System Diagram Workshop Introduction

Please Visit This Link While We Are Waiting to Begin

https://tinyurl.com/PECSystDgmD1Intro

Presented By:
David Sellers
Senior Engineer, Facility Dynamics Engineering

Disclaimer

- The information in this document is believed to accurately describe the technologies described herein and are meant to clarify and illustrate typical situations, which must be appropriately adapted to individual circumstances. These materials were prepared to be used in conjunction with a free, educational program and are not intended to provide legal advice or establish legal standards of reasonable behavior. Neither Pacific Gas and Electric Company (PG&E) nor any of its employees and agents:
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Learning Objectives

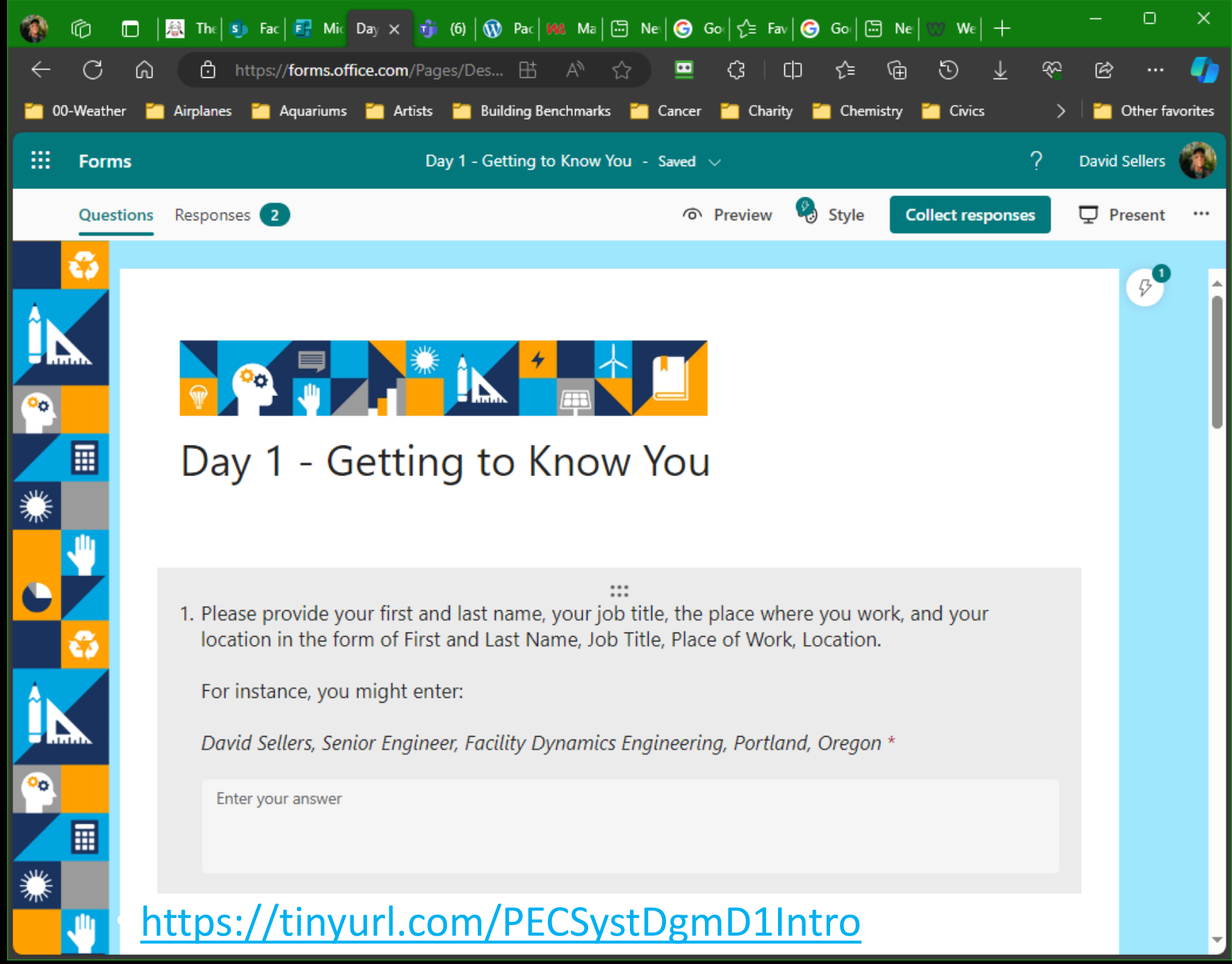
By the end of this workshop, attendees will be able to:

1. Discuss the value of system diagrams and the system concept as design, commissioning, training and persistence tools.
2. Discuss the key concepts and techniques that are used to develop a system diagram
3. Develop a simple water system diagram.
4. Develop a simple air system diagram.
5. Use a system diagram to perform a node analysis to identify different operating modes for a system.

Agenda

1. Introduction
2. Why Do I Want to Learn to Do This?
3. System Diagram Concepts
4. Developing a Simple Air System Diagram
5. Expanding a Chilled Water System Diagram

Introductions



https://tinyurl.com/PECSystDgmD1Intro

A Bit About Me

- I intended to be an aircraft maintenance engineer

A Bit About Me

- I intended to be an aircraft maintenance engineer
  - I'm doing something *<u>totally</u>* different

A Bit About Me

I'm doing something *totally* different

- HVAC field technician

A Bit About Me

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- Control system designer

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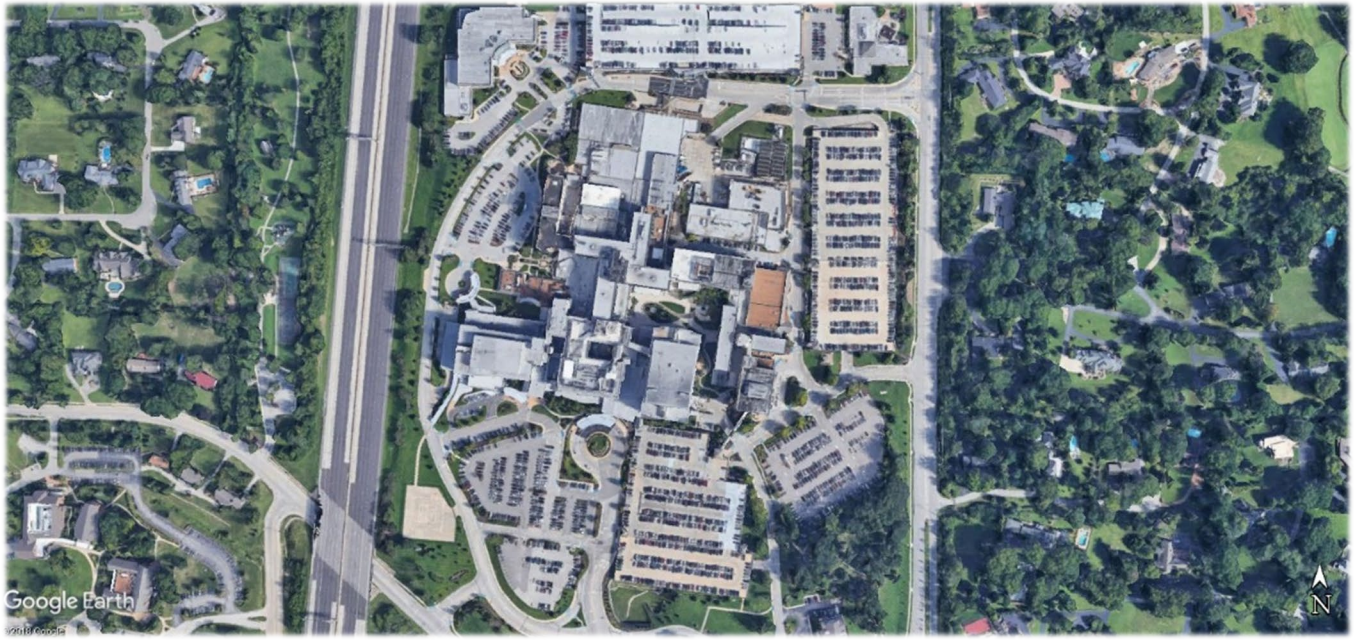
- Project engineer



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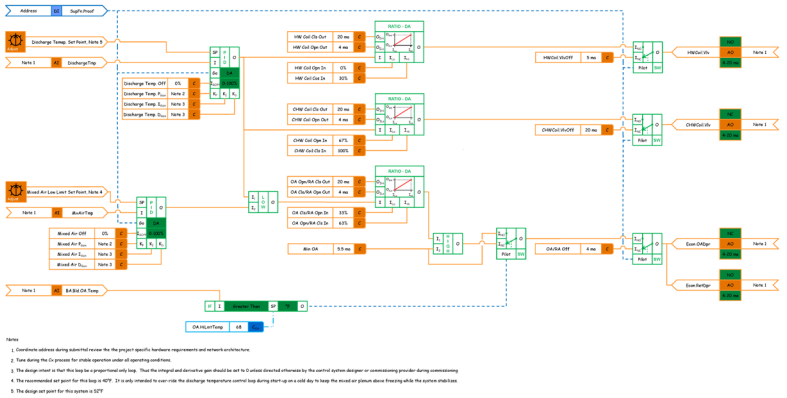
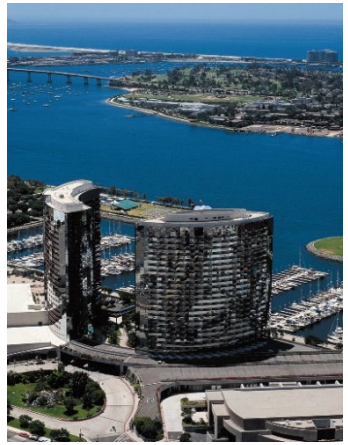
- FDE Senior Engineer



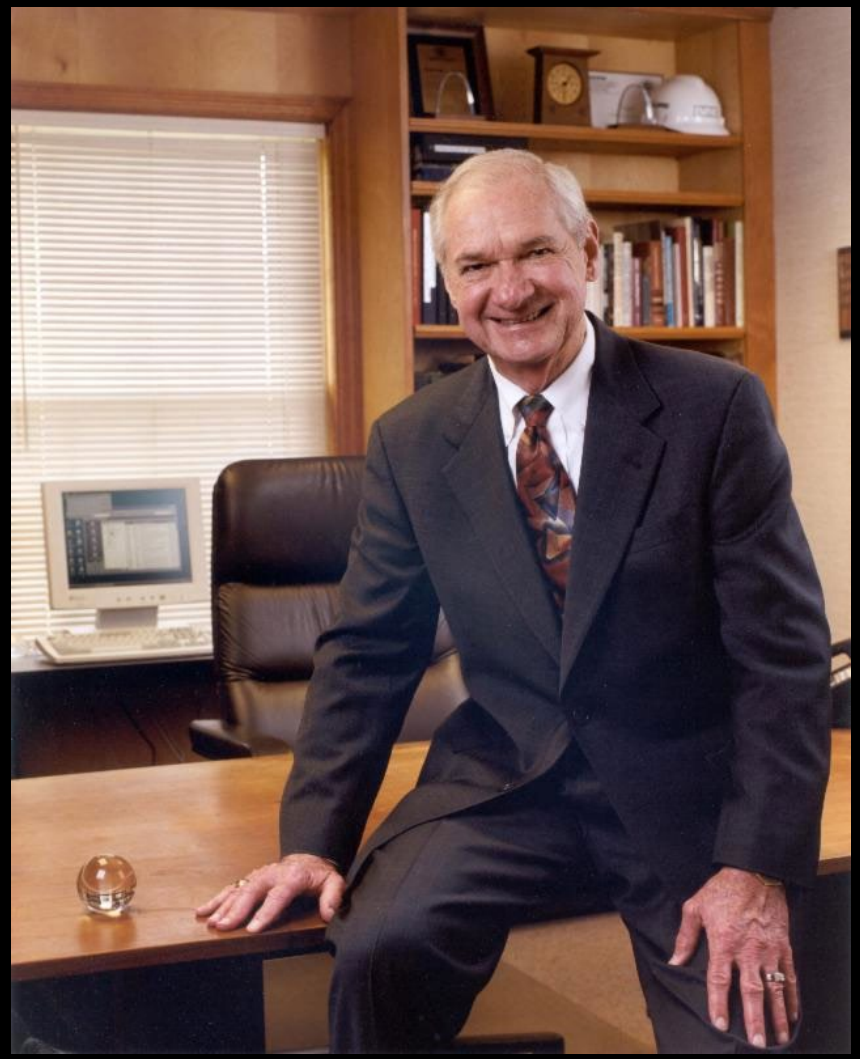


I’ve Had Great Mentors Along the Way

- "… that is to practice our profession with an emphasis upon our responsibility to protect the long-range interests of the society we serve and, specifically, to incorporate the ethics of energy conservation and environmental preservation in everything we do."

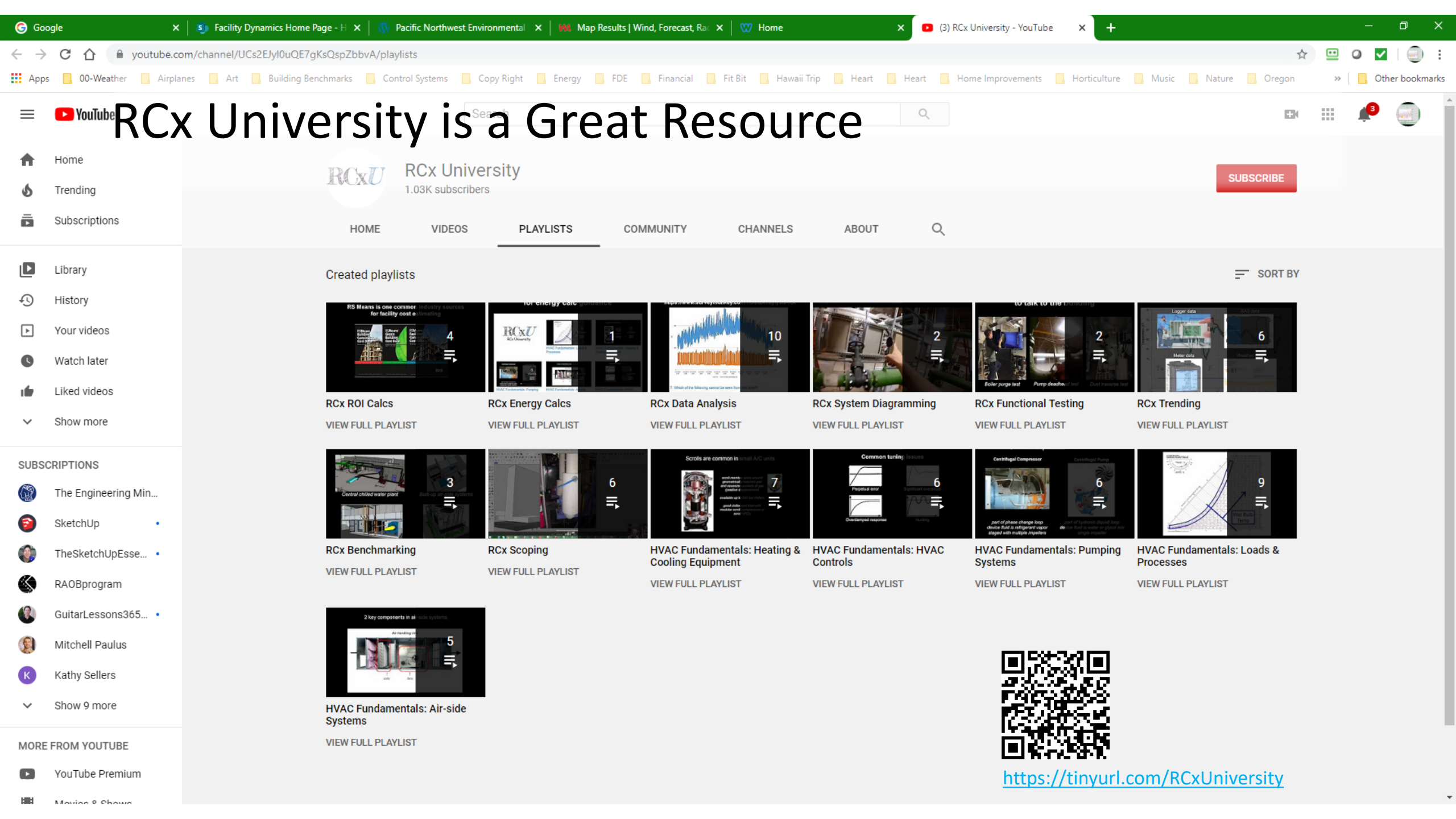
- Energy Conservation is an Ethic
- ASHRAE Journal, vol. 42, no. 7, p. 16-21

PDF available at
https://tinyurl.com/EnergyConservationEthic



A Few Resources

RCx University is a Great Resource



A Blog with a Field Perspective on Building Systems

https://av8rdas.wordpress.com/

A Field Perspective on Engineering

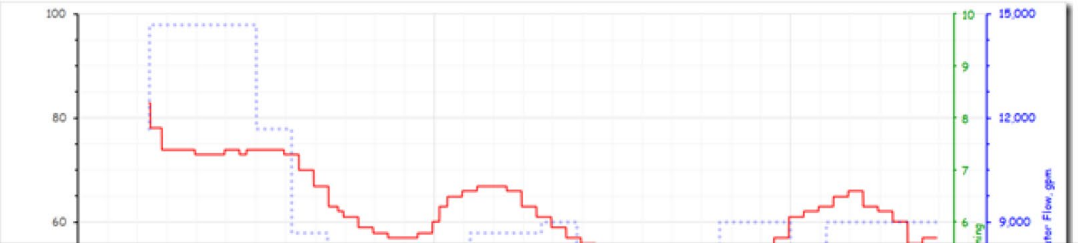
Engineering lessons from the field

Home About

Creating a Third Axis In Excel

Posted on April 19, 2019

One of the challenges that came up when I was creating the time series graph of a 9,000 ton chiller plant load profile that I show in my previous post was that I wanted to plot data series that had numbers in them with very large differences in the order of magnitude.



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What's New? | Search

Buildings are Talking to Us

We Just Need to Learn How to Listen

My Goal

Welcome to A Field Perspective on Engineering's commissioning resource website. For those who don't know me from my blog or some other venue, I am a senior engineer for a company named Facility Dynamics Engineering a.k.a FDE, which specializes in commissioning, control system design, and some forensic engineering work.

Facility Dynamics ENGINEERING

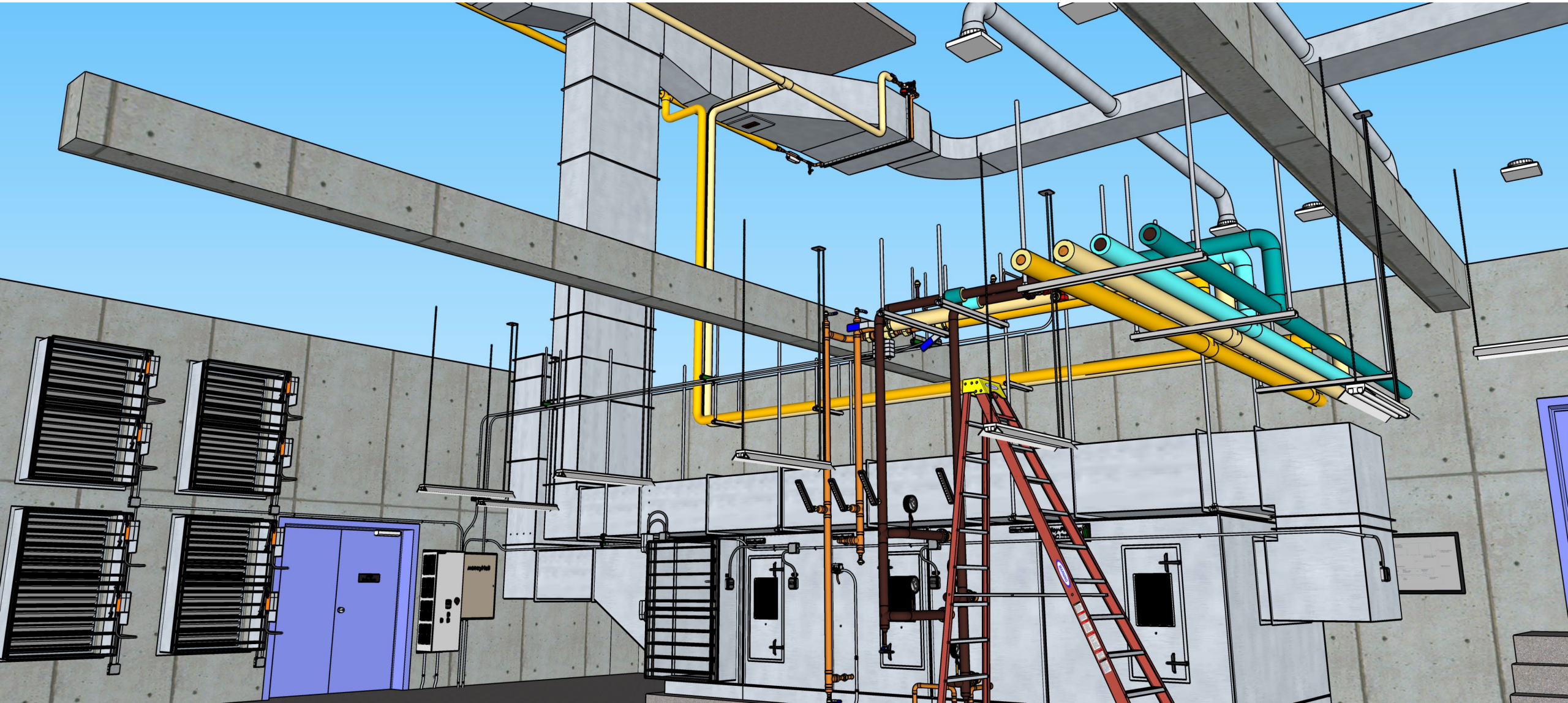
http://www.av8rdas.com/

The System Concept

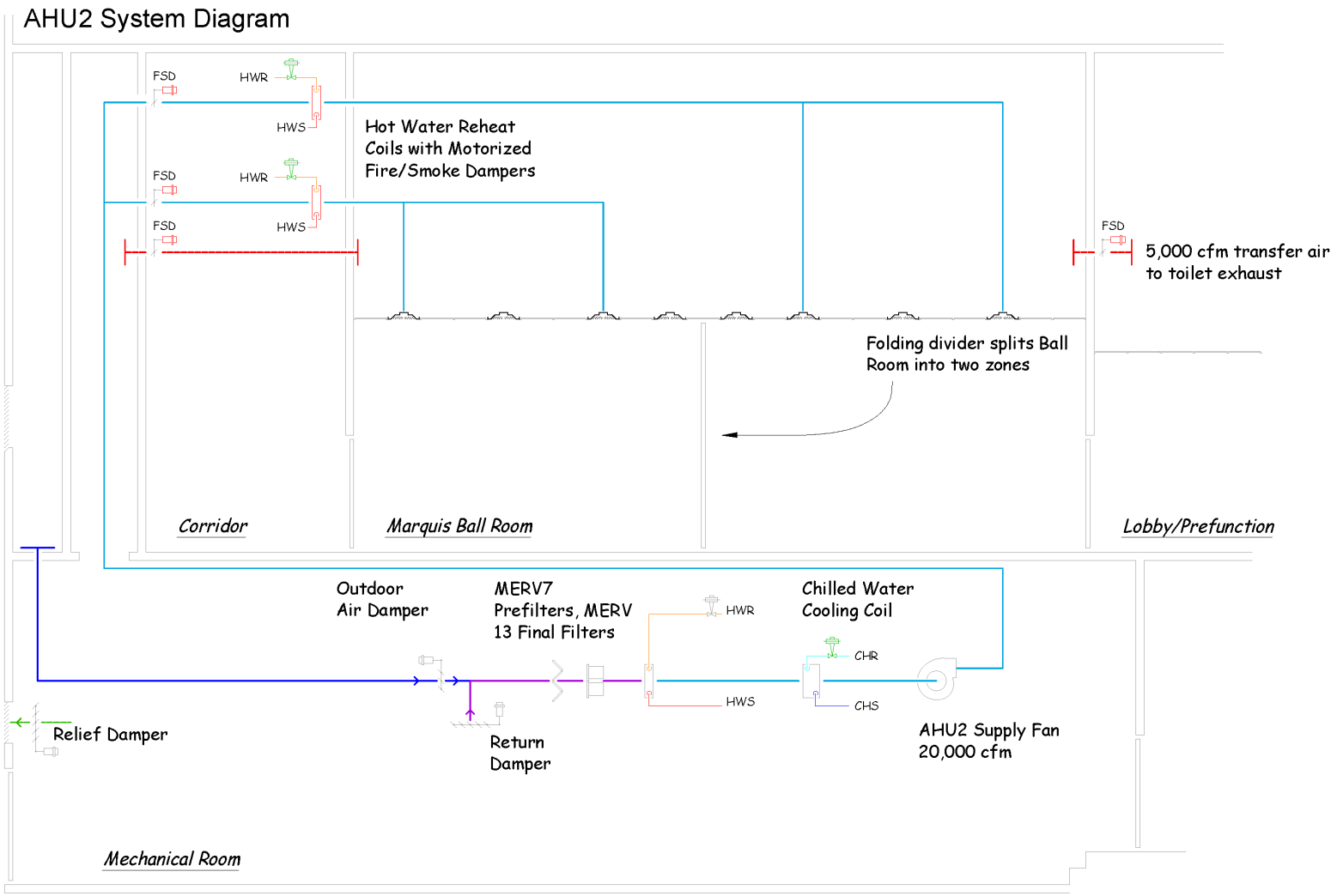
Not Just an Air Handling Unit

The System Concept

Not Just an Air Handling Unit; Rather It's an Air Handling System



The System Diagram; Visualizing the System Concept



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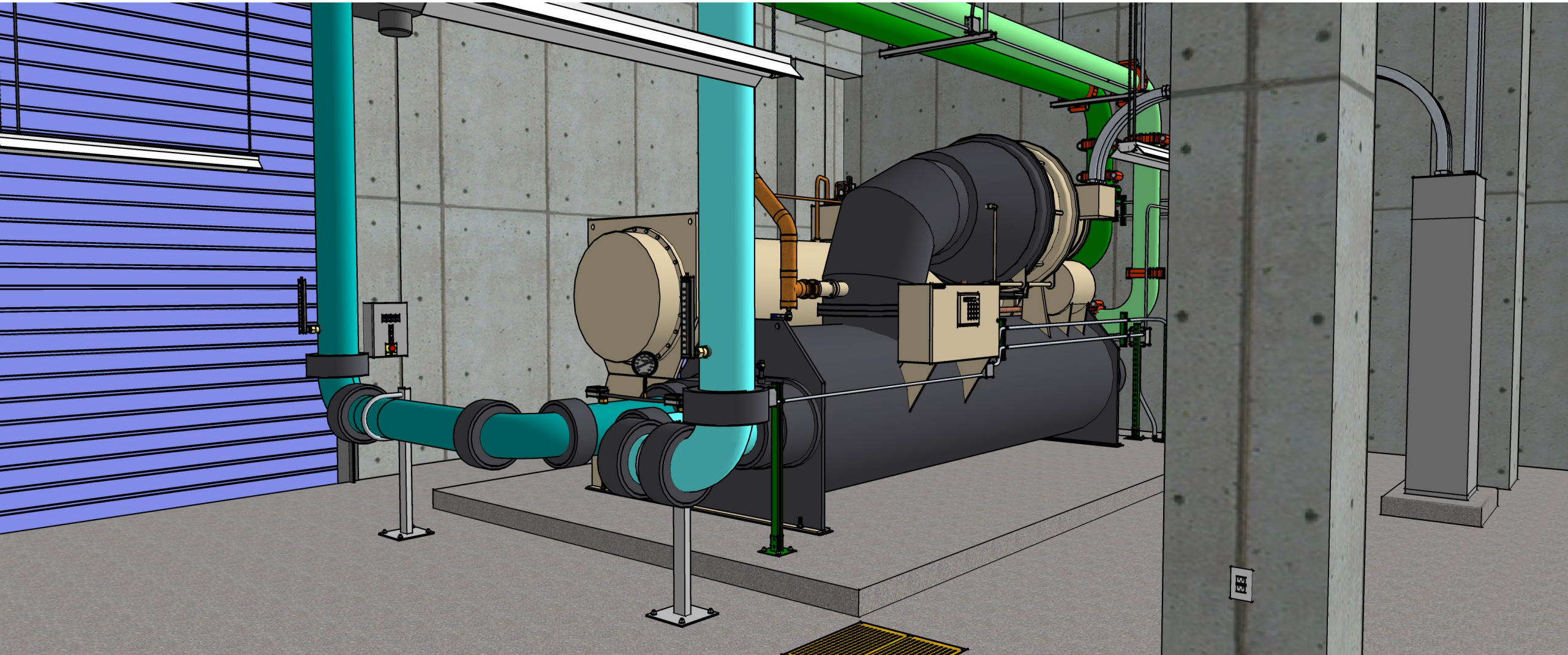
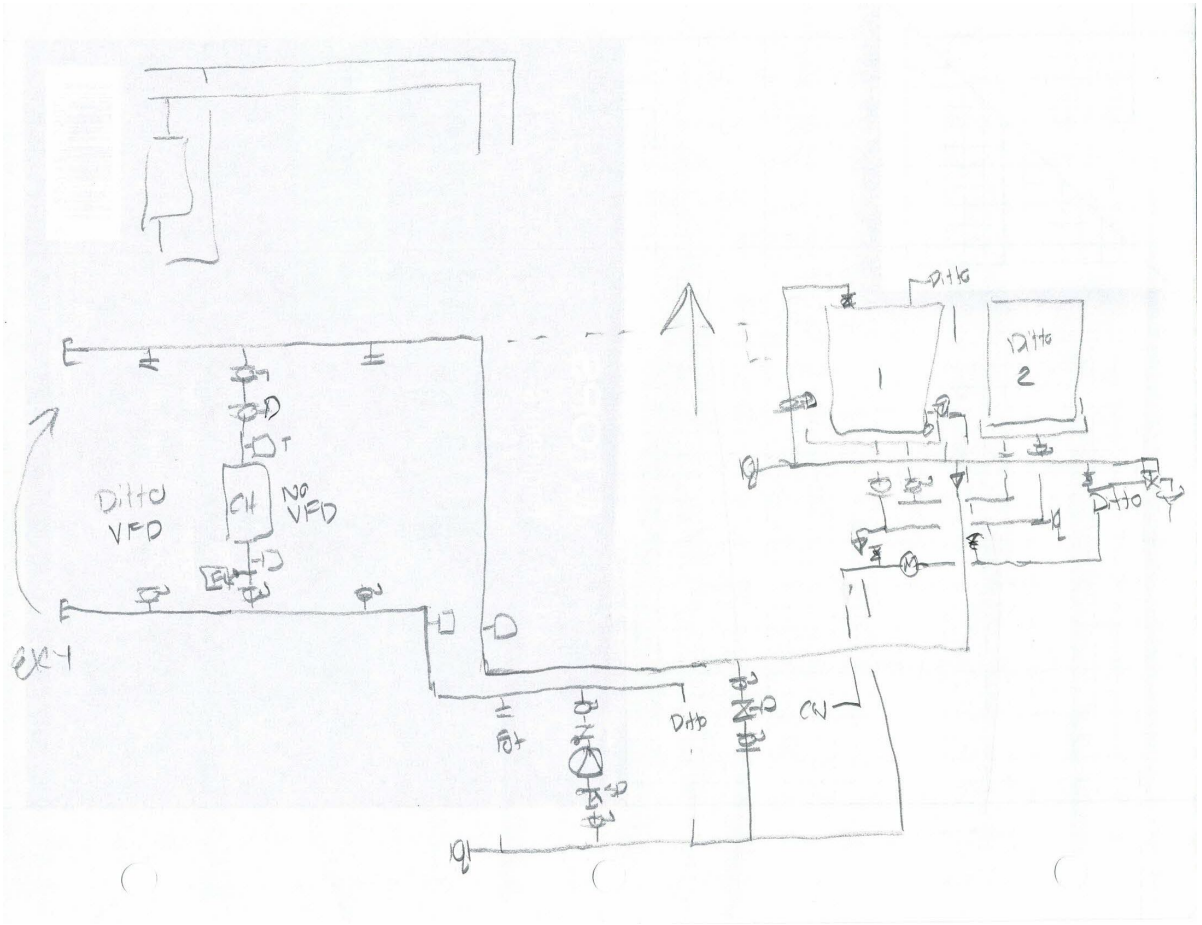


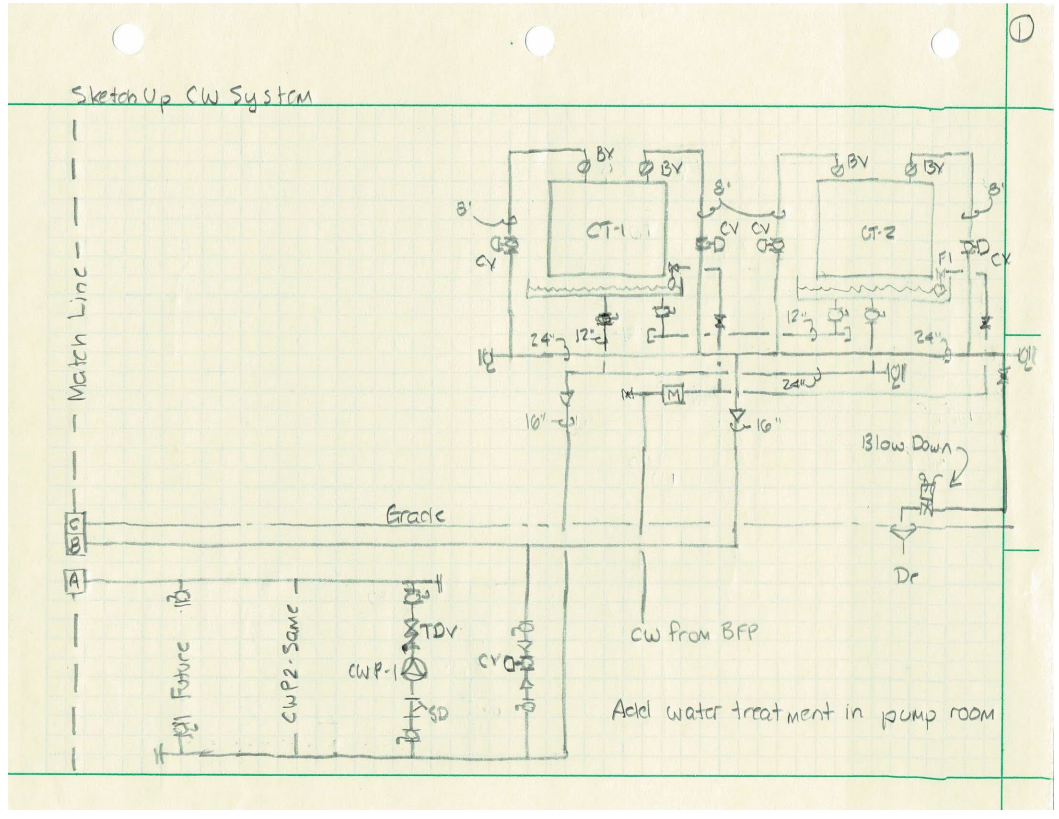
A Building Life Cycle Tool

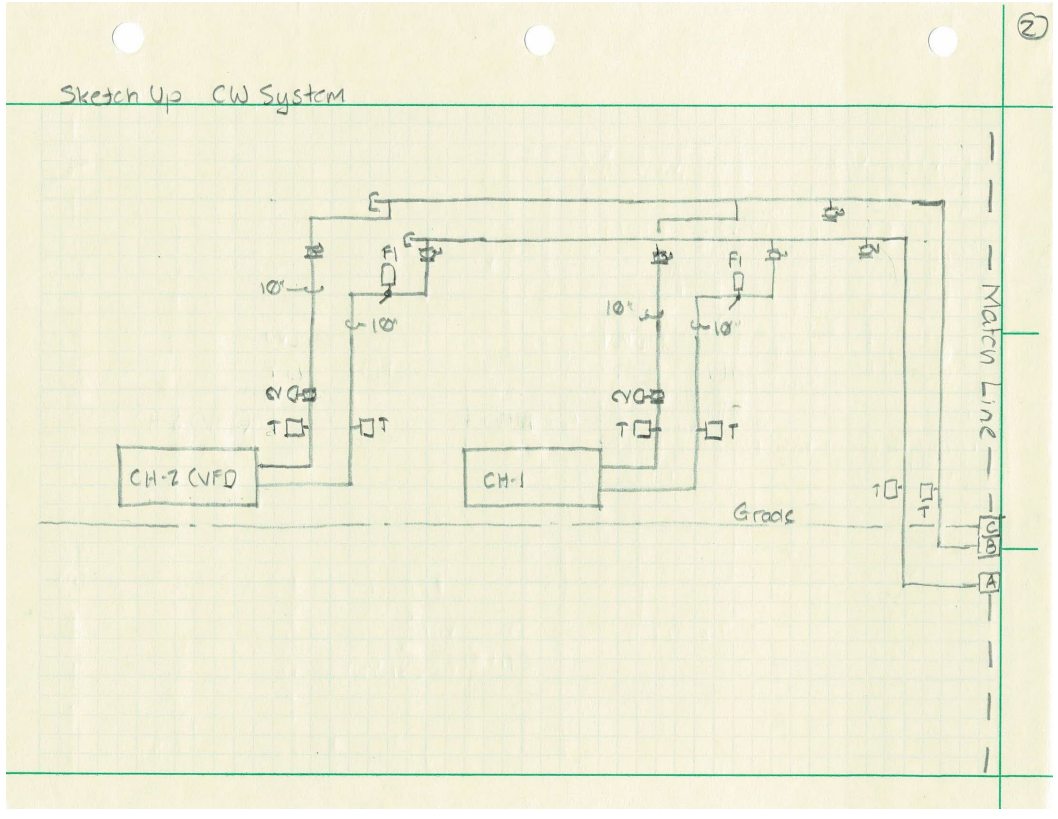
- A design tool for moving from concept



A Building Life Cycle Tool

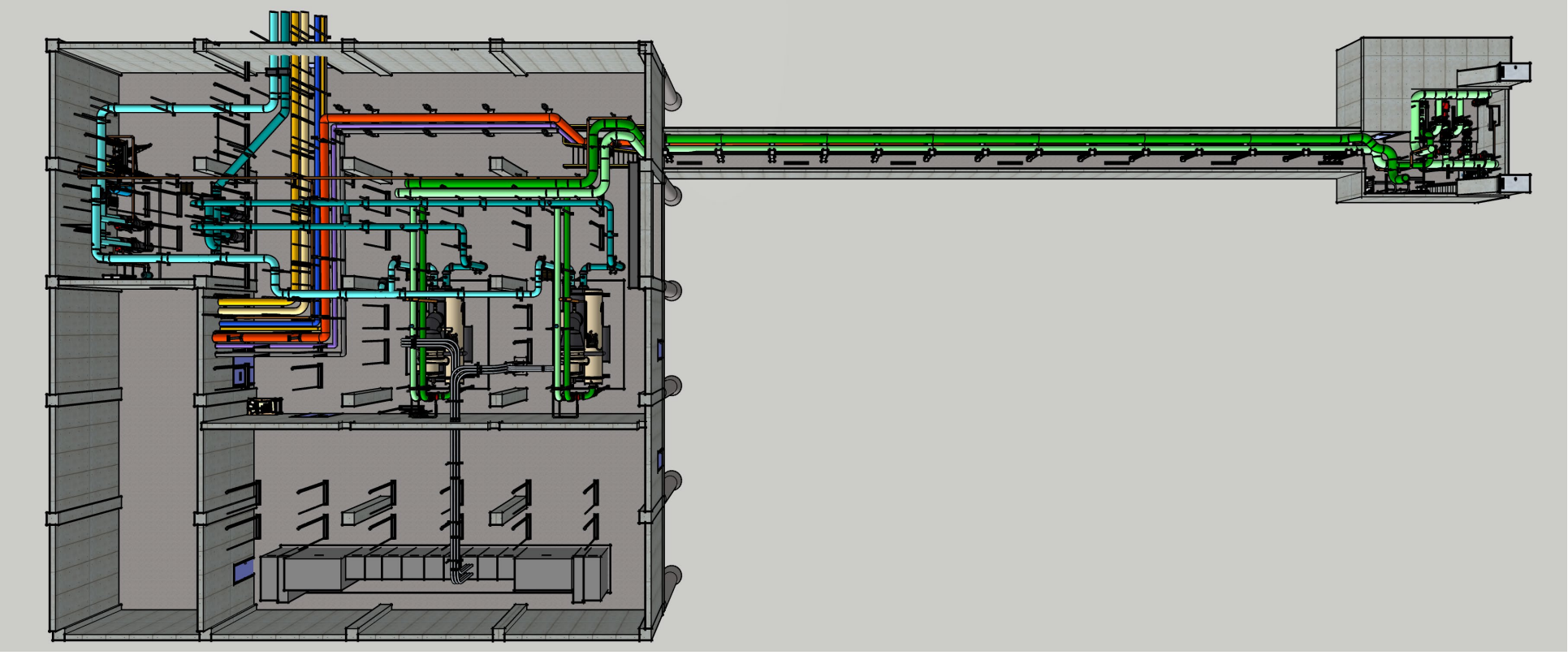
- A design tool for moving from concept through design development





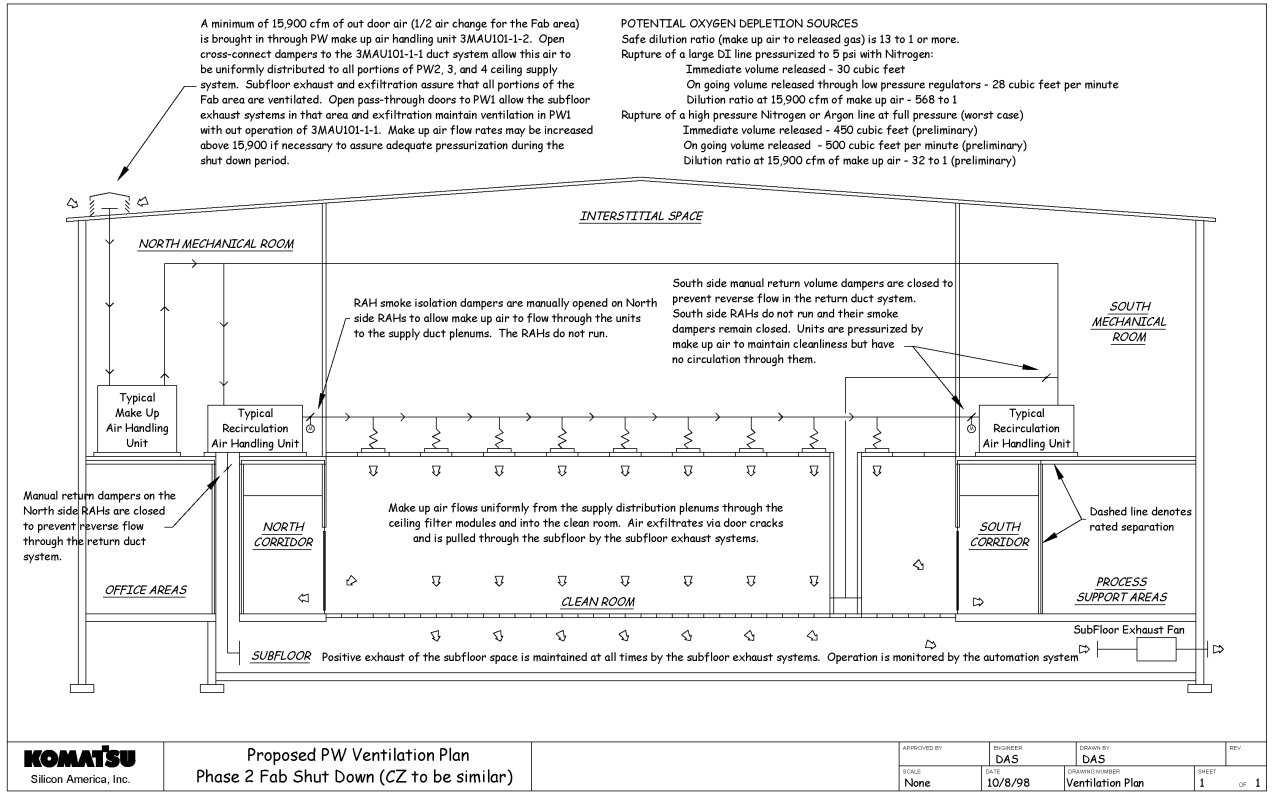
A Building Life Cycle Tool

- A design tool for moving from concept through design development to reality



A Building Life Cycle Tool

- A design tool for moving from concept through design development to reality
- A commissioning and diagnostic tool for identifying and resolving system issues
- As a training and ongoing commissioning tool



A minimum of 15,900 cfm of out door air (1/2 air change for the Fab area) is brought in through PW make up air handling unit 3MAU101-1-2. Open cross-connect dampers to the 3MAU101-1-1 duct system allow this air to be uniformly distributed to all portions of PW2, 3, and 4 ceiling supply system. Subfloor exhaust and exfiltration assure that all portions of the Fab area are ventilated. Open pass-through doors to PW1 allow the subfloor exhaust systems in that area and exfiltration maintain ventilation in PW1 with out operation of 3MAU101-1-1. Make up air flow rates may be increased above 15,900 if necessary to assure adequate pressurization during the shut down period.

POTENTIAL OXYGEN DEPLETION SOURCES

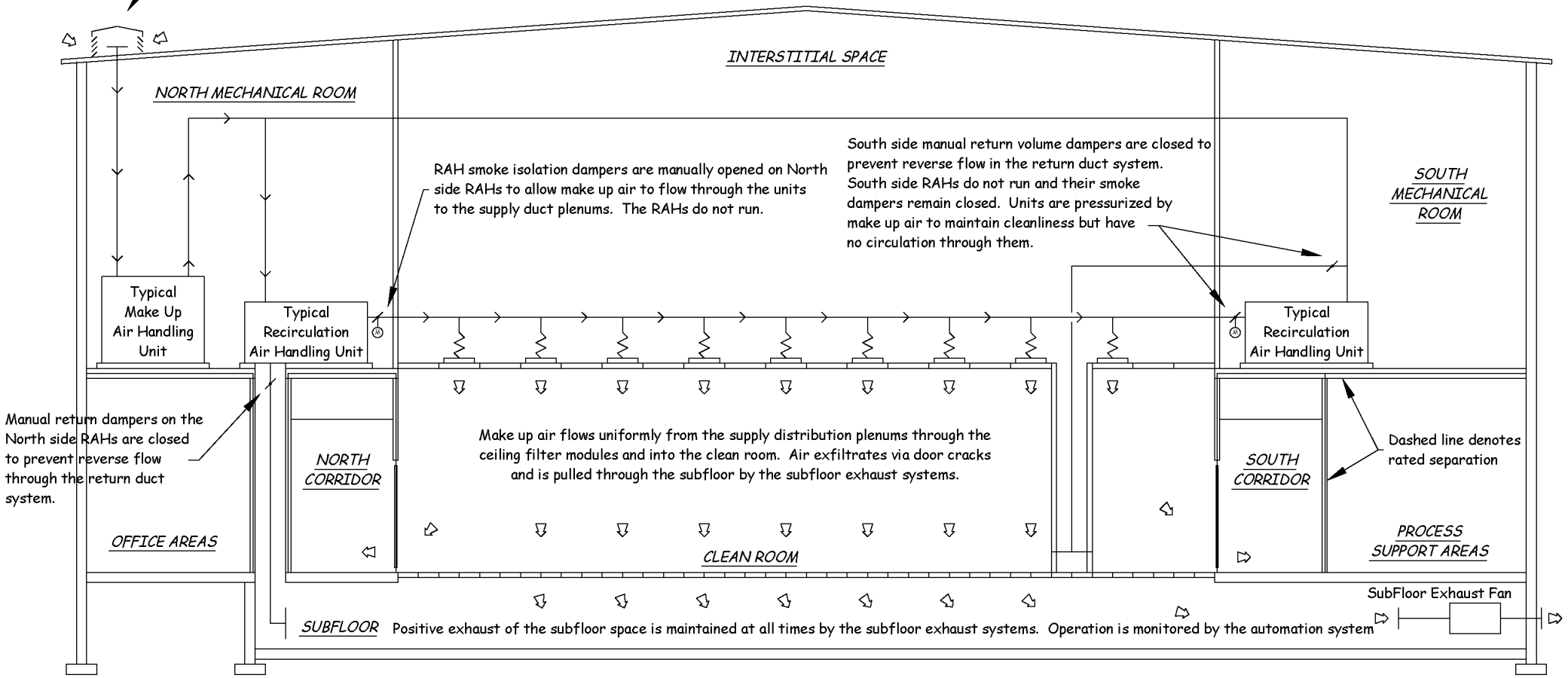
Safe dilution ratio (make up air to released gas) is 13 to 1 or more.

Rupture of a large DI line pressurized to 5 psi with Nitrogen:

- Immediate volume released - 30 cubic feet
- On going volume released through low pressure regulators - 28 cubic feet per minute
- Dilution ratio at 15,900 cfm of make up air - 568 to 1

Rupture of a high pressure Nitrogen or Argon line at full pressure (worst case)

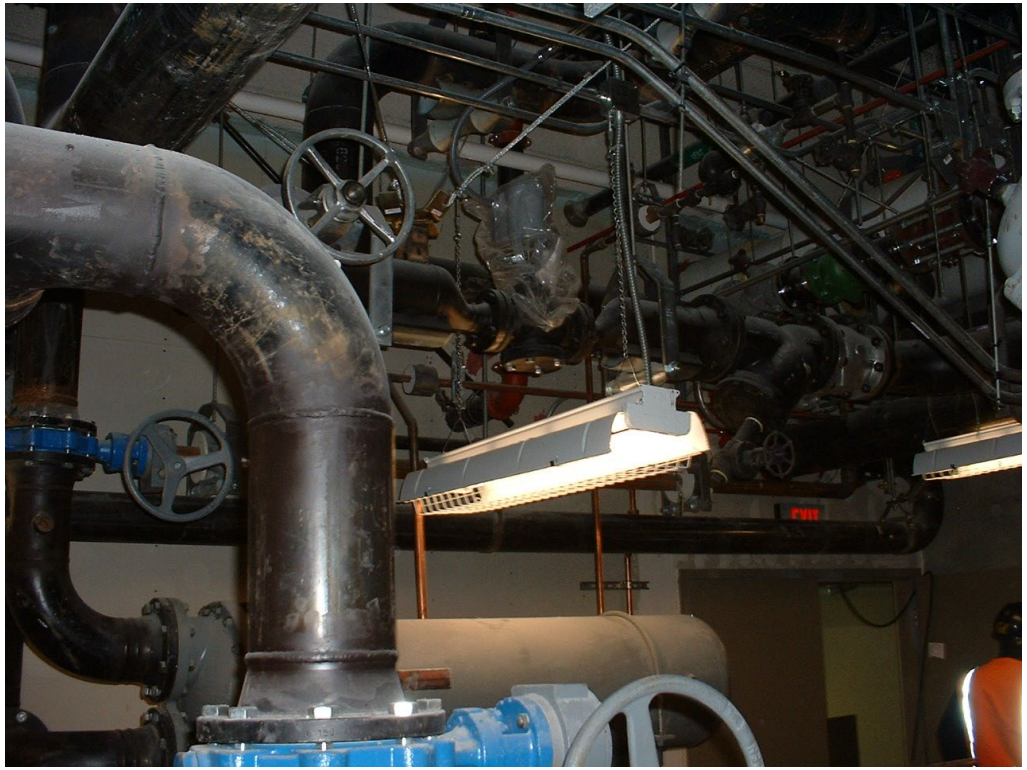
- Immediate volume released - 450 cubic feet (preliminary)
- On going volume released - 500 cubic feet per minute (preliminary)
- Dilution ratio at 15,900 cfm of make up air - 32 to 1 (preliminary)

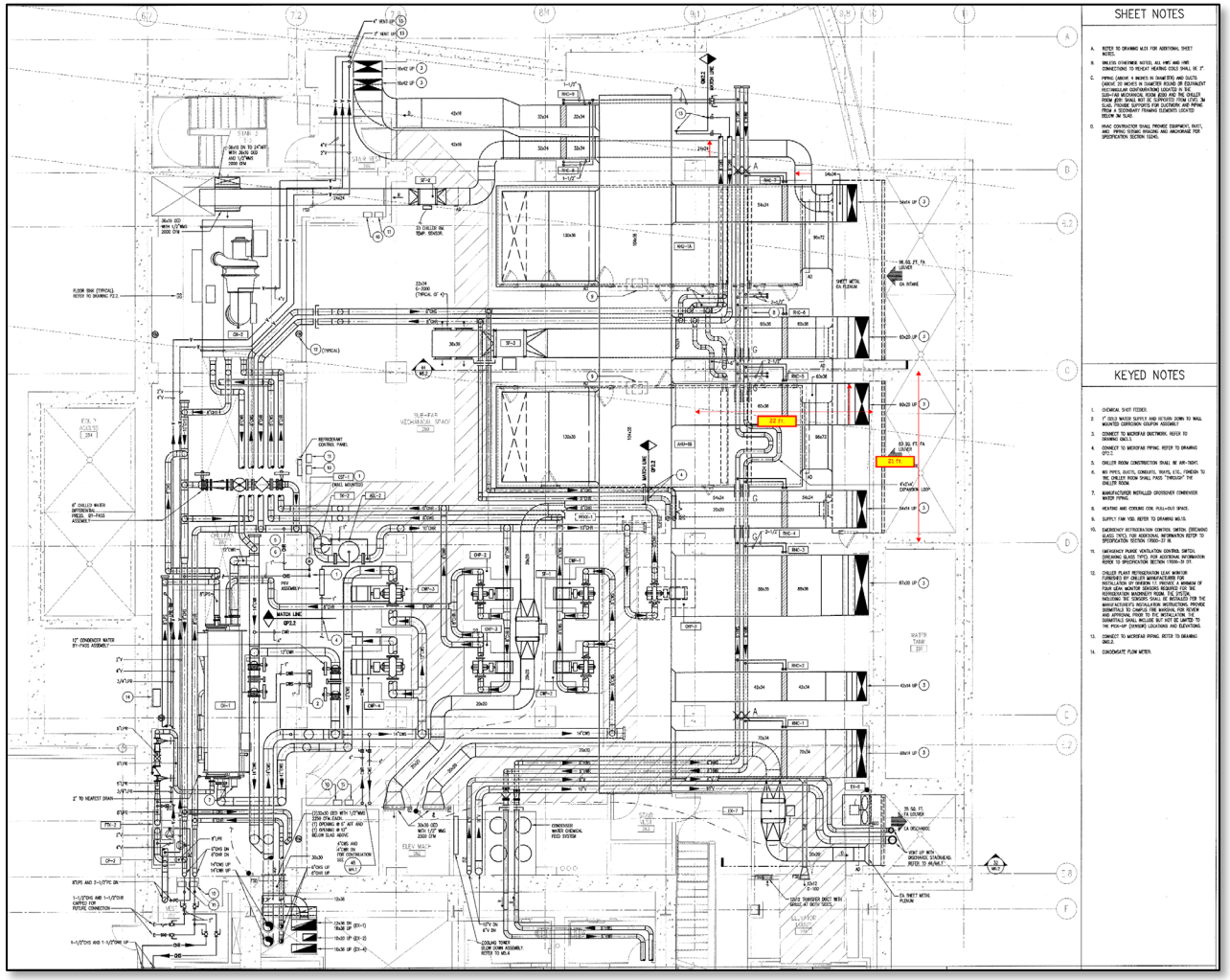


KOMATSU Silicon America, Inc.	Proposed PW Ventilation Plan Phase 2 Fab Shut Down (CZ to be similar)	APPROVED BY	ENGINEER DAS	DRAWN BY DAS		REV.
		SCALE None	DATE 10/8/98	DRAWING NUMBER Ventilation Plan	SHEET 1 OF 1	

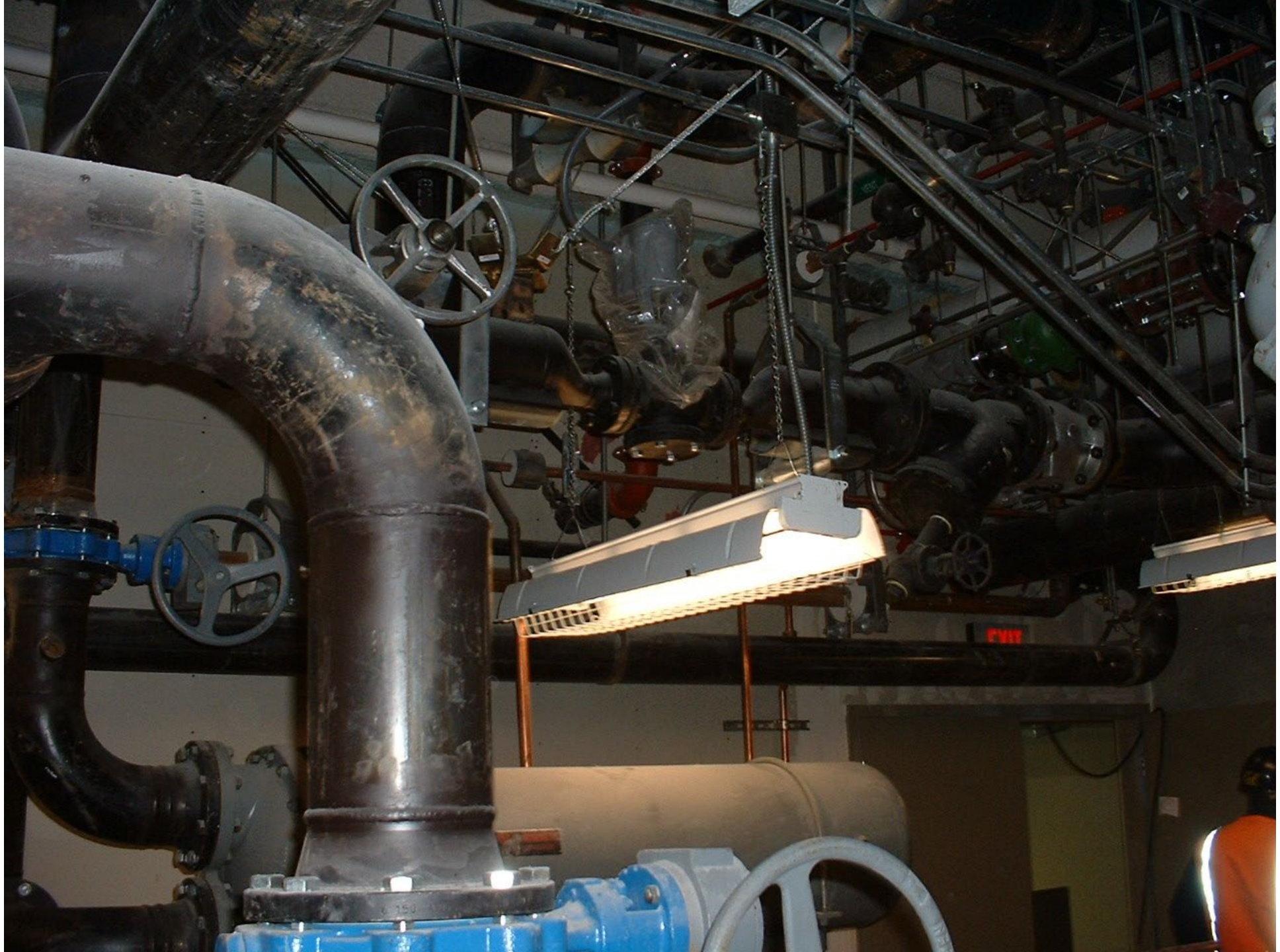
Developing a System Diagram

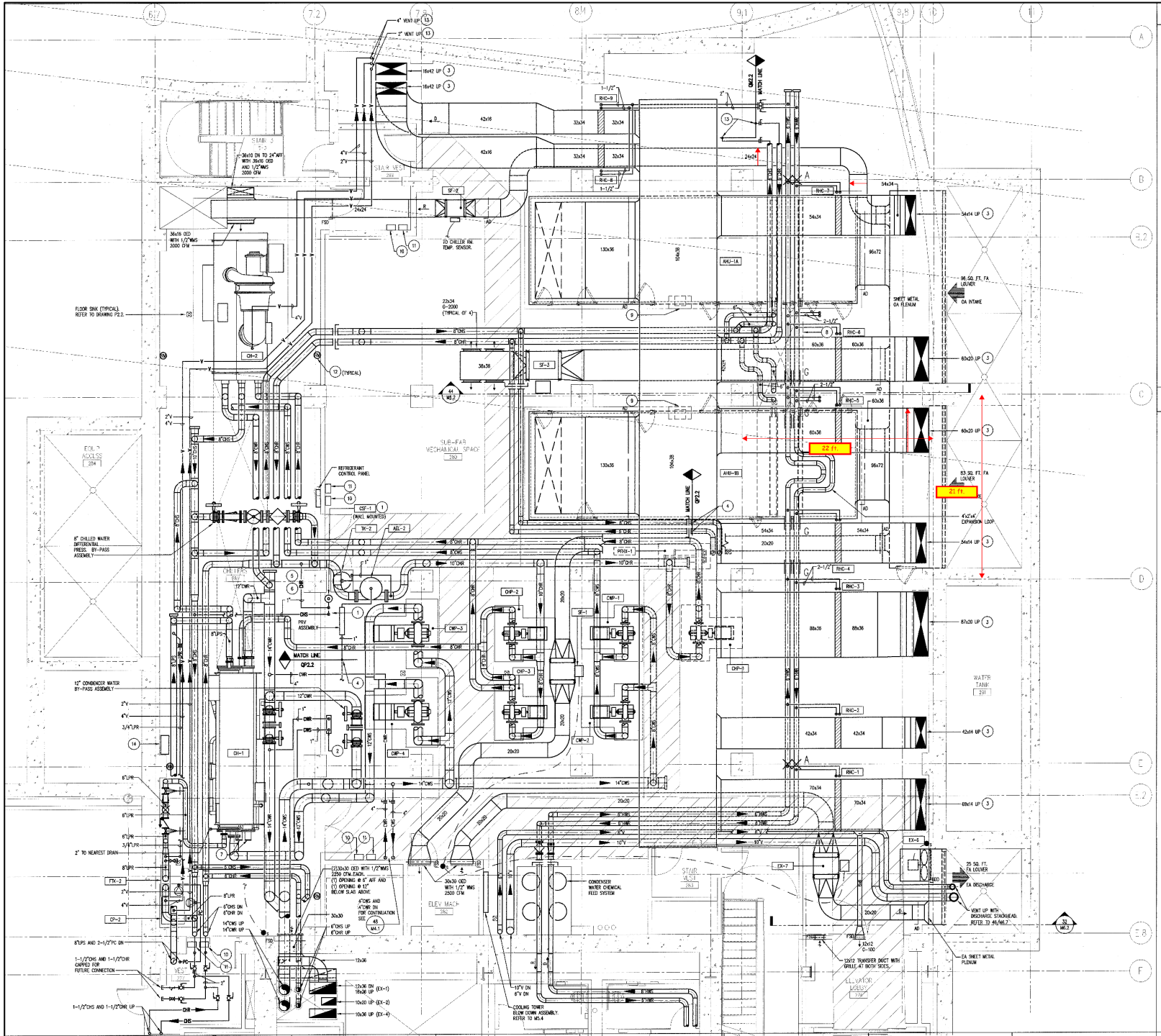
- A good way to learn the system prior to going on site





The Piping Plan


EXIT



SHEET NOTES

A. REFER TO DRAWING M.01 FOR ADDITIONAL SHEET NOTES.

B. UNLESS OTHERWISE NOTED, ALL HWS AND HWR CONNECTIONS TO REHEAT HEATING COILS SHALL BE 2".

C. PIPING (ABOVE 4 INCHES IN DIAMETER) AND DUCTS (ABOVE 20 INCHES IN DIAMETER ROUND OR EQUIVALENT RECTANGULAR CONFIGURATION) LOCATED IN THE SUB-FAB MECHANICAL ROOM @300 AND THE CHILLER ROOM @281 SHALL NOT BE SUPPORTED FROM LEVEL 3M SLAB. PROVIDE SUPPORTS FOR DUCTWORK AND PIPING FROM A SECONDARY FRAMING ELEMENTS LOCATED BELOW 3M SLAB.

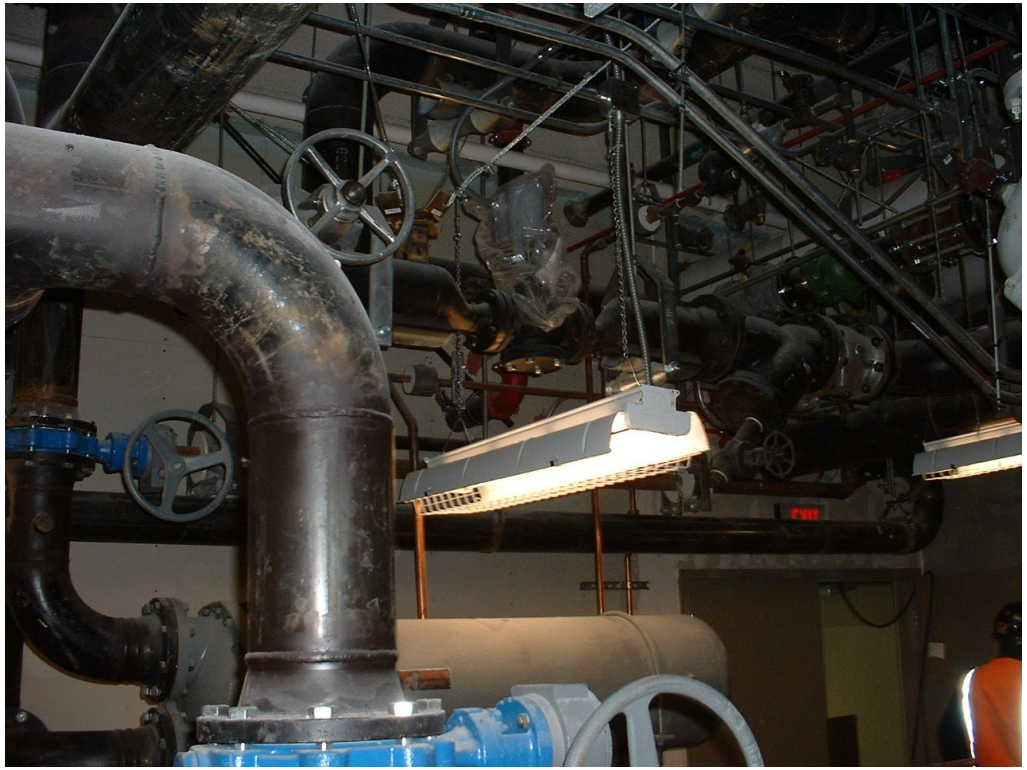
D. HVAC CONTRACTOR SHALL PROVIDE EQUIPMENT, DUCT, AND PIPING SEISMIC BRACING AND ANCHORAGE PER SPECIFICATION SECTION 15245.

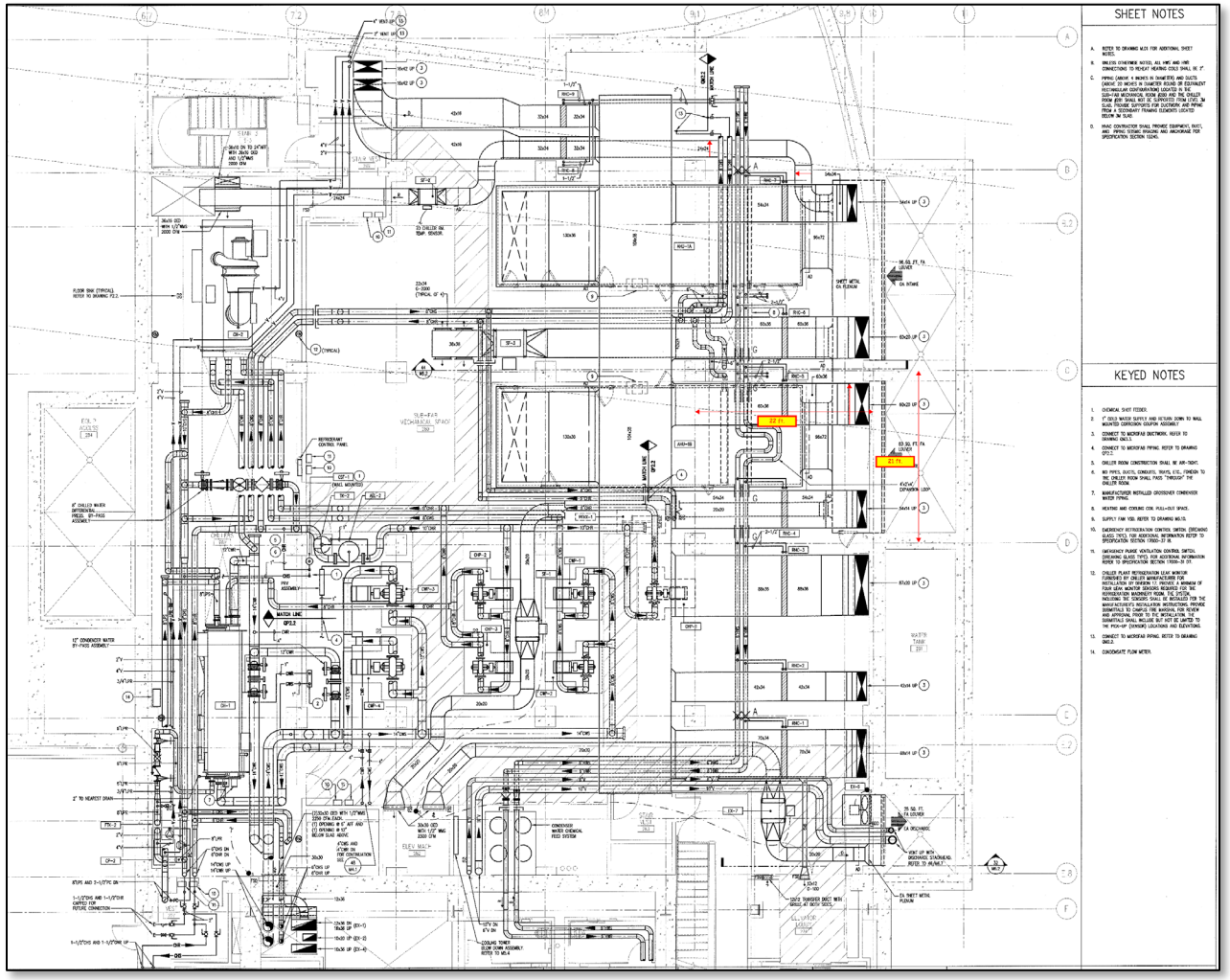
KEYED NOTES

1. CHEMICAL SHOT FEEDER.
2. 1" COLD WATER SUPPLY AND RETURN DOWN TO WALL MOUNTED CORROSION COUPON ASSEMBLY
3. CONNECT TO MICROFAB DUCTWORK. REFER TO DRAWING GM3.3.
4. CONNECT TO MICROFAB PIPING. REFER TO DRAWING GP2.2.
5. CHILLER ROOM CONSTRUCTION SHALL BE AIR-TIGHT.
6. NO PIPES, DUCTS, CONDUITS, TRAYS, ETC., FOREIGN TO THE CHILLER ROOM SHALL PASS "THROUGH" THE CHILLER ROOM.
7. MANUFACTURER INSTALLED CROSSOVER CONDENSER WATER PIPING.
8. HEATING AND COOLING COIL PULL-OUT SPACE.
9. SUPPLY FAN VSD. REFER TO DRAWING M5.10.
10. EMERGENCY REFRIGERATION CONTROL SWITCH. (BREAKING GLASS TYPE). FOR ADDITIONAL INFORMATION REFER TO SPECIFICATION SECTION 17000-37 18.
11. EMERGENCY PURGE VENTILATION CONTROL SWITCH. (BREAKING GLASS TYPE). FOR ADDITIONAL INFORMATION REFER TO SPECIFICATION SECTION 17000-31 07.
12. CHILLER PLANT REFRIGERATION LEAK MONITOR FURNISHED BY CHILLER MANUFACTURER FOR INSTALLATION BY DIVISION 17. PROVIDE A MINIMUM OF FOUR LEAK MONITOR SENSORS REQUIRED FOR THE REFRIGERATION MACHINERY ROOM. THE SYSTEM, INCLUDING THE SENSORS SHALL BE INSTALLED PER THE MANUFACTURER'S INSTALLATION INSTRUCTIONS. PROVIDE SUBMITTALS TO CAMPUS FIRE MARSHAL FOR REVIEW AND APPROVAL PRIOR TO THE INSTALLATION. THE SUBMITTALS SHALL INCLUDE BUT NOT BE LIMITED TO THE PICK-UP (SENSOR) LOCATIONS AND ELEVATIONS.
13. CONNECT TO MICROFAB PIPING. REFER TO DRAWING GM7.2.
14. CONDENSATE FLOW METER.

Developing a System Diagram

- A good way to learn the system prior to going on site





The Piping Plan

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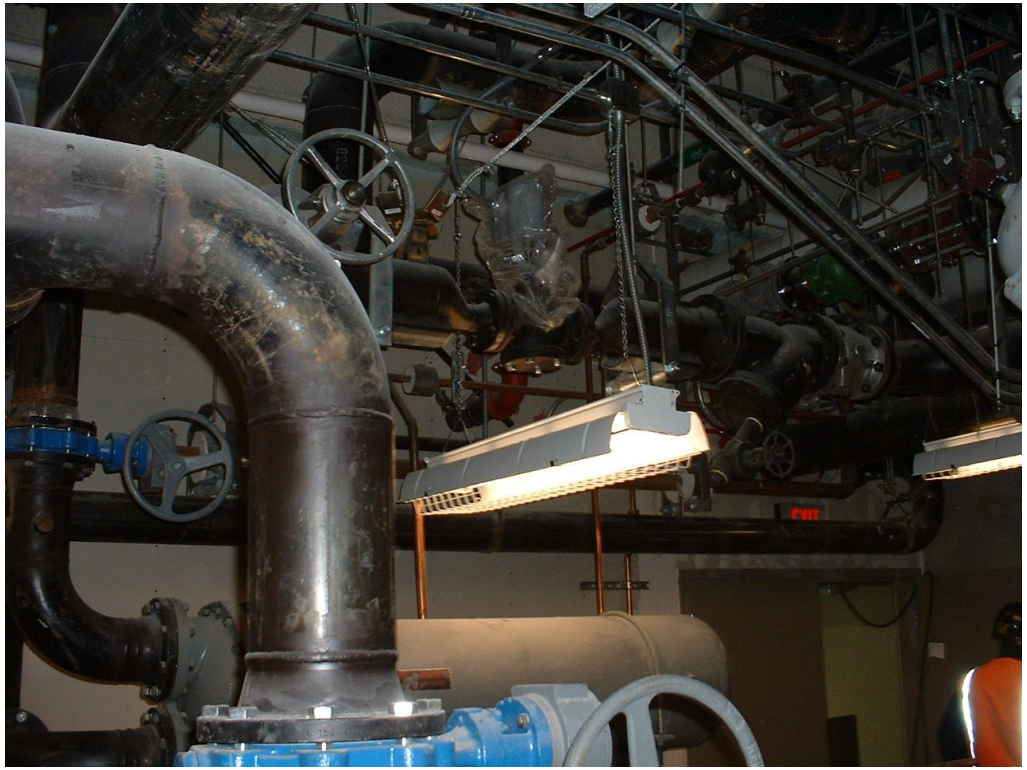
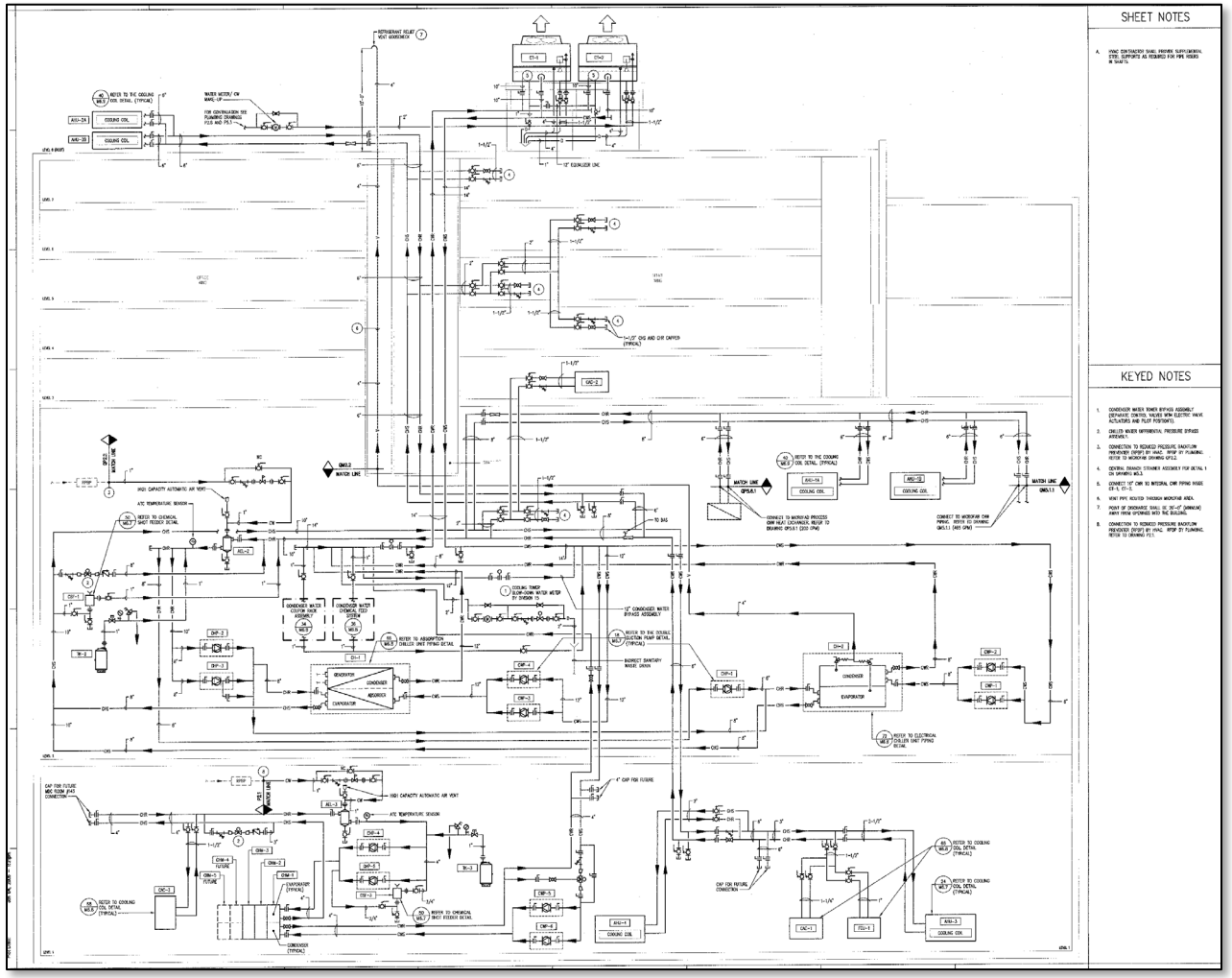
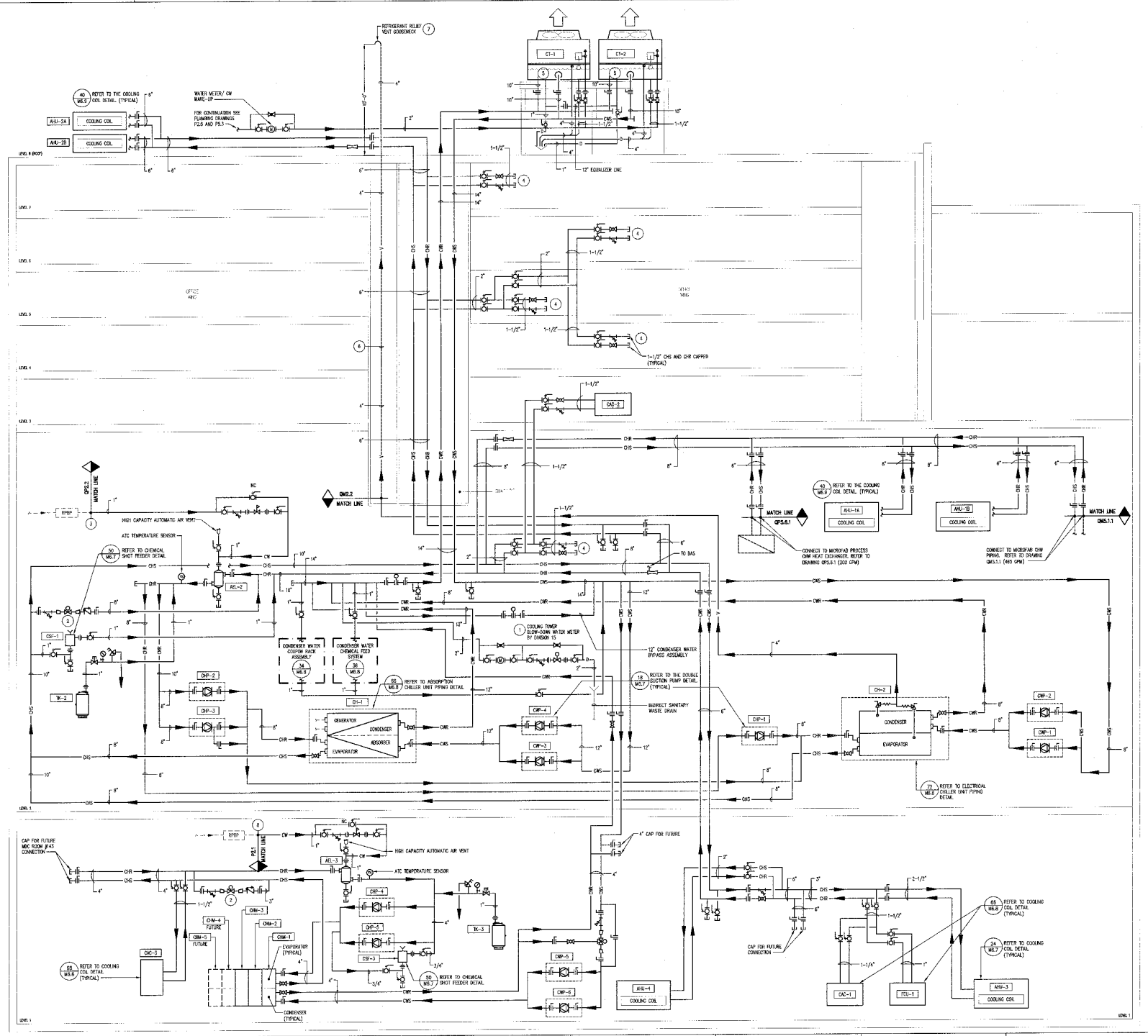




The “System Diagram” from the Drawing Set

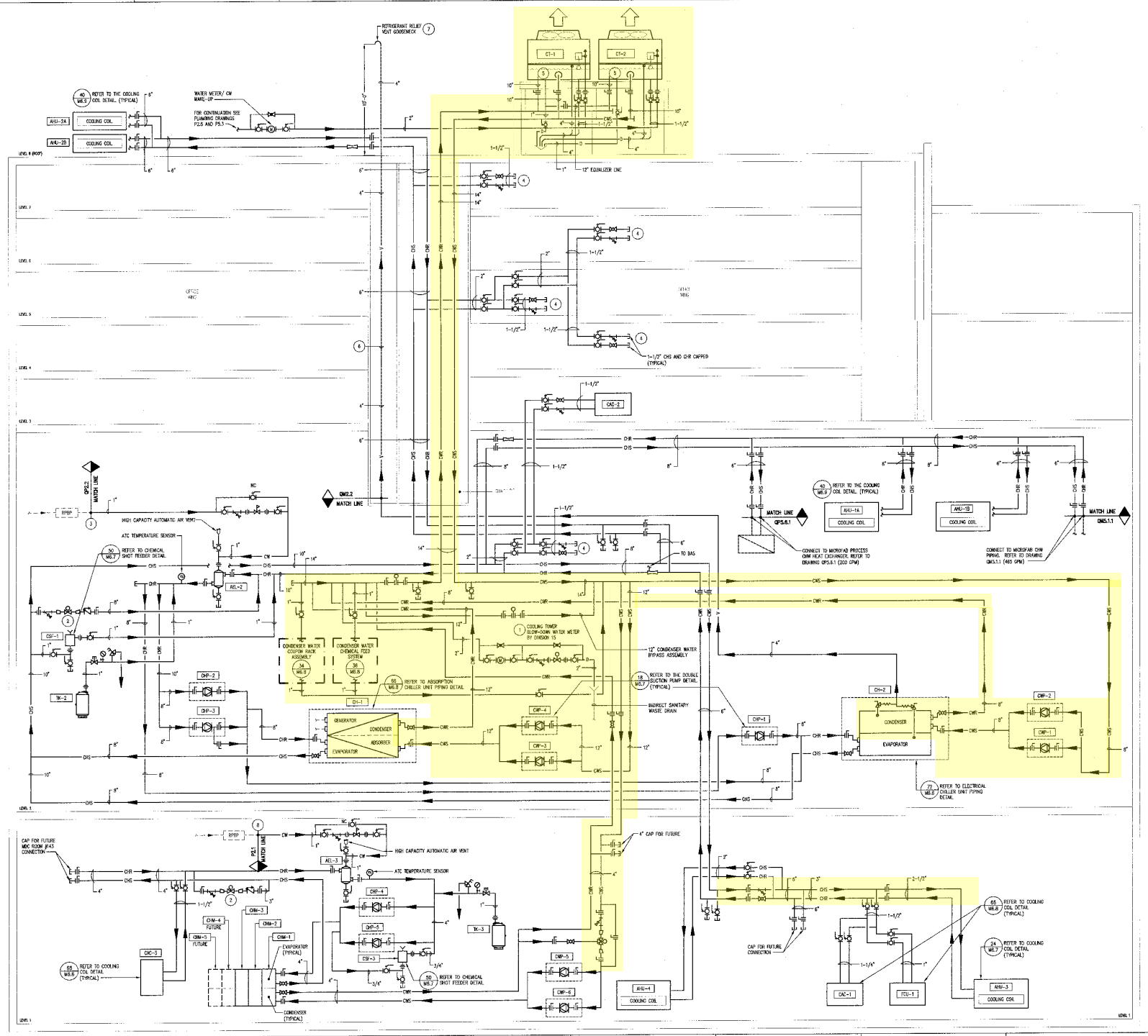


SHEET NOTES

A. HVAC CONTRACTOR SHALL PROVIDE SUPPLIMENTAL STEEL SUPPORTS AS REQUIRED FOR PIPE RISERS IN SHAFTS.

KEYED NOTES

1. CONDENSER WATER TOWER BYPASS ASSEMBLY (SEPARATE CONTROL VALVES WITH ELECTRIC VALVE ACTUATORS AND PILOT POSITIONS).
2. CHILLED WATER DIFFERENTIAL PRESSURE BYPASS ASSEMBLY.
3. CONNECTION TO REDUCED PRESSURE BACKFLOW PREVENTER (RPBP) BY HVAC. RPBP BY PLUMBING. REFER TO MICROFAB DRAWING GP2.2.
4. CENTRAL BRANCH STRAINER ASSEMBLY PER DETAIL 1 ON DRAWING M5.3.
5. CONNECT 10" CWR TO INTERNAL CWR PIPING INSIDE CT-1, CT-2.
6. VENT PIPE ROUTED THROUGH MICROFAB AREA.
7. POINT OF DISCHARGE SHALL BE 20'-0" (MINIMUM) AWAY FROM OPENINGS INTO THE BUILDING.
8. CONNECTION TO REDUCED PRESSURE BACKFLOW PREVENTER (RPBP) BY HVAC. RPBP BY PLUMBING. REFER TO DRAWING P2.1.



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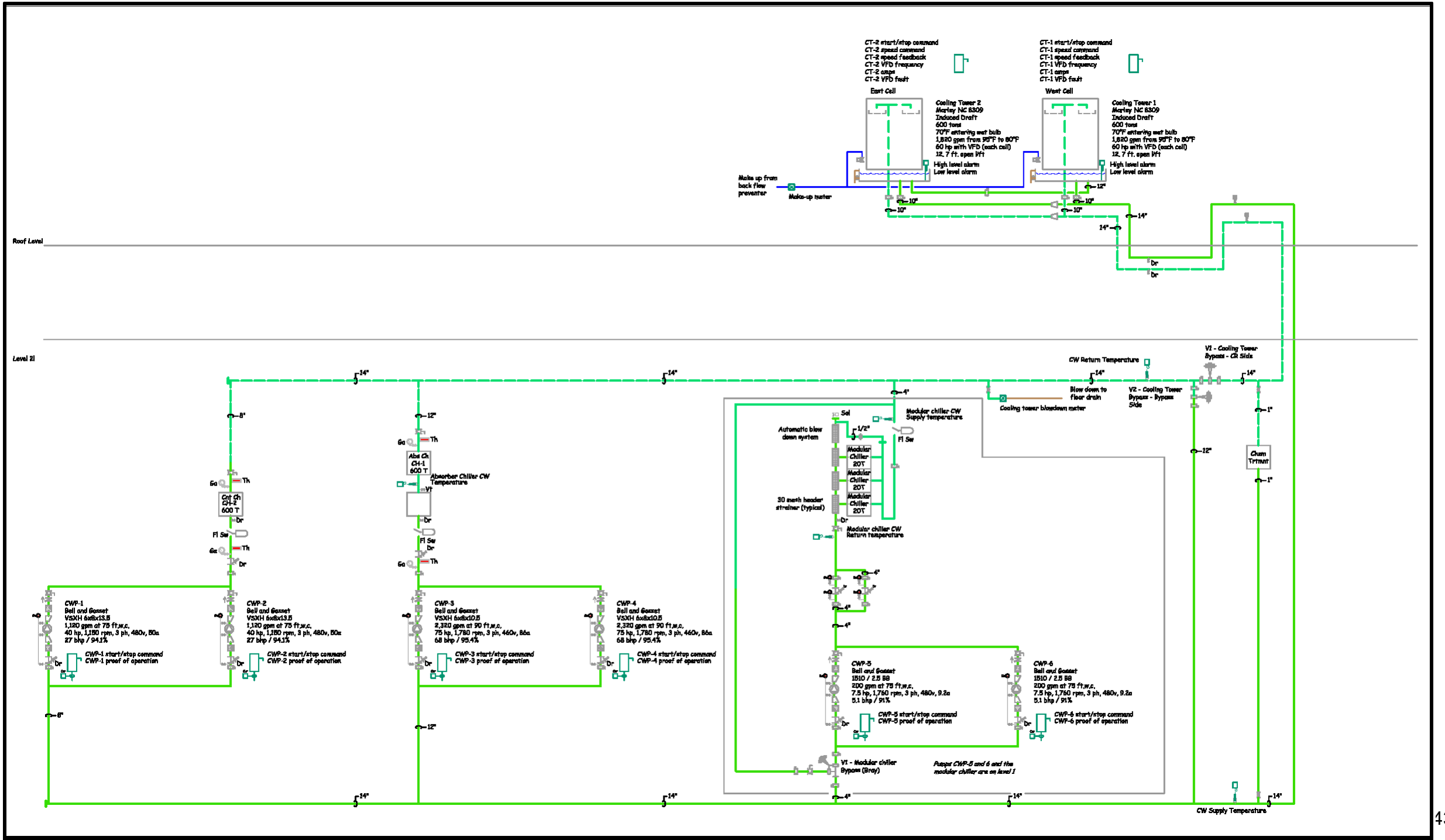
CT-2 start/stop command
CT-2 speed command
CT-2 speed feedback
CT-2 VFD frequency
CT-2 amps
CT-2 VFD fault
East Cell
Cooling Tower 2
Marley NC 8309
Induced Draft
600 tons
70°F entering wet bulb
1,820 gpm from 95°F to 80°F
60 hp with VFD (each cell)
12. 7 ft. open lift
High level alarm
Low level alarm
CT-1 start/stop command
CT-1 speed command
CT-1 speed feedback
CT-1 VFD frequency
CT-1 amps
CT-1 VFD fault
West Cell
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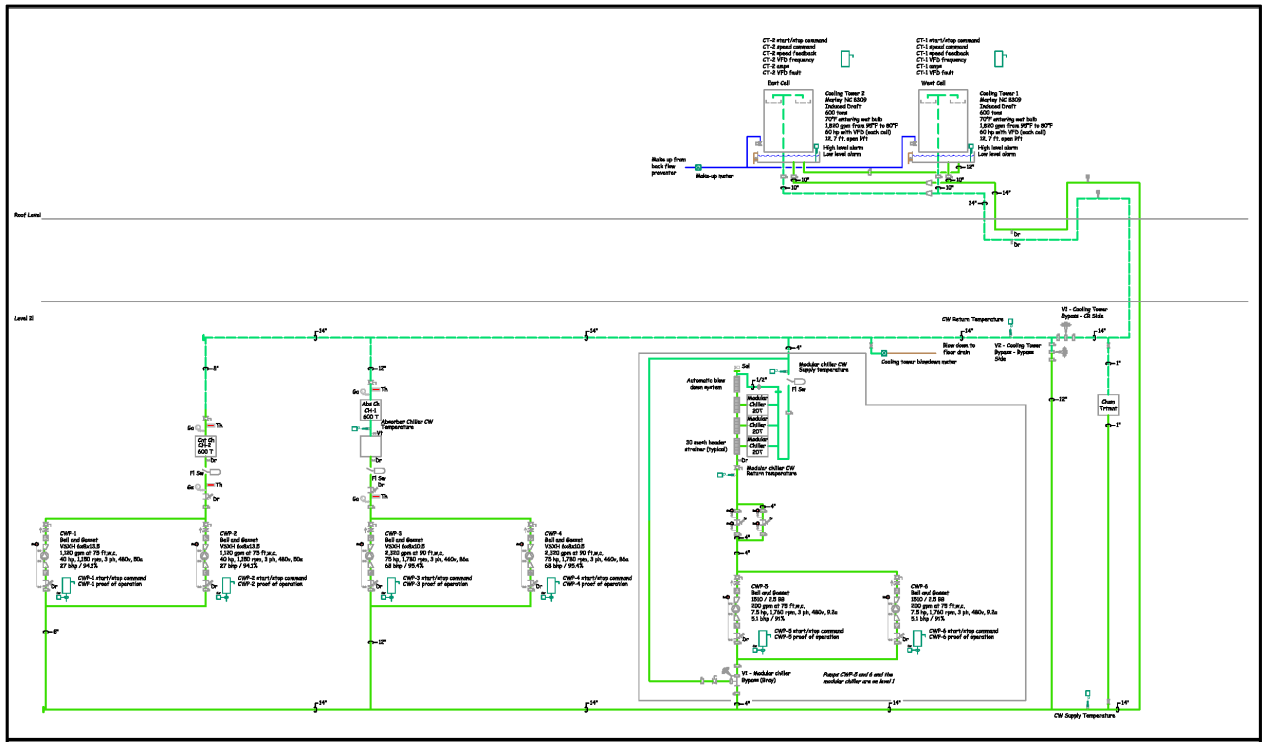
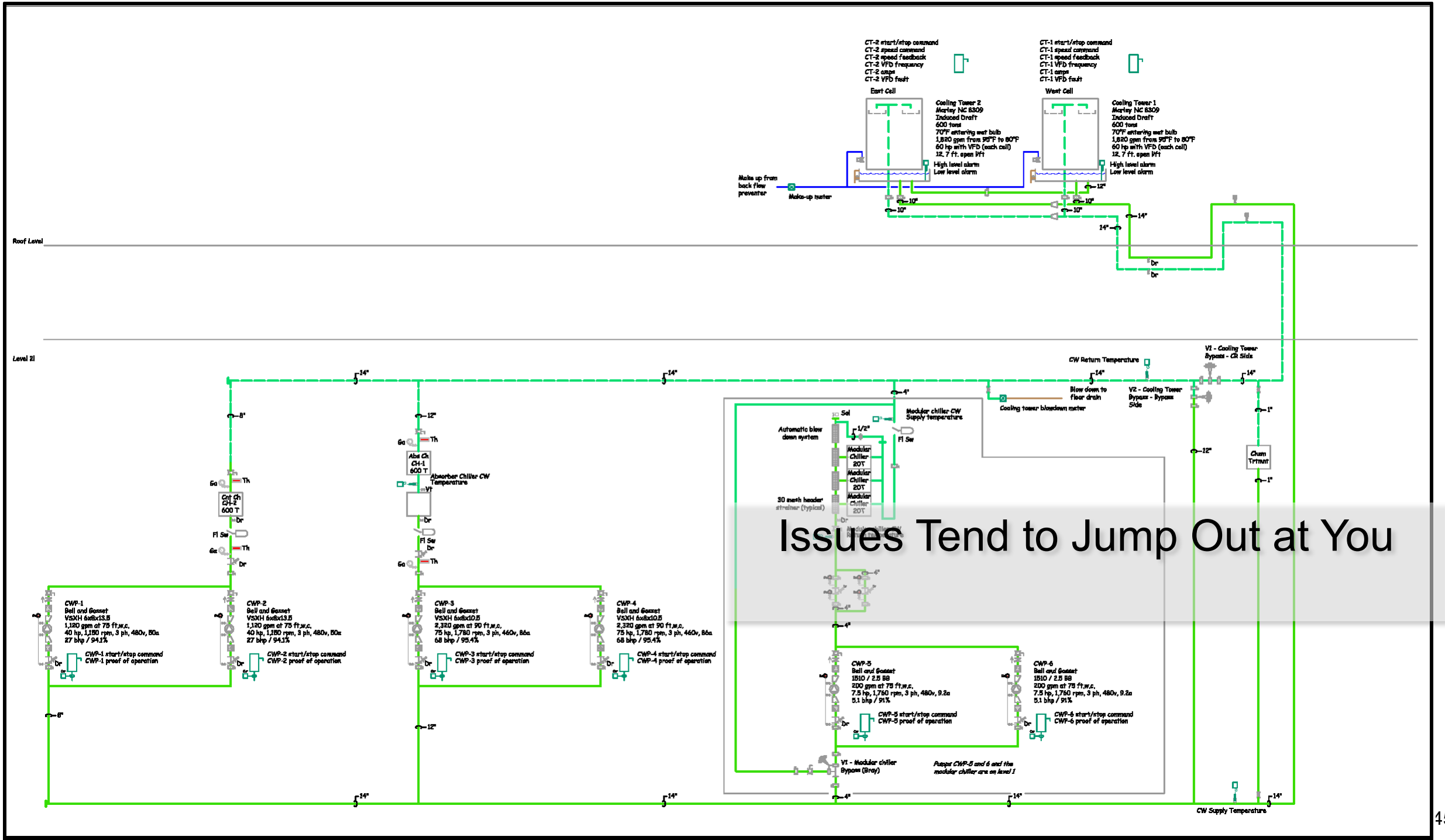
60 hp with VFD (each cell)
12. 7 ft. open lift
High level alarm
Low level alarm
Make up from back flow preventer
Make-up meter
Roof Level
Level 2l
CW Return Temperature
V1 - Cooling Tower Bypass - CR Side
Blow down to floor drain
V2 - Cooling Tower Bypass - Bypass Side
Cooling tower blowdown meter
Chem Trtmnt
Sol
Automatic blow down system
Modular chiller CW Supply temperature
Fl Sw
Modular Chiller 20T
Modular Chiller 20T
Modular Chiller 20T
30 mesh header strainer (typical)
Modular chiller CW Return temperature
Abs Ch CH-1 600 T
Absorber Chiller CW Temperature
Ch CH-2 600 T
CWP-1
Bell and Gasket
VSXH 6x8x13.5
1,120 gpm at 75 ft.w.c.
40 hp, 1,150 rpm, 3 ph, 480v, 50a
27 bhp / 94.1%
CWP-1 start/stop command
CWP-1 proof of operation
CWP-2
Bell and Gasket
VSXH 6x8x13.5
1,120 gpm at 75 ft.w.c.
40 hp, 1,150 rpm, 3 ph, 480v, 50a
27 bhp / 94.1%
CWP-2 start/stop command
CWP-2 proof of operation
CWP-3
Bell and Gasket
VSXH 6x8x10.5
2,320 gpm at 90 ft.w.c.
75 hp, 1,780 rpm, 3 ph, 460v, 86a
68 bhp / 95.4%
CWP-3 start/stop command
CWP-3 proof of operation
CWP-4
Bell and Gasket
VSXH 6x8x10.5
2,320 gpm at 90 ft.w.c.
75 hp, 1,780 rpm, 3 ph, 460v, 86a
68 bhp / 95.4%
CWP-4 start/stop command
CWP-4 proof of operation
CWP-5
Bell and Gasket
1510 / 2.5 BB
200 gpm at 75 ft.w.c.
7.5 hp, 1,750 rpm, 3 ph, 480v, 9.2a
5.1 bhp / 91%
CWP-5 start/stop command
CWP-5 proof of operation
CWP-6
Bell and Gasket
1510 / 2.5 BB
200 gpm at 75 ft.w.c.
7.5 hp, 1,750 rpm, 3 ph, 480v, 9.2a
5.1 bhp / 91%
CWP-6 start/stop command
CWP-6 proof of operation
V1 - Modular chiller Bypass (Bray)
Pumps CWP-5 and 6 and the modular chiller are on level 1
CW Supply Temperature

Developing a System Diagram

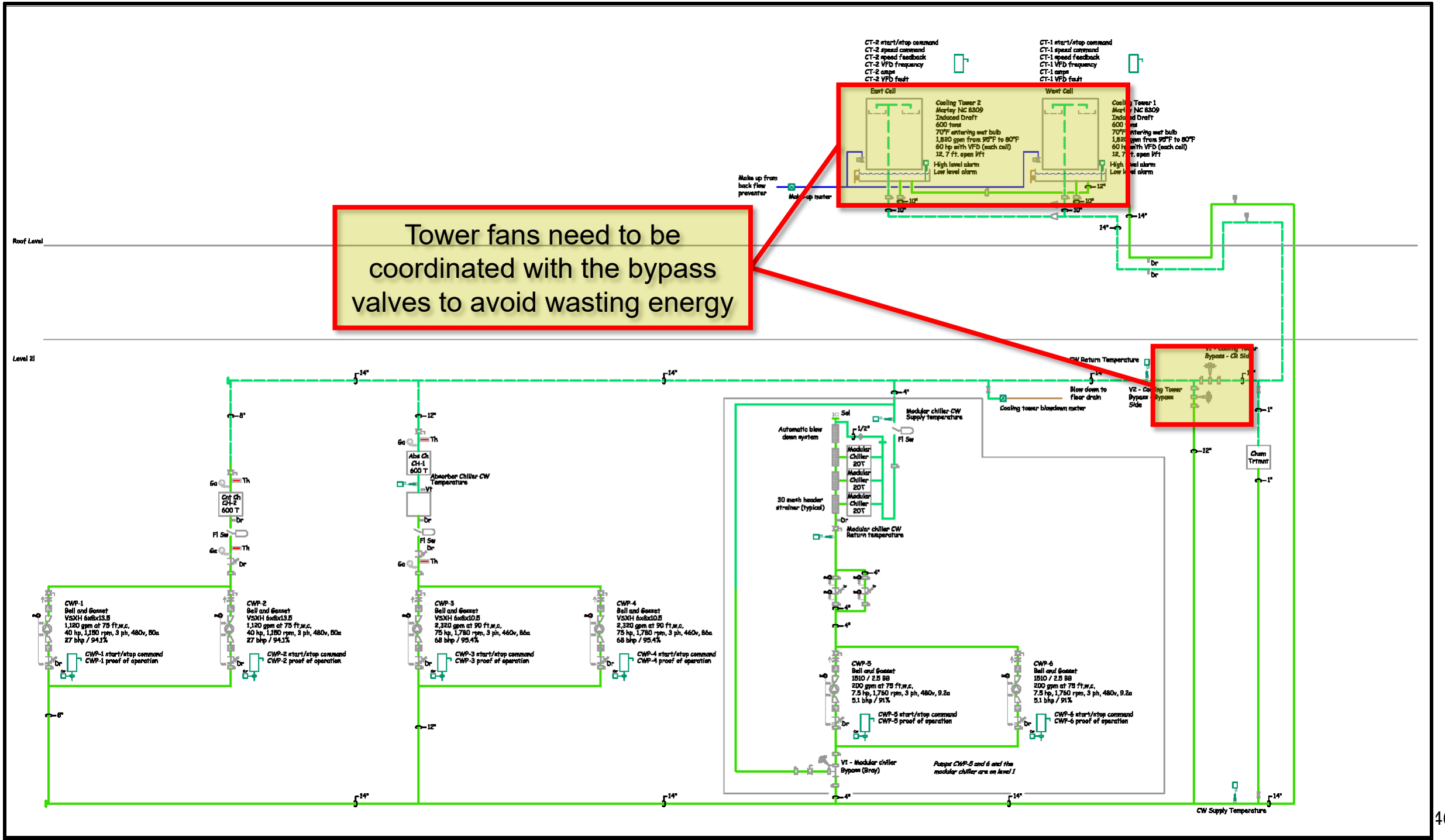
- A good way to learn the system prior to going on site
- Focusing on one system can be helpful
- “Untangling” can be helpful

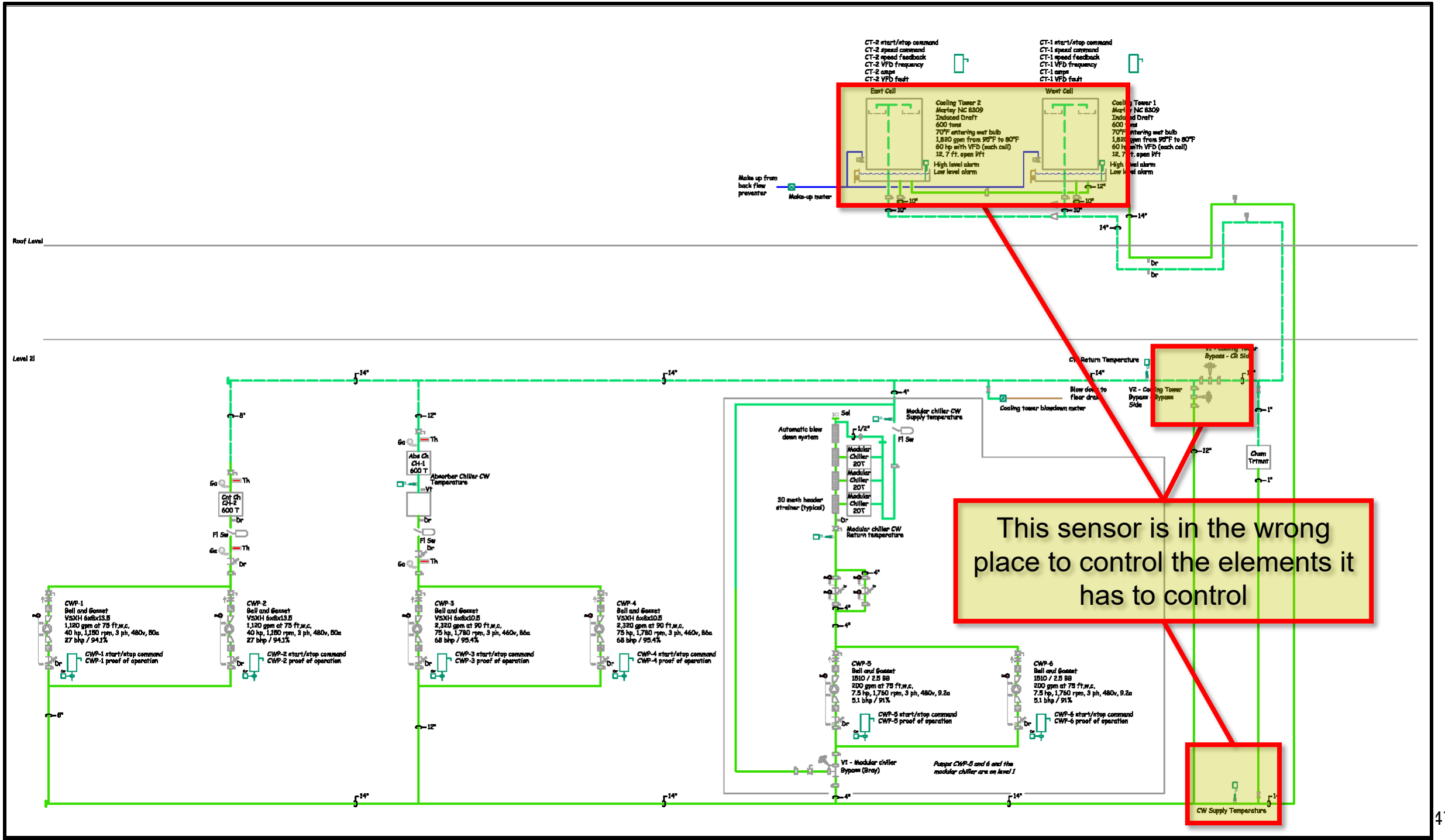


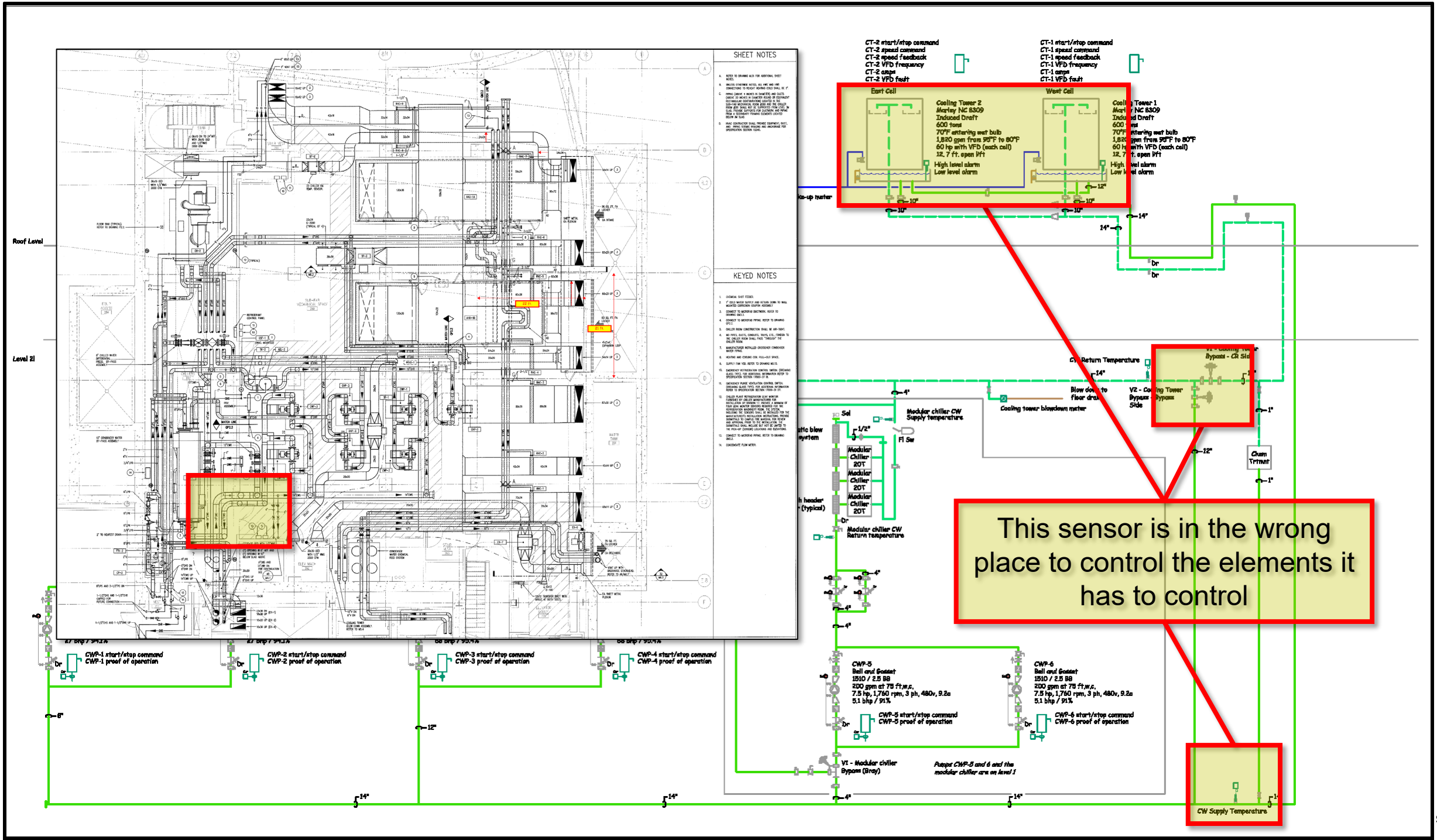
My “System Diagram” for the Condenser Water System

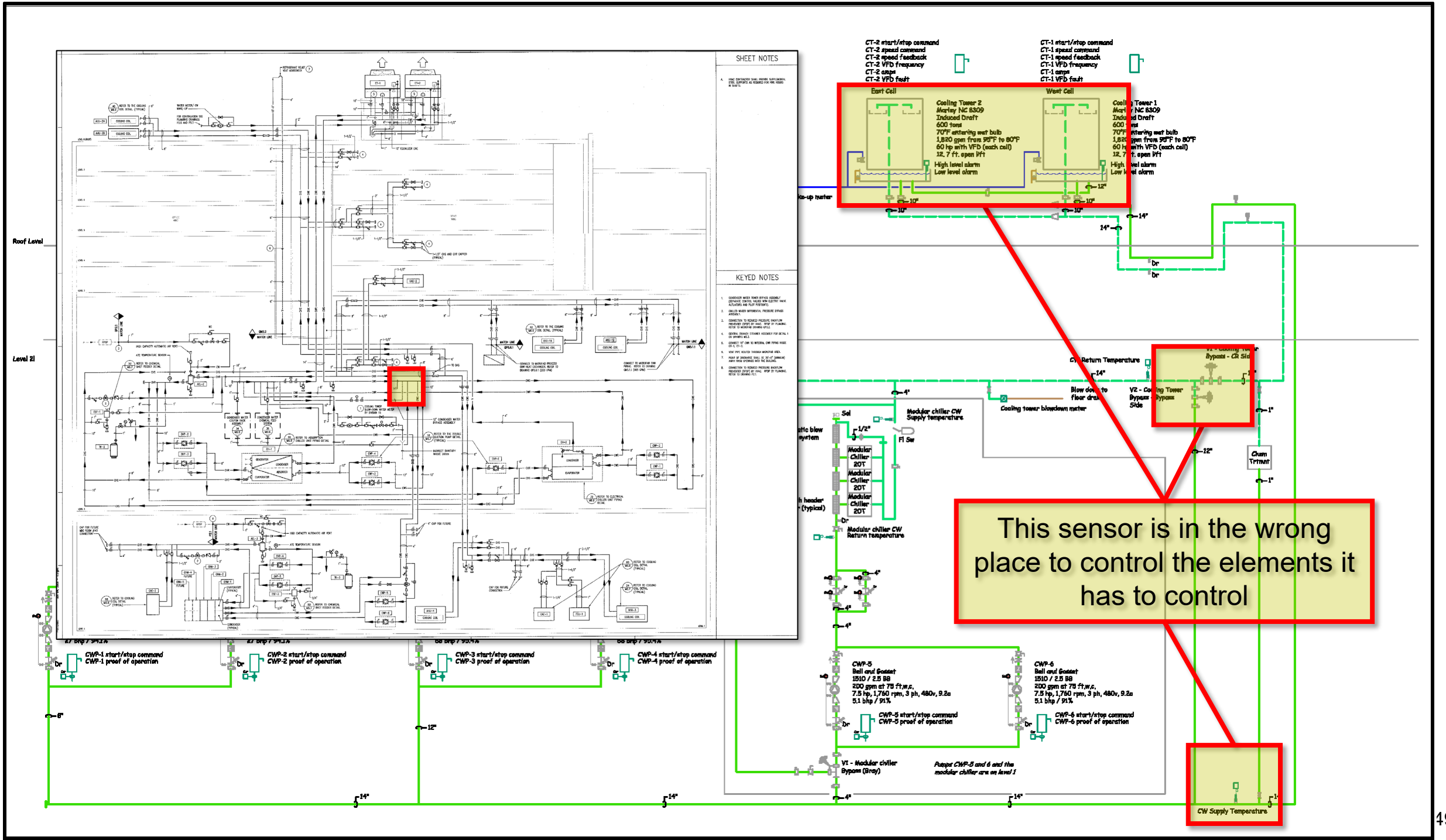


Issues Tend to Jump Out at You


Tower fans need to be coordinated with the bypass valves to avoid wasting energy
CT-2 start/stop command
CT-2 speed command
CT-2 speed feedback
CT-2 VFD frequency
CT-2 amps
CT-2 VFD fault
CT-1 start/stop command
CT-1 speed command
CT-1 speed feedback
CT-1 VFD frequency
CT-1 amps
CT-1 VFD fault
East Cell
West Cell
Cooling Tower 2
Marley NC 8309
Induced Draft
600 tons
70°F entering wet bulb
1,820 gpm from 95°F to 80°F
60 hp with VFD (each cell)
12. 7 ft. open lift
High level alarm
Low level alarm
Make up from back flow preventer
Roof Level
Level 2
CW Return Temperature
Blow down to floor drain
Cooling tower blowdown meter
Modular chiller CW Supply temperature
Automatic blow down system
Modular Chiller 20T
30 mesh header strainer (typical)
Modular chiller CW Return temperature
Absorber Chiller CW Temperature
CWP-1
Bell and Gasket
VSXH 6x8x13.5
1,120 gpm at 75 ft.w.c.
40 hp, 1,150 rpm, 3 ph, 480v, 50a
27 bhp / 94.1%
CWP-1 start/stop command
CWP-1 proof of operation
CWP-2
Bell and Gasket
VSXH 6x8x13.5
1,120 gpm at 75 ft.w.c.
40 hp, 1,150 rpm, 3 ph, 480v, 50a
27 bhp / 94.1%
CWP-2 start/stop command
CWP-2 proof of operation
CWP-3
Bell and Gasket
VSXH 6x8x10.5
2,320 gpm at 90 ft.w.c.
75 hp, 1,780 rpm, 3 ph, 460v, 86a
68 bhp / 95.4%
CWP-3 start/stop command
CWP-3 proof of operation
CWP-4
Bell and Gasket
VSXH 6x8x10.5
2,320 gpm at 90 ft.w.c.
75 hp, 1,780 rpm, 3 ph, 460v, 86a
68 bhp / 95.4%
CWP-4 start/stop command
CWP-4 proof of operation
CWP-5
Bell and Gasket
1510 / 2.5 BB
200 gpm at 75 ft.w.c.
7.5 hp, 1,750 rpm, 3 ph, 480v, 9.2a
5.1 bhp / 91%
CWP-5 start/stop command
CWP-5 proof of operation
CWP-6
Bell and Gasket
1510 / 2.5 BB
200 gpm at 75 ft.w.c.
7.5 hp, 1,750 rpm, 3 ph, 480v, 9.2a
5.1 bhp / 91%
CWP-6 start/stop command
CWP-6 proof of operation
V1 - Modular chiller Bypass (Gray)
Pumps CWP-5 and 6 and the modular chiller are on level 1
V2 - Cooling Tower Bypass Side
Chem Trtmnt
CW Supply Temperature


CT-2 start/stop command
CT-2 speed command
CT-2 speed feedback
CT-2 VFD frequency
CT-2 amps
CT-2 VFD fault
CT-1 start/stop command
CT-1 speed command
CT-1 speed feedback
CT-1 VFD frequency
CT-1 amps
CT-1 VFD fault
East Cell
West Cell
Cooling Tower 2
Marley NC 8309
Induced Draft
600 tons
70°F entering wet bulb
1,820 gpm from 95°F to 80°F
60 hp with VFD (each cell)
12. 7 ft. open lift
High level alarm
Low level alarm
Make up from back flow preventer
Make-up meter
Roof Level
Level 2
CW Return Temperature
Blow down to floor drain
Cooling tower blowdown meter
Chem Trtmnt
Automatic blow down system
Modular chiller CW Supply temperature
Modular Chiller 20T
30 mesh header strainer (typical)
Modular chiller CW Return temperature
Absorber Chiller CW Temperature
CWP-1
Bell and Gasket
VSXH 6x8x13.5
1,120 gpm at 75 ft.w.c.
40 hp, 1,150 rpm, 3 ph, 480v, 50a
27 bhp / 94.1%
CWP-1 start/stop command
CWP-1 proof of operation
CWP-2
Bell and Gasket
VSXH 6x8x13.5
1,120 gpm at 75 ft.w.c.
40 hp, 1,150 rpm, 3 ph, 480v, 50a
27 bhp / 94.1%
CWP-2 start/stop command
CWP-2 proof of operation
CWP-3
Bell and Gasket
VSXH 6x8x10.5
2,320 gpm at 90 ft.w.c.
75 hp, 1,780 rpm, 3 ph, 460v, 86a
68 bhp / 95.4%
CWP-3 start/stop command
CWP-3 proof of operation
CWP-4
Bell and Gasket
VSXH 6x8x10.5
2,320 gpm at 90 ft.w.c.
75 hp, 1,780 rpm, 3 ph, 460v, 86a
68 bhp / 95.4%
CWP-4 start/stop command
CWP-4 proof of operation
CWP-5
Bell and Gasket
1510 / 2.5 BB
200 gpm at 75 ft.w.c.
7.5 hp, 1,750 rpm, 3 ph, 480v, 9.2a
5.1 bhp / 91%
CWP-5 start/stop command
CWP-5 proof of operation
CWP-6
Bell and Gasket
1510 / 2.5 BB
200 gpm at 75 ft.w.c.
7.5 hp, 1,750 rpm, 3 ph, 480v, 9.2a
5.1 bhp / 91%
CWP-6 start/stop command
CWP-6 proof of operation
V1 - Modular chiller Bypass (Gray)
Pumps CWP-5 and 6 and the modular chiller are on level 1
CW Supply Temperature
This sensor is in the wrong place to control the elements it has to control


SHEET NOTES
KEYED NOTES
Roof Level
Level 21
CT-2 start/stop command
CT-2 speed command
CT-2 speed feedback
CT-2 VFD frequency
CT-2 amps
CT-2 VFD fault
CT-1 start/stop command
CT-1 speed command
CT-1 speed feedback
CT-1 VFD frequency
CT-1 amps
CT-1 VFD fault
East Cell
West Cell
Cooling Tower 2
Marley NC 8309
Induced Draft
600 tons
70°F entering wet bulb
1,820 gpm from 95°F to 80°F
60 hp with VFD (each cell)
12.7 ft. open lift
High level alarm
Low level alarm
Cooling Tower 1
Marley NC 8309
Induced Draft
600 tons
70°F entering wet bulb
1,820 gpm from 95°F to 80°F
60 hp with VFD (each cell)
12.7 ft. open lift
High level alarm
Low level alarm
CW Return Temperature
Blow down to floor drain
Cooling tower blowdown meter
V2 - Cooling Tower Bypass - Bypass Side
Modular chiller CW Supply temperature
Modular Chiller 20T
Modular Chiller 20T
Modular Chiller 20T
Modular chiller CW Return temperature
Chem Treatment
This sensor is in the wrong place to control the elements it has to control
CWP-1 start/stop command
CWP-1 proof of operation
CWP-2 start/stop command
CWP-2 proof of operation
CWP-3 start/stop command
CWP-3 proof of operation
CWP-4 start/stop command
CWP-4 proof of operation
CWP-5
Bell and Gossett
1510 / 2.5 BB
200 gpm at 75 ft.w.c.
7.5 hp, 1,750 rpm, 3 ph, 480v, 9.2a
5.1 bhp / 91%
CWP-5 start/stop command
CWP-5 proof of operation
CWP-6
Bell and Gossett
1510 / 2.5 BB
200 gpm at 75 ft.w.c.
7.5 hp, 1,750 rpm, 3 ph, 480v, 9.2a
5.1 bhp / 91%
CWP-6 start/stop command
CWP-6 proof of operation
V1 - Modular chiller Bypass (Bray)
Pumps CWP-5 and 6 and the modular chiller are on level 1
CW Supply Temperature


SHEET NOTES
KEYED NOTES
Roof Level
Level 21
CT-2 start/stop command
CT-2 speed command
CT-2 speed feedback
CT-2 VFD frequency
CT-2 amps
CT-2 VFD fault
CT-1 start/stop command
CT-1 speed command
CT-1 speed feedback
CT-1 VFD frequency
CT-1 amps
CT-1 VFD fault
East Cell
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CW Return Temperature
Blow down to floor drain
Cooling tower blowdown meter
V2 - Cooling Tower Bypass - Bypass Side
Chem Trtmnt
Modular chiller CW Supply temperature
Modular Chiller 20T
Modular Chiller 20T
Modular Chiller 20T
Modular chiller CW Return temperature
This sensor is in the wrong place to control the elements it has to control
CWP-1 start/stop command
CWP-1 proof of operation
CWP-2 start/stop command
CWP-2 proof of operation
CWP-3 start/stop command
CWP-3 proof of operation
CWP-4 start/stop command
CWP-4 proof of operation
CWP-5
Bell and Gossett
1510 / 2.5 BB
200 gpm at 75 ft.w.c.
7.5 hp, 1,750 rpm, 3 ph, 480v, 9.2a
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CWP-5 start/stop command
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CWP-6
Bell and Gossett
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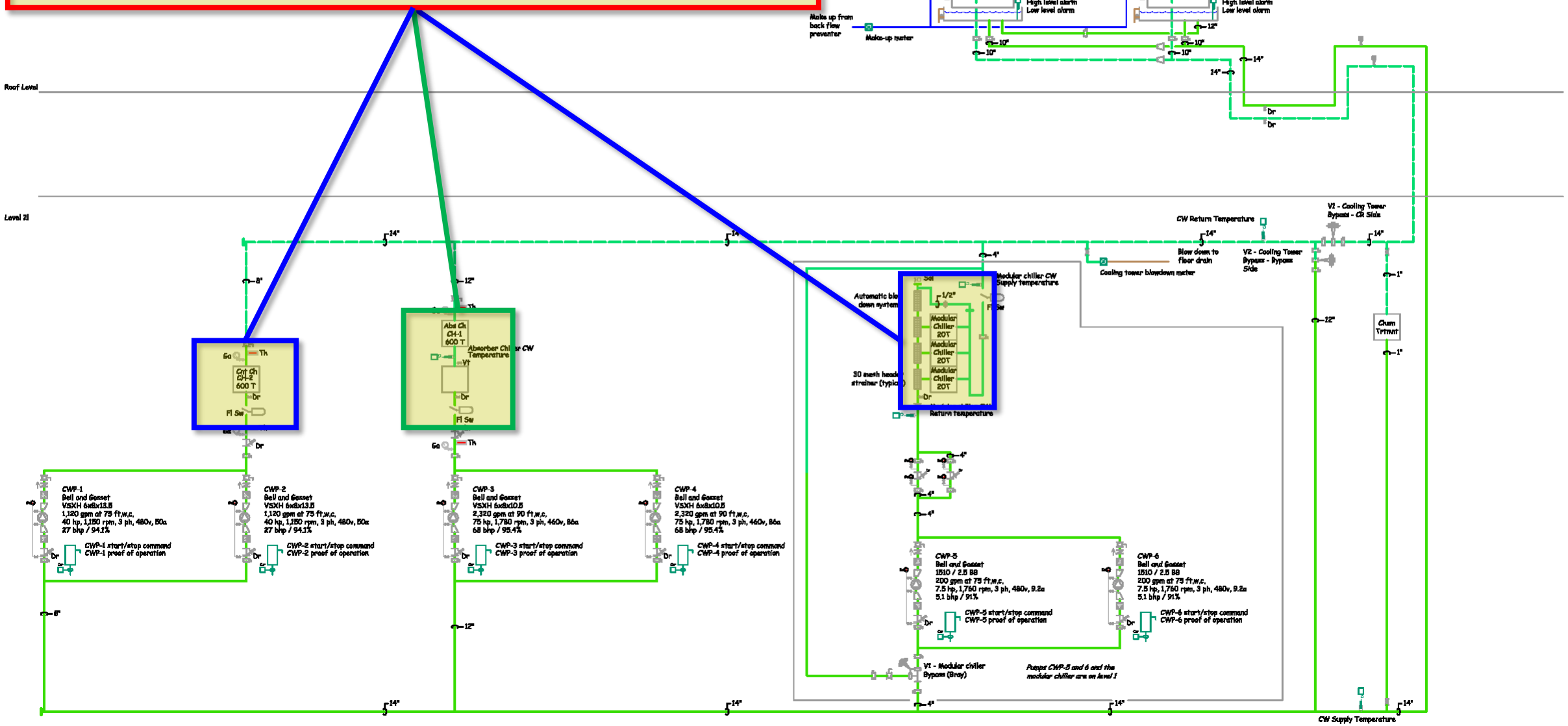
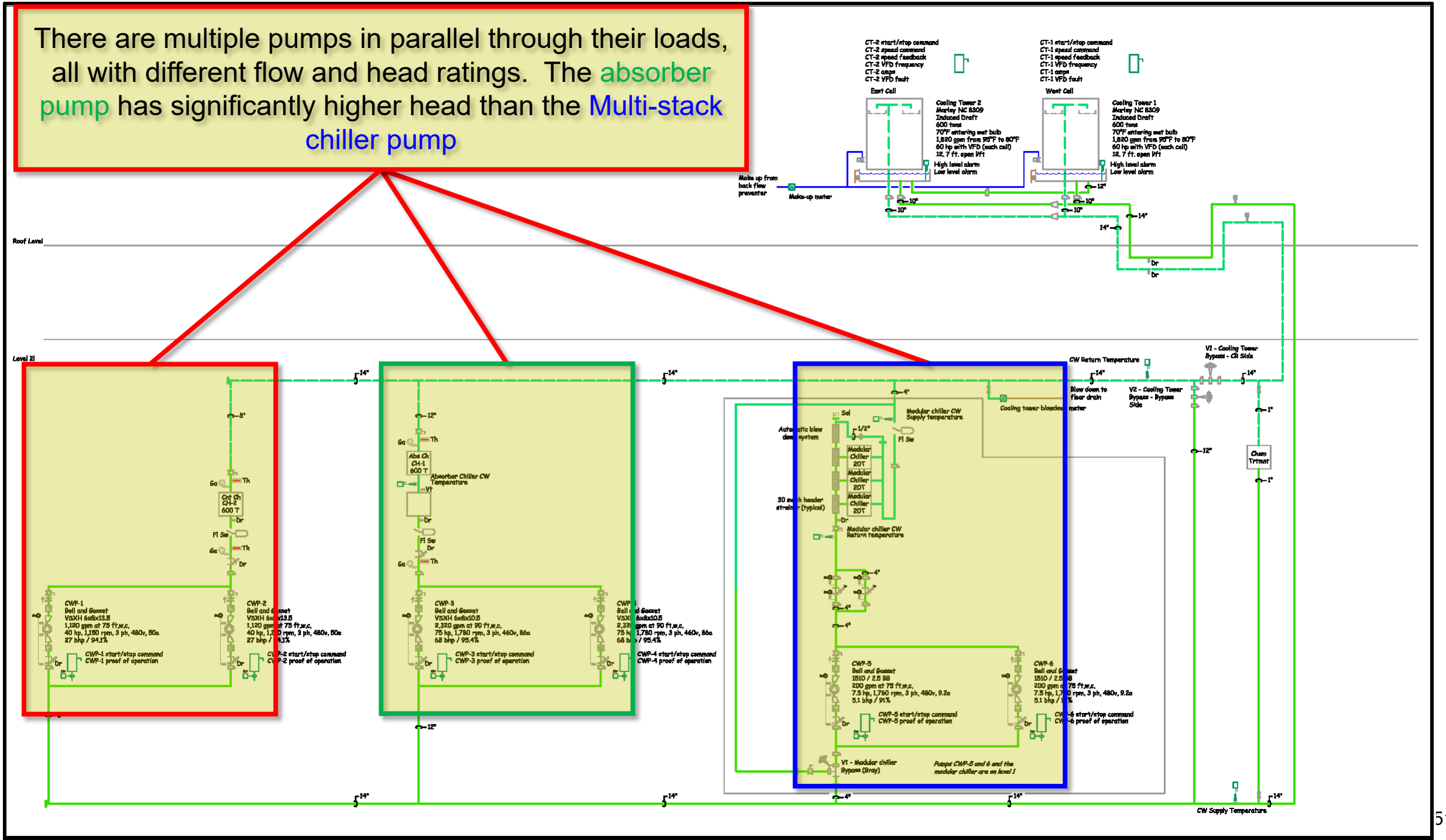
CWP-6 start/stop command
CWP-6 proof of operation
V1 - Modular chiller Bypass (Bray)
Pumps CWP-5 and 6 and the modular chiller are on level 1
CW Supply Temperature

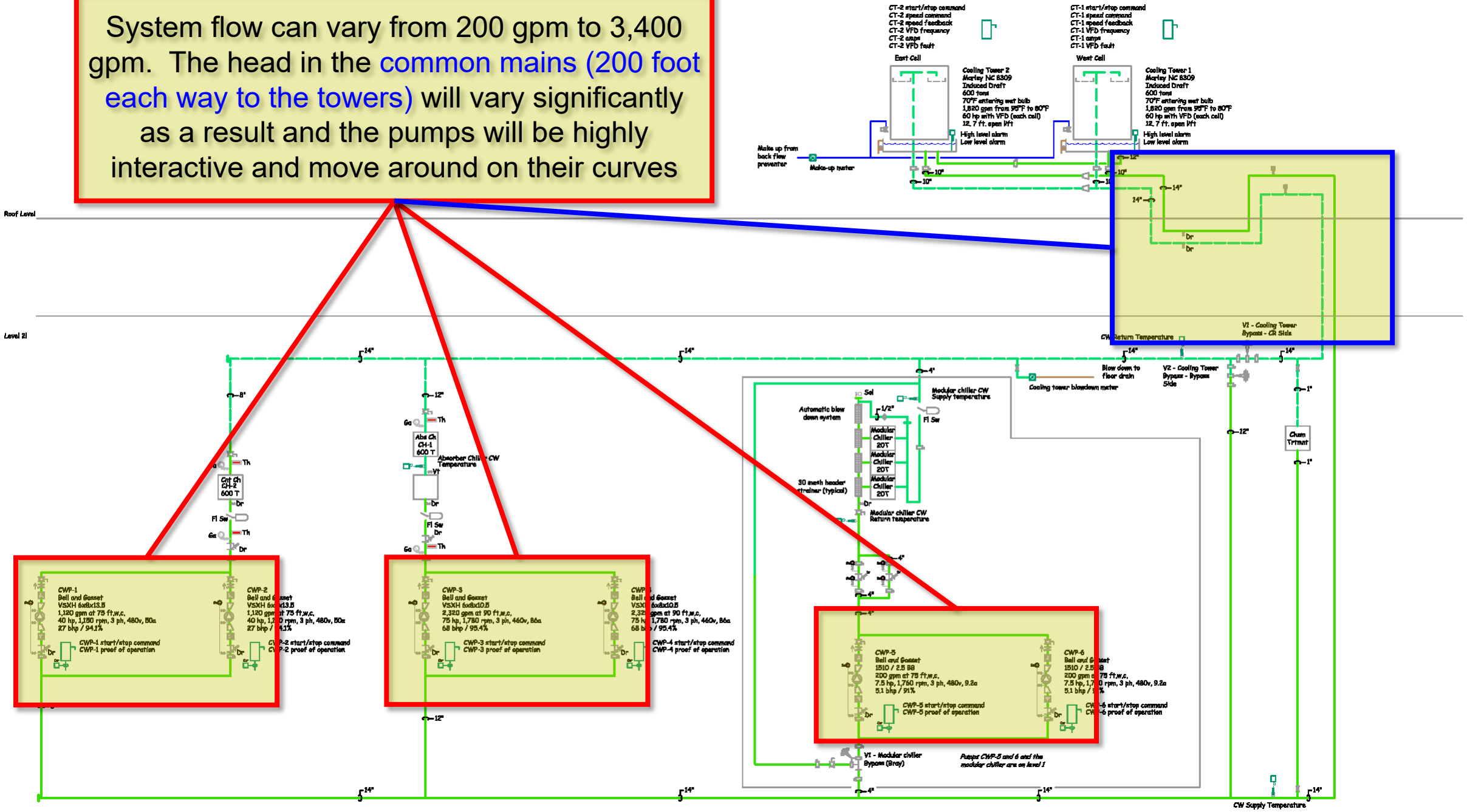
The absorption chiller will solidify if condenser water temperatures drop below 80°F; the centrifugal chillers will become more efficient with condenser water temperatures in the 65-75°F range



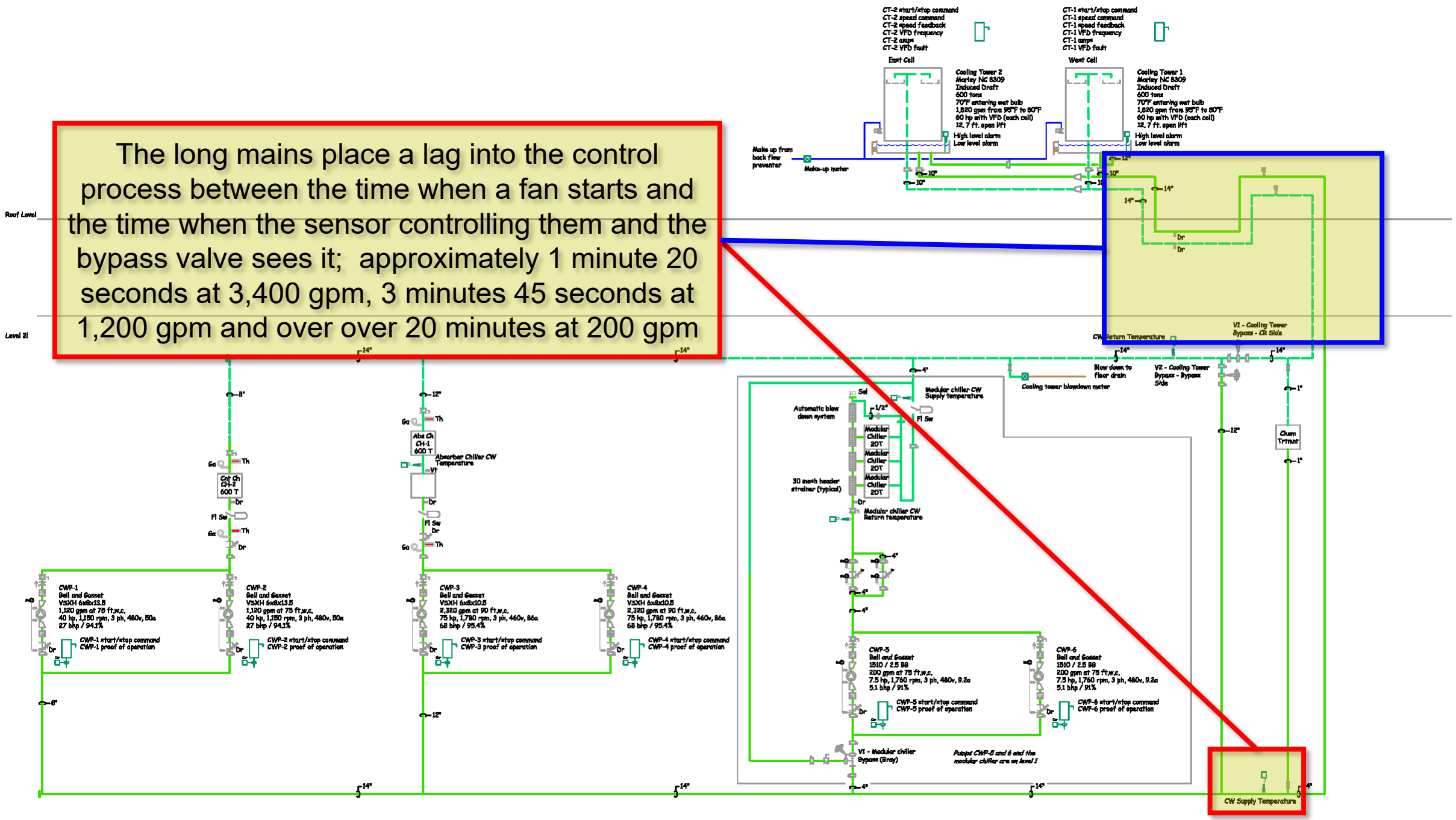
There are multiple pumps in parallel through their loads, all with different flow and head ratings. The absorber pump has significantly higher head than the Multi-stack chiller pump



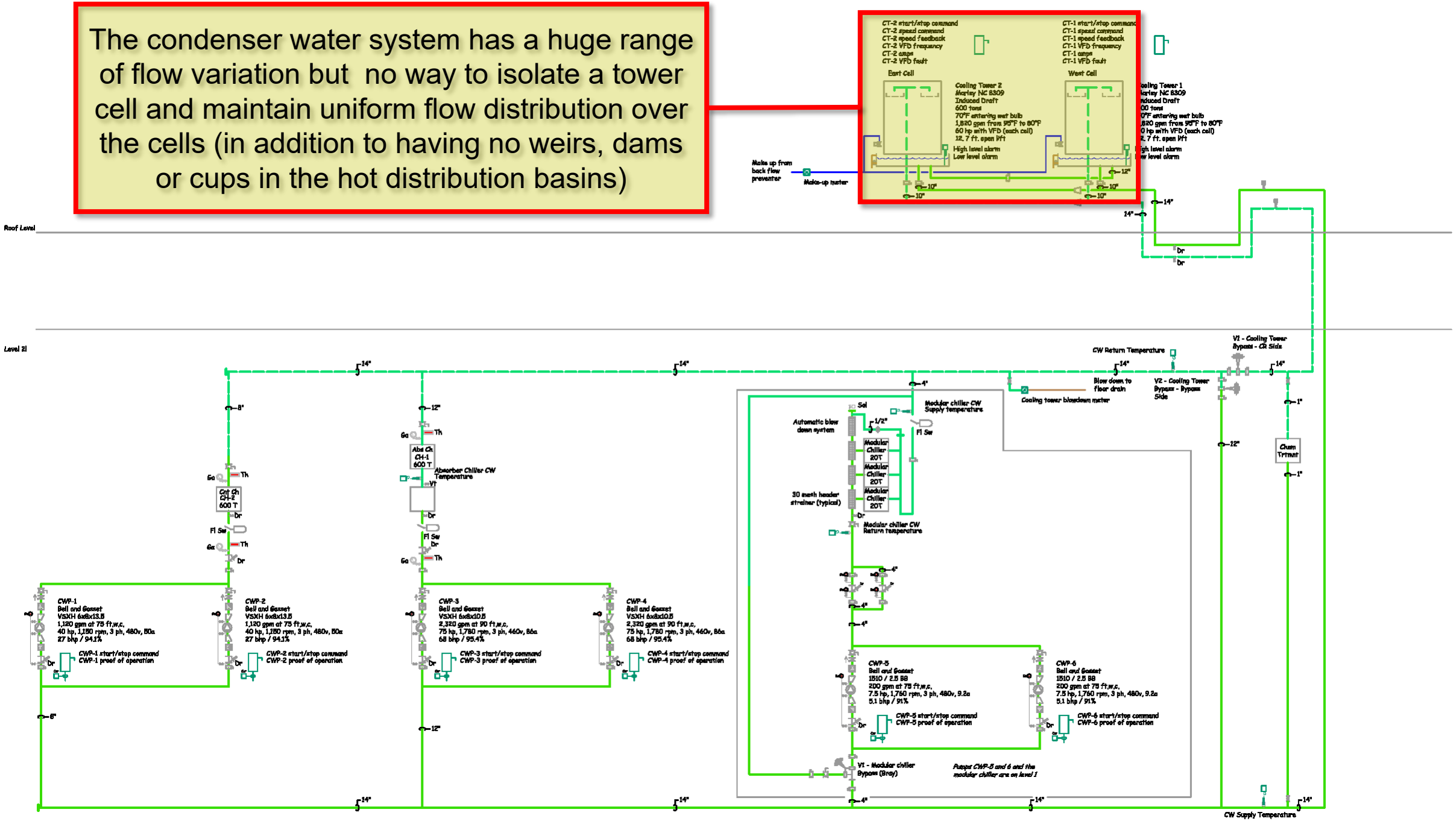
System flow can vary from 200 gpm to 3,400 gpm. The head in the common mains (200 foot each way to the towers) will vary significantly as a result and the pumps will be highly interactive and move around on their curves



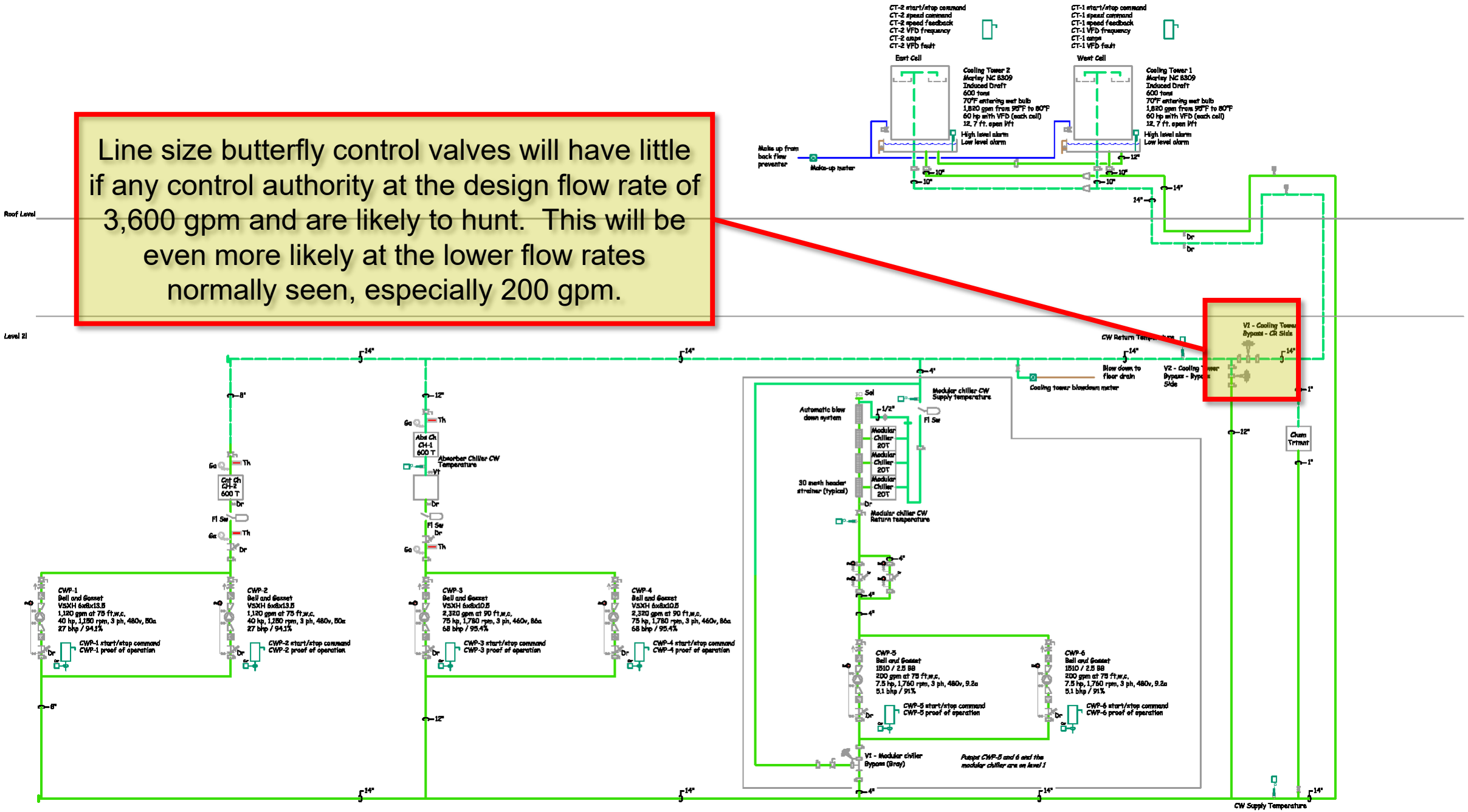
The long mains place a lag into the control process between the time when a fan starts and the time when the sensor controlling them and the bypass valve sees it; approximately 1 minute 20 seconds at 3,400 gpm, 3 minutes 45 seconds at 1,200 gpm and over over 20 minutes at 200 gpm



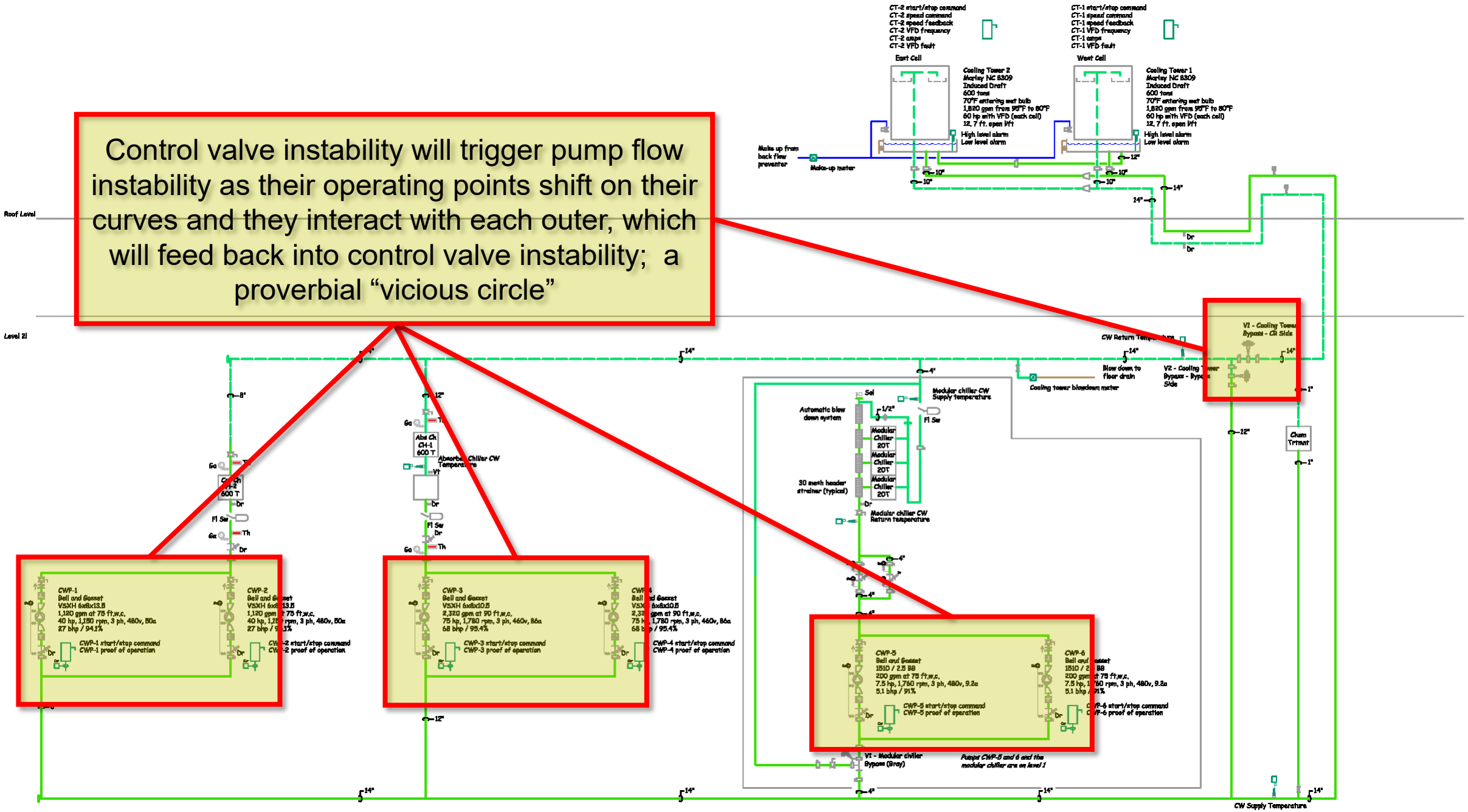
The condenser water system has a huge range of flow variation but no way to isolate a tower cell and maintain uniform flow distribution over the cells (in addition to having no weirs, dams or cups in the hot distribution basins)



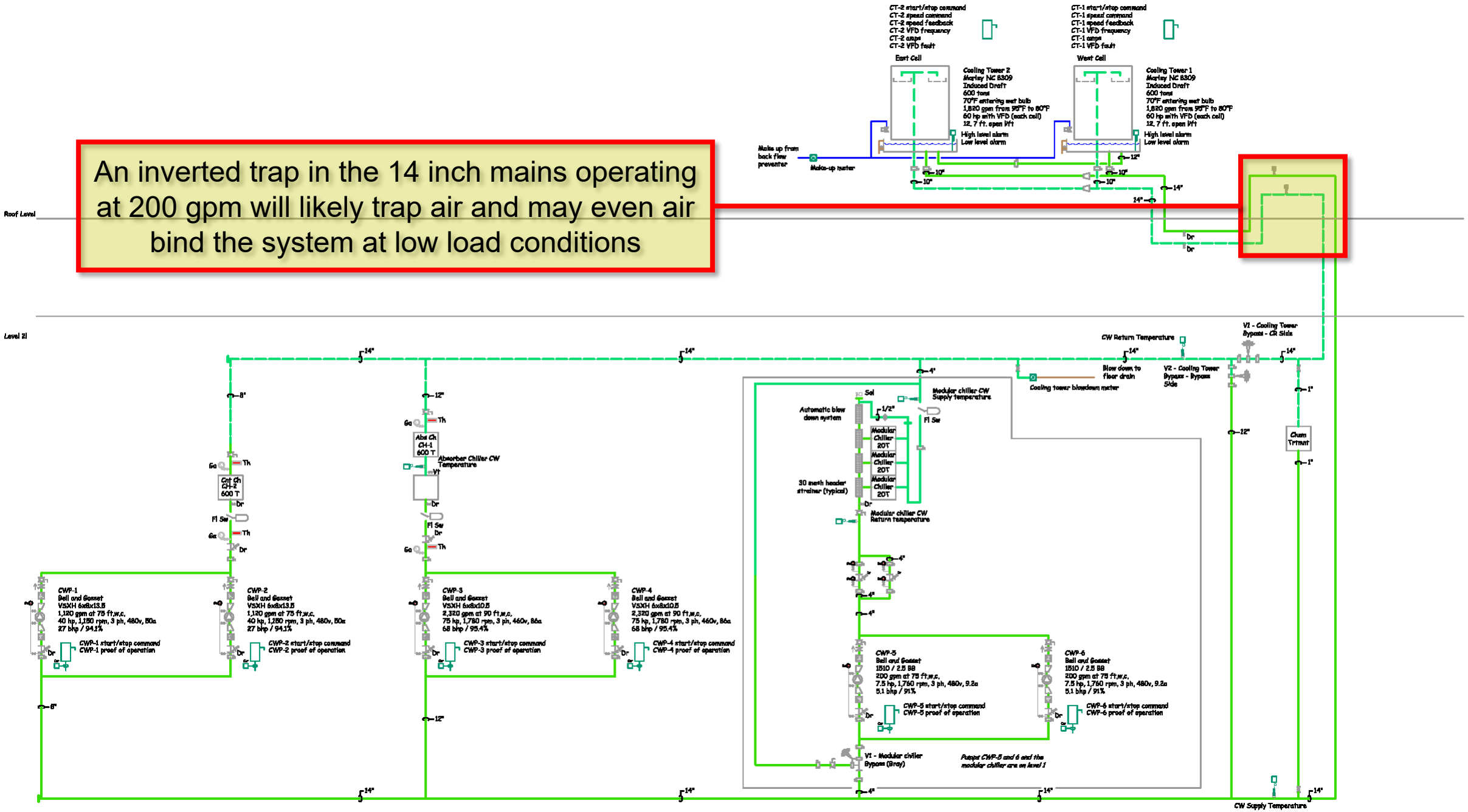
Line size butterfly control valves will have little if any control authority at the design flow rate of 3,600 gpm and are likely to hunt. This will be even more likely at the lower flow rates normally seen, especially 200 gpm.



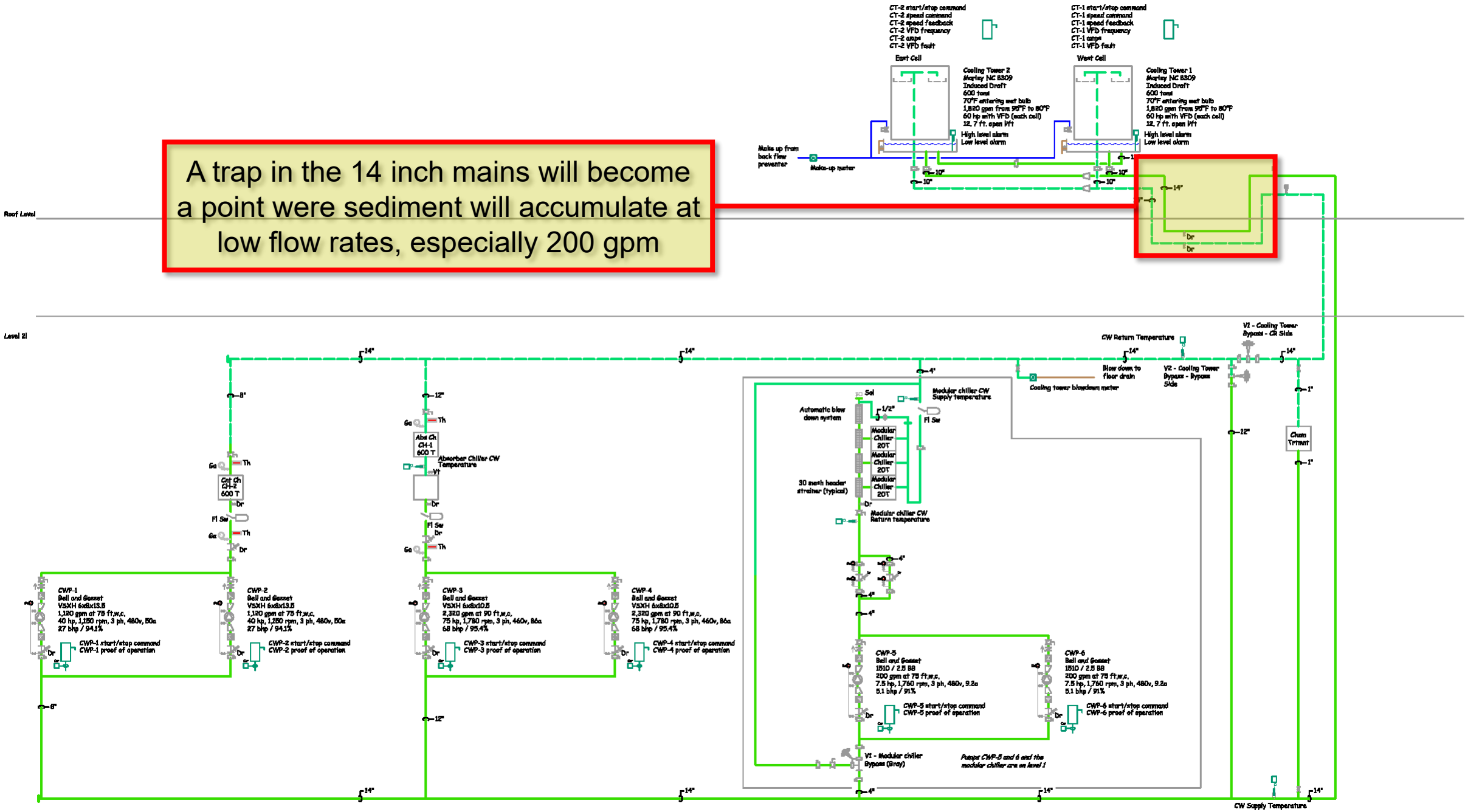
Control valve instability will trigger pump flow instability as their operating points shift on their curves and they interact with each outer, which will feed back into control valve instability; a proverbial “vicious circle”



An inverted trap in the 14 inch mains operating at 200 gpm will likely trap air and may even air bind the system at low load conditions

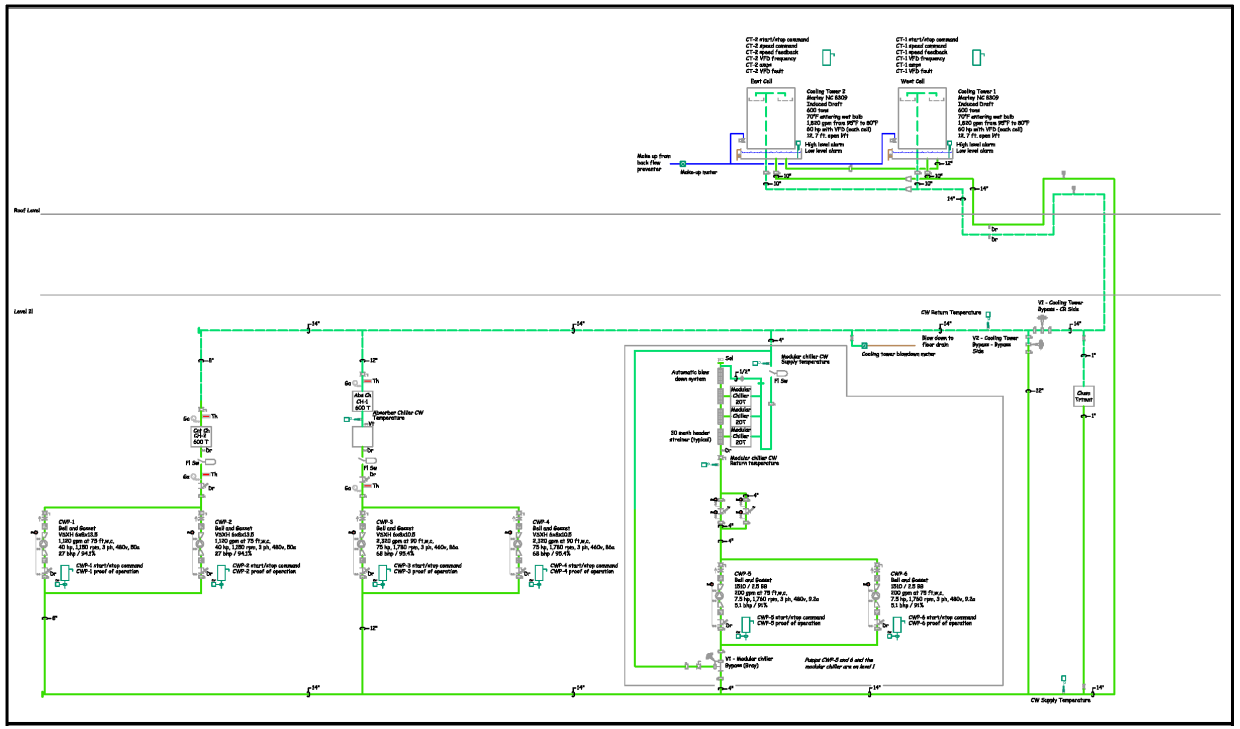


A trap in the 14 inch mains will become a point were sediment will accumulate at low flow rates, especially 200 gpm



Developing a System Diagram

- A good way to learn the system prior to going on site
- Focusing on one system can be helpful
- “Untangling” can be helpful
- A good way to spot problems
- Once field verified, it’s a valuable commissioning resource



My “System Diagram” for the Condenser Water System

A Resource for Learning to Do System Diagrams

https://av8rdas.wordpress.com/category/system-diagrams/