# System Diagram Workshop

## Introduction

**Instructor:**

David Sellers

Senior Engineer

Facility Dynamics Engineering

# Class Material Location

The slides and other supporting information for the class can be found in the Current Class Materials section at:

- http://www.av8rdas.com/pacific-energy-center-classes1.html
- They will be there until the next class, at which time they will be relocated further down the page under Variable Speed Drives;  Design, Performance, and Commissioning Issues

About using my spreadsheets and other resources:

- They are my tools vs. tools I developed to be used by others
- Use at your own risk;  I provide them as a resource for you to use as a starting point
- You still need to understand how it works and fix it if it doesn't work for you

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# Learning Objectives

After taking this class attendees:

1. Should be familiar with the system concept.
2. Understand the relationship between the system concept and a system diagram.
3. Understand the value of a system diagram as a design tool, a commissioning tool, and training tool.
4. Understand basic system diagram development concepts.
5. Understand the similarities and differences between a water system diagram and an air system diagram and had experience developing each type of diagram.

# Agenda

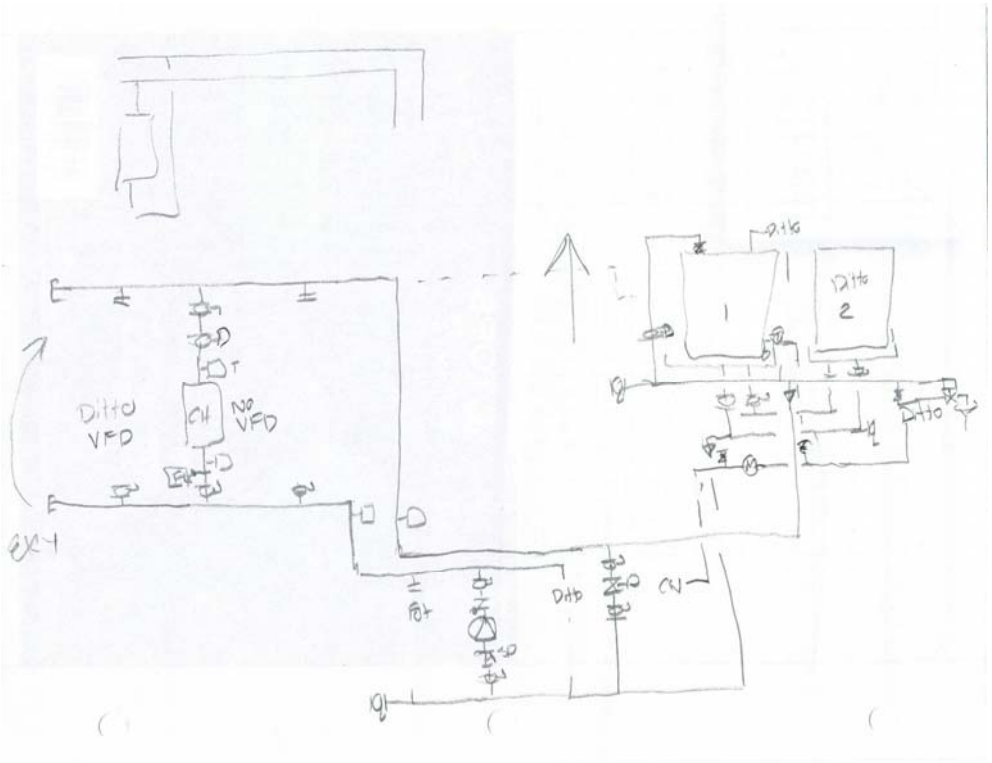
- Introduction and Overview to the System Concept
- System Diagram Concepts
    - Key Characteristics
    - Tools and Development Resources
    - Water System Diagrams
    - Air System Diagrams
- Maria’s Perspective on System Diagrams

# Agenda (continued)

- Working with System Diagrams
  - Diagramming the chilled water side of a central chilled water plant.
  - Diagramming a Ball Room air handling system.
  - Diagramming the condenser water side of a central chilled water plant (time permitting).

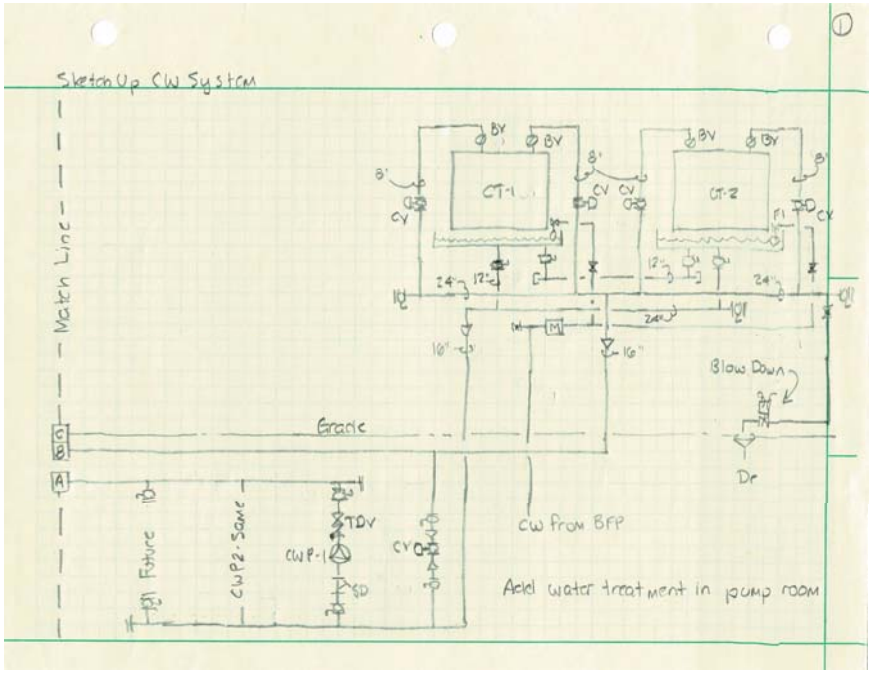
# A Building Life Cycle Tool

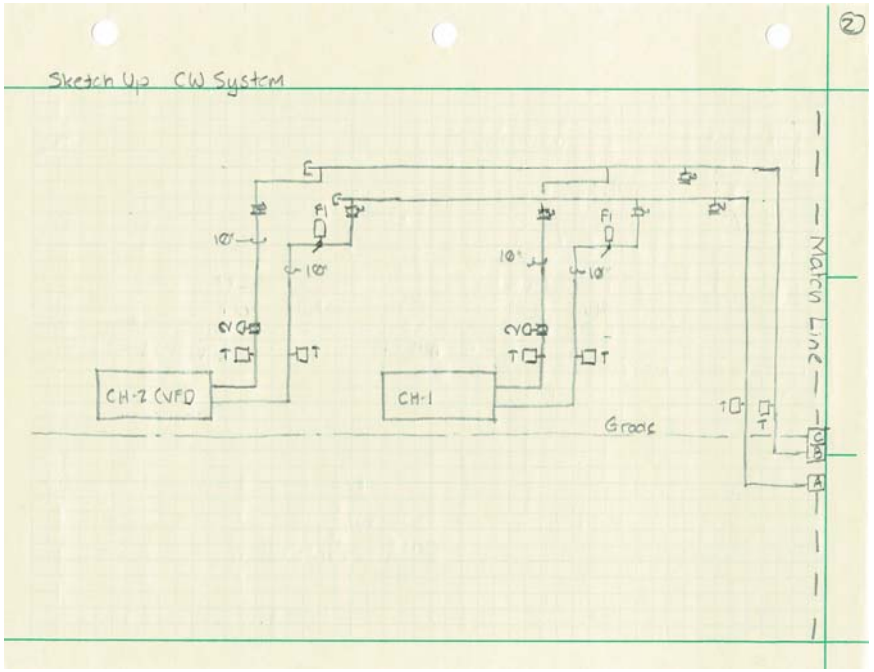
- A design tool for moving from concept



# A Building Life Cycle Tool

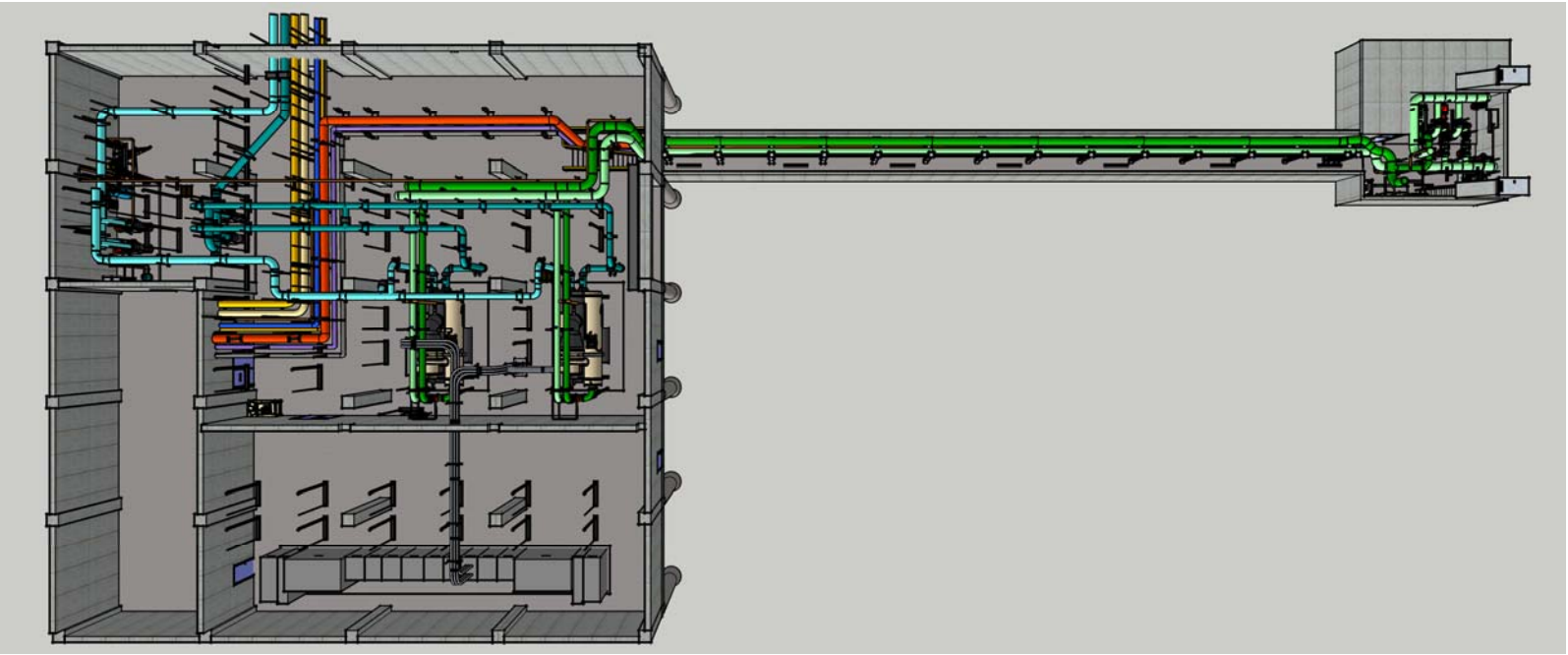
- A design tool for moving from concept through design development



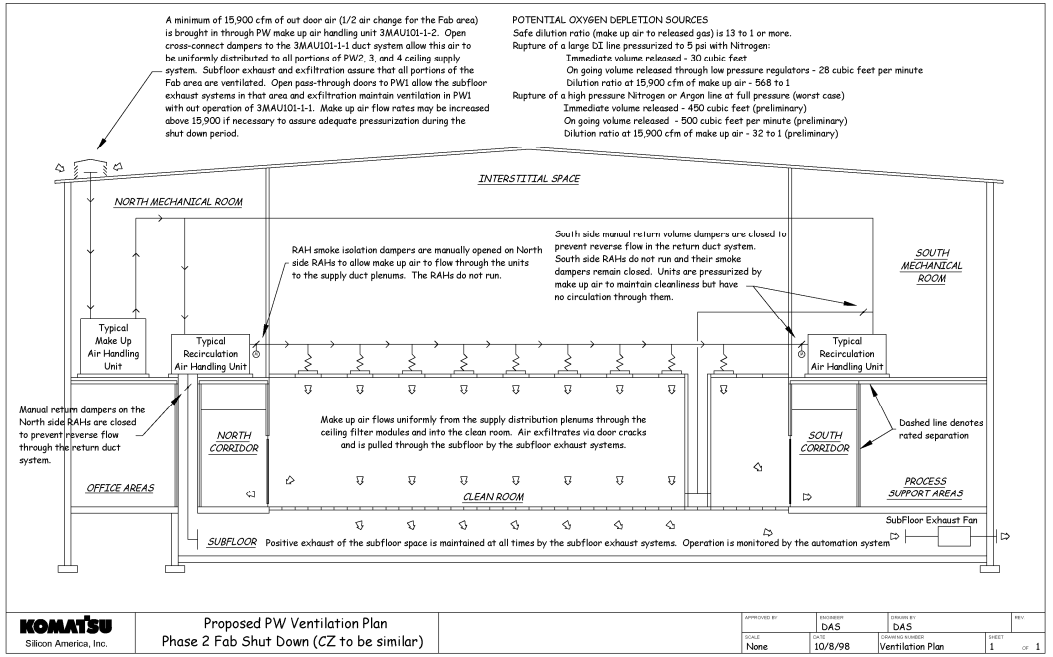
# A Building Life Cycle Tool

- 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

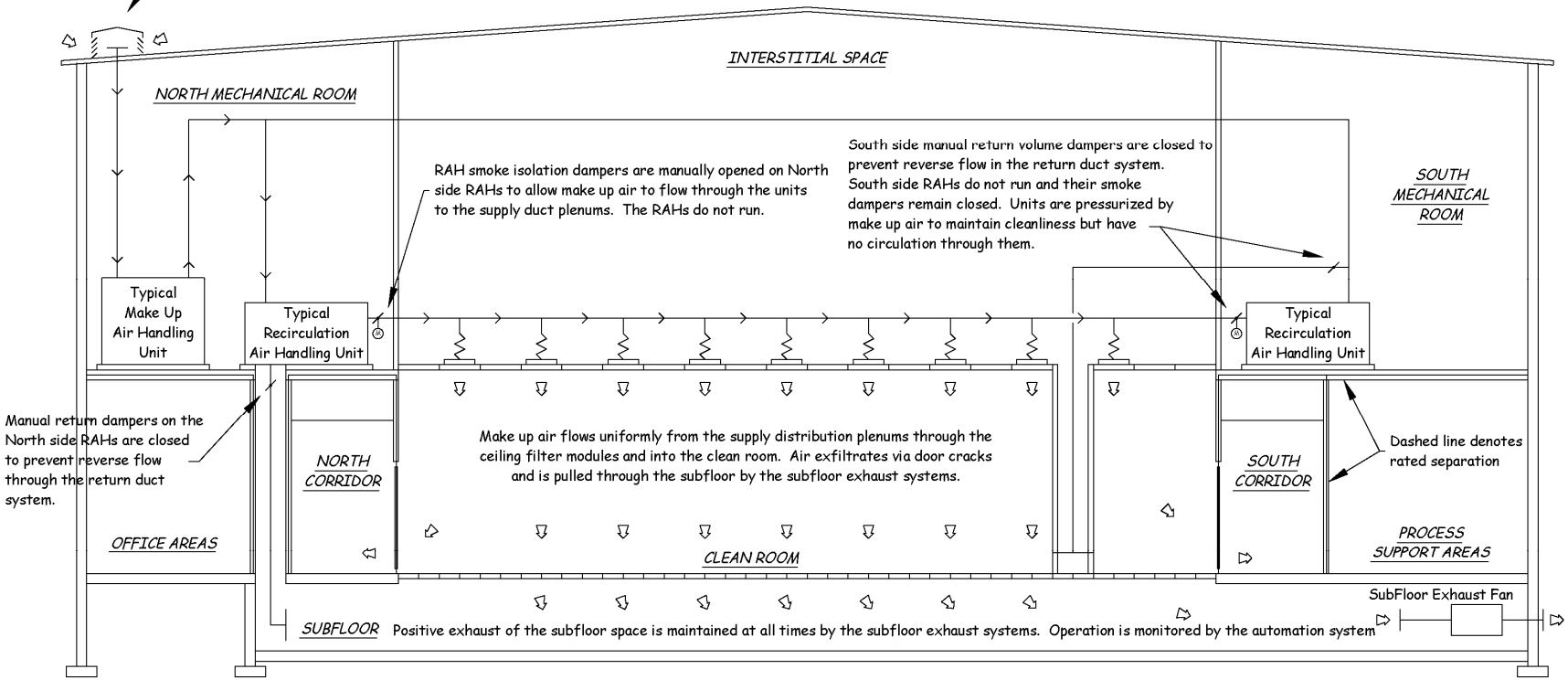
Safe dilution ratio (make up air to released gas) is 13 to 1 or more.

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)

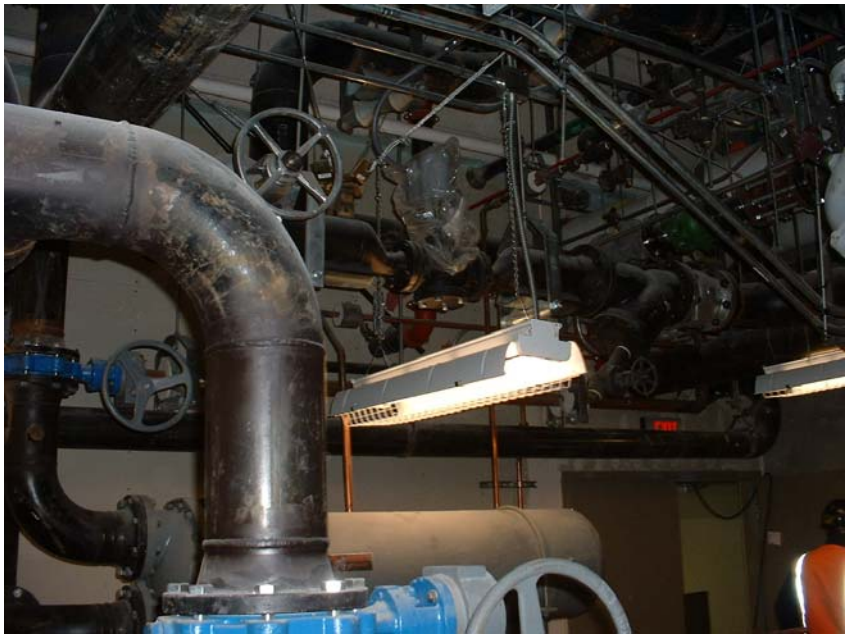
- Immediate volume released - 450 cubic feet (preliminary)
- On going volume released - 500 cubic feet per minute (preliminary)
- Dilution ratio at 15,900 cfm of make up air - 32 to 1 (preliminary)

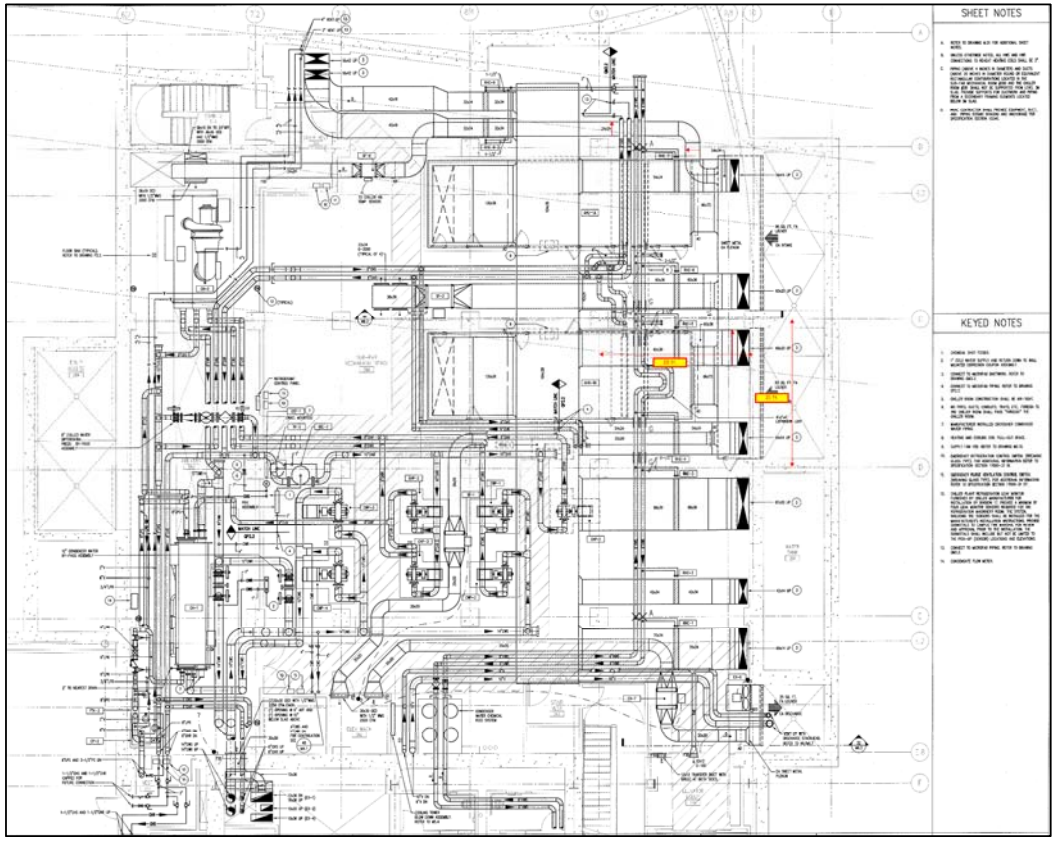



| | | | | | |
|---|---|---|---|---|---|
| KOMATSU Silicon America, Inc. | Proposed PW Ventilation Plan<br>Phase 2 Fab Shut Down (CZ to be similar) | APPROVED BY | ENGINEER: DAS | DRAWN BY: DAS | REV. |
| | | SCALE: None | DATE: 10/8/98 | DRAWING NUMBER: Ventilation Plan | SHEET: 1 OF 1 |

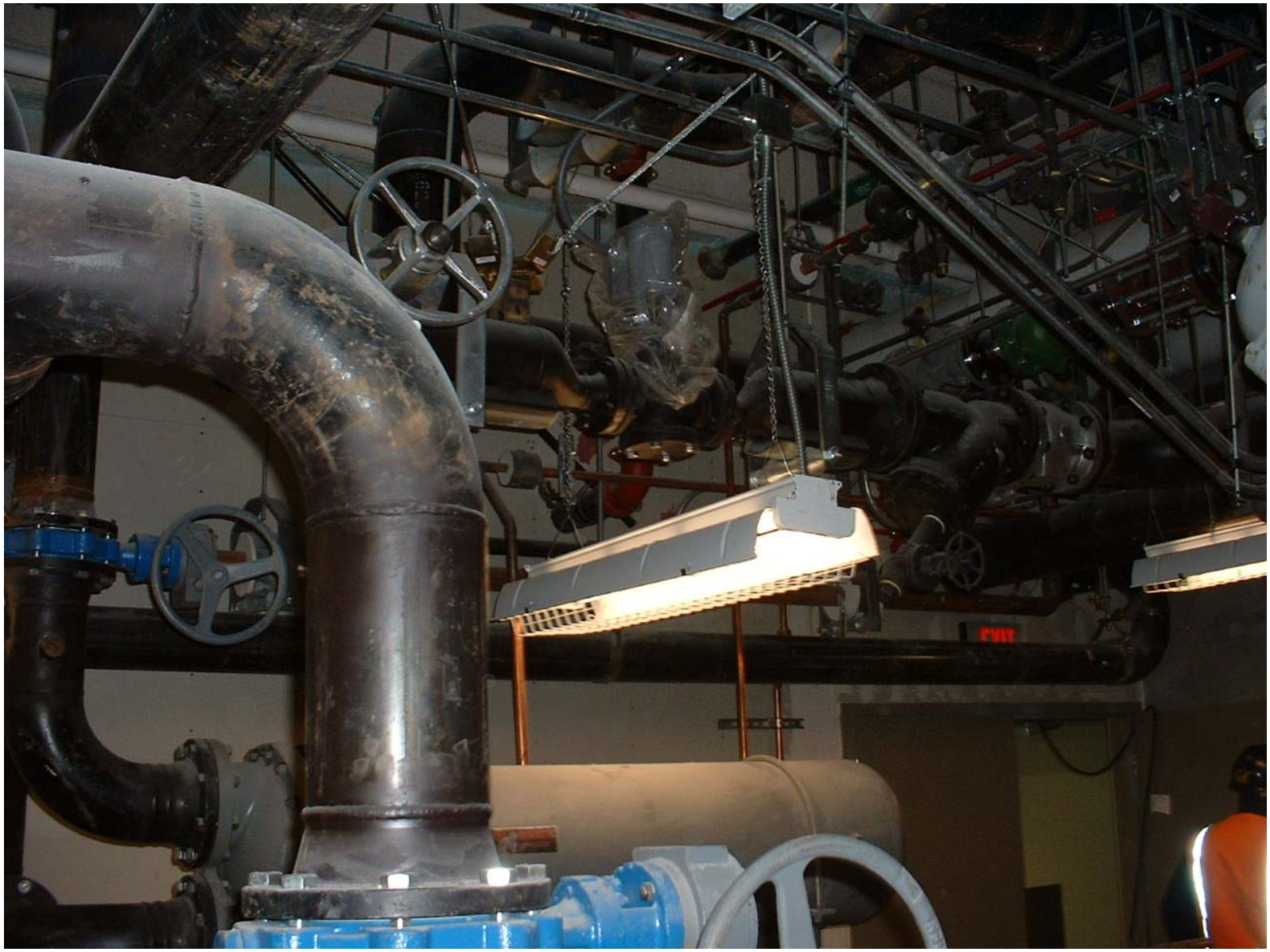
# Developing a System Diagram

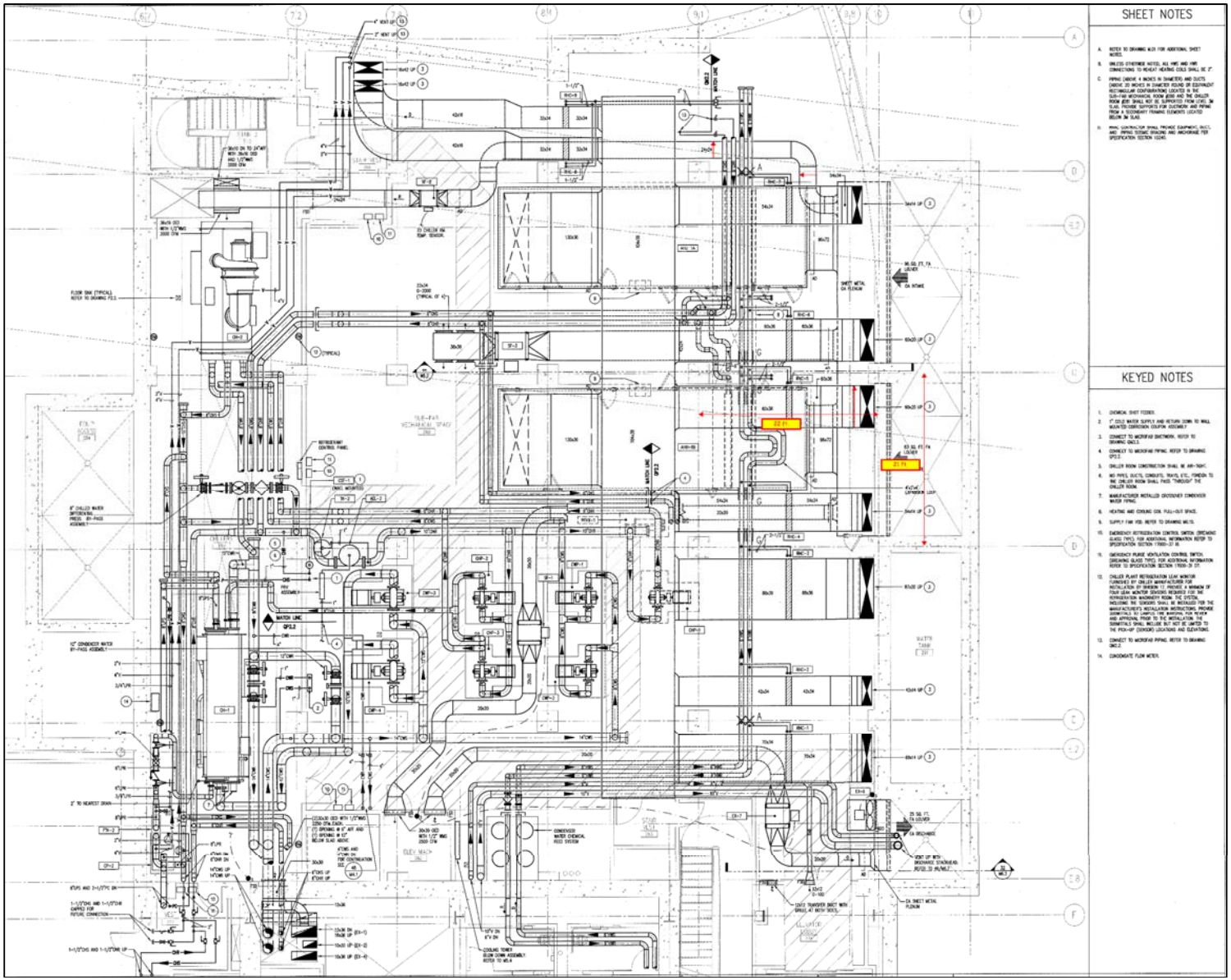
- A good way to learn the system prior to going on site





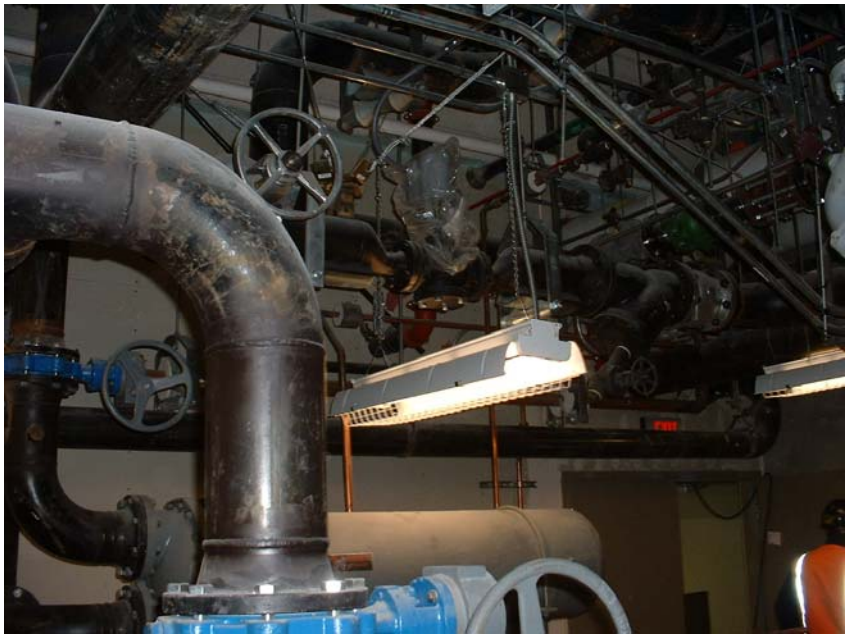

The Piping Plan

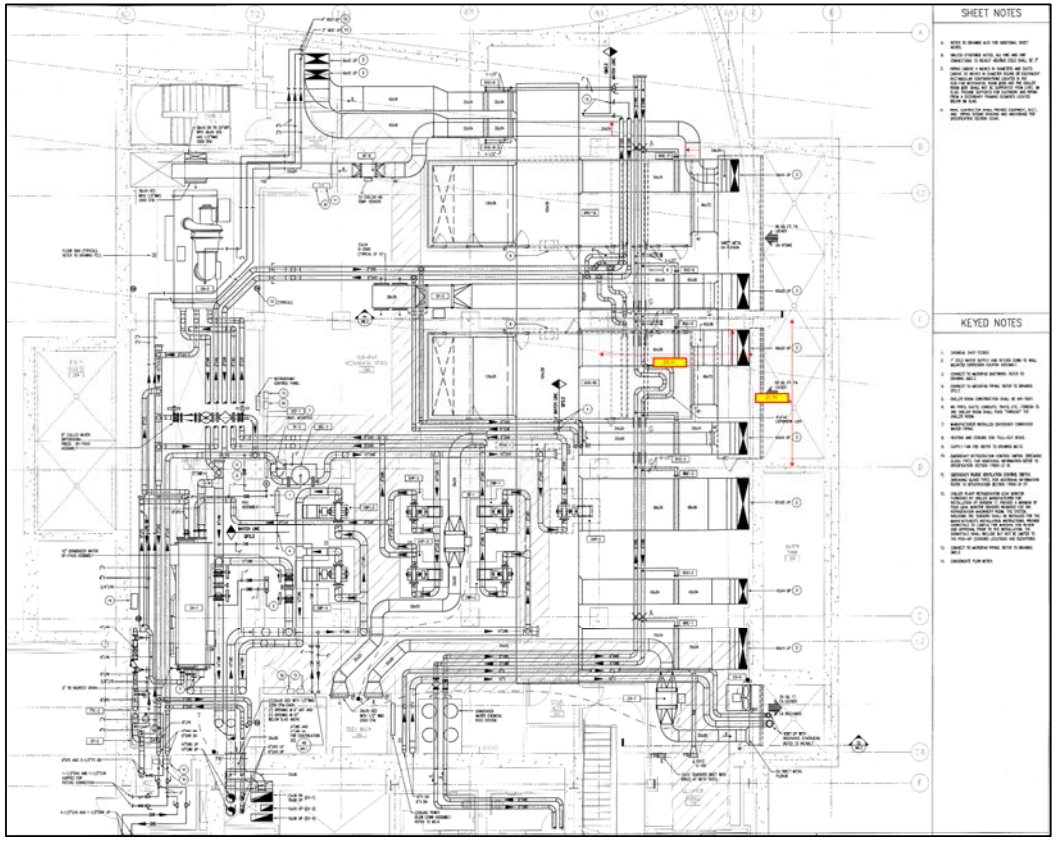

EXIT


SHEET NOTES
KEYED NOTES

# Developing a System Diagram

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






The Piping Plan

# Developing a System Diagram

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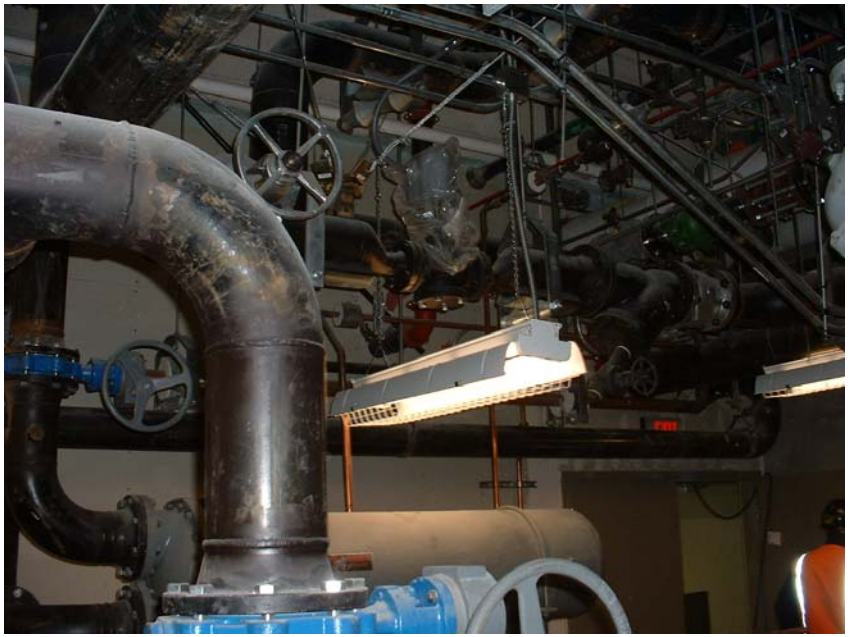
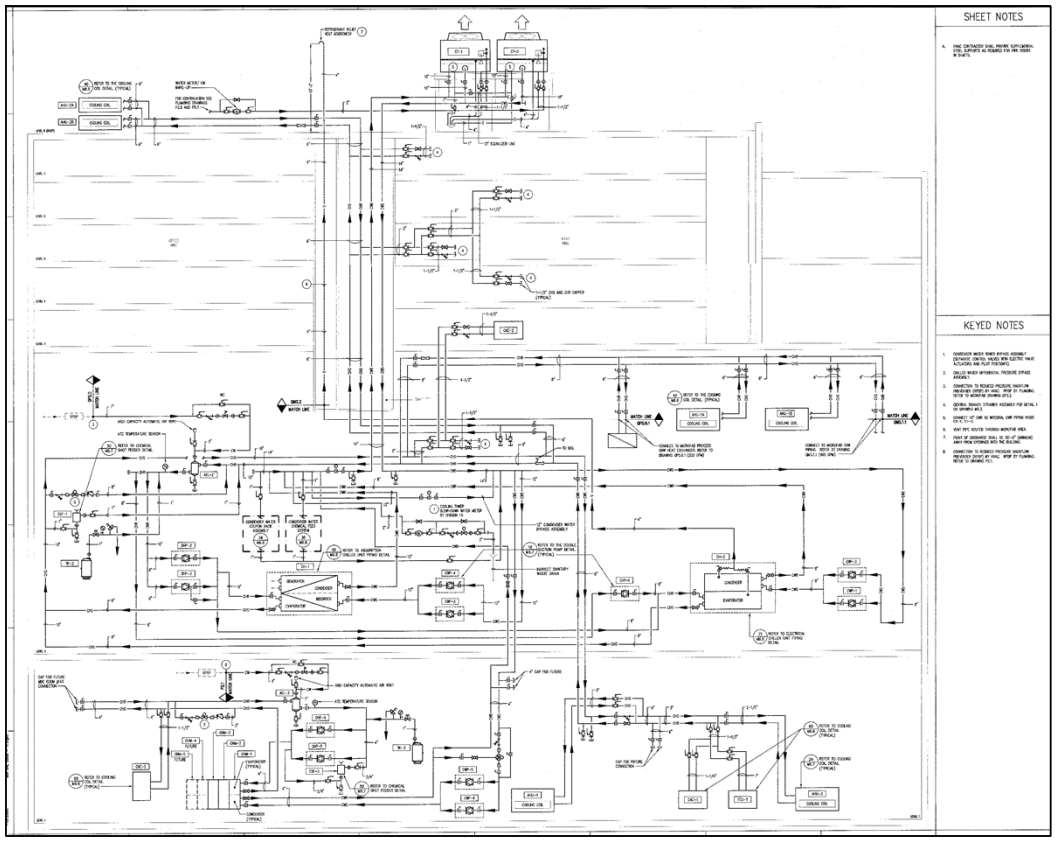
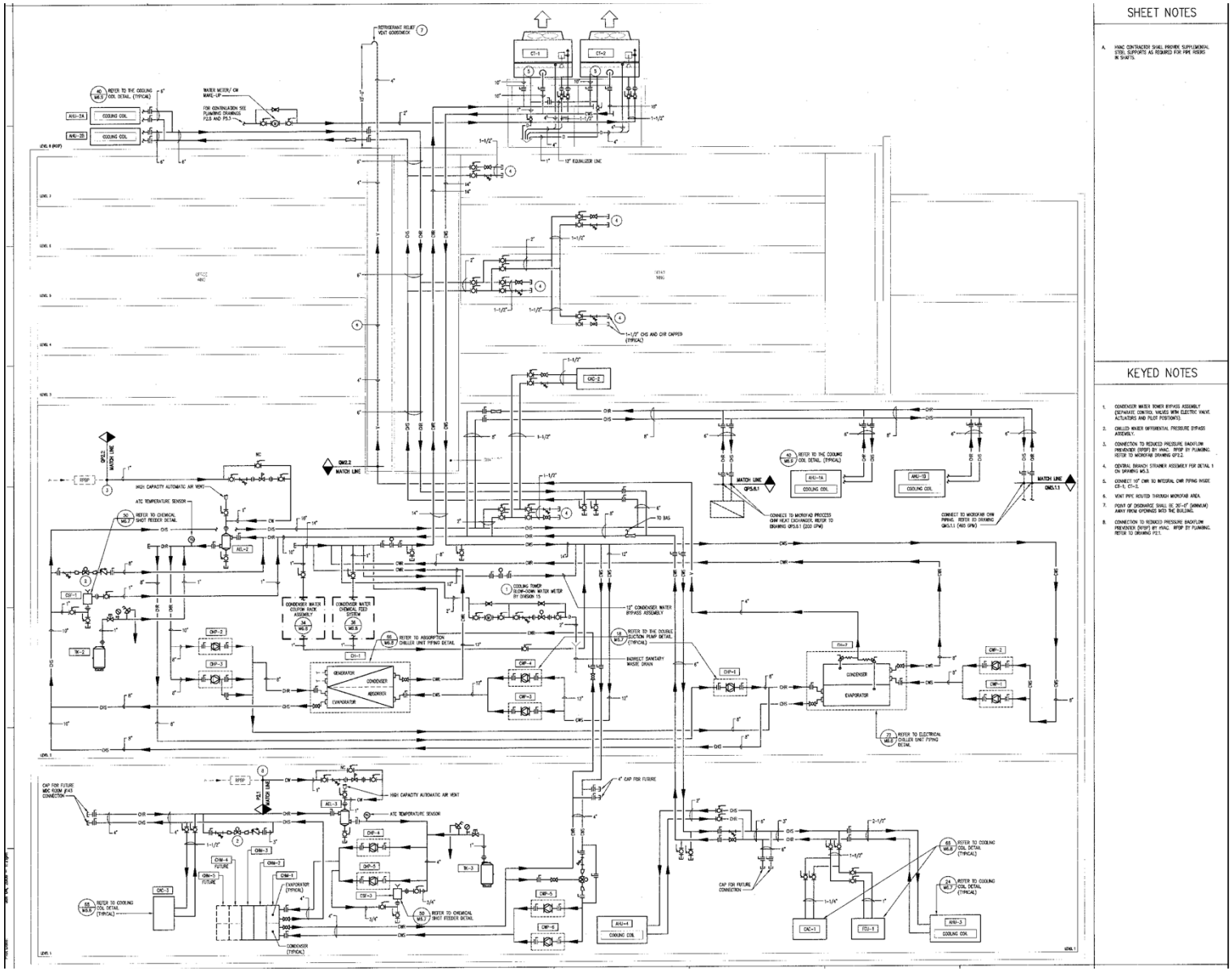





The “System Diagram” from the Drawing Set

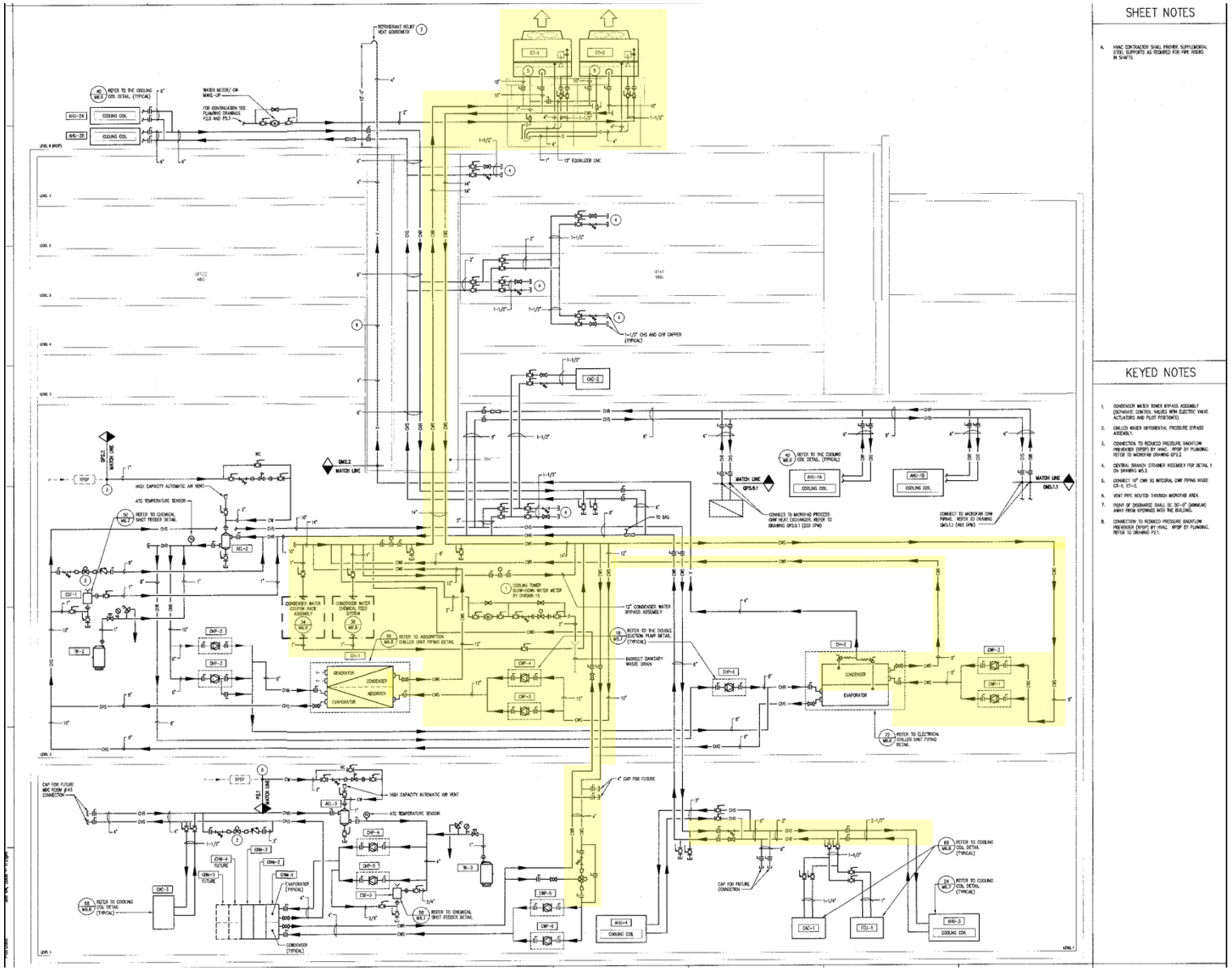


## SHEET NOTES

A. HVAC CONTRACTOR SHALL PROVIDE SUPPLEMENTAL 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 FOR DETAIL 1 ON DRAWING M3.3.
5. CONNECT OF CHW TO INTEGRAL CHW PIPING INSIDE CH-1, CT-1.
6. VENT PIPE ROUTED THROUGH MICROFAB AREA.
7. POINT OF DISCHARGE SHALL BE 30'-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.

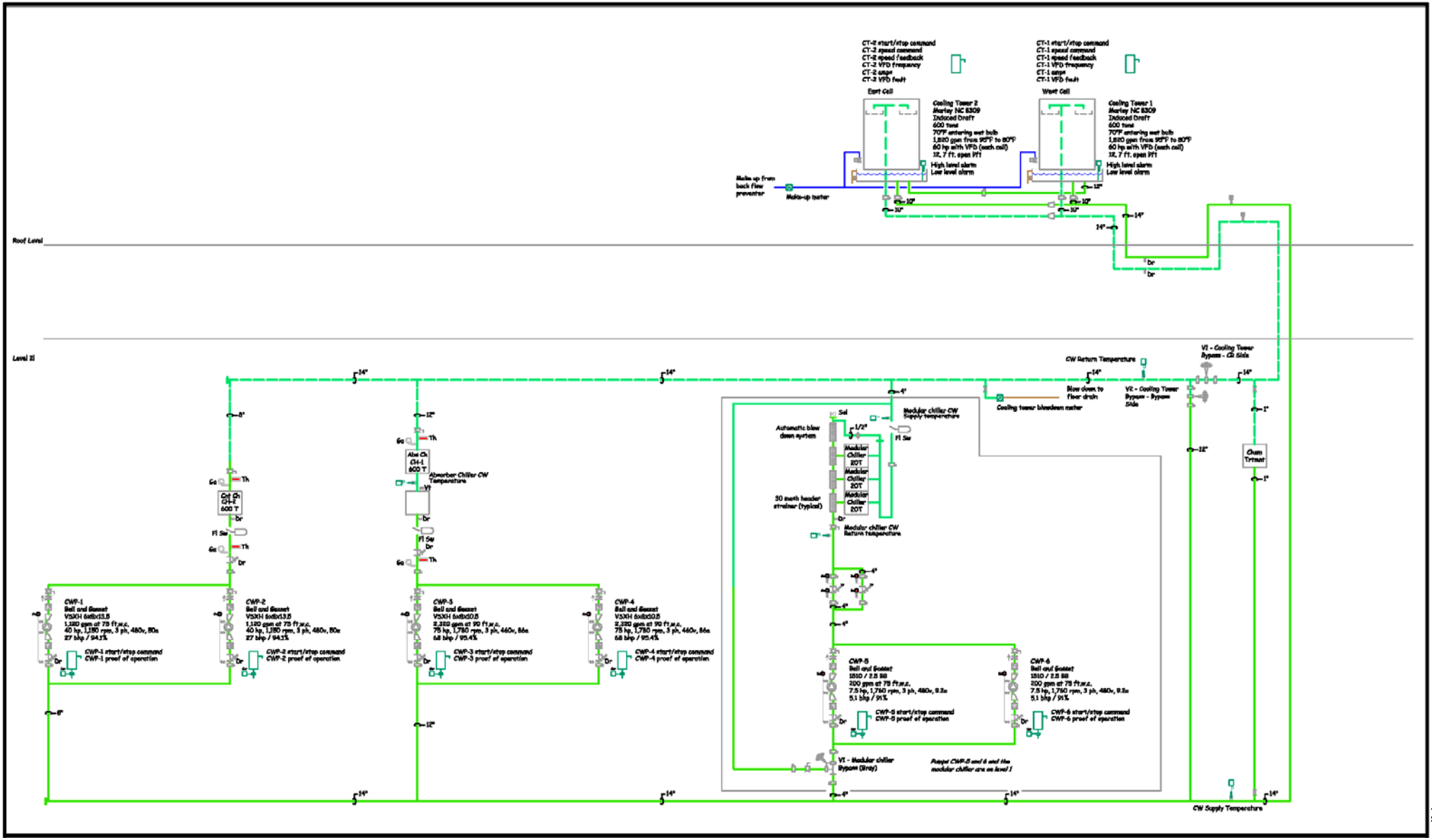


## SHEET NOTES

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

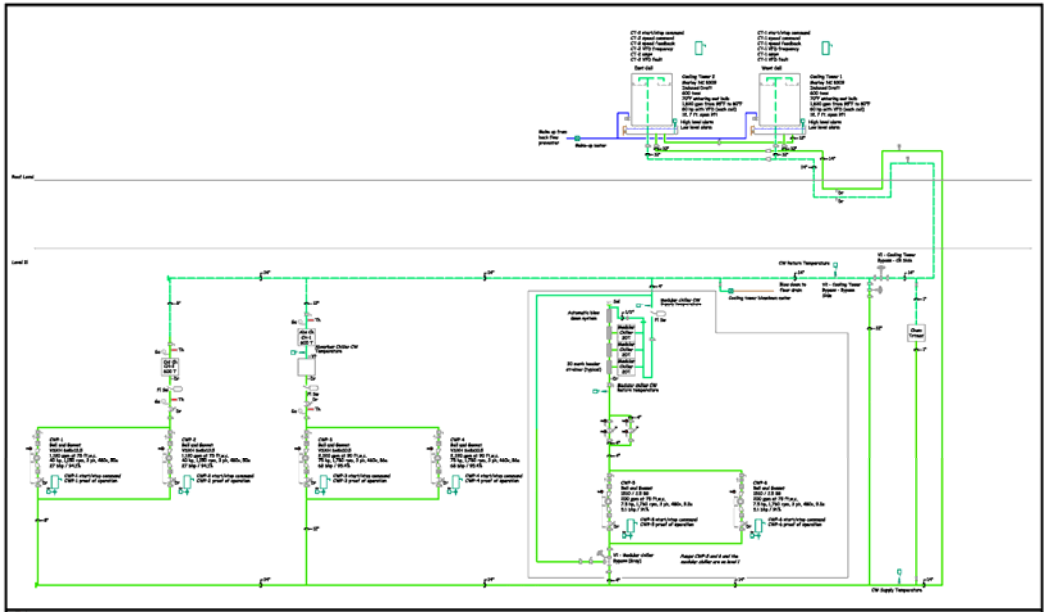
## KEYED NOTES

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 CP1.2.
4. CENTRAL BRANCH STRAINER ASSEMBLY FOR DETAIL 1 ON DRAWING MC3.
5. CONNECT HP CHW TO INTEGRAL CHW PIPING INSIDE CH-1, CT-1.
6. VENT PIPE ROUTED THROUGH MICROFAB AREA.
7. POINT OF DISCHARGE SHALL BE 30'-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.

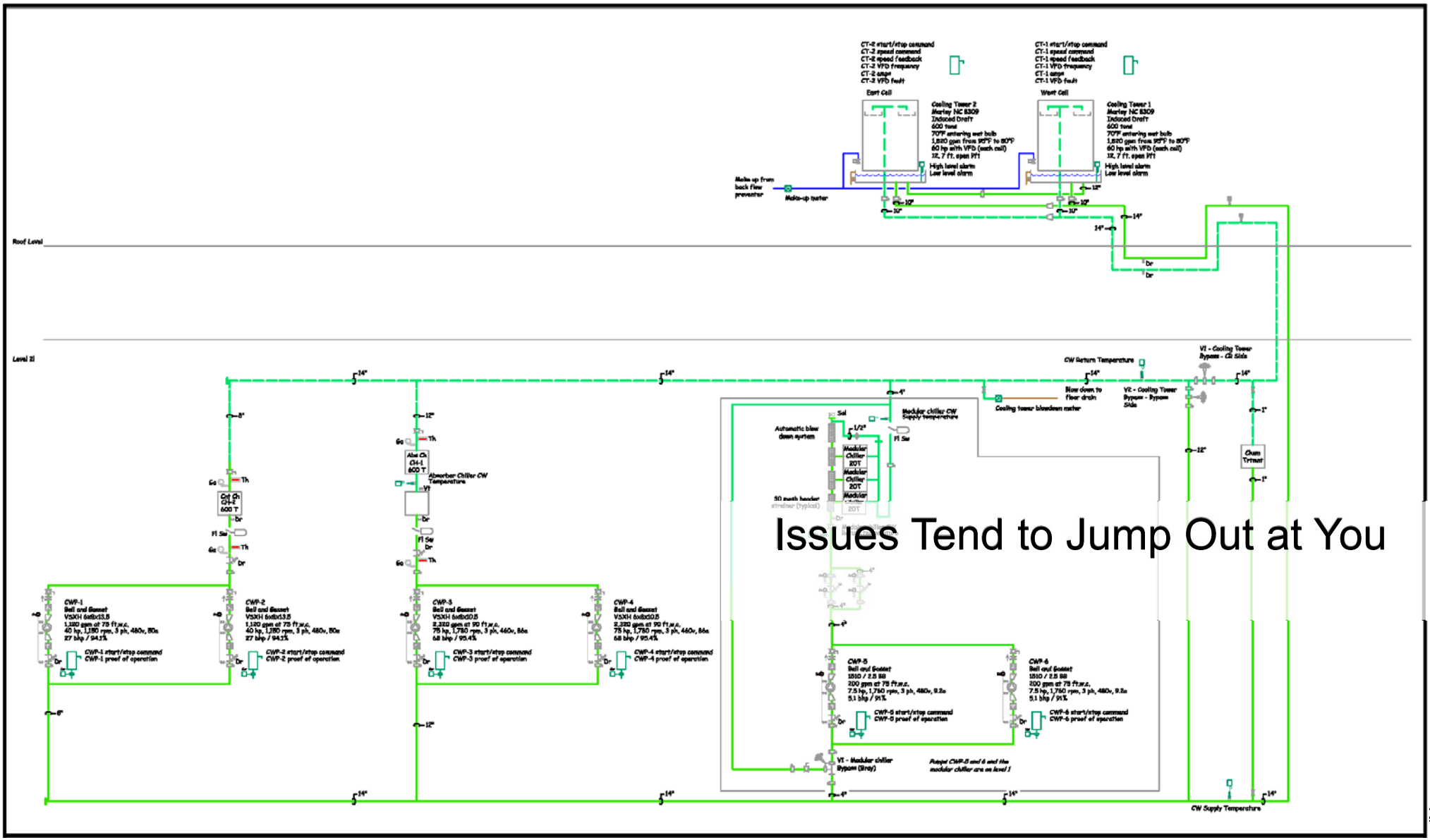

CT-2 start/stop command
CT-2 speed command
CT-2 speed feedback
CT-2 VFD frequency
CT-2 amps
CT-2 VFD fault
East Cell
Cooling Tower 2
Marley NC 8309
Induced Draft
600 tons
70°F entering wet bulb
1,820 gpm from 95°F to 80°F
60 hp with VFD (each cell)
12, 7 ft. span FFT
High level alarm
Low level alarm
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
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. span FFT
High level alarm
Low level alarm
Make up from back flow preventer
Make-up water
Roof Level
Level 2
CW Return Temperature
VI - Cooling Tower Bypass - CE Side
Blow down to floor drain
Cooling tower blowdown meter
VI - Cooling Tower Bypass - Bypass Side
Chem Trimer
Absorber Chiller CW Temperature
Modular chiller CW Supply Temperature
Automatic blow down system
30 mesh header strainer (typical)
Modular Chiller 20T
Modular Chiller 20T
Modular Chiller 20T
Modular chiller CW Return Temperature
CWP-1
Bell and Gasset
VSXH 6x8x13.5
1,820 gpm at 75 ft.w.c.
40 hp, 1,780 rpm, 3 ph, 480v, 80a
27 bhp / 94.1%
CWP-1 start/stop command
CWP-1 proof of operation
CWP-2
Bell and Gasset
VSXH 6x8x13.5
1,820 gpm at 75 ft.w.c.
40 hp, 1,780 rpm, 3 ph, 480v, 80a
27 bhp / 94.1%
CWP-2 start/stop command
CWP-2 proof of operation
CWP-3
Bell and Gasset
VSXH 6x8x20.5
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 Gasset
VSXH 6x8x20.5
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 Gasset
1510 / 2.5 SS
200 gpm at 75 ft.w.c.
7.5 hp, 1,760 rpm, 3 ph, 480v, 9.2a
5.1 bhp / 91%
CWP-5 start/stop command
CWP-5 proof of operation
CWP-6
Bell and Gasset
1510 / 2.5 SS
200 gpm at 75 ft.w.c.
7.5 hp, 1,760 rpm, 3 ph, 480v, 9.2a
5.1 bhp / 91%
CWP-6 start/stop command
CWP-6 proof of operation
VI - Modular chiller Bypass (Grey)
Pumps CWP-5 and 6 and the modular chiller are on level 1
CW Supply Temperature

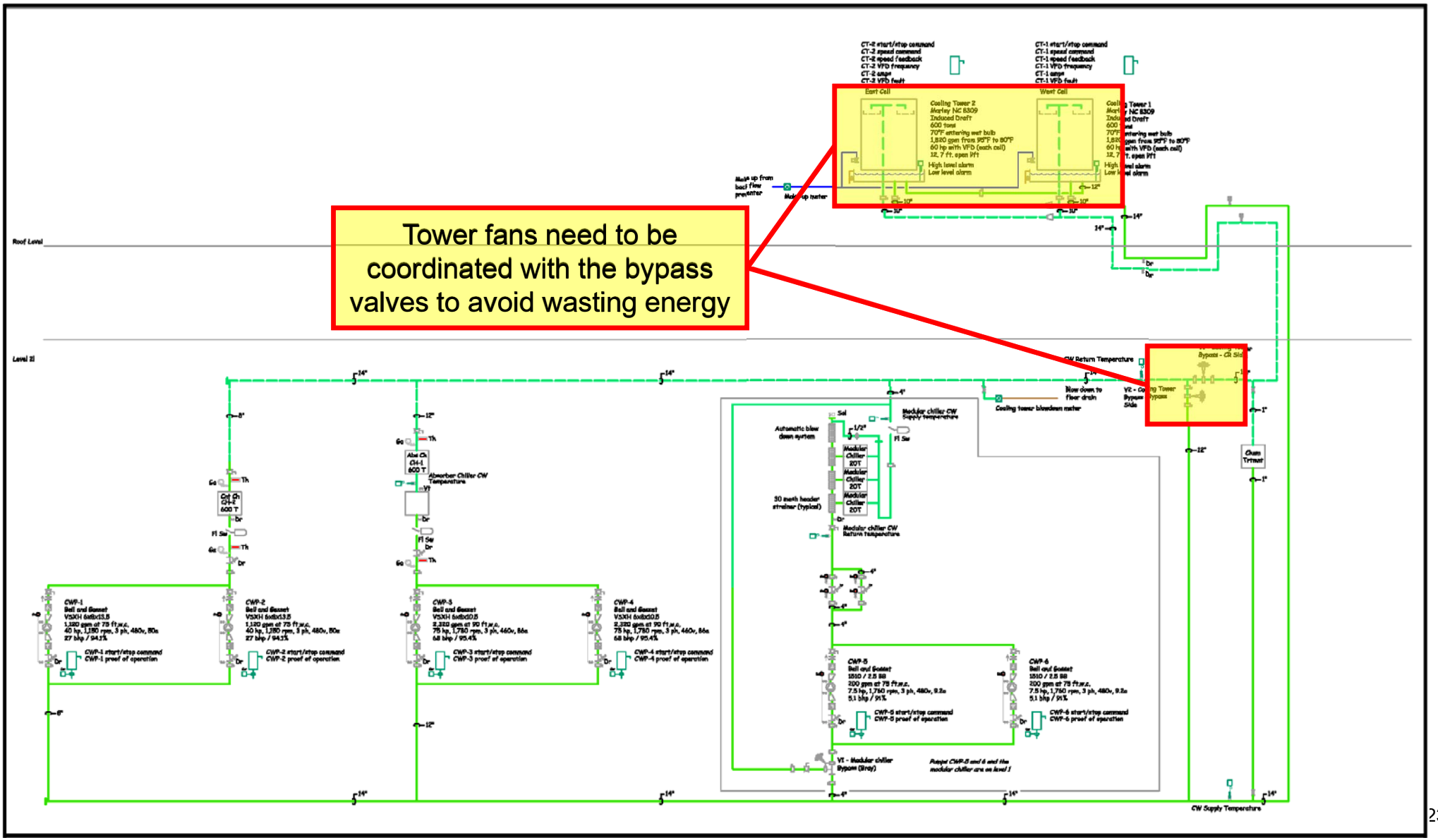
# Developing a System Diagram

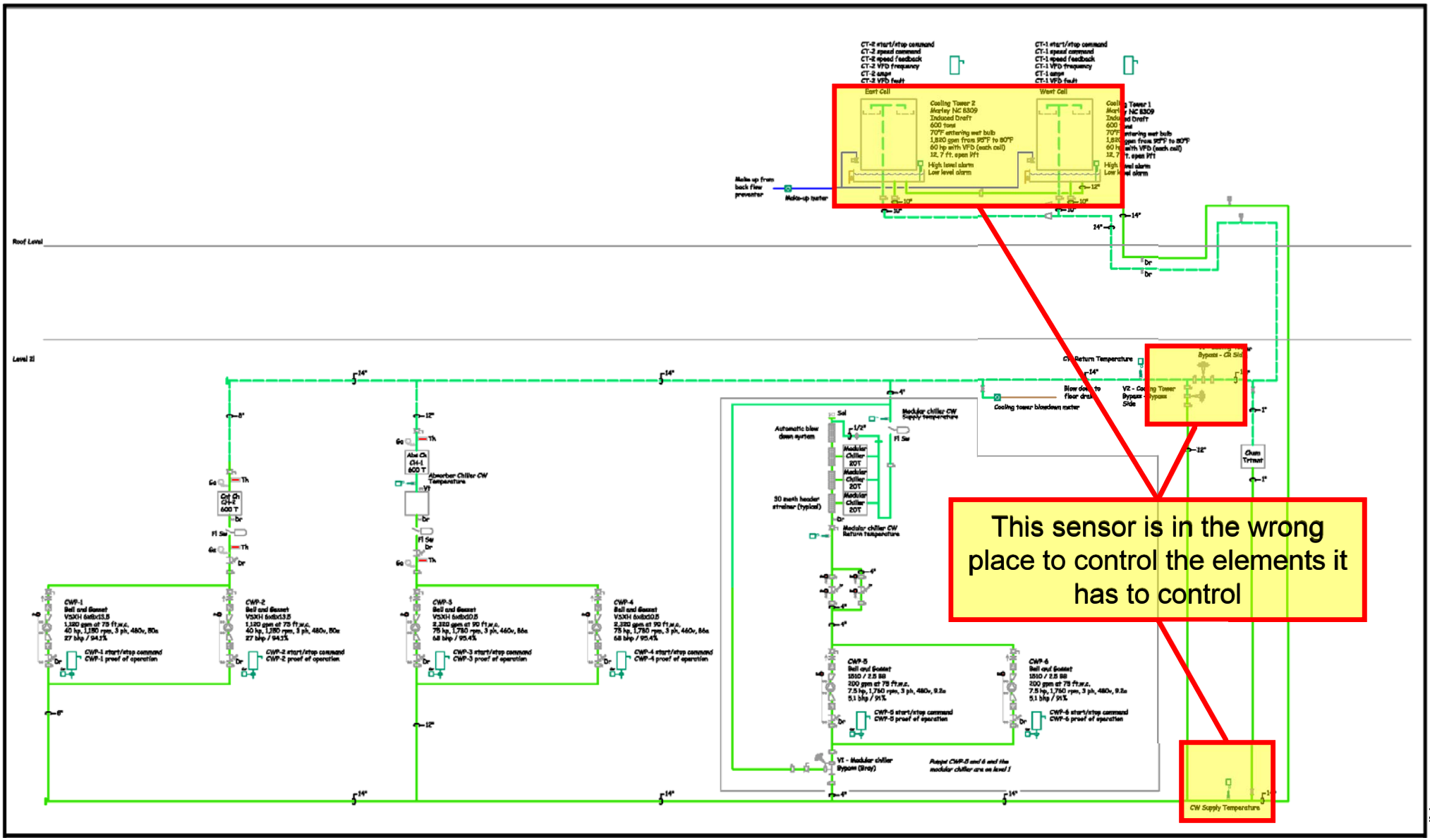
- A good way to learn the system prior to going on site
- Focusing on one system can be helpful
- “Untangling” can be helpful

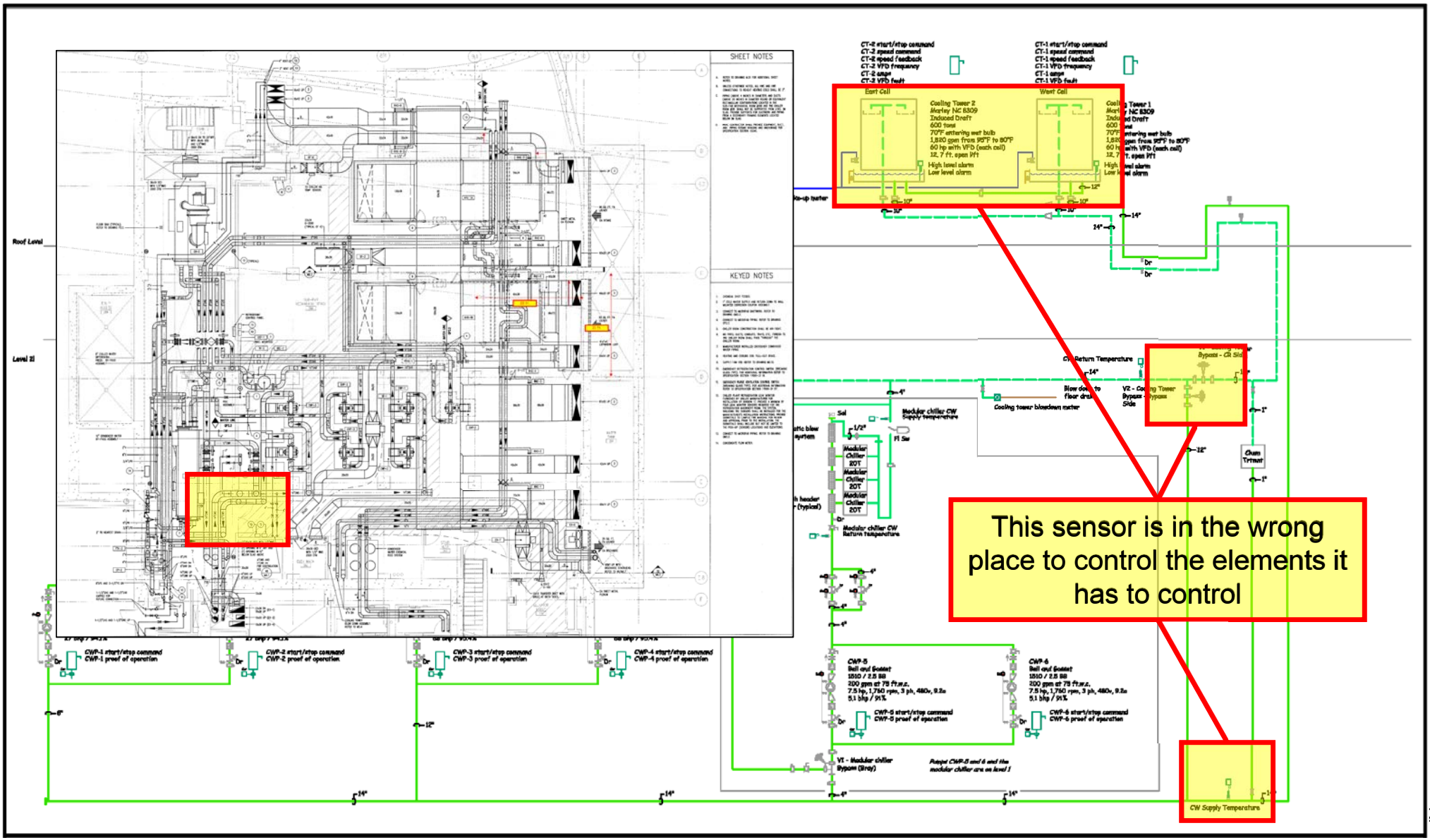


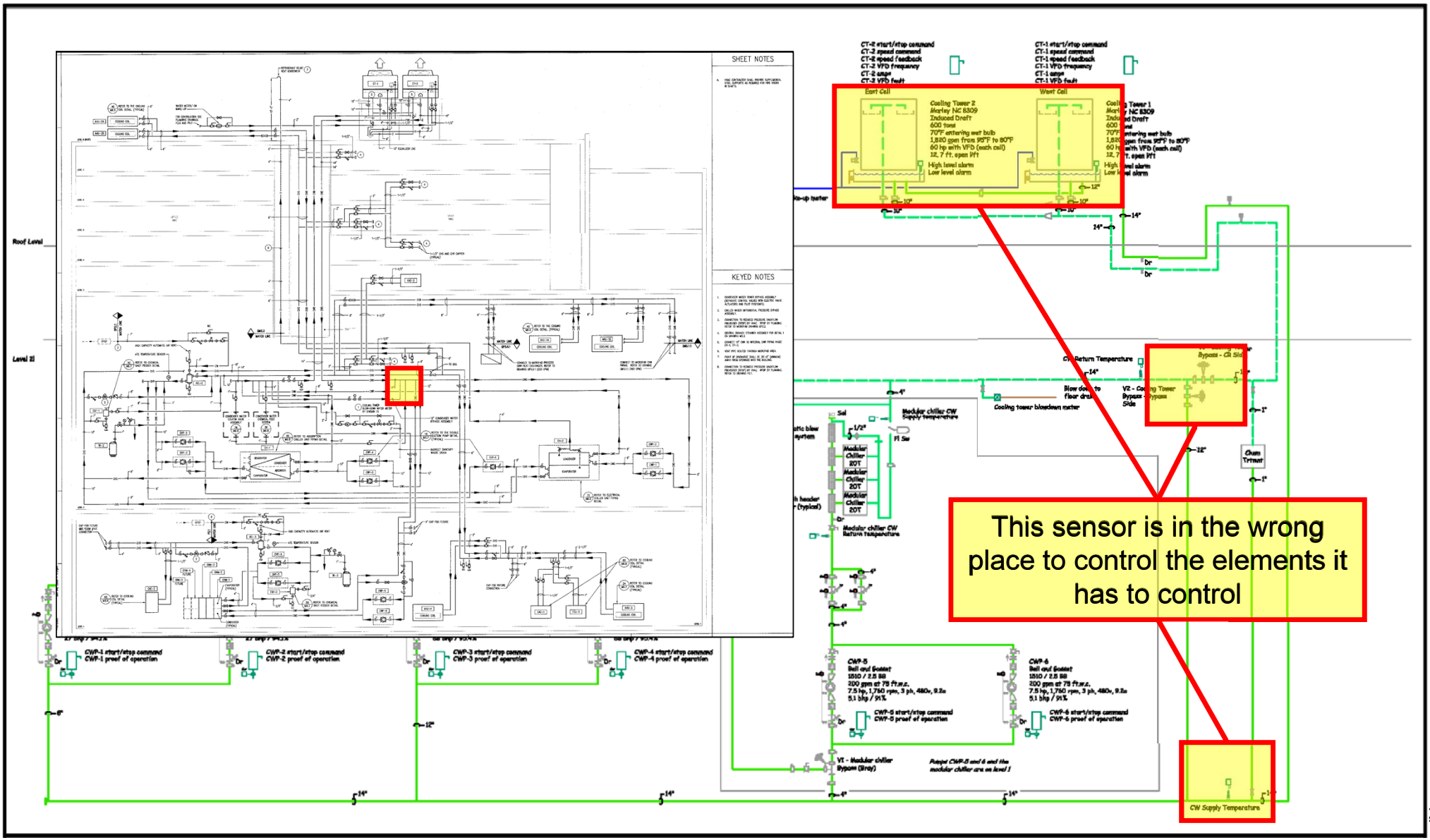
My “System Diagram” for the Condenser Water System


Roof Level
Level 2
Issues Tend to Jump Out at You


Tower fans need to be coordinated with the bypass valves to avoid wasting energy
Roof Level
Level 2
CW Return Temperature
Blow down to floor drain
Cooling tower blowdown meter
Automatic blow down system
Modular chiller CW Supply temperature
Modular chiller CW Return temperature
30 mesh header strainer (typical)
Absorber Chiller CW Temperature
CW Supply Temperature
Chem Trimer
CWP-1
CWP-2
CWP-3
CWP-4
CWP-5
CWP-6
Pumps CWP-5 and 6 and the modular chiller are on level 1


Roof Level
Level 2
Cooling Tower 2
Marley NC 8309
Induced Draft
600 tons
Cooling Tower 1
Marley NC 8309
Induced Draft
600 tons
Make up from back flow preventer
Make-up water
Cooling tower blowdown meter
Automatic blow down system
30 mesh header strainer (typical)
Modular chiller CW Supply temperature
Modular chiller CW Return temperature
Modular Chiller 20T
Modular Chiller 20T
Modular Chiller 20T
CWP-1
CWP-2
CWP-3
CWP-4
CWP-5
CWP-6
Absorber Chiller CW Temperature
Chem Trimer
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 2
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. span Pft
High level alarm
Low level alarm
Cooling tower blowdown meter
Modular chiller CW Supply temperature
Modular chiller CW Return temperature
Modular Chiller 20T
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 Gosset
1510 / 2.5 SB
200 gpm at 75 ft.w.c.
7.5 hp, 1,760 rpm, 3 ph, 480v, 9.2a
5.1 bhp / 91%
CWP-6
CWP-5 start/stop command
CWP-5 proof of operation
CWP-6 start/stop command
CWP-6 proof of operation
V1 - Modular chiller Bypass (Grey)
Pumps CWP-5 and 6 and the modular chiller are on level 1
CW Return Temperature
Bypass - CR Side
V2 - Cooling Tower Bypass - Bypass Side
Chem Trimer
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 2
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Cooling Tower 2
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Modular chiller CW Supply Temperature
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Modular Chiller 20T
Modular Chiller 20T
Modular Chiller 20T
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 Gosset
1510 / 2.5 SS
200 gpm at 75 ft.w.c.
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CWP-5 start/stop command
CWP-5 proof of operation
CWP-6
Bell and Gosset
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7.5 hp, 1,760 rpm, 3 ph, 480v, 9.2a
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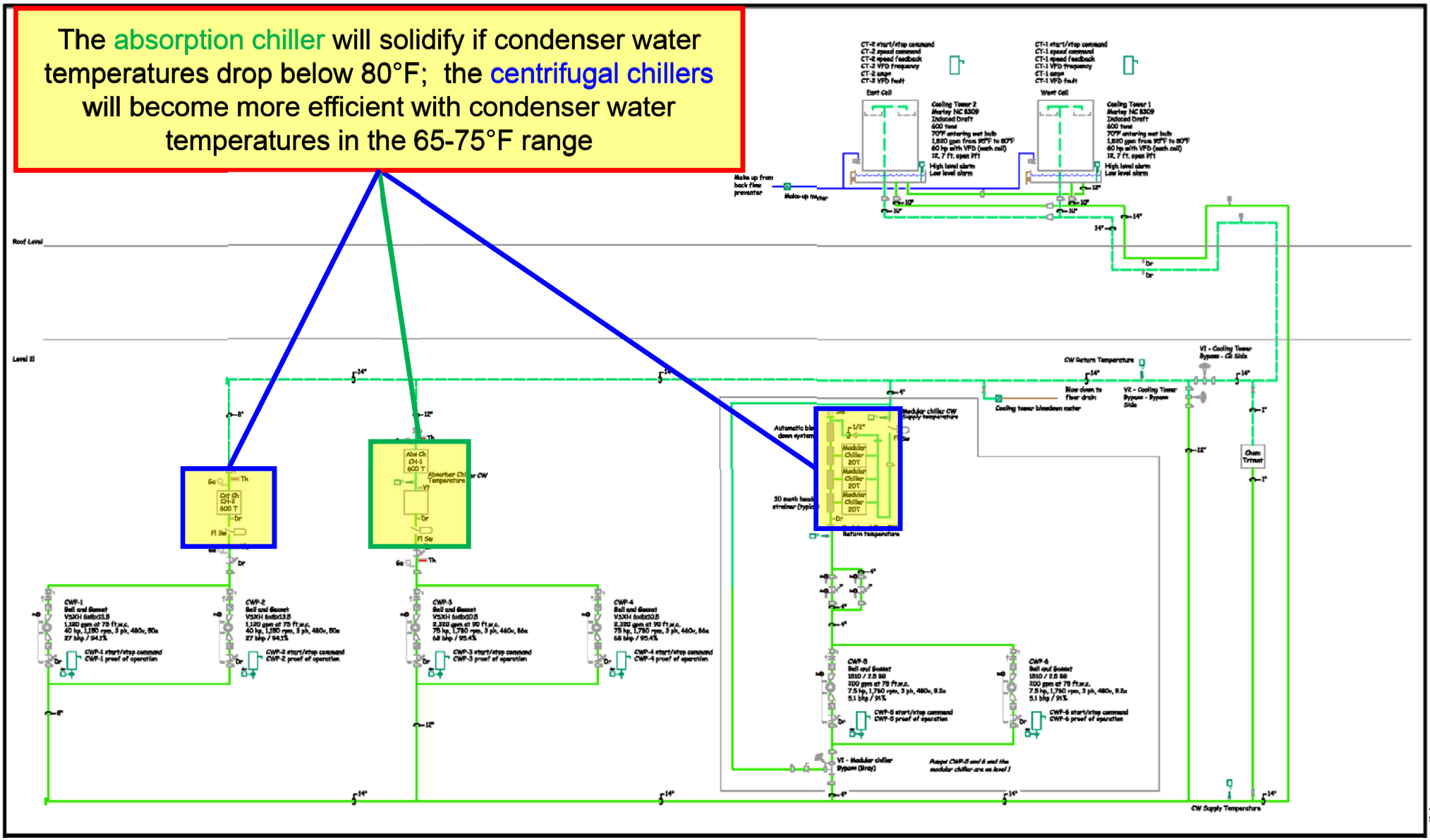
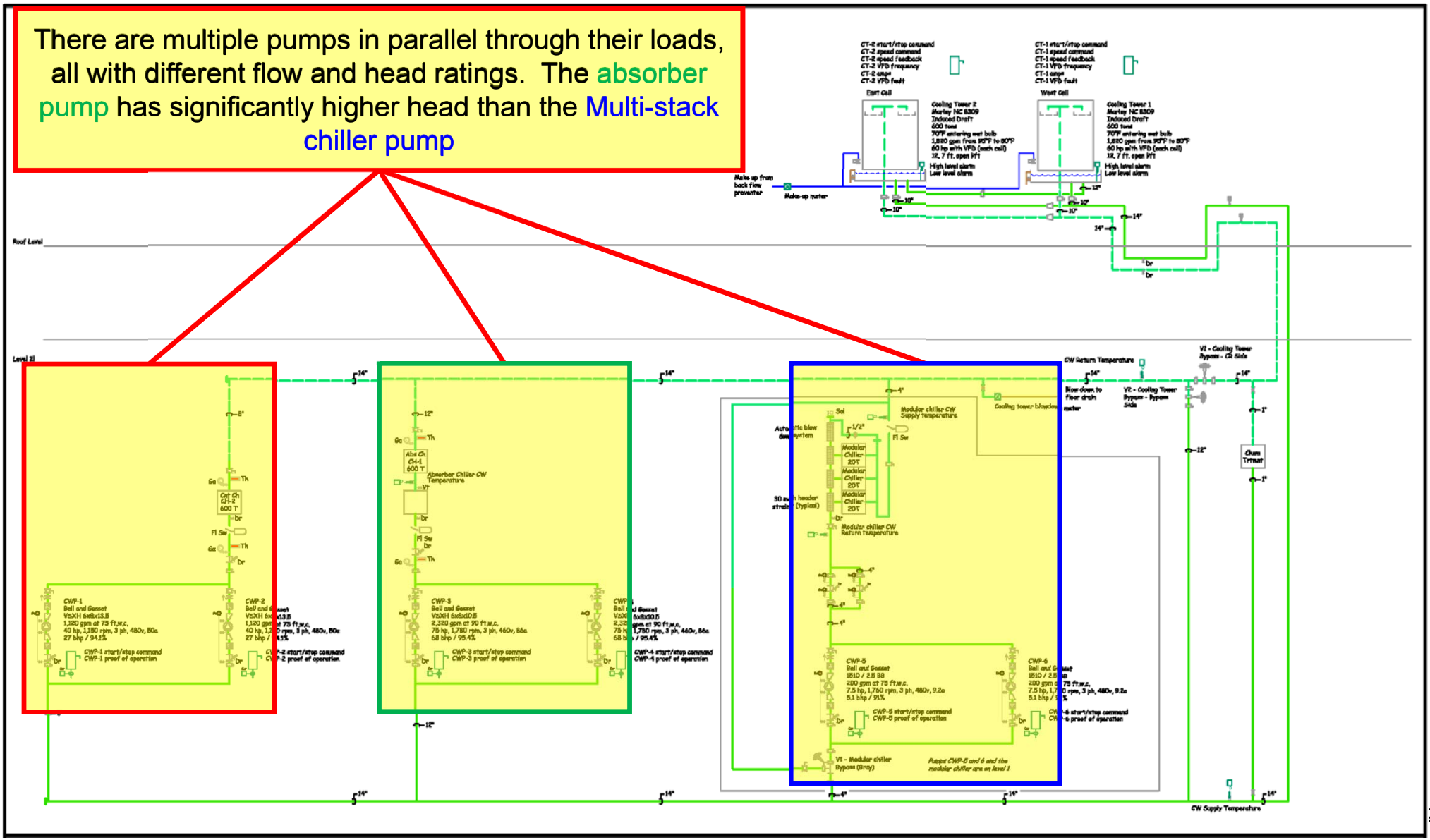
CWP-6 start/stop command
CWP-6 proof of operation
V1 - Modular chiller Bypass (Grey)
Pumps CWP-5 and 6 and the modular chiller are on level 1
CW Supply Temperature
This sensor is in the wrong place to control the elements it has to control

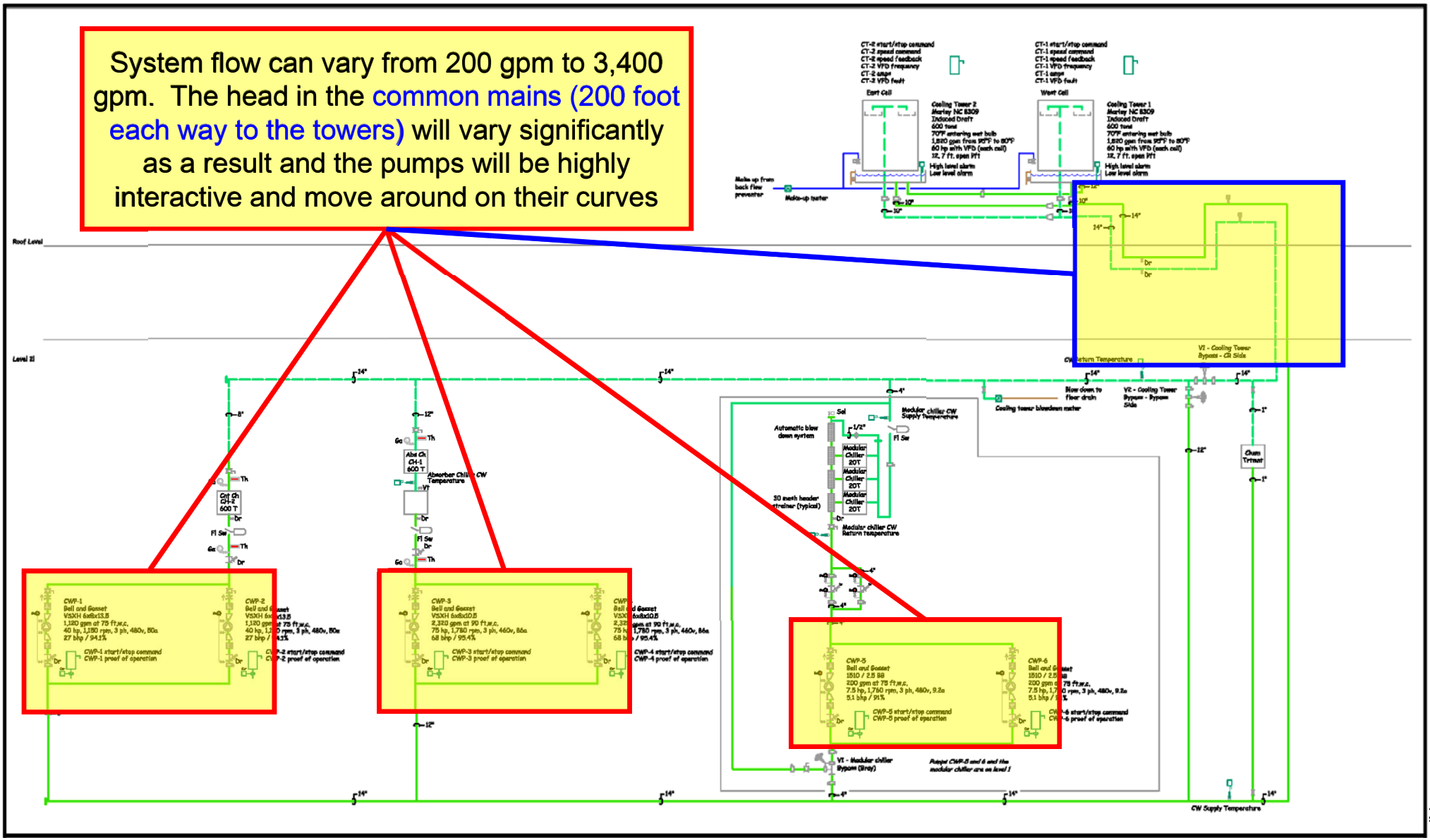
The absorption chiller will solidify if condenser water temperatures drop below 80°F; the centrifugal chillers will become more efficient with condenser water temperatures in the 65-75°F range

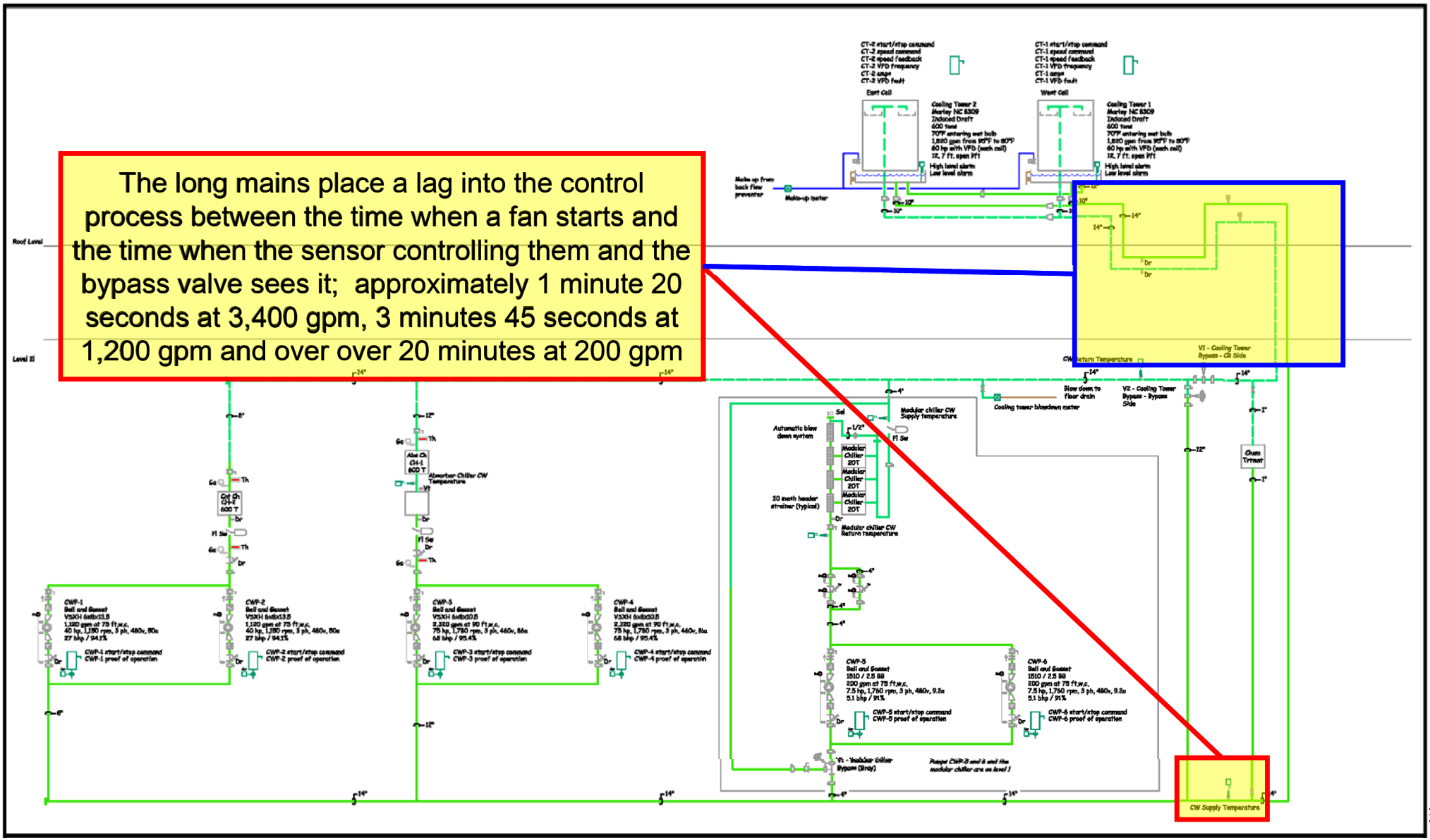


There are multiple pumps in parallel through their loads, all with different flow and head ratings. The absorber pump has significantly higher head than the Multi-stack chiller pump

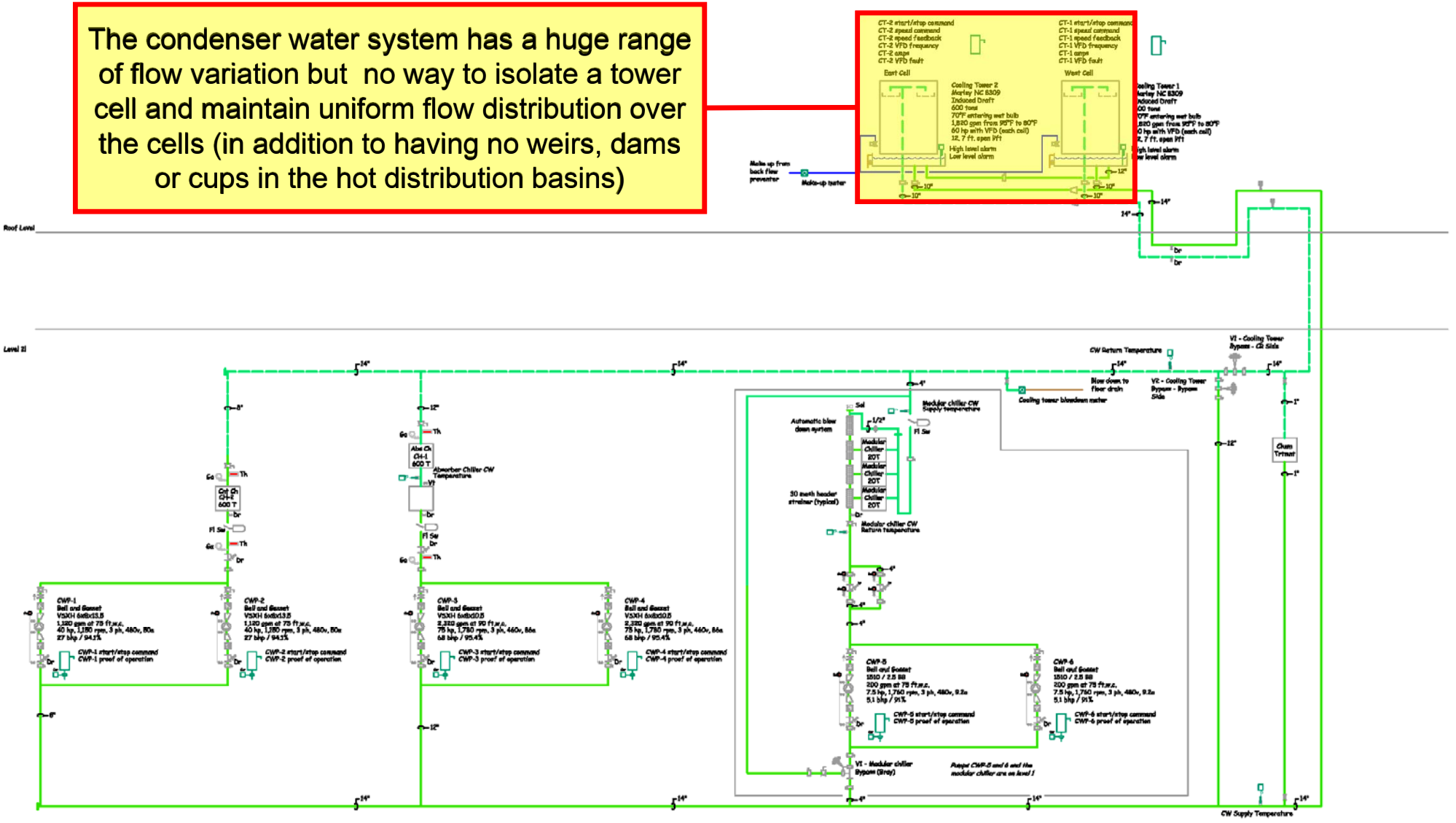


System flow can vary from 200 gpm to 3,400 gpm. The head in the common mains (200 foot each way to the towers) will vary significantly as a result and the pumps will be highly interactive and move around on their curves

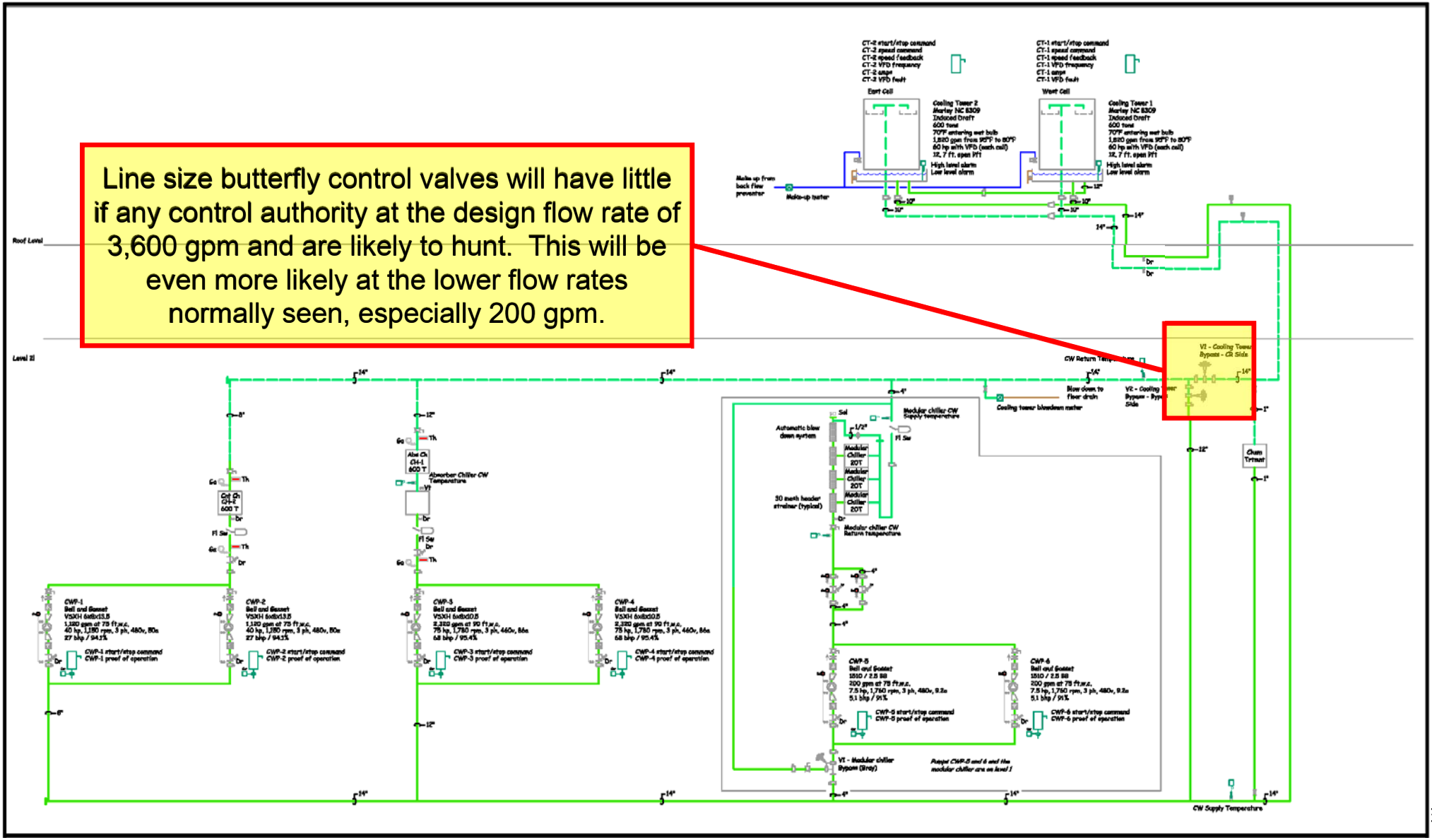



The long mains place a lag into the control process between the time when a fan starts and the time when the sensor controlling them and the bypass valve sees it; approximately 1 minute 20 seconds at 3,400 gpm, 3 minutes 45 seconds at 1,200 gpm and over over 20 minutes at 200 gpm
Roof Level
Level 2
CW Supply Temperature

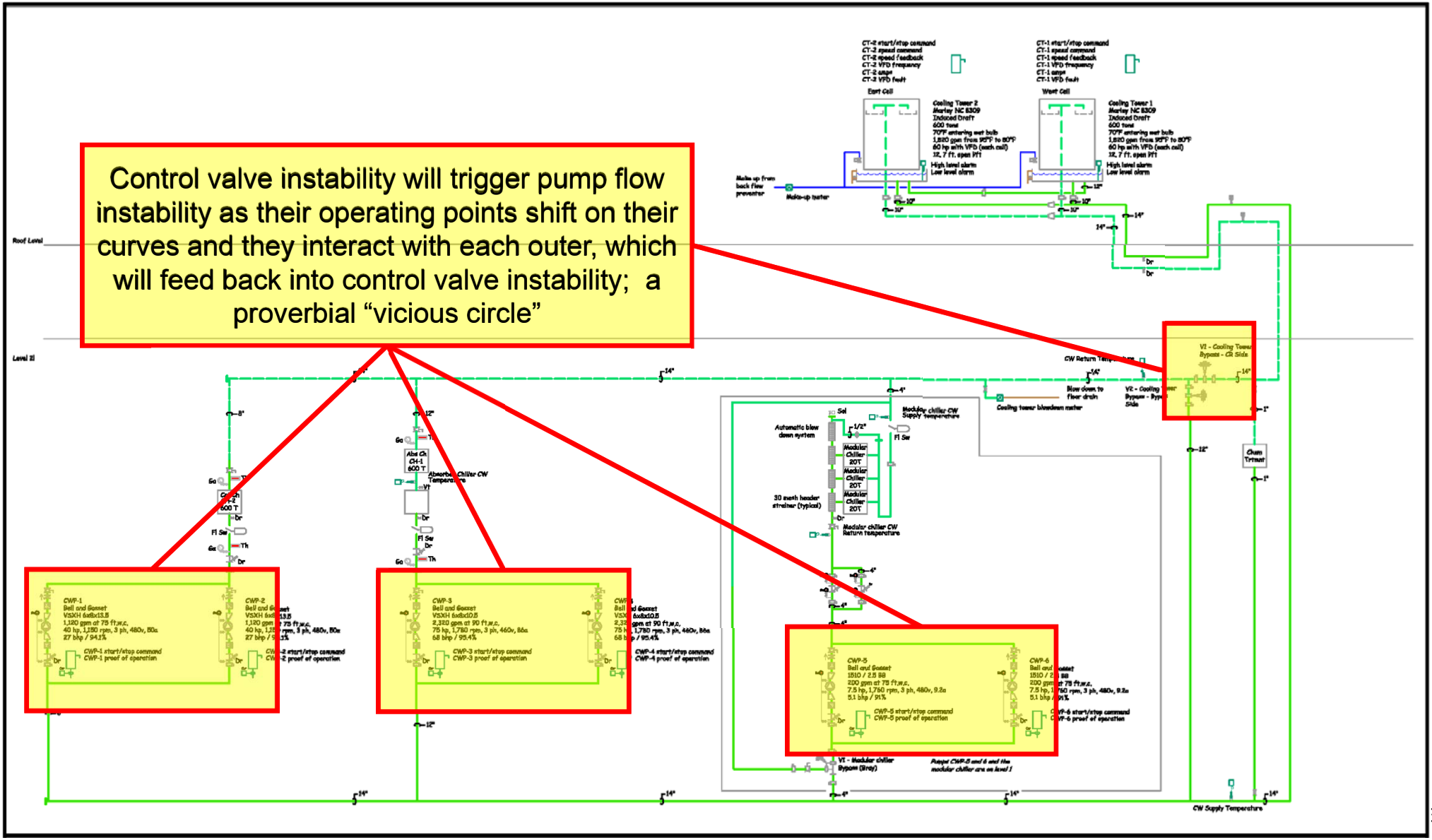
The condenser water system has a huge range of flow variation but no way to isolate a tower cell and maintain uniform flow distribution over the cells (in addition to having no weirs, dams or cups in the hot distribution basins)



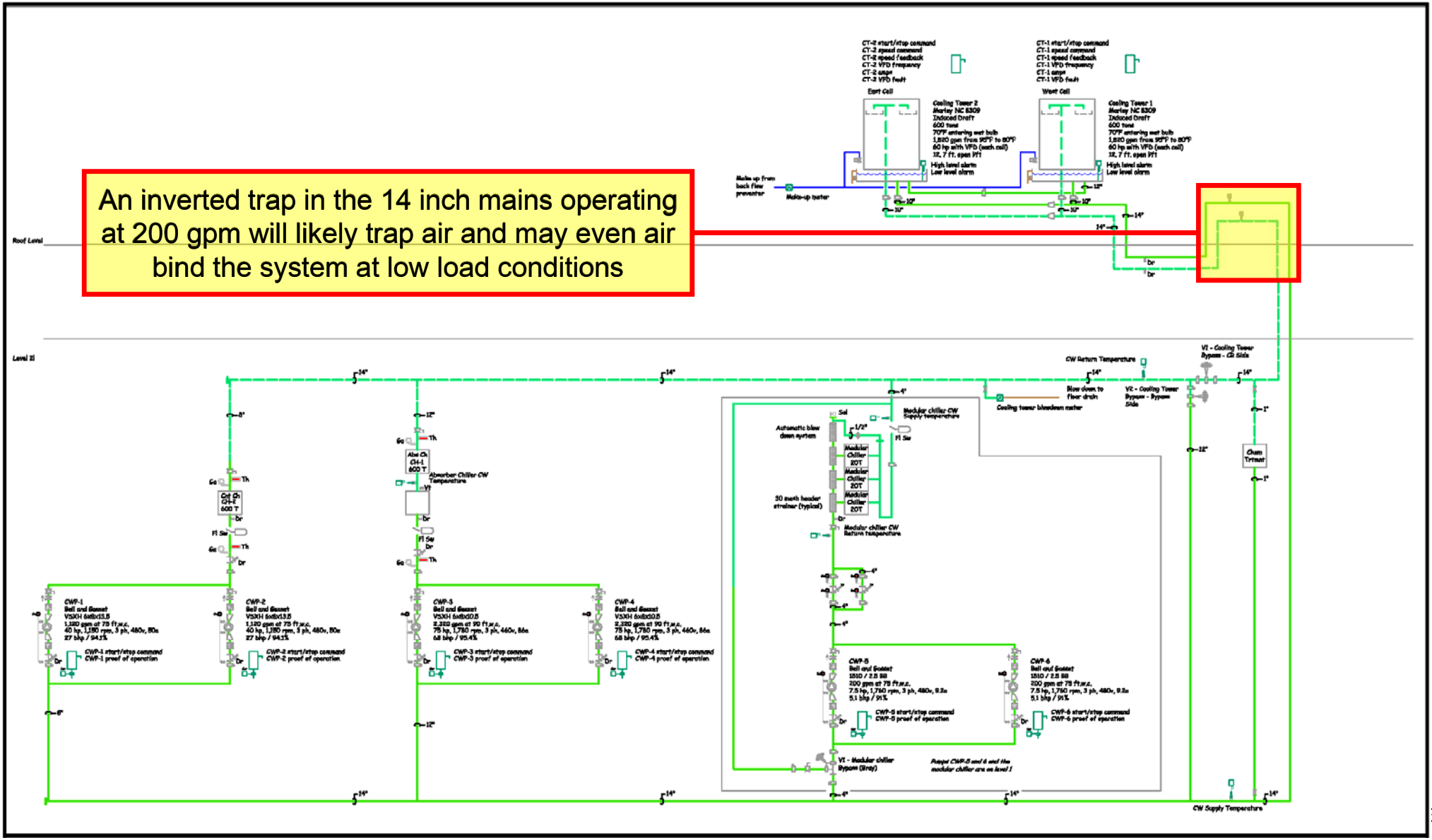
Line size butterfly control valves will have little if any control authority at the design flow rate of 3,600 gpm and are likely to hunt. This will be even more likely at the lower flow rates normally seen, especially 200 gpm.



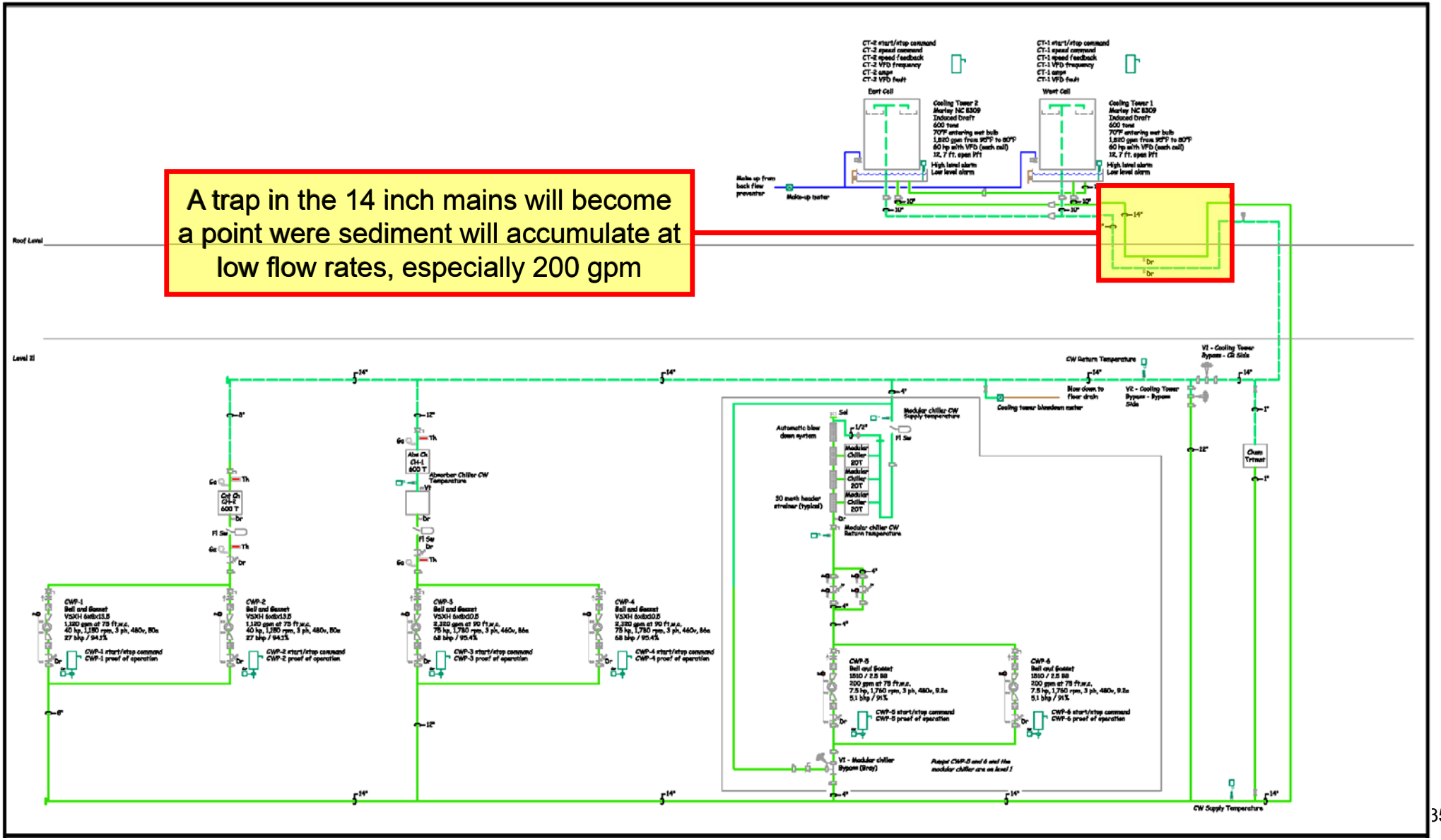
Control valve instability will trigger pump flow instability as their operating points shift on their curves and they interact with each outer, which will feed back into control valve instability; a proverbial “vicious circle”



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

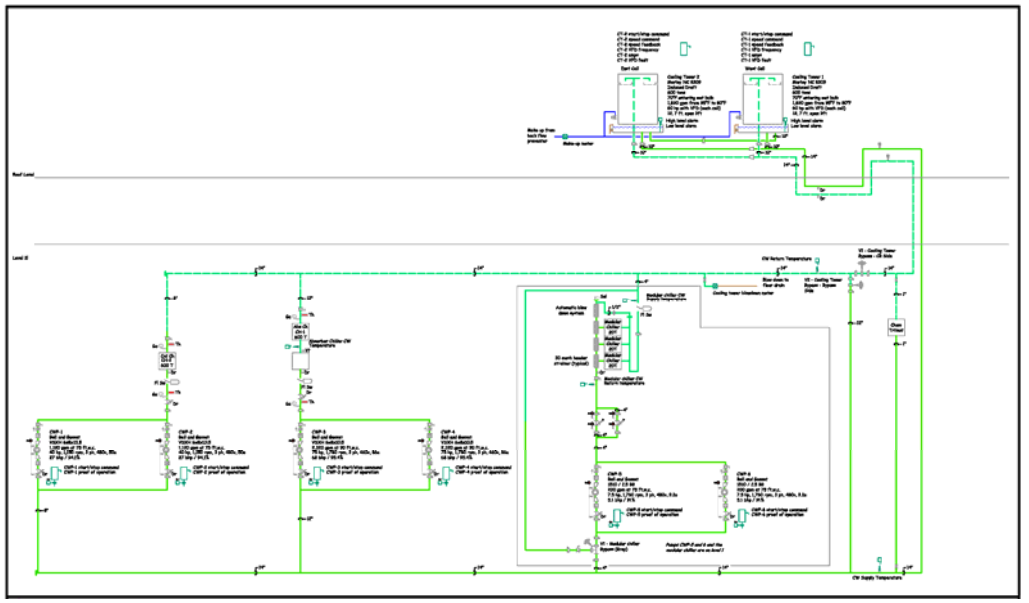


A trap in the 14 inch mains will become a point were sediment will accumulate at low flow rates, especially 200 gpm



# 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/