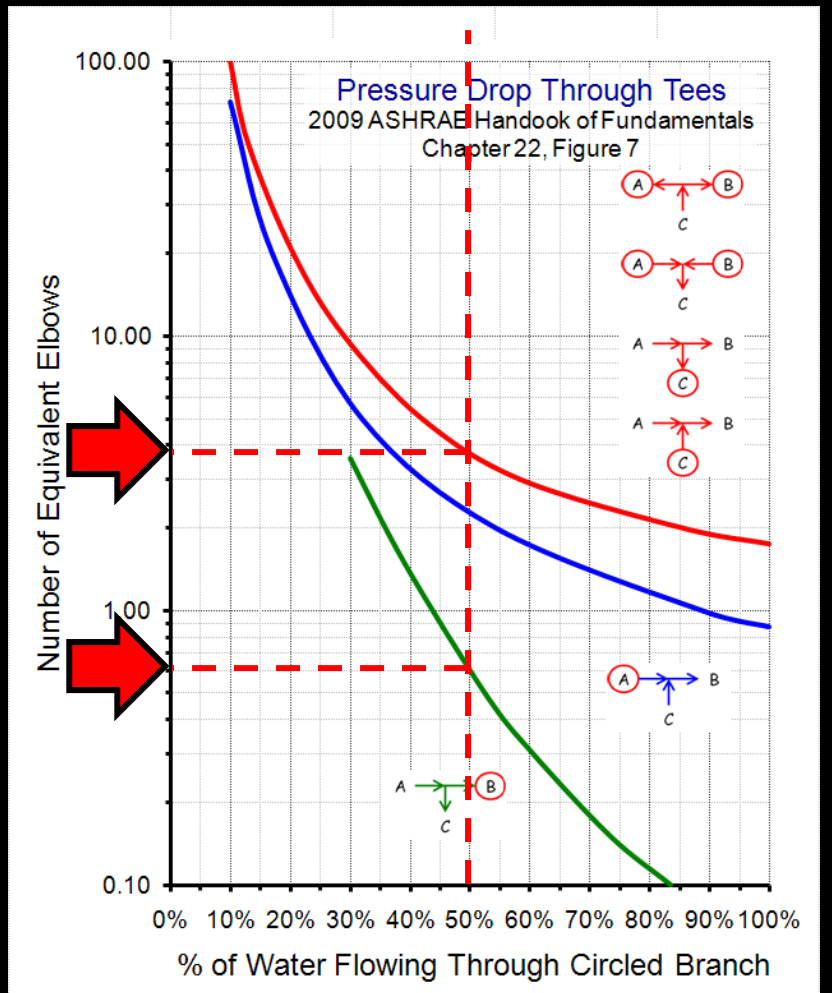
Tee's are Important

For both the physical system and the system diagram:

- Divergence or convergence of flow
- An opportunity to introduce a problem if the order of connection is not correct

For the physical system, they represent a pressure drop

- Significant
- Highly variable with configuration



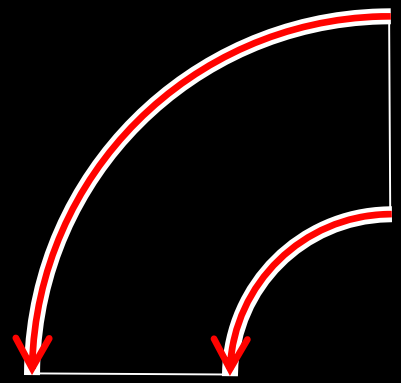
Notes:

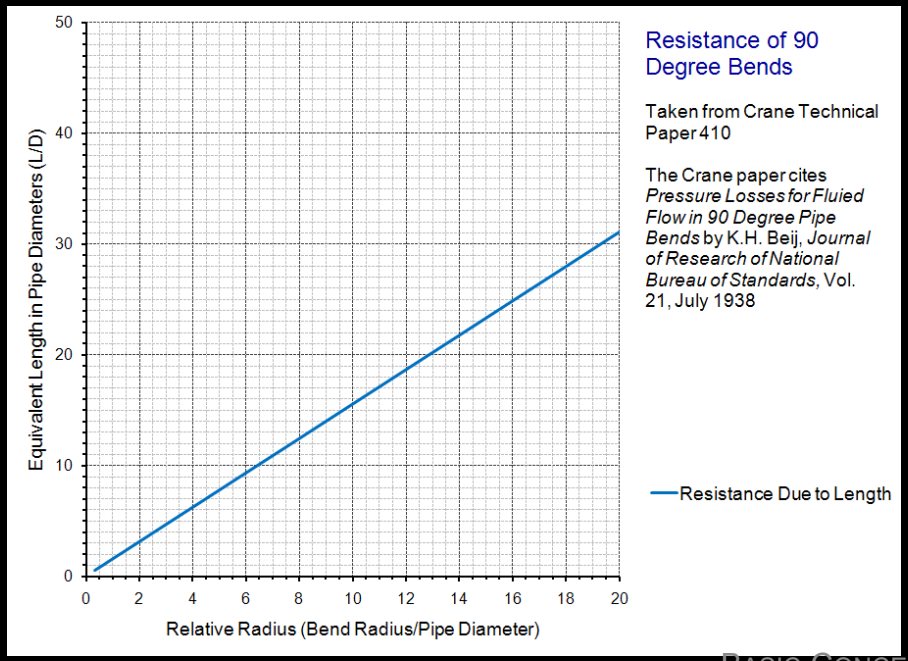
1. Chart is based on straight tees (i.e., branches A, B, and C are the same size).
2. Pressure loss in desired circuit is obtained by selecting the proper curve according to illustrations, determining the flow at the circled branch, and multiplying the pressure loss for the same size elbow at the flow rate in the circled branch by the equivalent elbows indicated.
3. When the size of an outlet is reduced, the equivalent elbows shown in the chart do not apply. Therefore, the maximum loss for any circuit for any flow will not exceed 2 elbow equivalents at the maximum flow occurring in any branch of the tee.
4. Top curve is average of 4 curves, one for each circuit shown.
5. Data from Giesecke and Badgett 1931, 1932.

Elbows; Not So Much Maybe

From the perspective of the system diagram:

- Just a bent piece of straight pipe
- Water in = Water out





One way to think of elbow resistance is to consider it as composed of:

Resistance due to interaction with the pipe wall

Elbows; Not So Much Maybe

From the perspective of the system diagram:

- Just a bent piece of straight pipe
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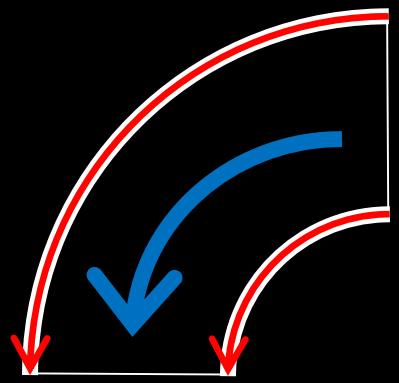

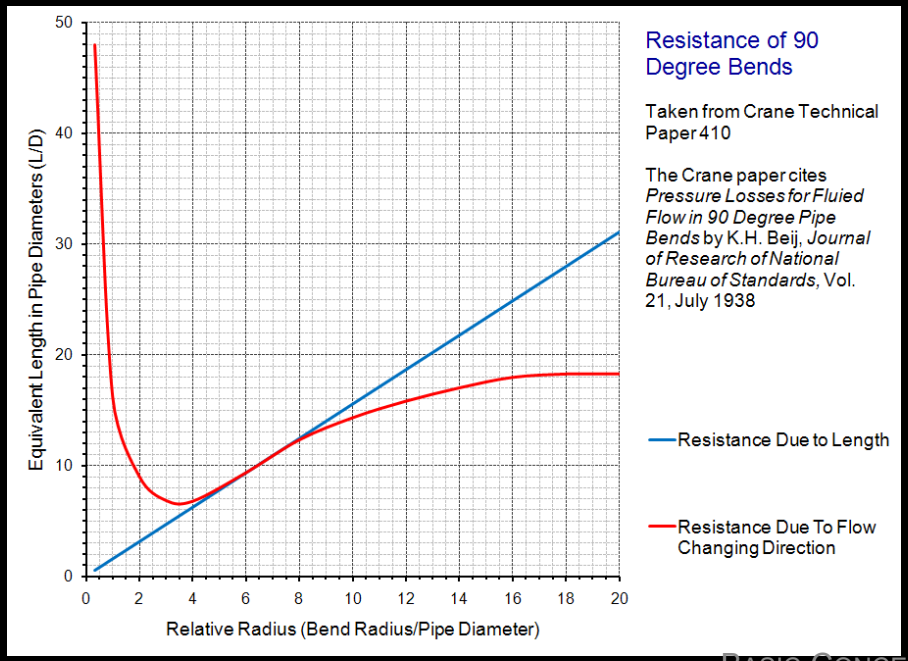

One way to think of elbow resistance is to consider it as composed of:

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\+ Resistance due to a change in direction

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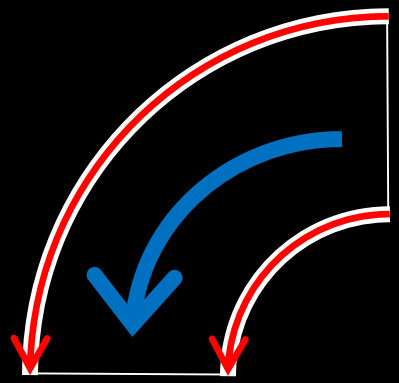
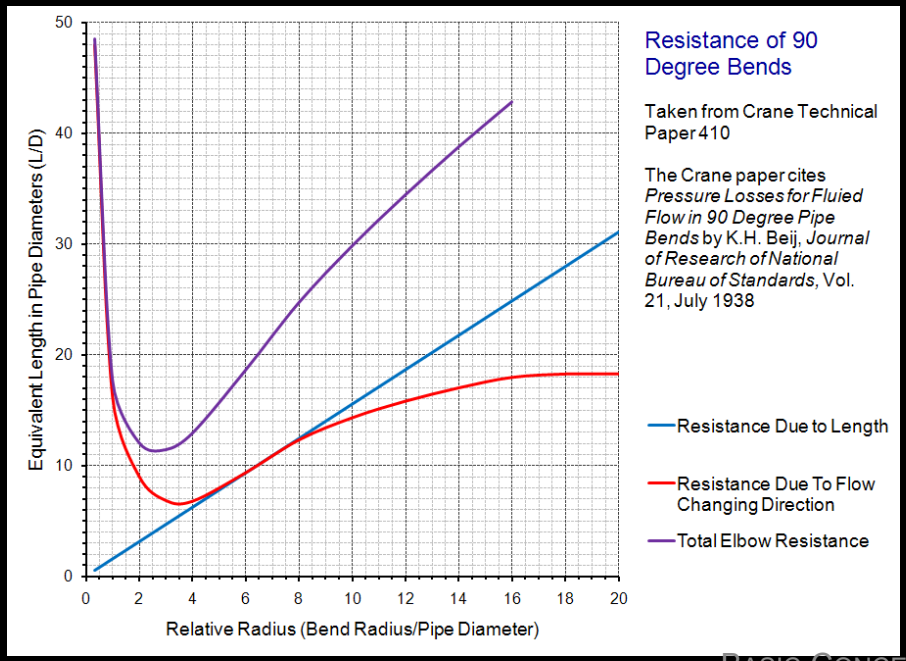




One way to think of elbow resistance is to consider it as composed of:

Resistance due to interaction with the pipe wall

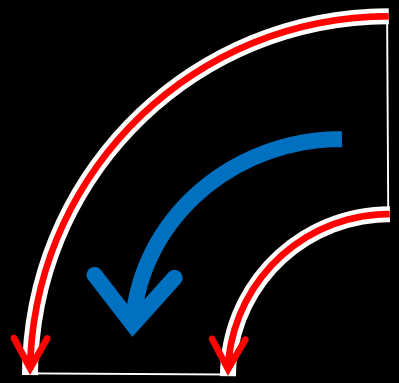
\+ Resistance due to a change in direction

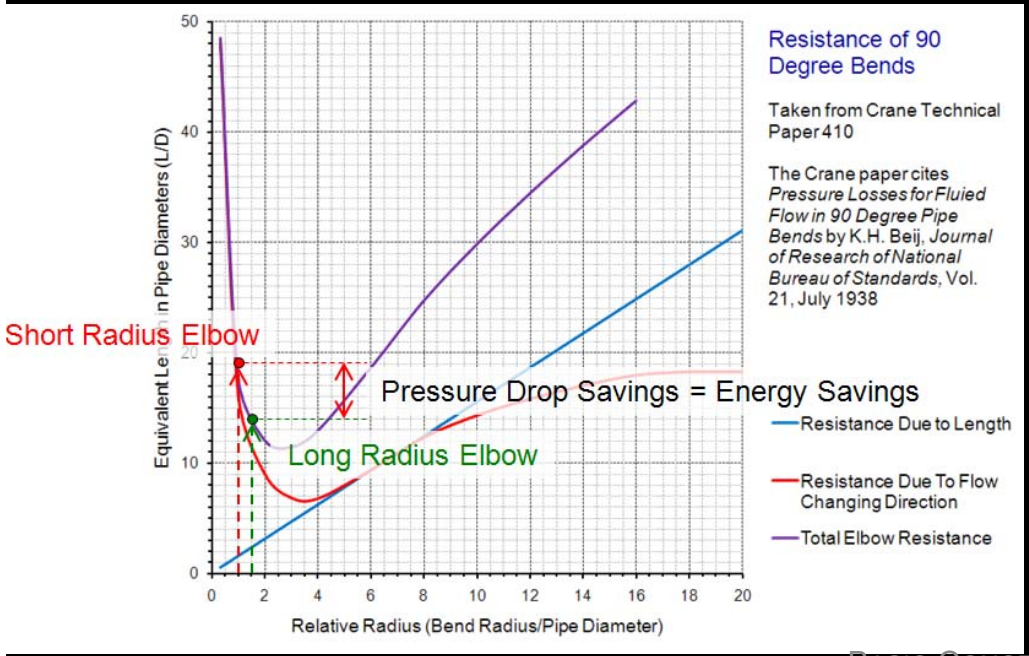
Total Resistance for the Elbow

Elbows; Not So Much Maybe

From the perspective of the physical system:

- Pump energy required
- Long radius = optimized loss = energy savings





One way to think of elbow resistance is to consider it as composed of:

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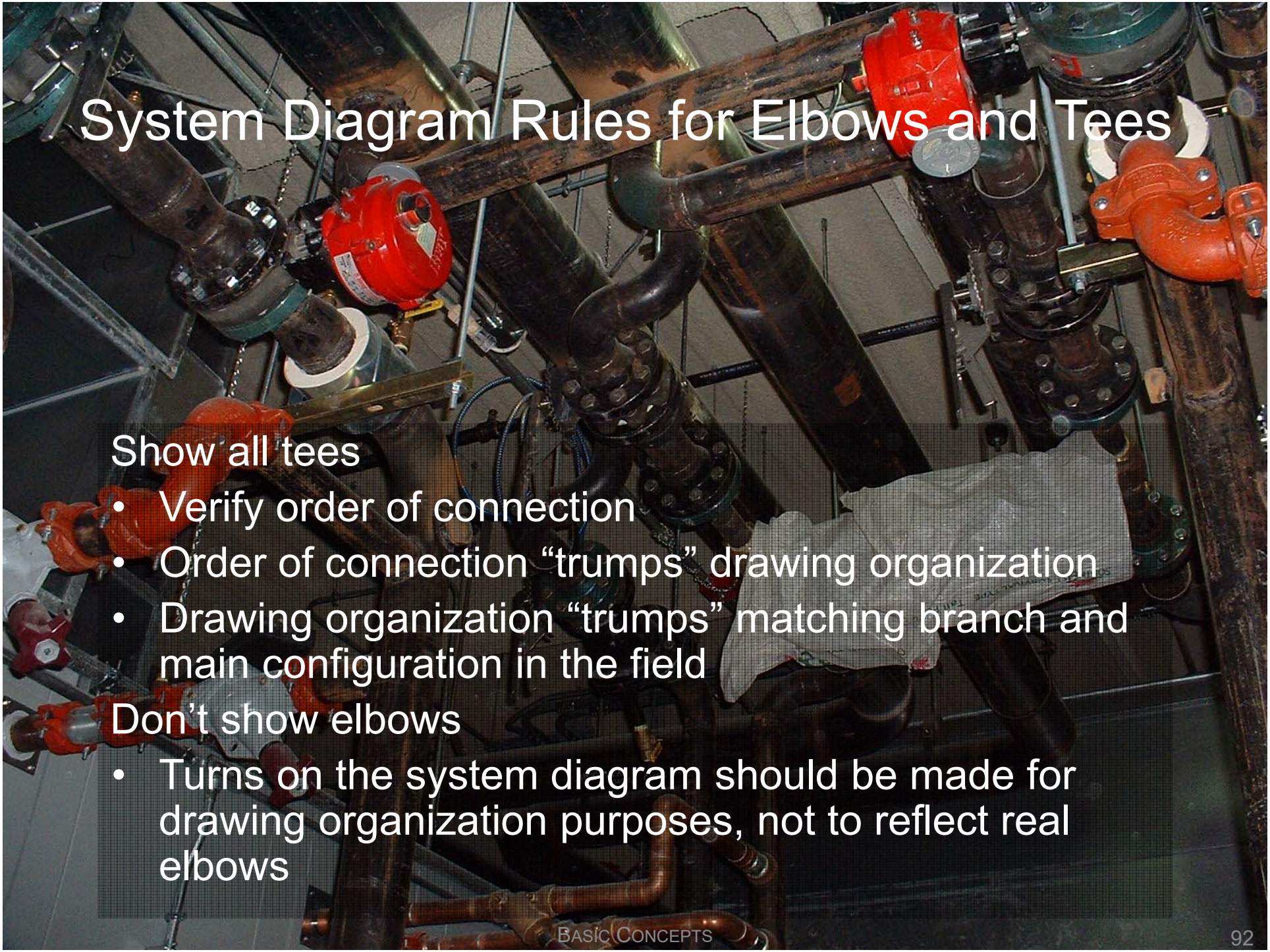
Total Resistance for the Elbow

System Diagram Rules for Elbows and Tees



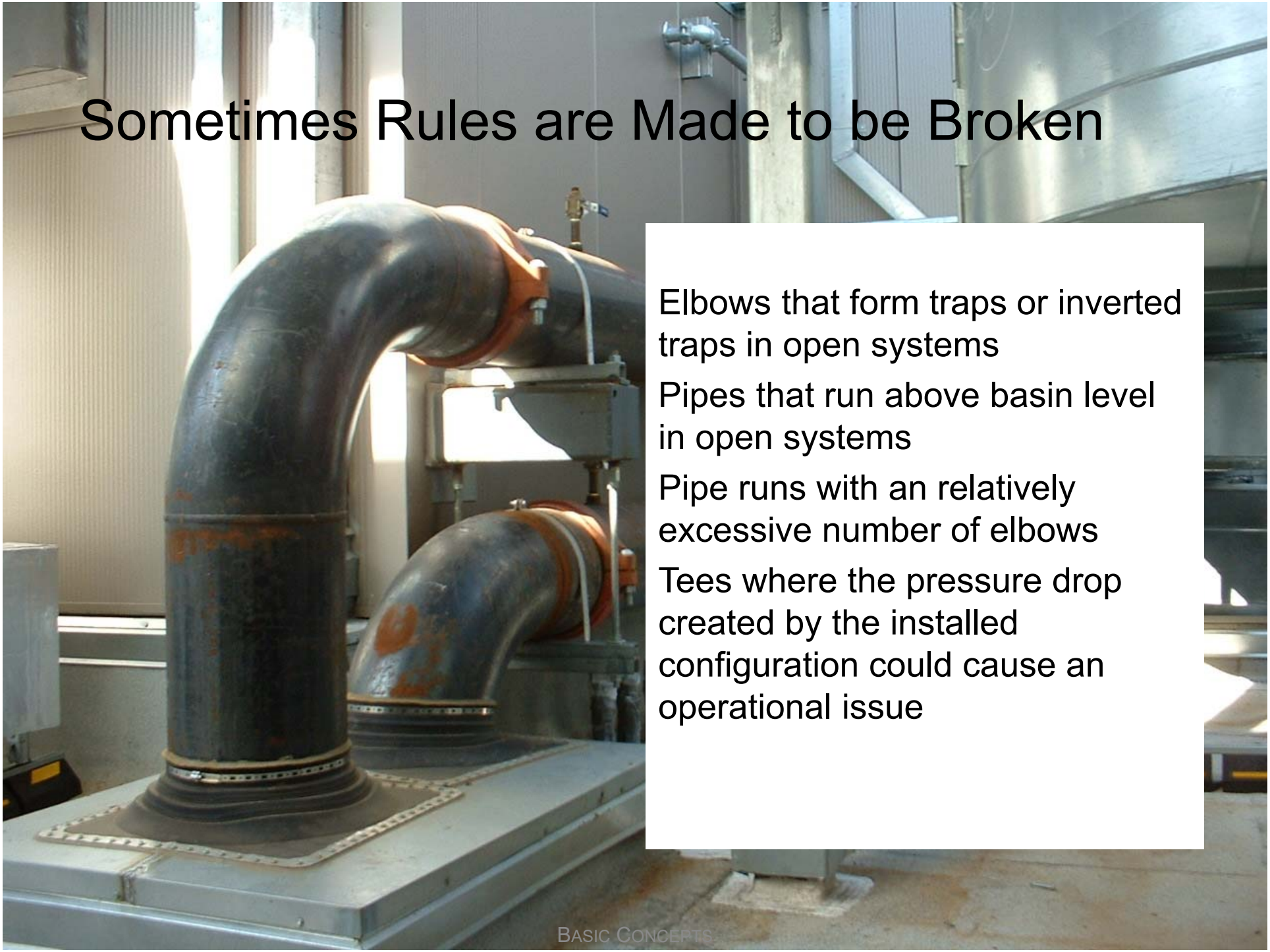
Show all tees

- Verify order of connection
- Order of connection “trumps” drawing organization
- Drawing organization “trumps” matching branch and main configuration in the field

Don’t show elbows

- Turns on the system diagram should be made for drawing organization purposes, not to reflect real elbows

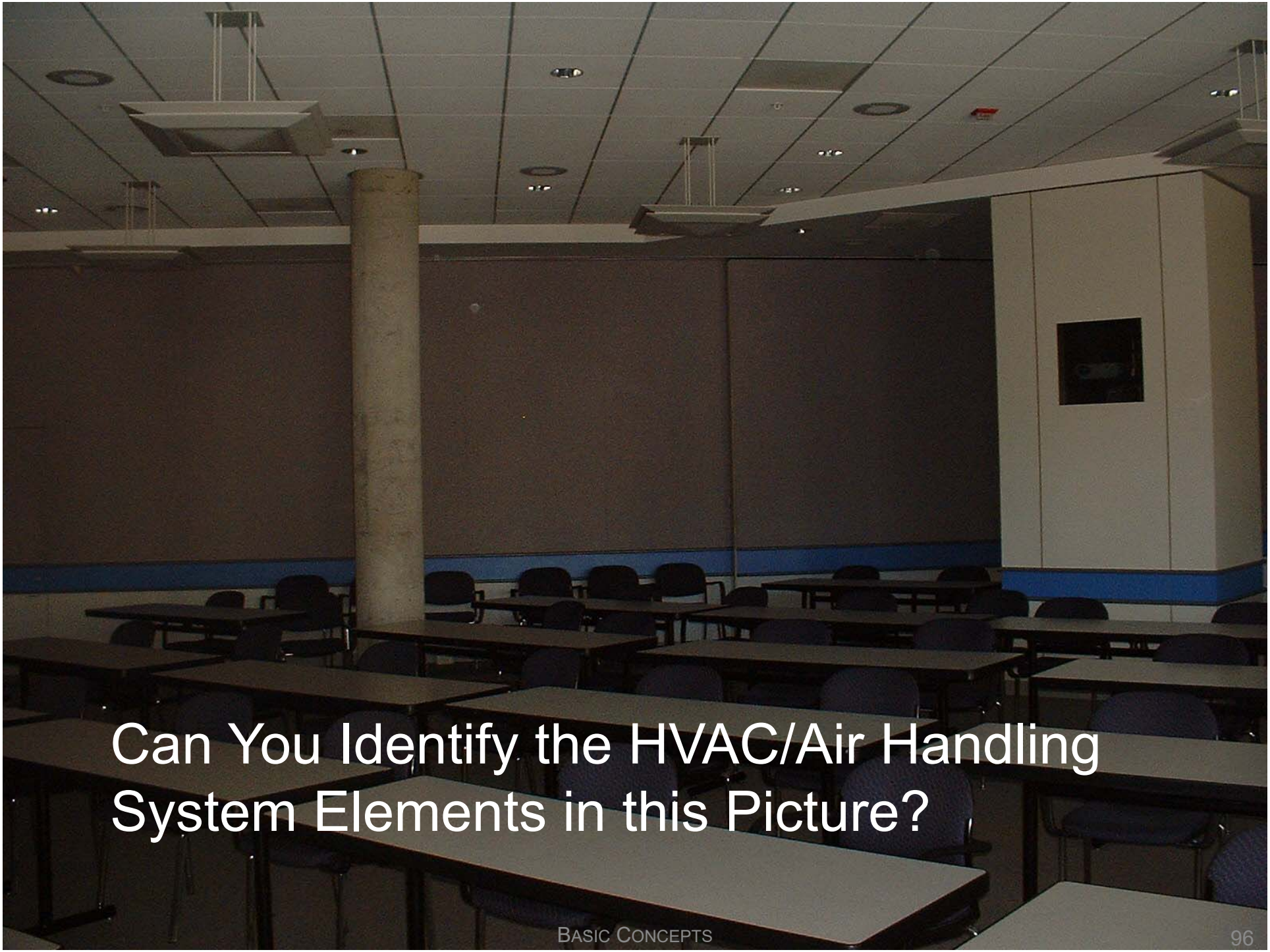
Sometimes Rules are Made to be Broken



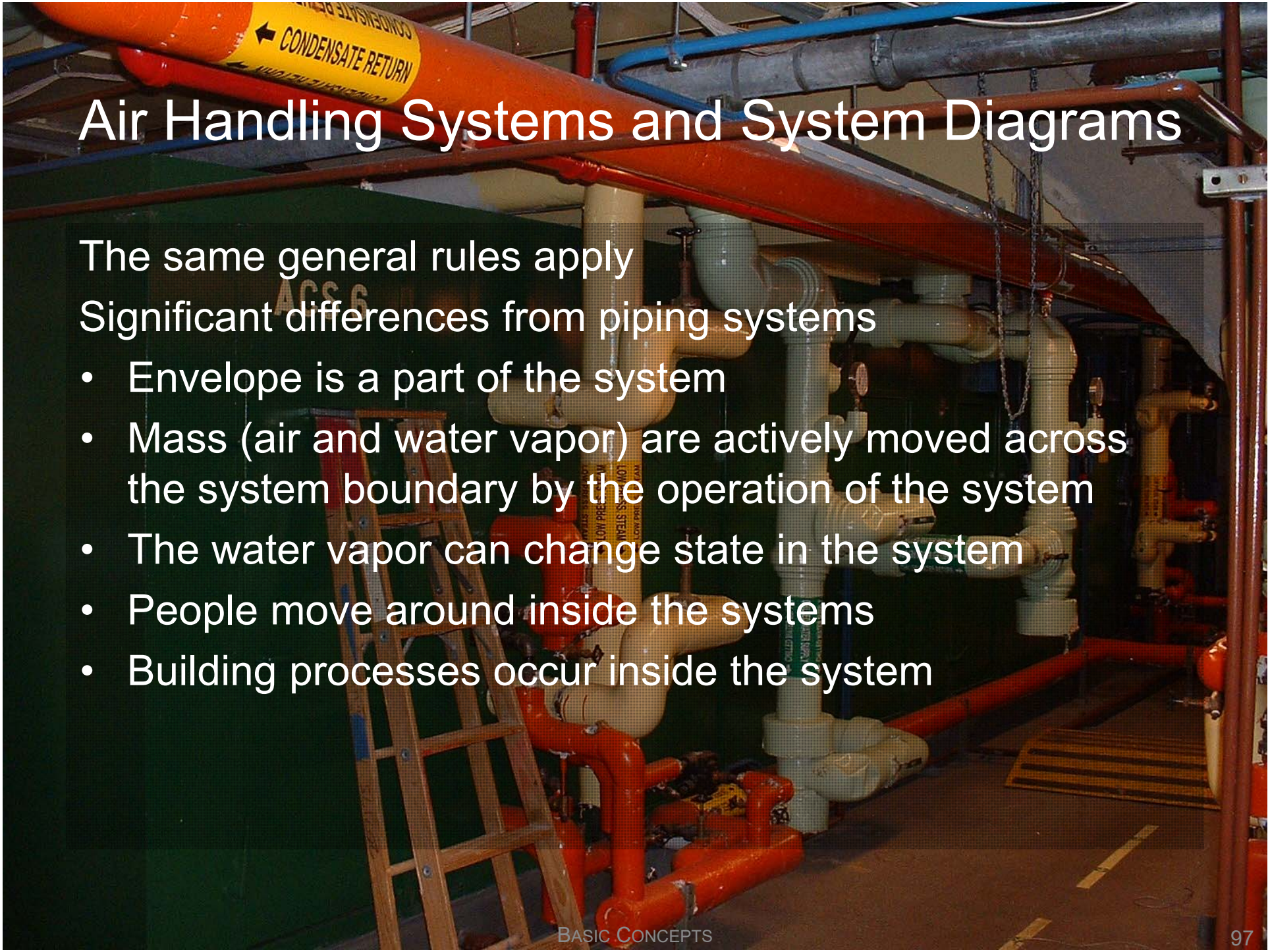
- Elbows that form traps or inverted traps in open systems
- Pipes that run above basin level in open systems
- Pipe runs with an relatively excessive number of elbows
- Tees where the pressure drop created by the installed configuration could cause an operational issue

Let’s Try One


So Far, Our Focus Has Been Hydronic Systems; What About Air Systems?


Can You Identify the HVAC/Air Handling System Elements in this Picture?

Air Handling Systems and System Diagrams

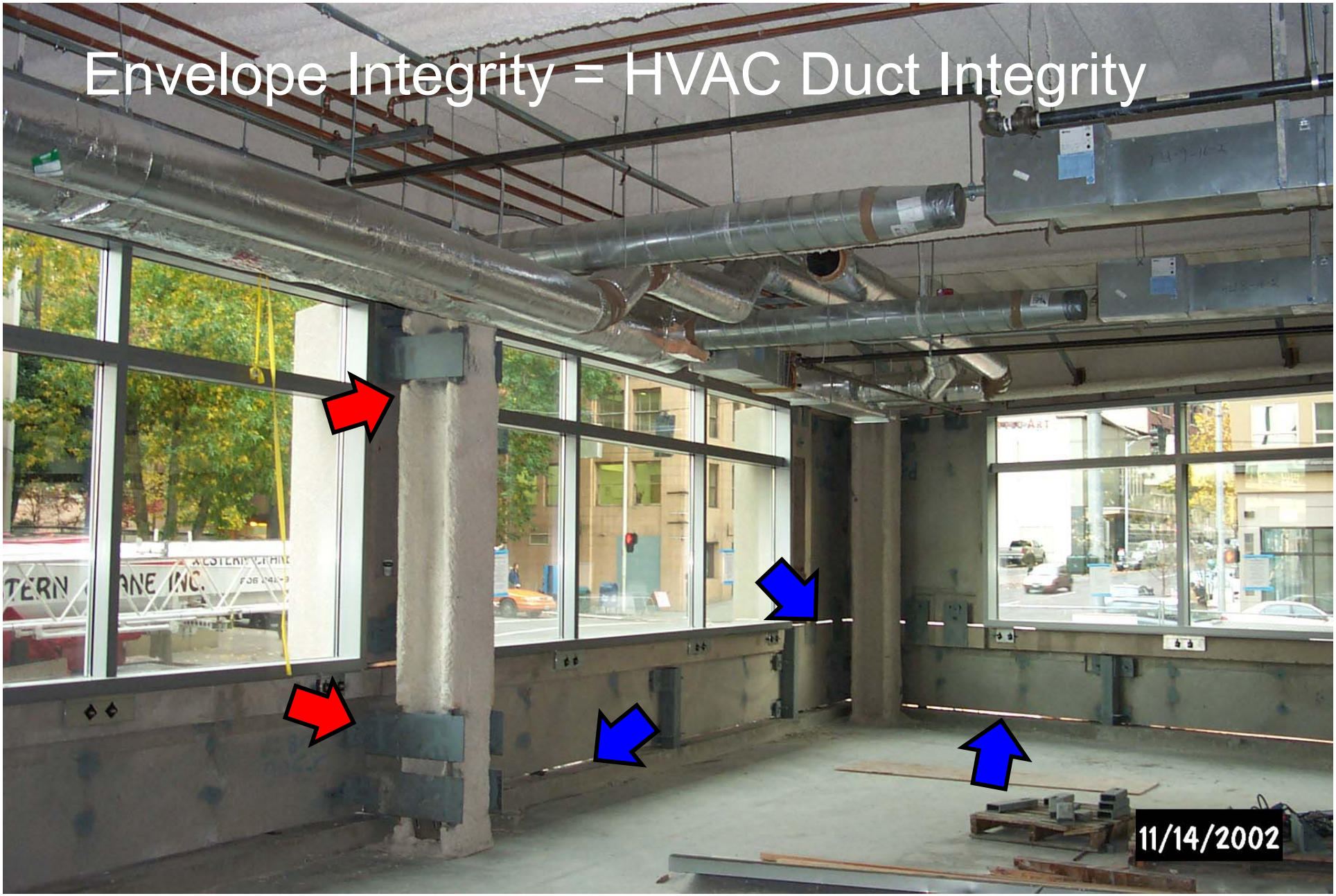


The same general rules apply

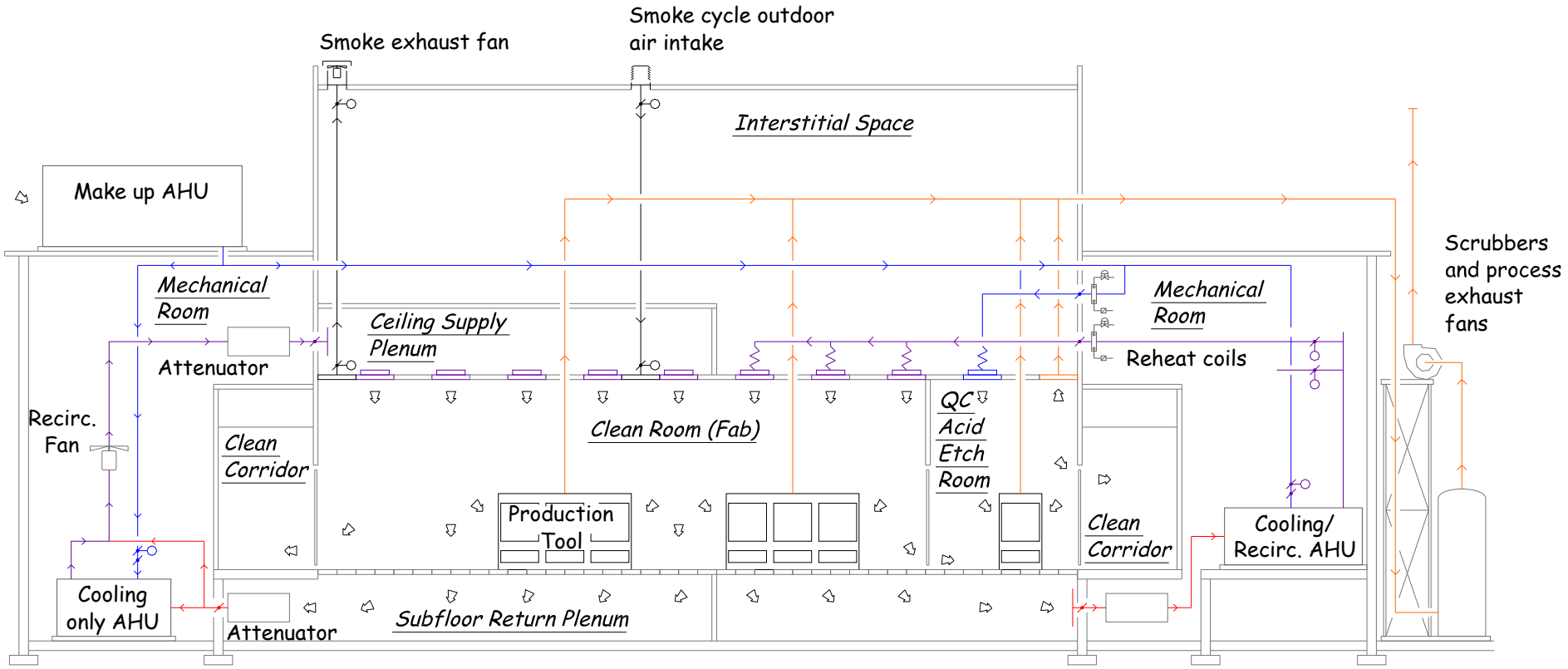
Significant differences from piping systems

- Envelope is a part of the system
- Mass (air and water vapor) are actively moved across the system boundary by the operation of the system
- The water vapor can change state in the system
- People move around inside the systems
- Building processes occur inside the system

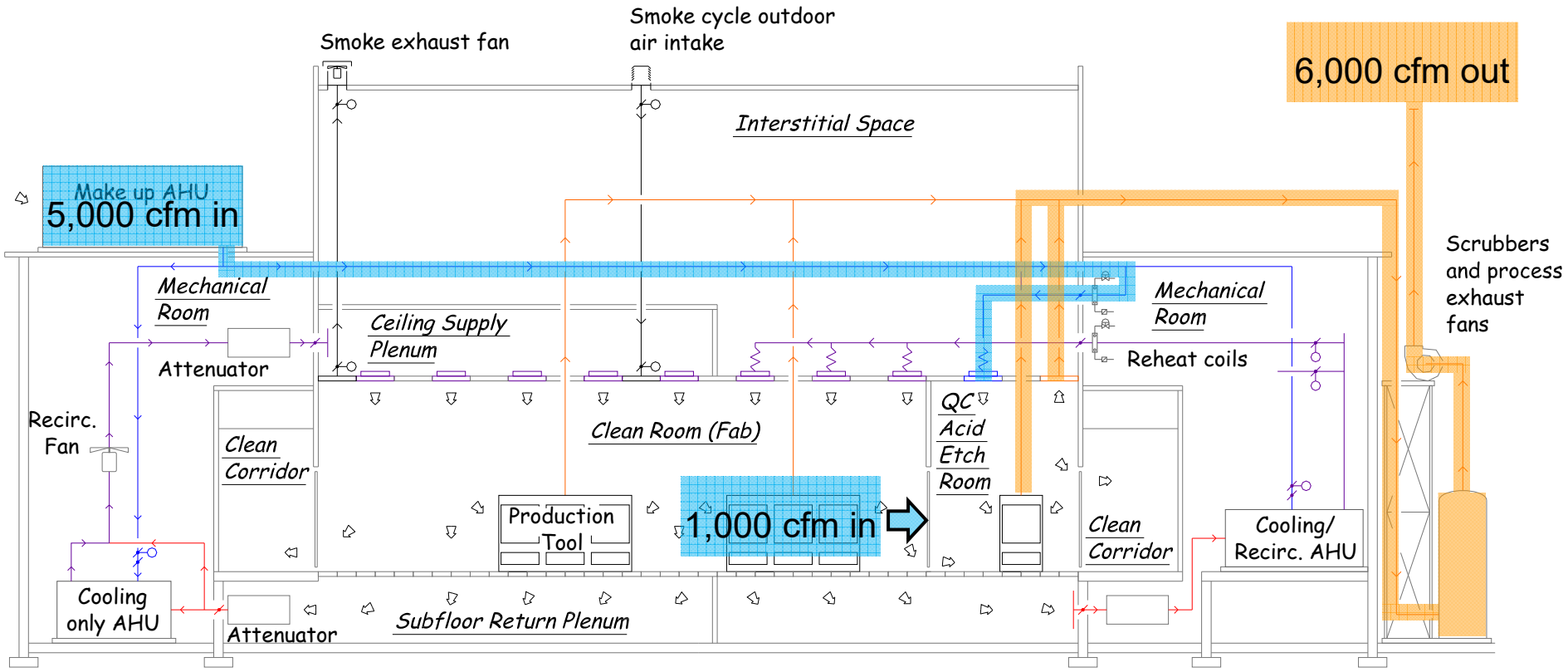
Envelope Integrity = HVAC Duct Integrity



Envelope Integrity = Process Integrity = Cash Flow Integrity

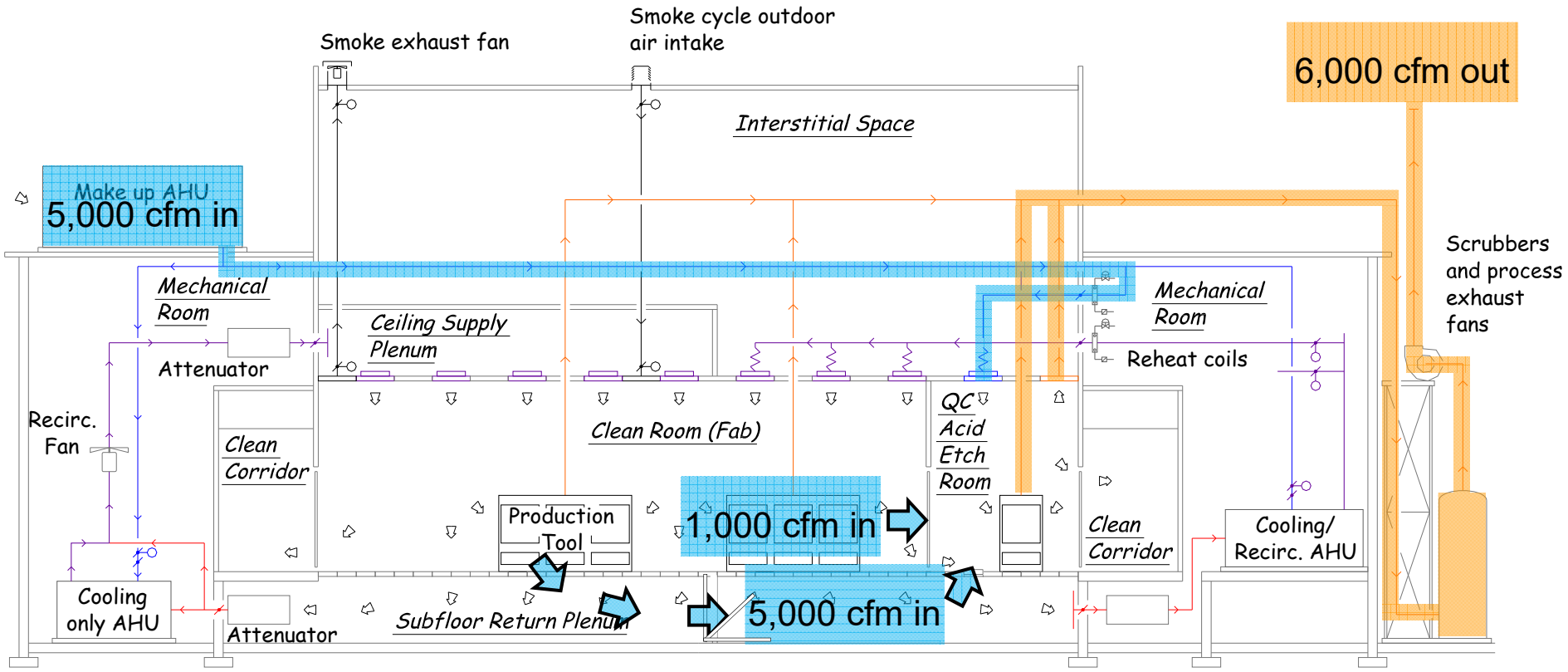


A Demonstration of Fundamental Principles



Conservation of Mass;

A.K.A *The Goes Intas gotta equal the Goes Outa's*



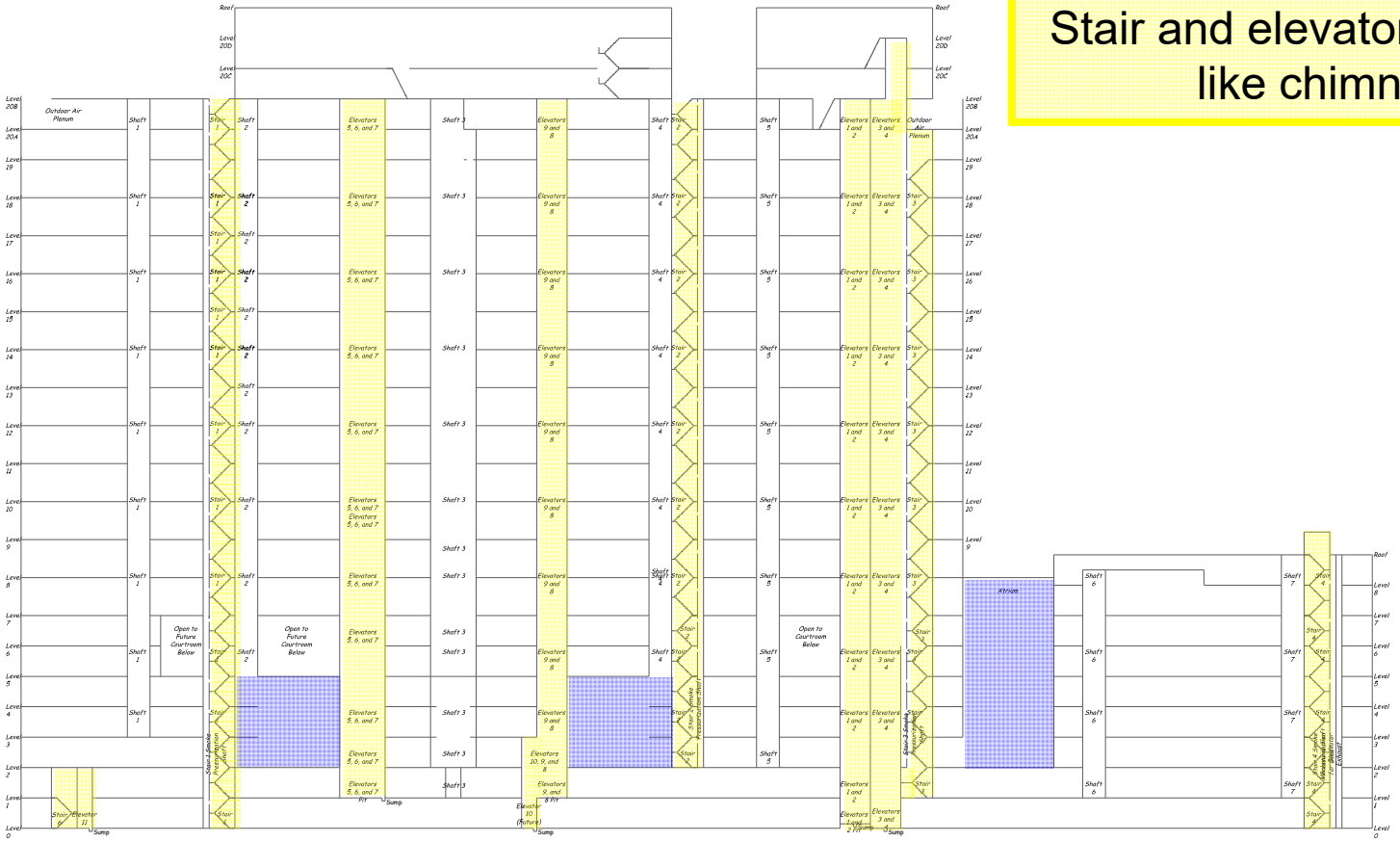
The Envelope is Significant(l

Atriums interconnect floors

The Envelope is Significantly Complex

Atriums interconnect floors

Stair and elevator shafts act like chimneys

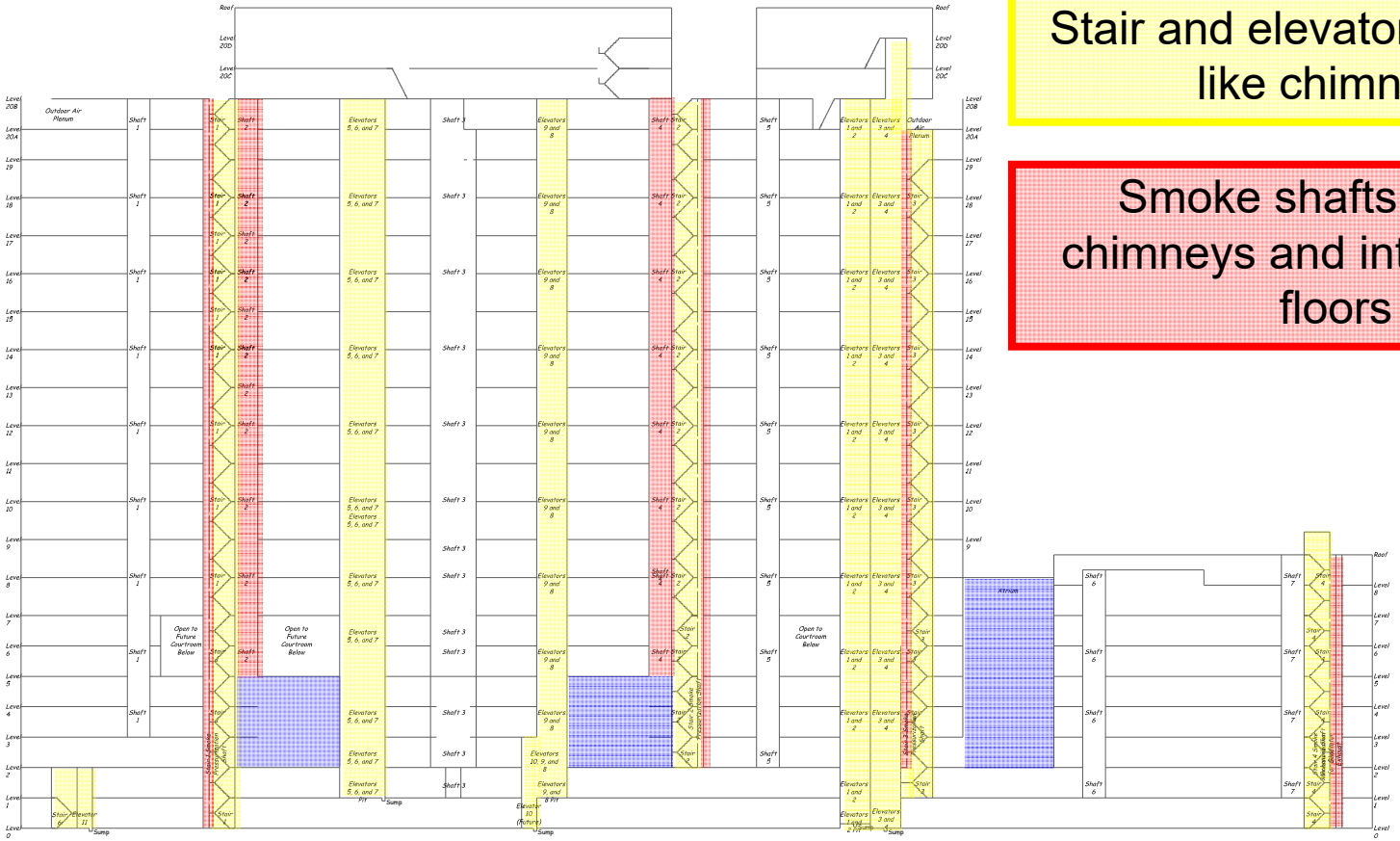


The Envelope is Significantly Complex

Atriums interconnect floors

Stair and elevator shafts act like chimneys

Smoke shafts act like chimneys and interconnect floors



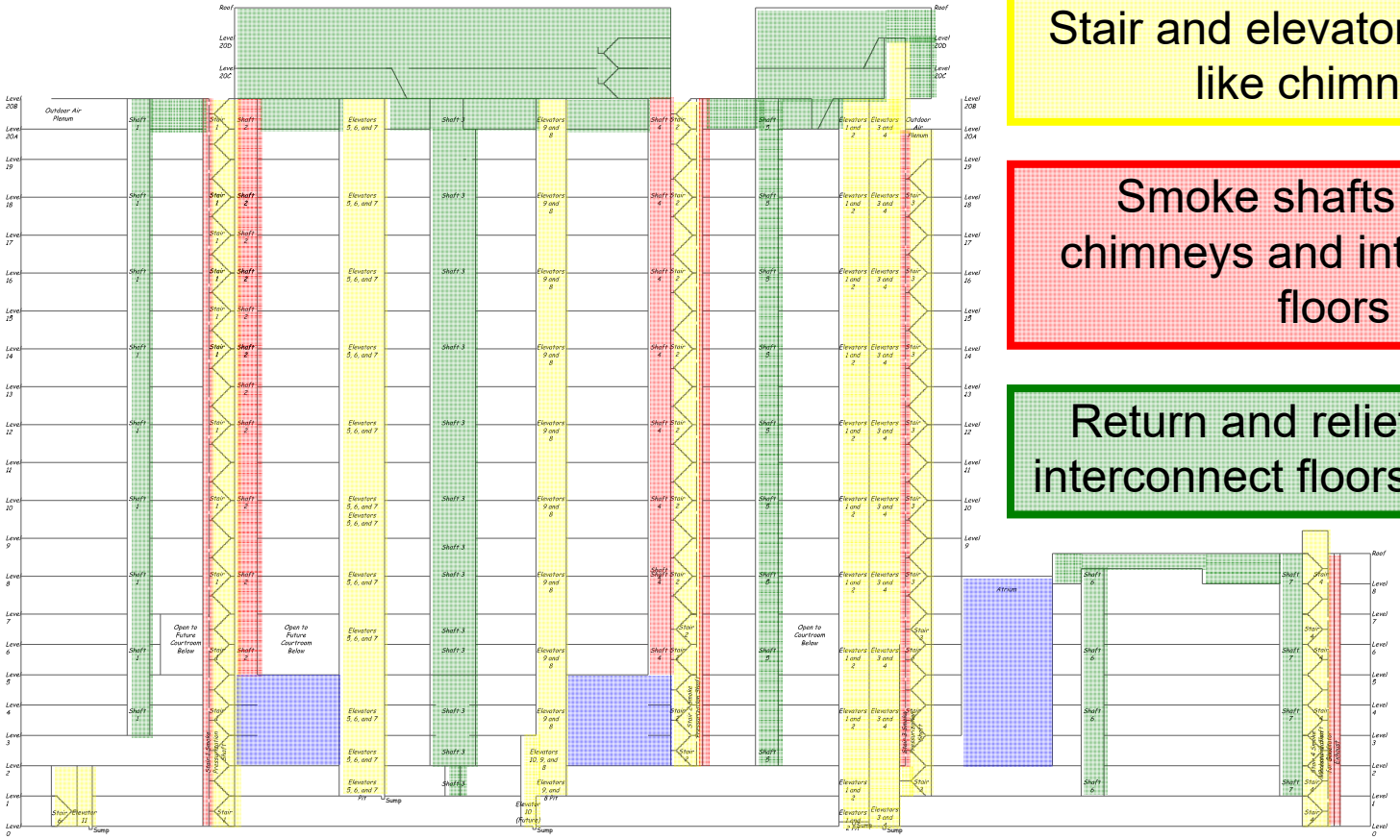
The Envelope is Significantly Complex

Atriums interconnect floors

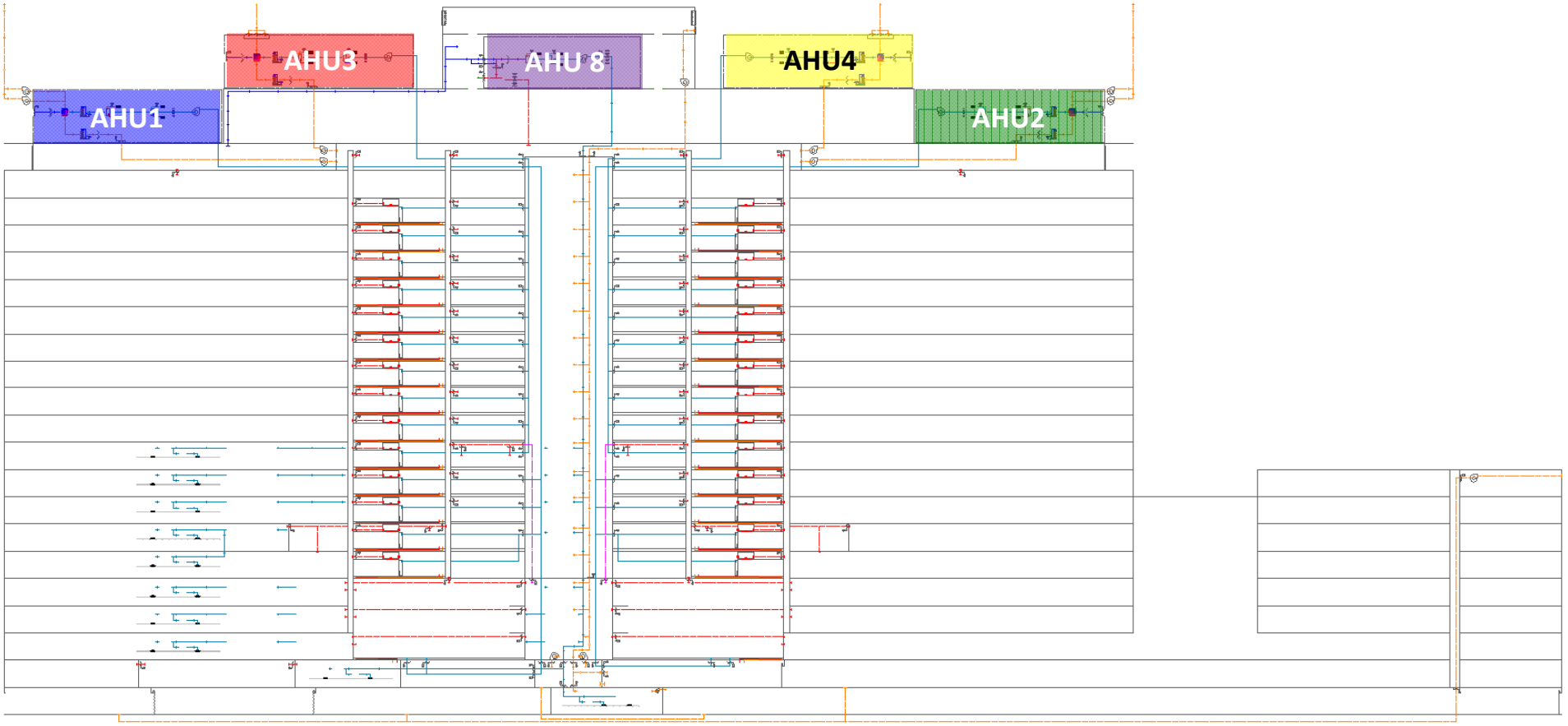
Stair and elevator shafts act like chimneys

Smoke shafts act like chimneys and interconnect floors

Return and relief plenums interconnect floors and shafts

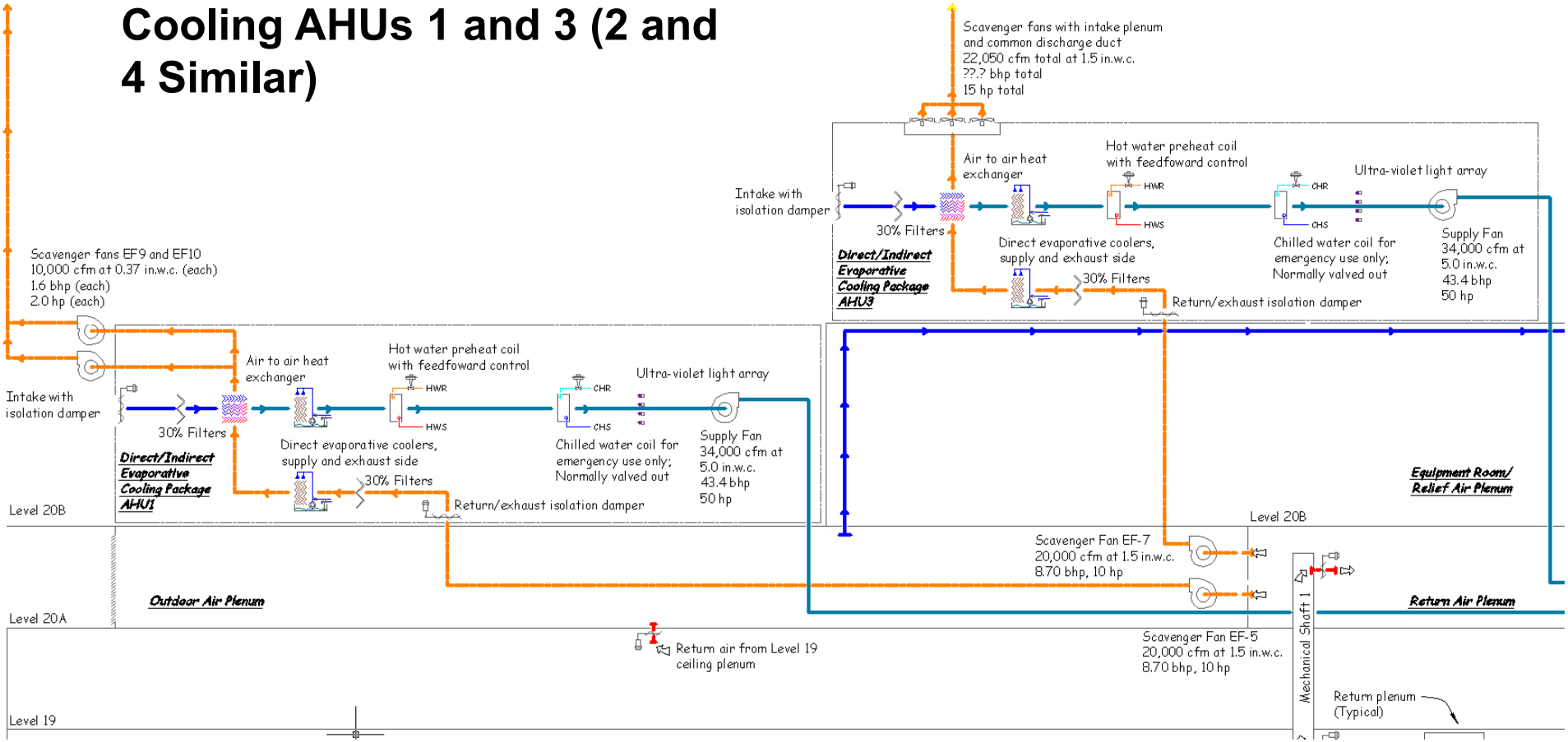


The Envelope as the Framework for the Air Handling System Diagram



The Envelope as the Framework for the Air Handling System Diagram

Direct/Indirect Evaporative Cooling AHUs 1 and 3 (2 and 4 Similar)



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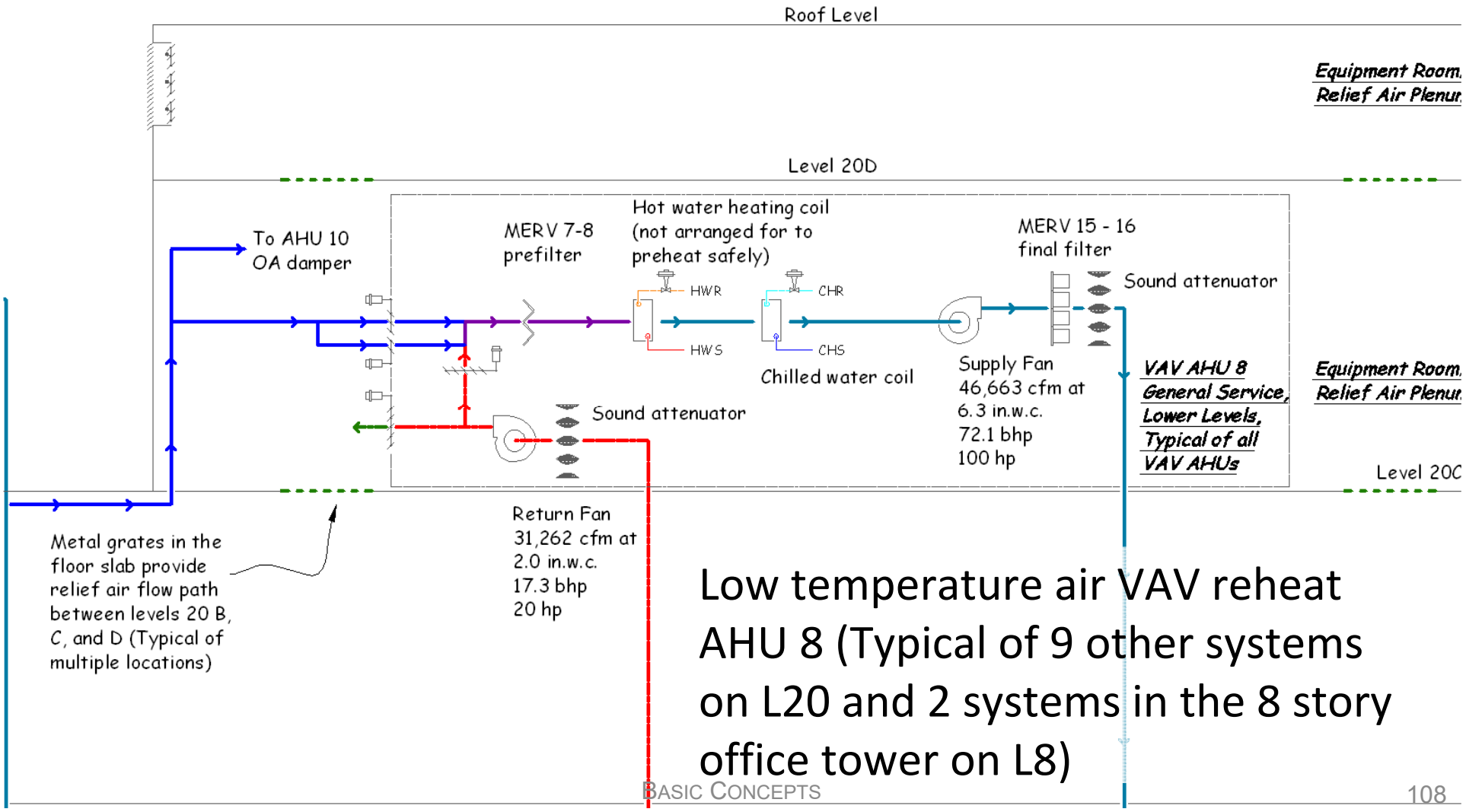
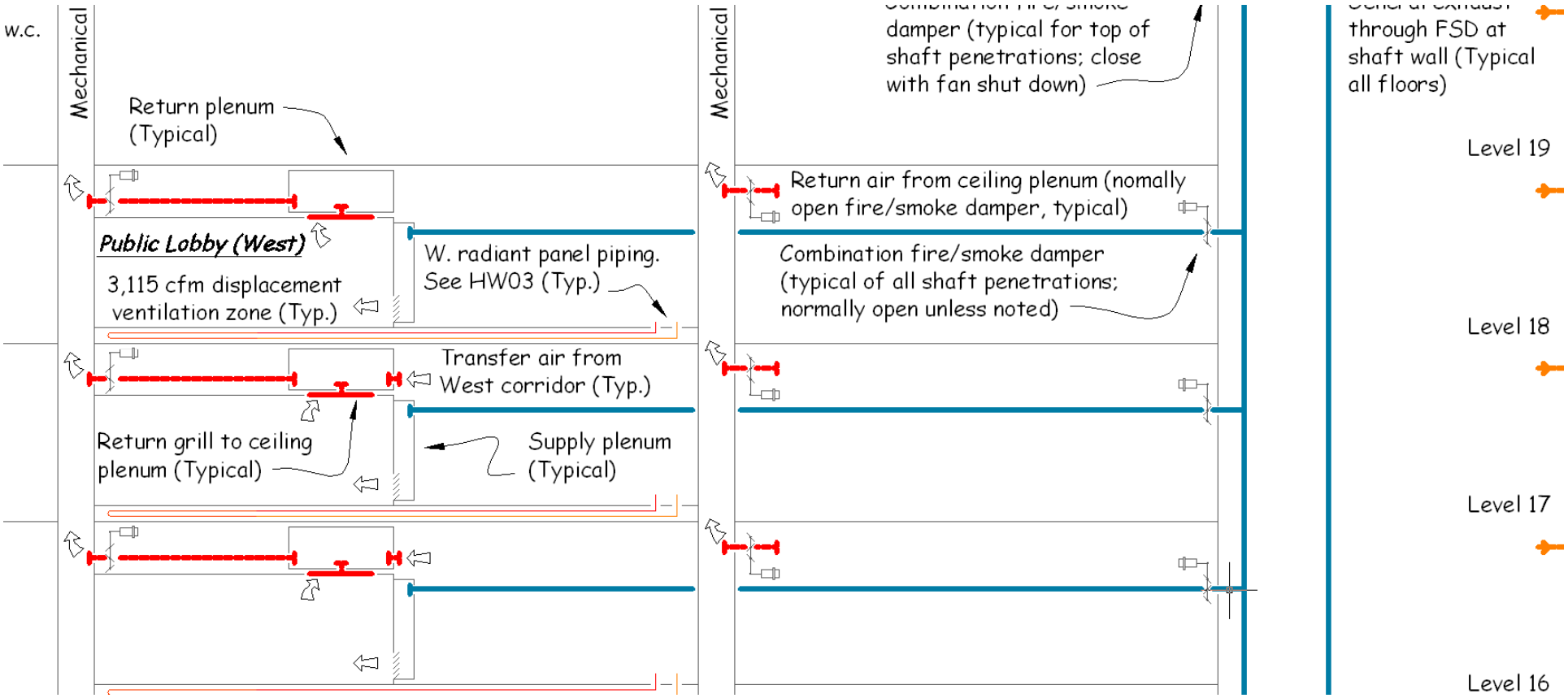


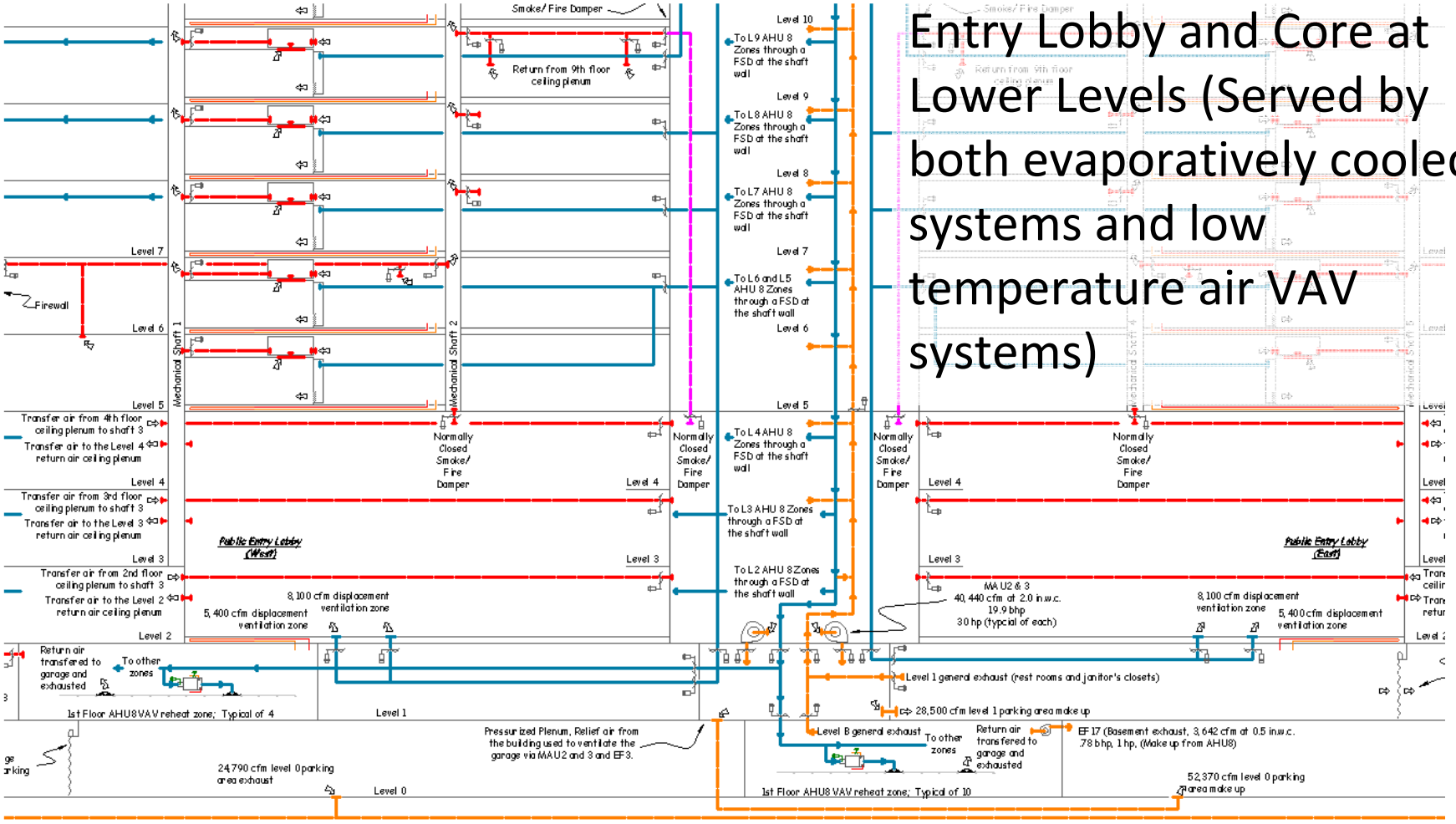
Low temperature air VAV reheat AHU 8 (Typical of 9 other systems on L20 and 2 systems in the 8 story office tower on L8)

The Envelope as the Framework for the Air Handling System Diagram



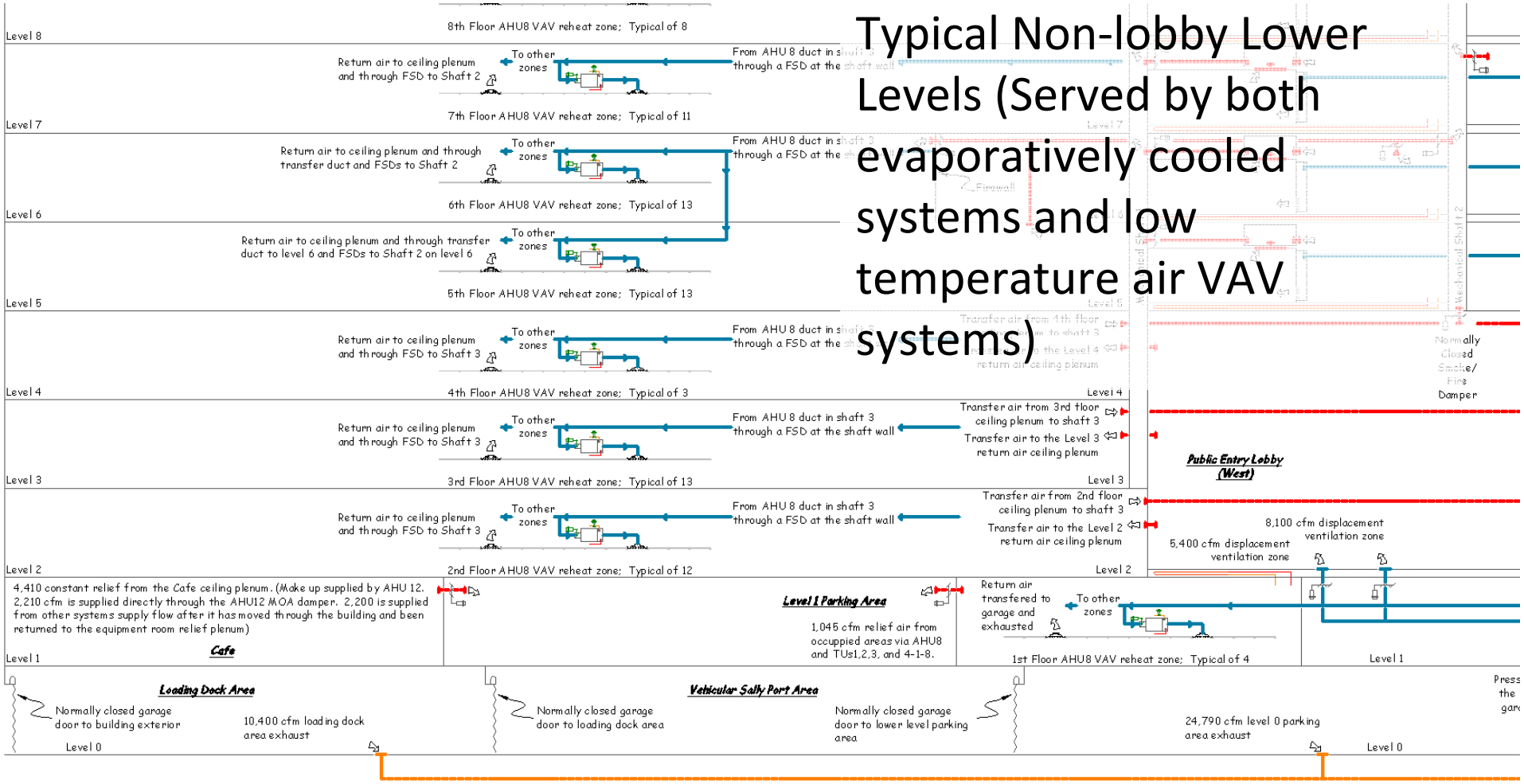
Typical Public Lobby Area (Served Direct/Indirect Evaporative Cooled AHU)

The Envelope as the Framework for the Air Handling System Diagram



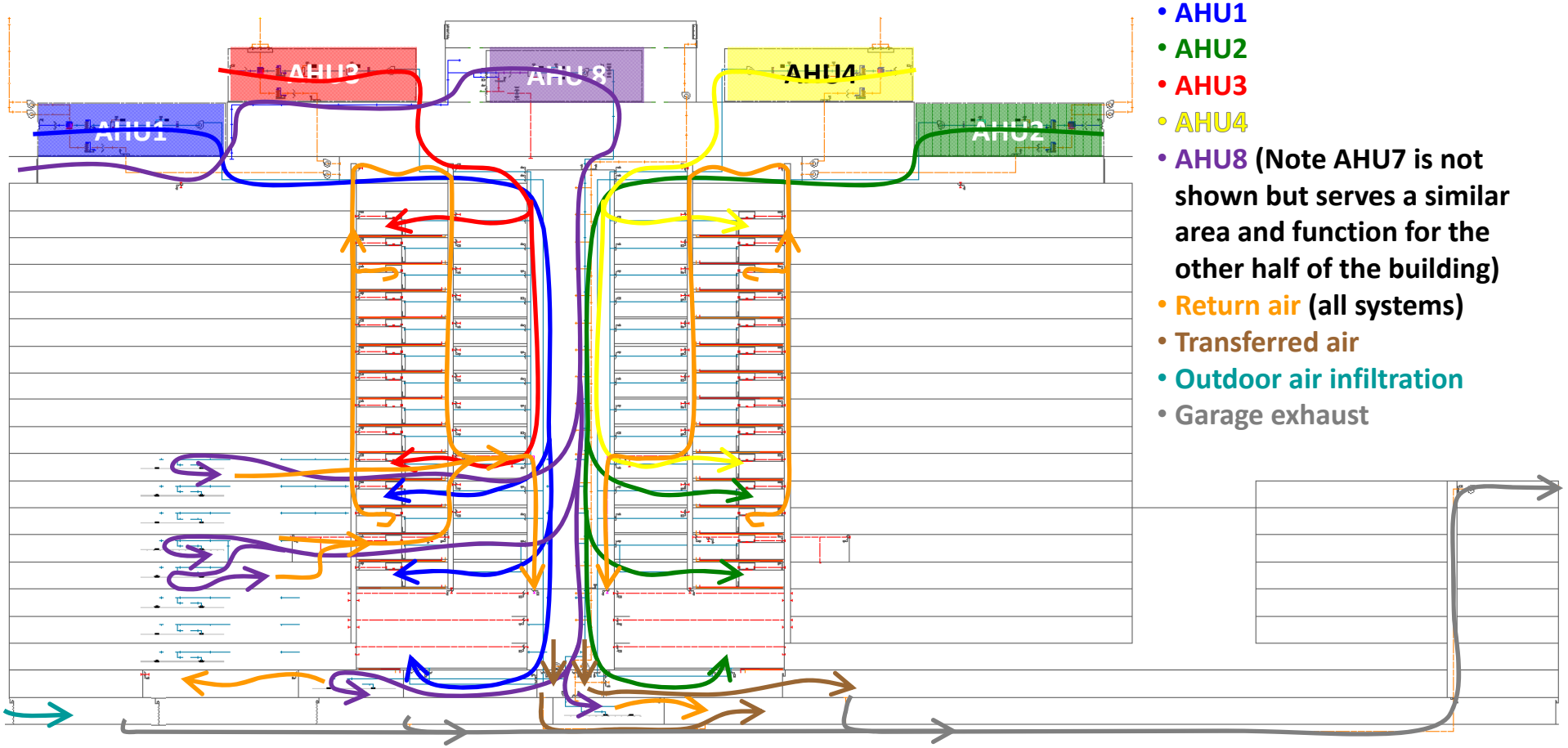
Entry Lobby and Core at Lower Levels (Served by both evaporatively cooled systems and low temperature air VAV systems)

The Envelope as the Framework for the Air Handling System Diagram



Typical Non-lobby Lower Levels (Served by both evaporatively cooled systems and low temperature air VAV systems)

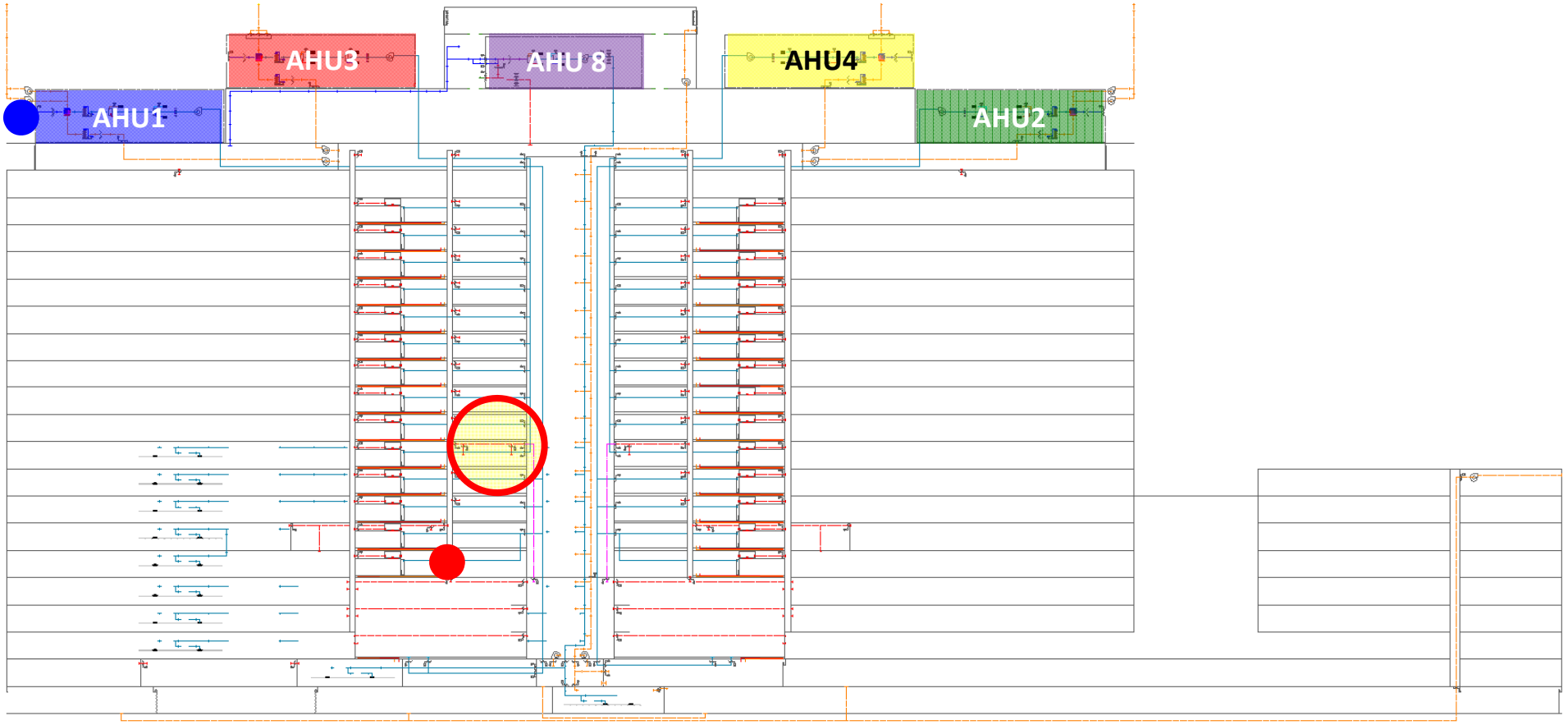
The Envelope as the Framework for the Air Handling System Diagnostics



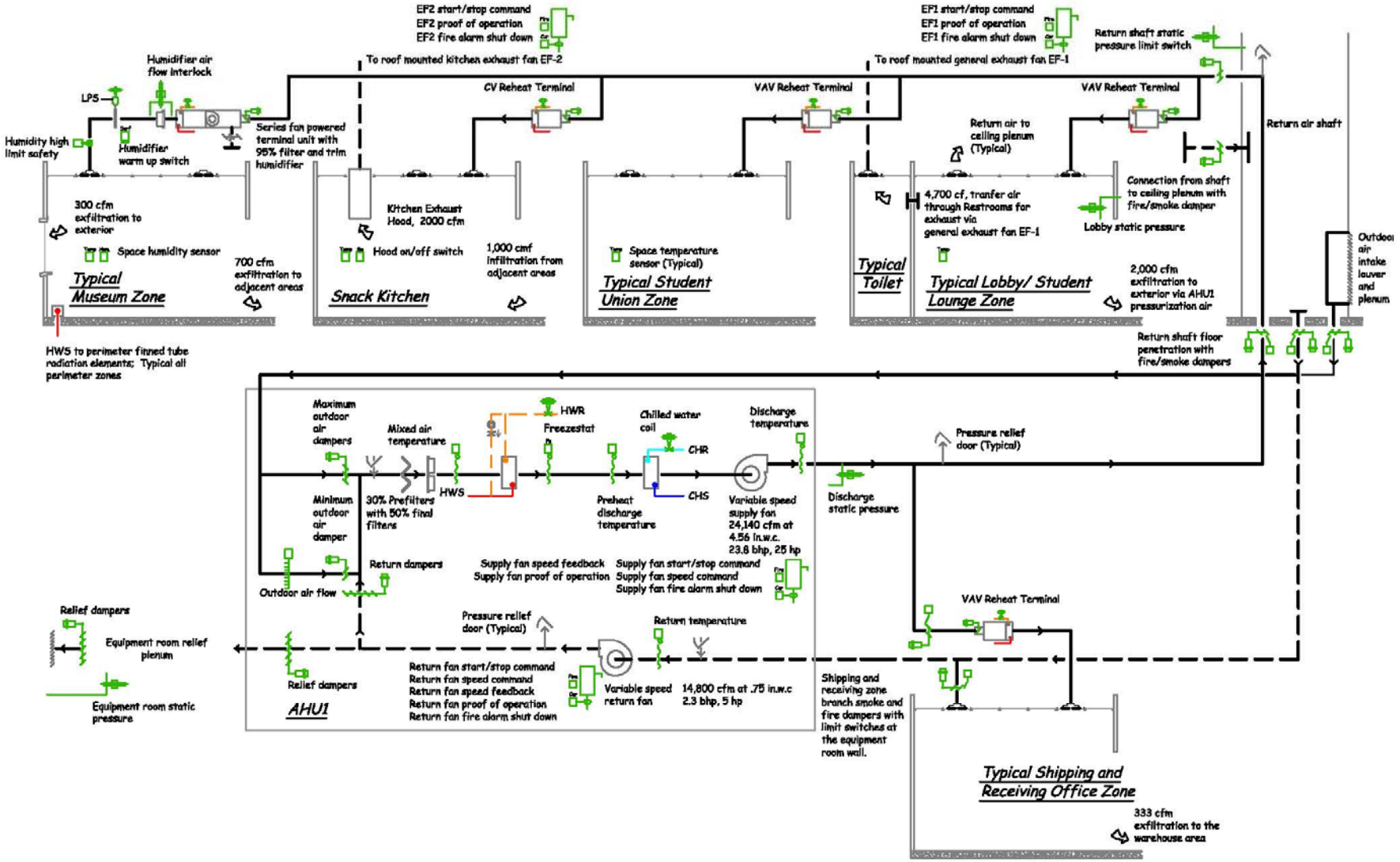
Flow Arrow Color Codes

- **AHU1**
- **AHU2**
- **AHU3**
- **AHU4**
- **AHU8 (Note AHU7 is not shown but serves a similar area and function for the other half of the building)**
- **Return air (all systems)**
- **Transferred air**
- **Outdoor air infiltration**
- **Garage exhaust**

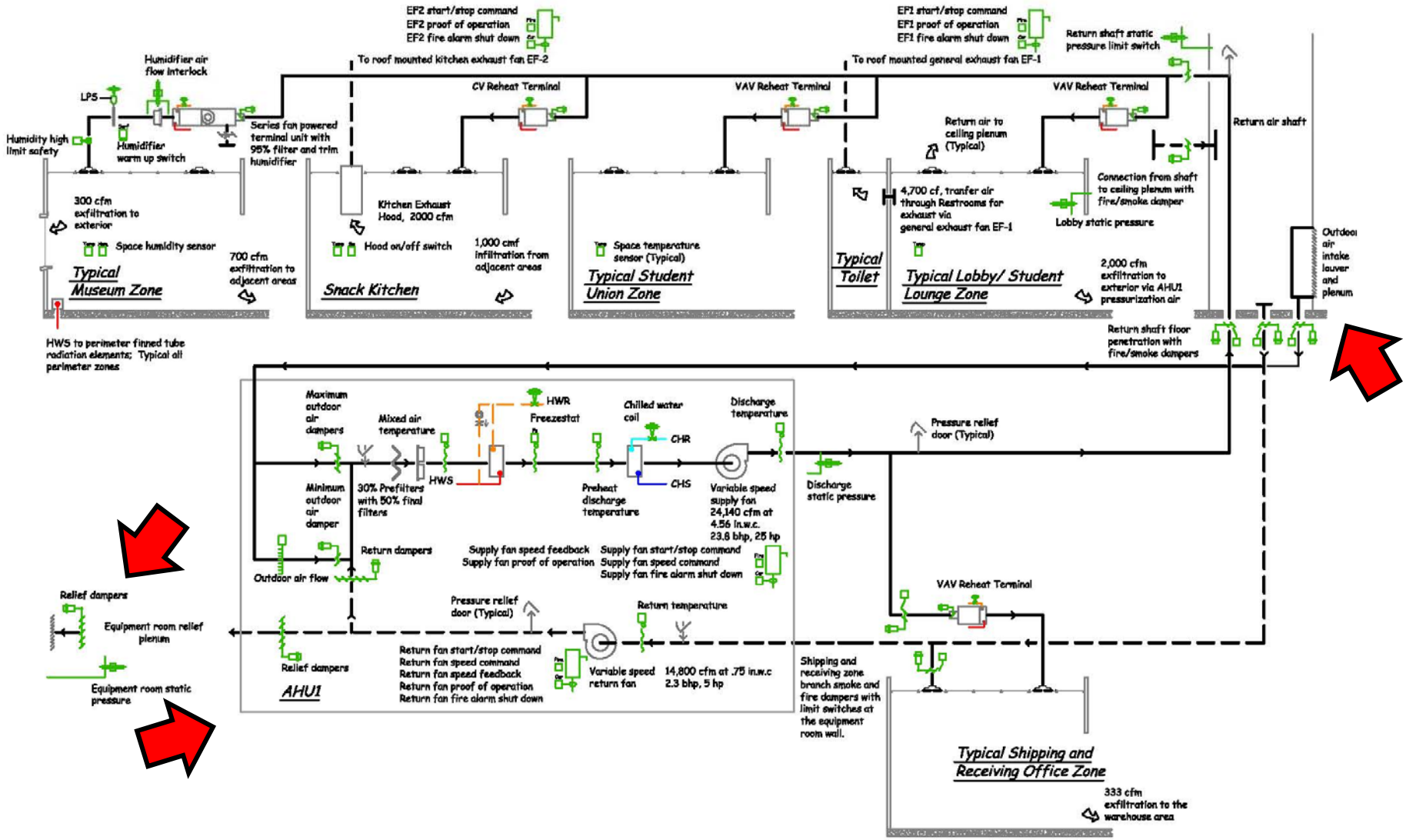
The Envelope as the Framework for the Air Handling System Diagnostics



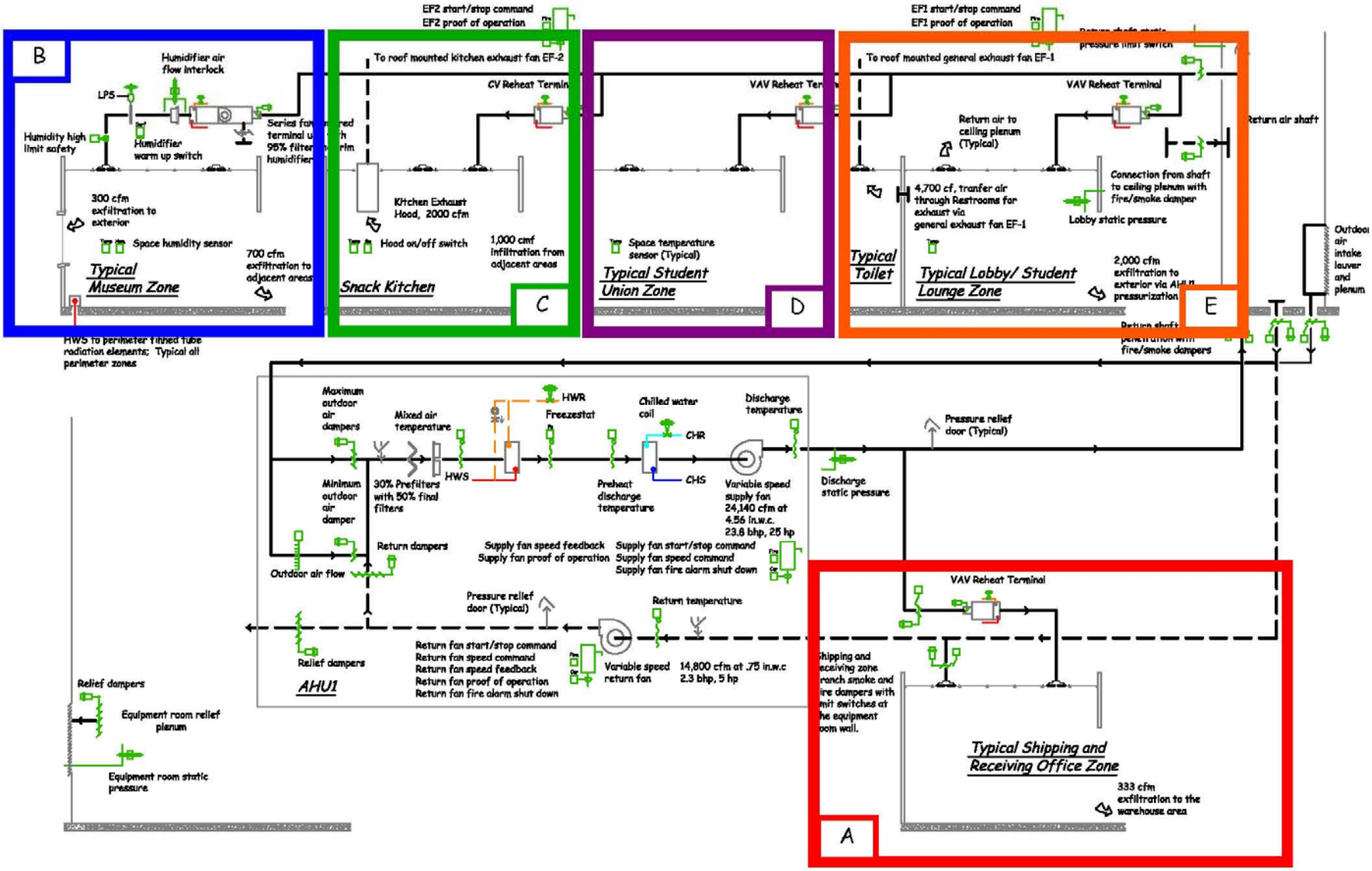
Air Handling System Diagram Characteristics



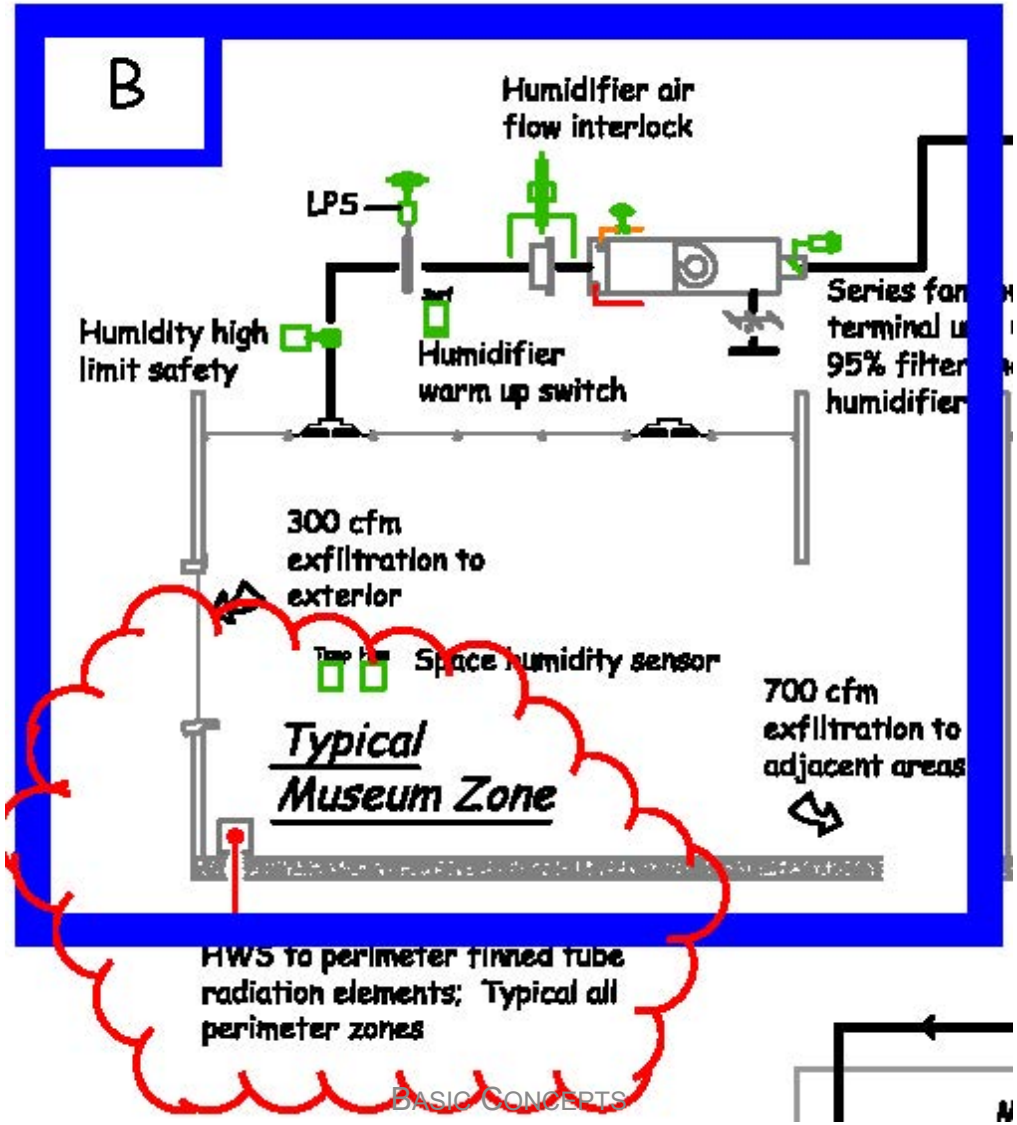
Reflect the Building Physical Arrangement



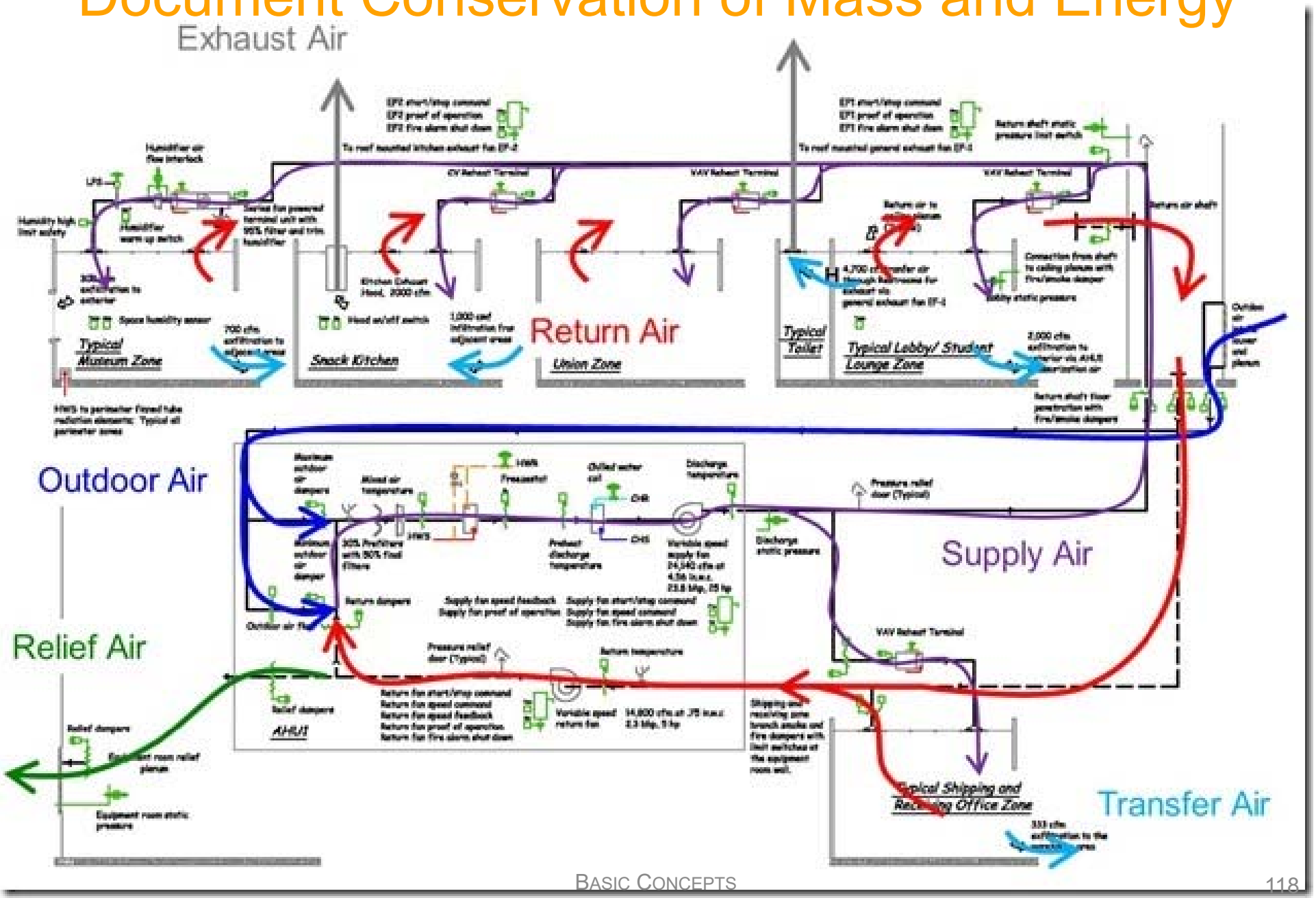
Include Examples of Each Zone Type



Include the Impacts of Other Systems



Document Conservation of Mass and Energy



Let's Try One