WELCOME

David Sellers; Senior Engineer, Facility Dynamics Engineering

Commissioning Heat Pump Systems: Existing Buildings

May 28, 2024

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Safety

Earthquake:
Drop
Cover
Hold

Evacuation Plan

Review Emergency Plan
& Pack Go-Bag

Stretch,
Get Up & Move

Visit: www.pge.com/emergencypreparedness

Class Survey coming…

At the end of this class, we'll share a class survey. We'd love to hear your feedback and if the class met your expectations. Your comments will help us improve future classes.

Class Survey

The survey should only take 2 minutes and your responses can be confidential.

Here's how to participate:

- Click the provided link: https://www.surveymonkey.com/r/EWB20240528CHP
  Scan the QR code with your phone's camera

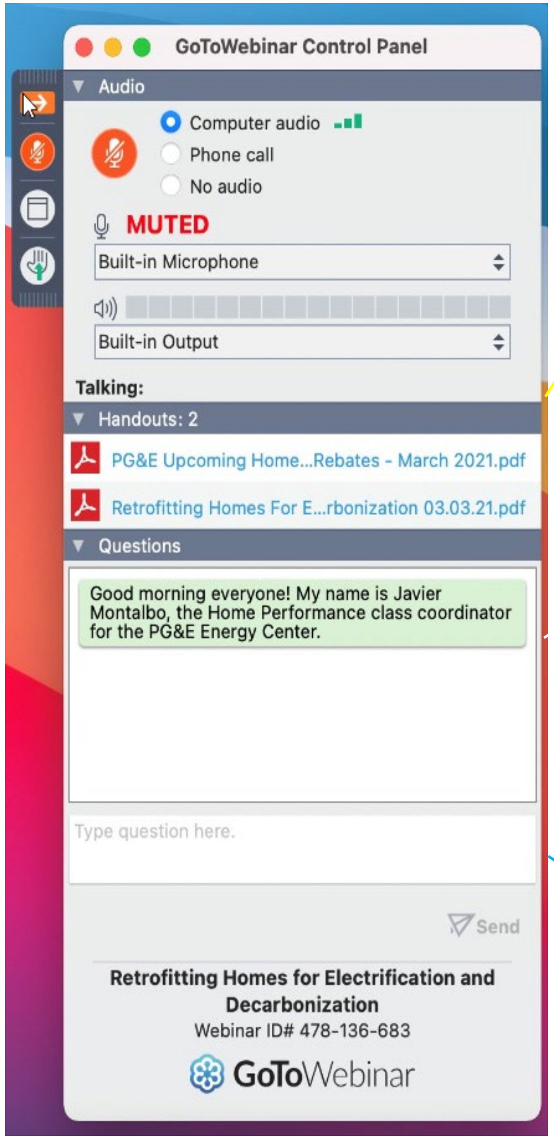
Using GoTo Webinar

- On the right-hand side of the GoTo panel you will find:

Handouts Tab

In-Class Resources

Questions Tab



Click the links to download today's course materials

Access links to in-class resources & the class survey in the 'Questions' pane

Let's engage! Type your questions in the text box.

Introduction

Today's Agenda

1. Introduction
2. Previously on Commissioning Heat Pump Systems
3. A Closer Look at Functional Testing for a Water Source Heat Pump Loop in a New Construction Process
4. The Existing Building Commissioning Process
5. Case Studies
   - Retrocommissioning a Water Source Heat Pump Loop
   - A Common VRF System Commissioning Issue (time permitting)

A Bit About Me

(See Module 1 and the Bio on the PG&E Training Site for Details)

A Senior Engineer for Facility Dynamics Engineering Focusing On:

- EBCx
- NCx Support
- Hands-on Technical Training
- System Analysis
- Control System Design

I Will Tend to Discuss Things in the RCx/Re-Cx/OCx Context (a.k.a Operating the Building Properly)

Resources

(See Module 1 for Details)

© Brother Placid Sellers; Saint Vincent Archabbey, Latrobe, Pennsylvania

What's New?

Search

Buildings are Talking to Us

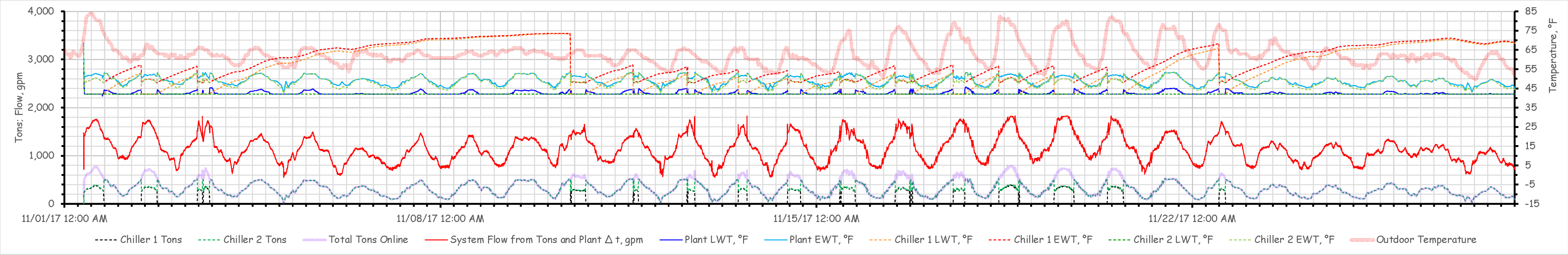
We Just Need to Learn How to Listen

My Goal

Previously on Commissioning Heat Pump Systems

My Biggest Lesson from the Very Start

Its All About the Load Profile



My Biggest Lesson from the Very Start

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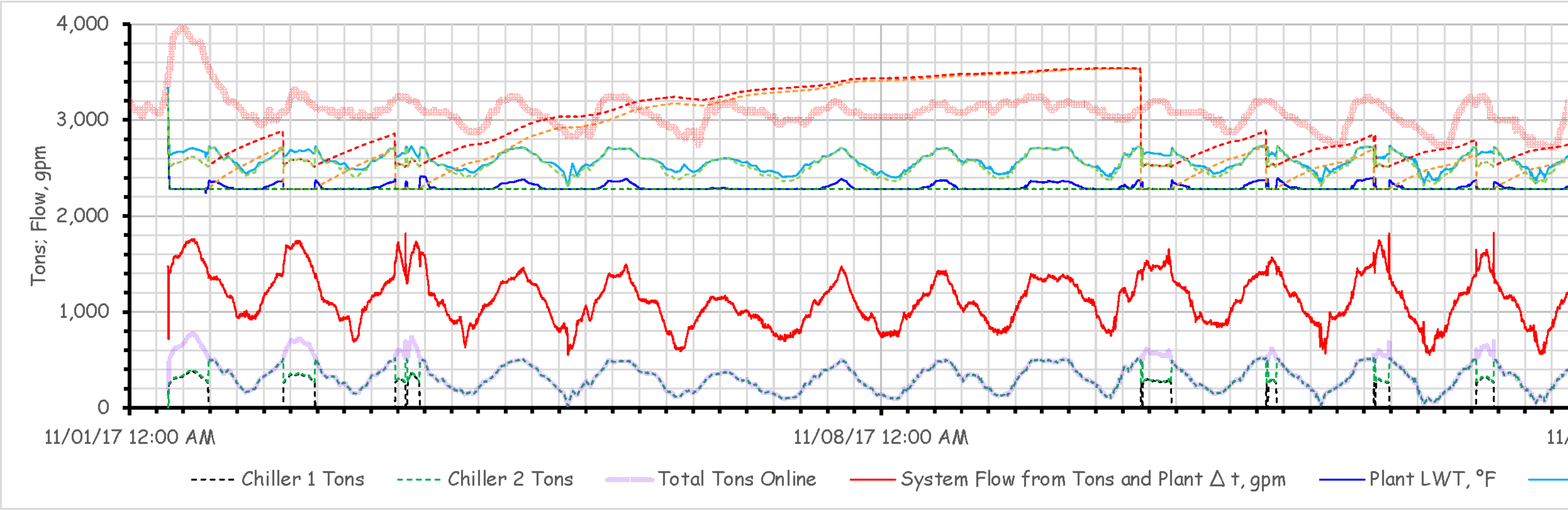

A Common Industry Definition of Commissioning

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the Owner's operational needs

- Begins in predesign
- Documents the design intent
- Continues through construction, acceptance, the warranty period, and through the building's life cycle
- Includes functional testing
- Includes training
- Documents performance

Ultimately, commissioning is about performance and integration

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Introduction to Heat Pumps (1st Module)

A Few Definitions

Heat Pump

- A heat pump extracts heat from a source and transfers it to a sink at a higher temperature

2020 ASHRAE Handbook of Systems and Equipment, Chapter 9

Common Examples of Heat Pumps

Air Conditioner

Refrigerator

Common Examples of Heat *Pumps*

The "pump" term is important

- Energy naturally flows from Hot to Cold

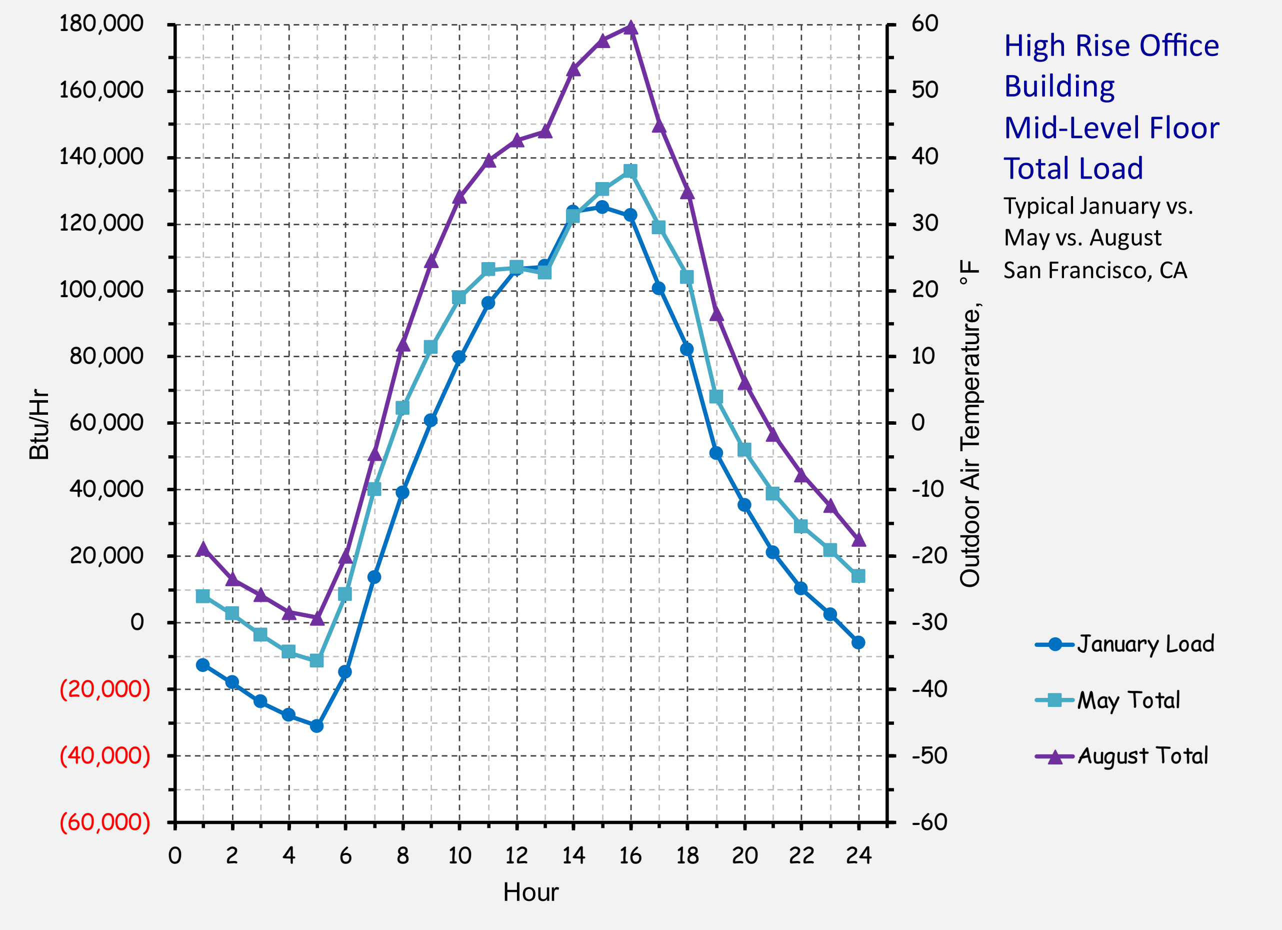
  Heat pumps move heat in the opposite direction

- They don't create energy; they use energy to move additional energy from a Cold Location to a Hot Location

https://tinyurl.com/HeatPumpBlogPost

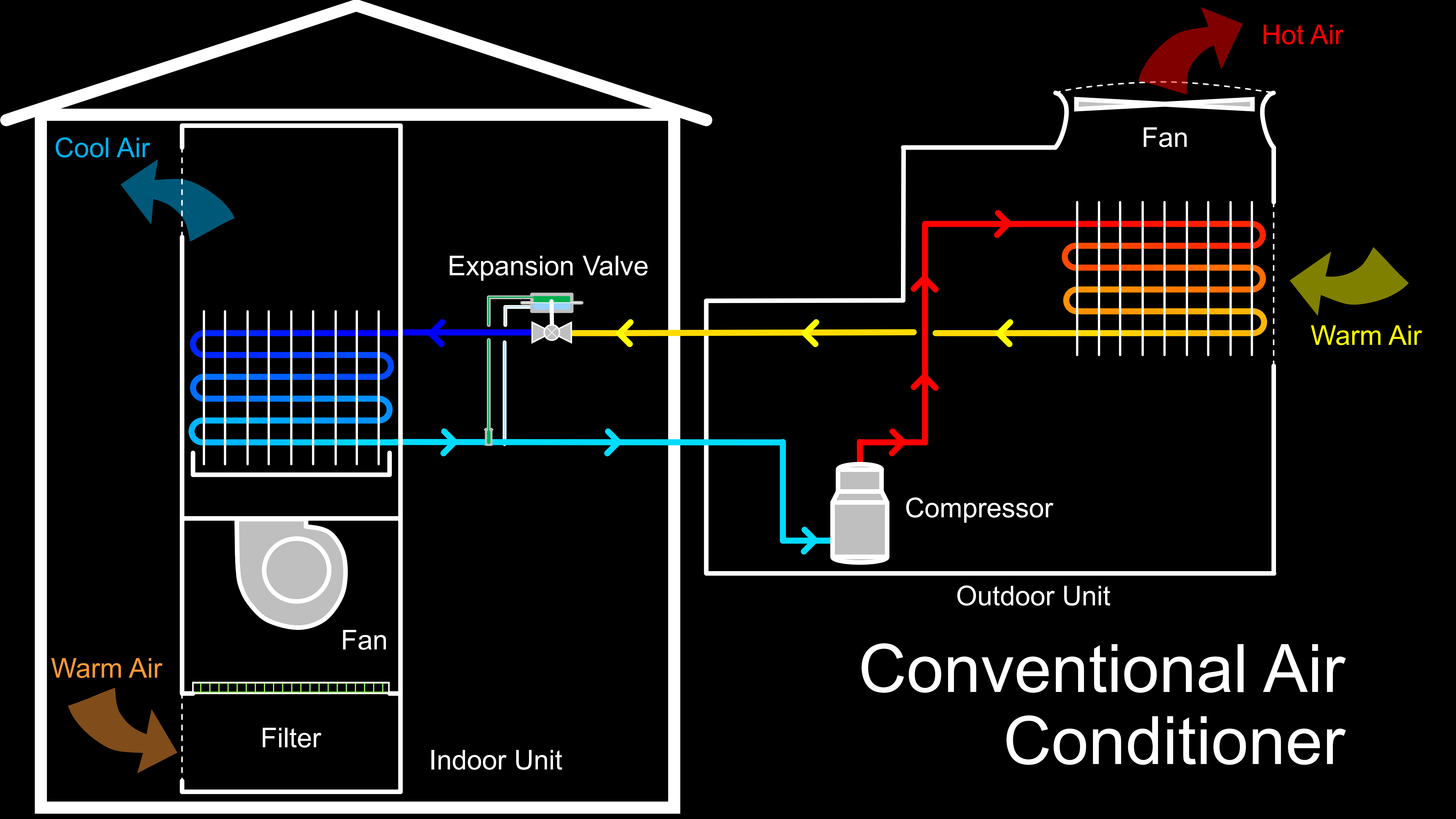
Bottom Line

- Modern buildings generate a lot of heat
- Heat pumps allow us to move that heat from where it is not needed to where it is needed
- Economizer processes may be throwing away the heat we would like to recover

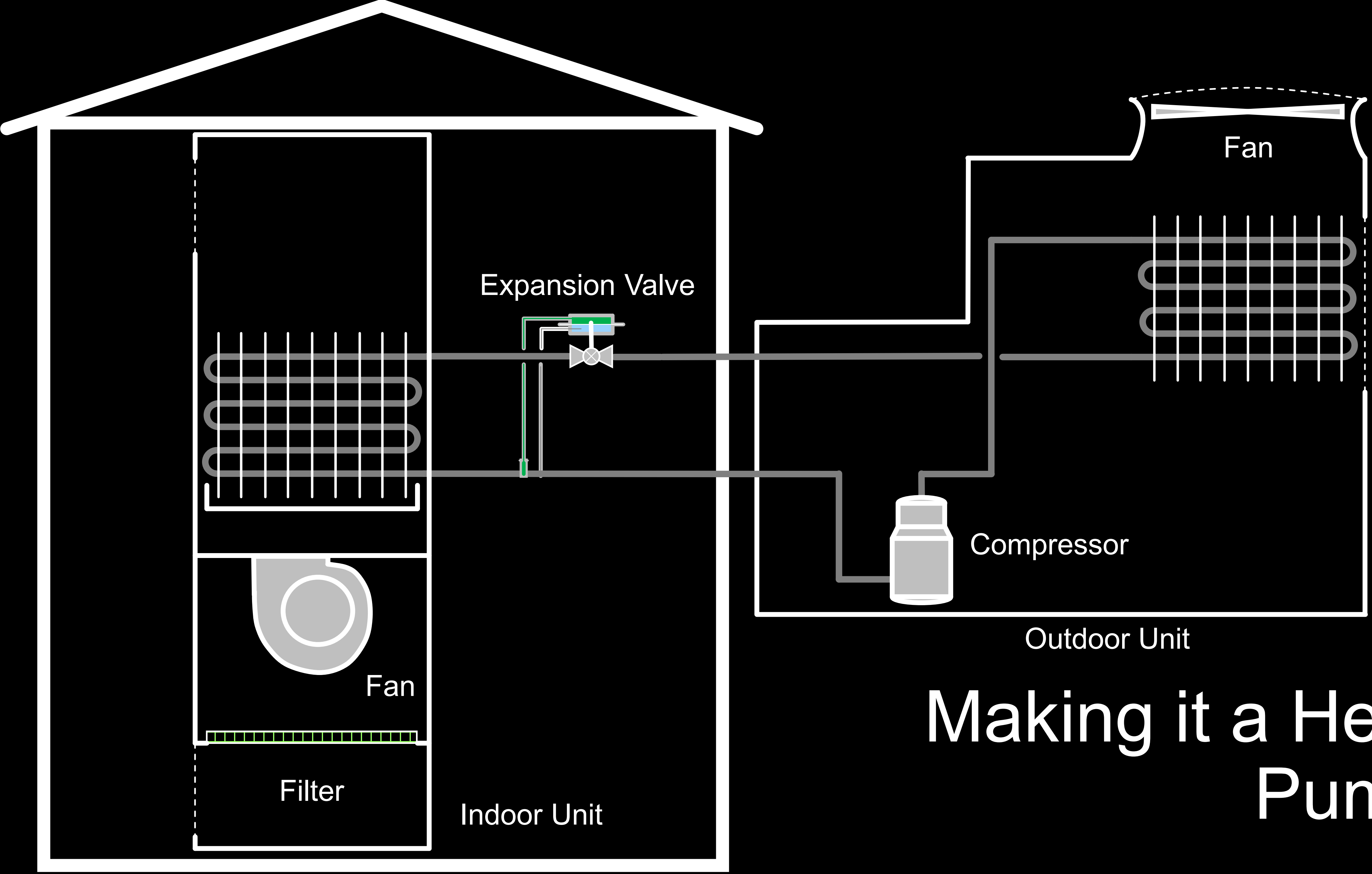


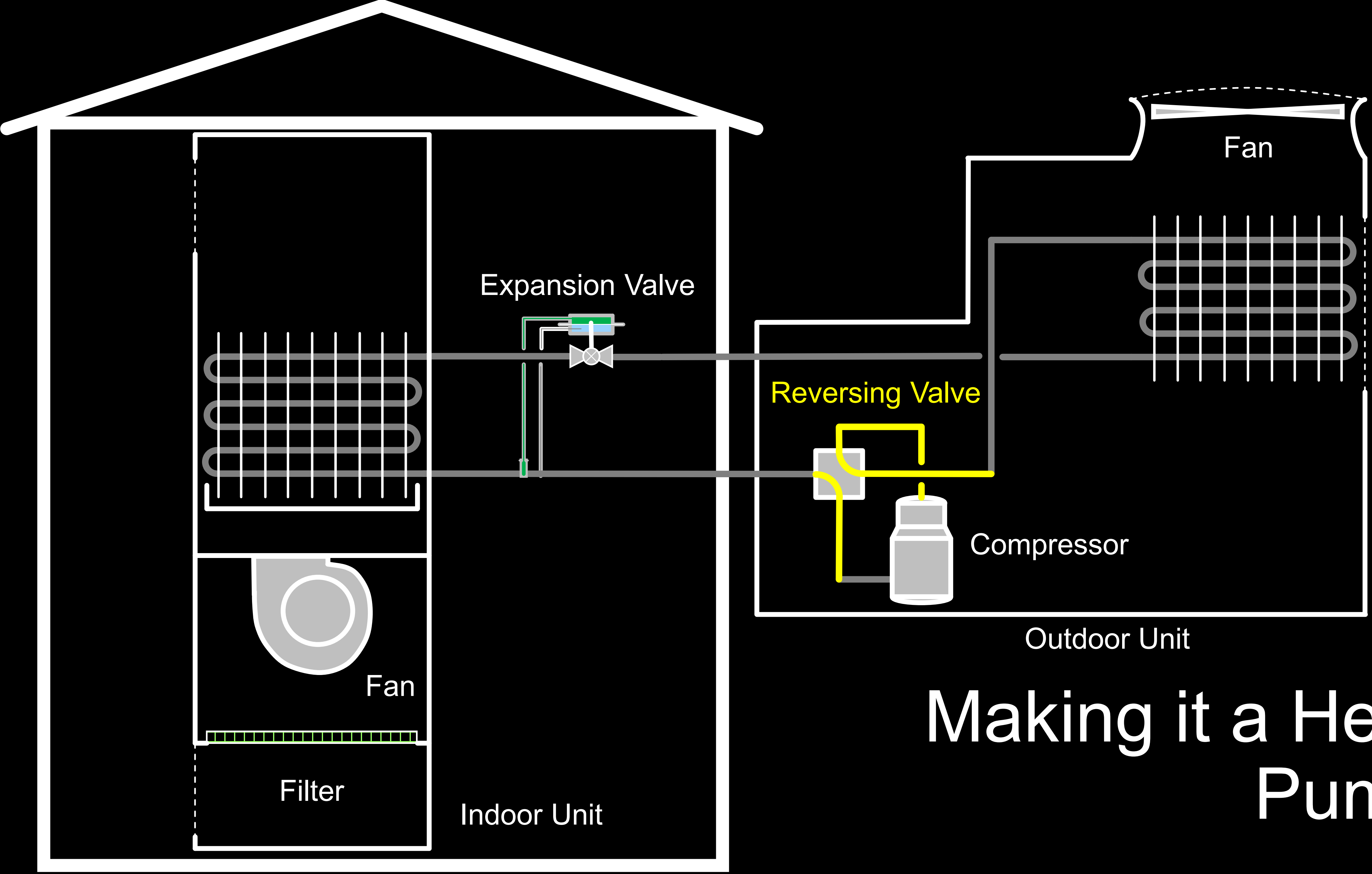
How Buildings Use Heat

Application	Electrification Target	Heat Pump Target	Conservation EBCx Target
• Heating ✓	✓	✓	✓
• Preheat ✓	✓	✓	✓
• Reheat ✓	✓	✓	✓
• Cooling ✓	✓	✓	✓
• Humidification ✓	✓	✓	✓
• Power Generation			✓


Hot Air
Fan
Cool Air
Expansion Valve
Warm Air
Compressor
Fan
Outdoor Unit
Warm Air
Filter
Indoor Unit
Conventional Air Conditioner

Making it a Heat Pump





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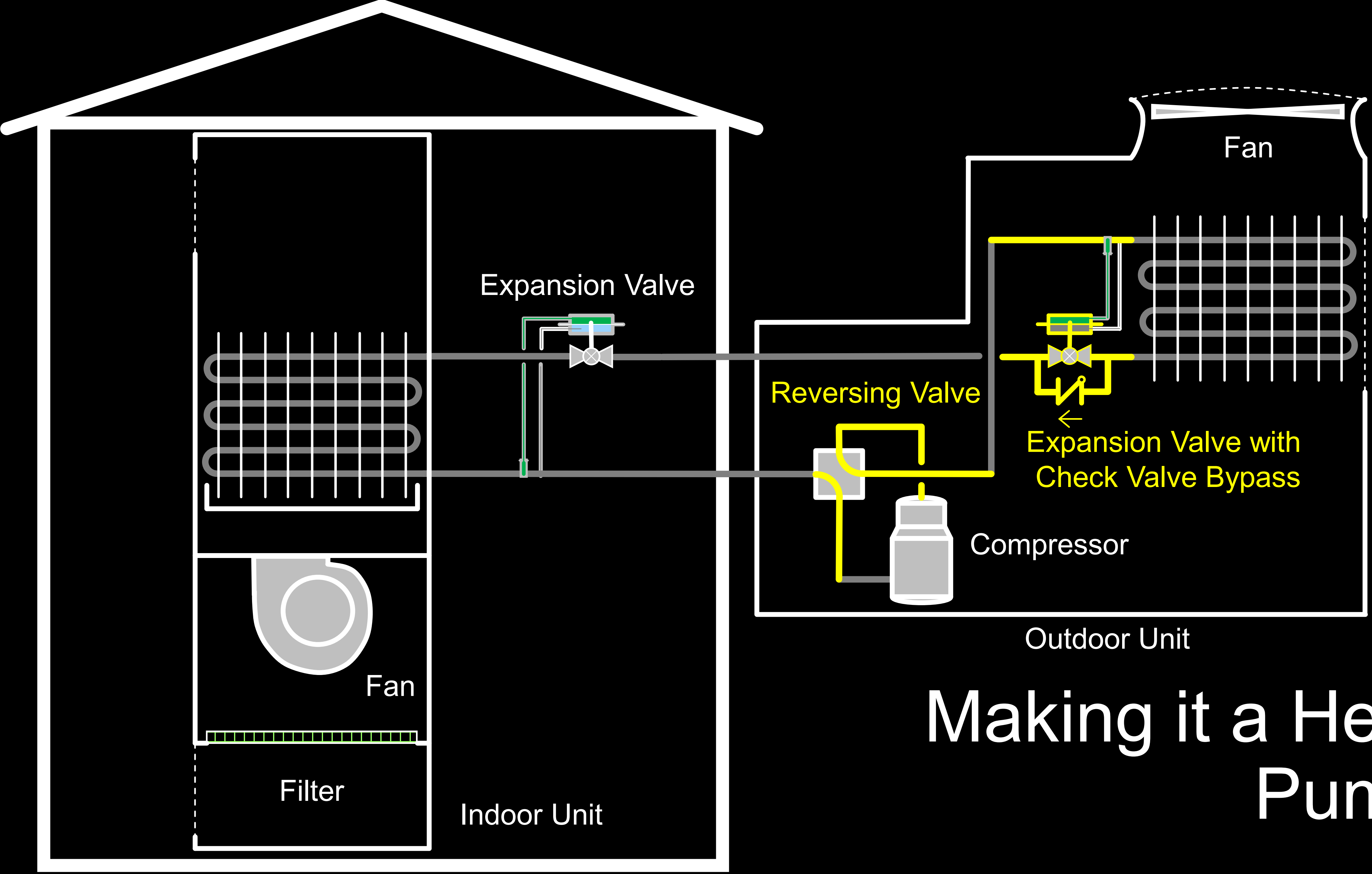

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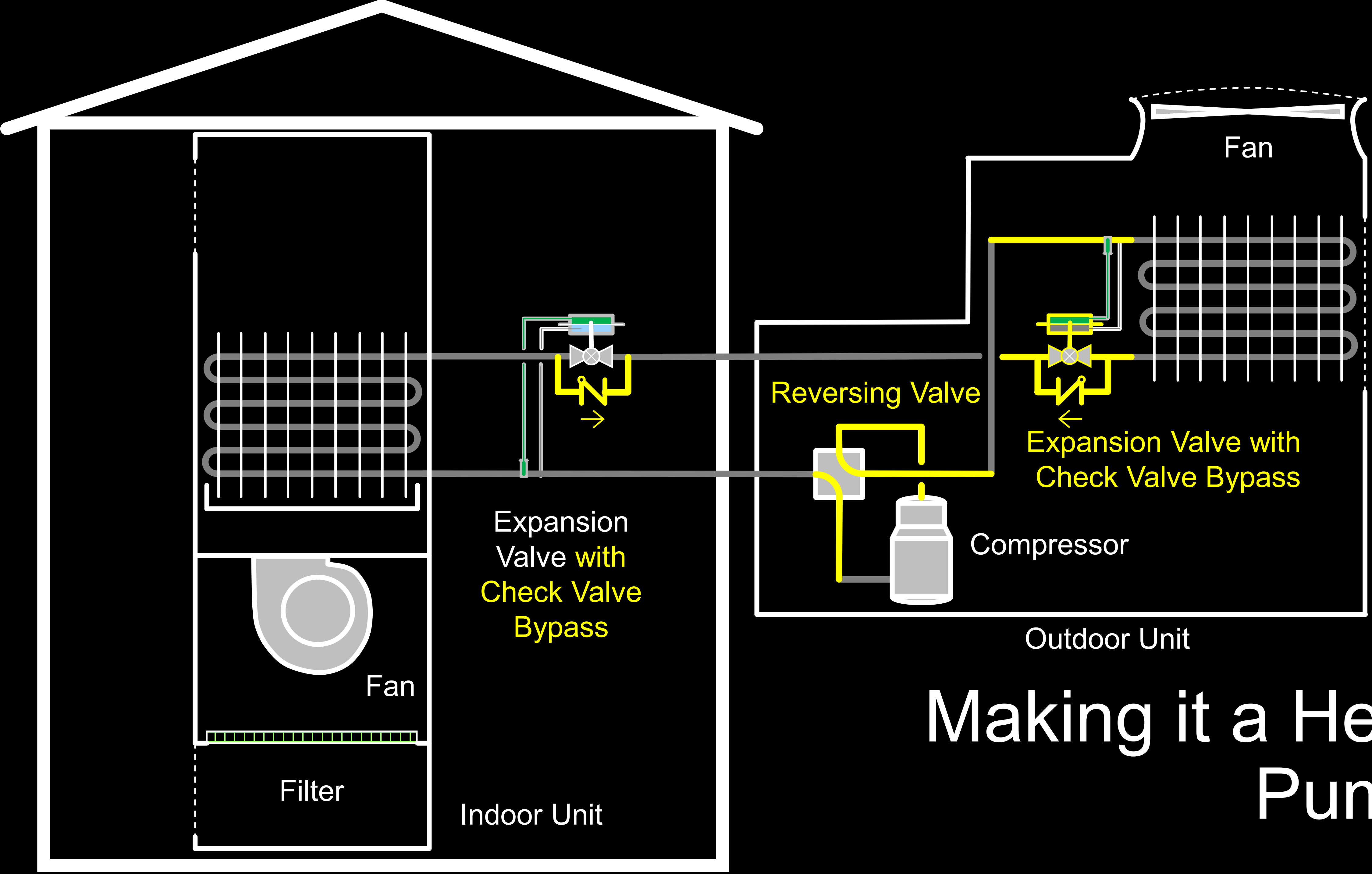

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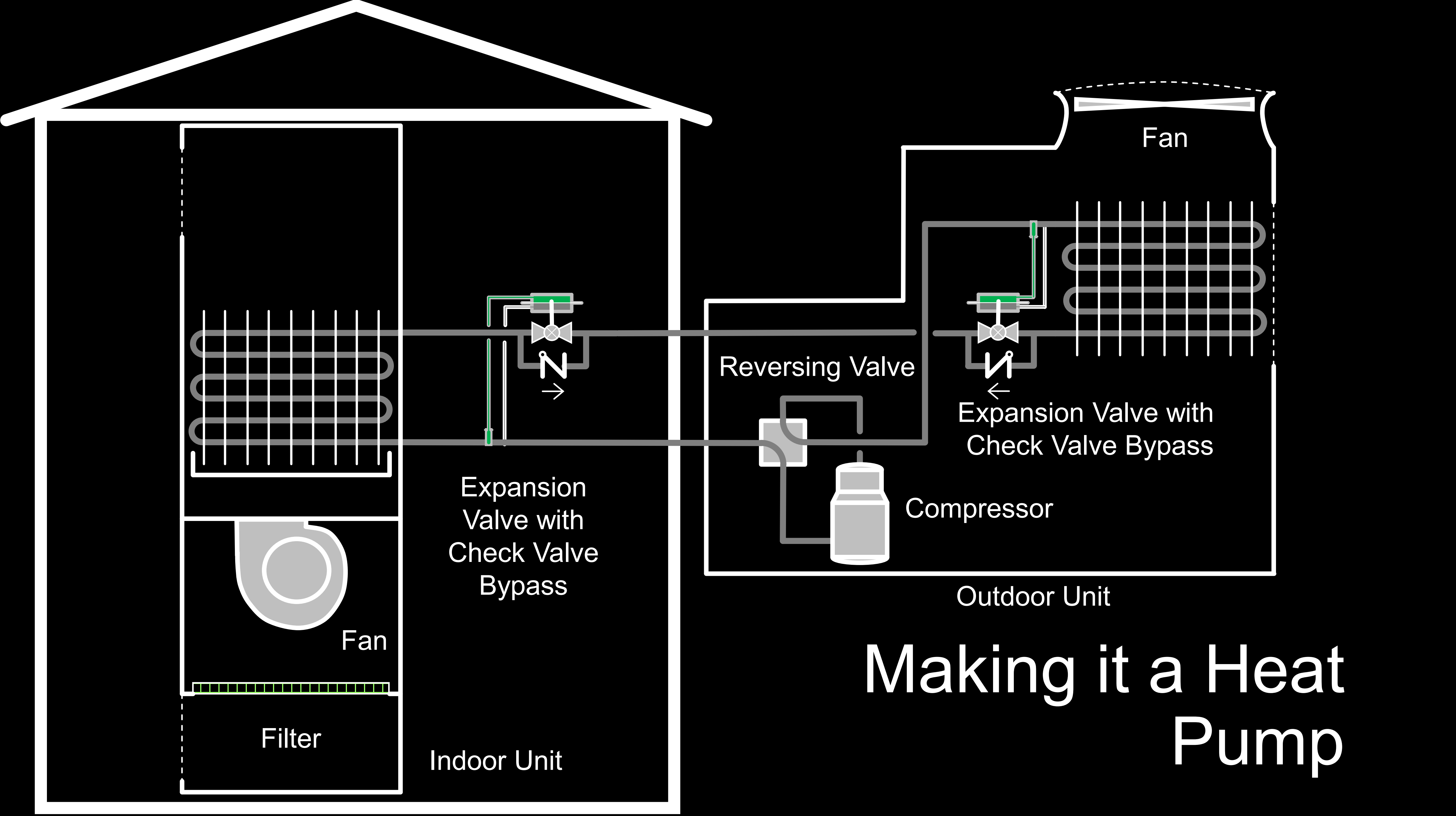
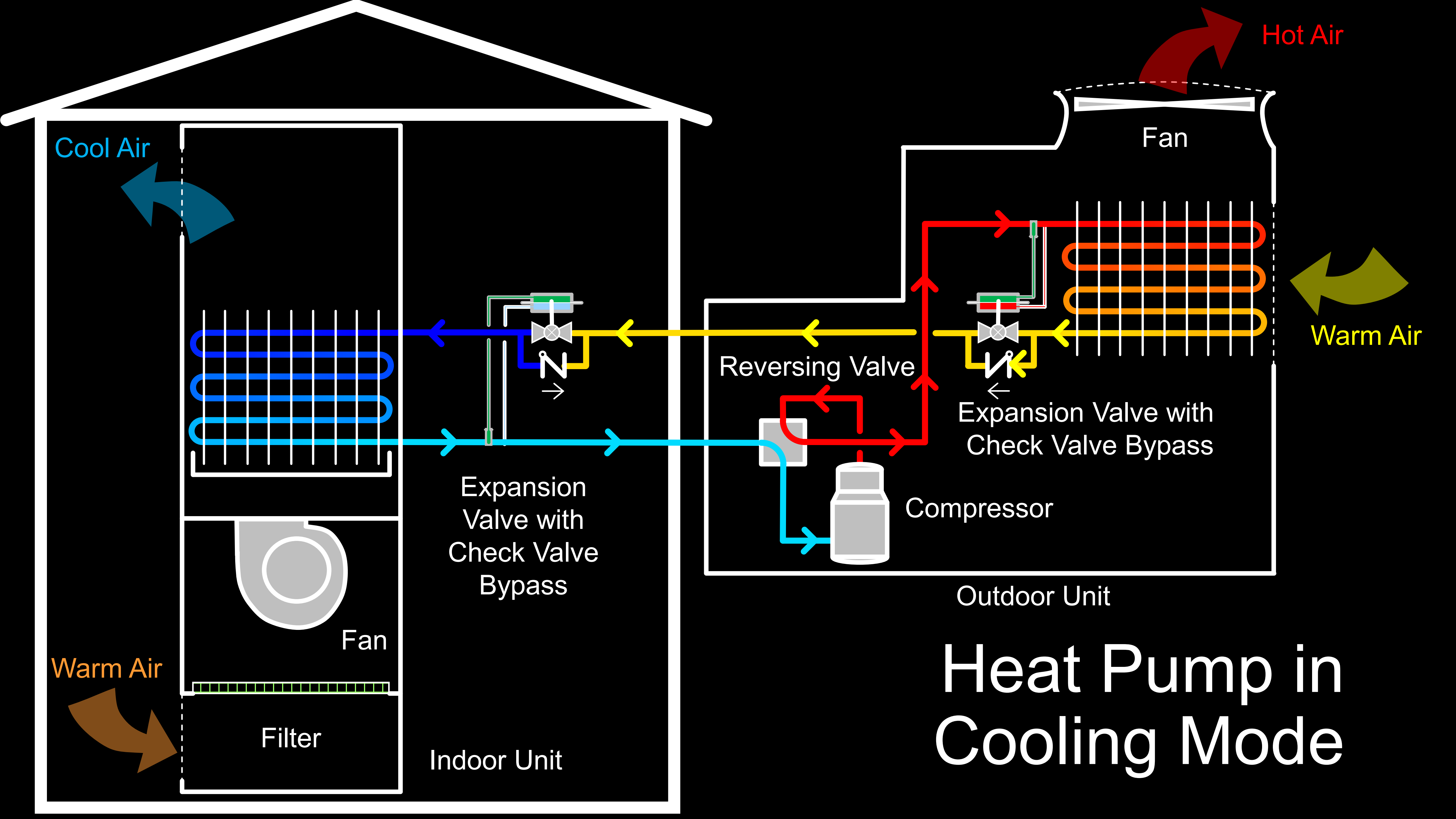
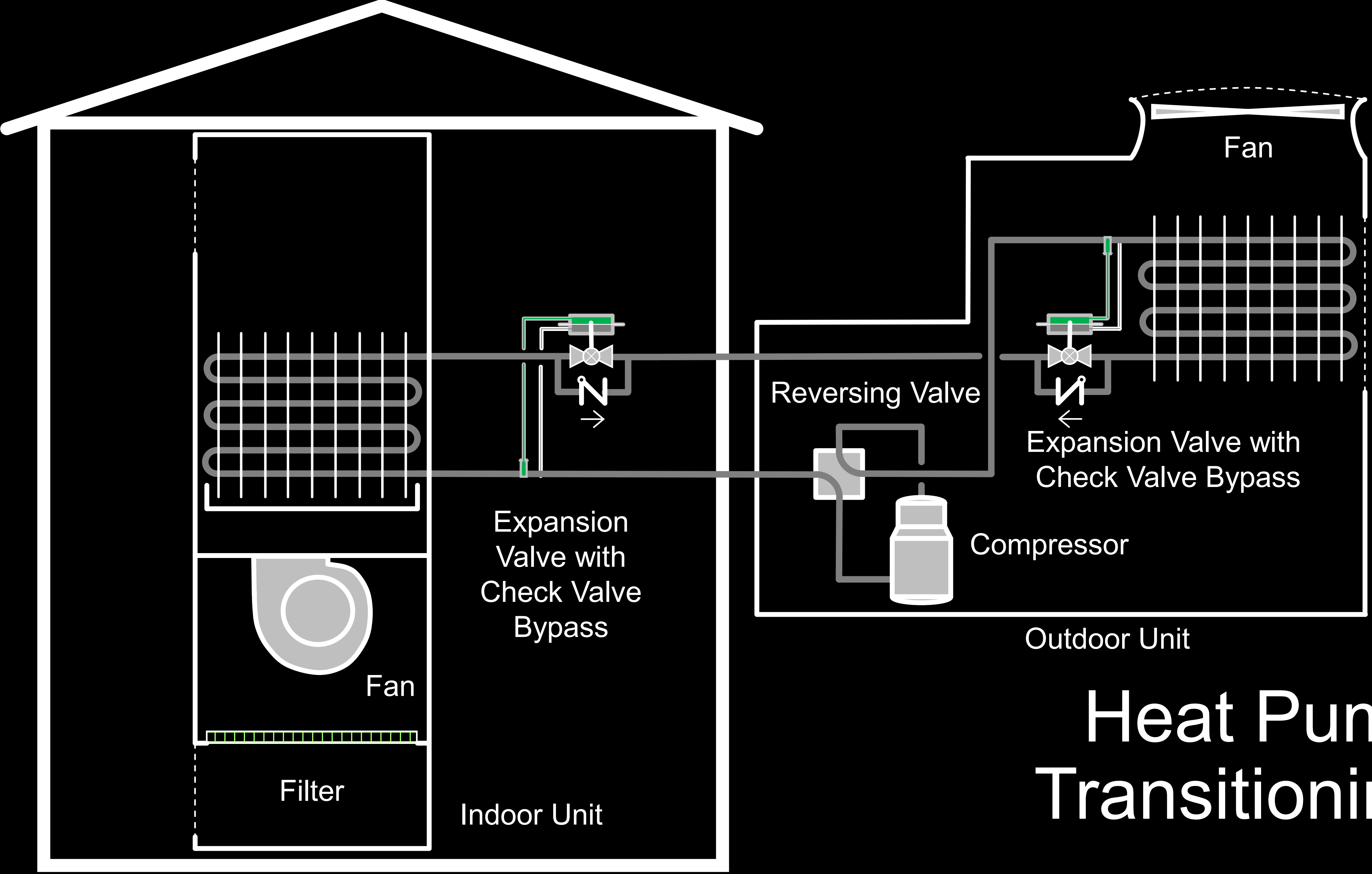
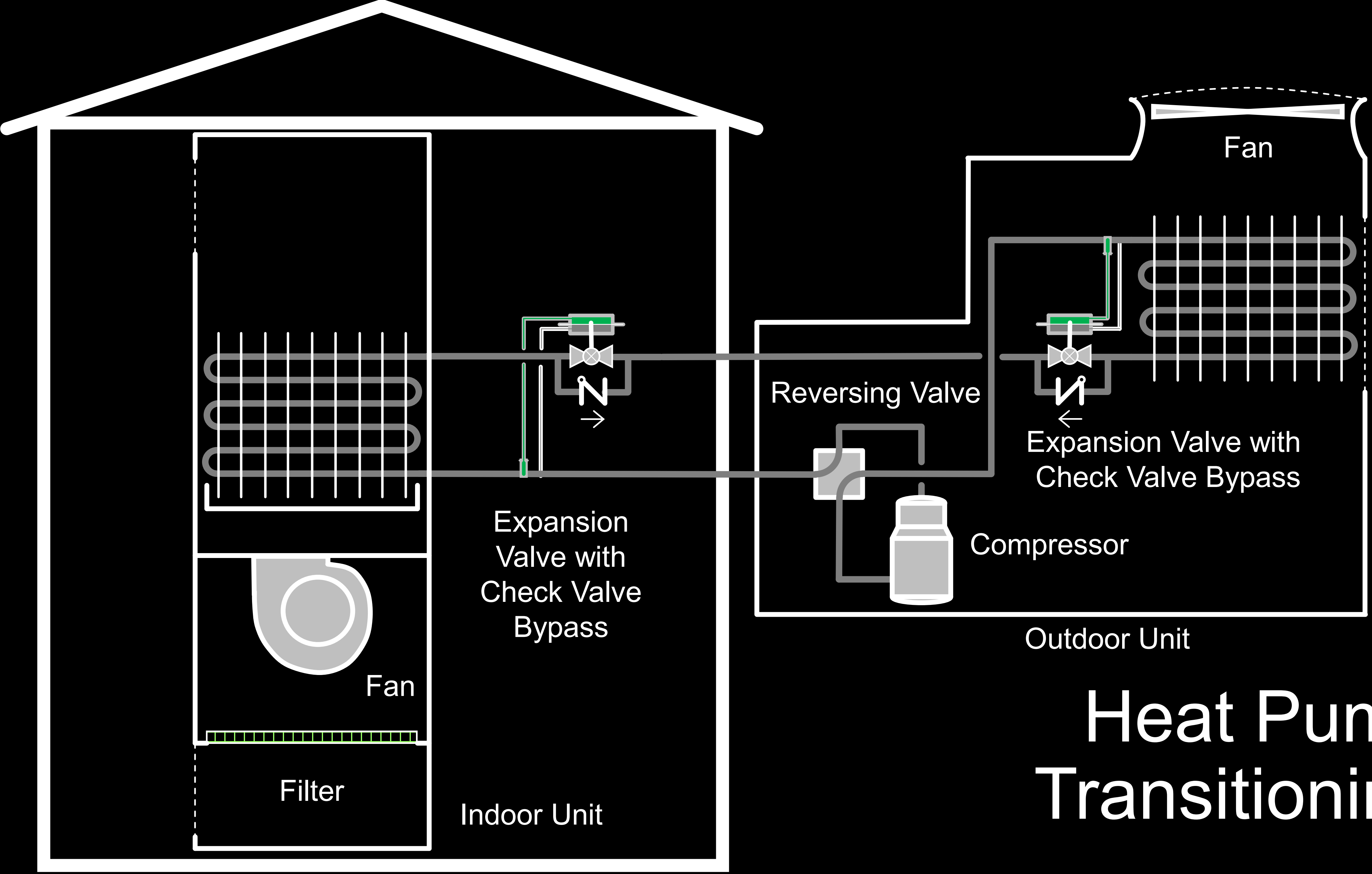


Heat Pump in Cooling Mode





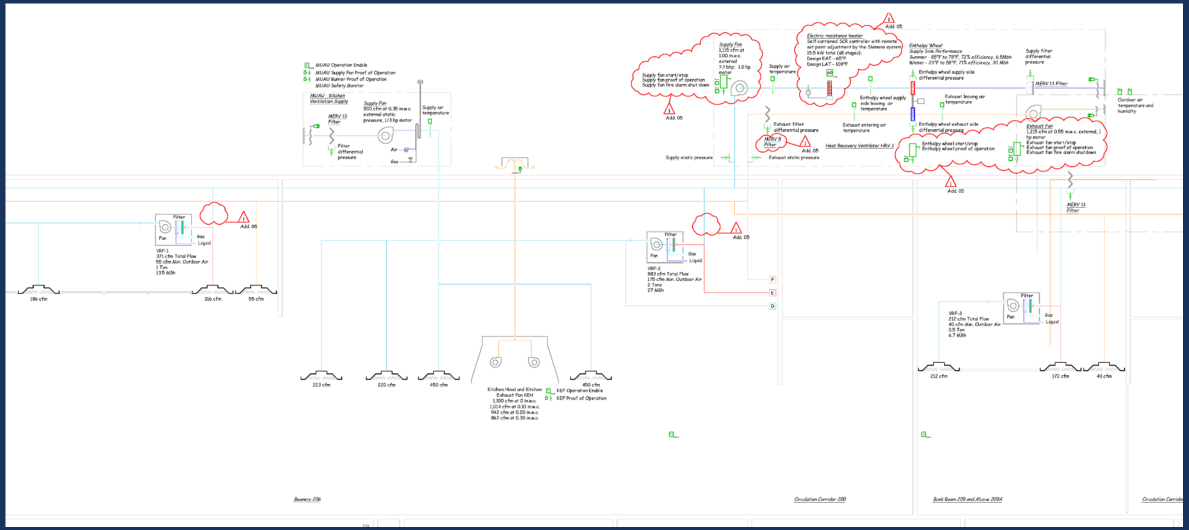
Heat Pump Transitioning

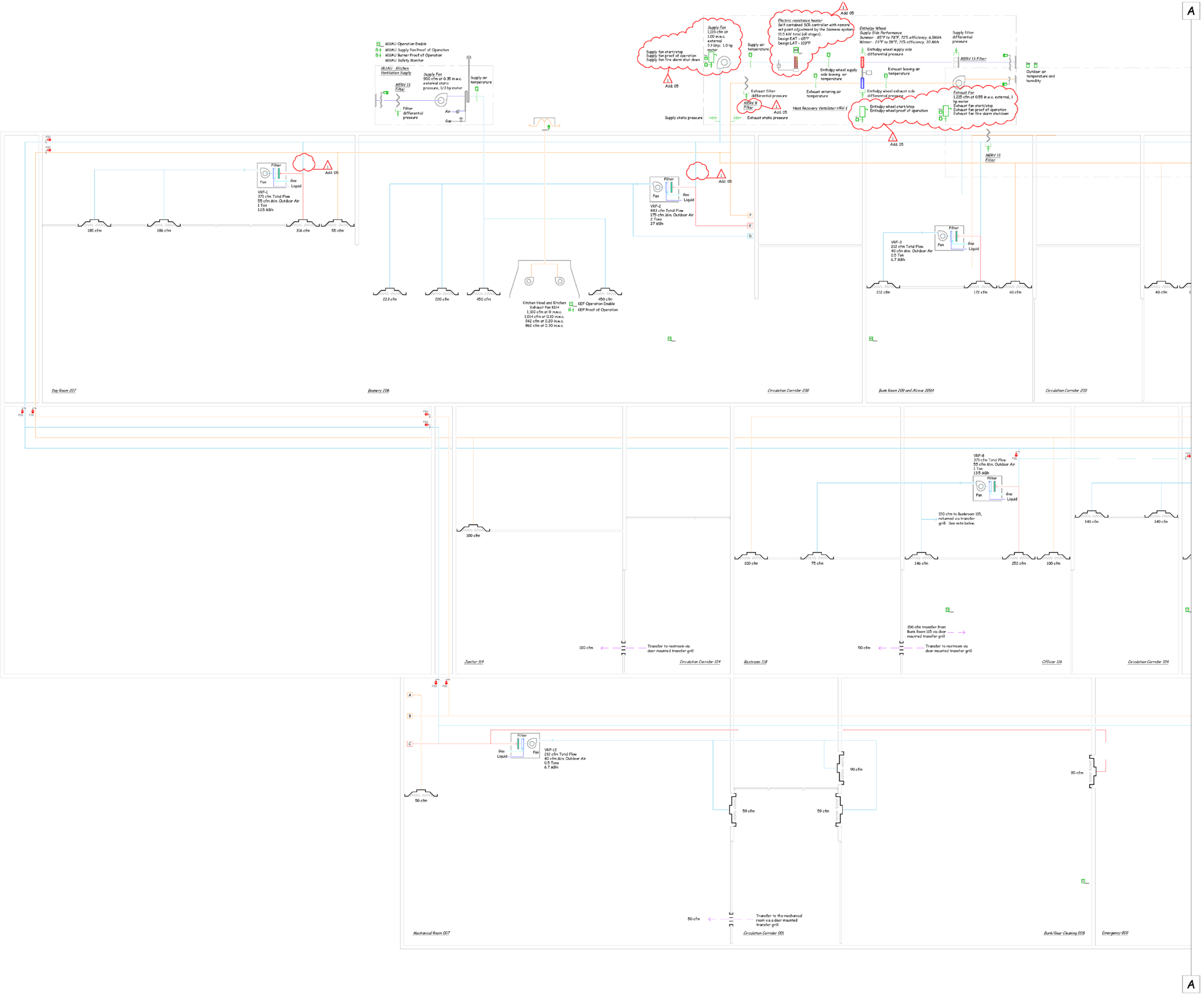


Heat Pump Transitioning

Ventilation

(2nd Module)




A
MUAU Operation Enable
MUAU Supply Fan Proof of Operation
MUAU Burner Proof of Operation
MUAU Safety Monitor
MUAU - Kitchen Ventilation Supply
MERV 13 Filter
Supply Fan
900 cfm at 0.35 in.w.c. external static pressure, 1/3 hp motor
Supply air temperature
Filter differential pressure
Air
Gas
Supply fan start/stop
Supply fan proof of operation
Supply fan fire alarm shut down
Add. 05
Supply Fan
1,115 cfm at 1.00 in.w.c. external
?.? bhp; 1.0 hp motor
Supply air temperature
Electric resistance heater
Self contained SCR controller with remote set point adjustment by the Siemens system
15.5 kW total (all stages);
Design EAT - 65°F
Design LAT - 109°F
Add. 05
Enthalpy Wheel
Supply Side Performance
Summer - 85°F to 78°F, 72% efficiency, 6.5Mbh
Winter - 23°F to 58°F, 71% efficiency, 30 Mbh
Enthalpy wheel supply side differential pressure
Enthalpy wheel supply side leaving air temperature
Exhaust leaving air temperature
Supply filter differential pressure
MERV 13 Filter
Outdoor air temperature and humidity
Exhaust filter differential pressure
MERV 8 Filter
Add. 05
Exhaust entering air temperature
Heat Recovery Ventilator HRV-1
Enthalpy wheel exhaust side differential pressure
Enthalpy wheel start/stop
Enthalpy wheel proof of operation
Exhaust Fan
1,215 cfm at 0.55 in.w.c. external, 1 hp motor
Exhaust fan start/stop
Exhaust fan proof of operation
Exhaust fan fire alarm shutdown
Supply static pressure
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371 cfm Total Flow
55 cfm Min. Outdoor Air
1 Ton
13.5 MBh
Add. 05
185 cfm
186 cfm
316 cfm
55 cfm
Filter
Fan
Gas
Liquid
VRF-2
883 cfm Total Flow
175 cfm Min. Outdoor Air
2 Tons
27 MBh
Add. 05
223 cfm
220 cfm
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Kitchen Hood and Kitchen Exhaust Fan KEH
1,100 cfm at 0 in.w.c.
1,014 cfm at 0.10 in.w.c.
942 cfm at 0.20 in.w.c.
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450 cfm
KEF Operation Enable
KEF Proof of Operation
Filter
Fan
Gas
Liquid
VRF-3
212 cfm Total Flow
40 cfm Min. Outdoor Air
0.5 Ton
6.7 MBh
212 cfm
172 cfm
40 cfm
40 cfm
Day Room 207
Beanery 206
Circulation Corridor 200
Bunk Room 209 and Alcove 209A
Circulation Corridor 200
100 cfm
VRF-8
371 cfm Total Flow
55 cfm Min. Outdoor Air
1 Ton
13.5 MBh
Filter
Fan
Gas
Liquid
150 cfm to Bunkroom 115, returned via transfer grill. See note below.
140 cfm
140 cfm
100 cfm
75 cfm
146 cfm
250 cfm
100 cfm
150 cfm transfer from Bunk Room 115 via door mounted transfer grill
100 cfm
Transfer to restroom via door mounted transfer grill
50 cfm
Transfer to restroom via door mounted transfer grill
Janitor 114
Circulation Corridor 104
Restroom 118
Officer 116
Circulation Corridor 104
A
B
C
Filter
Gas
Liquid
Fan
VRF-12
212 cfm Total Flow
40 cfm Min. Outdoor Air
0.5 Tons
6.7 MBh
50 cfm
90 cfm
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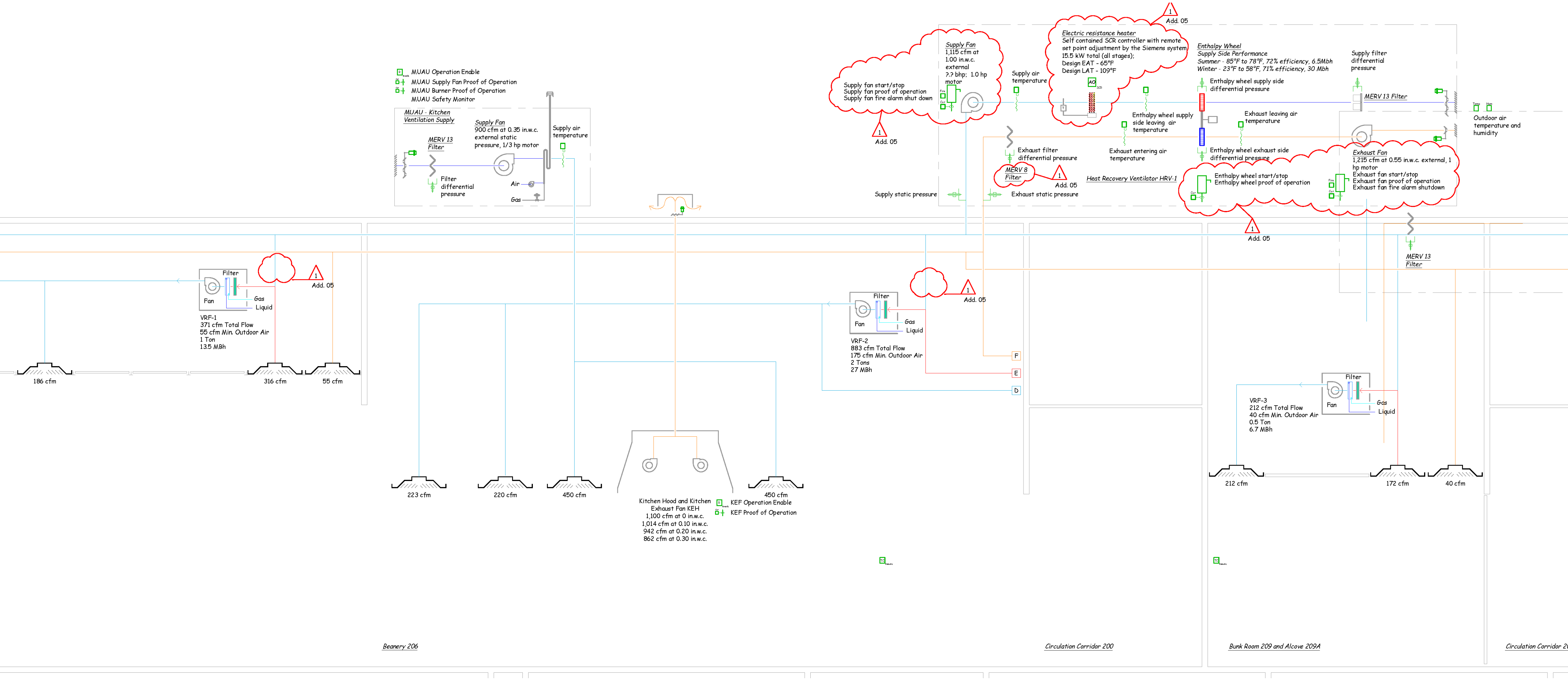
Transfer to the mechanical room via a door mounted transfer grill
Mechanical Room 007
Circulation Corridor 001
Bunk/Gear Cleaning 008
Emergency 009
A



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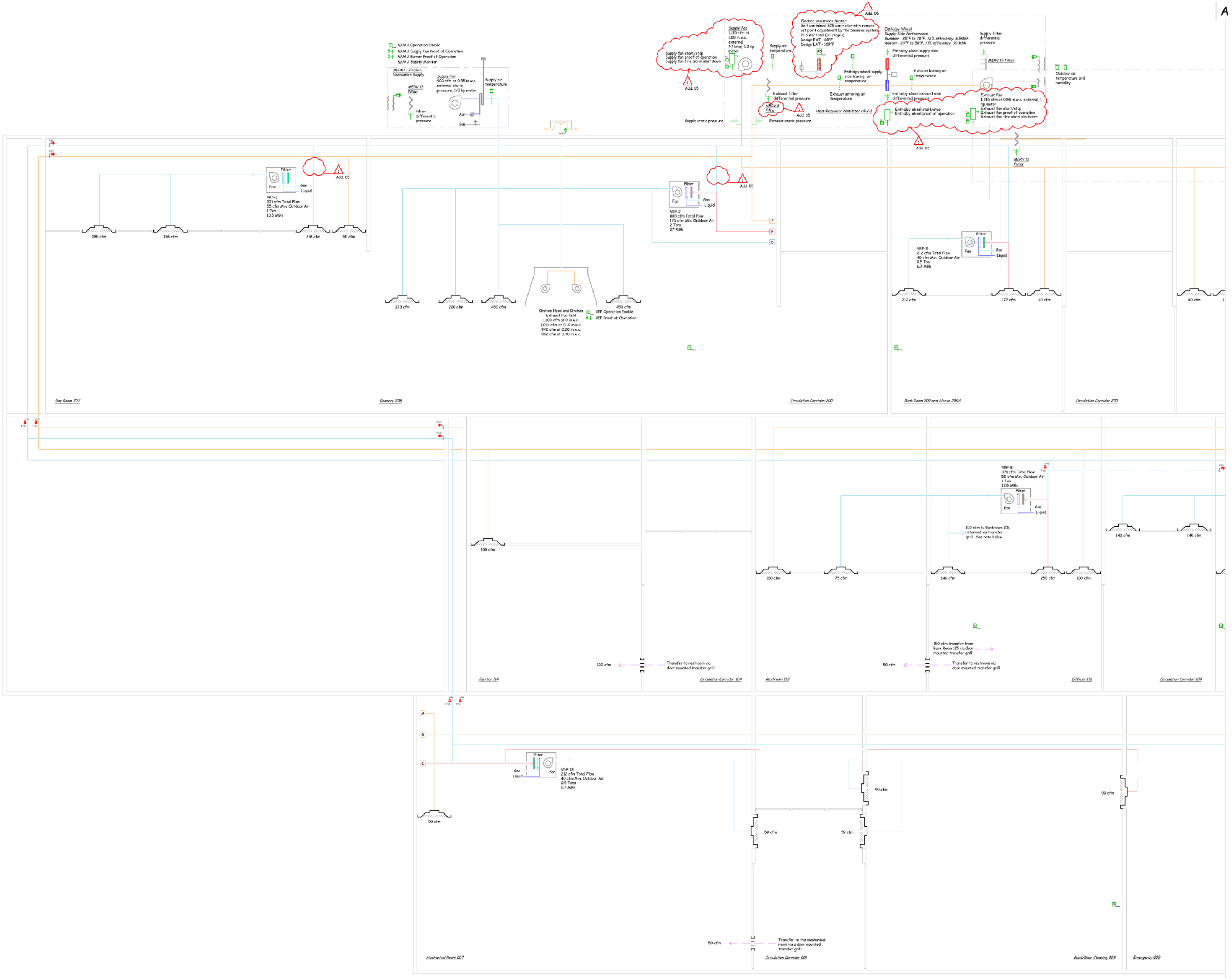

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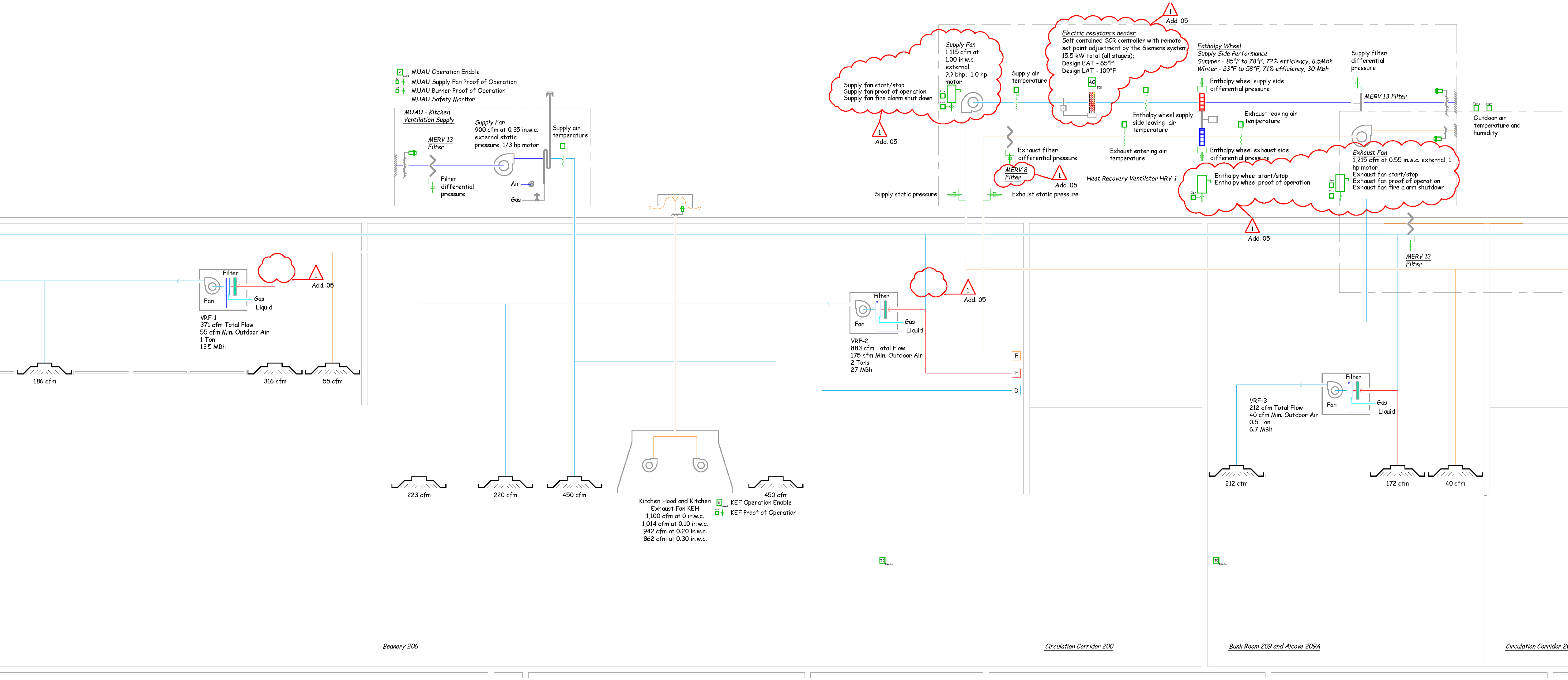

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Energy Recovery Strategies

Options

- Plate Heat Exchangers
- Wheels
- Heat Pipes
- Run Around Coils
- Thermosiphons
- Liquid Desiccant Recovery
- Fixed Bed Regenerator

ASHRAE Systems and Equipment Handbook
Chapter 26 is a good reference

A Few More Definitions

Effectiveness

- Can be defined in terms of:
  - Total energy (enthalpy)
  - Sensible energy
  - Latent energy

$$\varepsilon = \left(\frac{\text{Actual transfer of energy}}{\text{Maximum transfer of energy possible}} \right)$$

Therefore, we can say ...

$$\varepsilon = \left(\frac{m_{Exh} \times \left(\eta_{Exh_{Lvg}} - \eta_{Exh_{Ent}} \right)}{m_{Min} \times \left(\eta_{Sup_{Ent}} - \eta_{Exh_{Ent}} \right)} \right) \text{. and .} \varepsilon = \left(\frac{m_{Sup} \times \left(\eta_{Sup_{Ent}} - \eta_{Sup_{Lvg}} \right)}{m_{Min} \times \left(\eta_{Sup_{Ent}} - \eta_{Exh_{Ent}} \right)} \right)$$

Where:

ε = Wheel effectiveness

m_{Exh} = Exhaust mass flow rate

m_{Sup} = Supply mass flow rate

m_{Min} = Minimum of the two mass flow rates

$\eta_{Exh_{Lvg}}$ = Exhaust air leaving enthalpy

$\eta_{Exh_{Ent}}$ = Exhaust air entering enthalpy

$\eta_{Sup_{Ent}}$ = Supply air entering enthalpy

$\eta_{Sup_{Lvg}}$ = Supply air leaving enthalpy

A Few More Definitions

Recovery Efficiency Ratio

- Considers the energy it takes to recover energy
  - Extra fans
  - Additional filter static losses
  - Energy recovery device static losses
  - Run around coil pumps

$$RER_{Total} = \frac{Q_{Recovered}}{Q_{Input}}$$

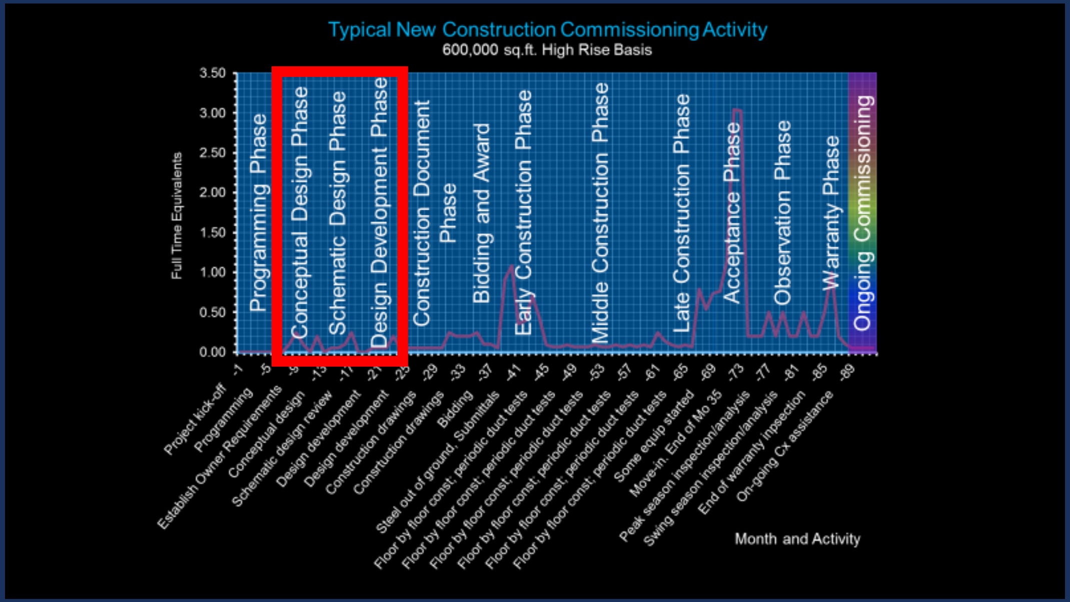
$$= \frac{Q_{Recovered}}{\left(W_{SupplyFan} + W_{ExhaustFan} + W_{WheelMotor}\right)}$$

$$= \frac{\varepsilon \times m_{Min} \times \left(\eta_{Sup_{Ent}} - \eta_{Exh_{Ent}}\right)}{\left(+W_{SupplyFan} + W_{ExhaustFan} + W_{WheelMotor}\right)}$$

Where:

RER_{Total}	=	Recovery efficiency ratio, total energy basis, Btu per watt hour
ε	=	Recovery device effectiveness
$\eta_{Sup_{Ent}}$	=	Supply air entering enthalpy, Btu/lb
$\eta_{Exh_{Ent}}$	=	Exhaust air entering enthalpy, Btu/lb
m_{Min}	=	Minimum of the two mass flow rates associated with the wheel (m_{Sup} and m_{Exh})
m_{Sup}	=	Supply mass flow rate, lb/hr
m_{Exh}	=	Exhaust mass flow rate, lb/hr
$W_{SupplyFan}$	=	Supply fan energy, watts
$W_{ExhaustFan}$	=	Exhaust fan energy, watts
$W_{WheelMotor}$	=	Wheel (or other power consuming recovery device) motor energy, watts

Heat Pumps and Design Phase Cx (3rd Module)



Recall That There Are Grades of Heat

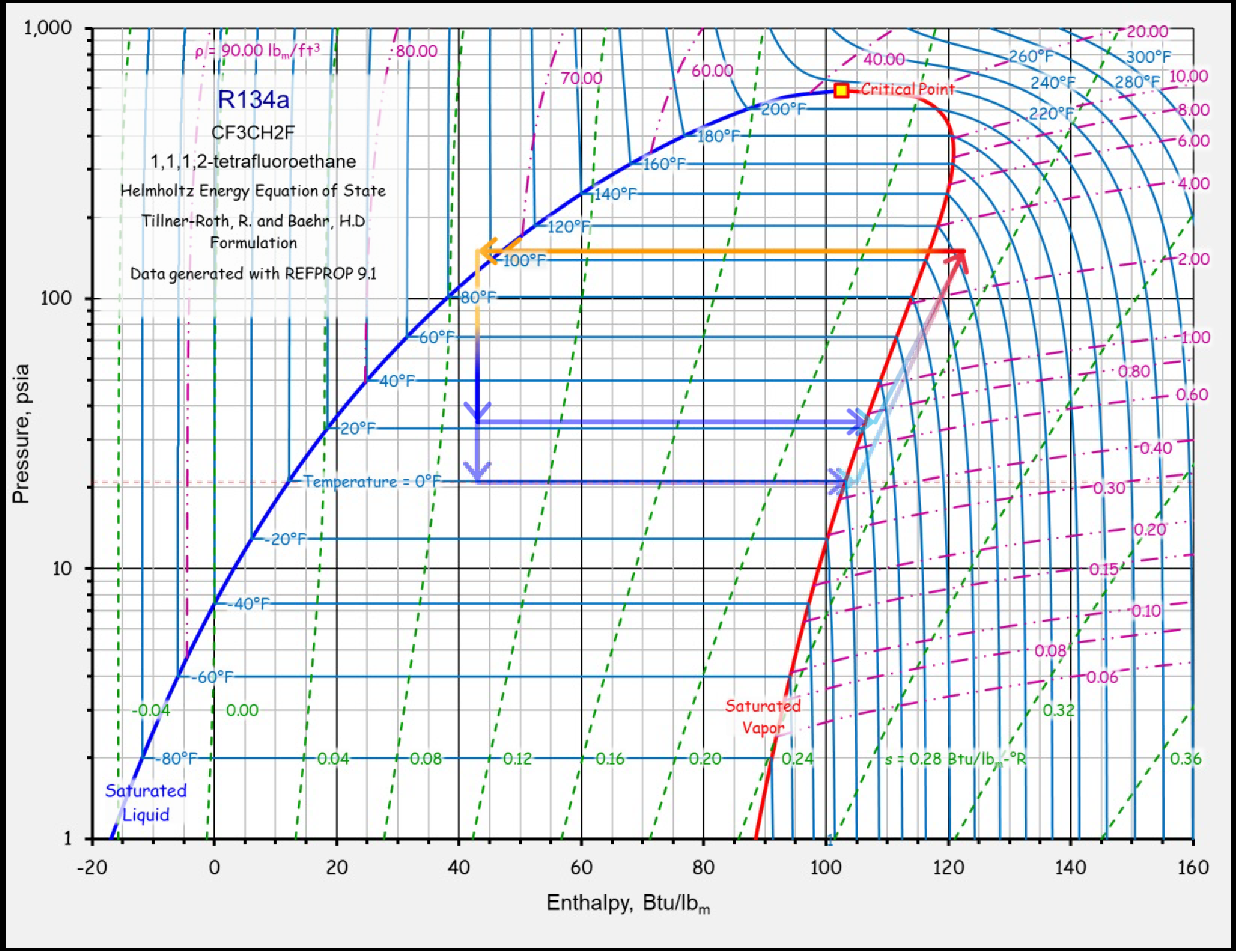
Heat

- Energy in motion; the amount of energy flowing from one object to another due to their temperature difference
- There are grades of heat
    - High – Temperature greater that 650°C/1,202°F
    - Medium – Temperatures between 200°C and 650°C/392°F and 1,202°F
    - Low – Temperatures below 200°C/392°F
- Low grade heat is harder to make use of

Recall How Lift Impacts Heat Pump Performance

Big source to sink temperature differentials mean:

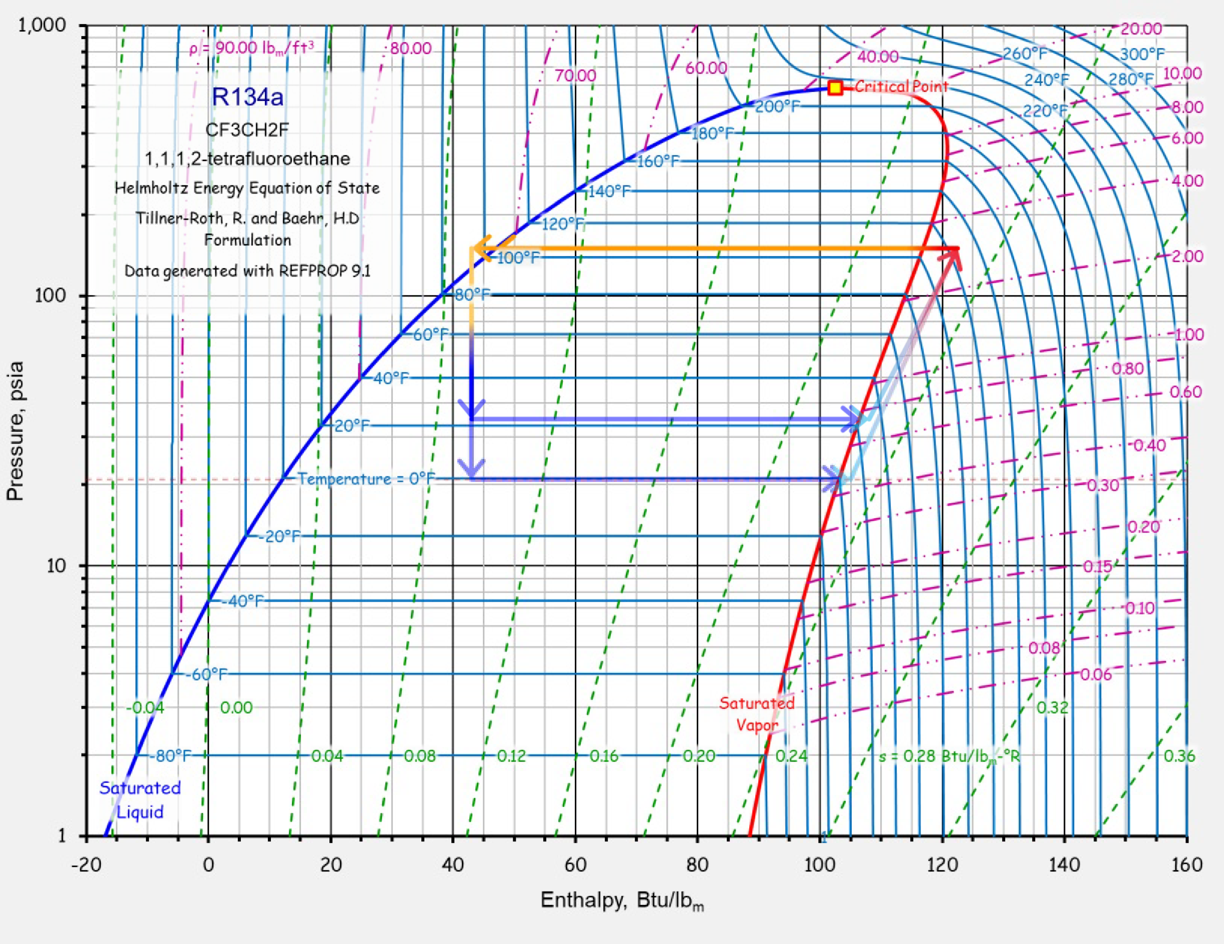
- More energy expended per Btu of energy moved



Recall How Lift Impacts Heat Pump Performance

Big source to sink temperature differentials mean:

- For air source heat pumps, the ease of recovering energy drops off as the need for recovered energy increases



The Ideal Heat Pump Application

Energy Available to Recover from Facility Internal Gains

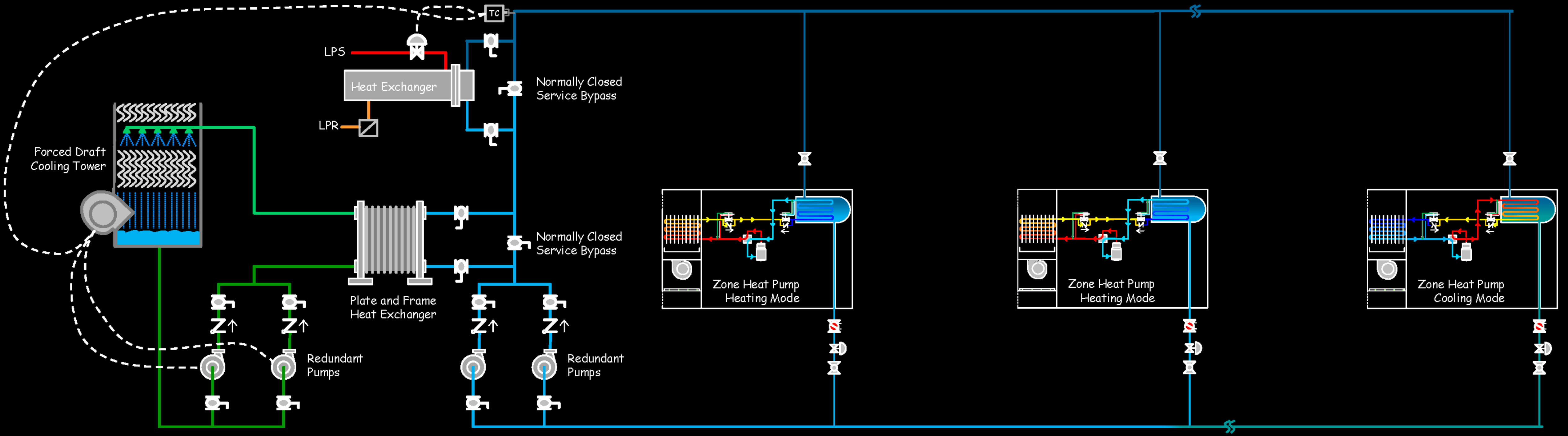
And/Or

An Alternative Energy Source that is not Extremely Cold

And

Loads that can Use Low Grade Heat

Considering a Water Source Heat Pump Loop

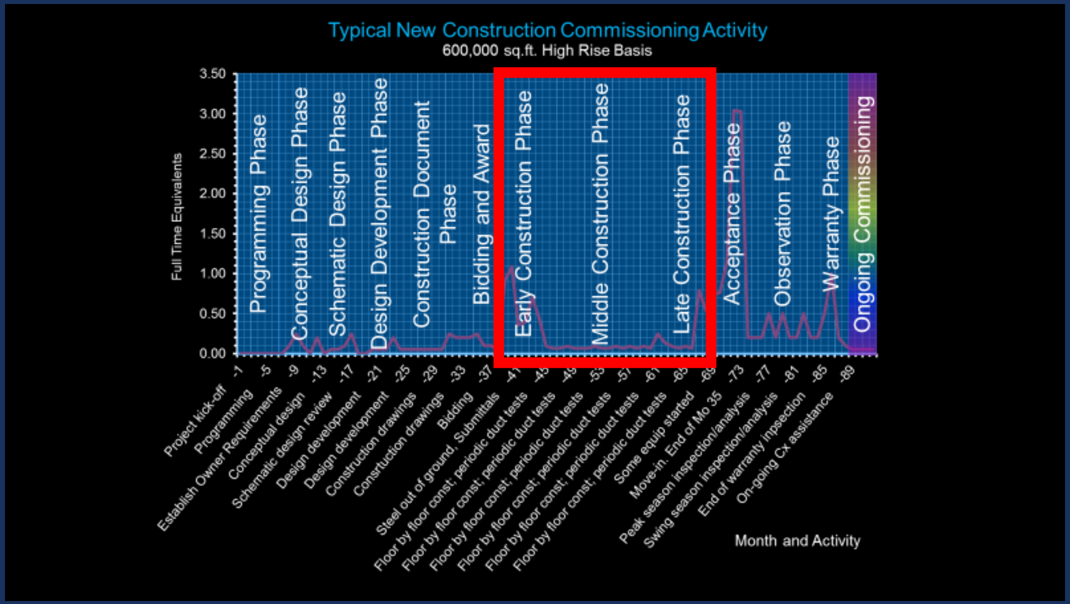


Water Source Heat Pump Loop
2022-11-16
DS

Heat Pump Application Bottom Lines

1. There has to be heat to recover
2. Design phase is the time to recognize the impacts of load profile
3. Design phase is the time to understand the equipment performance characteristics
4. Design phase is the time to think about how you will operate the system and ensure the persistence of any energy efficiency benefits
5. Design phase is the time to “think outside the box”

Heat Pumps and Construction Observation (3^{rd} Module)



Refrigerant Piping Installation Practices

Refrigerant piping installation practice critical to short and long term system integrity

- General requirements no different from those employed with any built-up refrigeration system
- Details associated with R410 systems may vary from standard practice in the field at this point in time

There Can Be A Lot to Coordinate

IDU Remote Controller Features and Settings

Mitsubishi PAR-U01MEDU Remote Controller Feature

User Menu Settings; X = Selected Option, L= Locked, U= Unlocked, N/A Not Applicable, D = Disabled, E = Enabled, Sie - Managed by Siemens, AE = Managed by the AE-200 Central Controller, En = English, Sh = Show, Hi = Hide, Dft = Default, AR = As Reqired, NU = Not Used, H = Hide, S = Show, SI = Single, DU - Dual, , N## = See note referenced by the number, Lit = Light, Drk = Dark, Cx = Set During Commissioning, CSB = Color Selection by Architect (Note 15)

Service Menu Settings; Abbrevations are the same as for the User Menu

HVAC System	Area Served	VRF Zone Type (see Sequence)	Function Settings (Nt. 18) – Use Remote Controller Temperature – Use Remote Sensor	Use Internal Sensor	Power Failure Recovery Mode – Automatically Restart	Do not restart (Note 16)	External Static Pressure Setting, in.w.c. (Note 17)	Password Protected – User Password (Note 8)	BACnet Access – Service Password (Note 8)	Basic Operation Settings – On/Off	Operating Mode	Set Temperature	Override (Note 10)	Fan Speed	Air Direction	Louver Swing	LOSSNAY Fan Speed	Hold	Set Humidity	Date and Time	Date/Time Format	Daylight Savings Time	Schedule	Timer – On-Off	Auto-Off	Display Format – Language	Temperature Unit	Show/hide Room Temp.	Backlight Timeout	Sound/ Contrast – Sound	Contrast	Energy Savings Assistant – Mode Settings – Select 1 (Note 11) – Non-Use	Thermo-off	Temp. Offset	Fan Spd. Down	On/Off	Operating Mode
									▶	X	X	X		X	X	X	N/A		N/A				N10														
								▶	▶								N/A		N/A	X	X	X	X	X		X				X		X					
DOAS 1																																					
IDU-1.2	Room 101 - Dispatch B	8	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-1.3	Room 100 - Dispatch A	8	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
DOAS 2																																					
IDU-1.14	Room 124 – Break-out	2	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-1.15	Room 130 – CCTV Workroom	6	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-2.1	Room 211 – Open Office	1	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-2.2	Room 222 – Office	3	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-2.3	Room 212 - Breakout	1	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-2.4A	Room 230 - Conference	5	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-2.4B	Room 230 - Conference	5	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-2.5	Room 231 - Conference	4	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-2.6	Room 210 - Breakout	4	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
DOAS 3																																					
IDU-1.4	Room 111 - Lobby	1	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft	X					
IDU-1.5	Room 140 - ERC	3	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft	X					
IDU-1.6	Room 144 - Lunch Room	4	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft	X					
IDU-1.7	Room 145 – Shared Support	1	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-2.6	Room 210 - Breakout	4	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-2.7	Room 242 – Office	3	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-2.8	IDU Number Not Used	N/A	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
IDU-2.9	Room 213 – Open Office	1	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft						X
DOAS 4																																					
IDU-1.8	Room 150 – Women's Locker	1	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft	X					
IDU-1.9	Room 152 – Women's Drying Room	10	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft	X					
IDU-1.10	Room 151 – Men's Locker Room	1	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft	X					
IDU-1.11	Room 153 – Men's Drying Room	10	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft	X					
HRV-1																																					
IDU-1.12	Room 161 – Warehouse Office	7	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft	X					
HRV-2																																					
IDU-1.13	Room 164 – Tool Office	7	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft	X					
HRV-3																																					
IDU-1.1	Room 105 – Source Control Work Room	9	X			X		AR	AR	N12	N12	N12	L	N12	N/A	N/A	N/A	L	N/A	AE	AE	AE	SIE	D	D	En	°F	Sh	Dft	Dft	Dft	X					

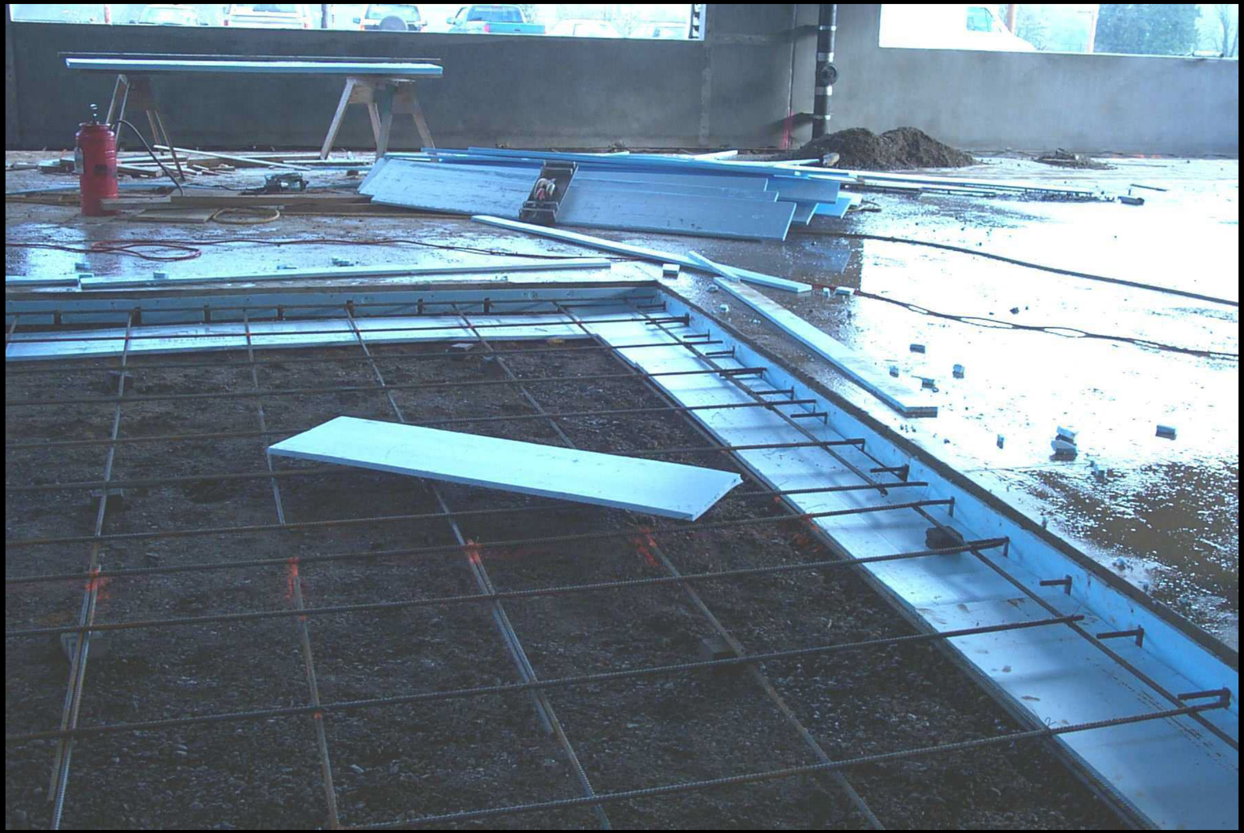
HVAC System	Energy Savings Assistant – Mode Settings – Note 13 – Offset Value	Auto-Away Time	Detection Level	Invalidate Item Setting – Date and Time	Light Sensor – Enable/Disable	Condition	LED Indicator – Basic Display Mode – Function, Select One – Non-use	Mode	Room Temp.	Mode Color Settings – Cooling	Heating	Fan	Auto	Dry	Setback	Room Temp. Settings – Note 14 – Normal, Low	Normal, High	Temp. Bands – Below Normal	Normal	Above Normal	Bright-ness – High	Low	Color During Energy Savings	Occupancy Detection Indication	Switch LED Brightness via Space Brightness – Enable/Disable	Light Detected	Dark Detected	Touch Panel Calibration	Lockable Remote Controller Functions Lock State – On/Off	Operating Mode	Set Temp.	Fan Speed	Air Direction	Lover Swing	LOSSNAY Speed	Hold
							X																					X	X							
DOAS 1																																				
IDU-1.2	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-1.3	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
DOAS 2																																				
IDU-1.14	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-1.15	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-2.1	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-2.2	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-2.3	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-2.4A	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-2.4B	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-2.5	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-2.6	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
DOAS 3																																				
IDU-1.4	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-1.5	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-1.6	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-1.7	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-2.6	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-2.7	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-2.8	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-2.9	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
DOAS 4																																				
IDU-1.8	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-1.9	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-1.10	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
IDU-1.11	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
HRV-1																																				
IDU-1.12	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
HRV-2																																				
IDU-1.13	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L
HRV-3																																				
IDU-1.1	NU	NU	NU	NU	NU	AR		X		CBA	CBA	CBA	CBA	CBA	CBA	NU	NU	NU	NU	NU	AR	AR	CBA	E	AR	AR	AR	AR	L	L	U	L	N/A	N/A	N/A	L

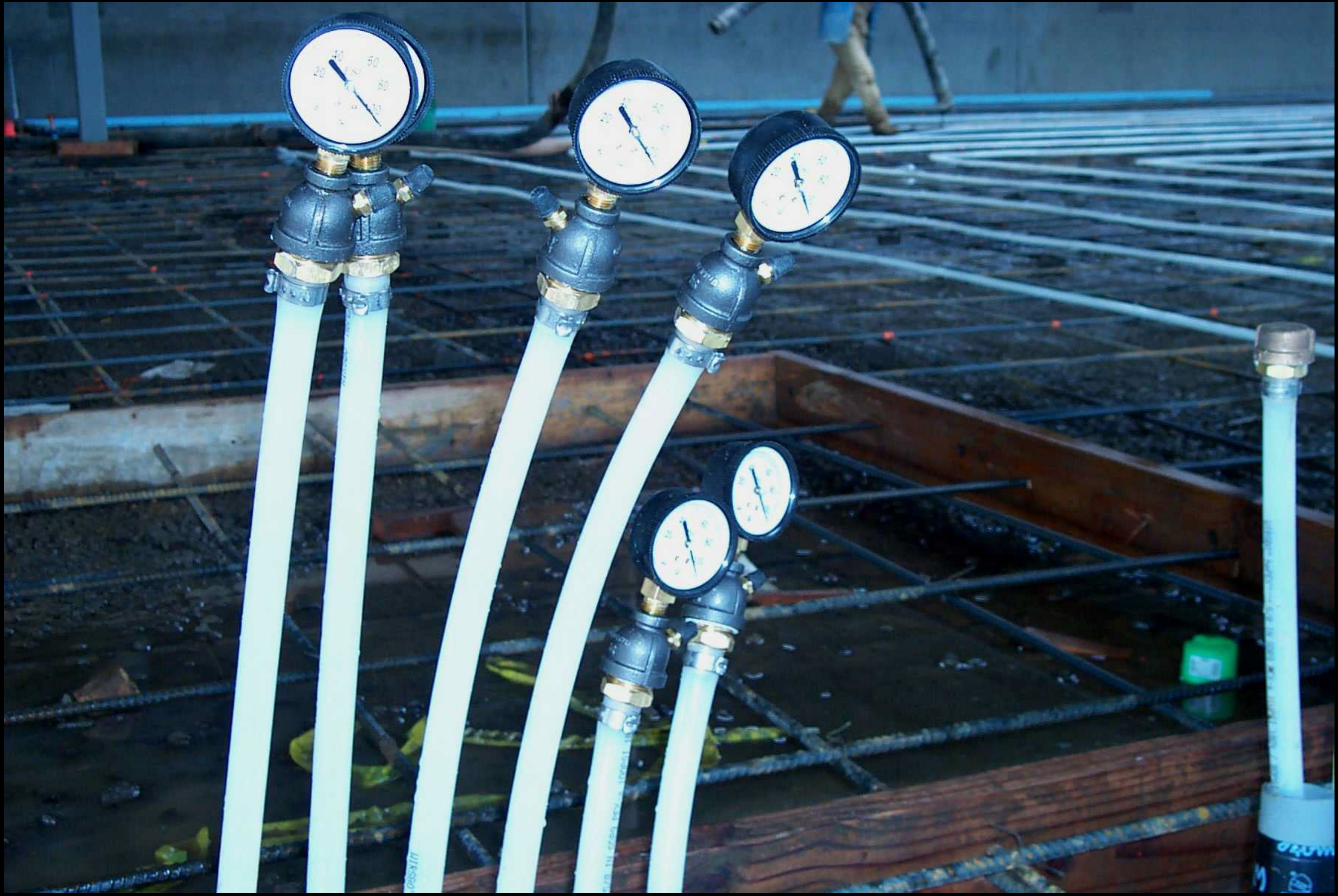
HVAC System	Sensor Threshold – Occupancy	Brightness Sensor – Light Threshold	Dark Threshold	Temperature Range Limit – Auto Upper	Auto Lower	Cooling Upper	Cooling Lower	Heating Upper	Heating Lower	Auto Return – Enable/Disable	Cool - Return After Time	Cool - Temp. to Return To	Heat - Return After Time	Heat - Temp. to Return To	Screen Cleaning	Filter Information	Group Settings	Interlocked LOSSNAY	Cool-Heat Display – Auto Mode	Setback Mode	Override Control – Enable/Disable	Operating Time	Temp. Sensor Offset	Humidity Sensor Offset	Auto Mode (Select 1) – Single Setpoint	Dual Setpoint	Room Name	Telephone Number	LED Colors	Extra Occupancy Sensor, Note 1	Notes
	X			X						X					X	X	X	X	X	X		X	X	X	X		X	X	X		
DOAS 1																															
IDU-1.2	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
IDU-1.3	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
DOAS 2																															
IDU-1.14	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	2
IDU-1.15	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
IDU-2.1	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
IDU-2.2	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	3	5
IDU-2.3	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	4
IDU-2.4A	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	7
IDU-2.4B	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	7
IDU-2.5	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
IDU-2.6	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
DOAS 3																															
IDU-1.4	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
IDU-1.5	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	3
IDU-1.6	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
IDU-1.7	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	3	
IDU-2.6	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
IDU-2.7	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	6
IDU-2.8	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
IDU-2.9	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
DOAS 4																															
IDU-1.8	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
IDU-1.9	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
IDU-1.10	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
IDU-1.11	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
HRV-1																															
IDU-1.12	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
HRV-2																															
IDU-1.13	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	
HRV-3																															
IDU-1.1	AR	NU	NU	77	68	77	73	72	68	D	NU	NU	NU	NU	AR	NU	AR	N/A	H	H	D	NU	AR	AR	X		AR	NU	Dft	0	

Notes

1. This is the number of supplemental occupancy sensors provided and wired to the Siemens system to suppport IDUs that serve multiple zones.
2. This is the IDU controller location. The unit also serves Room 120 – Hallway, Room 127 – Recovery Room, Room 128 – Restroom, Room 129 - Janitor's Closet, and Room 131 – Waste/Recycle
3. This is the IDU controller location. The IDU also serves Room 141 - Break-out, Room 142 - Breakout and Room 143 - Conference.
4. This is the IDU controller location. The IDU also serves Room 200 – Hallway,
5. This is the IDU controller location. The IDU also serves Room 221 – Office, Room 223 – Office, and Room 221 – Office
6. This is the IDU controller location. The IDU also serves Room 241 – Breakout, Room 243 – Office, and Room 244 – Breakout.
7. There are two IDUs serving this space controlled together by one Mutsubishi controller.
8. Replace the default password with a new password that is as requested and approved by the Owner.
9. Disabled from the service menu (vs. the user menu).
10. Even thought there is not BACnet access to the Schedule feature of the remote controller, the Siemens system can use the other BACnet points to manage the schedule of the IDUs. See the Seauence of Operation for more information.
11. Only one of the options can be selected. "X" = the option that should be selected for the indicated unit.
12. If locked, the setting can not be adjusted from the remote controller by it still can be adjusted via the BACnet object associated with it. If it is unlocked, it can be adjusted from the remote controller as well as by the associated BACnet object and the "last command wins" (see the sequence of operation).
13. These settings only apply if the Temperature Offset mode is selected.
14. If the schedule feature is used, it is possible to set up to 8 operating patterns for each day of a week. Each operating pattern allows you to set the on and off time, mode, and temperature setpoint(s).
15. LED color options are Blue, Light blue, Purple, Red, Pink, Orange, Yellow, Green, Lime, and White. The mode selection and colors are initial suggestions. Final mode selection to drive the LEDs shall be as required by the Owner, with color selections by the Architect and Owner.
16. The design intent is for Siemens to manage the restart after a power failure to allow it to be coordinated with the other equipment on the project.
17. The indicated values are based on the design documents. Coordinate the final setting with the testing and balaincing contractor based on their test results.

Problems Can Become Cast in Stone

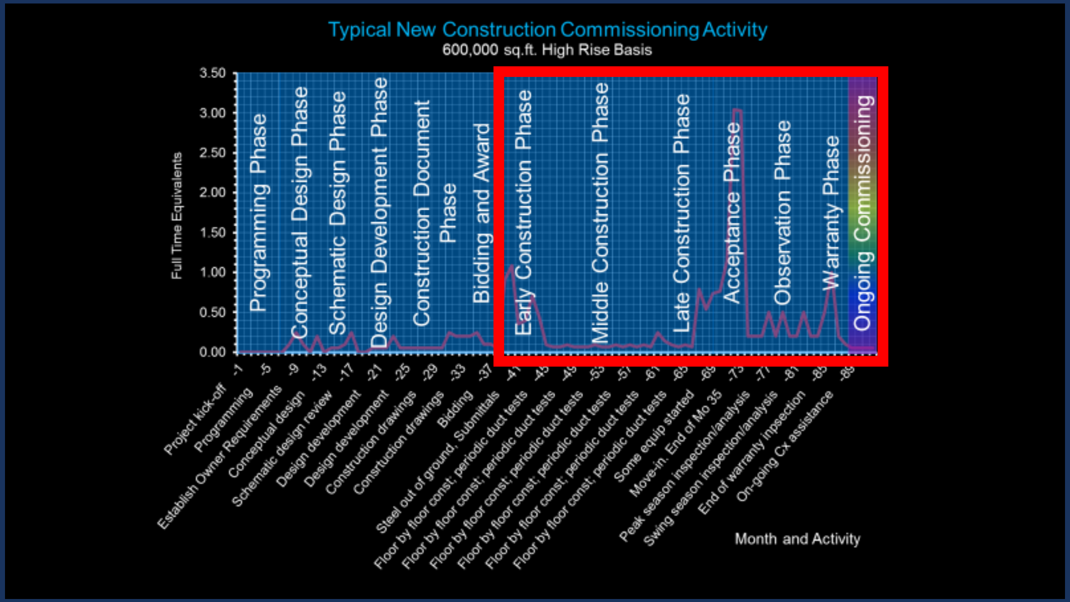




Bottom Lines

1. Construction observation targets are directly related to the technology that is being applied
2. The things you are looking for during construction for a VRF heat pump system are no different than what you would look for if you were monitoring a built up refrigeration system serving a cooling only load
3. For water based systems, the things you would look for are no different than any other piping or pumping system
4. Air side targets are no different from any other air system

NCx Functional Testing (3rd Module)



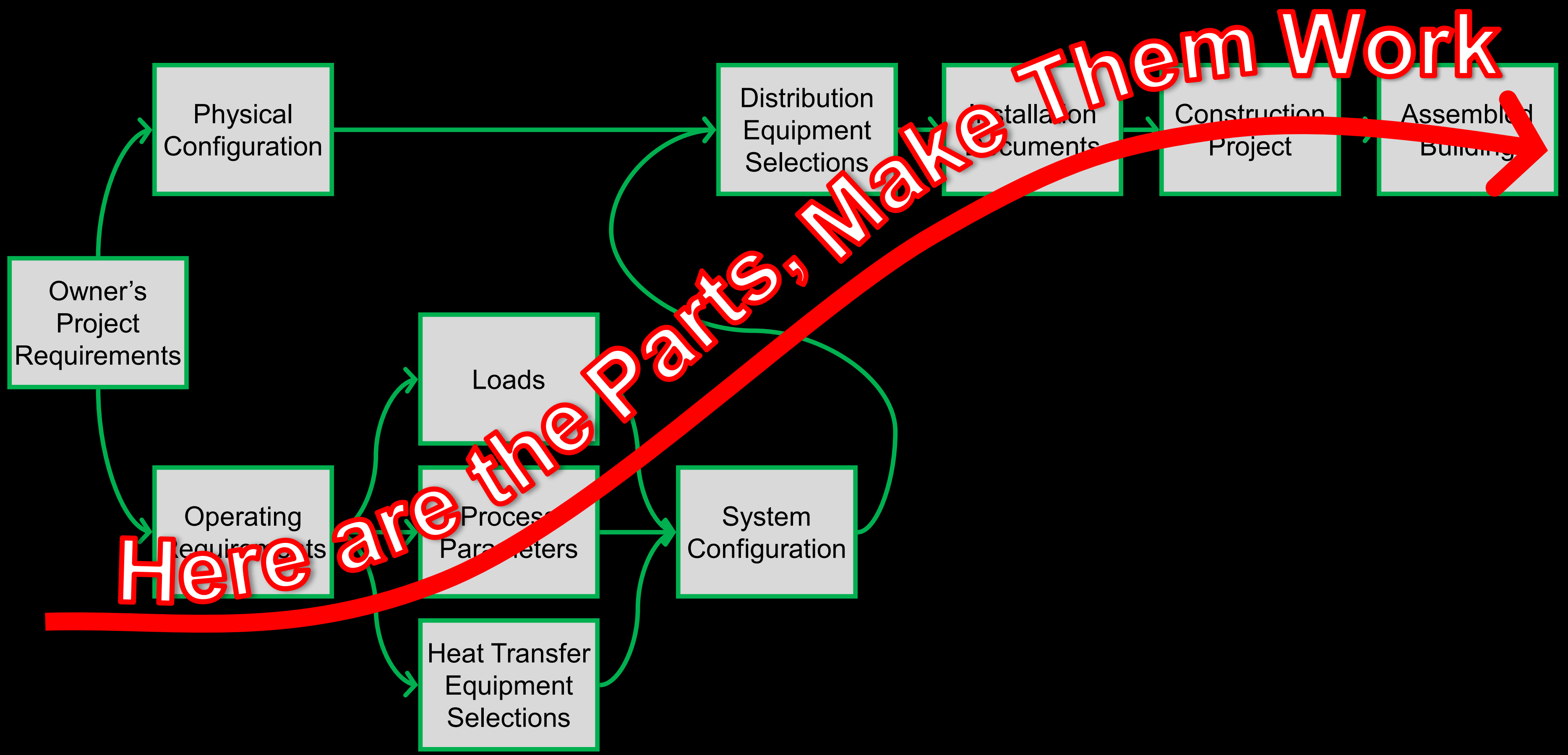
Functional Testing

- Core element of any commissioning process
- Validates machinery and systems
  - Do they deliver?
  - Why don’t they deliver?
  - Do the work well together?
  - Why aren’t they working well together
  - Was it big enough?
  - How big should it be?

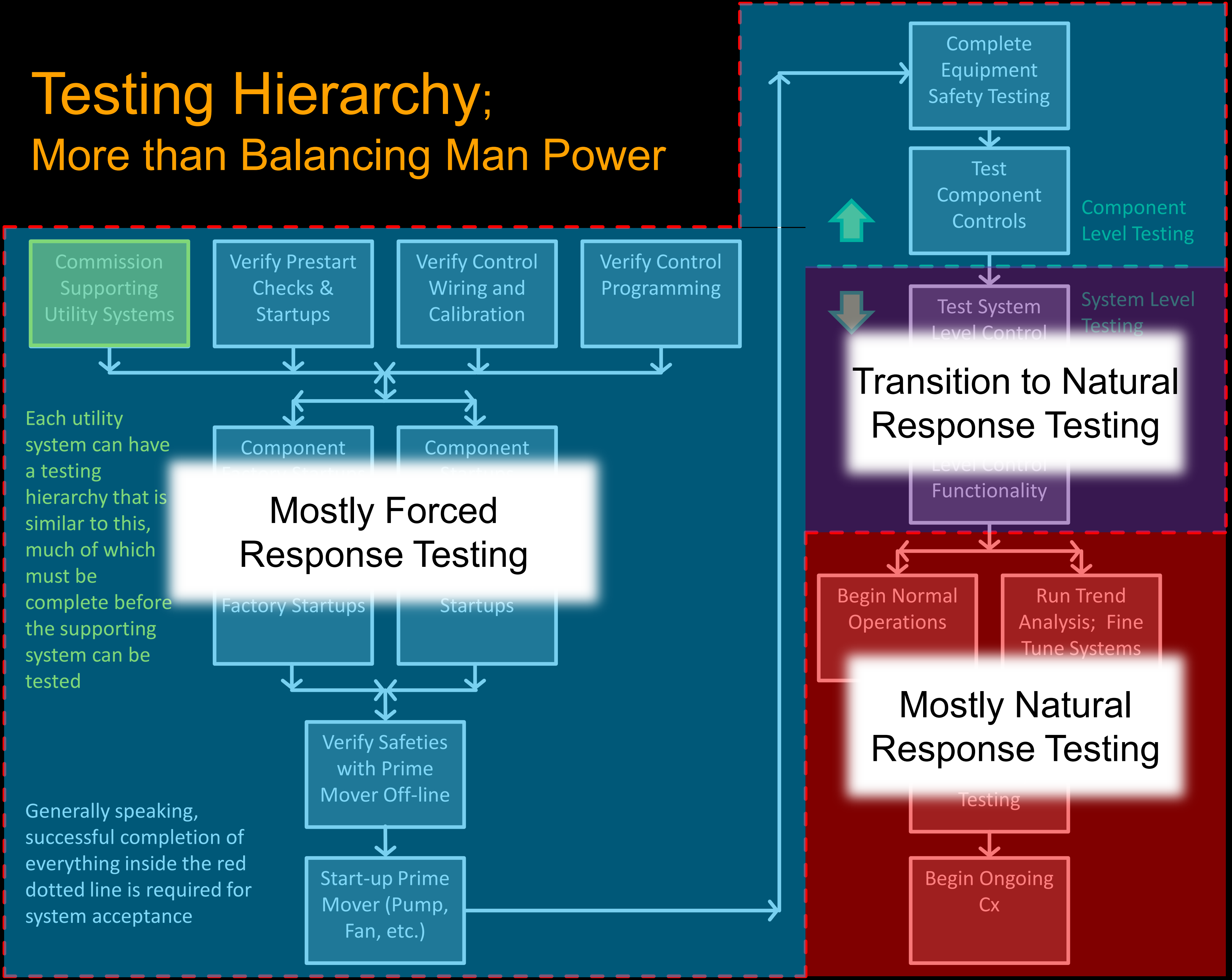
Functional Testing

- Core element of any commissioning process
- Validates machinery and systems for an NCx Process
  - Do they deliver?
  - Do the work well together?
  - Was it big enough?

Functional Testing as it Relates to the Metrics of the Systems We Test – New Construction Perspective



Testing Hierarchy;
More than Balancing Man Power



Functional Testing

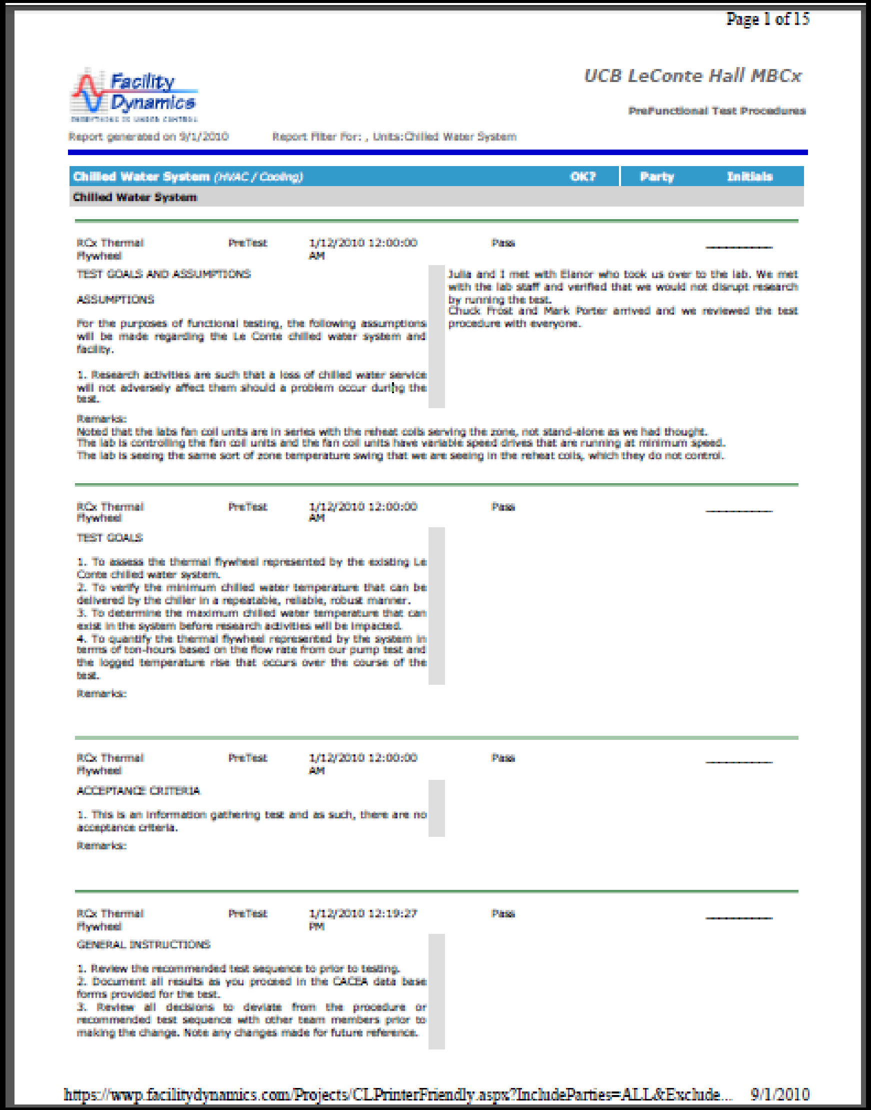
One of the ways we have a dialog with the building

How Do We Dialog with a Building?

We perform a functional test

Functional test components

- Statement of purpose
- Instructions for using the test form
- Equipment requirements
- Acceptance criteria
- Precautions
- Documentation
- Procedure
- Return to Normal and Follow-up


Page 1 of 15

Facility Dynamics

UCB LeConte Hall MBCx

PreFunctional Test Procedures

Report generated on 9/1/2010   Report Filter For: , Units:Chilled Water System

Chilled Water System (HVAC / Cooling)	OK?	Party	Initials
Chilled Water System			

RCx Thermal Flywheel | PreTest | 1/12/2010 12:00:00 AM | Pass | __________

TEST GOALS AND ASSUMPTIONS

ASSUMPTIONS

For the purposes of functional testing, the following assumptions will be made regarding the Le Conte chilled water system and facility.

1. Research activities are such that a loss of chilled water service will not adversely affect them should a problem occur during the test.

Julia and I met with Elanor who took us over to the lab. We met with the lab staff and verified that we would not disrupt research by running the test.
Chuck Frost and Mark Porter arrived and we reviewed the test procedure with everyone.

Remarks:
Noted that the labs fan coil units are in series with the reheat coils serving the zone, not stand-alone as we had thought.
The lab is controlling the fan coil units and the fan coil units have variable speed drives that are running at minimum speed.
The lab is seeing the same sort of zone temperature swing that we are seeing in the reheat coils, which they do not control.

RCx Thermal Flywheel | PreTest | 1/12/2010 12:00:00 AM | Pass | __________

TEST GOALS

1. To assess the thermal flywheel represented by the existing Le Conte chilled water system.
2. To verify the minimum chilled water temperature that can be delivered by the chiller in a repeatable, reliable, robust manner.
3. To determine the maximum chilled water temperature that can exist in the system before research activities will be impacted.
4. To quantify the thermal flywheel represented by the system in terms of ton-hours based on the flow rate from our pump test and the logged temperature rise that occurs over the course of the test.

Remarks:

RCx Thermal Flywheel | PreTest | 1/12/2010 12:00:00 AM | Pass | __________

ACCEPTANCE CRITERIA

1. This is an information gathering test and as such, there are no acceptance criteria.

Remarks:

RCx Thermal Flywheel | PreTest | 1/12/2010 12:19:27 PM | Pass | __________

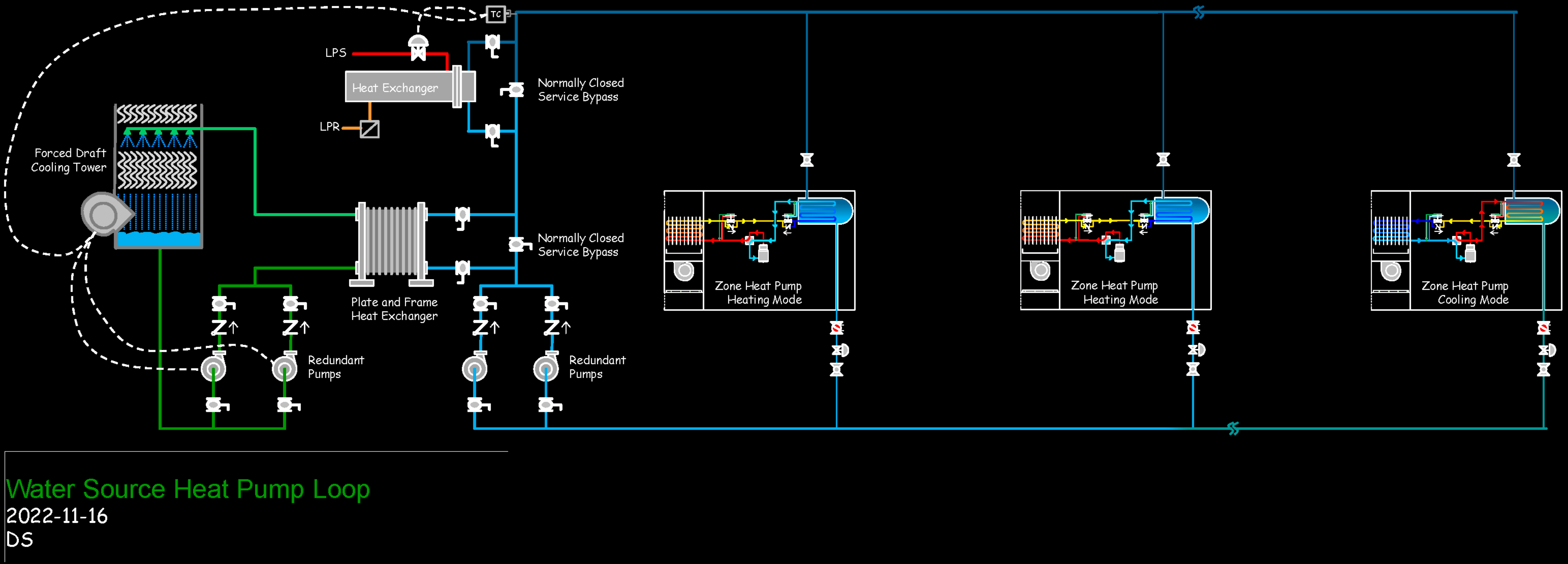
GENERAL INSTRUCTIONS

1. Review the recommended test sequence to prior to testing.
2. Document all results as you proceed in the CACEA data base forms provided for the test.
3. Review all decisions to deviate from the procedure or recommended test sequence with other team members prior to making the change. Note any changes made for future reference.

https://wwp.facilitydynamics.com/Projects/CLPrinterFriendly.aspx?IncludeParties=ALL&Exclude...   9/1/2010

Commissioning the Water Source Heat Pump Loop (3rd Module)

Forced vs. Natural Response Testing

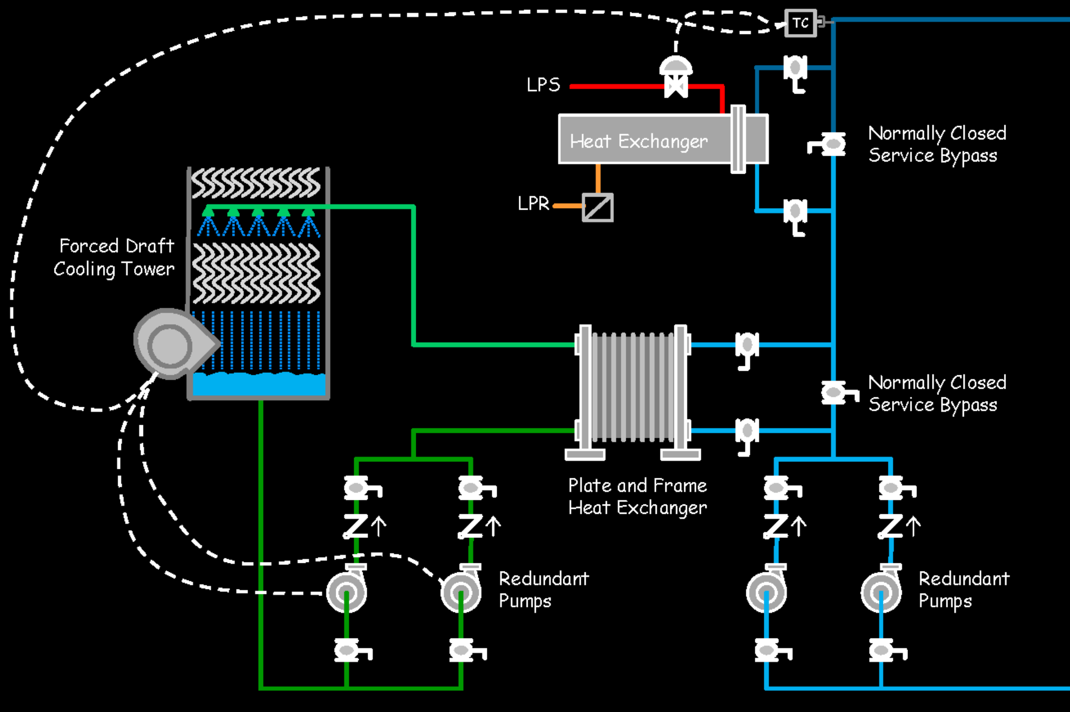


Forced vs. Natural Response Testing

Forced Response Testing

- With the system stable at a 70°F supply temperature, and
- No heat being added by the heat exchanger, and
- Some heat being rejected by the cooling tower fan operating at low speed

I override the supply temperature input and make the system "think" the supply temperature has gone up to 80°F



Water Source Heat Pump Loop
2022-11-16
DS

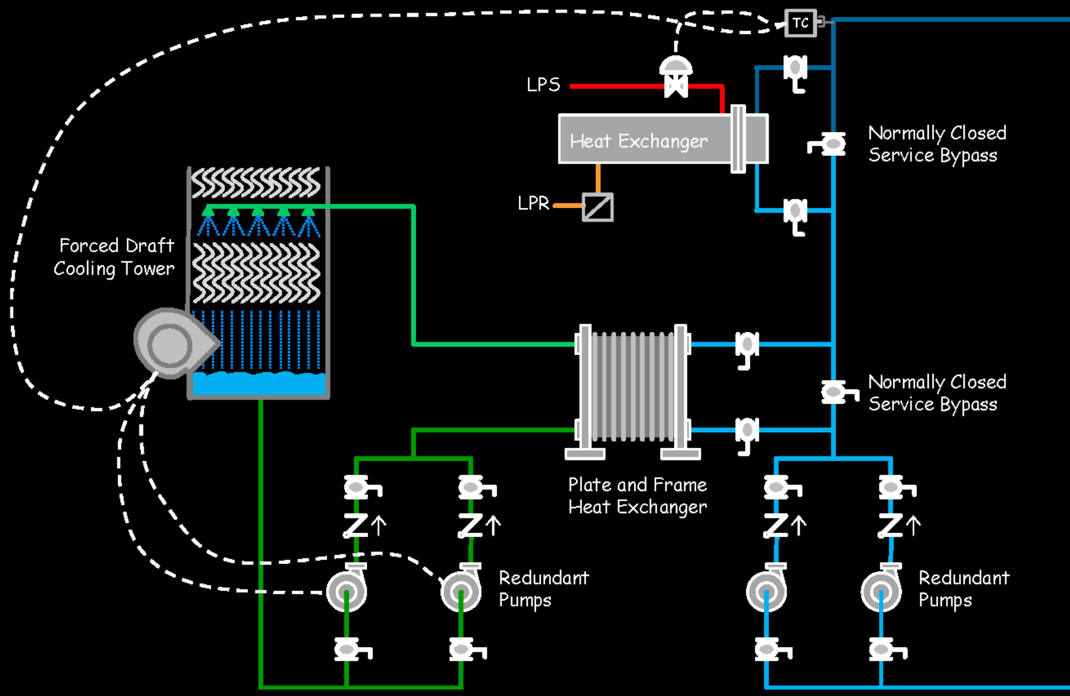
Forced vs. Natural Response Testing

Forced Response Testing

I Observe That:

- The heat exchanger valve remains closed
- The cooling tower fan speeds up to try to reject more heat and bring the temperature down to set point

I override the supply temperature input and make the system "think" the supply temperature has dropped up to 60°F (with a 70°F set point)



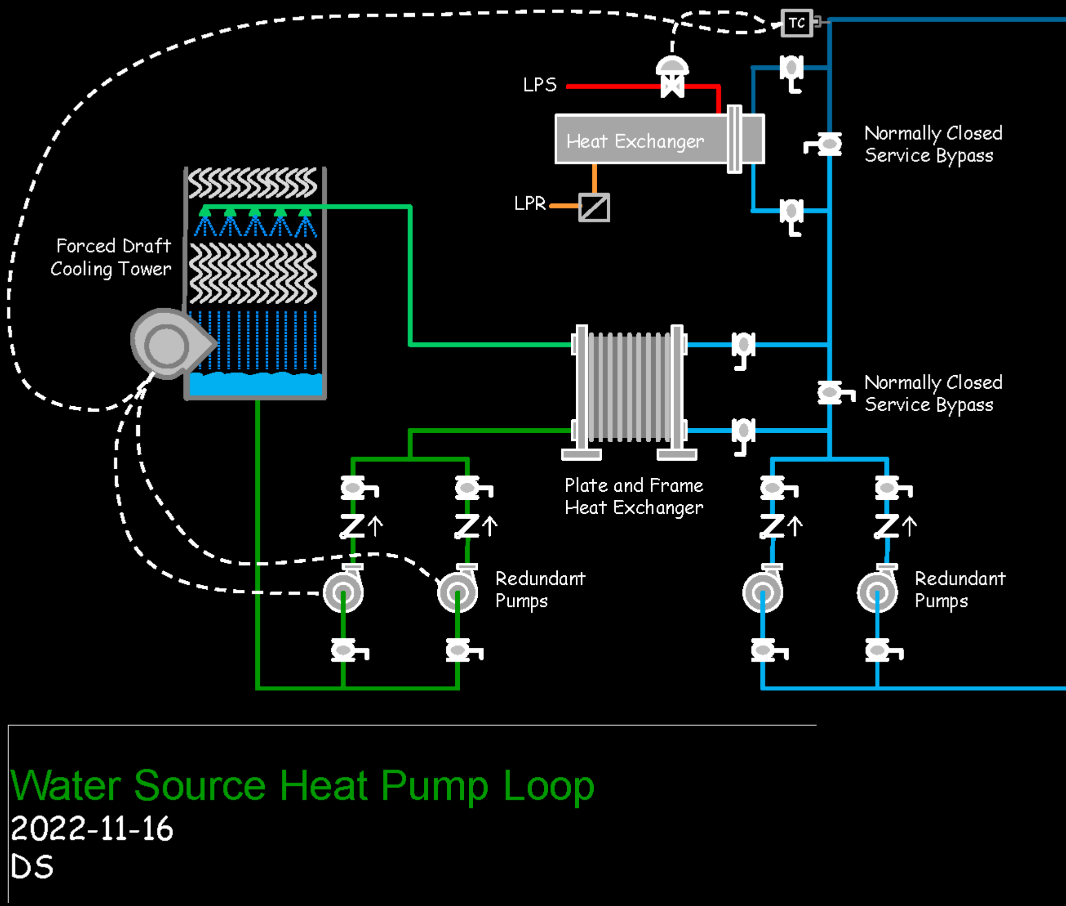
Water Source Heat Pump Loop
2022-11-16
DS

Forced vs. Natural Response Testing

Forced Response Testing

I Observe That:

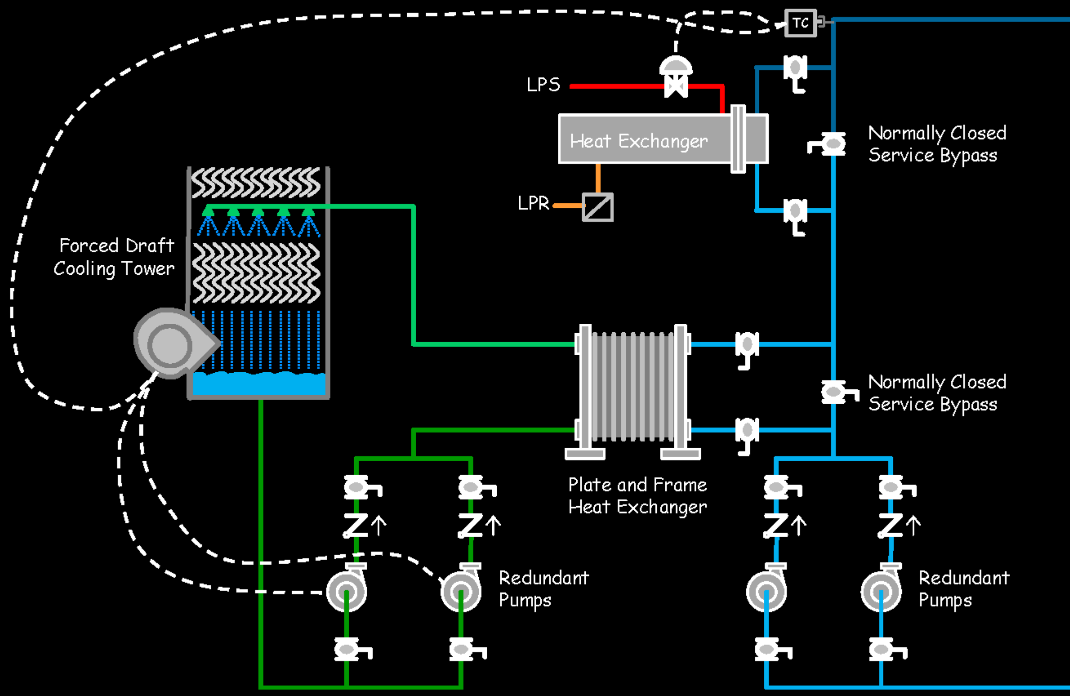
- The cooling tower fan speed is reduced, and then
- The fan is cycled off, and then
- The pumps are cycled off, and then
- The heat exchanger valve starts to modulate open to add heat to the system to bring it back up to set point



Forced vs. Natural Response Testing

Natural Response Testing

- I pull trend data from the system for a day when the outdoor air temperature swung from 53 – 98°F



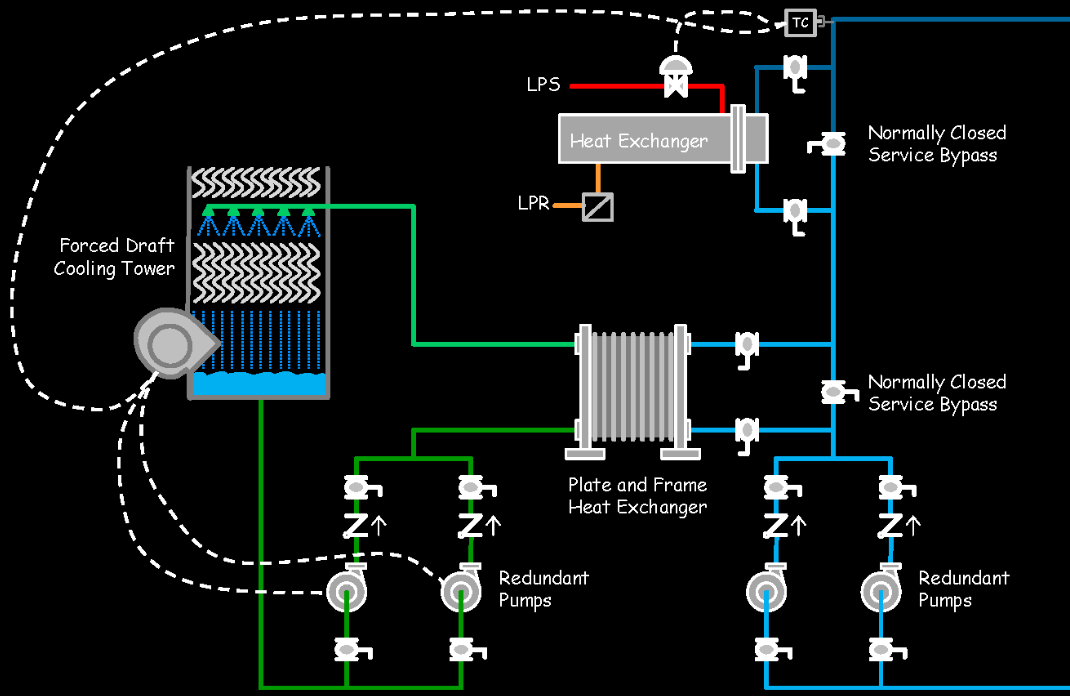
Water Source Heat Pump Loop
2022-11-16
DS

Forced vs. Natural Response Testing

Natural Response Testing

I Observe That

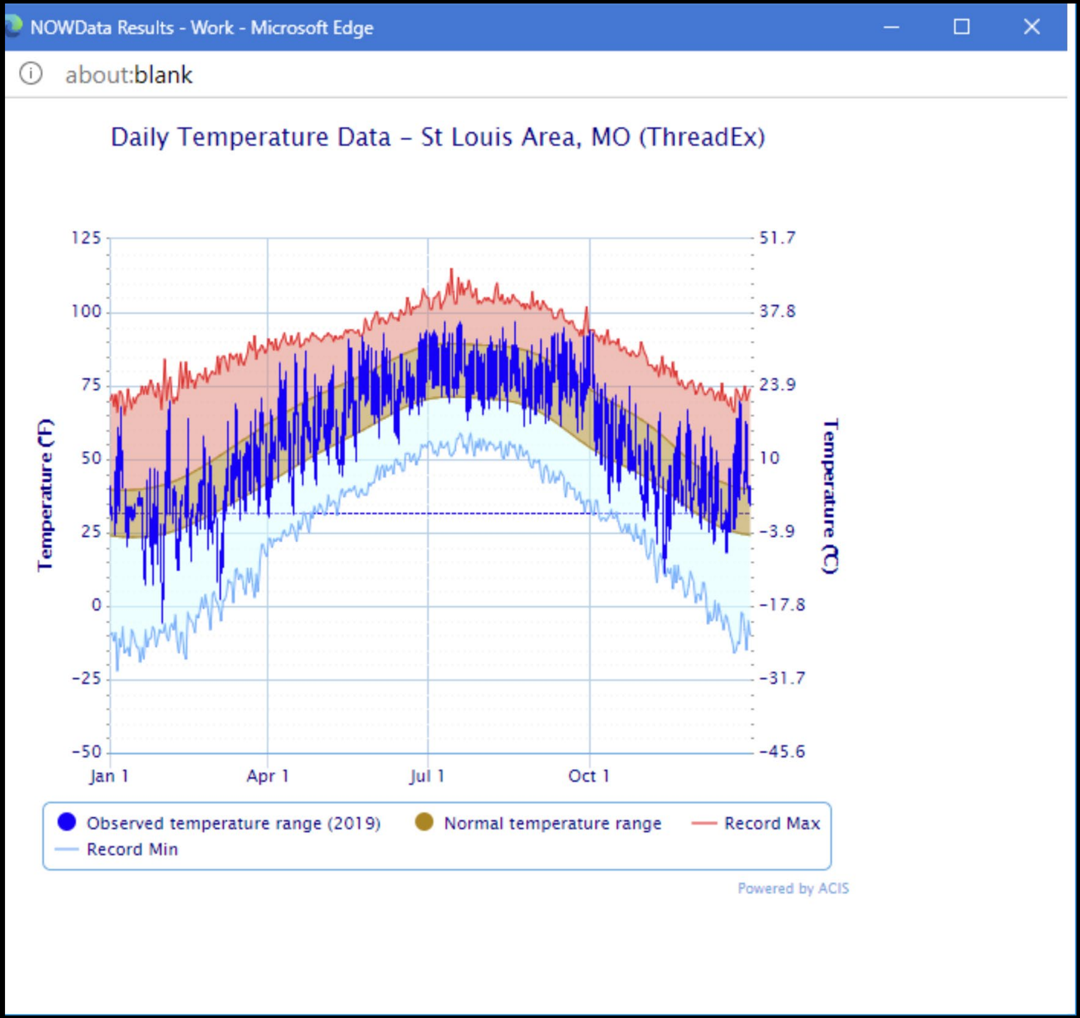
- The heat exchanger adds heat if the loop temperature drops below set point, and
- The cooling tower rejects heat when the loop temperature rises above set point, and
- The heat exchanger is never active when the cooling tower is active, but
- The loop temperature is very unstable when there is a small load on the heat exchanger and,
- The cooling tower fan short cycles when the heat rejection requirement is modest

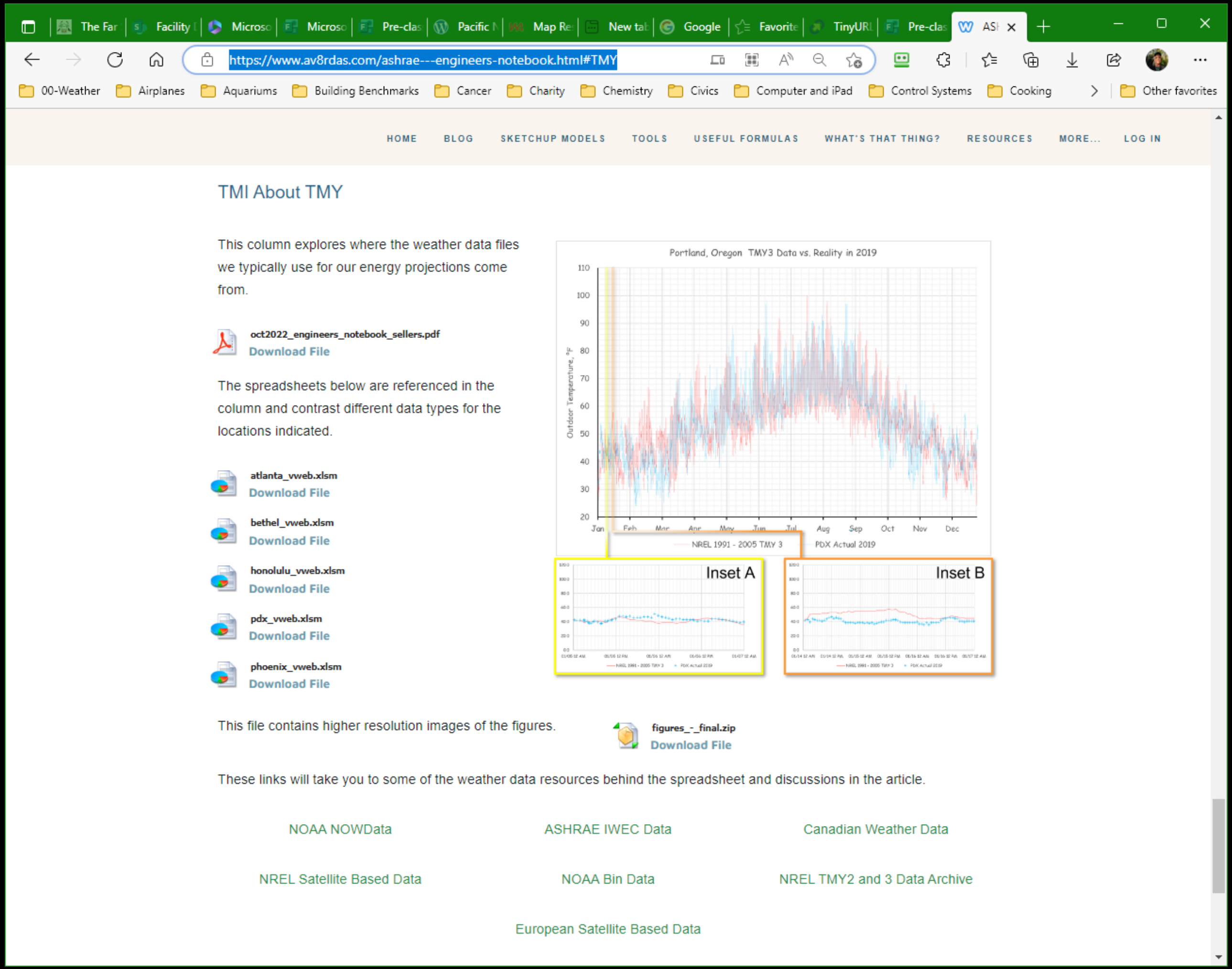


Water Source Heat Pump Loop
2022-11-16
DS

Finding the Day You Want to Observe

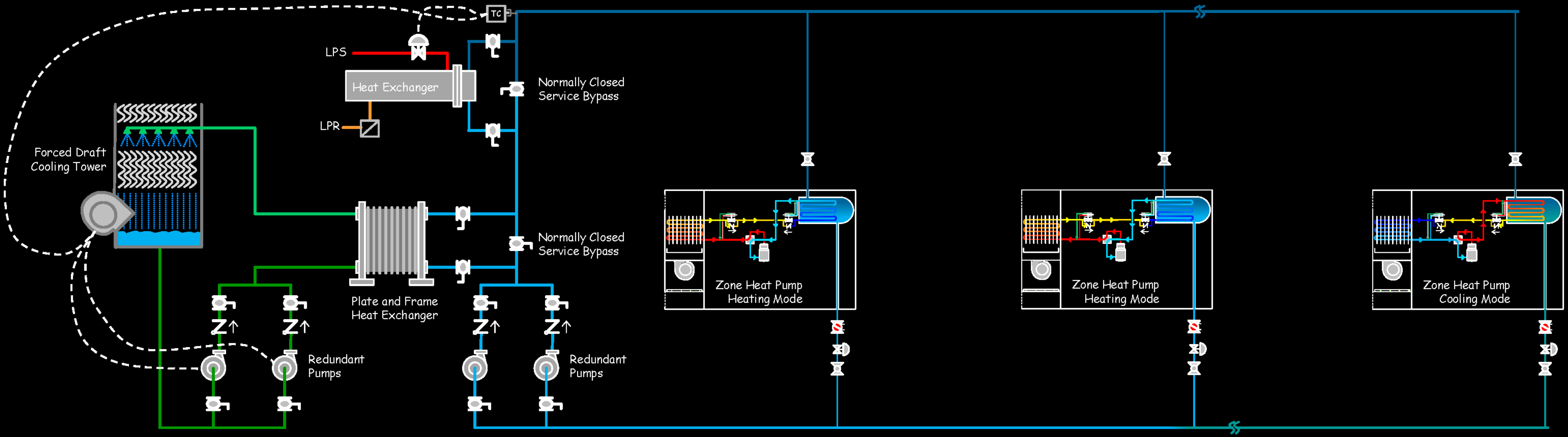
https://tinyurl.com/TMIAboutTMY





A Question For You

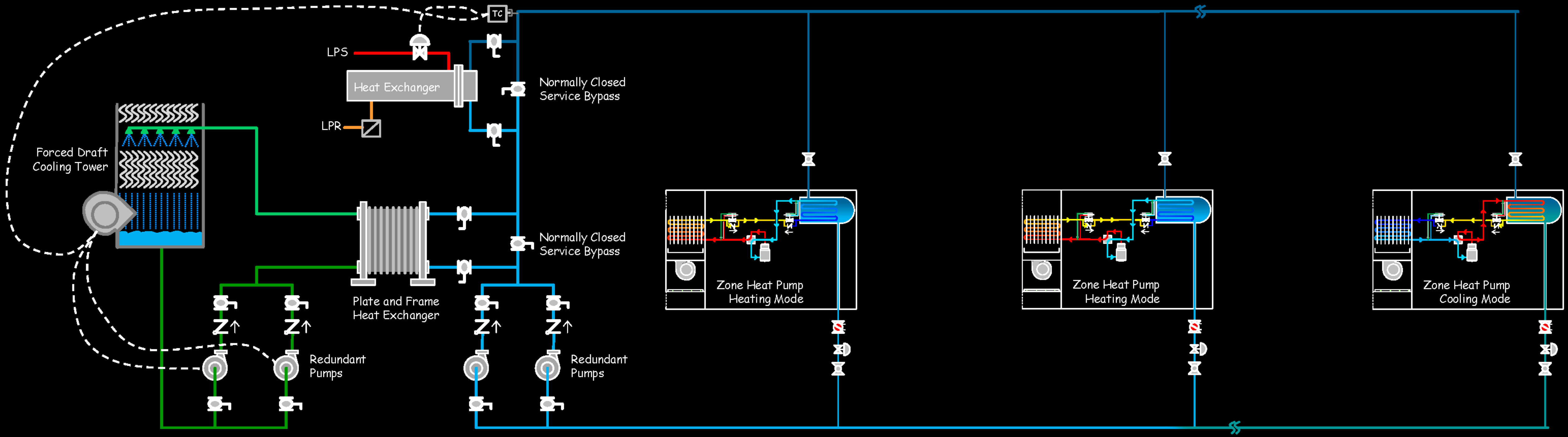
What would be the best order for starting up the water source heat pump loop shown below?



Water Source Heat Pump Loop
2022-11-16
DS

Yet Another Question For You

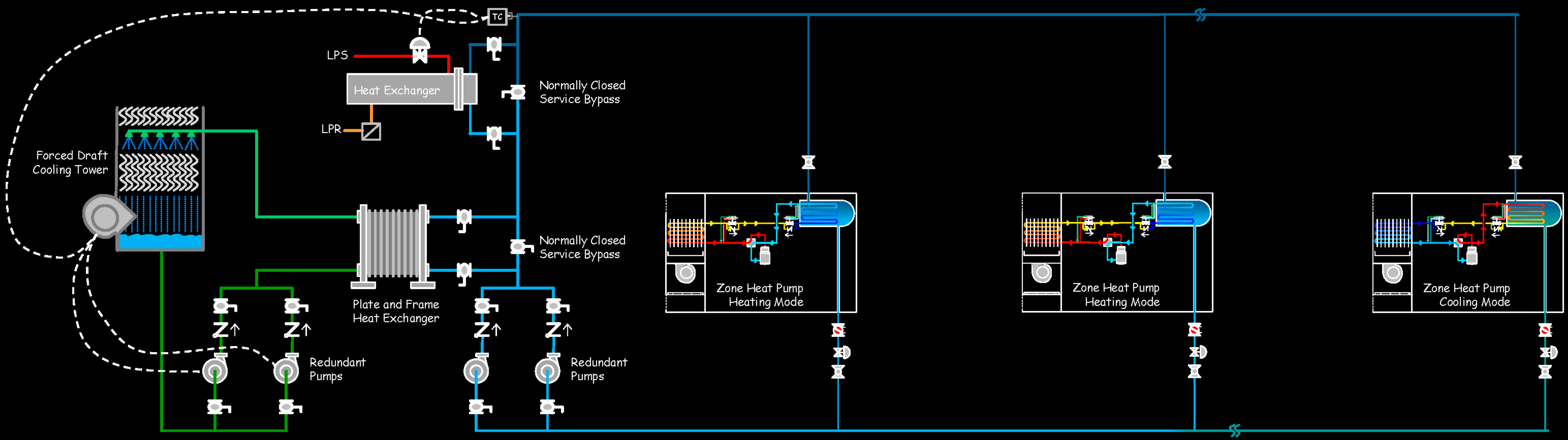
What resources would you use to develop your prefunctional and functional tests?



Water Source Heat Pump Loop
2022-11-16
DS

Yet Another Question For You

What should the targets be for functional tests that will verify proper integrated operation of the system and all of its components?



Water Source Heat Pump Loop
2022-11-16
DS

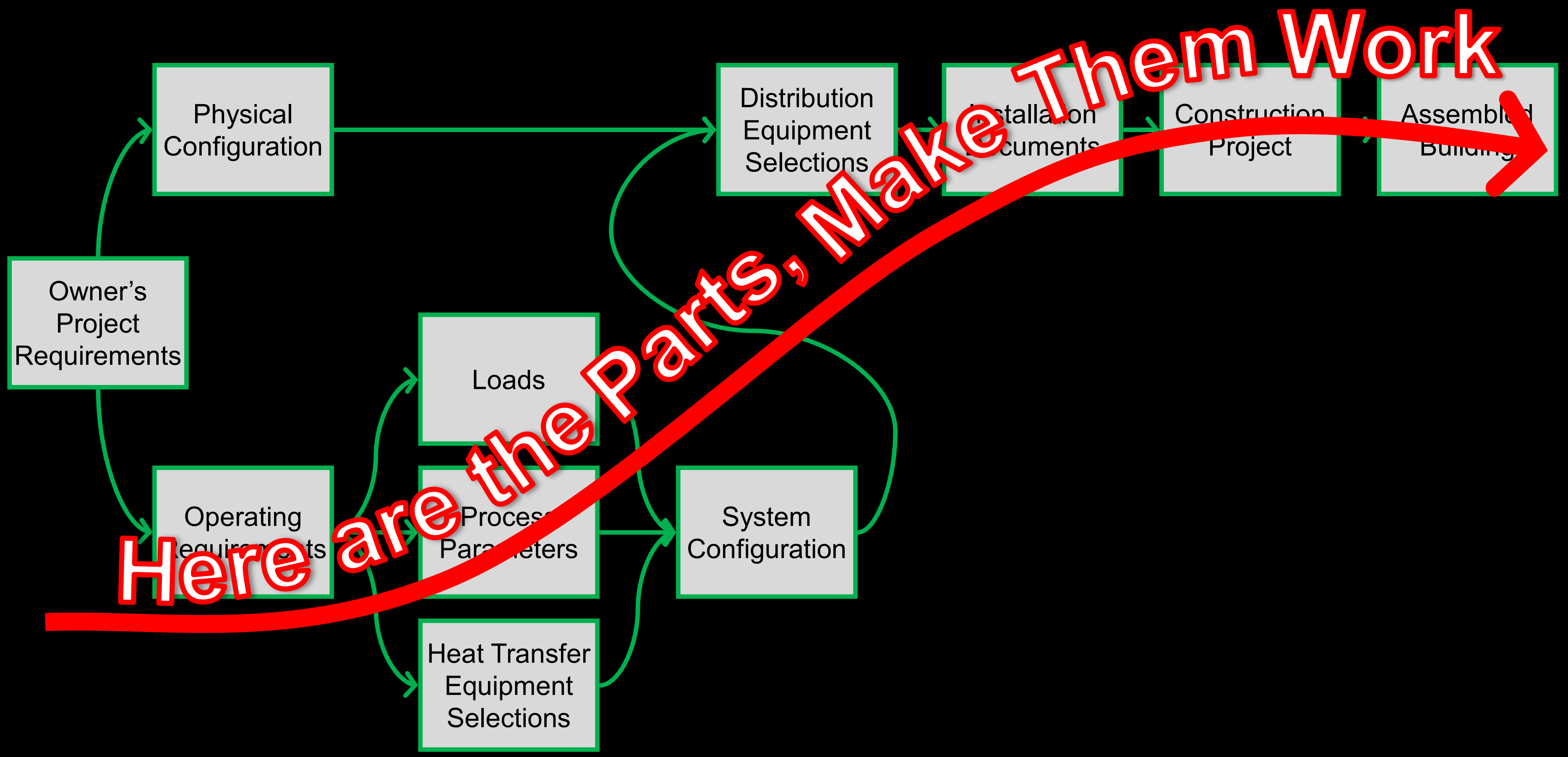
EBCx Commissioning Process (Today's Topic)

EBCx Commissioning Phases

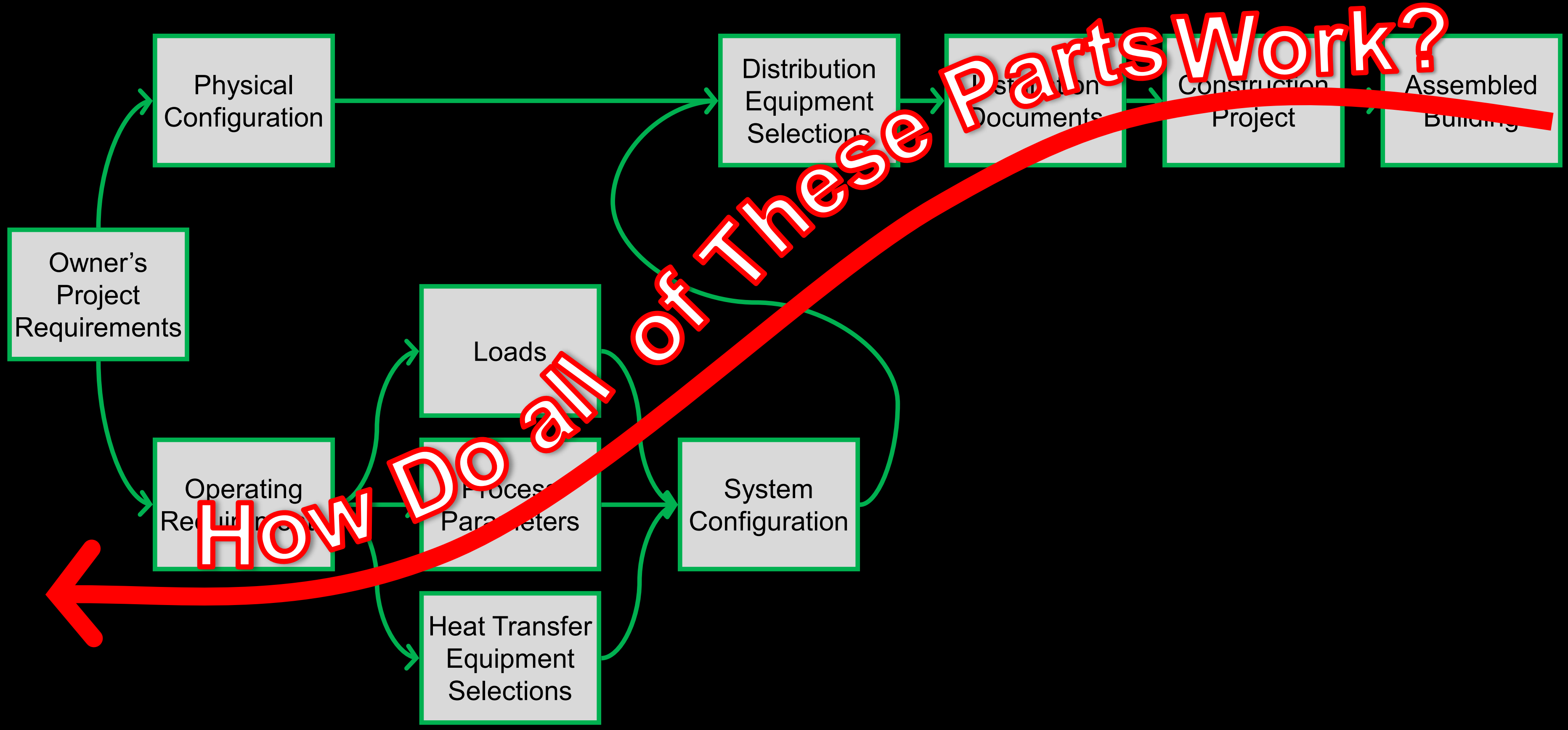
- Scoping
  - Benchmarking and utility analysis
  - Site Visit
    - Start to learn the facility
    - Look for obvious indicators
- Investigation
  - Data logging and trend analysis
  - Functional testing
  - Cost/benefit analysis
- Implementation
  - Make improvements based on the results of investigation
  - Owner vetted
- Verification
  - Make sure things work as expected
  - Make sure targeted saving are delivered
  - A mini new construction commissioning process

EBCx Functional Testing

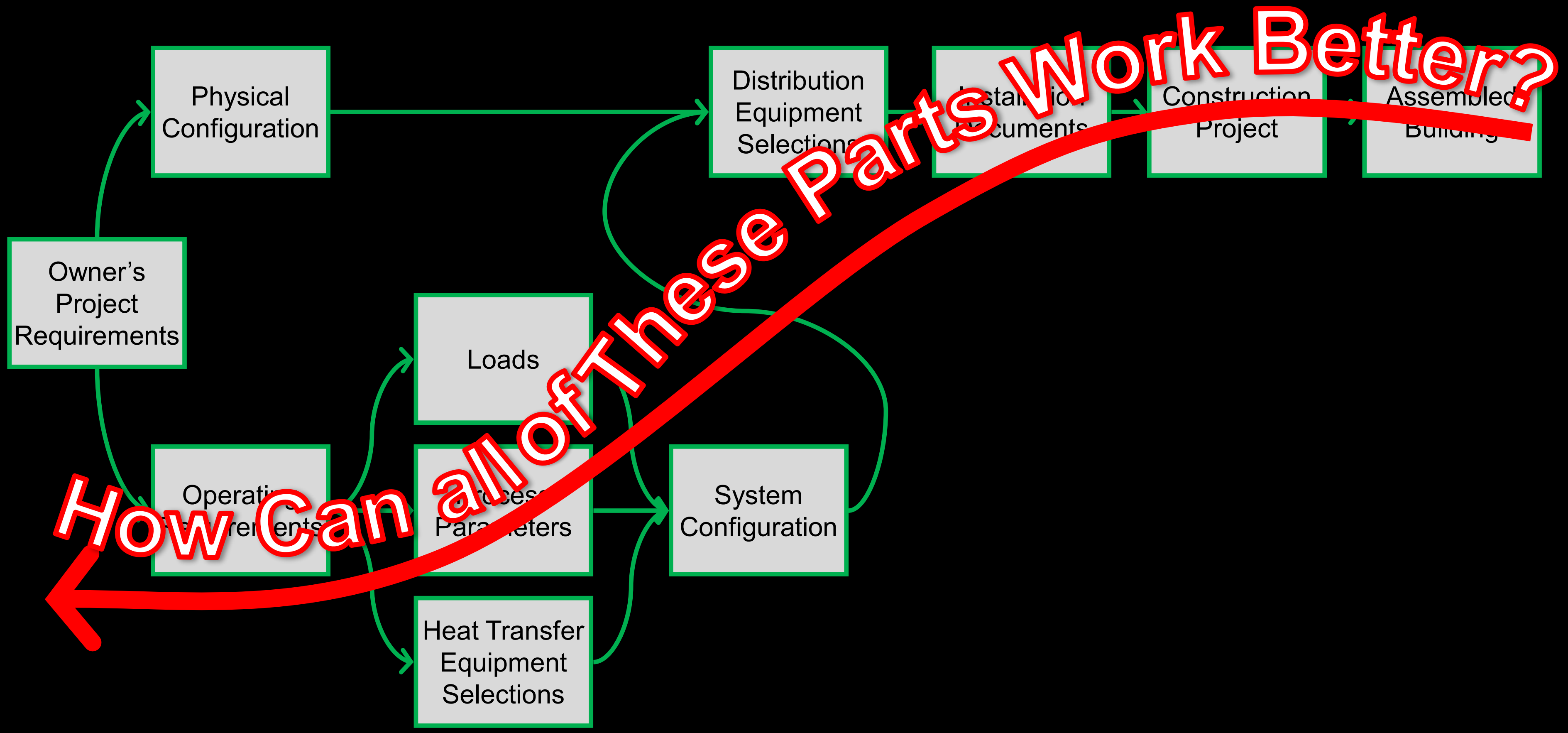
Functional Testing as it Relates to the Metrics of the Systems We Test – New Construction Perspective



Functional Testing as it Relates to the Metrics of the Systems We Test – Existing Building Perspective



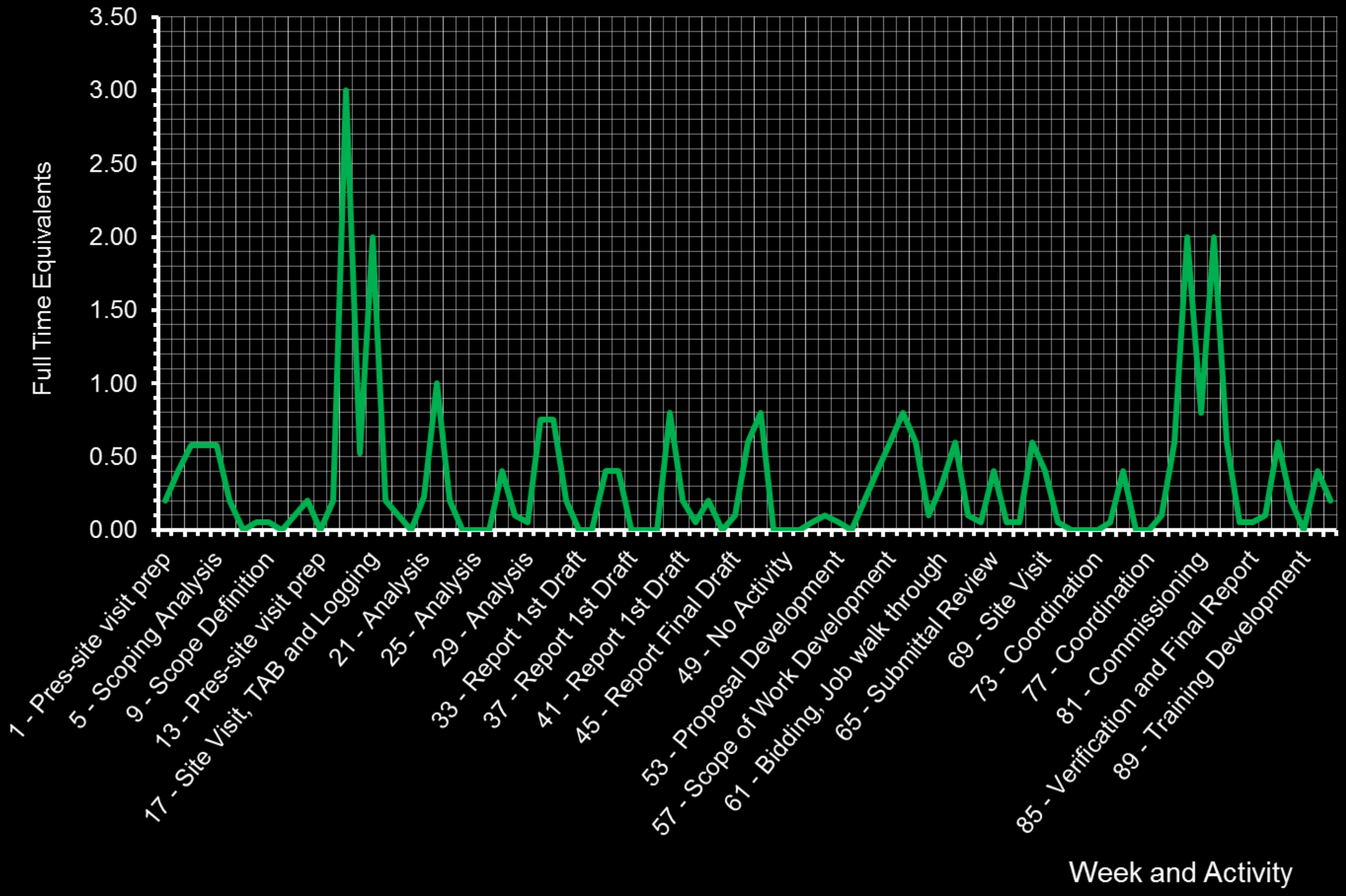
Functional Testing as it Relates to the Metrics of the Systems We Test – Existing Building Perspective



Functional Testing as it Relates to the Project Timeline

Typical Existing Building Construction Commissioning Activity

750,000 sq.ft. Hospital Basis



Typical Existing Building Construction Commissioning Activity

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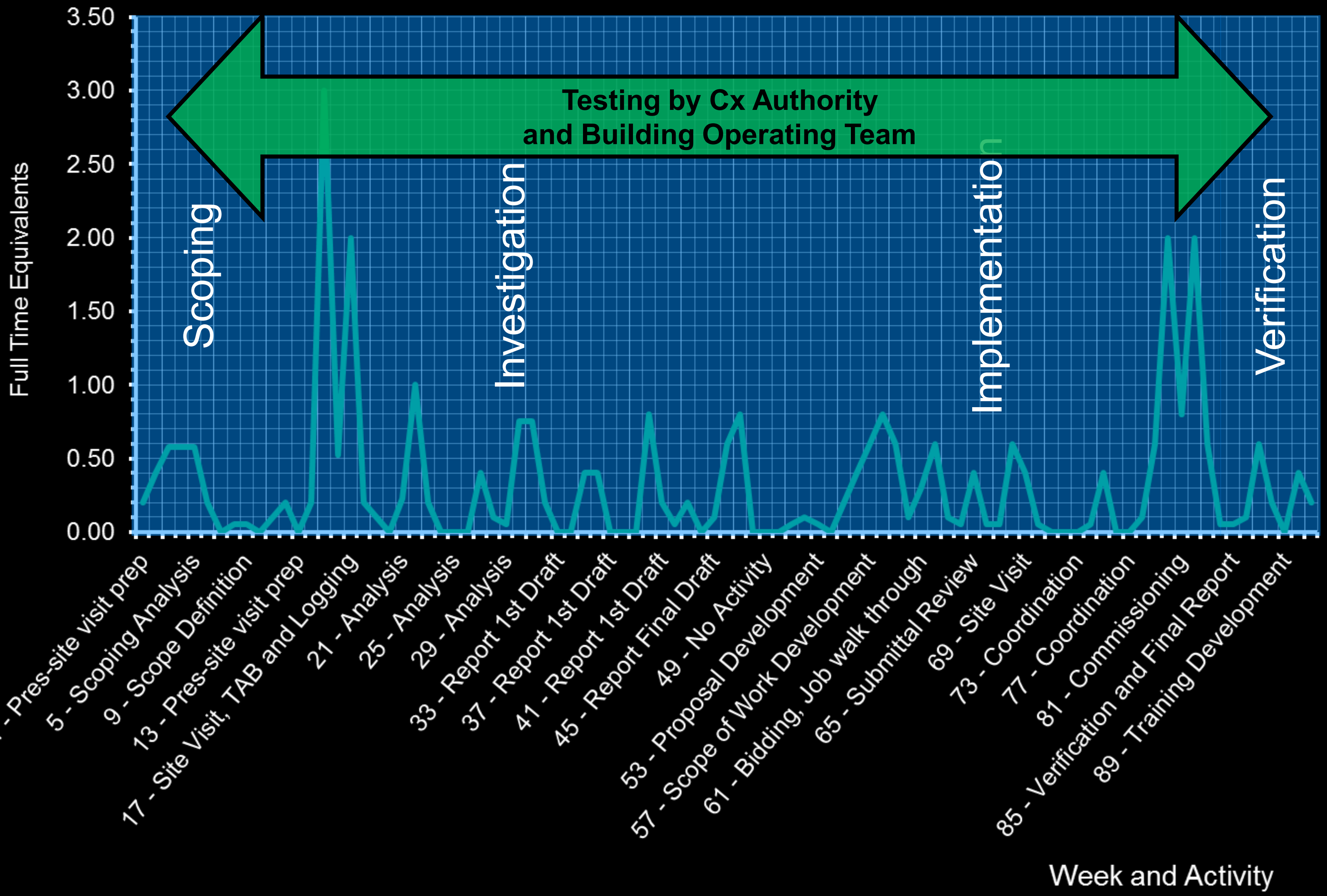

Typical Existing Building Construction Commissioning Activity

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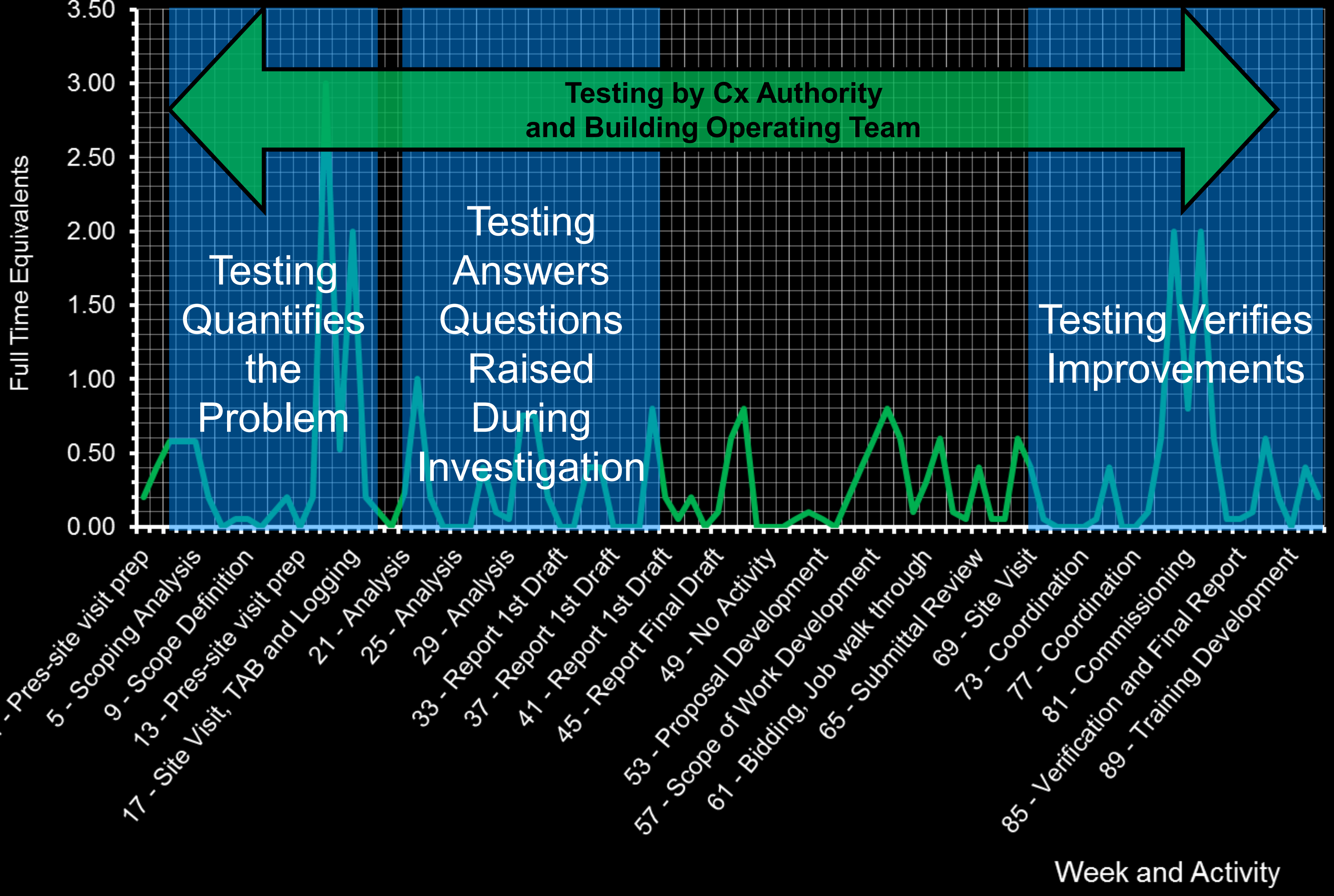


New Construction versus EBCx Testing

New Construction

- Trying to prove design intent
- Demonstrate all elements of the system meet requirements
- Verification and quality assurance process

EBCx

- Trying to understand design intent
- Focused on certain elements of the system
- Diagnostic and troubleshooting process

Functional Testing

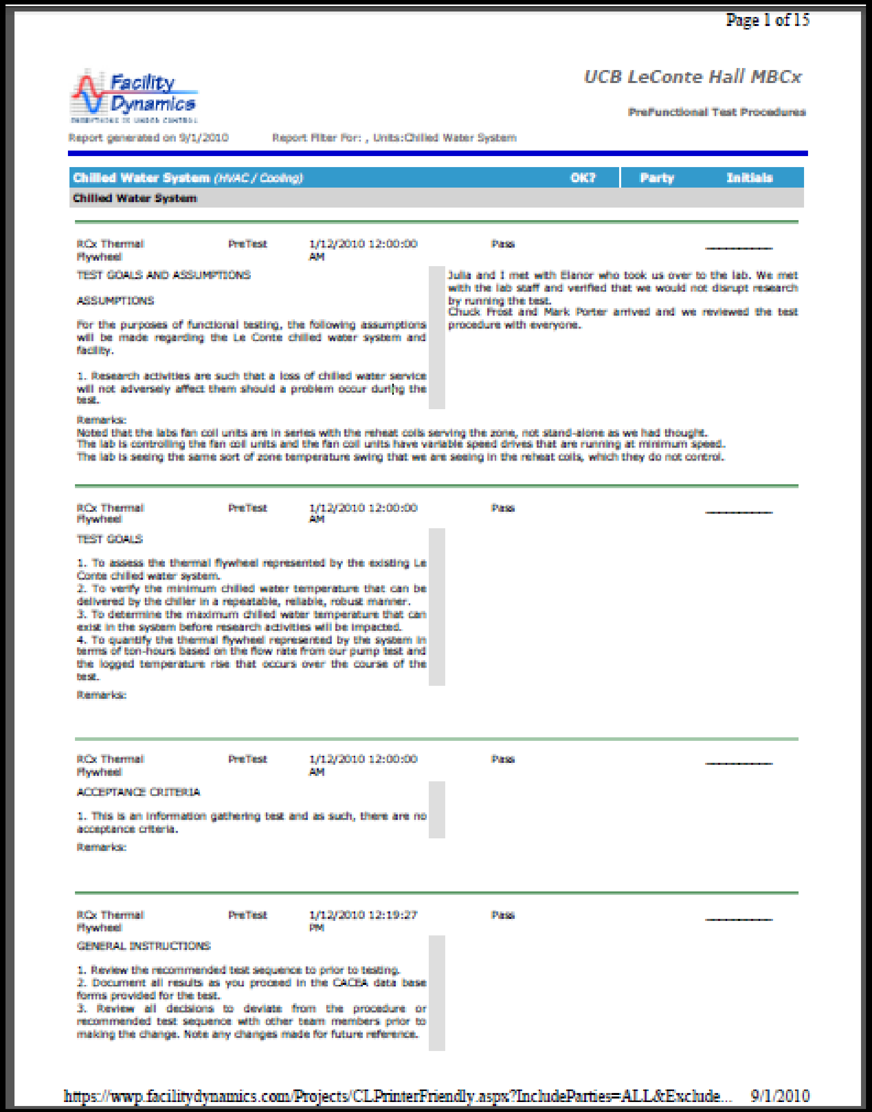
One of the ways we have a dialog with the building

How Do We Dialog with a Building?

We perform a functional test

Functional test components

- Statement of purpose
- Instructions for using the test form
- Equipment requirements
- Acceptance criteria
- Precautions
- Documentation
- Procedure
- Return to Normal and Follow-up
- https://tinyurl.com/CHWFlywheelTest



Page 1 of 15

Facility Dynamics

UCB LeConte Hall MBCx

PreFunctional Test Procedures

Report generated on 9/1/2010 Report Filter For: , Units:Chilled Water System

Chilled Water System *(HVAC / Cooling)*				OK?	Party	Initials
Chilled Water System						
RCx Thermal Flywheel	PreTest	1/12/2010 12:00:00 AM		Pass		________
RCx Thermal Flywheel	PreTest	1/12/2010 12:00:00 AM		Pass		________
RCx Thermal Flywheel	PreTest	1/12/2010 12:00:00 AM		Pass		________
RCx Thermal Flywheel	PreTest	1/12/2010 12:19:27 PM		Pass		________

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TEST GOALS

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3. To determine the maximum chilled water temperature that can exist in the system before research activities will be impacted.
4. To quantify the thermal flywheel represented by the system in terms of ton-hours based on the flow rate from our pump test and the logged temperature rise that occurs over the course of the test.

Remarks:

ACCEPTANCE CRITERIA

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Remarks:

GENERAL INSTRUCTIONS

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https://wwp.facilitydynamics.com/Projects/CLPrinterFriendly.aspx?IncludeParties=ALL&Exclude... 9/1/2010

The Real Trick

Figuring out what to ask

Figuring Out What to Ask for New Construction Projects

General Goal - NCx

Validate the machinery and systems

1. Do the systems deliver?
2. Do the systems work well together?
3. Was the machine big enough?

Figuring Out What to Ask for Existing Building Projects

General Goal EBCx

Troubleshooting, Diagnostics, Data Gathering for Investigation and Analysis

1. Do the systems deliver?
2. Do the systems work well together?
3. Was the machine big enough?

Figuring Out What to Ask for New Construction Projects

General Goal EBCx

Troubleshooting, Diagnostics, Data Gathering for Investigation and Analysis

1. Why don’t the systems deliver?
2. Do the systems work well together?
3. Was the machine big enough?

Figuring Out What to Ask for New Construction Projects

General Goal EBCx

Troubleshooting, Diagnostics, Data Gathering for Investigation and Analysis

1. Why don't the systems deliver?
2. Why don't the systems work well together?
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Figuring Out What to Ask for New Construction Projects

General Goal EBCx

Troubleshooting, Diagnostics, Data Gathering for Investigation and Analysis

1. Why don't the systems deliver?
2. Why don't the systems work well together?
3. How big does the machine need to be?

Figuring Out What to Ask for New Construction Projects

General Goal EBCx

Troubleshooting, Diagnostics, Data Gathering for Investigation and Analysis

1. Why don’t the systems deliver?
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3. How big does the machine need to be?
4. How much will I save if I make my targeted improvement?

Figuring Out What to Ask for New Construction Projects

General Goal EBCx

Troubleshooting, Diagnostics, Data Gathering for Investigation and Analysis

1. Why don't the systems deliver?
2. Why don't the systems work well together?
3. How big does the machine need to be?
4. How much will I save if I make my targeted improvement?

Resources

- The design documents
- Manufacturers literature
- The control system design narrative and logic diagrams

  This could be different from the information on the vendor control drawings!

- The Functional Testing Guide

  https://tinyurl.com/FTGBlogPost

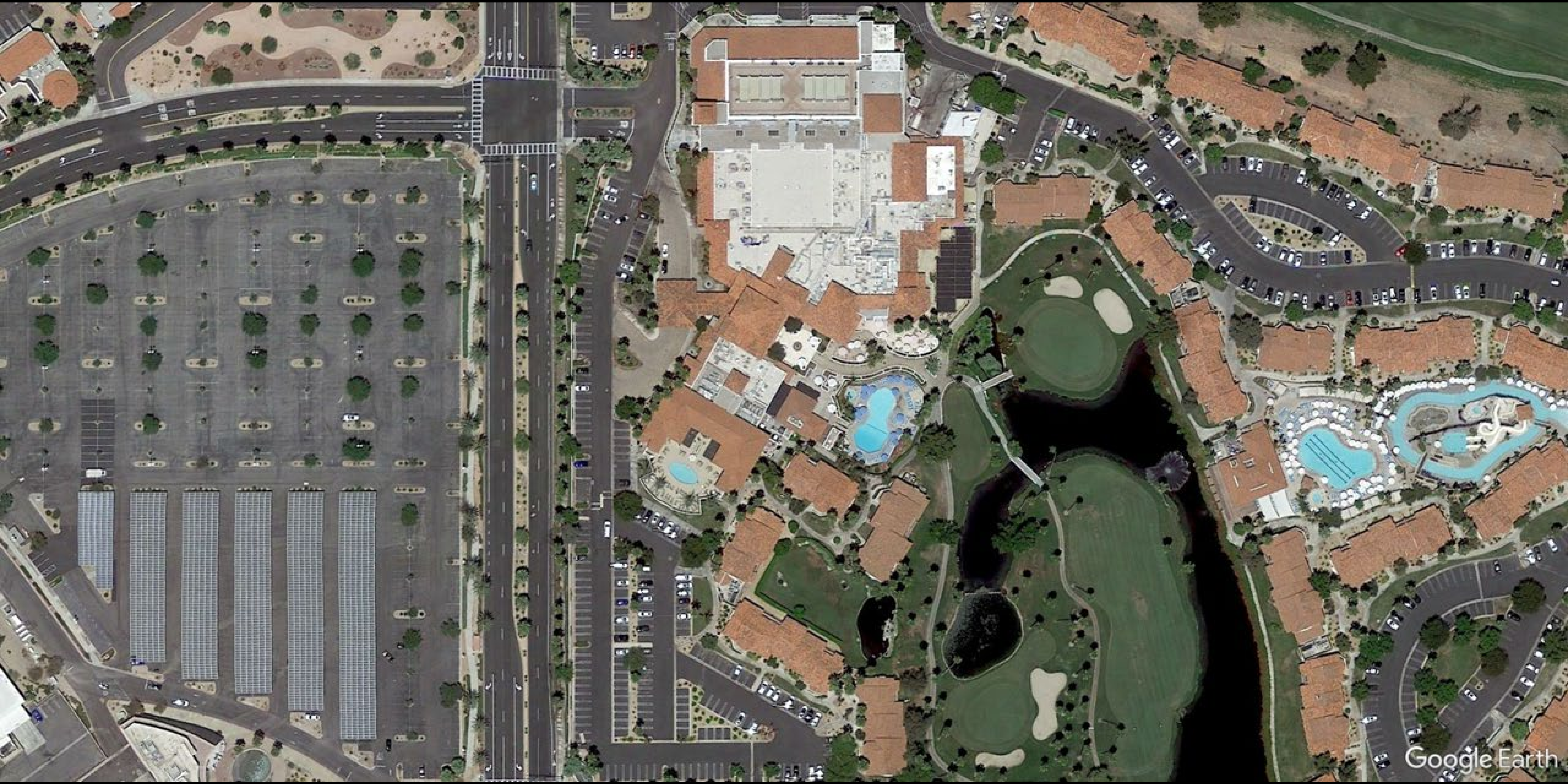
- Your knowledge and experience

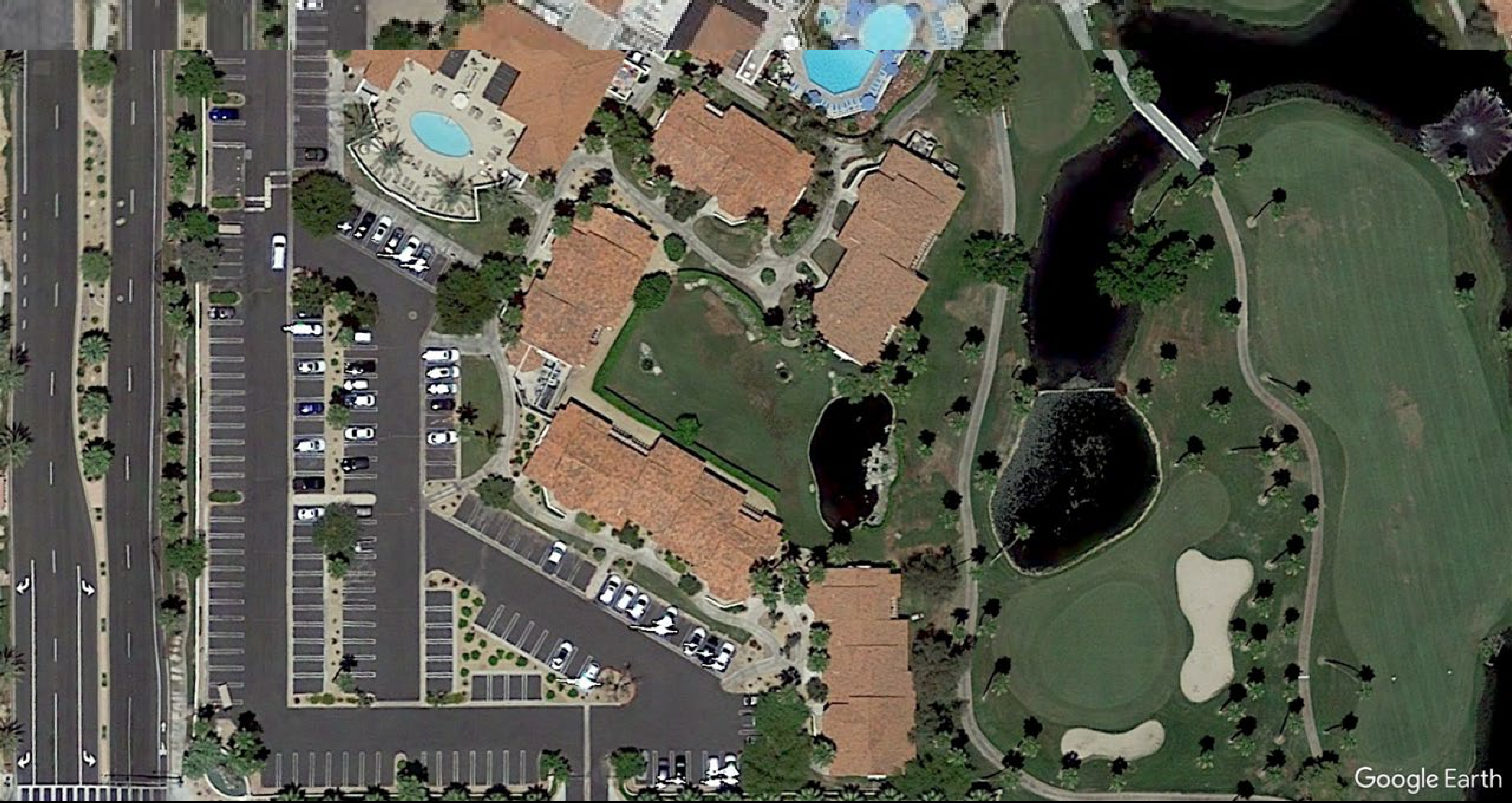
Gaining Some Experience

Focusing on an Existing System

A Hospitality Industry Campus Style Location

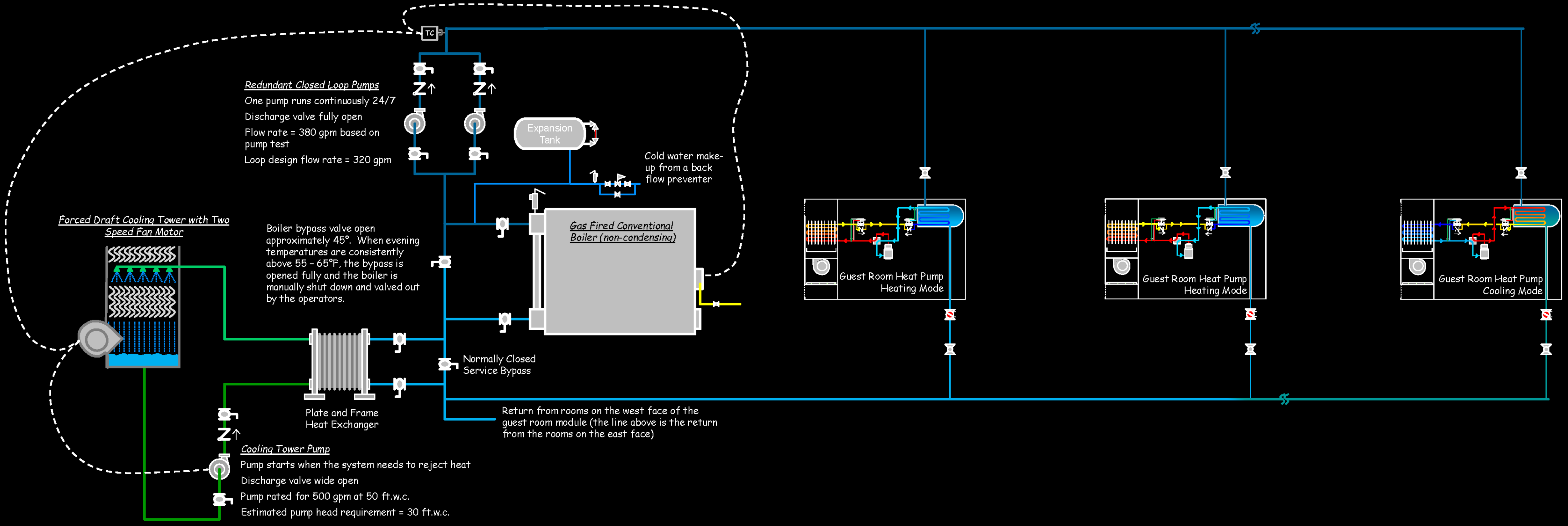
- Palm Springs, CA
- North is towards the top of the image
- Focusing on the guest room buildings


Google Earth

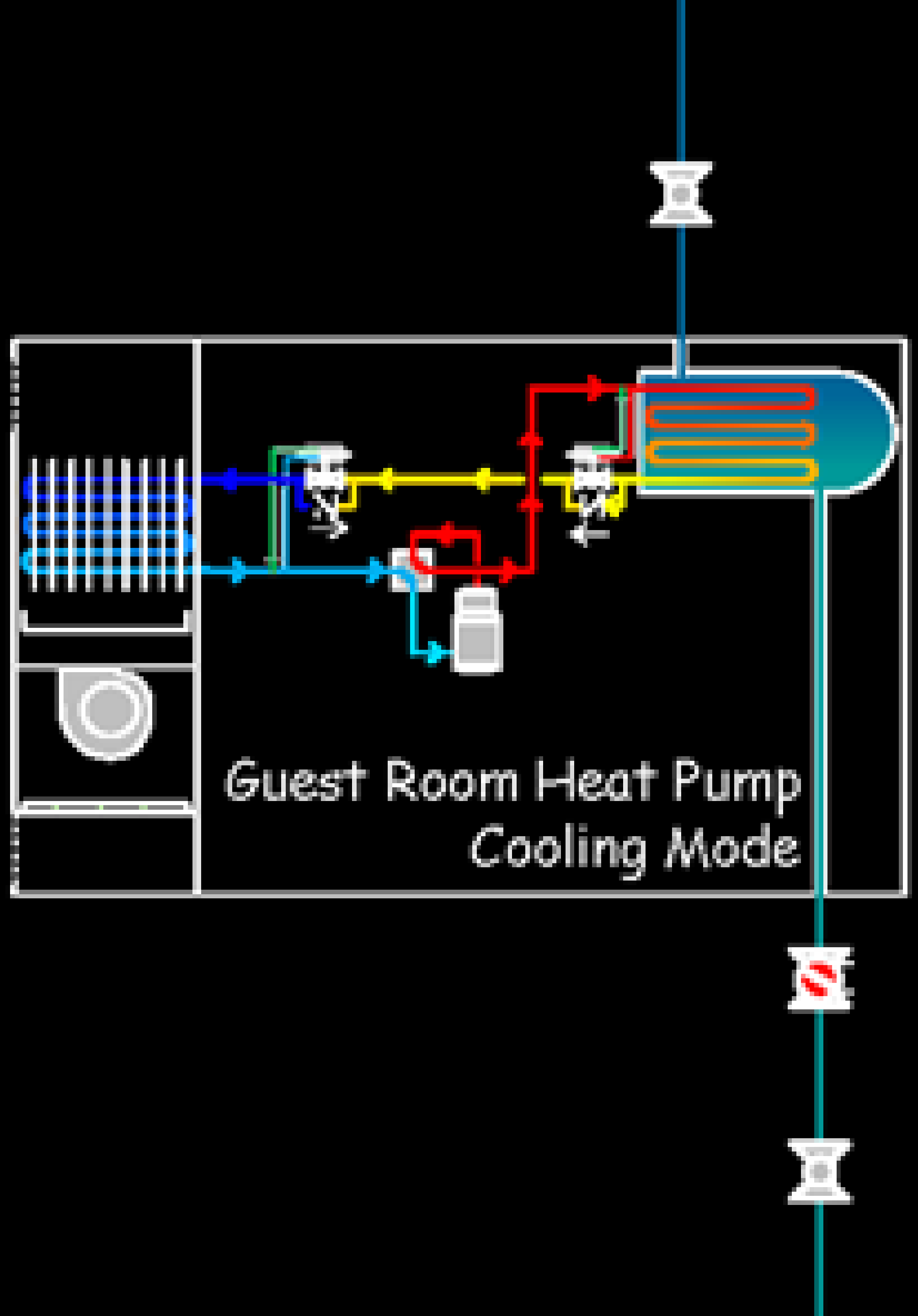

Google Earth

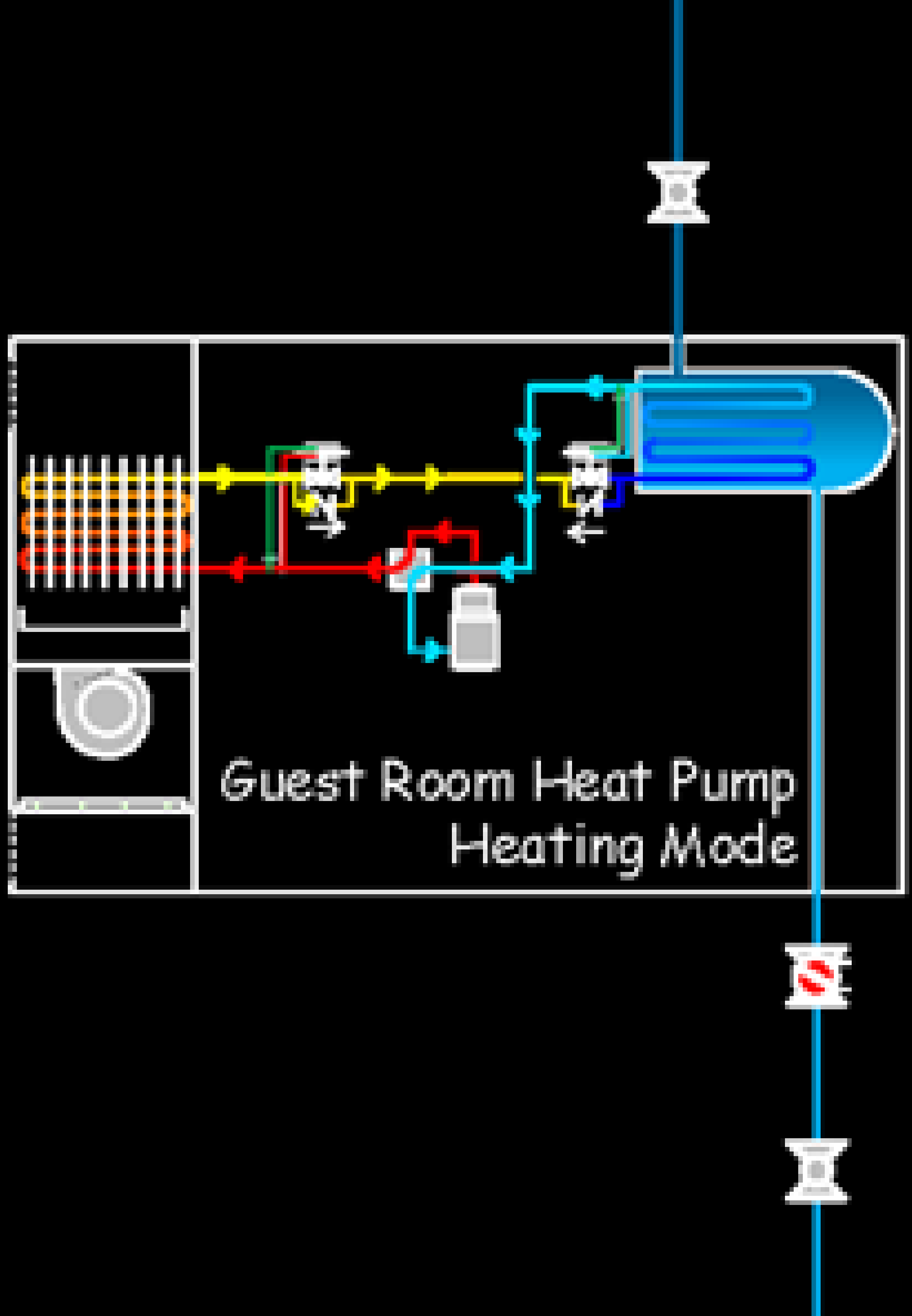


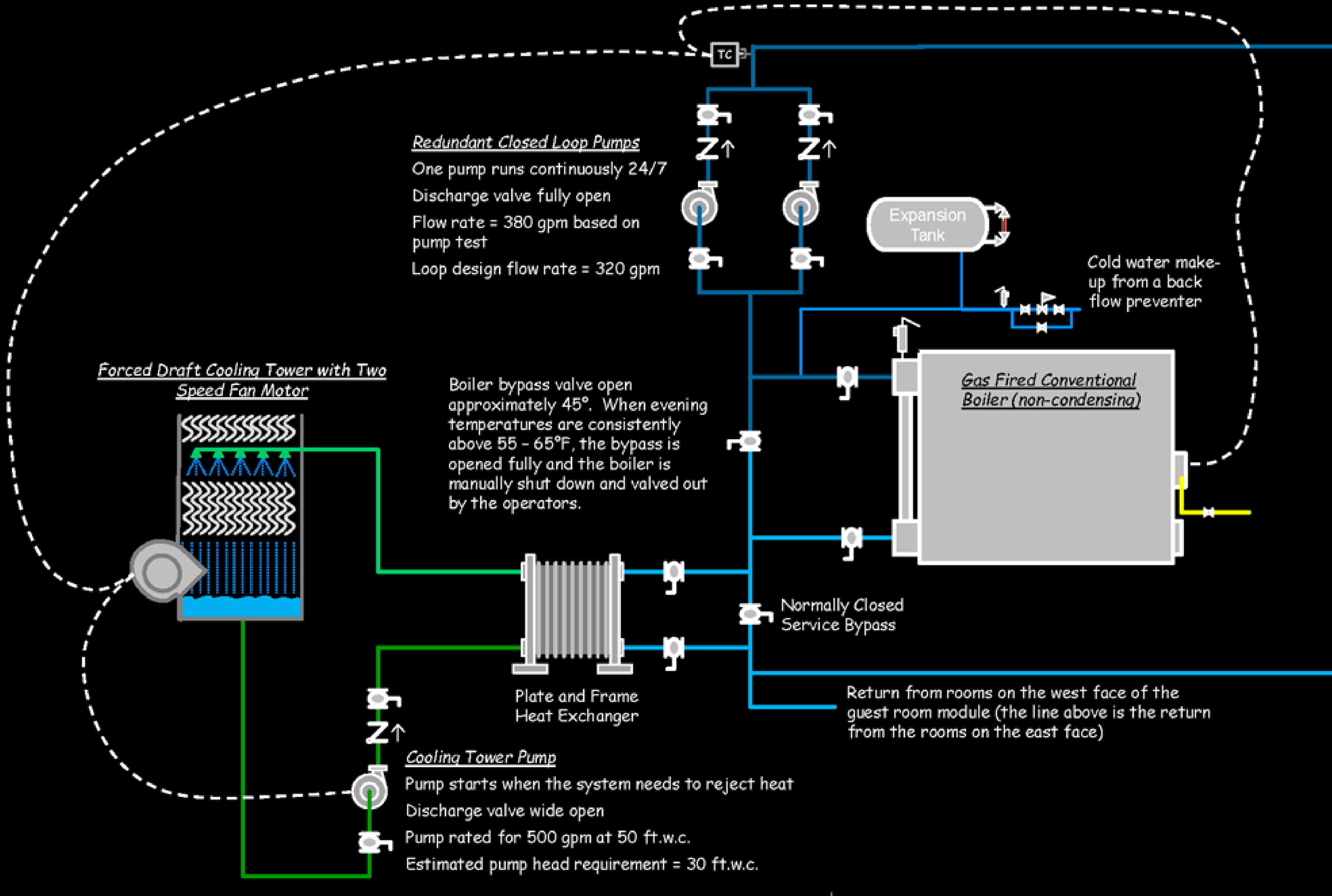

A Typical Guest Room Heat Pump Loop



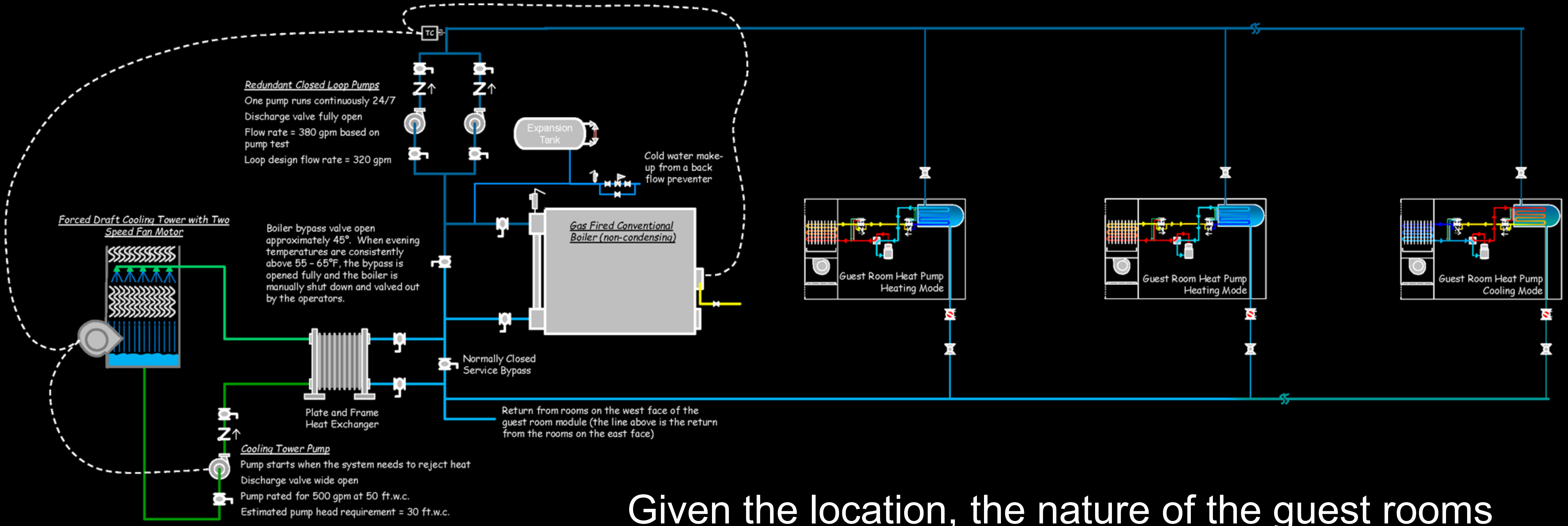
Water Source Heat Pump Loop
2022-11-16, DS


Guest Room Heat Pump
Cooling Mode


Guest Room Heat Pump
Heating Mode


TC
Redundant Closed Loop Pumps
One pump runs continuously 24/7
Discharge valve fully open
Flow rate = 380 gpm based on pump test
Loop design flow rate = 320 gpm
Expansion Tank
Cold water make-up from a back flow preventer
Forced Draft Cooling Tower with Two Speed Fan Motor
Boiler bypass valve open approximately 45°. When evening temperatures are consistently above 55 - 65°F, the bypass is opened fully and the boiler is manually shut down and valved out by the operators.
Gas Fired Conventional Boiler (non-condensing)
Normally Closed Service Bypass
Plate and Frame Heat Exchanger
Return from rooms on the west face of the guest room module (the line above is the return from the rooms on the east face)
Cooling Tower Pump
Pump starts when the system needs to reject heat
Discharge valve wide open
Pump rated for 500 gpm at 50 ft.w.c.
Estimated pump head requirement = 30 ft.w.c.

Some Questions For You



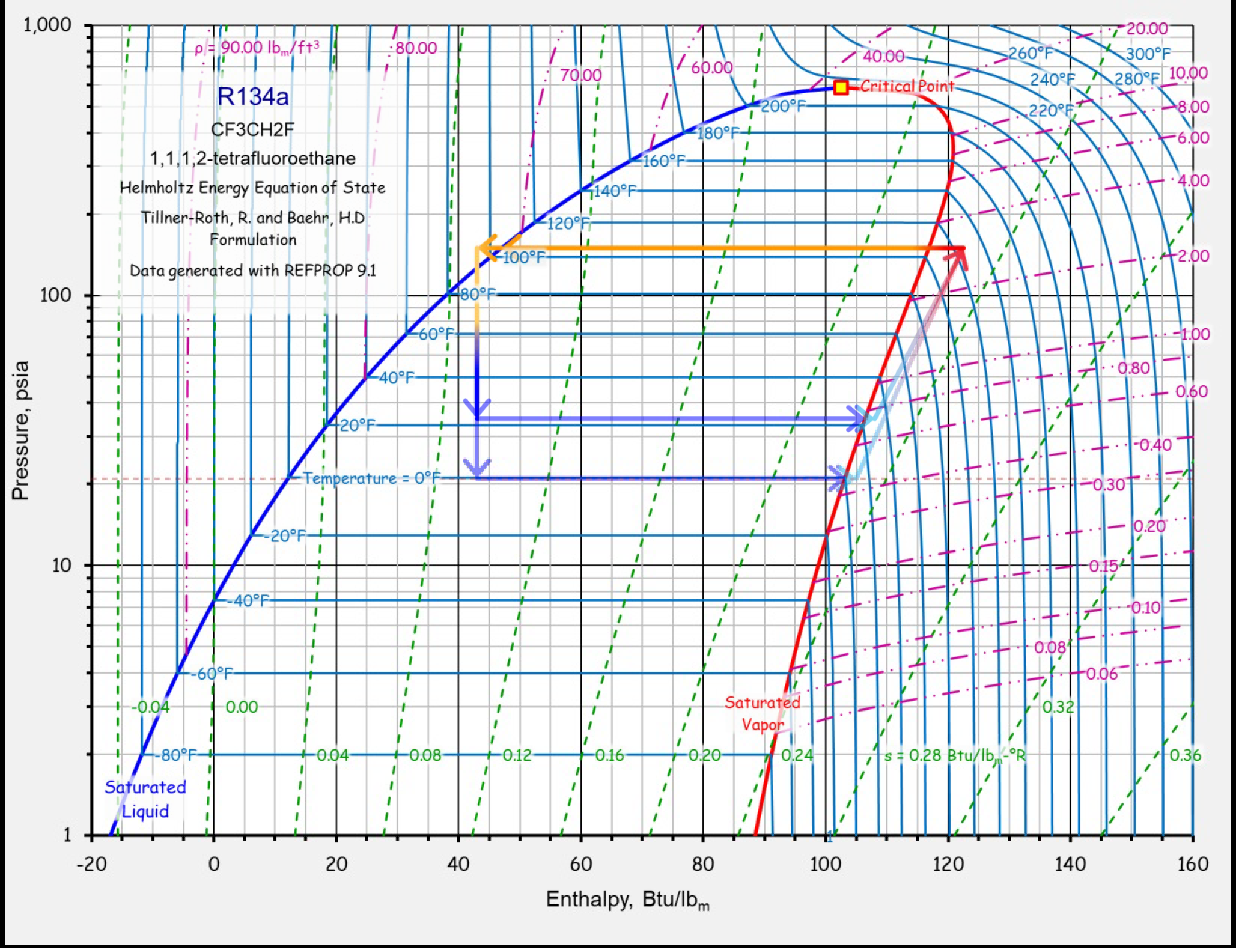
Water Source Heat Pump Loop
2022-11-16, DS

Given the location, the nature of the guest rooms and their architectural design, do you think there would be much heat available to pump?

Some Questions For You

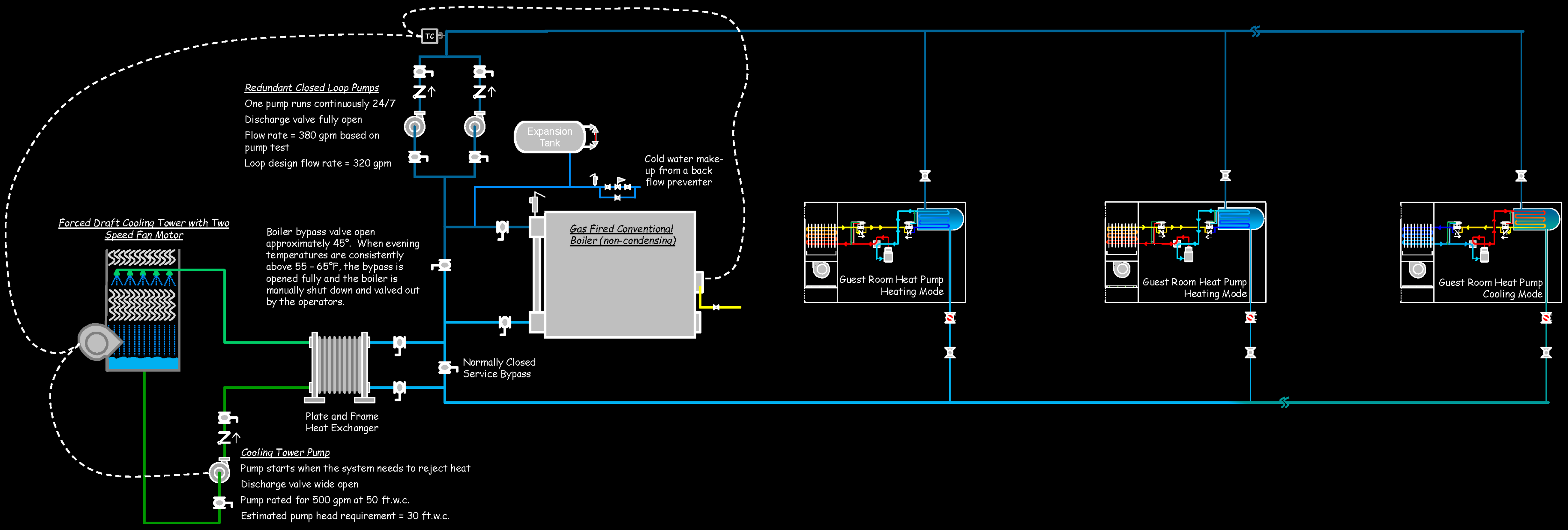
Given the location, the nature of the guest rooms and their architectural design, do you think there would be much heat available to pump?

Some Questions For You



If there was not a lot of heat to recover, are there any other reasons for someone to select water source heat pumps in this location compared to a different unitary option like a PTAC?

Thinking About Monitoring



Water Source Heat Pump Loop

2022-11-16, DS

Monitoring Plan Targets

- Firm up (or not) opportunities identified during scoping
- Provide data
  - Support more detailed investigations
  - Diagnostics and trouble shooting
  - Calculations
    - Looking for common opportunities
    - Are schedules actually working?
    - Are VAV systems VAVing?
    - Are optimization strategies working?
- Support expansion of the findings list
- Support cost benefit assessments
- Support verification

Logger Serial Number (EMS indicates control system trend)	System	Point (use full point name for EMS Points)	Sensor	Sampling Time	Sensor Location	Logger Location	Link to Screenshots of deployed location of sensors and Logger / Link to Screenshot of Launch		Notes
10263770	Cooling Tower	Cell 1 Hot Basin Temperature	TMC50-HD	1 minute	Hot basin of cell 1	On magnet under the steel	Sensor 1	Overview	1. Put logger in a zip lock bag and then under something to protect it.
	Cooling Tower	Cell 2 Hot Basin Temperature	TMC50-HD	1 minute	Hot basin of cell 2		Sensor 2	Logger Location	
	Cooling Tower	Cell 1 Cold Basin Temperature	TMC50-HD	1 minute	Hot basin of cell 1		Sensor 3	Typical Basin Temperature Sensor	
	Cooling Tower	Cell 2 Cold Basin Temperature	TMC50-HD	1 minute	Hot basin of cell 1		Sensor 4		
							Logger	Screen shot of logger status at launch	
10263769	South Tower MCC	Cooling tower 1 fan amps	CTV-B (50 amp)	1 minute	CT 1 feed at MCC	At MCC	Sensor 1	Central Plant MCC	1. See general note 2
	South Tower MCC	Cooling tower 2 fan amps	CTV-B (50 amp)	1 minute	CT 2 feed at MCC		Sensor 2		
	South Tower MCC	CW Pump 1 amps	CTV-B (50 amp)	1 minute	CW Pump 1 feed at MCC		Sensor 3		
	South Tower MCC	CW Pump 2 amps	CTV-B (50 amp)	1 minute	CW Pump 2 feed at MCC		Sensor 4		
							Logger	Screen shot of logger 10263769	
	South Tower CHW	Chiller 1 Amps	CTV-D (600 amp)	1 minute	Chiller 1 main switch		Sensor 1		1. David will obtain 600 amp CTs for you to use.
	South Tower CHW	Chiller 2 Amps	CTV-D (600 amp)	1 minute	Chiller 2 main switch		Sensor 2		
							Sensor 3		
							Sensor 4		
							Logger		
10263774	South Tower CHW	Chiller 1 EWT - Chilled Water	TMC20-HD	1 minute	Thermometer well	At chiller	Sensor 1	Logger Location	1. See general notes 1 and 3
	South Tower CHW	Chiller 1 LWT - Chilled Water	TMC20-HD	1 minute	Thermometer well		Sensor 2	Sensors	
	South Tower CHW	Chiller 1 EWT - Condenser Water	TMC20-HD	1 minute	Thermometer well		Sensor 3	Sensor detail	
	South Tower CHW	Chiller 1 LWT - Condenser Water	TMC20-HD	1 minute	Thermometer well		Sensor 4		
							Logger	Logger 10263774 Launch	
10263767	South Tower CHW	Chiller 2 EWT - Chilled Water	TMC20-HD	1 minute	Thermometer well	At chiller	Sensor 1	Logger Location	1. See general notes 1 and 3.
	South Tower CHW	Chiller 2 LWT - Chilled Water	TMC20-HD	1 minute	Thermometer well		Sensor 2	Sensors	
	South Tower CHW	Chiller 2 EWT - Condenser Water	TMC20-HD	1 minute	Thermometer well		Sensor 3		
	South Tower CHW	Chiller 2 LWT - Condenser Water	TMC20-HD	1 minute	Thermometer well		Sensor 4		
							Logger	Screen shots with bad sensor and fix	
10263771	South Tower CHW	CHW Pump 1 Amps	CTV-D (200 amp)	1 minute	CT 1 feed at MCC	At MCC	Sensor 1	Central Plant MCC	1. See general note 2 2. I have assumed a 20 amp CT will be big enough for the domestic water pumps.
	South Tower CHW	CHW Pump 2 Amps	CTV-D (200 amp)	1 minute	CT 2 feed at MCC		Sensor 2		
	South Tower Dom Wtr	Pump 1 Amps	CTV-A (20 amp)	2 seconds	DW Pump 1 feed in MCC		Sensor 3		
	South Water Dom Wtr	Pump 2 Amps	CTV-A (20 amp)	2 seconds	DW Pump 2 feed in MCC		Sensor 4		
							Logger	Logger 10263771 deployment screenshot	
10359812 (Carlos's logger)	ST Bg Rm. Conditions	ST Bg Rm. Temperature	Internal	1 minute	On Top of DW Pump Panel	At DW Pumps	Sensor 1	Logger tied to conduit at Booster Pump	1. Borrow one of Carlos's loggers with an internal lighting sensor.
	ST Bg Rm. Conditions	ST Bg Rm RH	Internal	1 minute	On Top of DW Pump Panel		Sensor 2		
	ST Bg Rm. Conditions	ST Bg Rm. Lighting Level	Internal	1 minute	On Top of DW Pump Panel		Sensor 3		
							Sensor 4		
							Logger	Screen shot of 10359812 launch	
10263768	NT Lobby DD Unit	Supply fan amps	CTV-D (50 amp)	1 minute	VFD incoming line	Tie-wrapped to supply fan VFD	Sensor 1	Fan amps sensor	1. See general notes 1 and 4.
	NT Lobby DD Unit	Fan Leaving Air Temperature	TMC20-HD	1 minute	Downstream of fan		Sensor 2	Fan discharge sensor	
	NT Lobby DD Unit	Cold Deck Temperature	TMC20-HD	1 minute	Downstream of coil		Sensor 3	Cold deck sensor	
	NT Lobby DD Unit	Hot Deck Temperature	TMC20-HD	1 minute	Downstream of coil		Sensor 4	Hot deck sensor	
							Logger	Screen shot of logger at launch	
10264069	NT Lobby DD Unit	Return temperature	Internal	1 minute	In return duct	Tie-wrapped to duct support in the return duct	Sensor 1	Data logger - Initial deployment	1. Try to get the sensor into the system away from the door so the air leakage around the door does not influence the logger too much.
	NT Lobby DD Unit	Return RH	Internal	1 minute	In return duct		Sensor 2		
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							Logger	Screen shot of logger at launch Screen shot of logger re-deployment	

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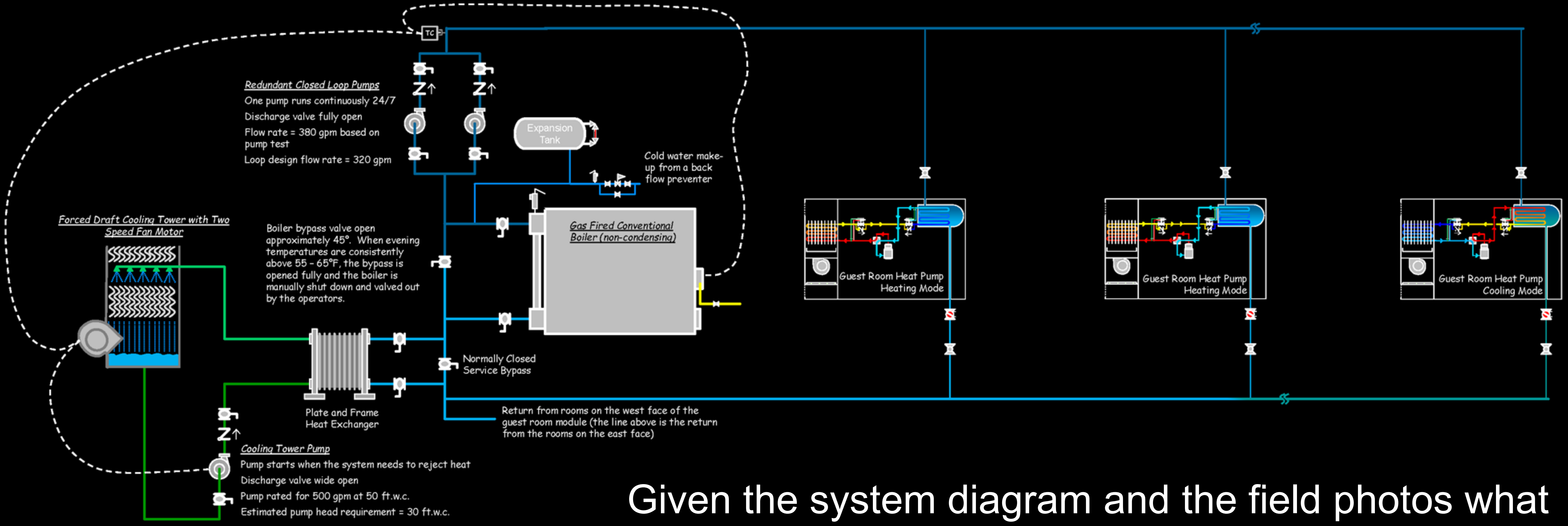
Monitoring Plan Resources

- Monitoring Plan Template (blank and a filled-out example)
- Monitoring Plan Blog Posts
- Data Logging Resources
- A Video
- All linked from this location
- https://tinyurl.com/MonitoringPlans

A Monitoring Question



Water Source Heat Pump Loop
2022-11-16, DS

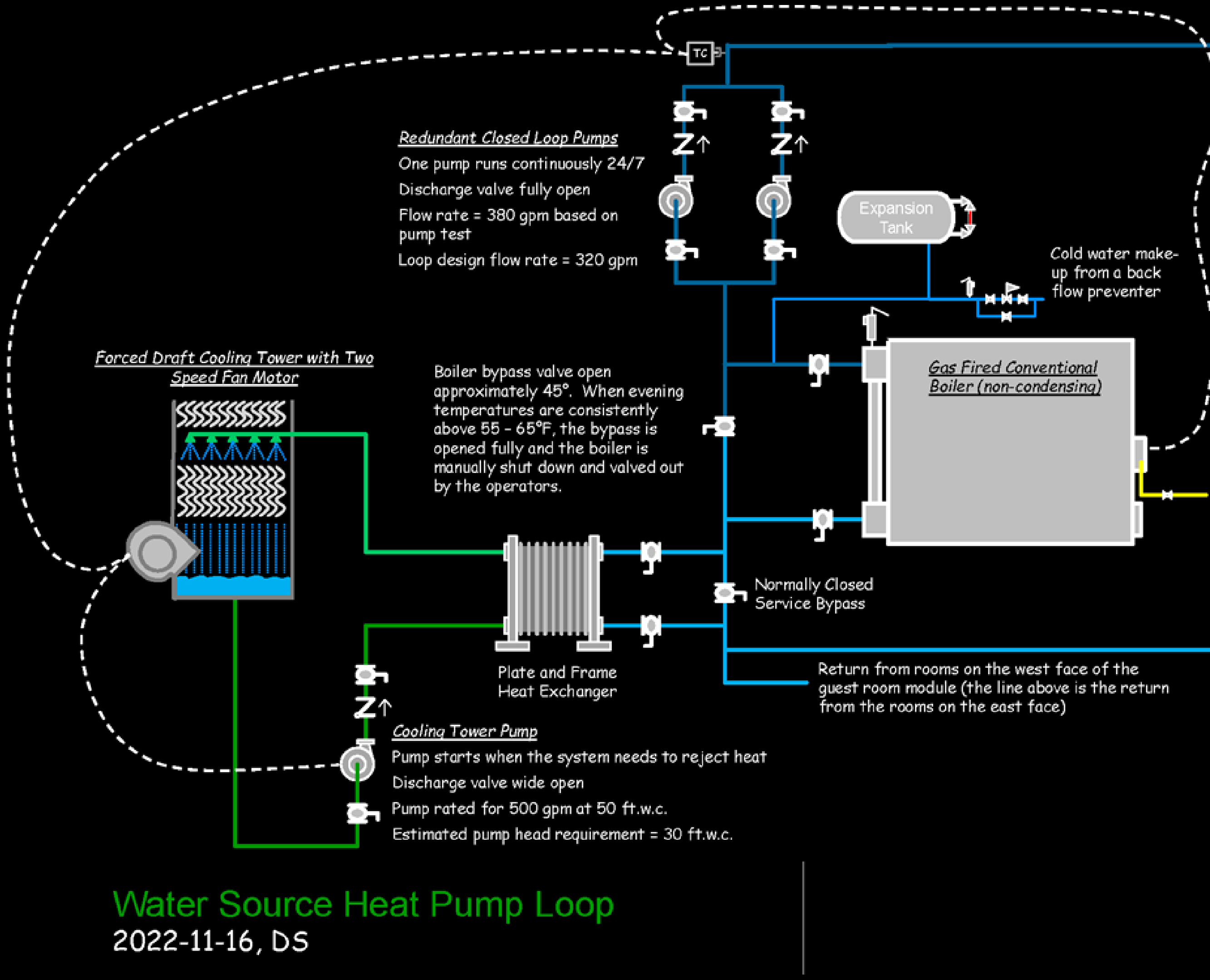
Given the system diagram and the field photos what points would you include in your monitoring plan? For each point you list, include the reason why you want to monitor it.

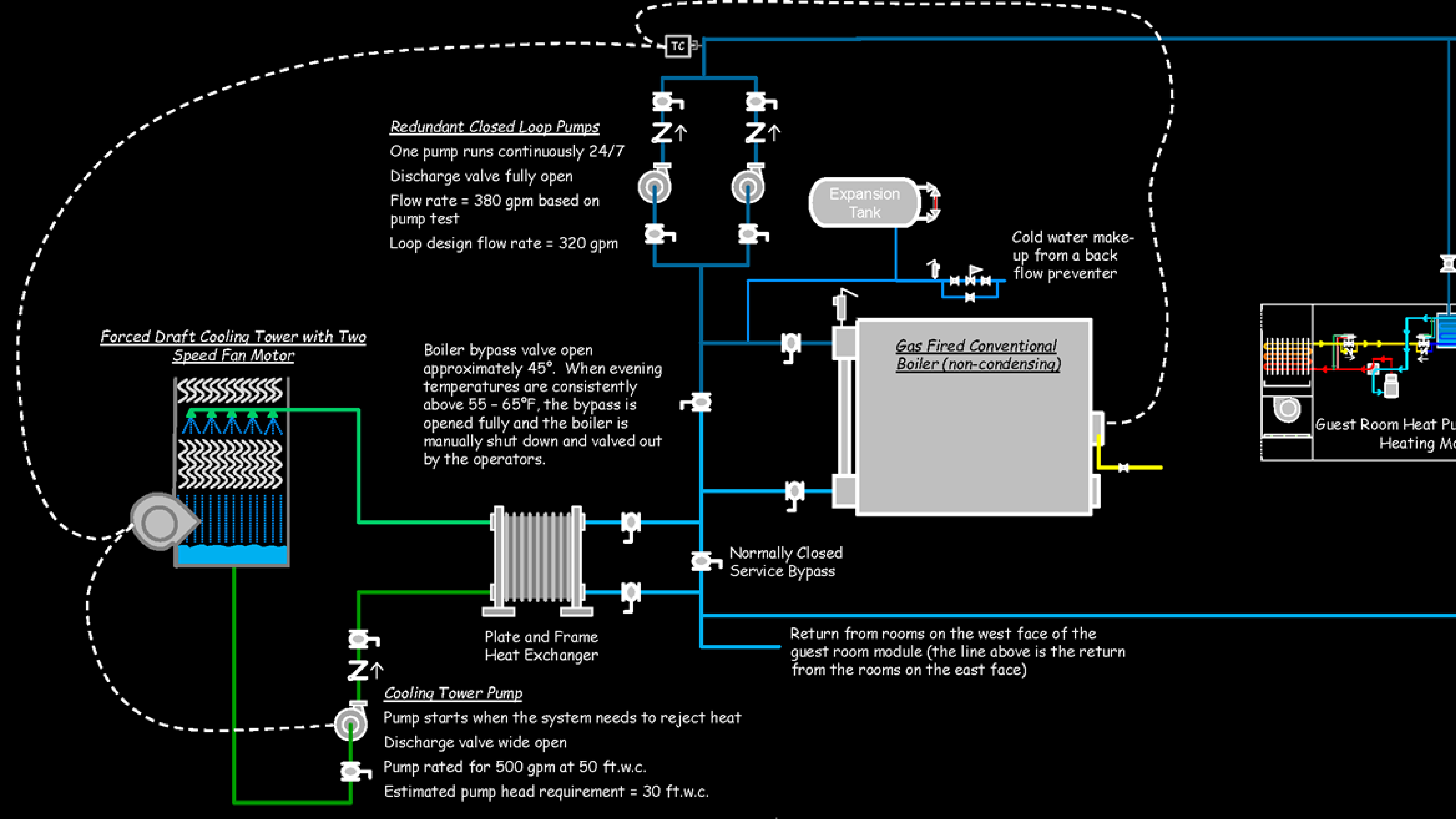
Adding Some Constraints

Your logger inventory

- 2 – four channel loggers
- 8 – temperature sensors
- 4 – CTs

What data points would you select to give you the most insight?




TC
Redundant Closed Loop Pumps
One pump runs continuously 24/7
Discharge valve fully open
Flow rate = 380 gpm based on pump test
Loop design flow rate = 320 gpm
Expansion Tank
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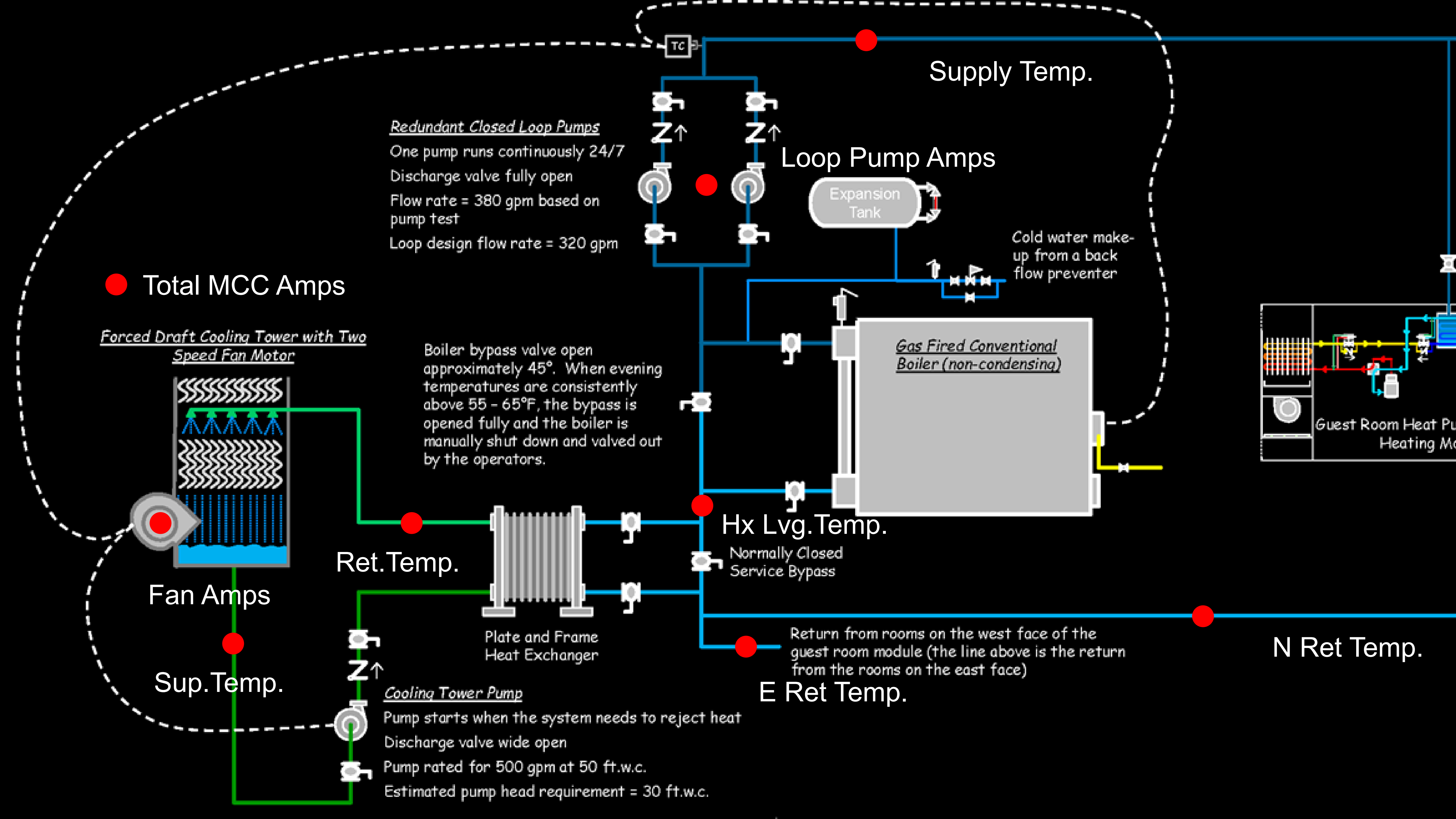
Pump rated for 500 gpm at 50 ft.w.c.
Estimated pump head requirement = 30 ft.w.c.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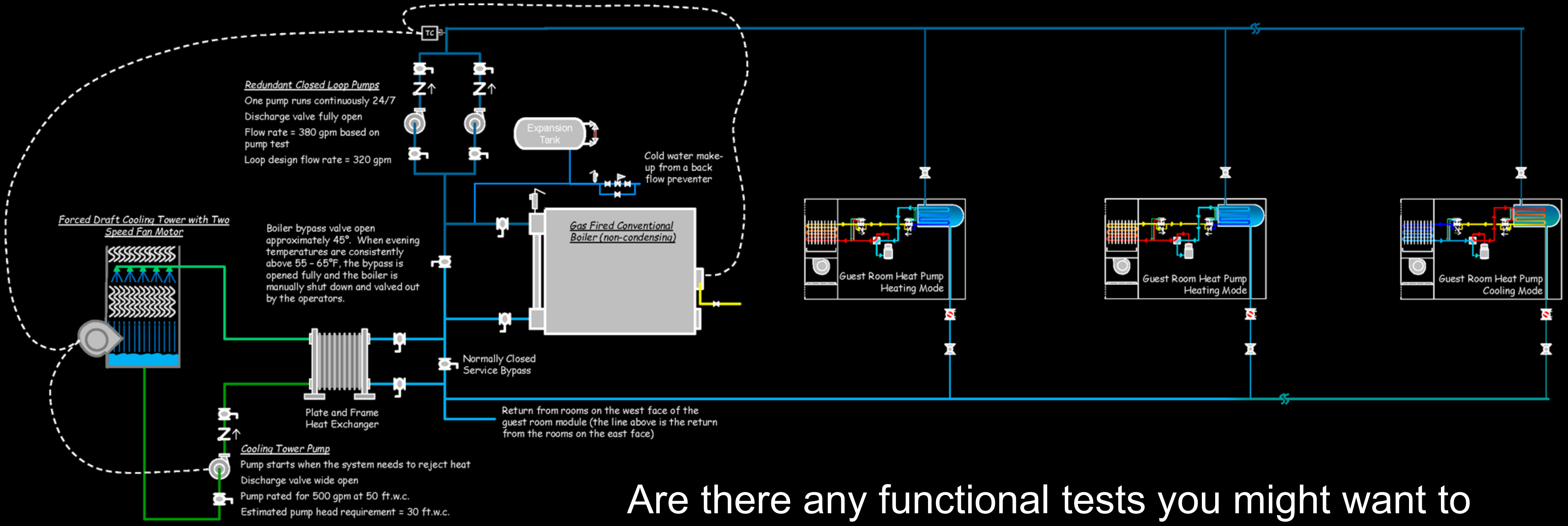
A Functional Testing Question



Water Source Heat Pump Loop
2022-11-16, DS

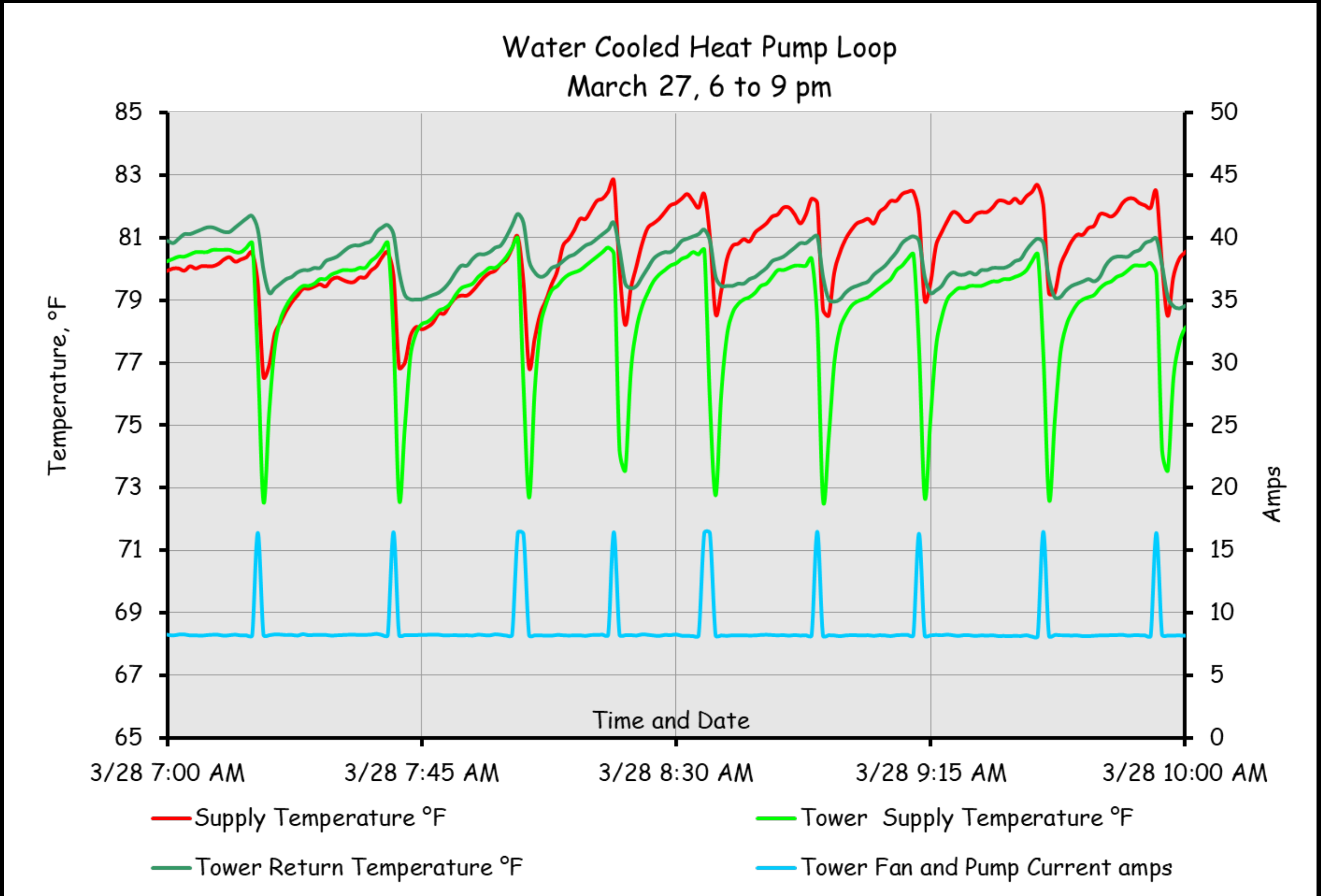
Are there any functional tests you might want to perform based on what you observed in the field or based on the data you plan to capture?

Let’s Look at Some Data

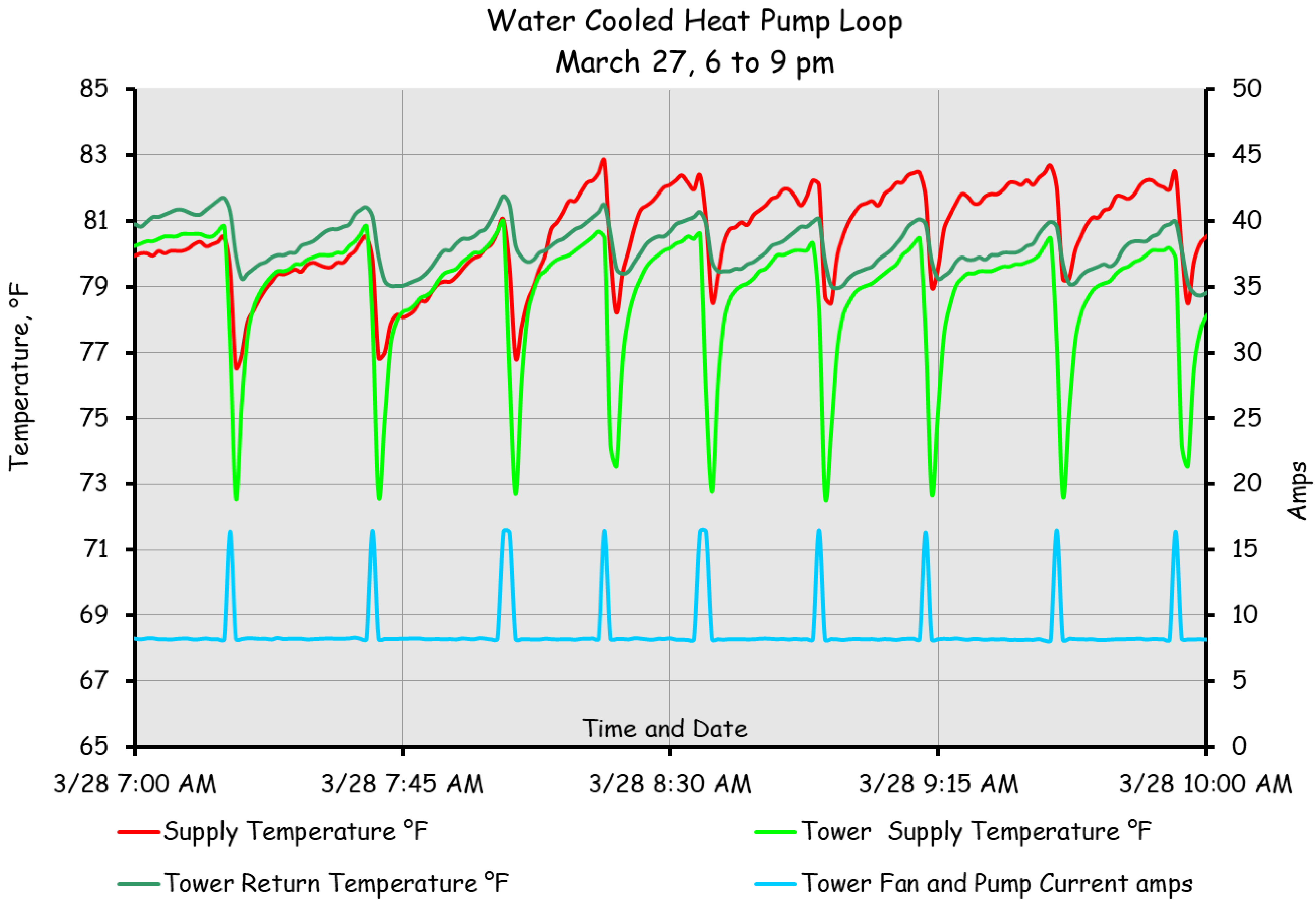
https://tinyurl.com/DataLoggingDecades


onset
CTV-D
onset
HOBO 4-channel analog logger
onset
StoP
onset
HOBO data node
temp
HOBO MX CO2 logger
onset
onset
esc
on/off
yes
next
no
alt
HOBO U-Shuttle
HOBO
RH
Temp
2 x External
onset

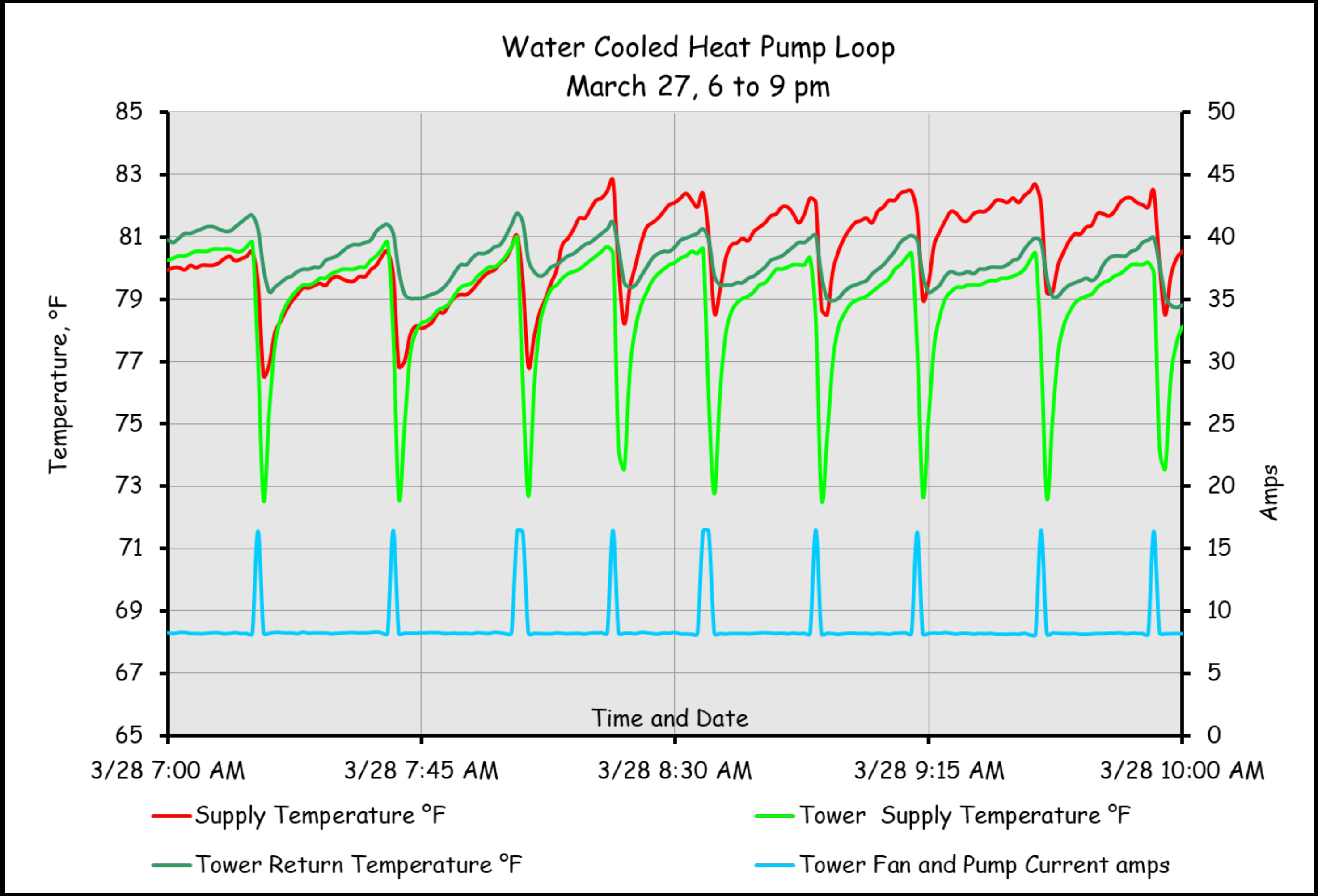
What You Might Learn



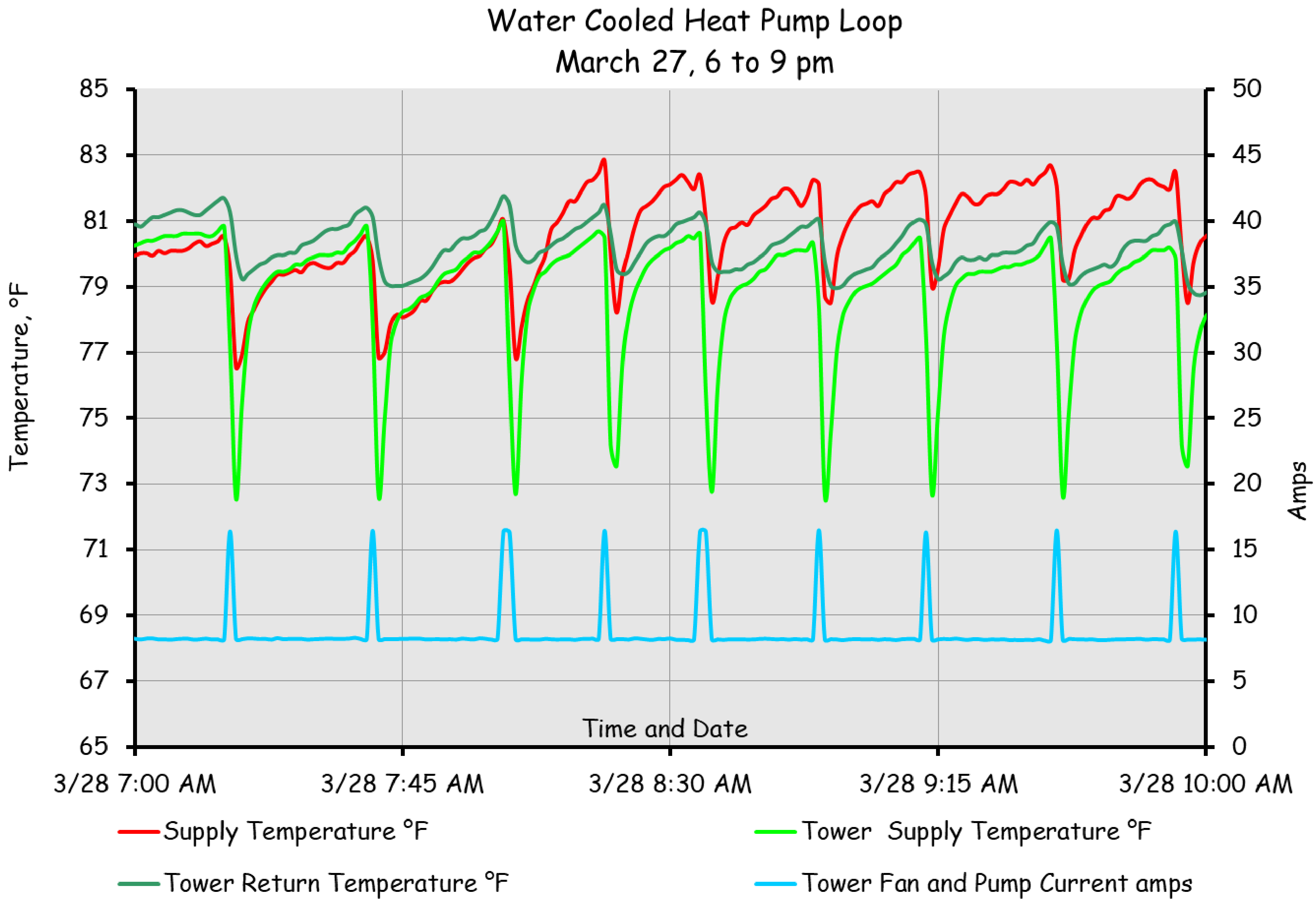
What opportunities are revealed in the amperage trend?


Water Cooled Heat Pump Loop
March 27, 6 to 9 pm
Temperature, °F
Amps
85
83
81
79
77
75
73
71
69
67
65
50
45
40
35
30
25
20
15
10
5
0
Time and Date
3/28 7:00 AM
3/28 7:45 AM
3/28 8:30 AM
3/28 9:15 AM
3/28 10:00 AM
Supply Temperature °F
Tower Supply Temperature °F
Tower Return Temperature °F
Tower Fan and Pump Current amps

What You Might Learn



What opportunities are revealed in the temperature trend data (assuming the temperature sensors were calibrated relative to each other)?


Water Cooled Heat Pump Loop
March 27, 6 to 9 pm
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83
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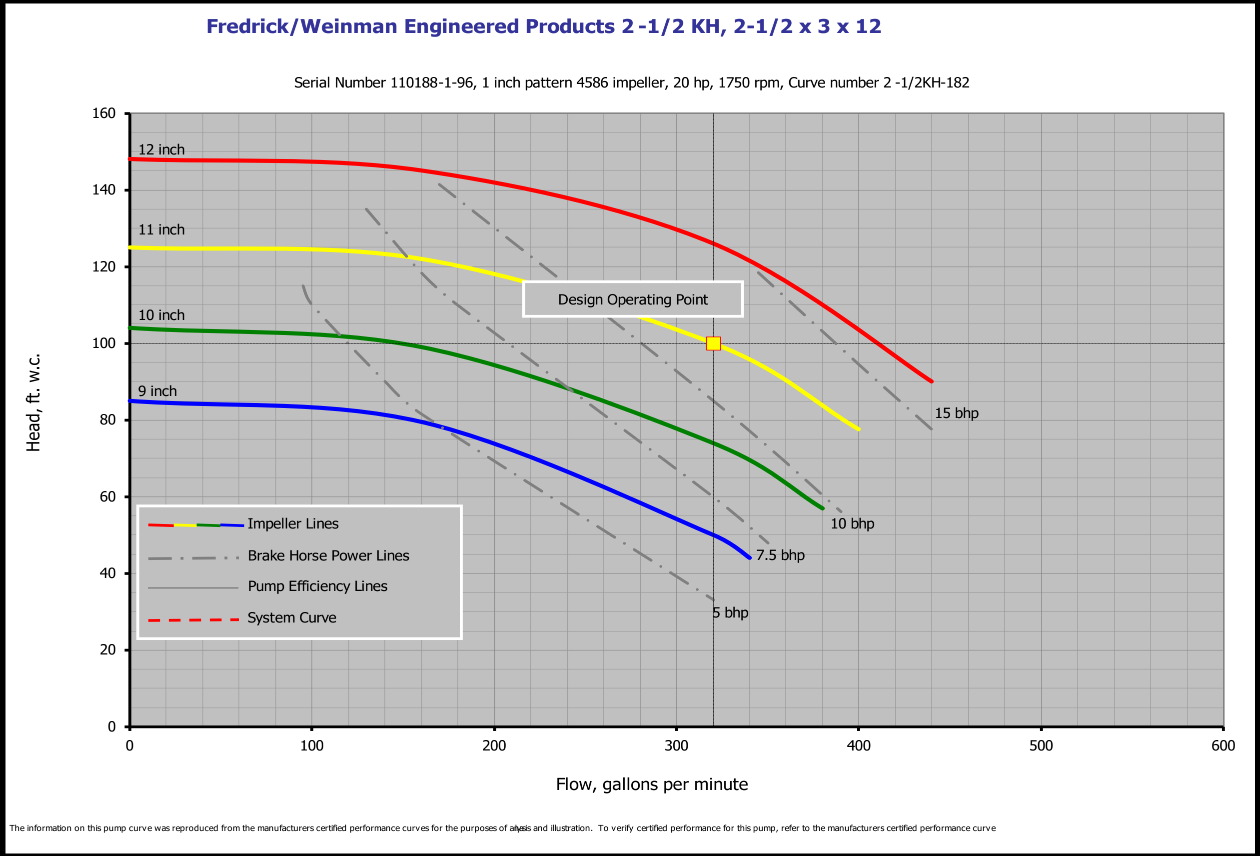
77
75
73
71
69
67
65
Temperature, °F
50
45
40
35
30
25
20
15
10
5
0
Amps
Time and Date
3/28 7:00 AM
3/28 7:45 AM
3/28 8:30 AM
3/28 9:15 AM
3/28 10:00 AM
Supply Temperature °F
Tower Supply Temperature °F
Tower Return Temperature °F
Tower Fan and Pump Current amps

What You Might Learn From the Pump

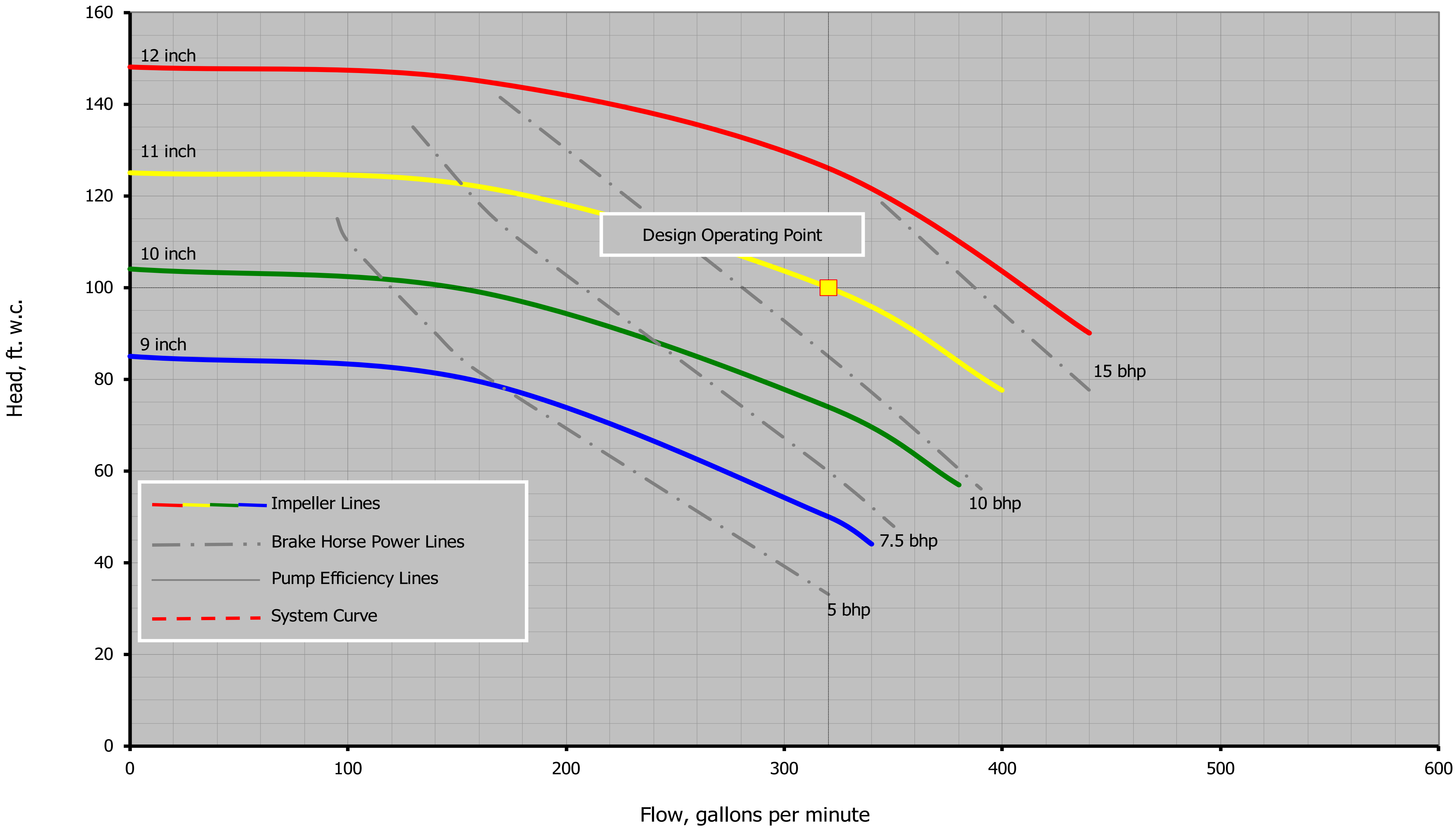


Design Condition

- 11 inch impeller
- Design Flow – 320 gpm
- Design Head – 100 ft.w.c.

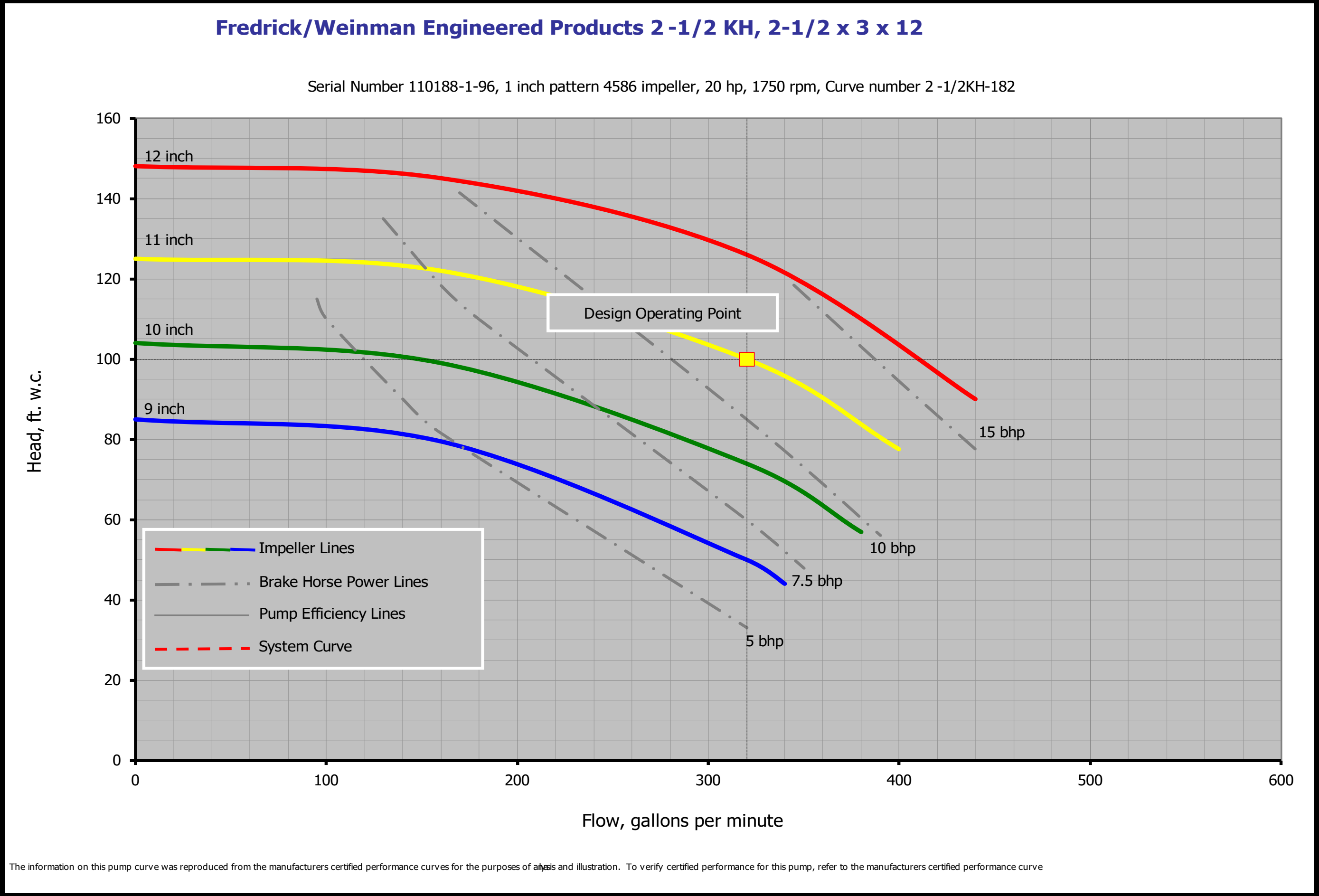
Fredrick/Weinman Engineered Products 2 -1/2 KH, 2-1/2 x 3 x 12

Serial Number 110188-1-96, 1 inch pattern 4586 impeller, 20 hp, 1750 rpm, Curve number 2 -1/2KH-182

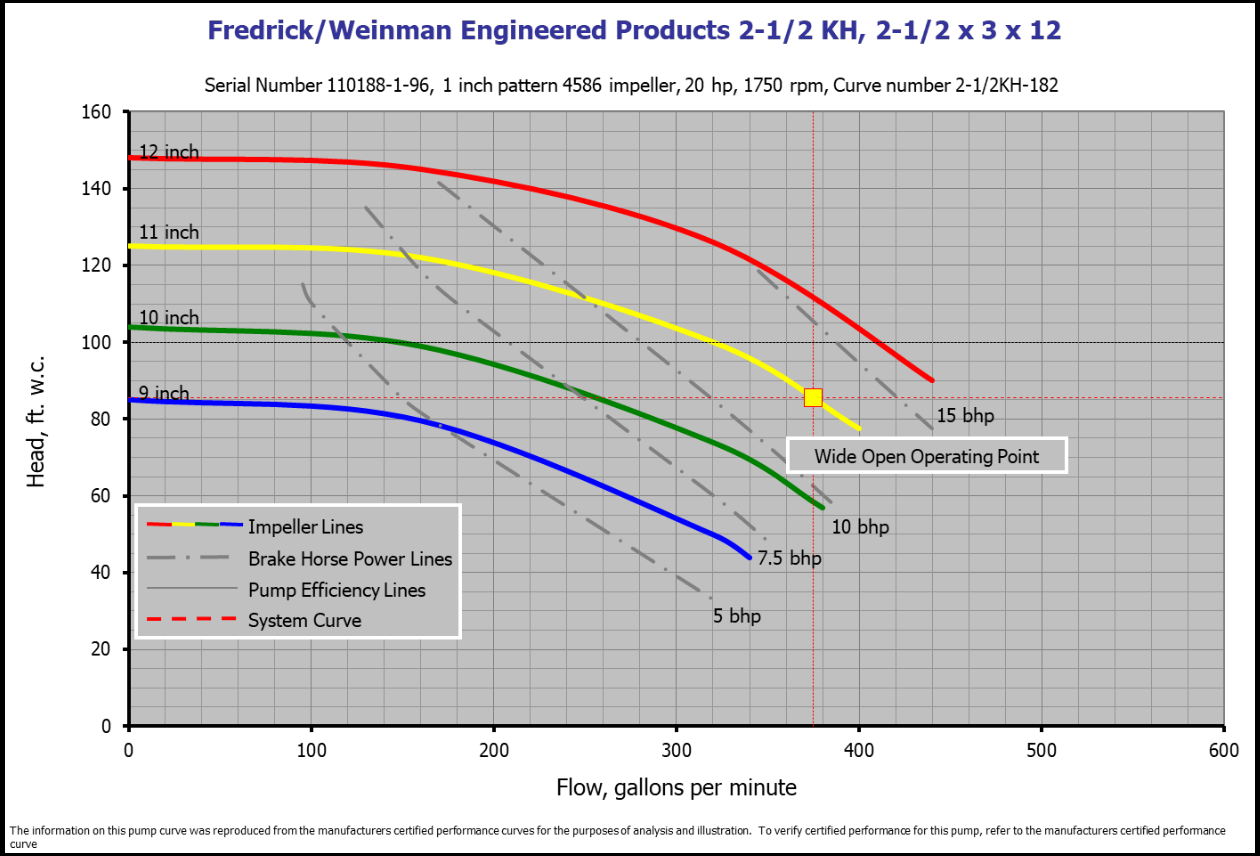


The information on this pump curve was reproduced from the manufacturers certified performance curves for the purposes of analysis and illustration. To verify certified performance for this pump, refer to the manufacturers certified performance curve

Does the Pump Head Seem Reasonable?



What You Might Learn From the Pump

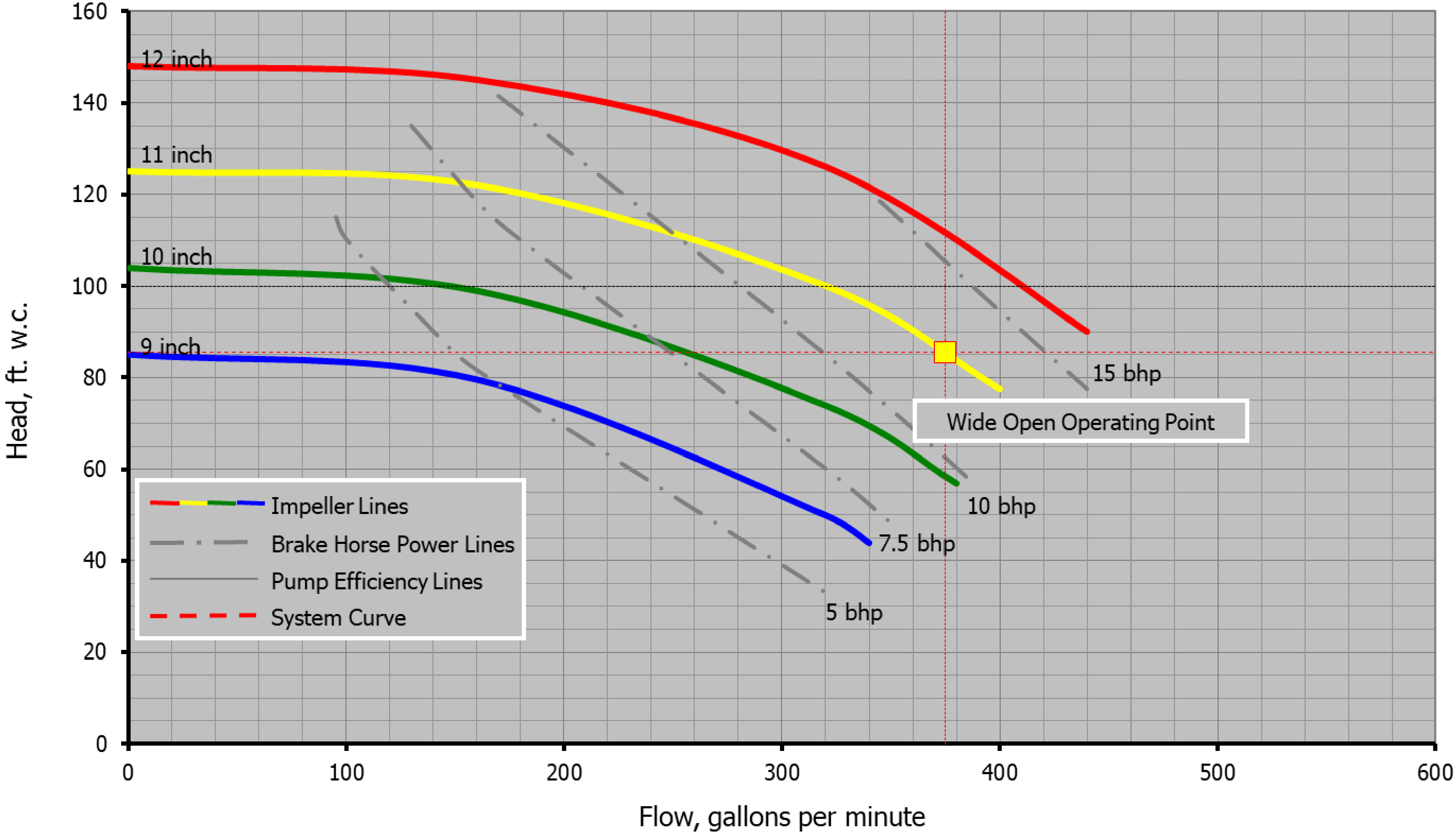


Pump Test Results

- 11 inch impeller
- Wide open head – 84 – 86 ft.w.c.
- Flow (from pump curve) – 375 - 380 gpm
- Design Flow – 320 gpm

Fredrick/Weinman Engineered Products 2-1/2 KH, 2-1/2 x 3 x 12

Serial Number 110188-1-96, 1 inch pattern 4586 impeller, 20 hp, 1750 rpm, Curve number 2-1/2KH-182



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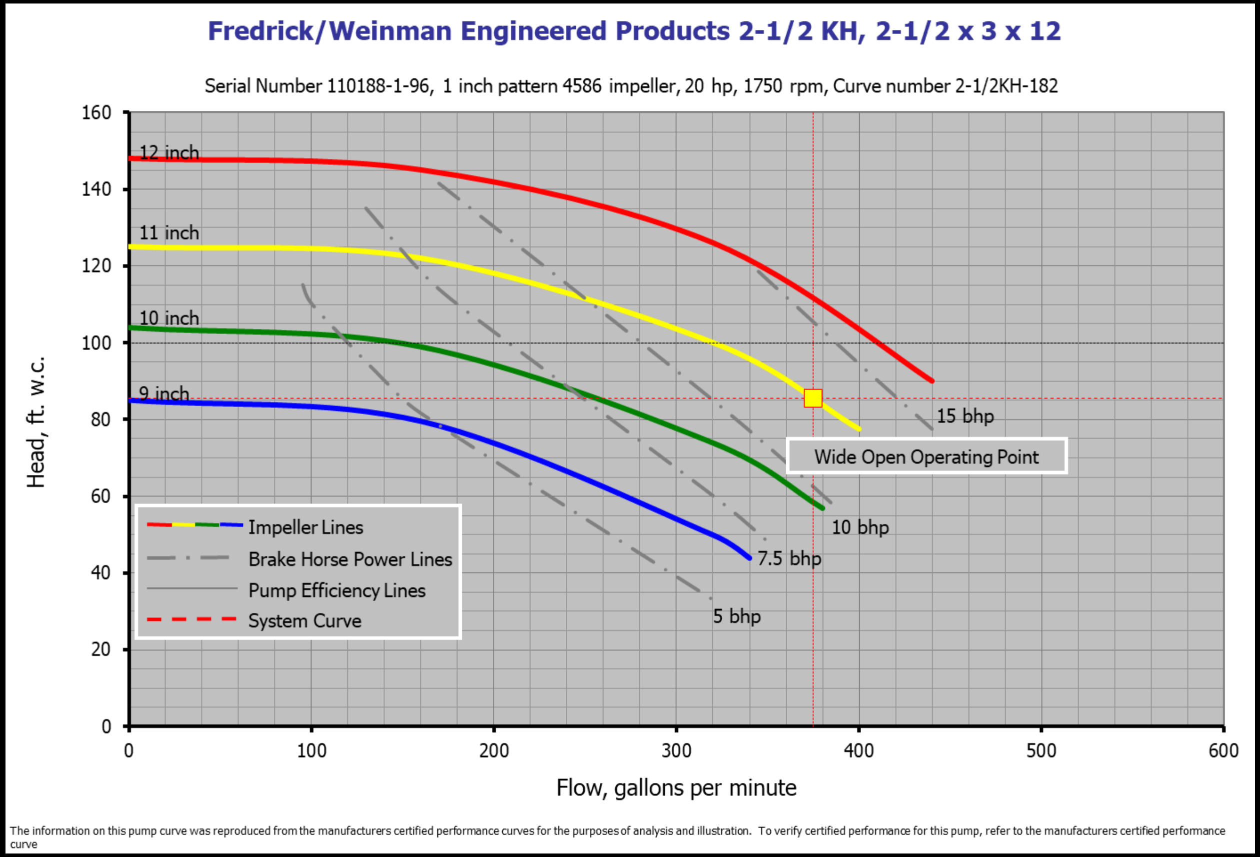
What Did You Learn?

What did the pump test results tell you about the closed loop pump performance relative to the design requirement of 320 gpm?



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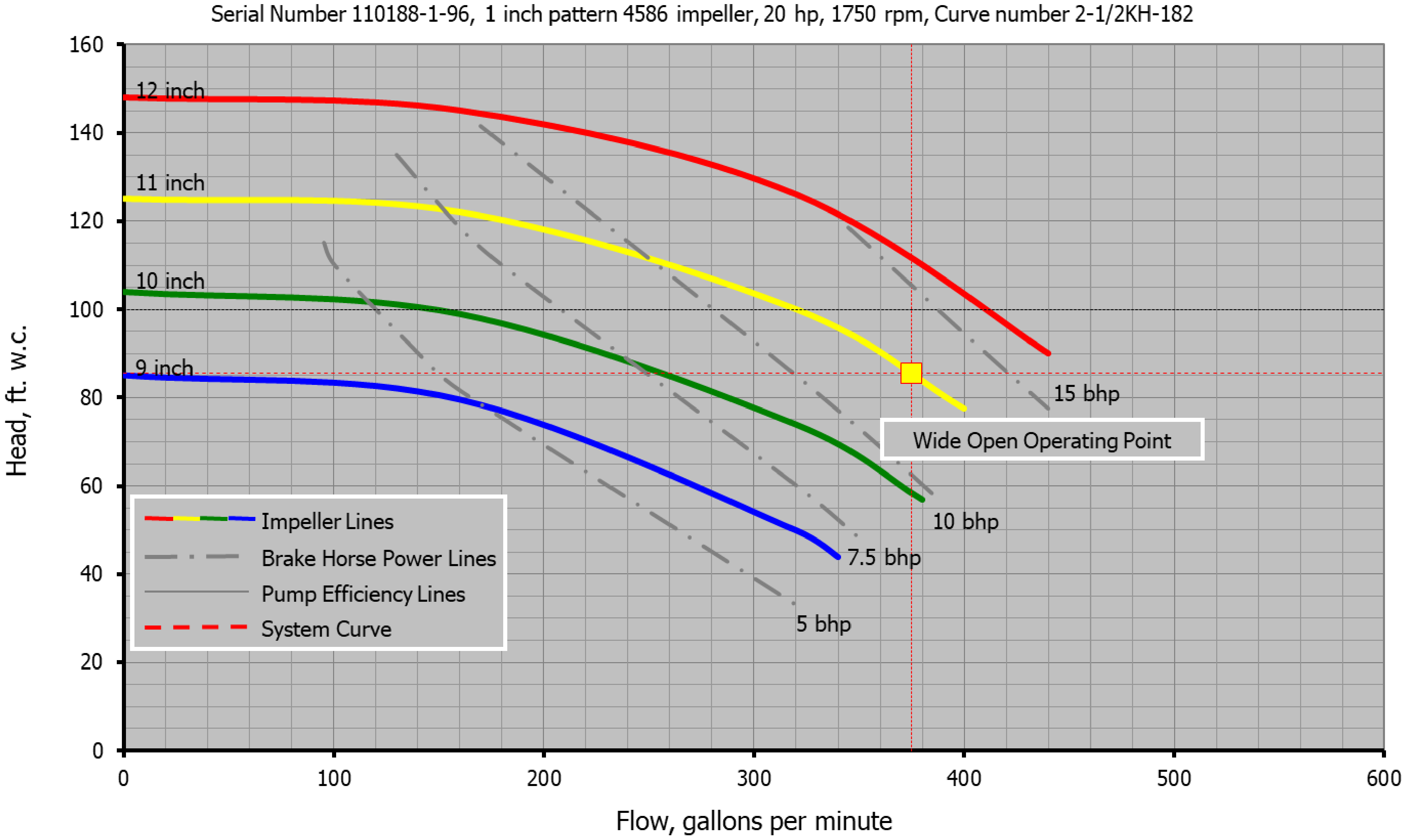

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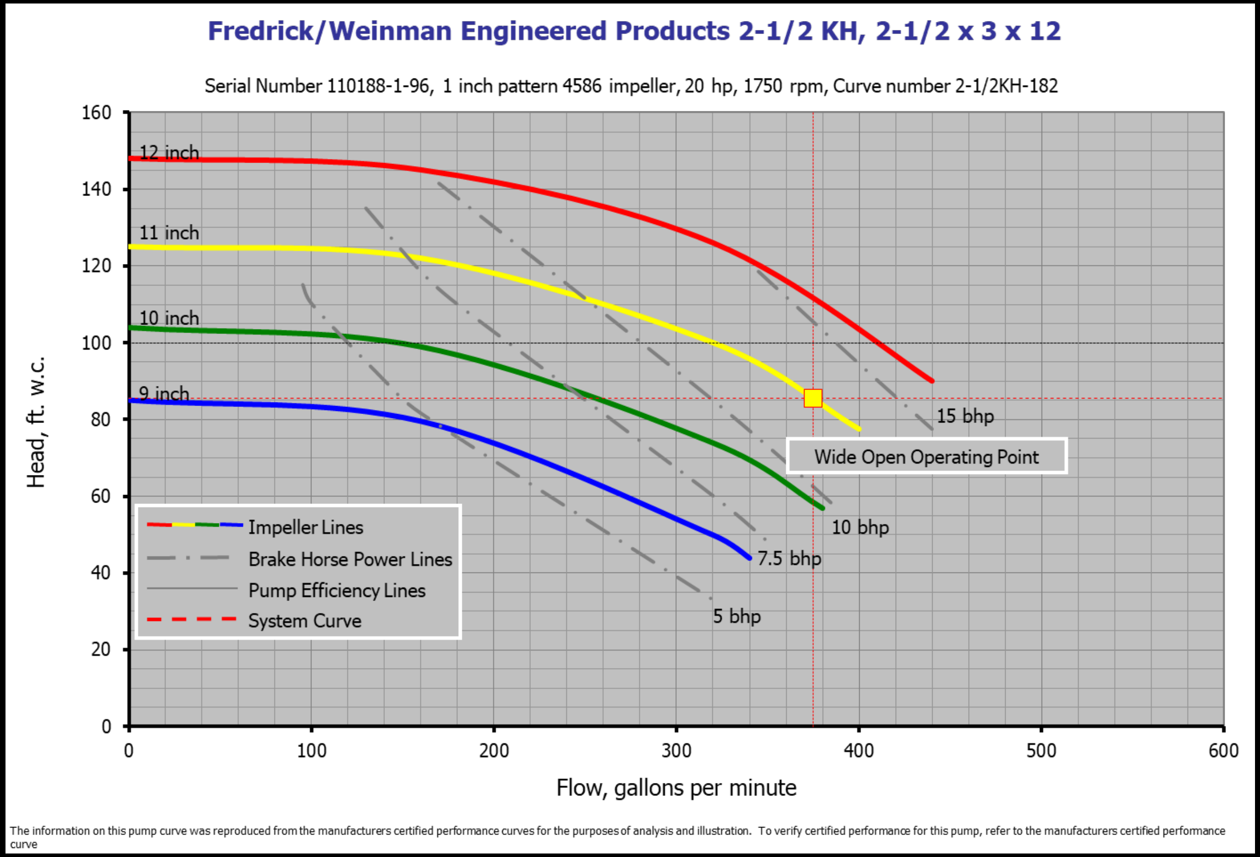
What Did You Learn?

Given the test data and the design flow requirement, is there a way you can predict the head required to deliver the design flow, and thus, the potential savings?



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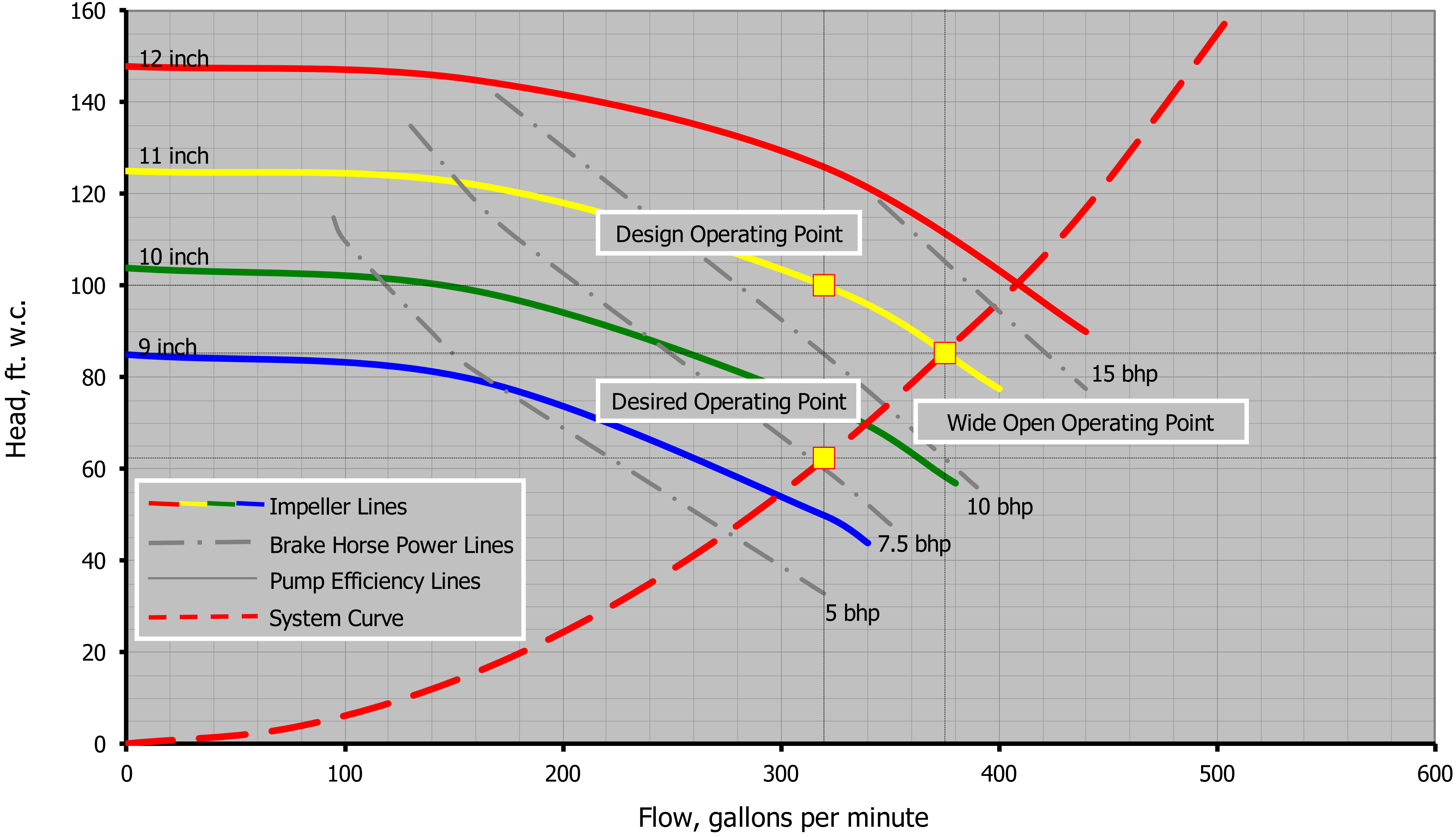

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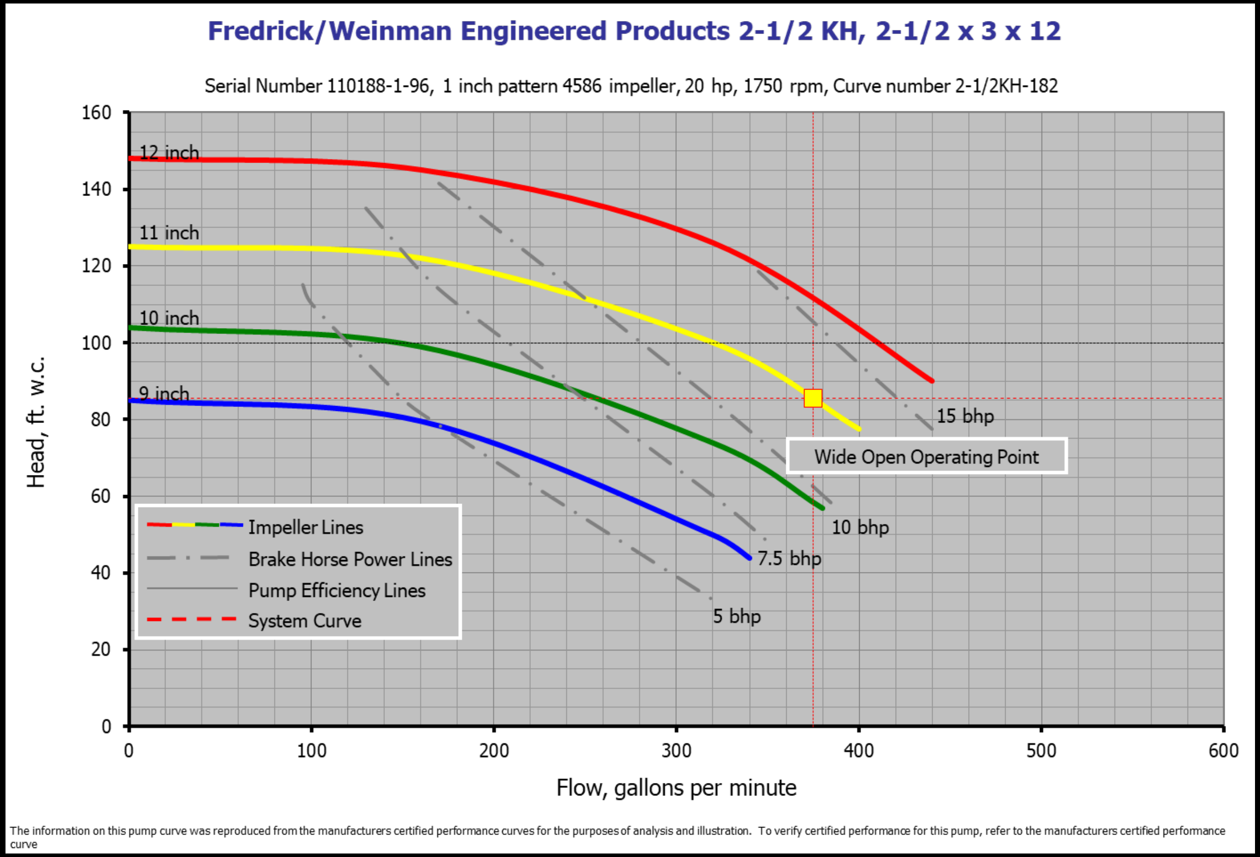
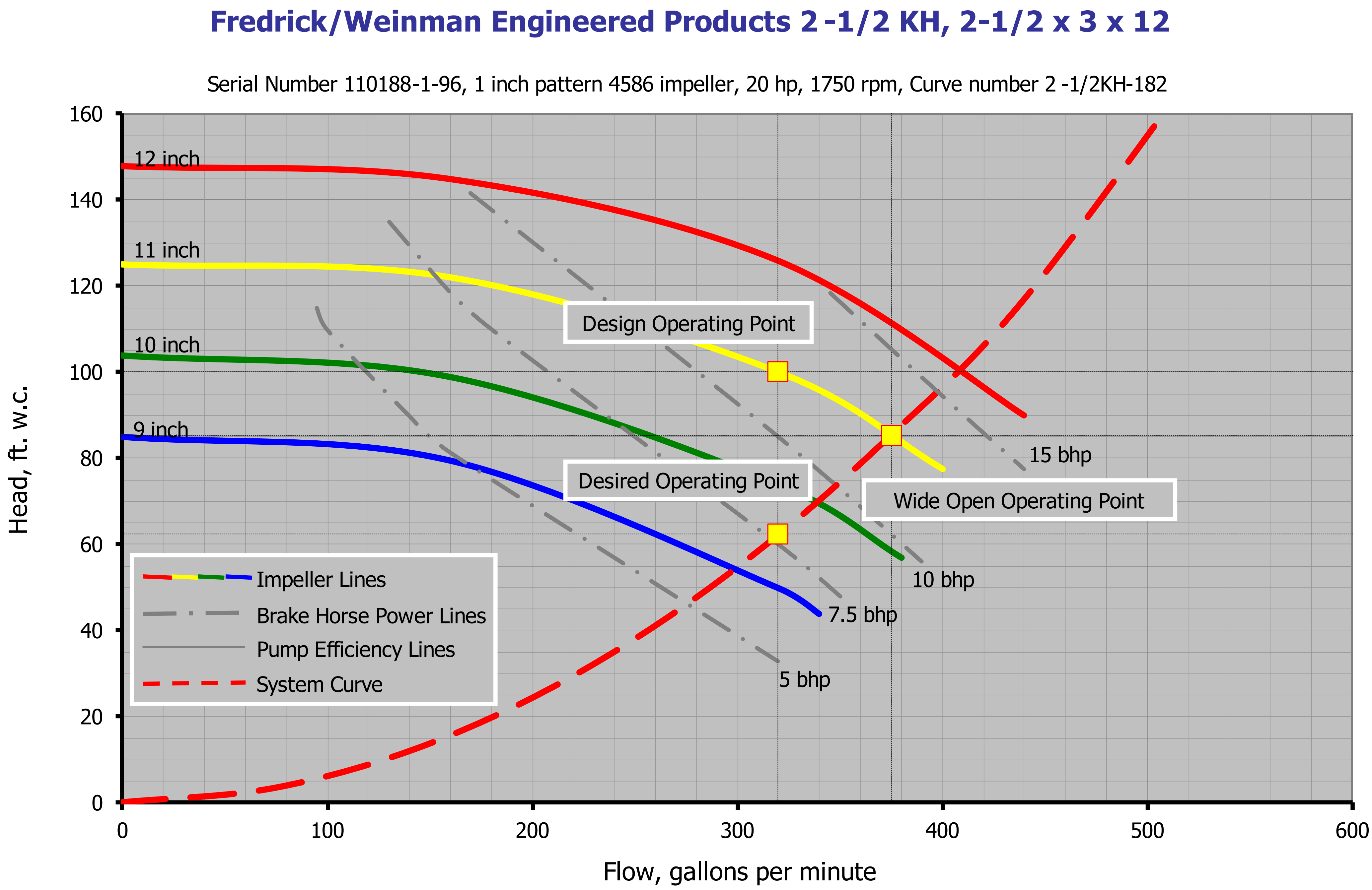
What Did You Learn?

What are the options for optimizing the pump?

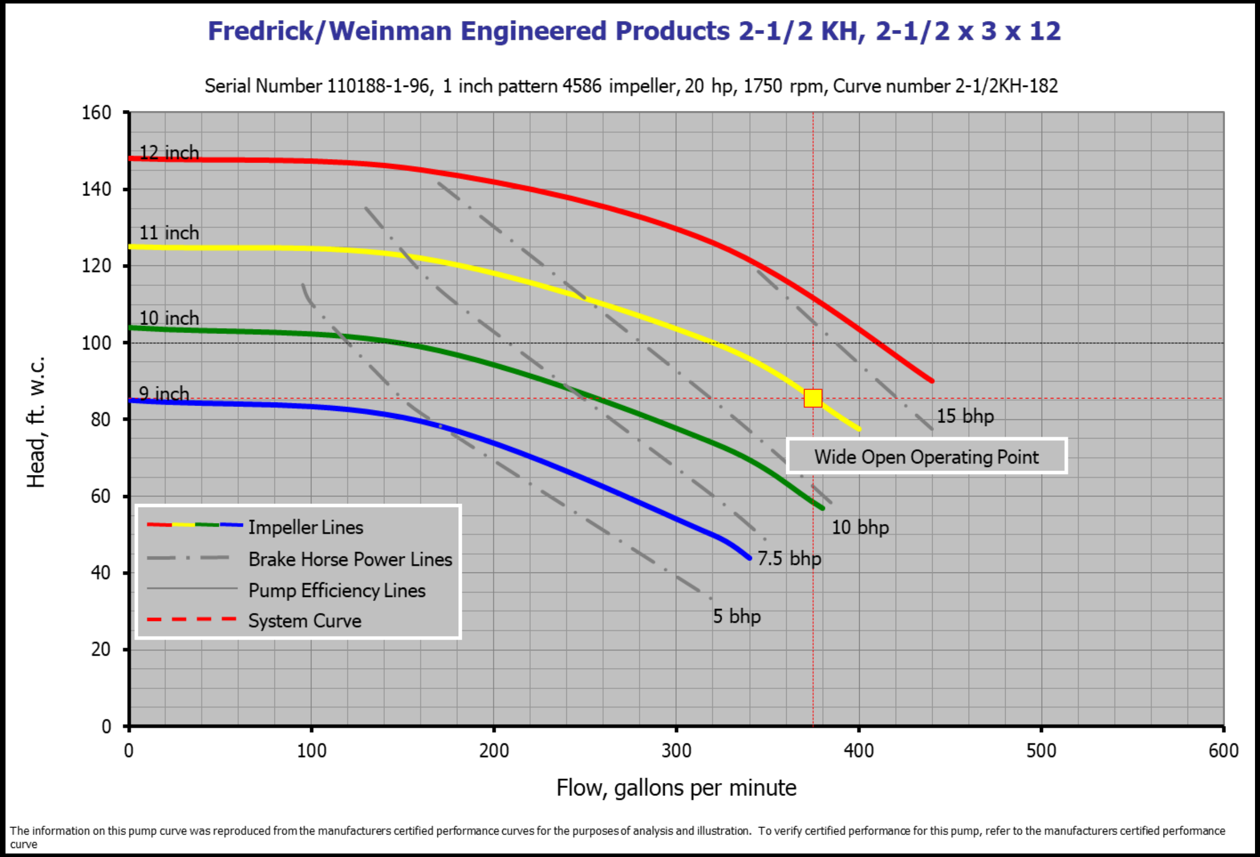




The information on this pump curve was reproduced from the manufacturers certified performance curves for the purposes of analysis and illustration. To verify certified performance for this pump, refer to the manufacturers certified performance curve

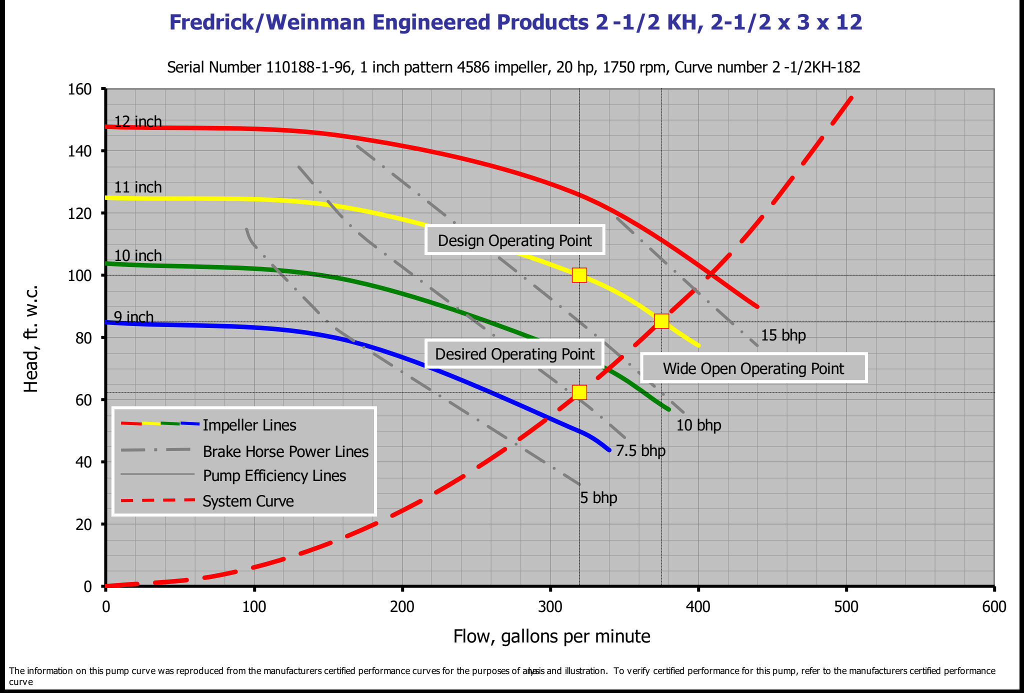
What Did You Learn?

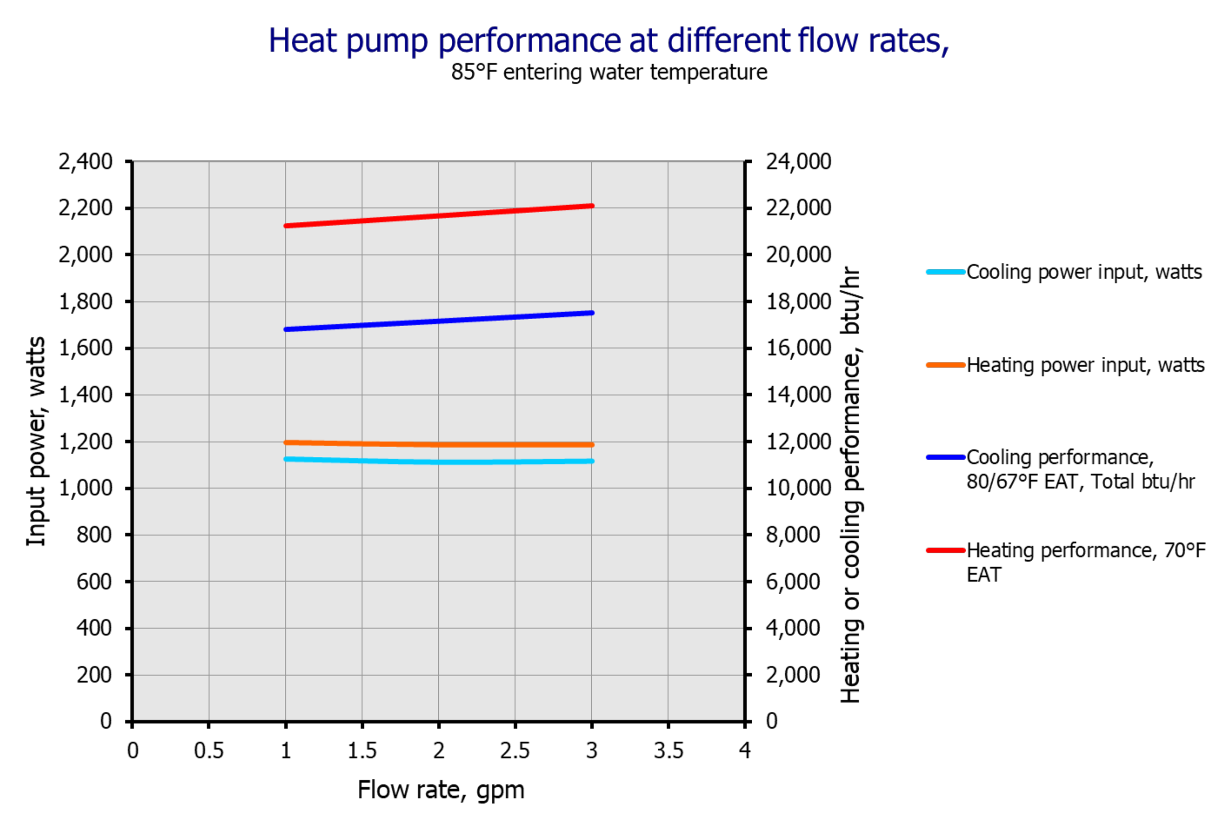
If the pump is moving more flow than the design requirement, are there any potential benefits and if so, what are they?



Considering Heat Pump Interactions

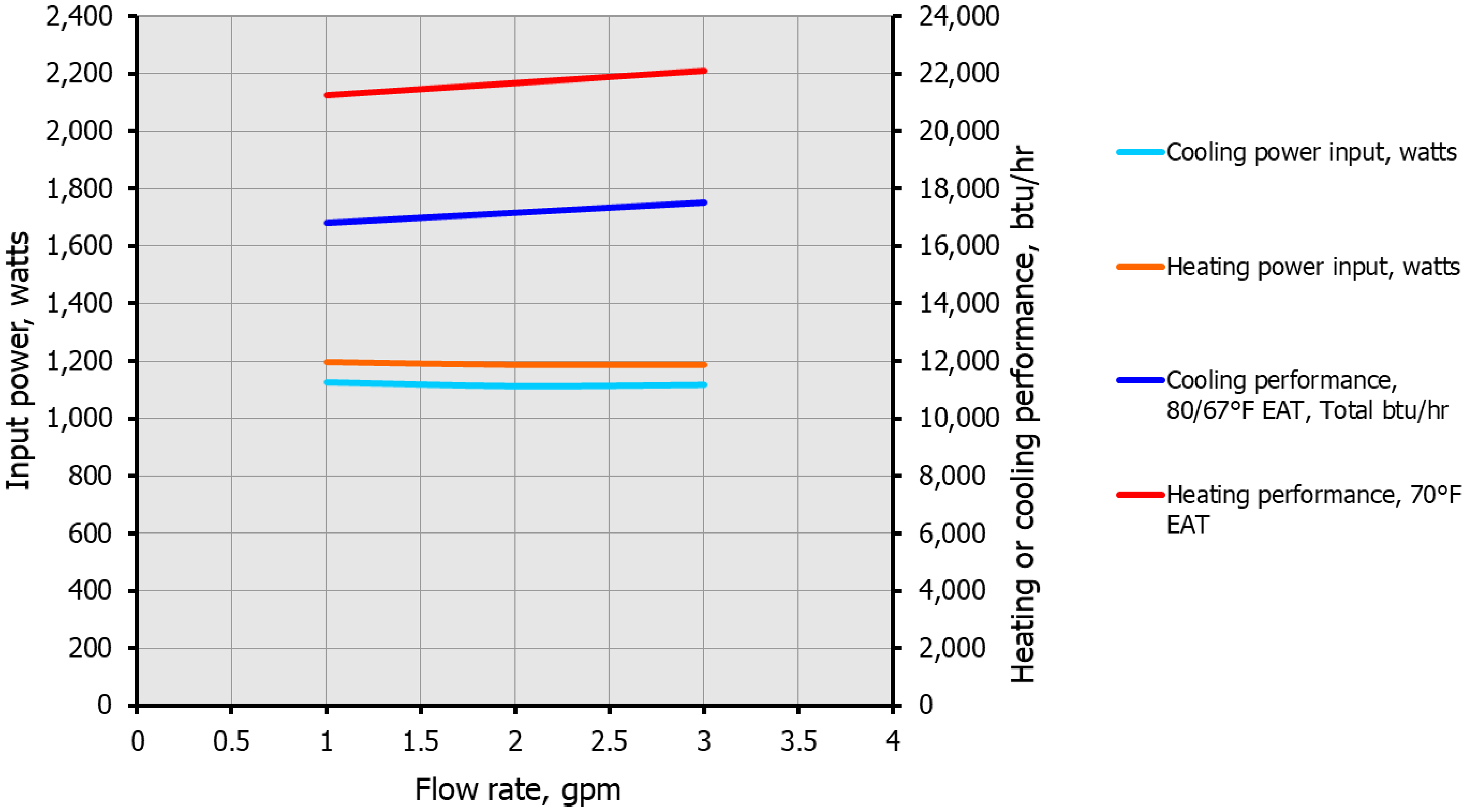
Heat pump performance can be impacted by the flows and temperatures in the system



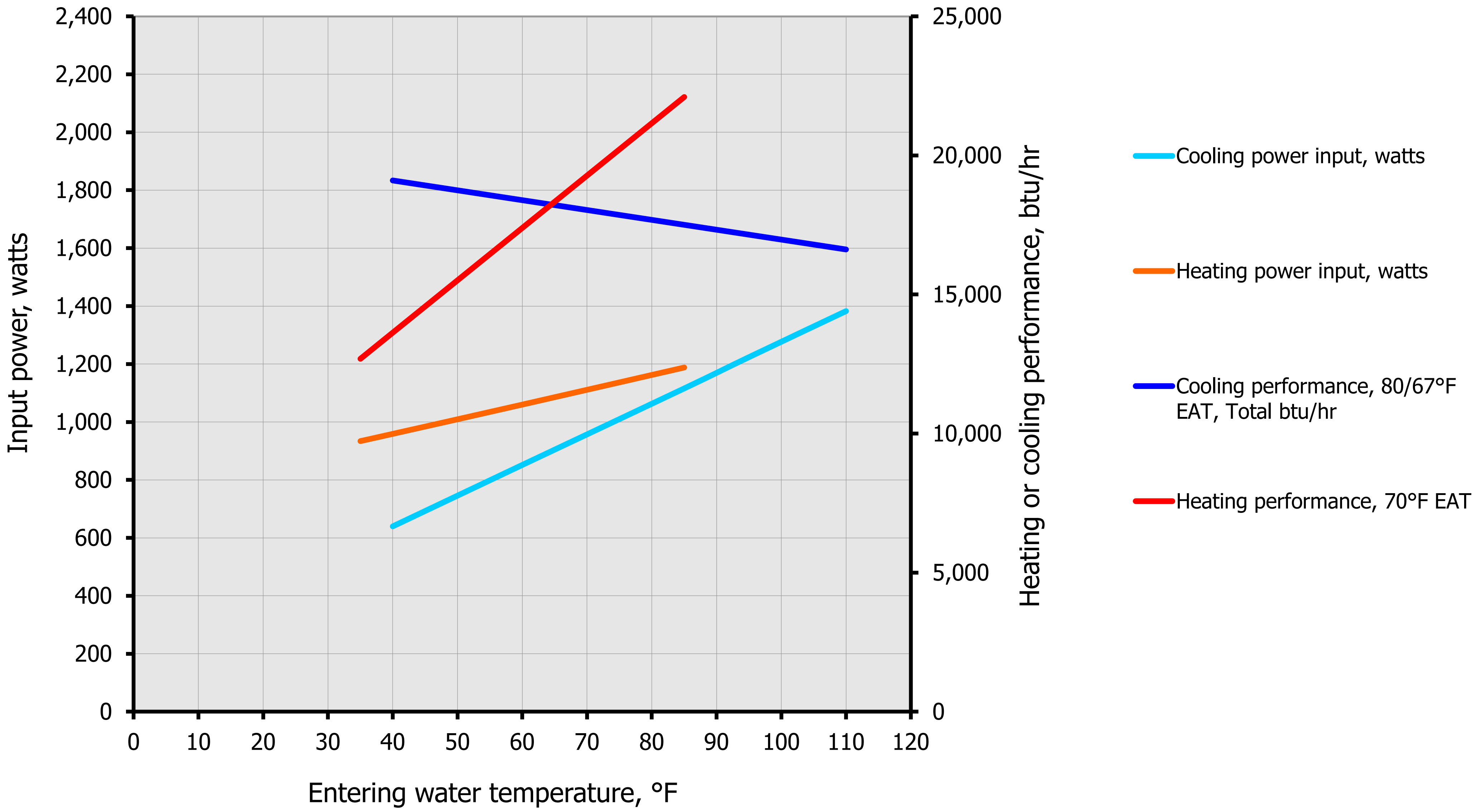


Heat pump performance at different flow rates,

85°F entering water temperature



Heat pump performand at different entering water temperatures, 3 gpm flow rate



Bottom Lines

Findings Summary Table		$0.10 per kWh		$0.78 per therm						
Item	Finding	Annual Electricity Savings		Annual Gas Savings		Total Annual Savings	Implementation Costs	Simple Payback	Recommended (Yes/No)	Note Reference
		kWh	$	Therms	$	$	$	Years		
Guest Housing Heat Pump Loops										
1	GHL4 - Potential to vary loop flow rate	41,540	$4,154	0	$0	$4,154	$22,704	5.5	Yes	Note 2
2	GHL2 - Cycle cooling tower pump as 1st stage	0	$0	0	$0	$0	$0	0.0	N/A	Note 1
3	GHL8 - Bypassing Flow around Heat Exchang	0	$0	0	$0	$0	$0	0.0	No	
4	GHL5 - Trim Cooling Tower Pump	40,396	$4,040	0	$0	$4,040	$9,000	2.2	Yes	
5	GHL1, GHL3 - Optimize closed loop	277,192	$27,719	48,094	$37,513	$65,232	$140,199	2.1	Yes	
Total for Guest Housing Heat Pump Loops		**359,127**	**$35,913**	**48,094**	**37,513**	**$73,426**	**$171,903**	**2.3**		
Notes	1. This finding has already been implemented by the operating staff									
	2 The simple payback for this finding could be as low as 4 years. The energy savings is a conservative estimate.									
	3 Further investigation is needed to estimate beneifts and cost for this measure.									
	4 Energy savings possible is a conservative estimate. The actual savings could be double from the amount listed									

Bottom Lines

Note that none of the savings opportunities are directly related to the heat pumps!

Findings Summary Table			$0.10 per kWh		$0.78 per therm					
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VRF Systems (Again)

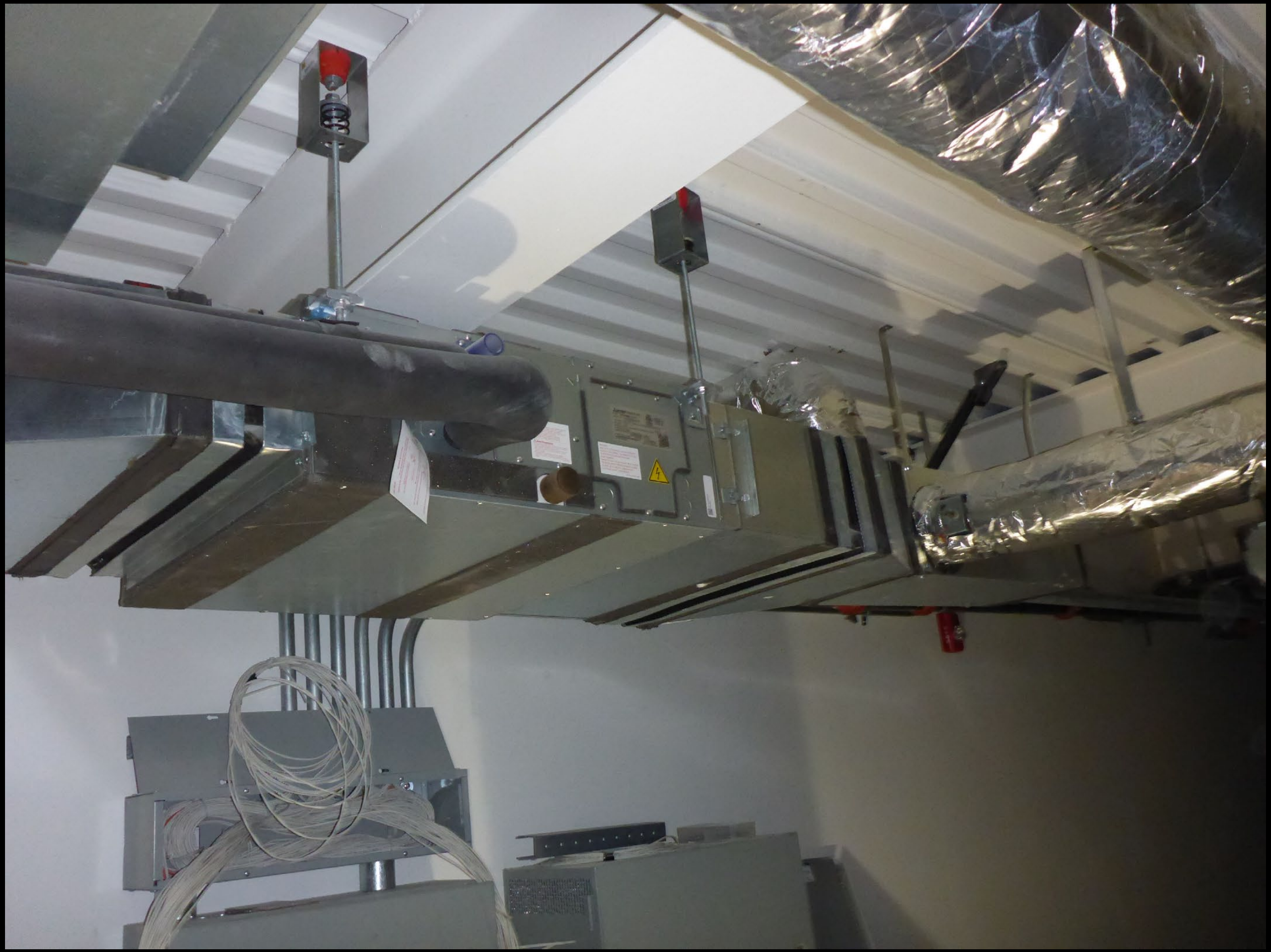
Variable Refrigerant Flow Systems (VRF)

- Complex!
- Move heat by using refrigerant instead of using water

  https://tinyurl.com/VRFAnnimation

Variable Refrigerant Flow Systems

- Key components
  - Indoor unit



Variable Refrigerant Flow Systems

- Key components
  - Indoor unit

Variable Refrigerant Flow Systems

- Key components
  - Indoor unit
  - Outdoor unit

Variable Refrigerant Flow Systems

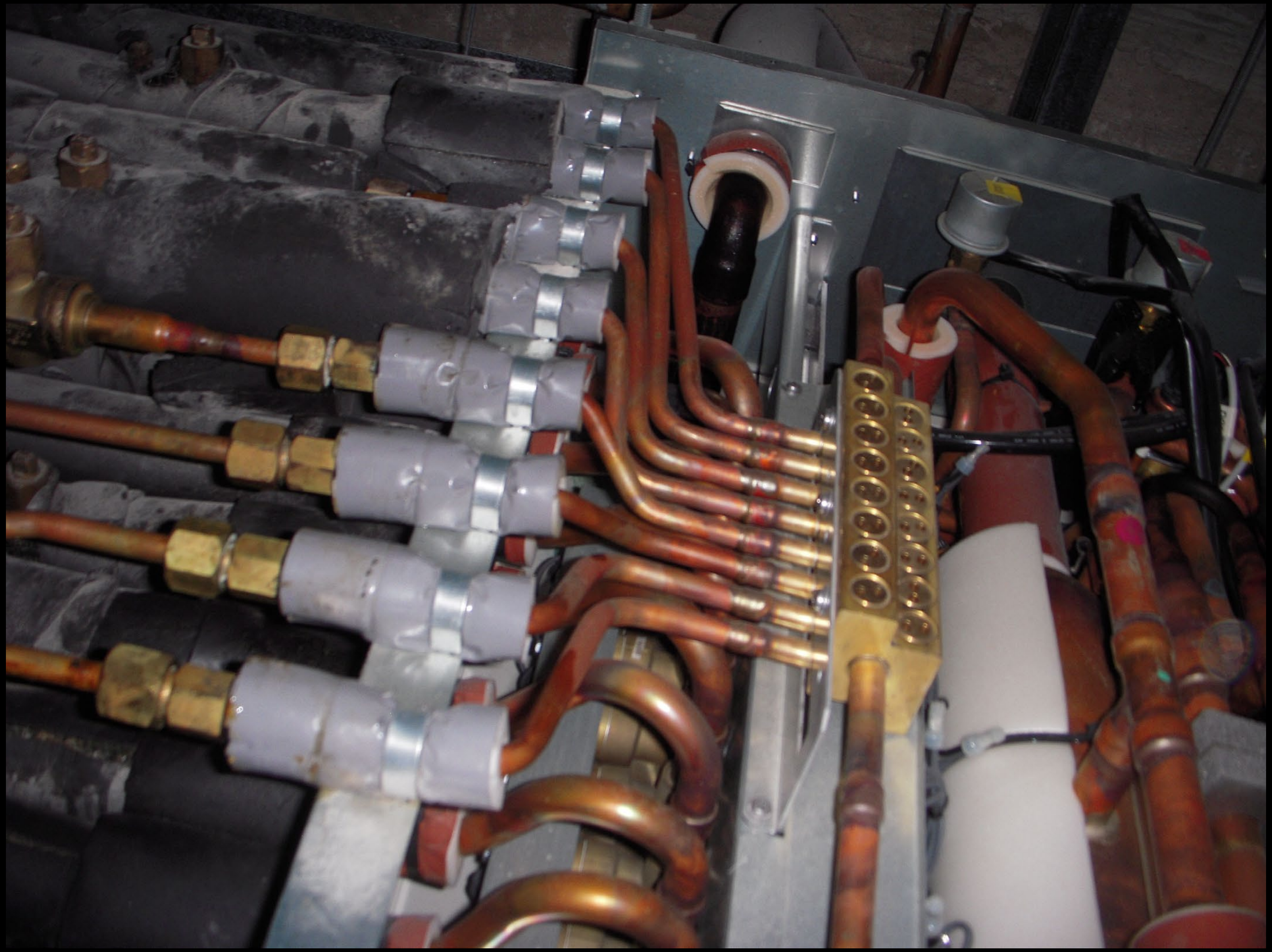
- Key components
  - Indoor unit
  - Outdoor unit
  - Branch Controller

Variable Refrigerant Flow Systems

- Key components
  - Indoor unit
  - Outdoor unit
  - Branch Controller

Variable Refrigerant Flow Systems

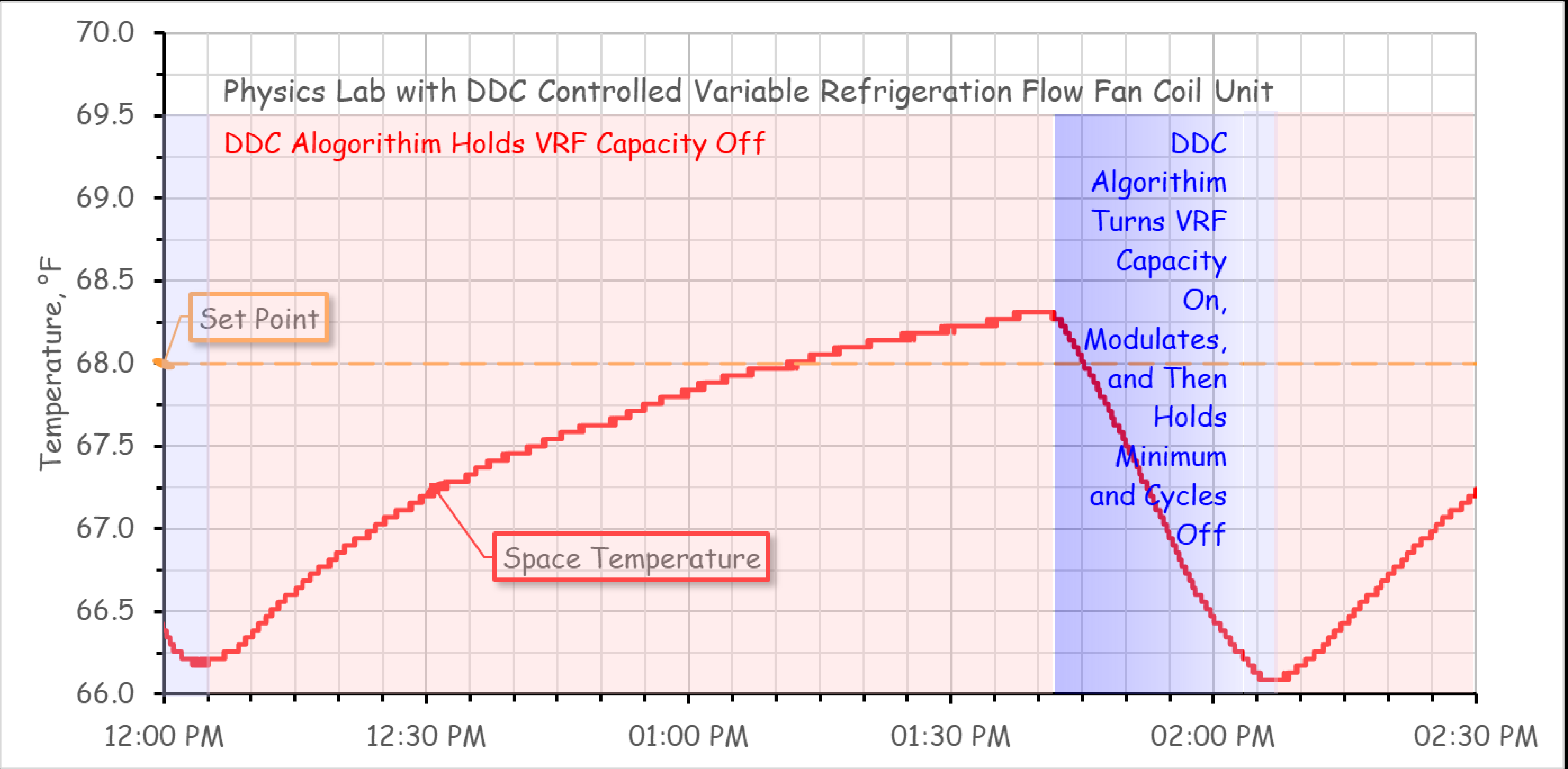
- Key components
  - Indoor unit
  - Outdoor unit
  - Branch Controller



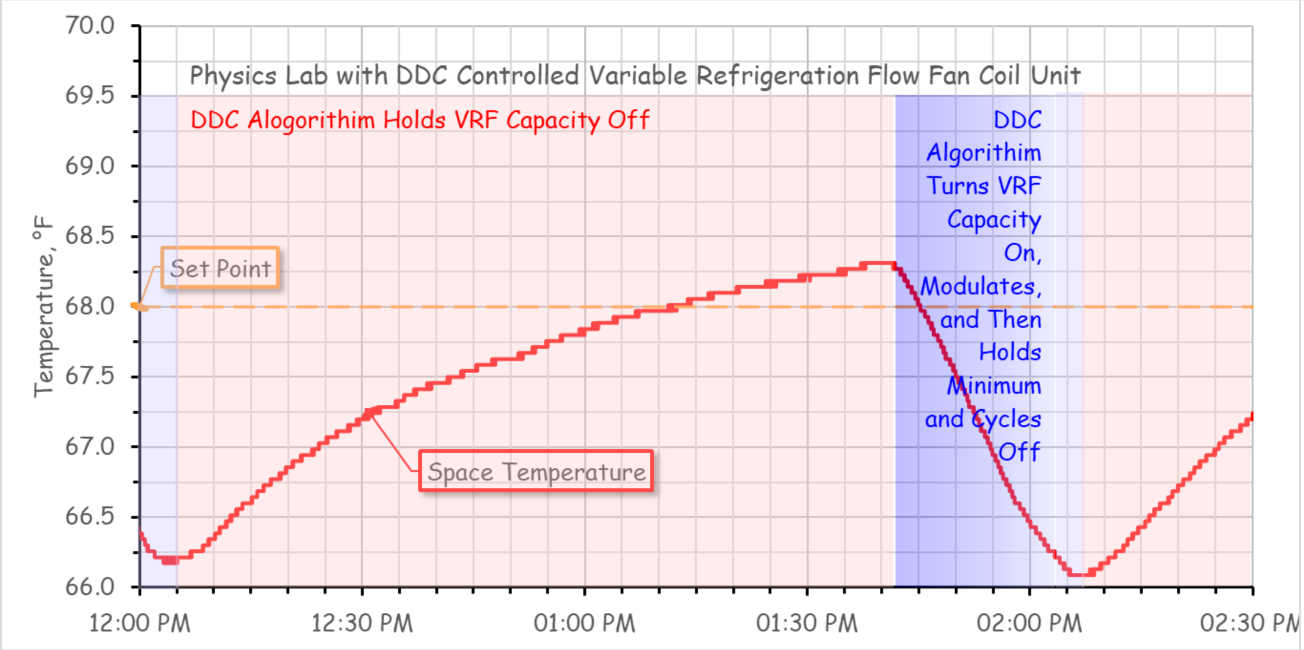
Variable Refrigerant Flow Systems

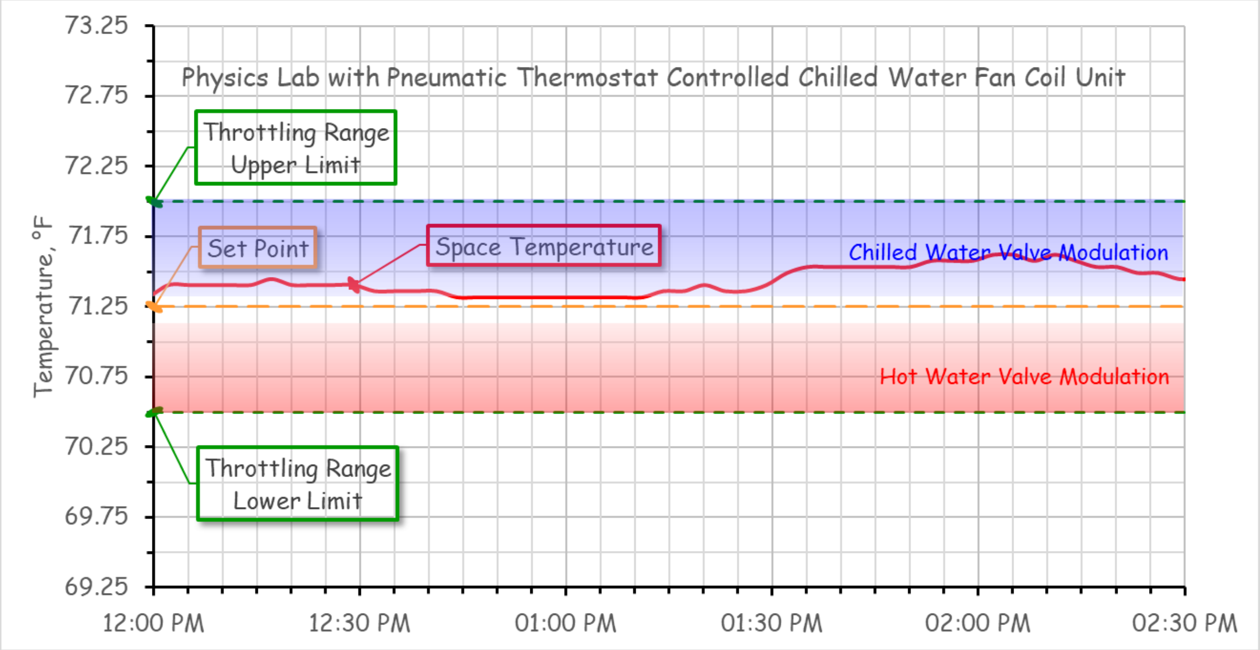
- Key components
  - Indoor unit
  - Outdoor unit
  - Branch Controller
  - Control System
    - Proprietary
    - Limited BACnet integration options
    - Maintenance tool is highly desirable option

Turn-Down Limitations

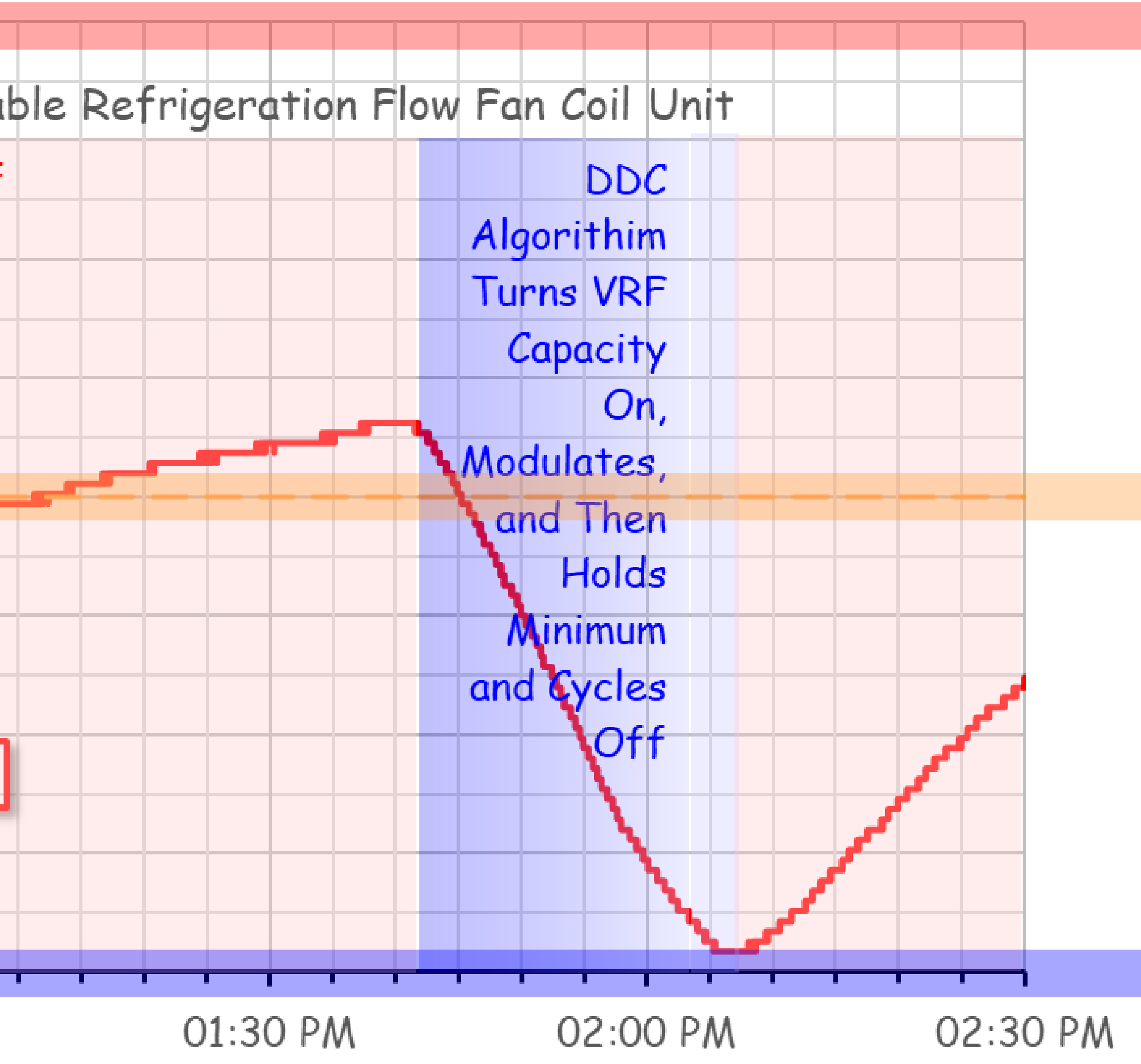


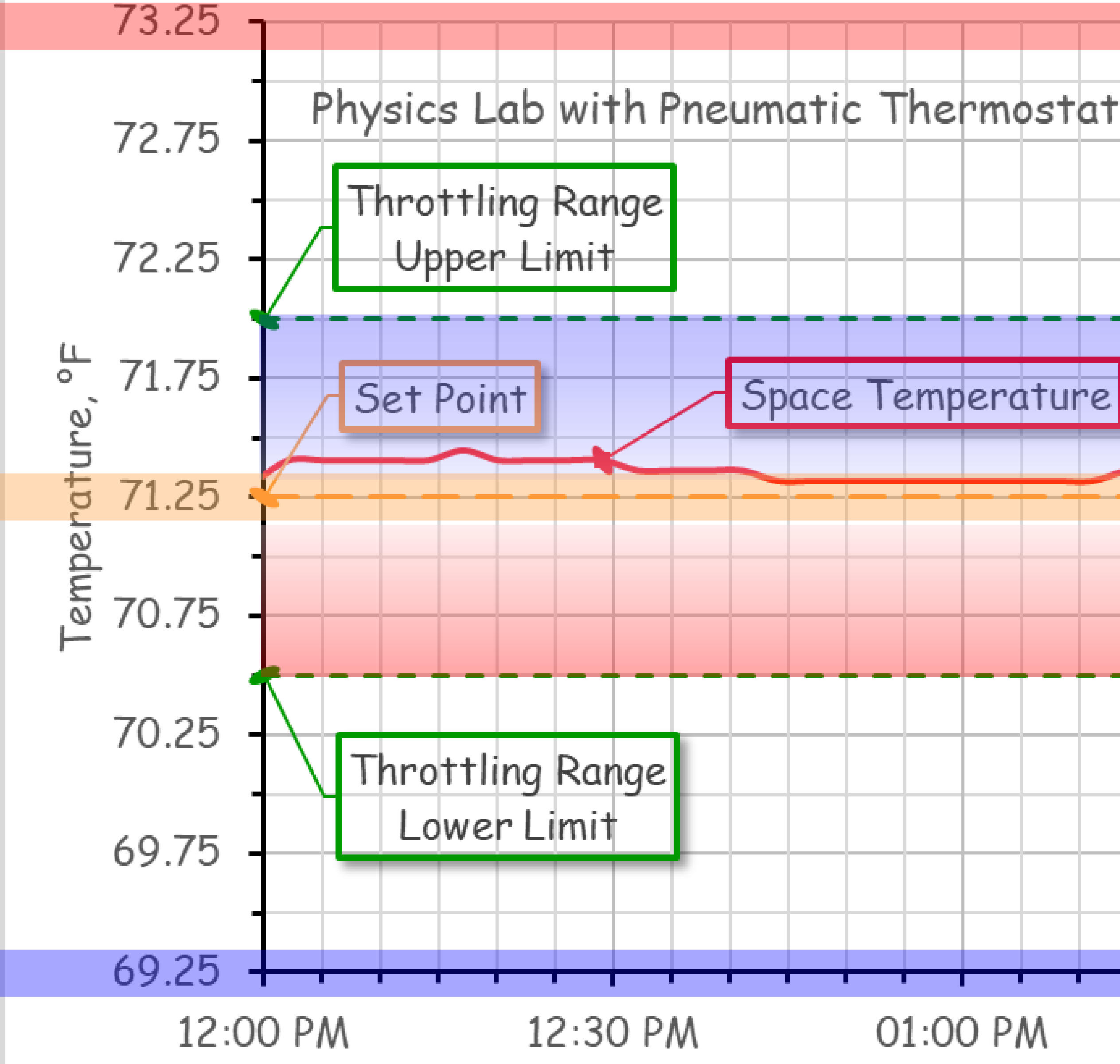
Turn-Down Limitations



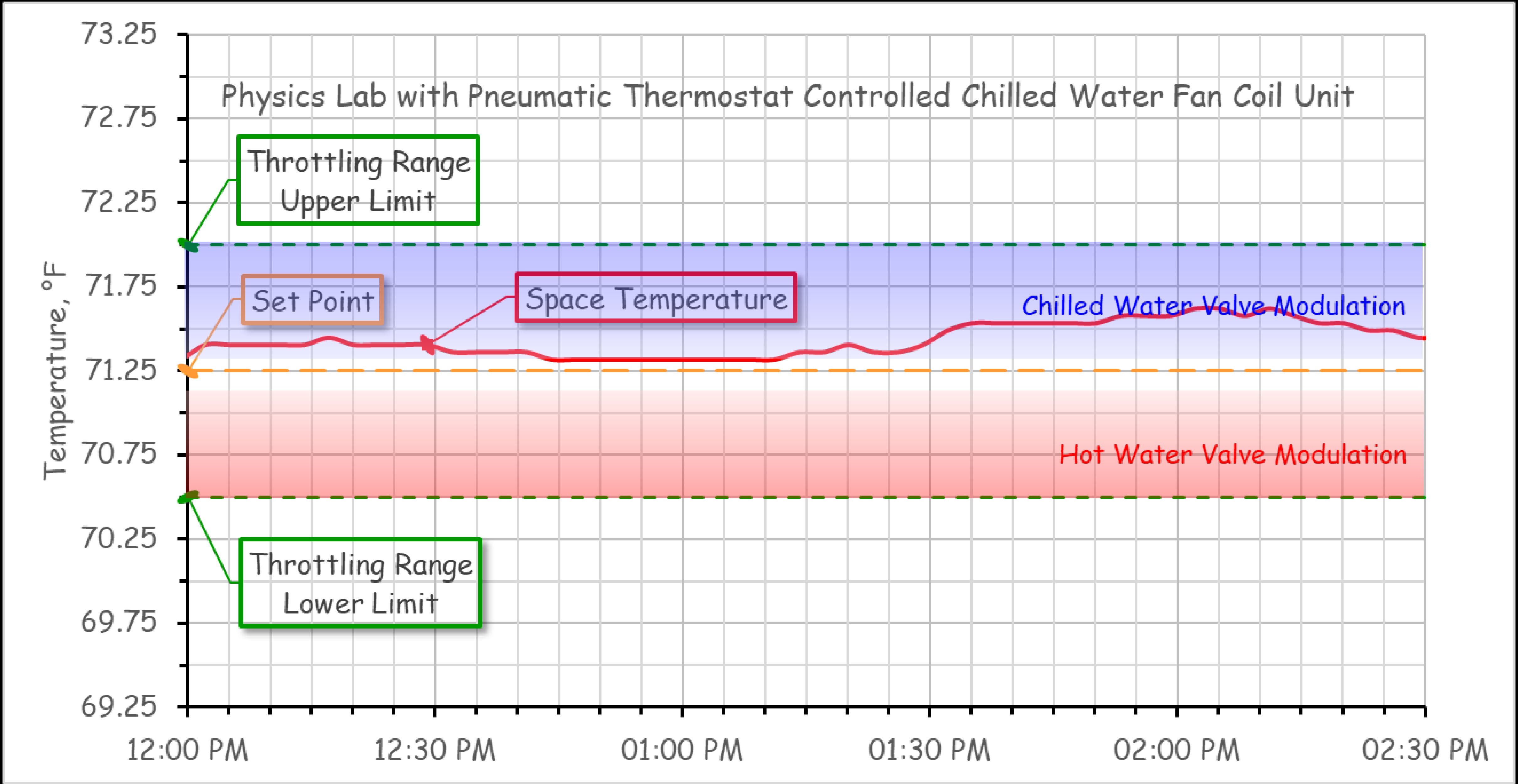


Turn-Down Limitations

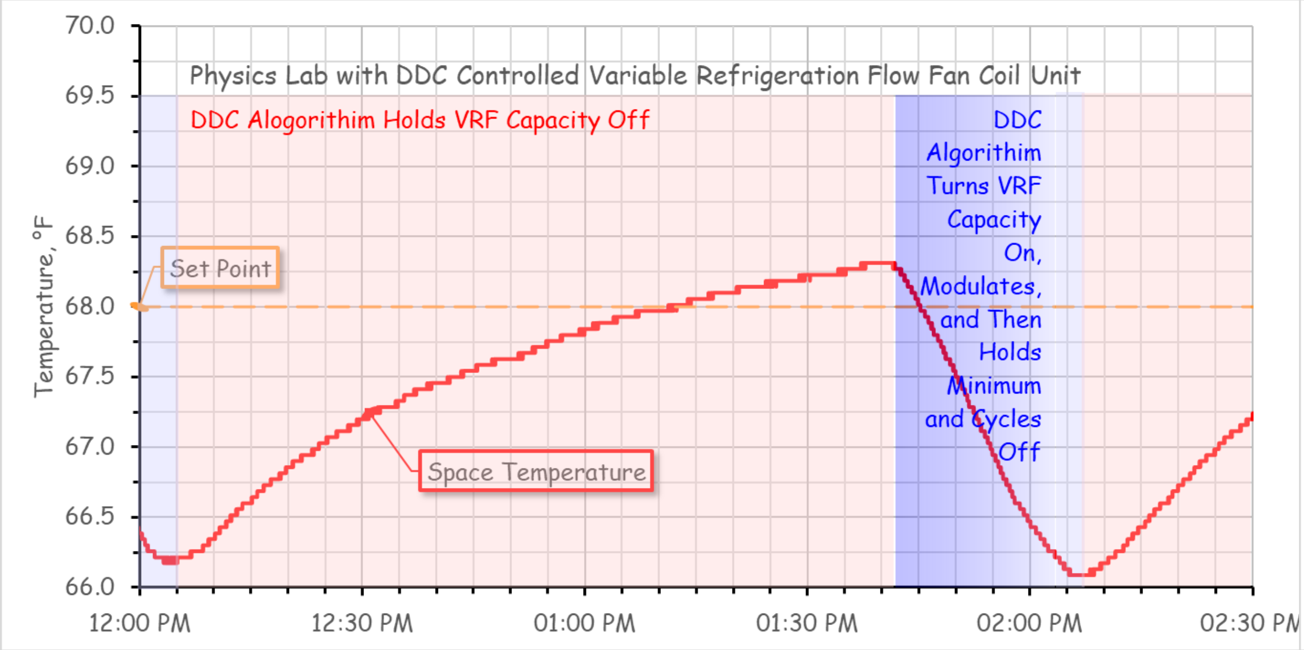


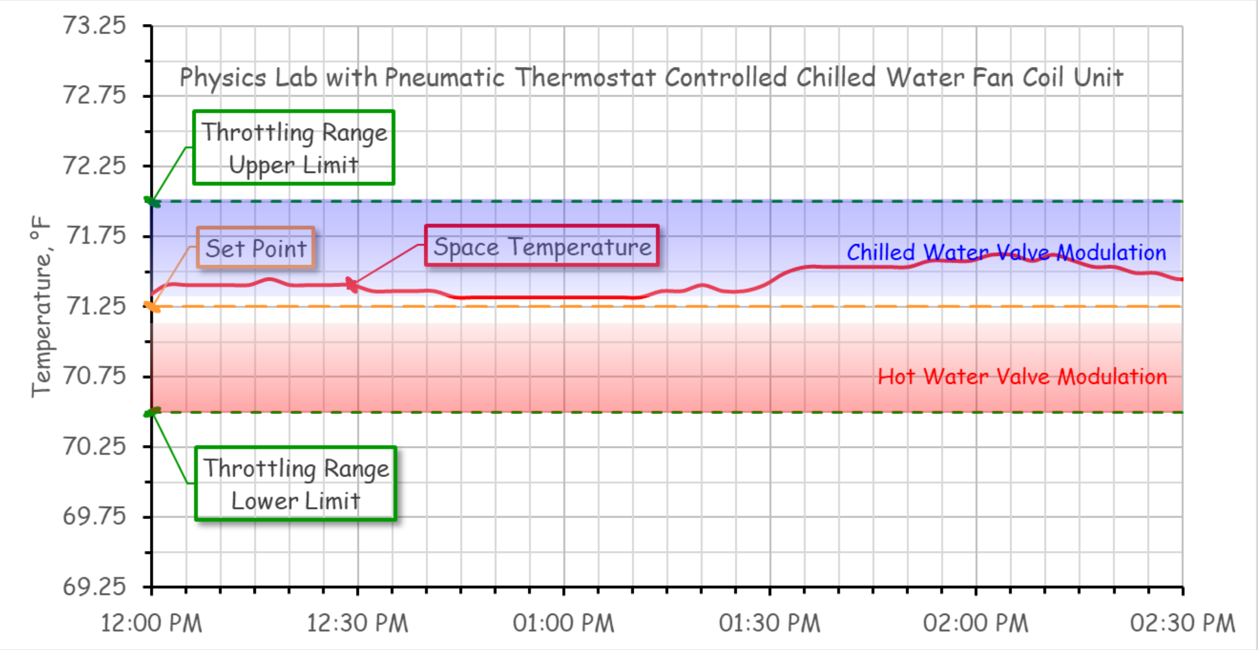


Turn-Down Limitations

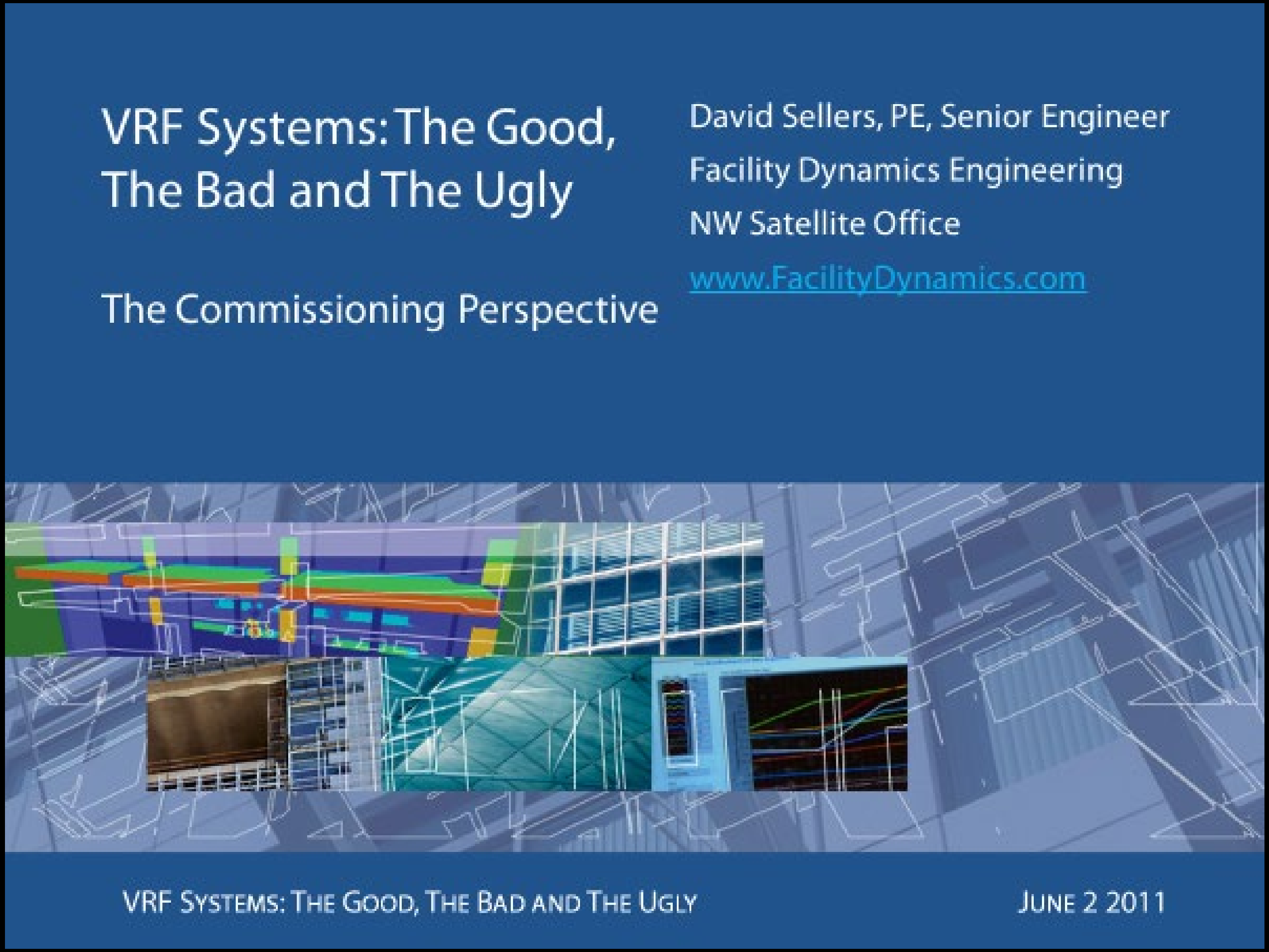


Turn-Down Limitations



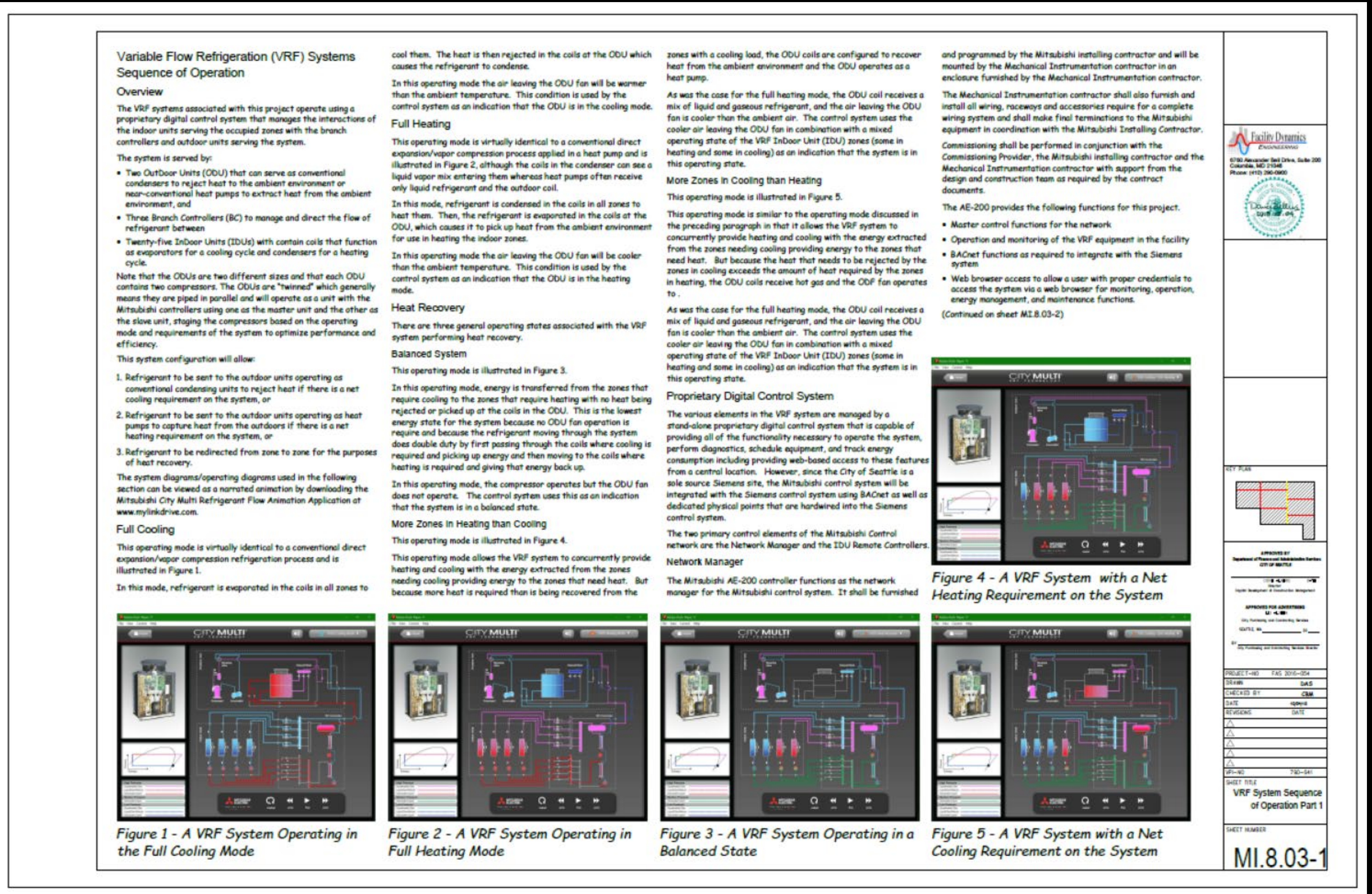


VRF Systems



https://tinyurl.com/VRFMemo

VRF Systems



Variable Flow Refrigeration (VRF) Systems Sequence of Operation

Overview

The VRF systems associated with this project operate using a proprietary digital control system that manages the interactions of the indoor units serving the occupied zones with the branch controllers and outdoor units serving the system.

The system is served by:

- Two OutDoor Units (ODU) that can serve as conventional condensers to reject heat to the ambient environment or near-conventional heat pumps to extract heat from the ambient environment, and
- Three Branch Controllers (BC) to manage and direct the flow of refrigerant between
- Twenty-five InDoor Units (IDUs) with contain coils that function as evaporators for a cooling cycle and condensers for a heating cycle.

Note that the ODUs are two different sizes and that each ODU contains two compressors. The ODUs are "twinned" which generally means they are piped in parallel and will operate as a unit with the Mitsubishi controllers using one as the master unit and the other as the slave unit, staging the compressors based on the operating mode and requirements of the system to optimize performance and efficiency.

This system configuration will allow:

1. Refrigerant to be sent to the outdoor units operating as conventional condensing units to reject heat if there is a net cooling requirement on the system, or
2. Refrigerant to be sent to the outdoor units operating as heat pumps to capture heat from the outdoors if there is a net heating requirement on the system, or
3. Refrigerant to be redirected from zone to zone for the purposes of heat recovery.

The system diagrams/operating diagrams used in the following section can be viewed as a narrated animation by downloading the Mitsubishi City Multi Refrigerant Flow Animation Application at www.mylinkdrive.com.

Full Cooling

This operating mode is virtually identical to a conventional direct expansion/vapor compression refrigeration process and is illustrated in Figure 1.

In this mode, refrigerant is evaporated in the coils in all zones to cool them. The heat is then rejected in the coils at the ODU which causes the refrigerant to condense.

In this operating mode the air leaving the ODU fan will be warmer than the ambient temperature. This condition is used by the control system as an indication that the ODU is in the cooling mode.

Full Heating

This operating mode is virtually identical to a conventional direct expansion/vapor compression process applied in a heat pump and is illustrated in Figure 2, although the coils in the condenser can see a liquid vapor mix entering them whereas heat pumps often receive only liquid refrigerant and the outdoor coil.

In this mode, refrigerant is condensed in the coils in all zones to heat them. Then, the refrigerant is evaporated in the coils at the ODU, which causes it to pick up heat from the ambient environment for use in heating the indoor zones.

In this operating mode the air leaving the ODU fan will be cooler than the ambient temperature. This condition is used by the control system as an indication that the ODU is in the heating mode.

Heat Recovery

There are three general operating states associated with the VRF system performing heat recovery.

Balanced System

This operating mode is illustrated in Figure 3.

In this operating mode, energy is transferred from the zones that require cooling to the zones that require heating with no heat being rejected or picked up at the coils in the ODU. This is the lowest energy state for the system because no ODU fan operation is require and because the refrigerant moving through the system does double duty by first passing through the coils where cooling is required and picking up energy and then moving to the coils where heating is required and giving that energy back up.

In this operating mode, the compressor operates but the ODU fan does not operate. The control system uses this as an indication that the system is in a balanced state.

More Zones in Heating than Cooling

This operating mode is illustrated in Figure 4.

This operating mode allows the VRF system to concurrently provide heating and cooling with the energy extracted from the zones needing cooling providing energy to the zones that need heat. But because more heat is required than is being recovered from the zones with a cooling load, the ODU coils are configured to recover heat from the ambient environment and the ODU operates as a heat pump.

As was the case for the full heating mode, the ODU coil receives a mix of liquid and gaseous refrigerant, and the air leaving the ODU fan is cooler than the ambient air. The control system uses the cooler air leaving the ODU fan in combination with a mixed operating state of the VRF InDoor Unit (IDU) zones (some in heating and some in cooling) as an indication that the system is in this operating state.

More Zones in Cooling than Heating

This operating mode is illustrated in Figure 5.

This operating mode is similar to the operating mode discussed in the preceding paragraph in that it allows the VRF system to concurrently provide heating and cooling with the energy extracted from the zones needing cooling providing energy to the zones that need heat. But because the heat that needs to be rejected by the zones in cooling exceeds the amount of heat required by the zones in heating, the ODU coils receive hot gas and the ODF fan operates to .

As was the case for the full heating mode, the ODU coil receives a mix of liquid and gaseous refrigerant, and the air leaving the ODU fan is cooler than the ambient air. The control system uses the cooler air leaving the ODU fan in combination with a mixed operating state of the VRF InDoor Unit (IDU) zones (some in heating and some in cooling) as an indication that the system is in this operating state.

Proprietary Digital Control System

The various elements in the VRF system are managed by a stand-alone proprietary digital control system that is capable of providing all of the functionality necessary to operate the system, perform diagnostics, schedule equipment, and track energy consumption including providing web-based access to these features from a central location. However, since the City of Seattle is a sole source Siemens site, the Mitsubishi control system will be integrated with the Siemens control system using BACnet as well as dedicated physical points that are hardwired into the Siemens control system.

The two primary control elements of the Mitsubishi Control network are the Network Manager and the IDU Remote Controllers.

Network Manager

The Mitsubishi AE-200 controller functions as the network manager for the Mitsubishi control system. It shall be furnished and programmed by the Mitsubishi installing contractor and will be mounted by the Mechanical Instrumentation contractor in an enclosure furnished by the Mechanical Instrumentation contractor.

The Mechanical Instrumentation contractor shall also furnish and install all wiring, raceways and accessories require for a complete wiring system and shall make final terminations to the Mitsubishi equipment in coordination with the Mitsubishi Installing Contractor.

Commissioning shall be performed in conjunction with the Commissioning Provider, the Mitsubishi installing contractor and the Mechanical Instrumentation contractor with support from the design and construction team as required by the contract documents.

The AE-200 provides the following functions for this project.

- Master control functions for the network
- Operation and monitoring of the VRF equipment in the facility
- BACnet functions as required to integrate with the Siemens system
- Web browser access to allow a user with proper credentials to access the system via a web browser for monitoring, operation, energy management, and maintenance functions.

(Continued on sheet MI.8.03-2)

Figure 4 - A VRF System with a Net Heating Requirement on the System

Figure 1 - A VRF System Operating in the Full Cooling Mode

Figure 2 - A VRF System Operating in Full Heating Mode

Figure 3 - A VRF System Operating in a Balanced State

Figure 5 - A VRF System with a Net Cooling Requirement on the System

Facility Dynamics Engineering

VRF System Sequence of Operation Part 1

MI.8.03-1

Taking a closer look at the details

Thank You

Together, Building
a Better California

Class Survey

The survey should only take 2 minutes and your responses can be confidential.

Here's how to participate:

- Click the provided link: https://www.surveymonkey.com/r/EWB20240528CHP
  Scan the QR code with your phone's camera

Break Time

We will be back at 11:55 am Pacific Time

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