Commissioning Heat Pump Systems: New Construction Projects

Please Visit This Link While We Are Waiting to Begin

https://tinyurl.com/HeatPumpD3Refresh

Presented By:
David Sellers
Senior Engineer, Facility Dynamics Engineering

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Learning Objectives – Class Series

1. Attendees will be able to discuss some of the issues and opportunities associated with applying heat pumps as a source of heat for buildings as we move towards electrification

Learning Objectives – Class Series

2. Attendees will be able to name the common heat pump types and describe their general characteristics (ground source, air source, water source, variable flow refrigeration, etc.)

Learning Objectives – Class Series

3. Attendees will be able to discuss ventilation strategies that can be applied in conjunction with heat pump systems and how they can be integrated with the heat pumps and the zones they serve

Learning Objectives – Class Series

4. Attendees will be able to discuss the design and commissioning issues associated with applying heat pumps to new construction and retrofit projects

Learning Objectives – Class Series

5. Attendees will be able to identify existing building commissioning issues and opportunities associated with heat pumps and heat pump systems

Learning Objectives – Today's Session

1. Identify common design, construction, and commissioning issues associated with applying heat pumps to new construction projects

Learning Objectives – Today's Session

2. Recognize that the design and performance criteria associated with a system utilizing heat pumps will vary with the nature of the technology used (ground source, water source, etc.) and that integrating the heat pump with the auxiliary systems serving it, the loads it serves and the use patterns for the facility is critical to over-all success.

Learning Objectives – Today's Session

3. Identify the key heat pump system performance criteria that should be targeted by the pre-functional checks and functional tests specified for the commissioning process and if natural or forced response testing techniques should be applied to verify that the design intent has been achieved

Learning Objectives – Today's Session

4. Create a point list for the DDC system that includes the points needed to perform ongoing commissioning of the heat pump systems in addition to controlling them

Learning Objectives – Today's Session

5. Recognize the value of trend data for evaluating heat pump system performance to ensure that the design intent has been achieved

Agenda

1. Introduction
2. The New Construction (NCx) Commissioning Process
3. Key Cx Skills
4. NCx Functional Testing
5. Potpourri
6. Case Study

Introduction

A Bit About Me

A Bit About Me

I intended to be an aircraft maintenance engineer

I'm doing something totally different

A Bit About Me

- HVAC field technician
- Control system designer
- HVAC designer
- MCC Powers system engineer
- Murphy Company controls and start-up engineer
- Project engineer
- Wafer fab facilities engineer and system owner
- A happily married PECI technical support engineer and trainer
- FDE Senior Engineer



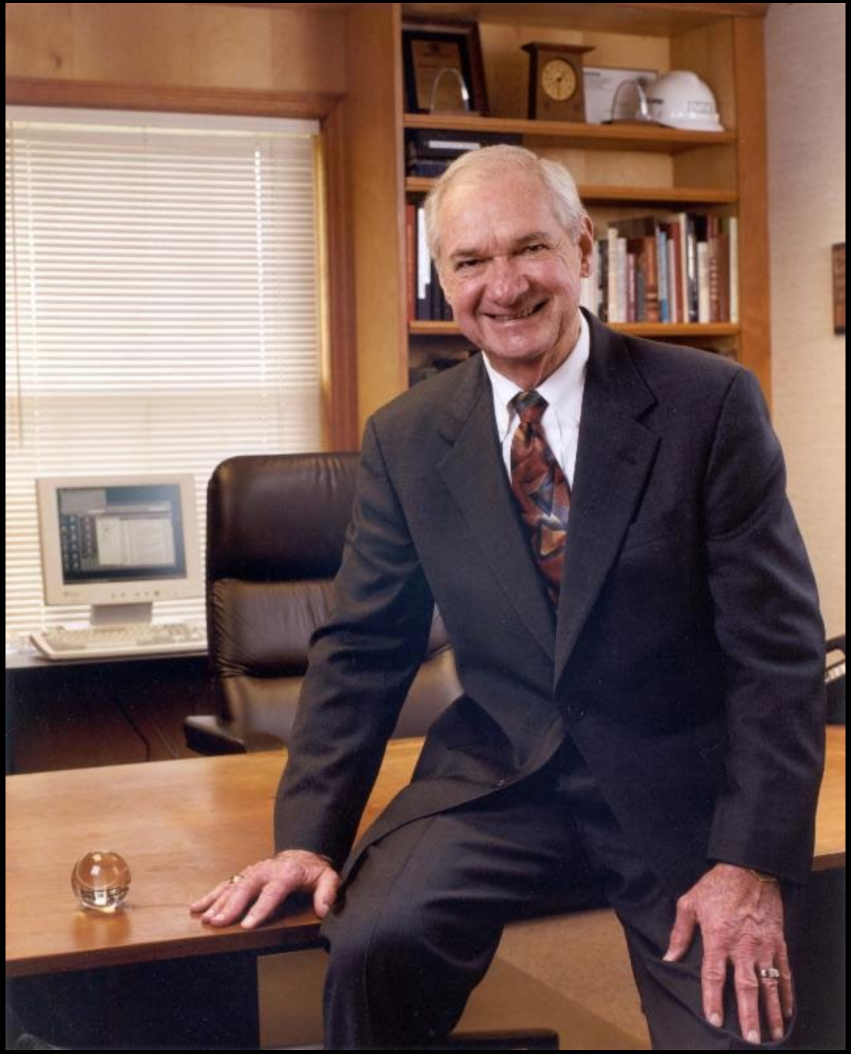
I’ve Had Great Mentors Along the Way

Bill Coad's Thoughts on Energy Conservation

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

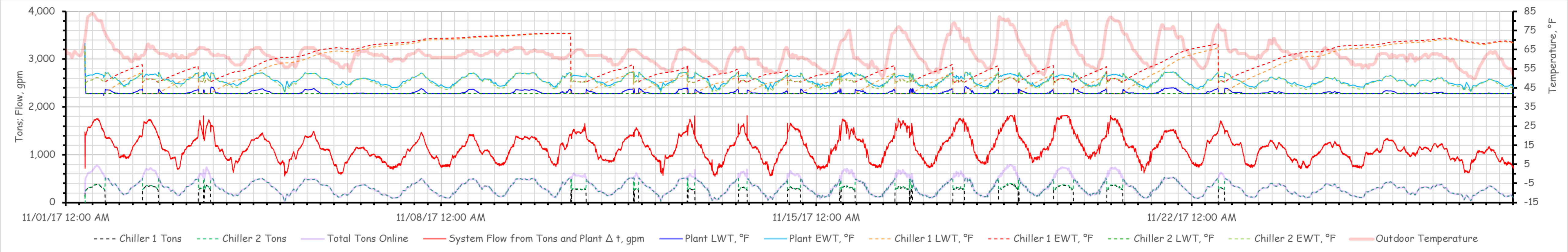
Energy Conservation is an Ethic
ASHRAE Journal, vol. 42, no. 7, p. 16-21

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



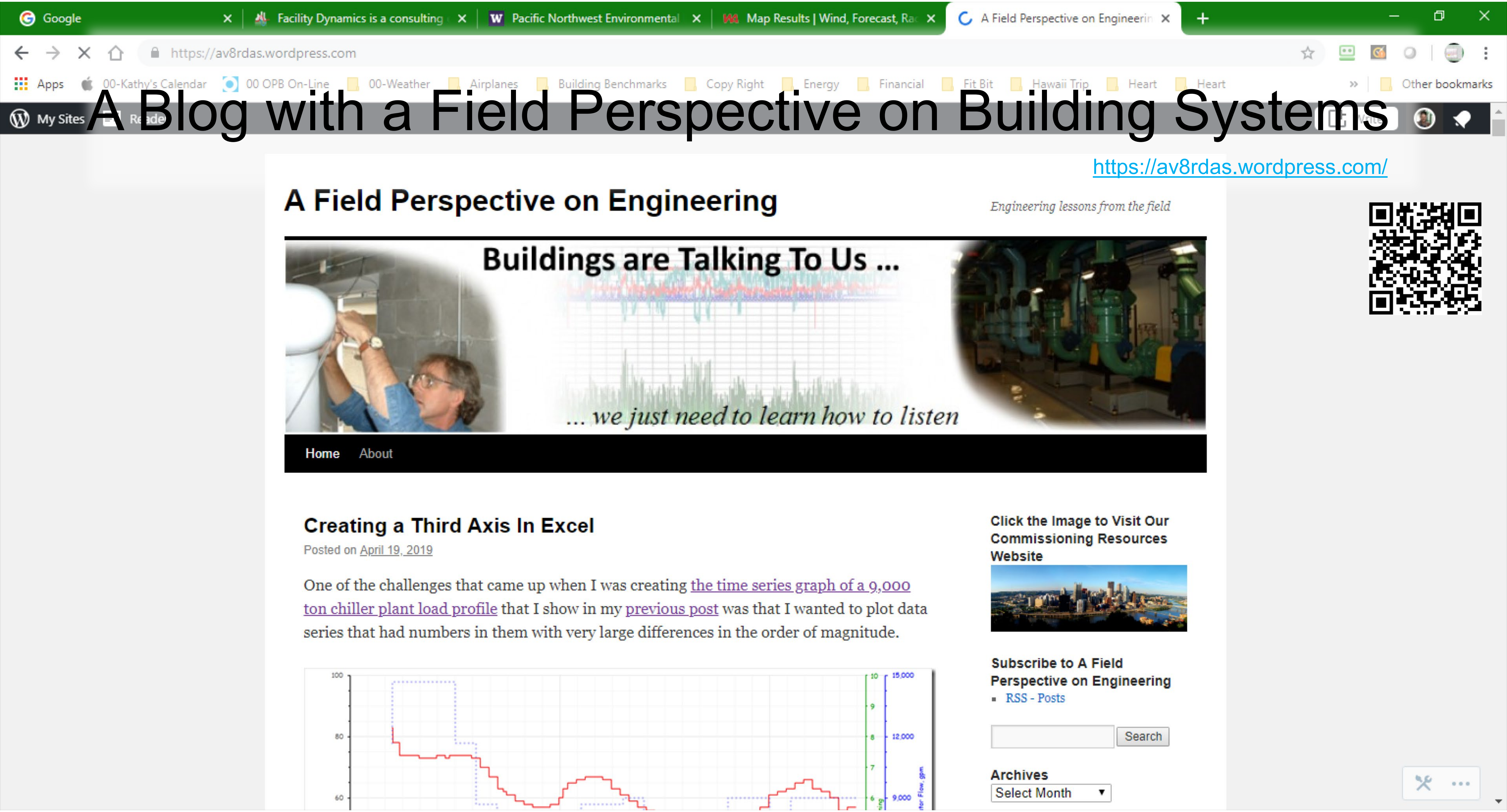
My Most Important Lesson

It's all about the load profile



A Blog with a Field Perspective on Building Systems

https://av8rdas.wordpress.com/



A Commissioning Resources Web Site

Google | Facility Dynamics is a consulting | Pacific Northwest Environmental | Map Results | Wind, Forecast, Ra | Home

Not secure | www.av8rdas.com

Apps | 00-Kathy's Calendar | 00 OPB On-Line | 00-Weather | Airplanes | Building Benchmarks | Copy Right | Energy | Financial | Fit Bit | Hawaii Trip | Heart | Heart | » | Other bookmarks

HOME BLOG RESOURCES TRAINING CONTACT

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What's New?

Search

Buildings are Talking to Us

We Just Need to Learn How to Listen

My Goal

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

Facility Dynamics ENGINEERING

http://www.av8rdas.com/

Key Commissioning Skills

Key Cx Skills

1. Be able to benchmark and perform utility analysis
2. Be able to scope a facility for obvious indicators of opportunity
3. Be familiar with fundamental principles and building systems
4. Understand and apply the system concept
5. Be able to perform data logging and trend analysis
6. Be familiar with functional testing techniques
7. Be familiar with data analysis techniques
8. Be familiar with basic HVAC and energy calculations
9. Be familiar with cost/benefit and return on investment calculations
10. Be familiar with implementation strategies and techniques

https://tinyurl.com/KeySkillsBlogPost

New Construction Commissioning Process

Dictionary definition

- Com·mis·sion
- kəˈmiSHən
- Verb; Gerund or present participle: Commissioning

1. Give an order for or authorize the production of (something such as a building, equipment, or work of art).

- *The portrait was commissioned by his widow in 1792*
- synonyms: order, authorize, bespeak

2. Bring (something newly produced, such as a factory or machine) into working condition.

- *We had a few hiccups getting the heating equipment commissioned*

Dictionary definition

An analogy to a ship's sea trials or "shake-down" cruise

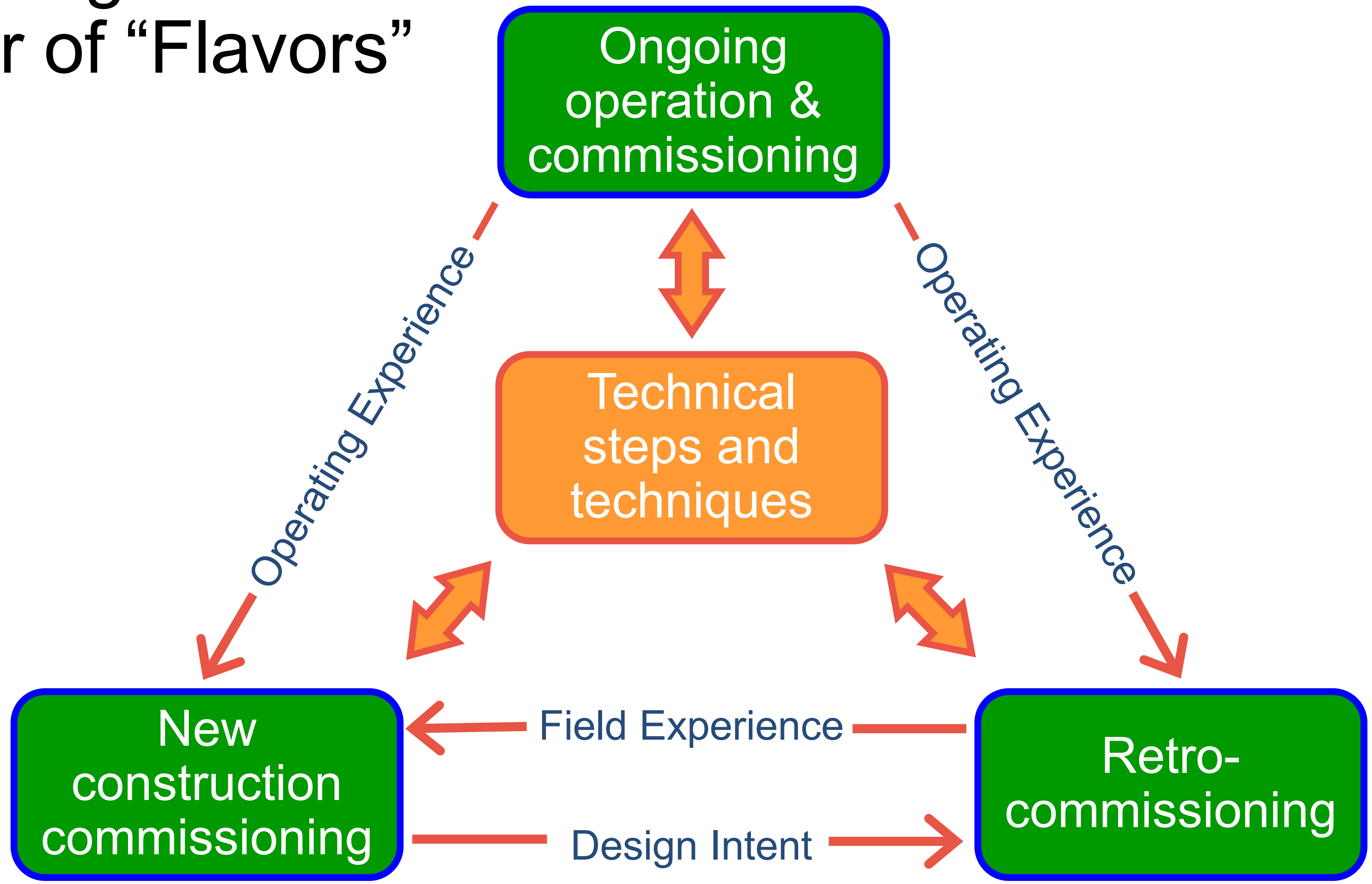
3. To put a ship into commission

Image courtesy www.public-domain-image.com

Industry Definition

- 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

Commissioning comes in a Number of "Flavors"



New Construction Commissioning Phases

- Programming
- Design Phase
  - Design Review
  - Develop Cx Specifications
  - Develop Draft Pre-functional Checks and Functional Tests
- Construction Phase
  - Submittal Review
  - Construction Observation
  - Functional Testing

Functional Testing

Pre-functional Checks

- Generally static vs. dynamic
- Validate equipment and system readiness for testing
  - Is everything there?
  - Control system point to point checks
  - Connections secure
  - Accessibility
  - Standard manufacturer's requirements

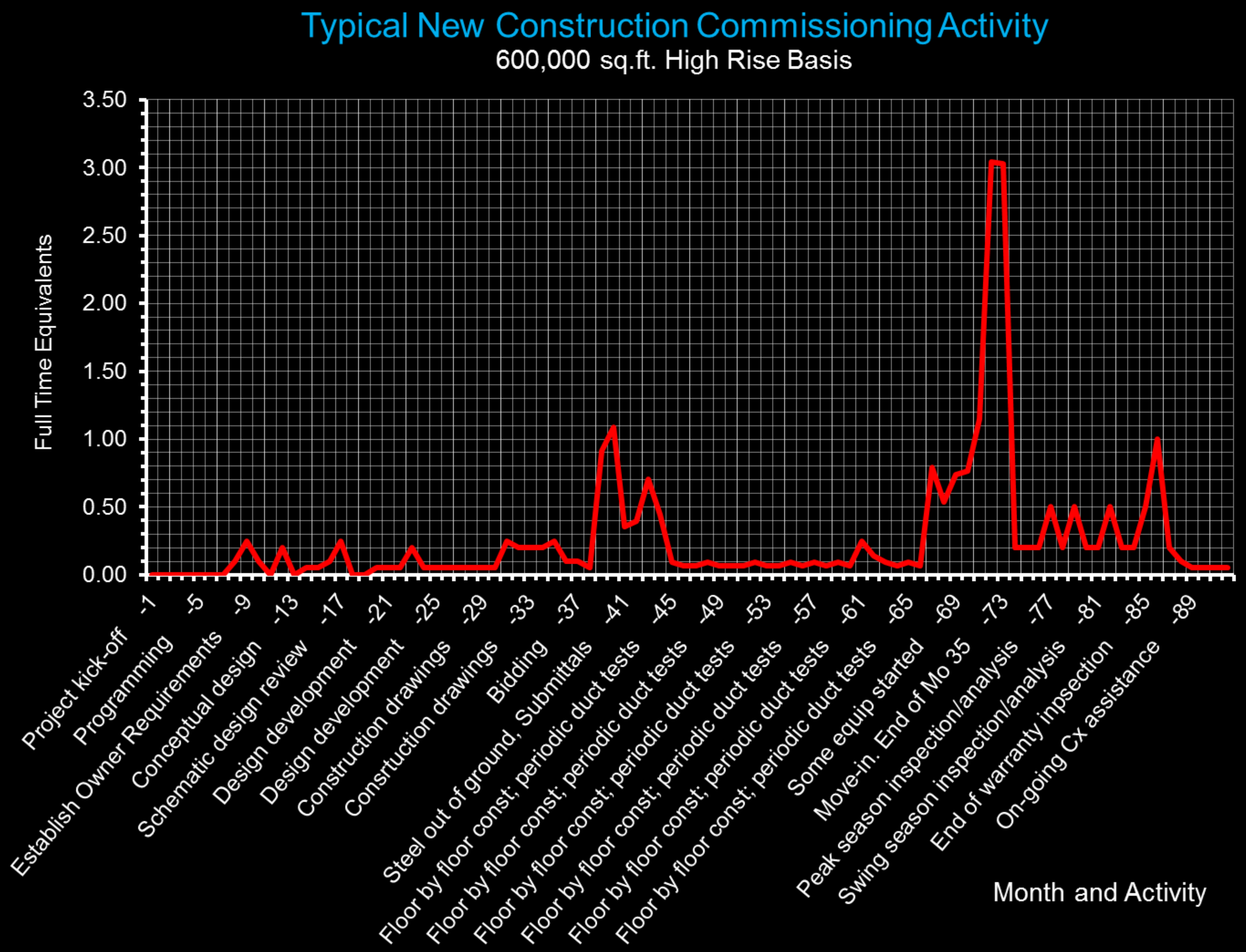
Functional Tests

- Generally dynamic
  - Forced response and natural response
  - Start at component level and build to system level
  - Verify integration
    - Components with the system
    - Systems with other systems
    - Systems with the facility

New Construction Commissioning Phases

- Programming
- Design Phase
  - Design Review
  - Develop Cx Specifications
  - Develop Draft Pre-functional Checks and Functional Tests
- Construction Phase
  - Submittal Review
  - Construction Observation
  - Functional Testing
  - Warranty
  - Ongoing Commissioning

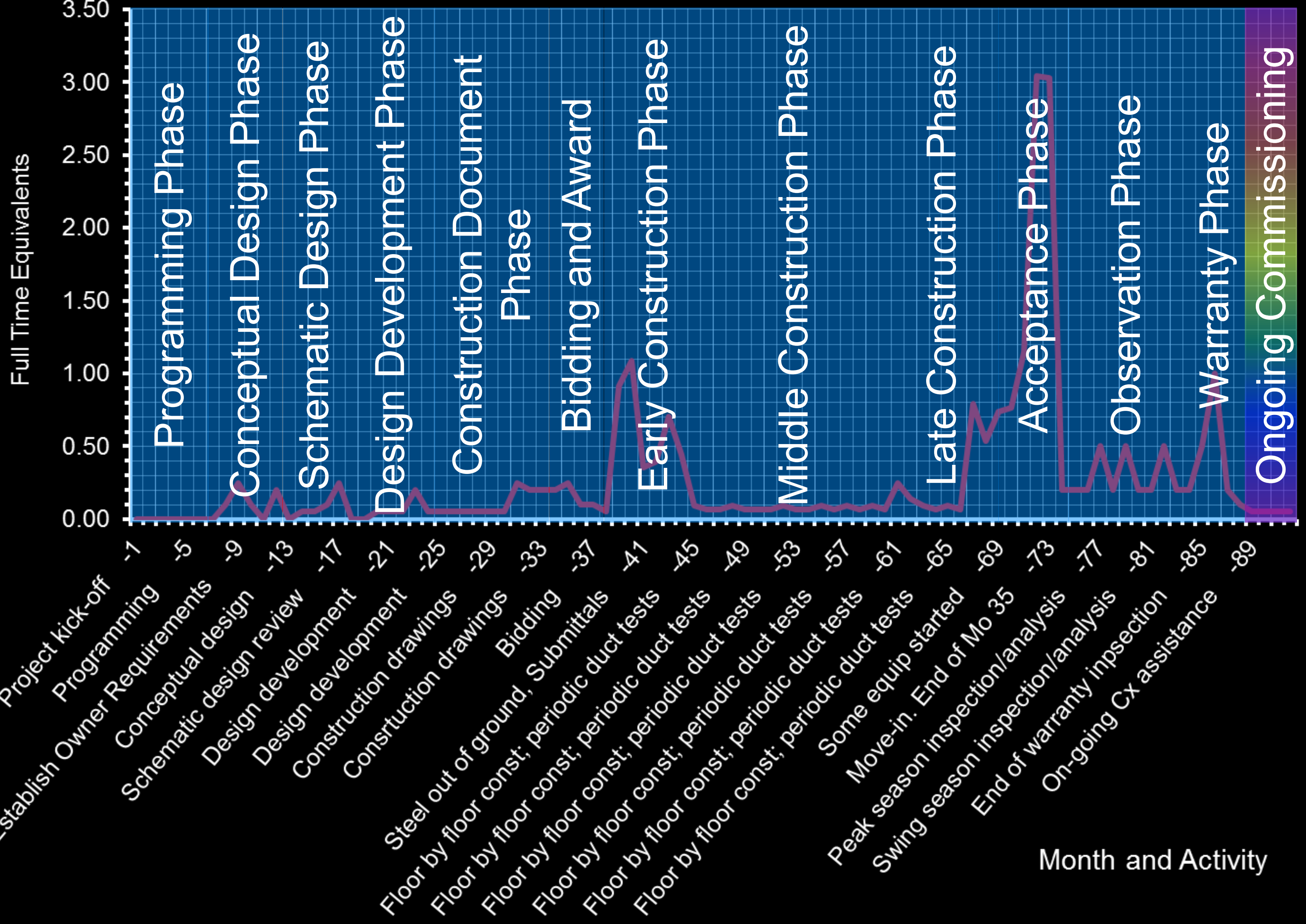
The NCx Commissioning Process and Project Timeline



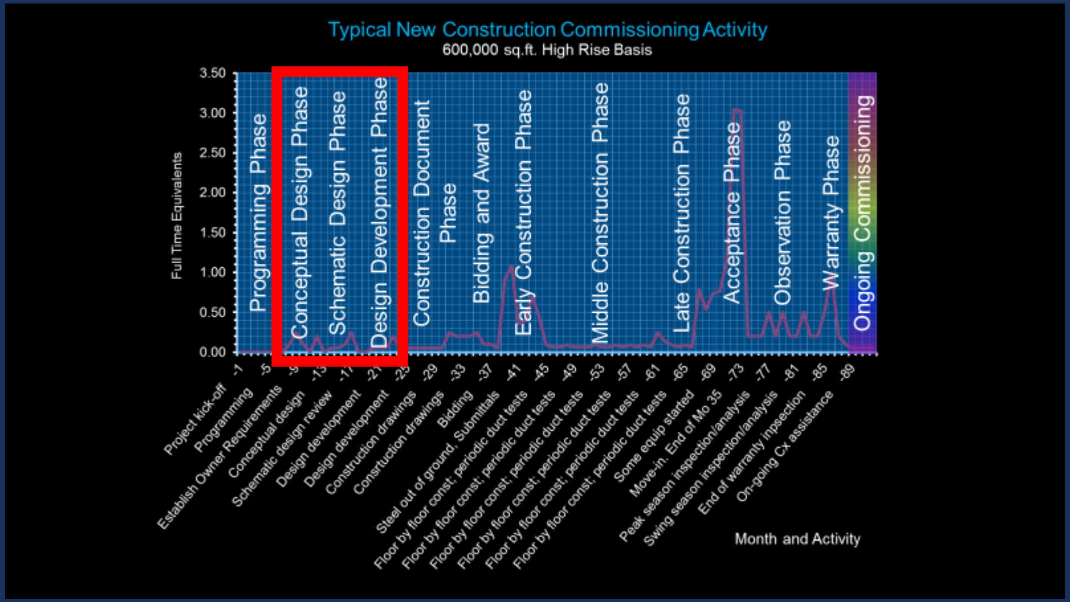
Typical New Construction Commissioning Activity
600,000 sq.ft. High Rise Basis
Full Time Equivalents
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-1
-5
-9
-13
-17
-21
-25
-29
-33
-37
-41
-45
-49
-53
-57
-61
-65
-69
-73
-77
-81
-85
-89
Project kick-off
Programming
Establish Owner Requirements
Conceptual design
Schematic design review
Design development
Design development
Construction drawings
Consrtuction drawings
Bidding
Steel out of ground, Submittals
Floor by floor const; periodic duct tests
Floor by floor const; periodic duct tests
Floor by floor const; periodic duct tests
Floor by floor const; periodic duct tests
Floor by floor const; periodic duct tests
Floor by floor const; periodic duct tests
Some equip started
Move-in. End of Mo 35
Peak season inspection/analysis
Swing season inspection/analysis
End of warranty inpsection
On-going Cx assistance
Month and Activity

Typical New Construction Commissioning Activity

600,000 sq.ft. High Rise Basis



Heat Pumps and Design Phase Cx



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 Buildings Use Heat

Application

- Heating
- Preheat
- Reheat
- Cooling
- Humidification
- Power Generation

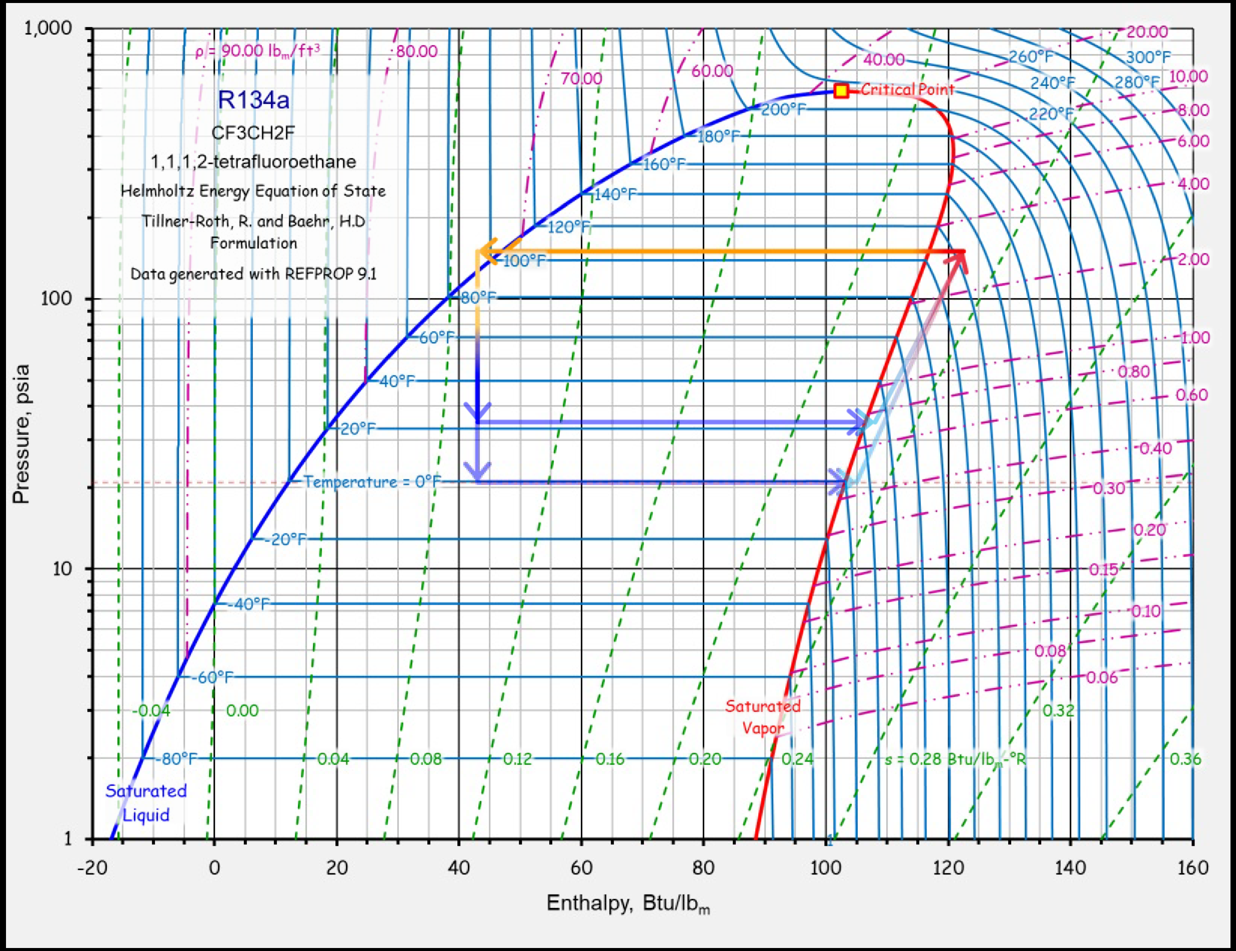
Recall Heat Pump Targets

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

Recall How Lift Impacts Heat Pump Performance

Big source to sink temperature differentials mean:

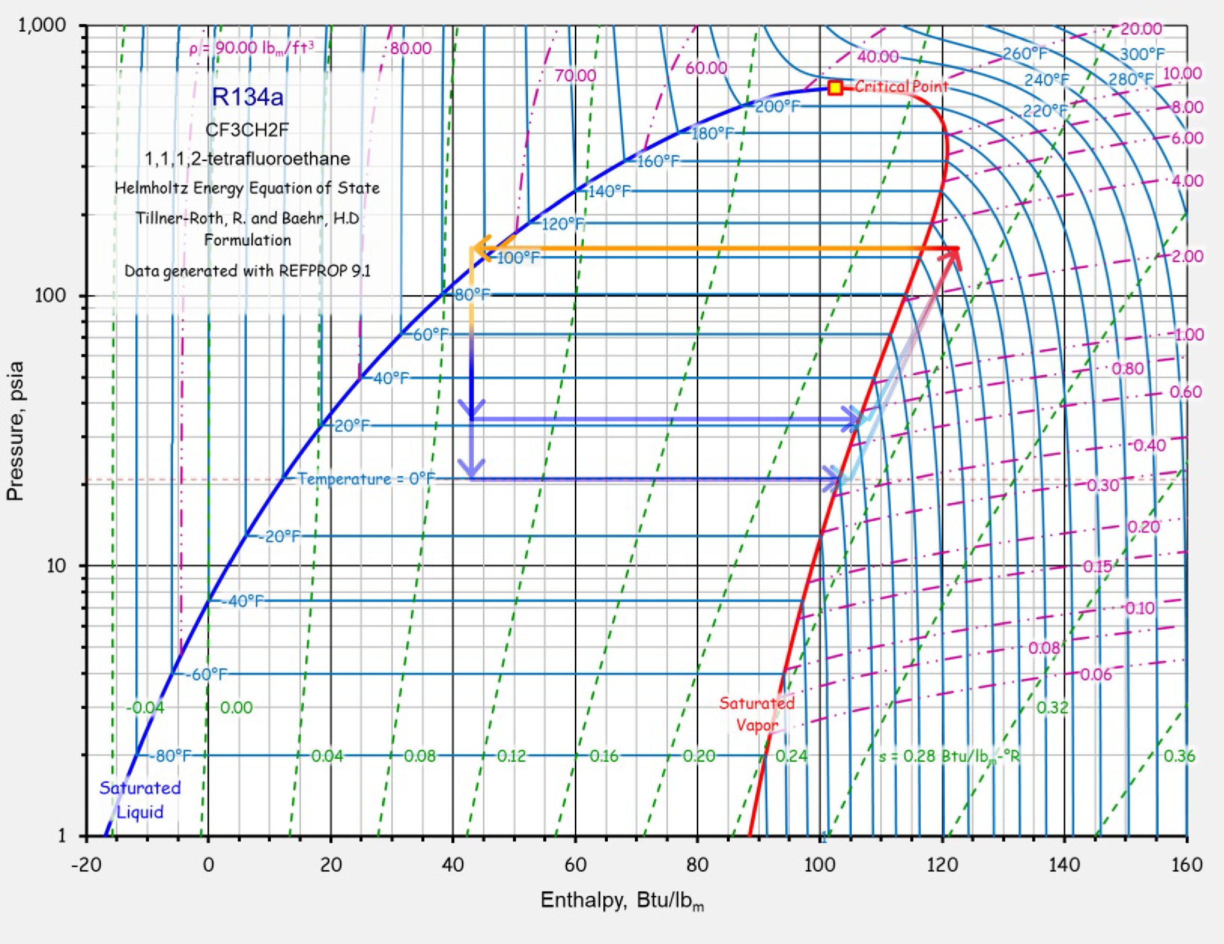
- More energy expended per Btu of energy moved



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

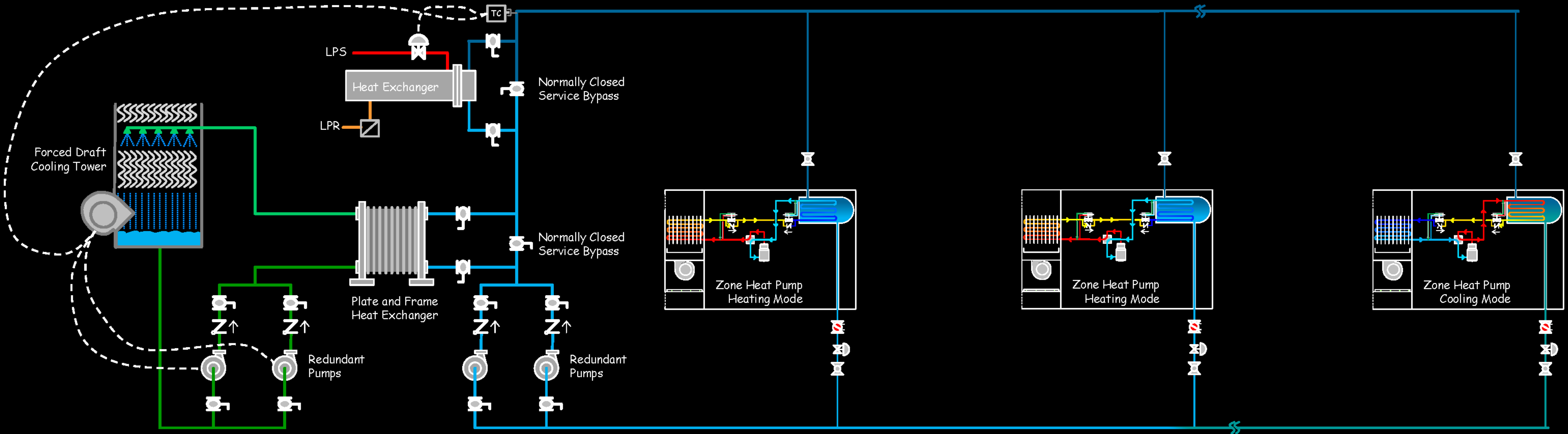
And/Or

An Alternative Energy Source that is not Extremely Cold

And

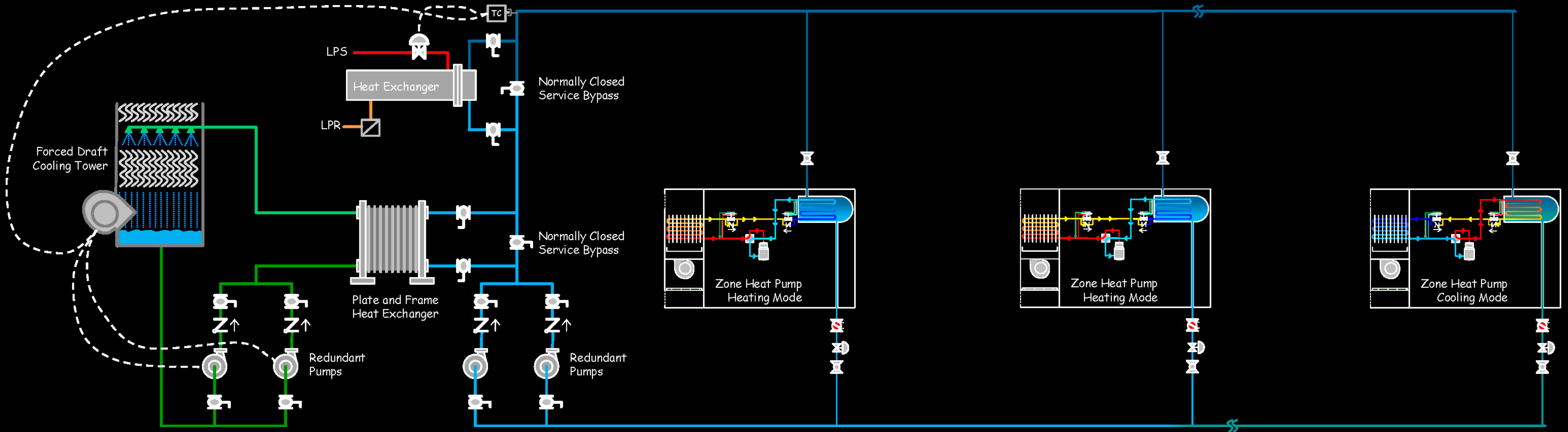
Loads that can Use Low Grade Heat

Considering a Water Source Heat Pump Loop



Water Source Heat Pump Loop
2022-11-16
DS

Thinking Through How It Works



Water Source Heat Pump Loop
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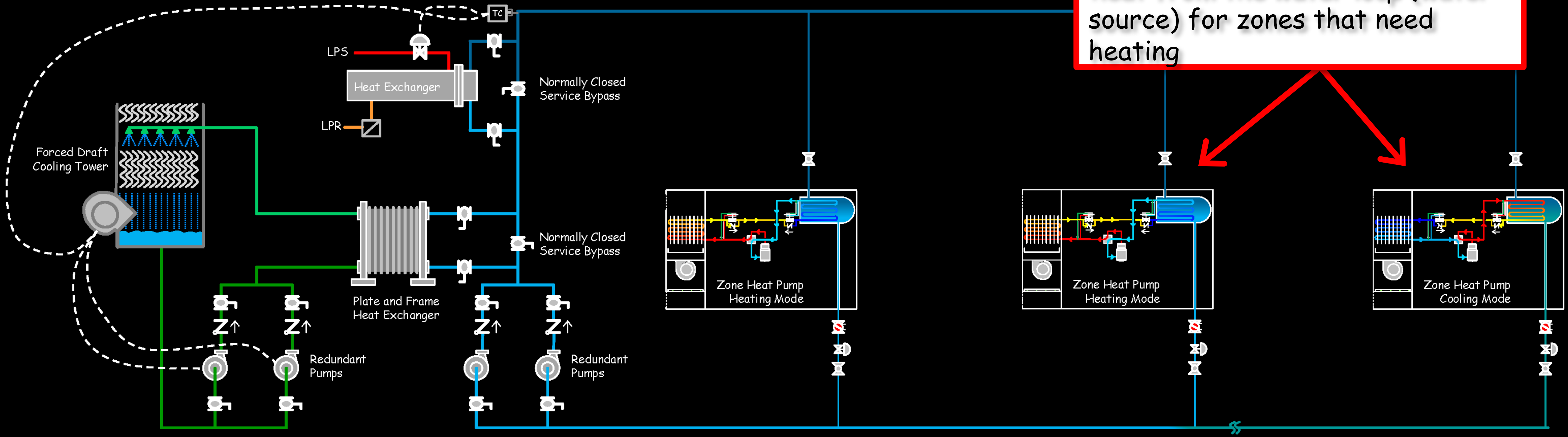

Heat pumps reject heat to the water loop (air source) for zones that need cooling and extract heat from the water loop (water source) for zones that need heating

Water Source Heat Pump Loop
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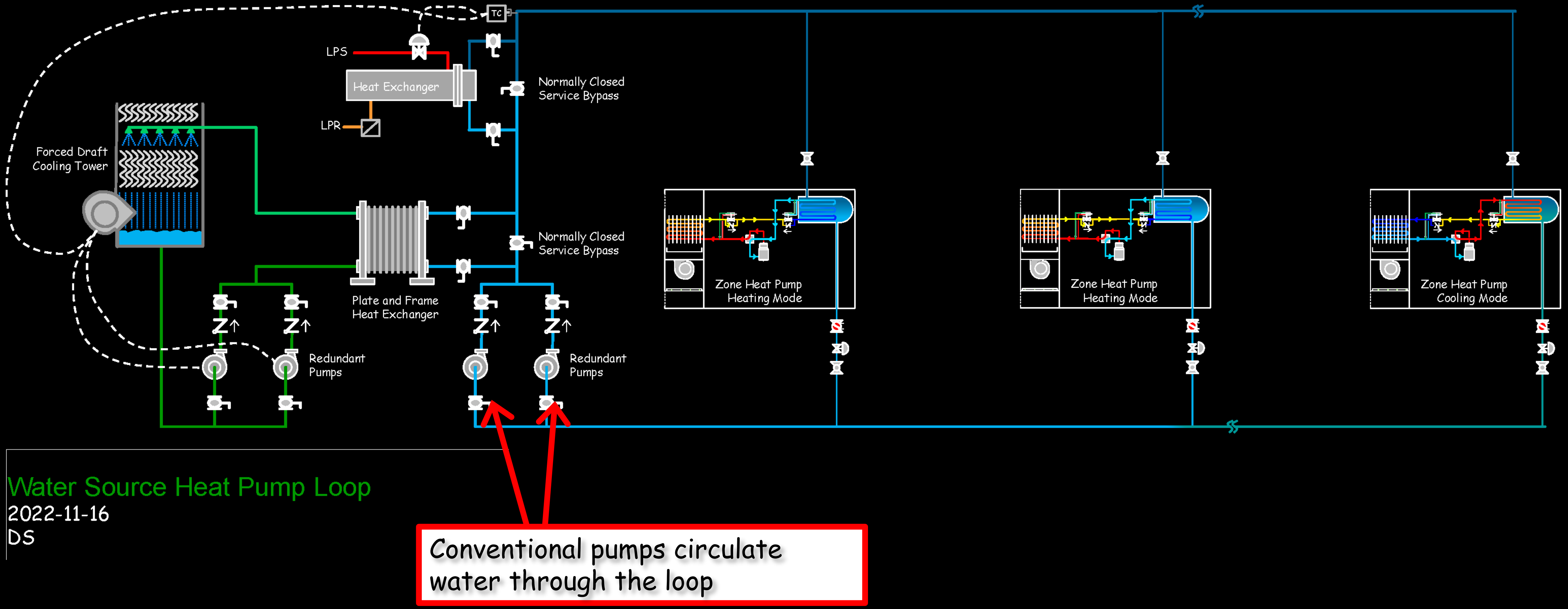
Thinking Through How It Works



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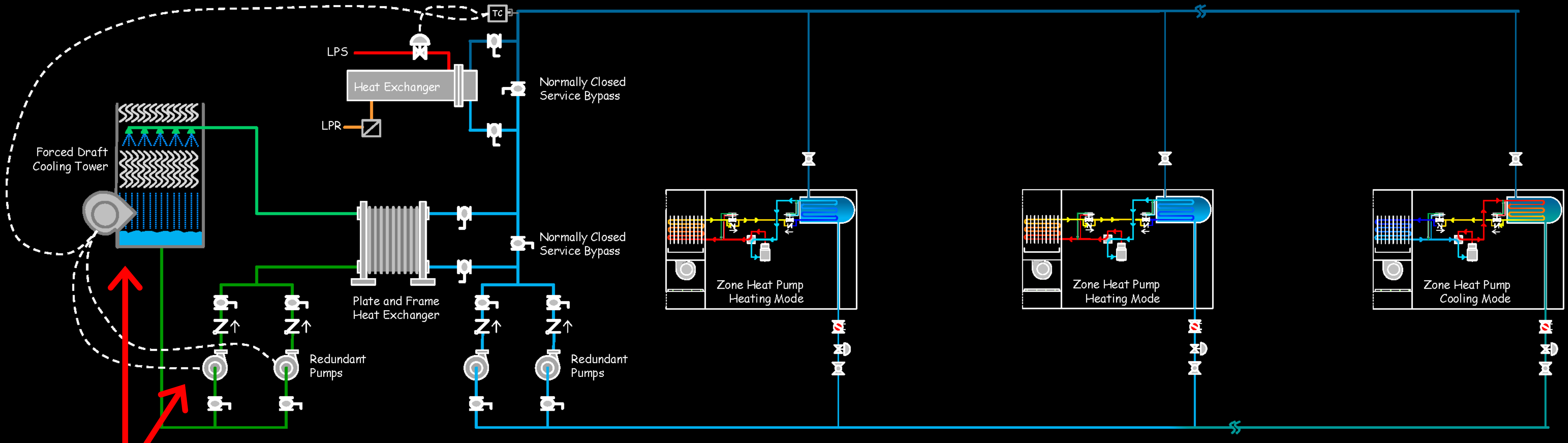
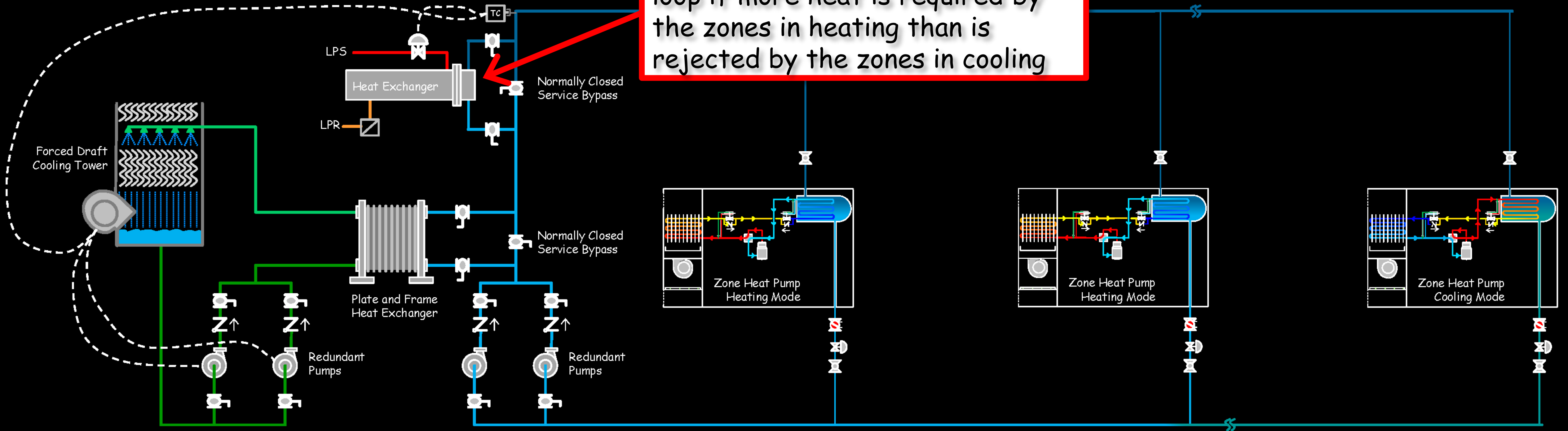


An open loop pumping circuit with a cooling tower provides a way to reject heat to atmosphere if more heat is being rejected by the zones in cooling than is needed by the heating zones in heating

Thinking Through How It Works

A steam to water heat exchanger provides a way to add heat to the loop if more heat is required by the zones in heating than is rejected by the zones in cooling



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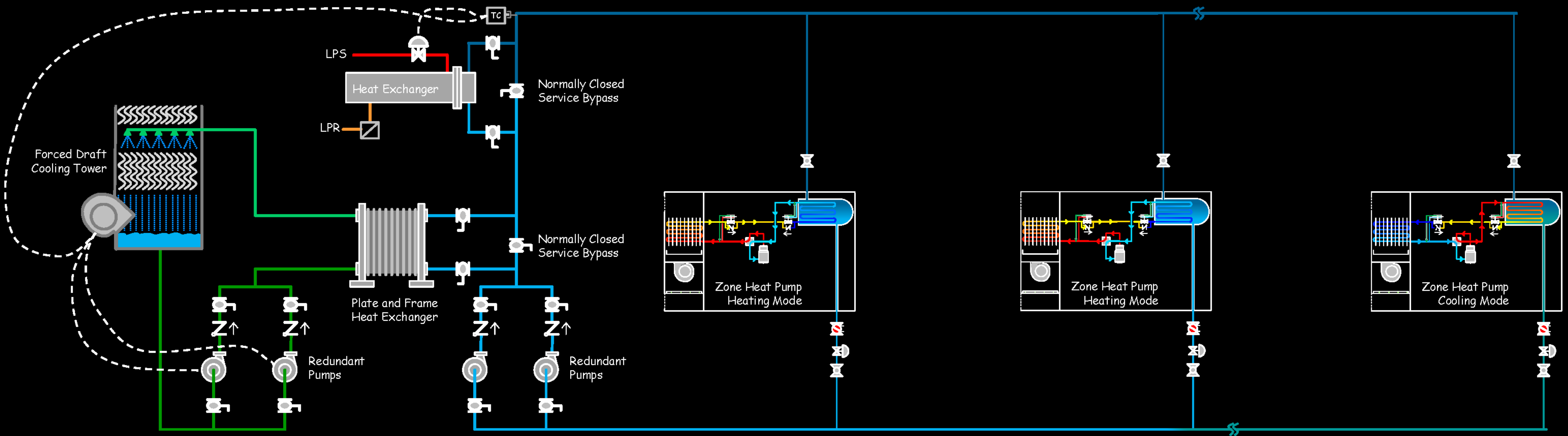
A Question For You

https://tinyurl.com/HeatPumpD3WSLoopQ1



Water Source Heat Pump Loop
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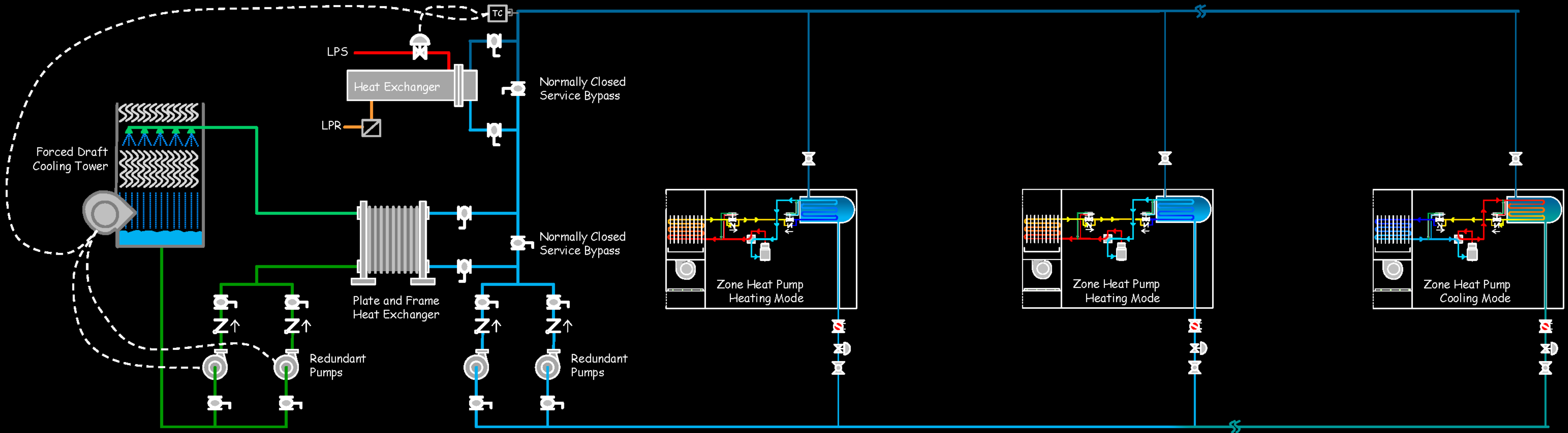
Perfection; Heat Rejected = Heat Needed



Water Source Heat Pump Loop
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There Are A Lot of Ways to Do This

$$N_{Config_{Sys}} = \left[\left(\sum_{All} HVAC\ Engineers \right)^2 \times K_{Climate} \times K_{BuildingType} \right] + \frac{\partial Y_{Earth-Moon}}{\partial Z_{Sun-Saturn}}$$

Where:

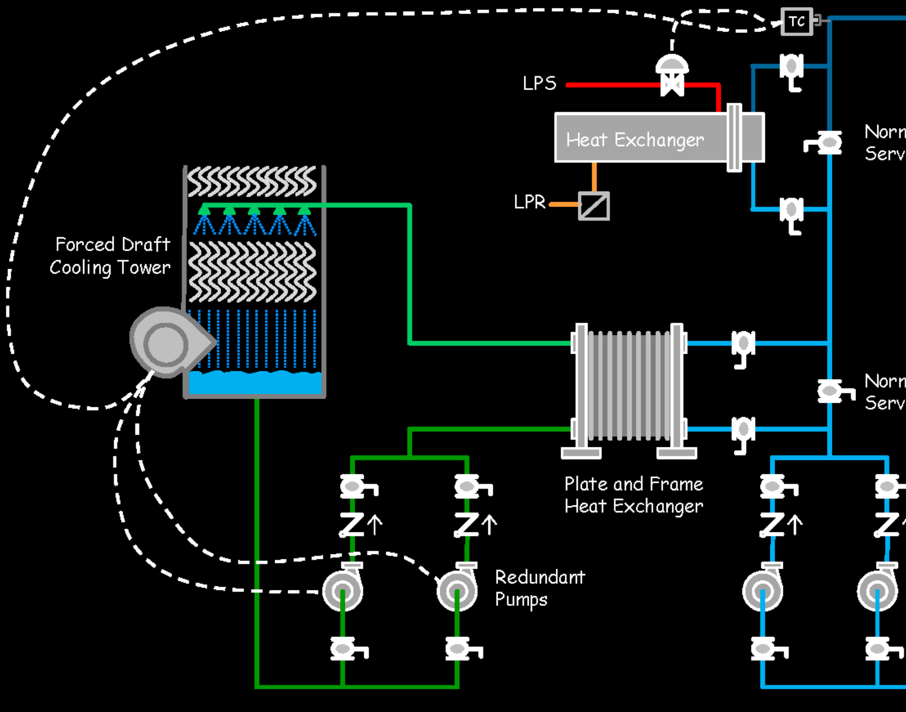
$N_{Config_{Sys}}$ = The number of potential HVAC system configurations

$\sum_{All} HVAC\ Engineers$ = The number of HVAC engineers

$K_{Climate}$ = Climate coefficient; adjusts for the climate type at the system location

$K_{BuildingType}$ = Building type coefficient; adjusts for the building type that the system serves

$\frac{\partial Y_{Earth-Moon}}{\partial Z_{Sun-Saturn}}$ = Planetary alignment compensation factor



Water Source Heat Pump Loop
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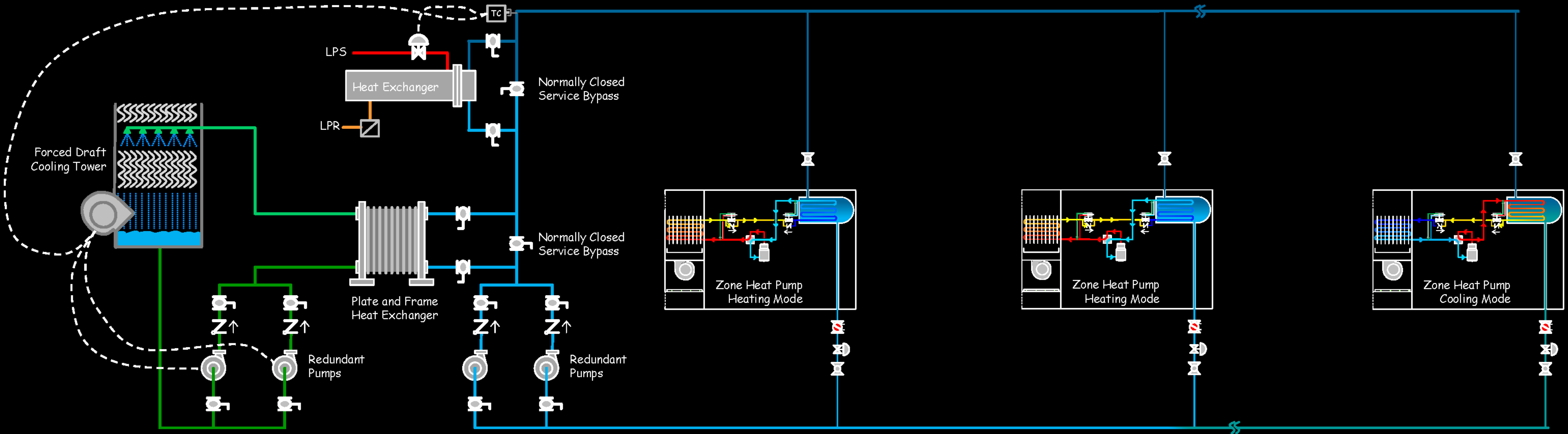
Atmospheric Sink and Fossil Fuel Source



Water Source Heat Pump Loop
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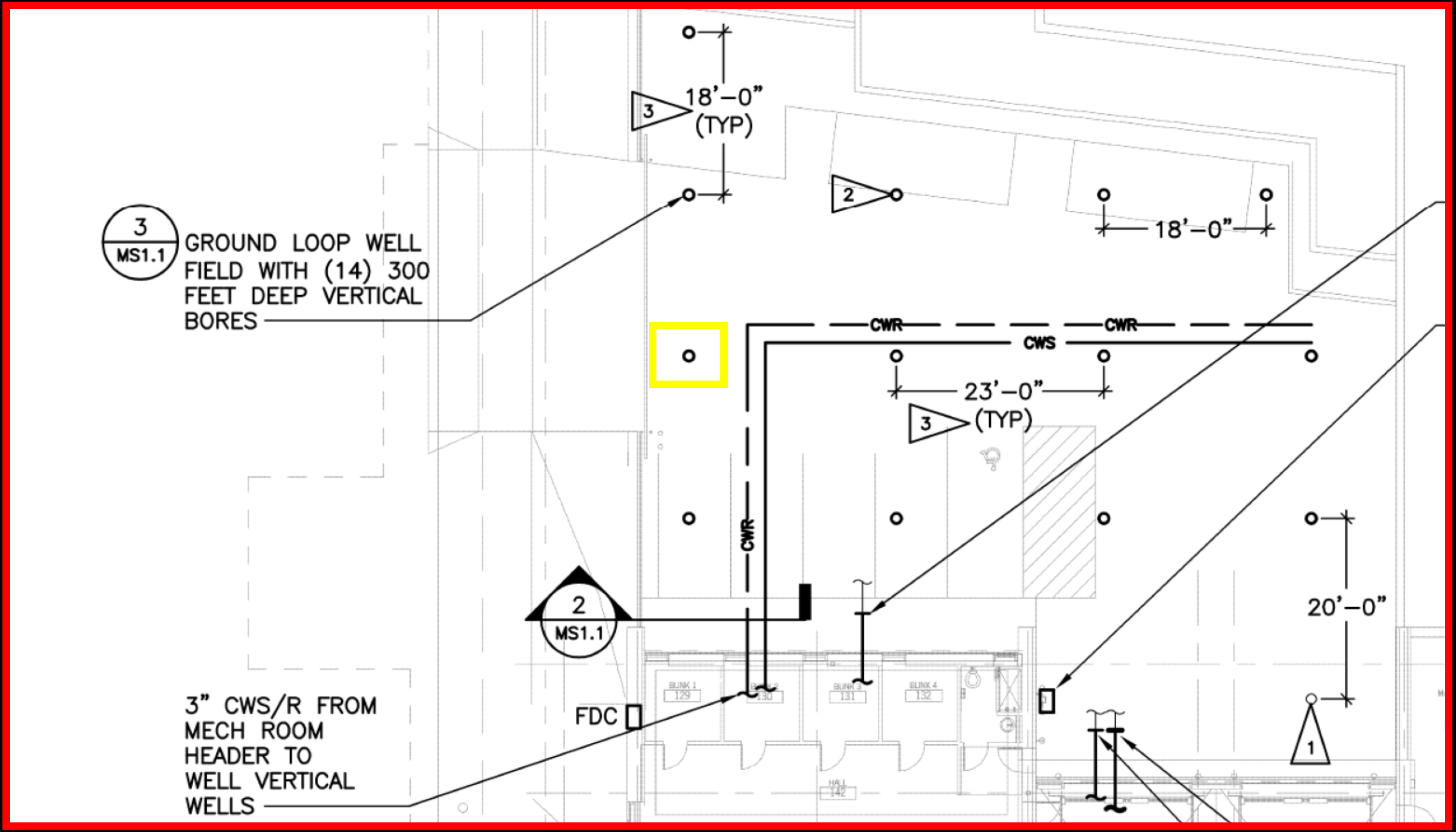
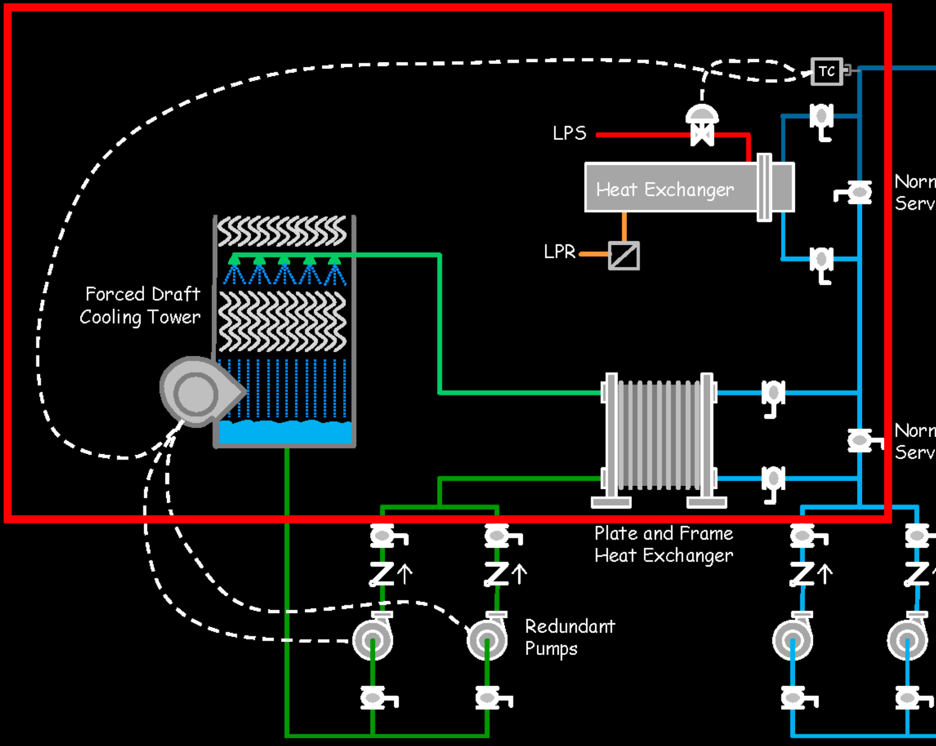
Ground Water Sink and Source





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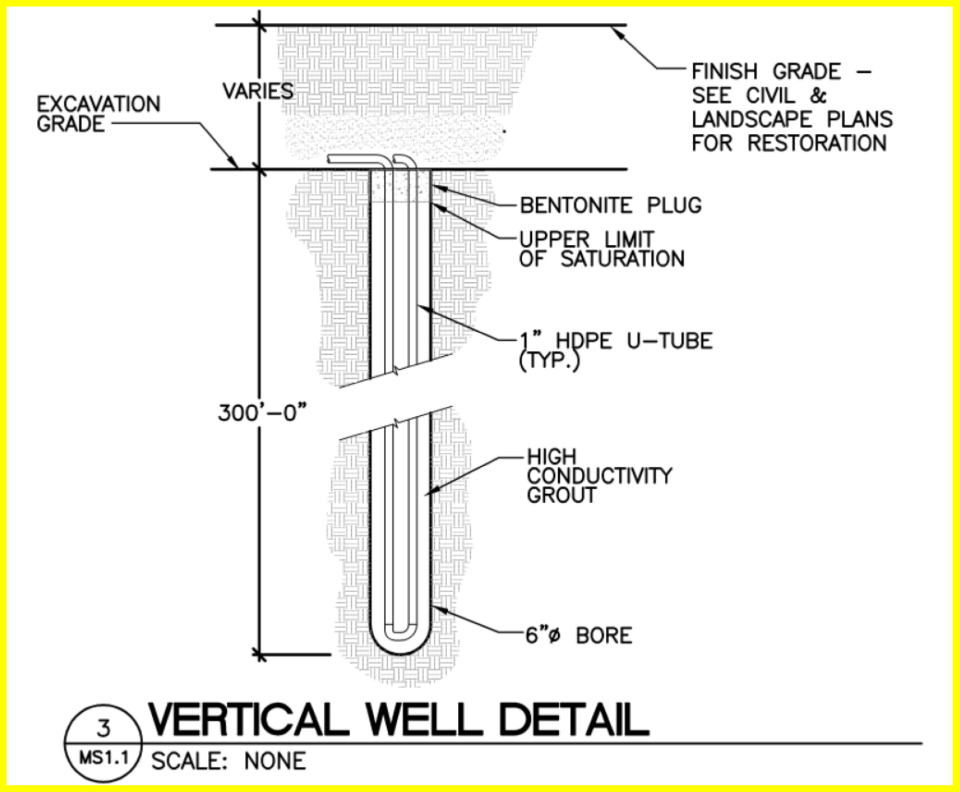
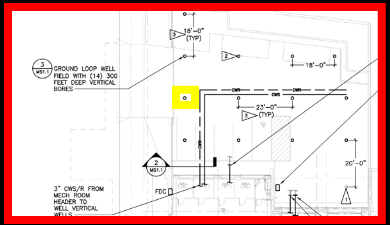
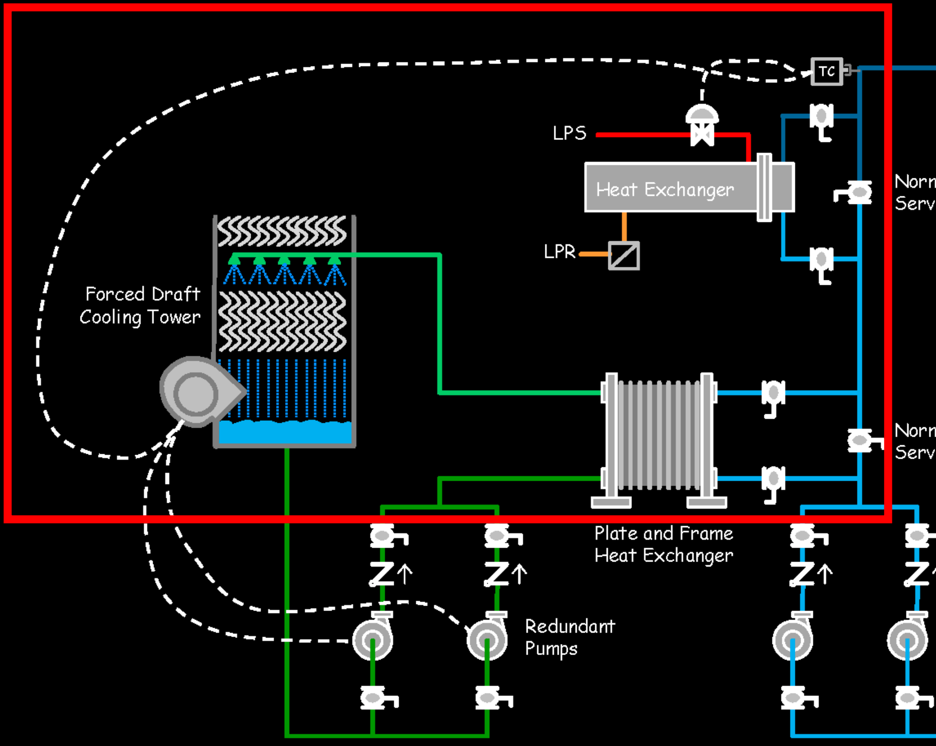
Ground Water Sink and Source







Water Source Heat Pump Loop
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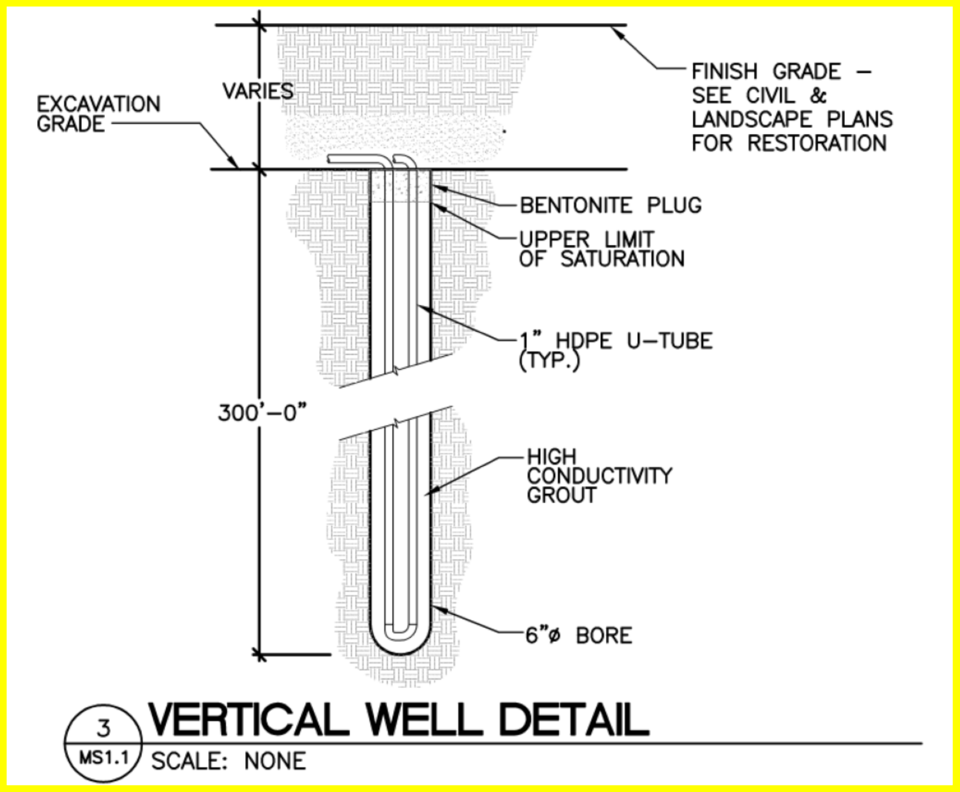
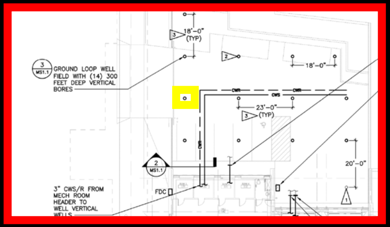
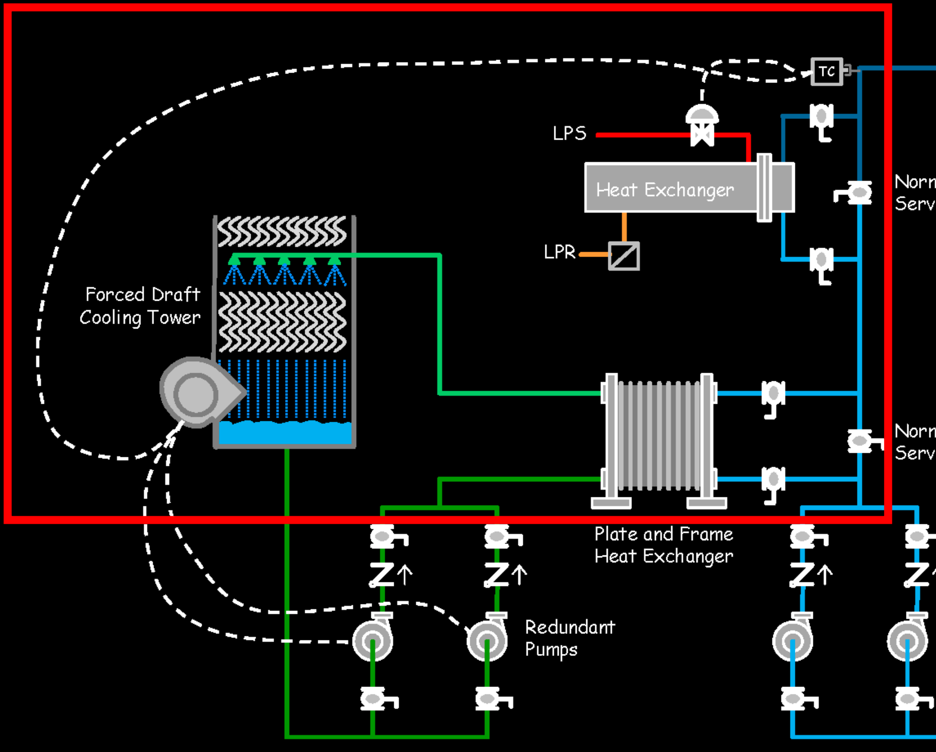
Ground Water Sink and Source







Water Source Heat Pump Loop
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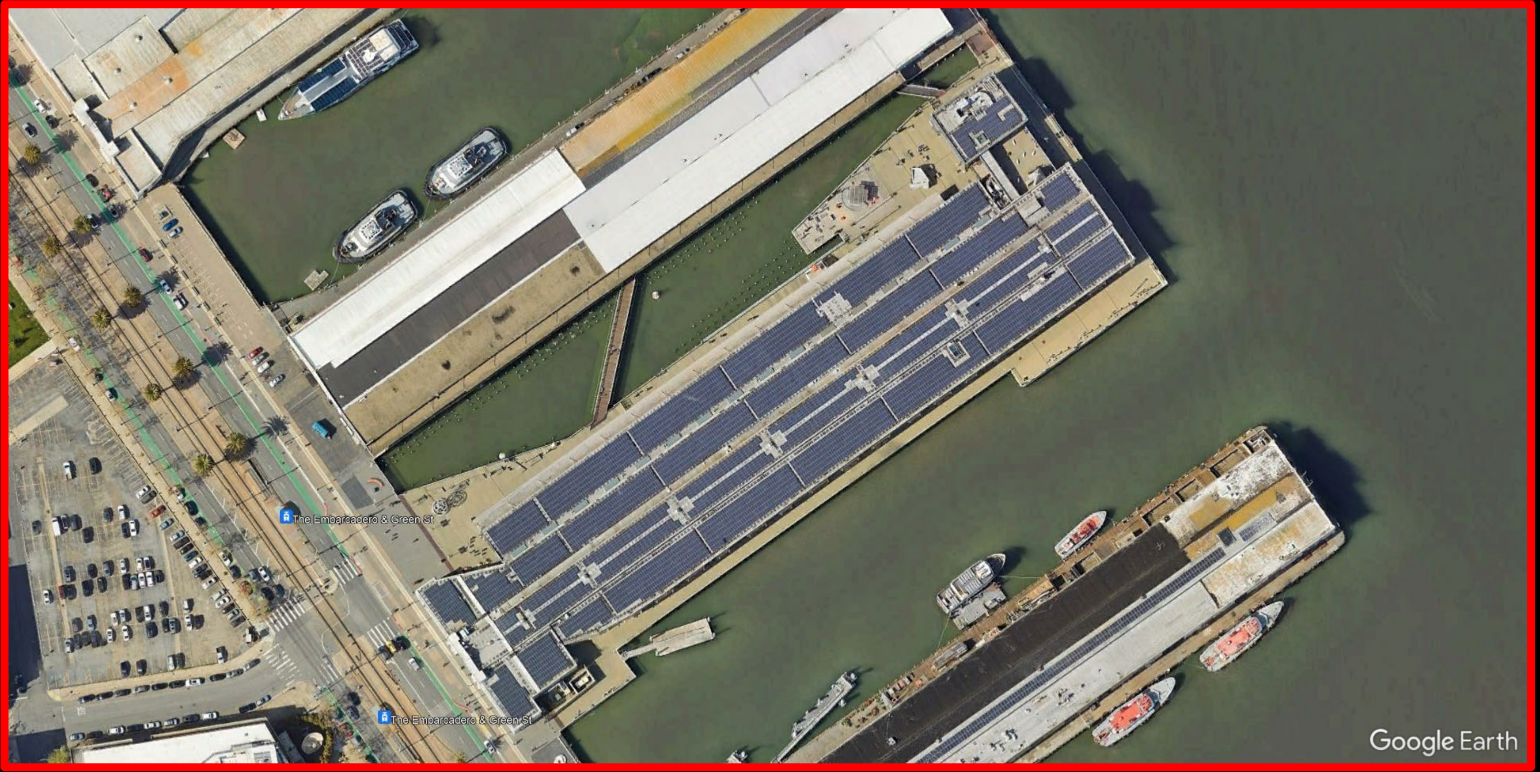
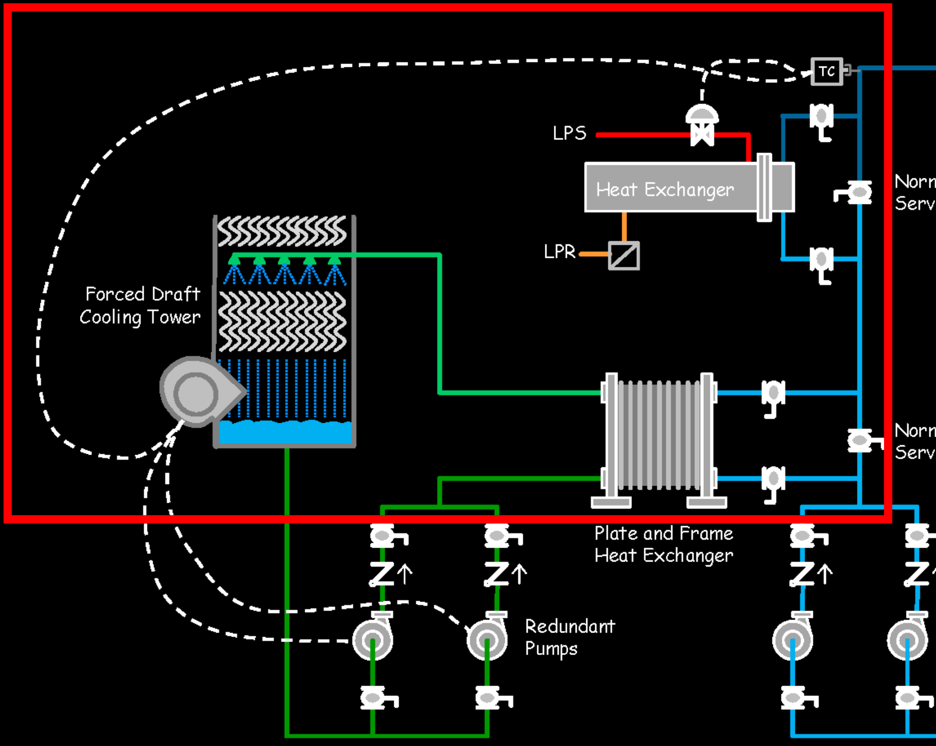
A Large Body of Water Sink and Source





Water Source Heat Pump Loop
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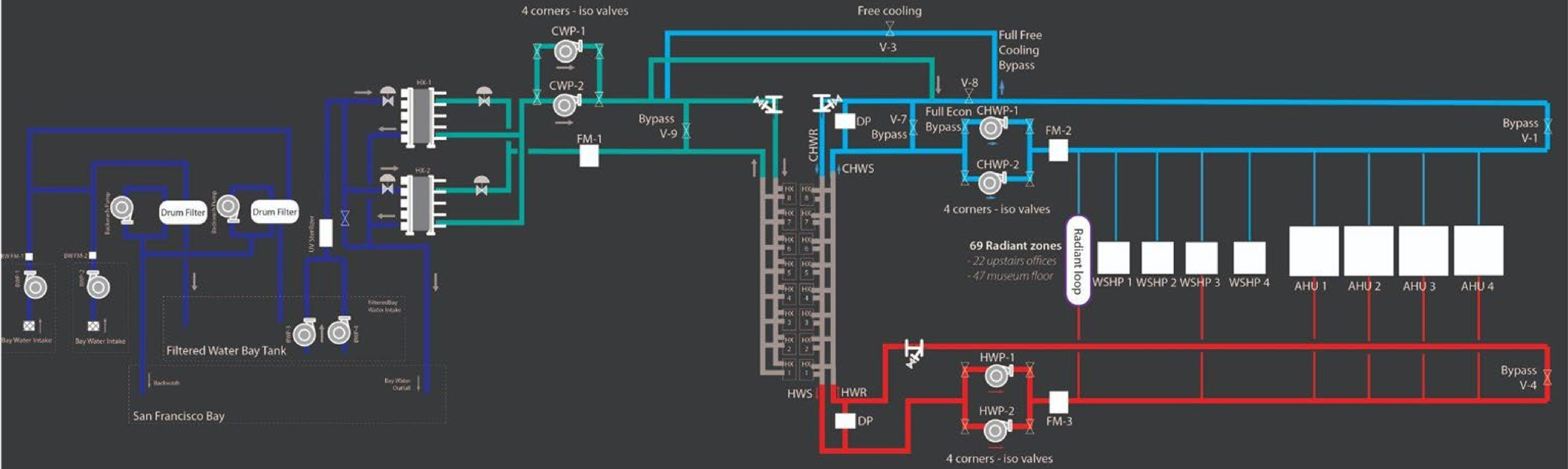
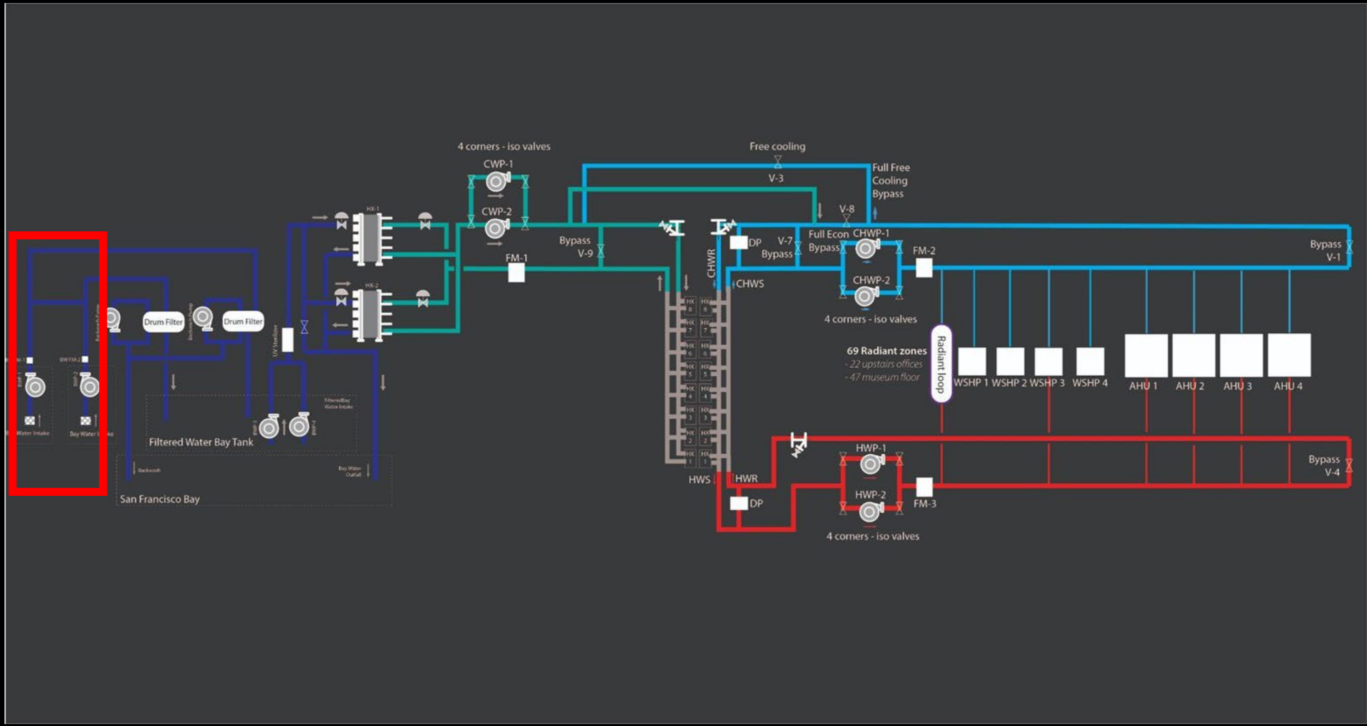
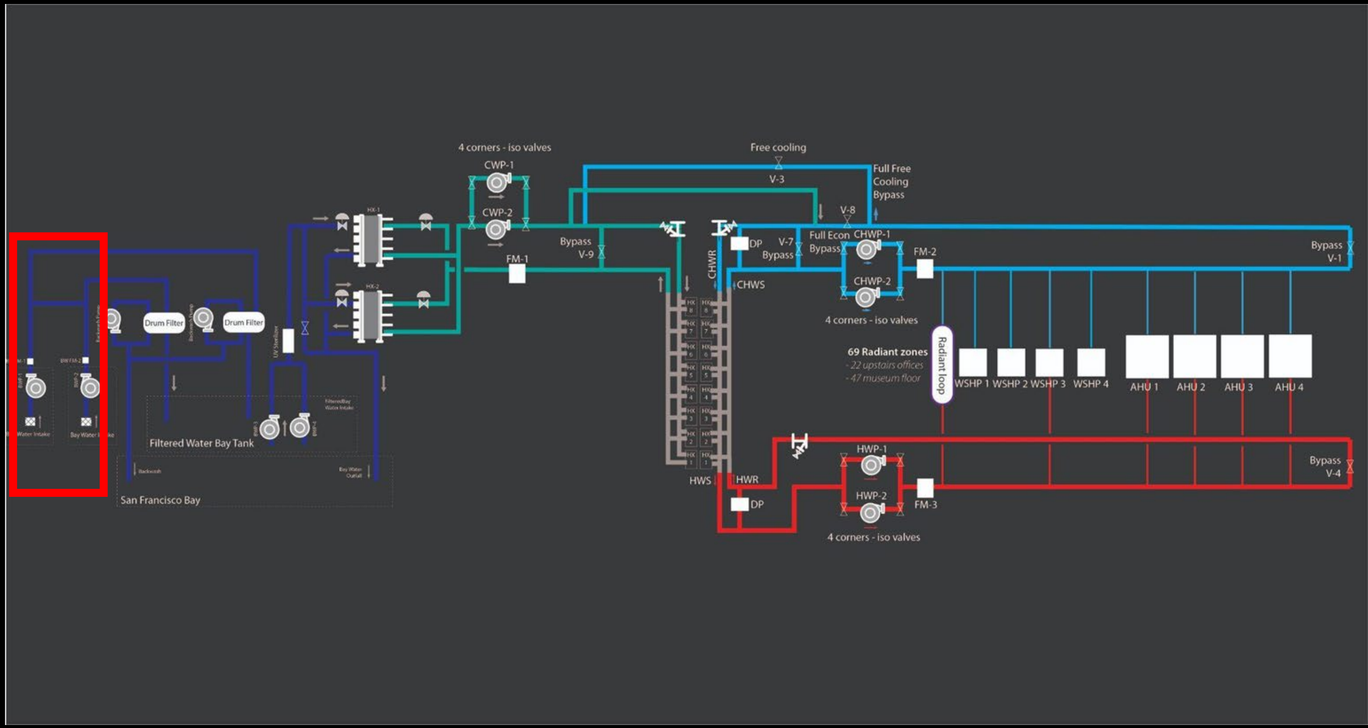
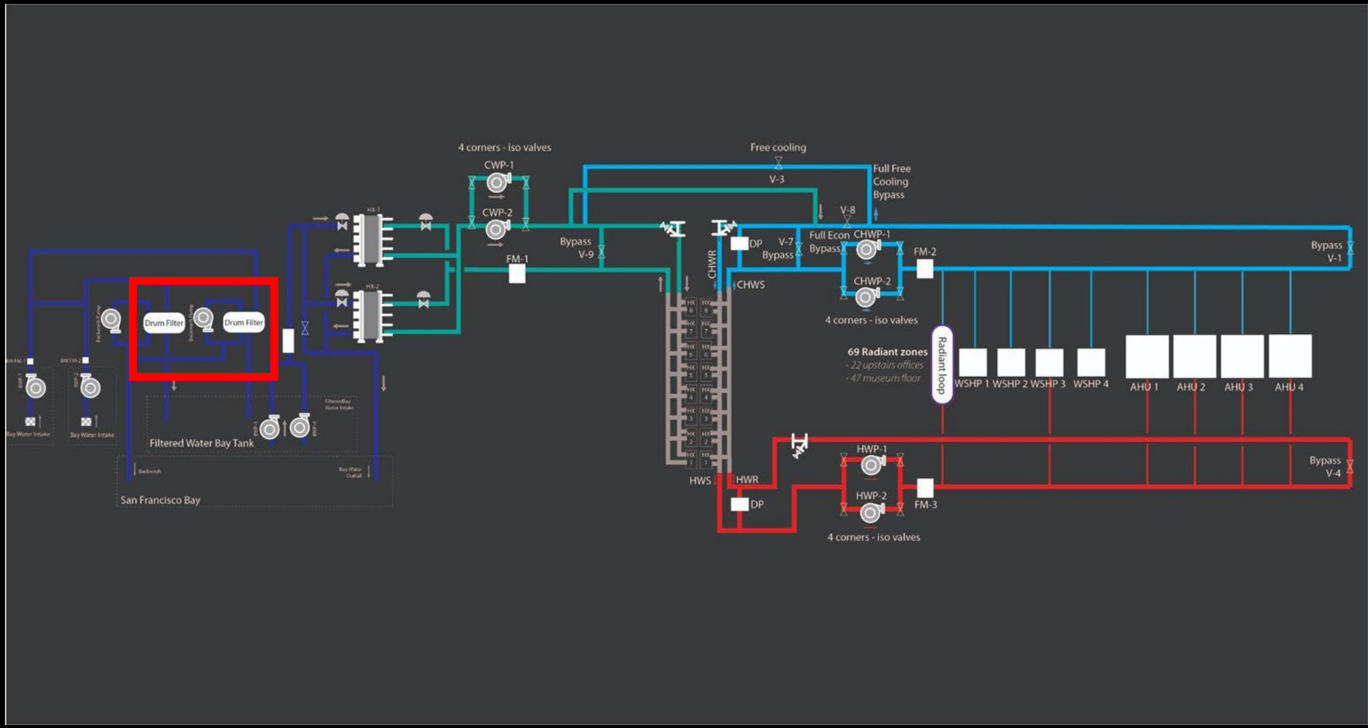

4 corners - iso valves
CWP-1
CWP-2
Free cooling
V-3
Full Free
Cooling
Bypass
V-8
Bypass
V-9
FM-1
DP
V-7
Bypass
Full Econ
Bypass
CHWP-1
CHWP-2
FM-2
Bypass
V-1
CHWR
CHWS
4 corners - iso valves
Drum Filter
Drum Filter
69 Radiant zones
- 22 upstairs offices
- 47 museum floor
Radiant loop
WSHP 1
WSHP 2
WSHP 3
WSHP 4
AHU 1
AHU 2
AHU 3
AHU 4
Filtered Water Bay Tank
San Francisco Bay
HWS
HWR
DP
HWP-1
HWP-2
FM-3
Bypass
V-4
4 corners - iso valves



Intake Screen



Pump Discharge


4 corners - iso valves
CWP-1
CWP-2
Drum Filter
Drum Filter
Filtered Water Bay Tank
San Francisco Bay
Bay Water Intake
Bay Water Intake
FM-1
Bypass
V-9
CHWR
CHWS
HWS
HWR
DP
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V-8
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AHU 4
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HWP-2
FM-3
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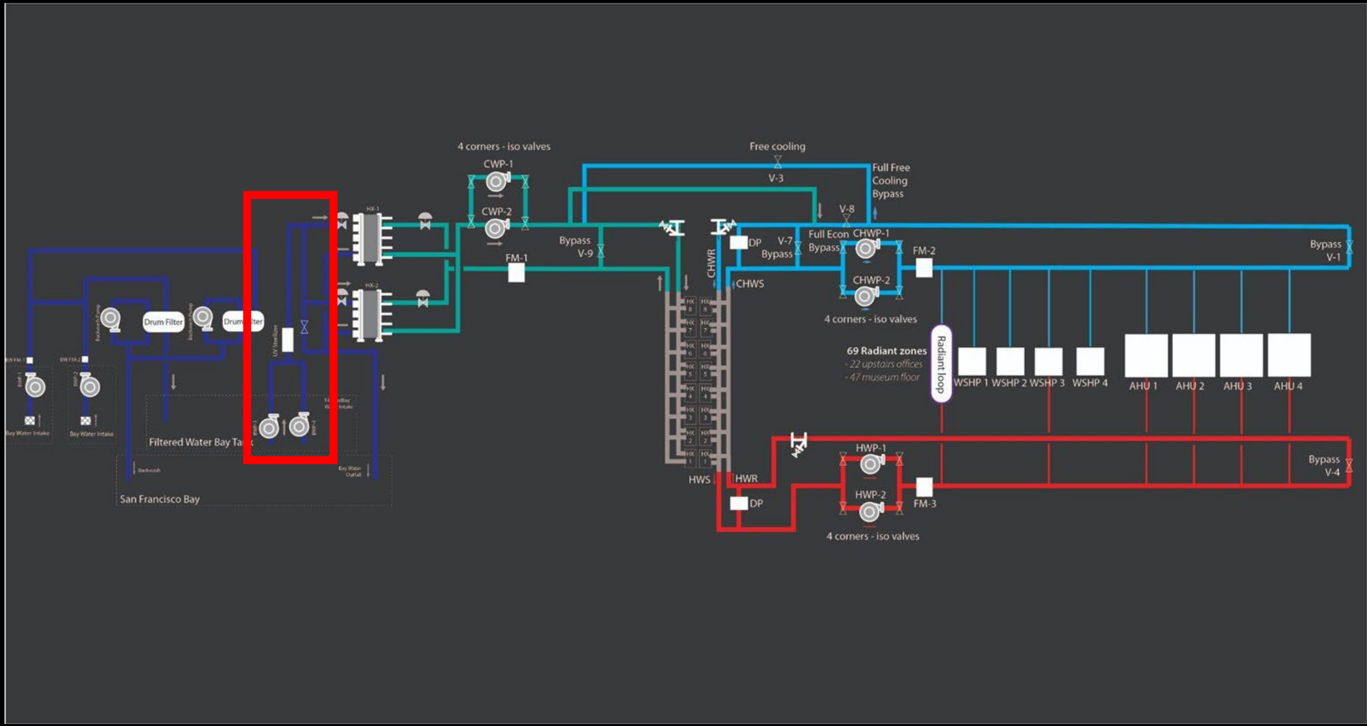
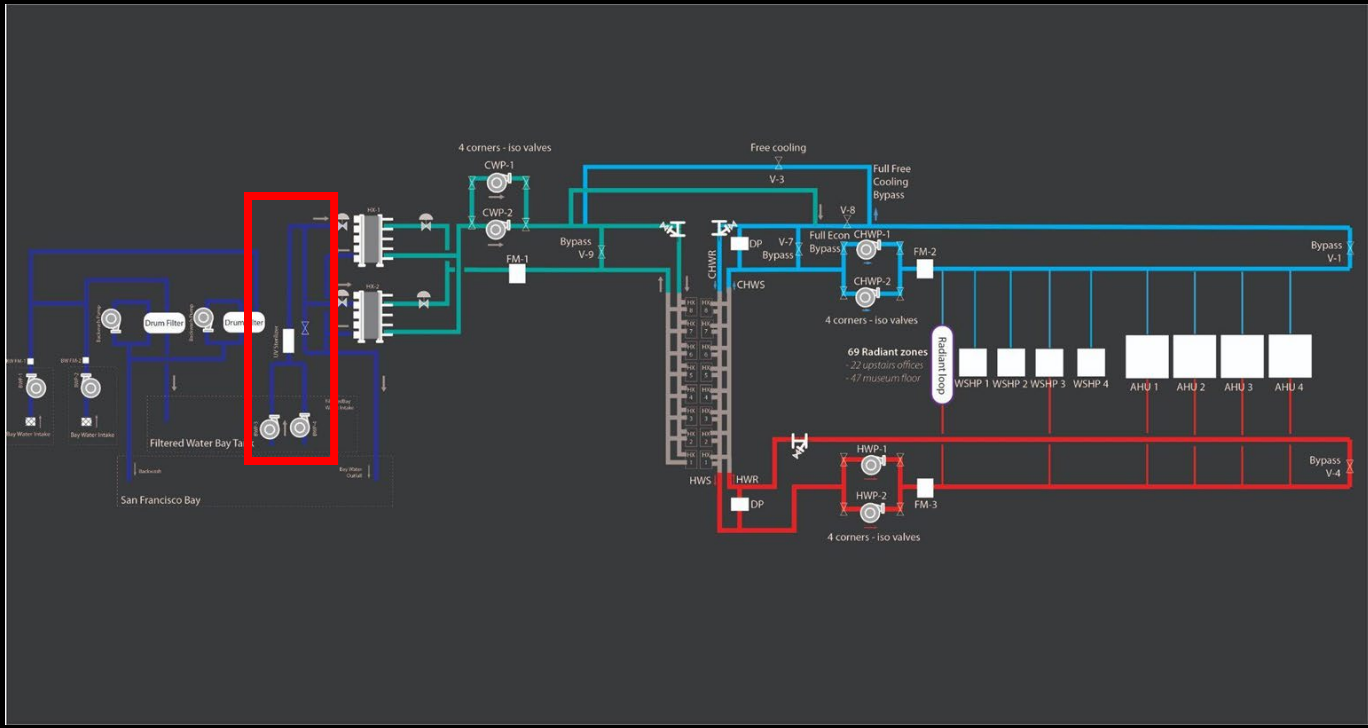
V-4

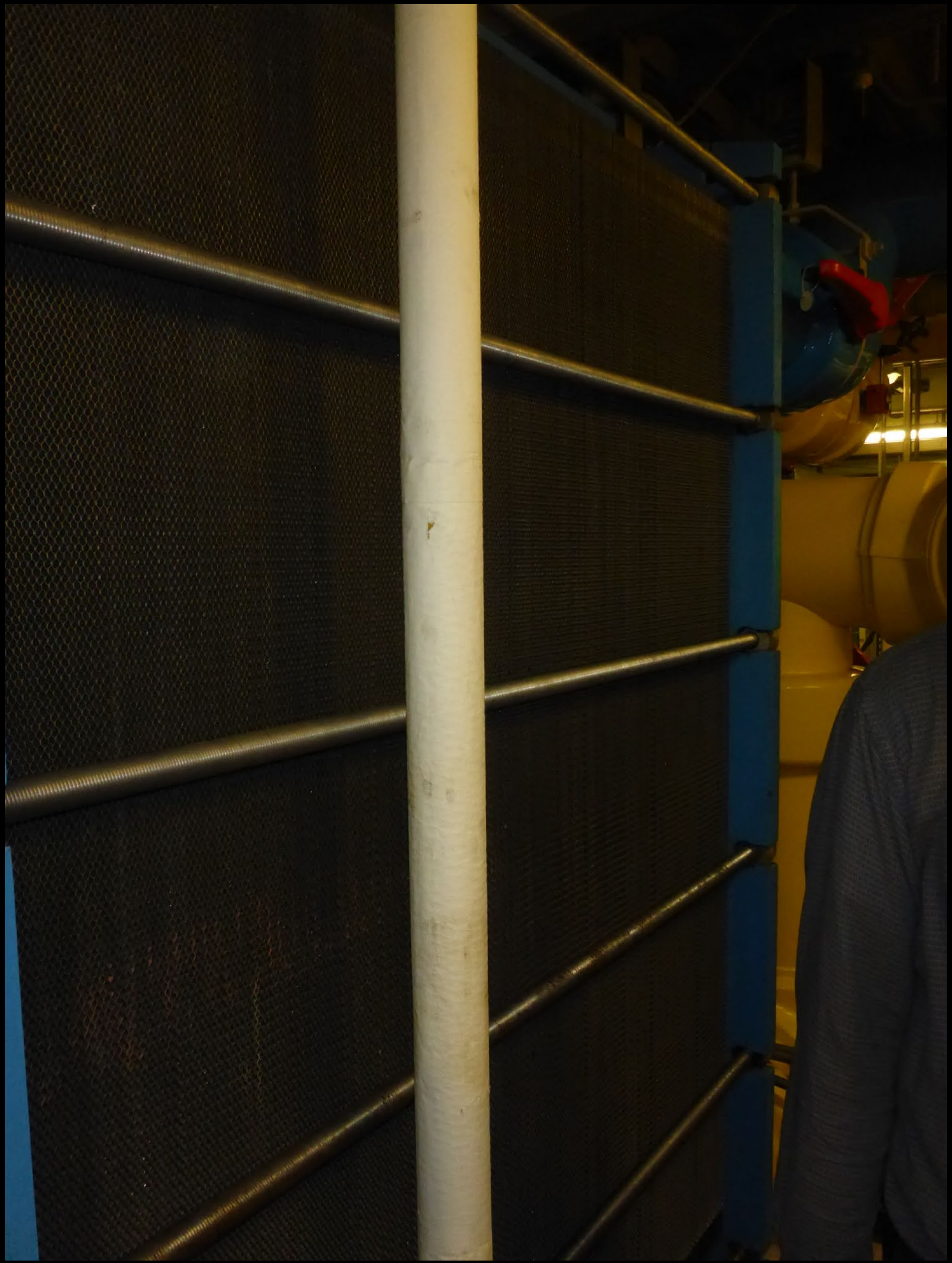
Drum Filter

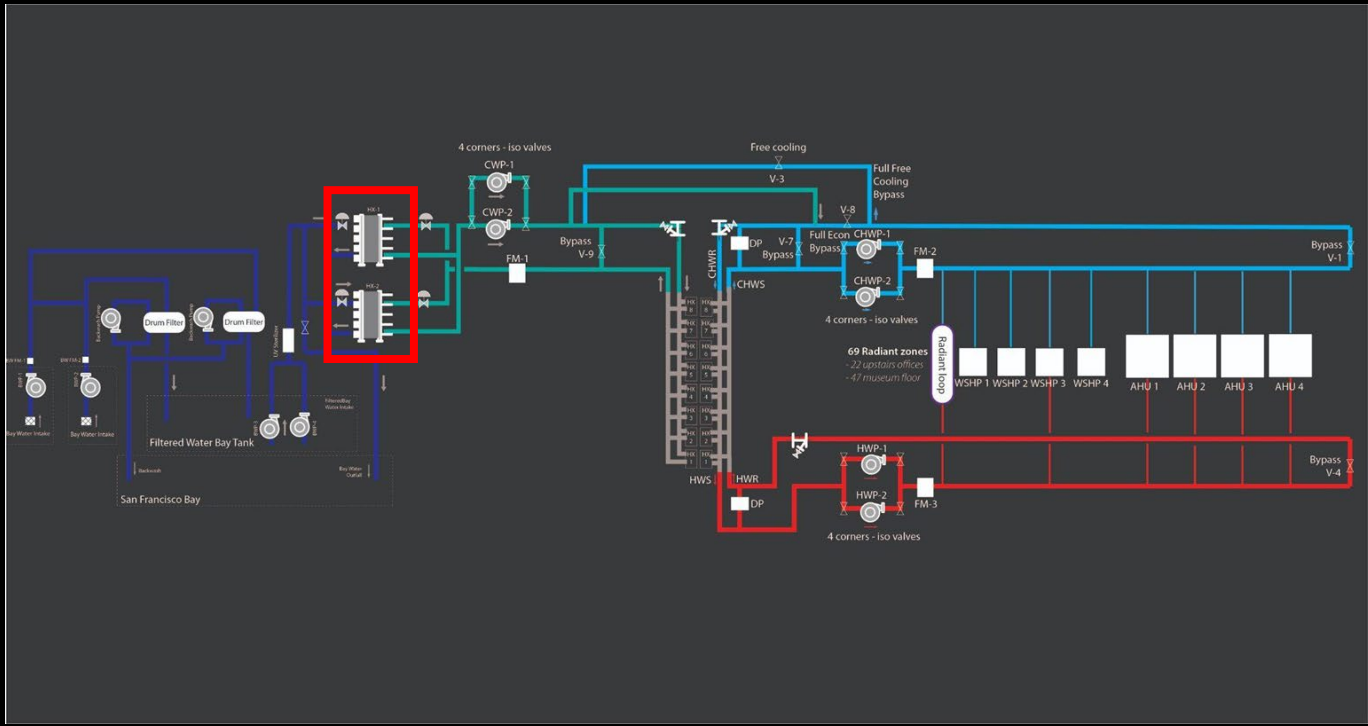


Filtered Water to Heat Exchanger

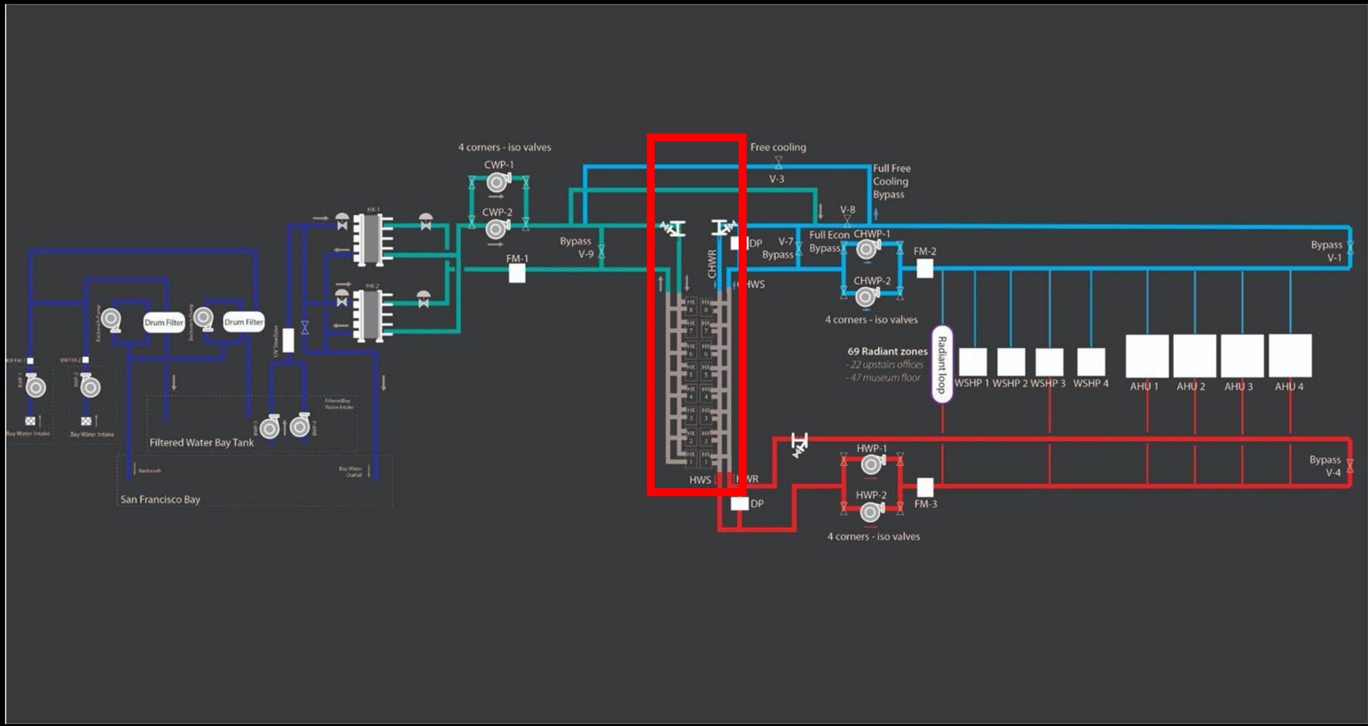


Filtered Water to Heat Exchanger





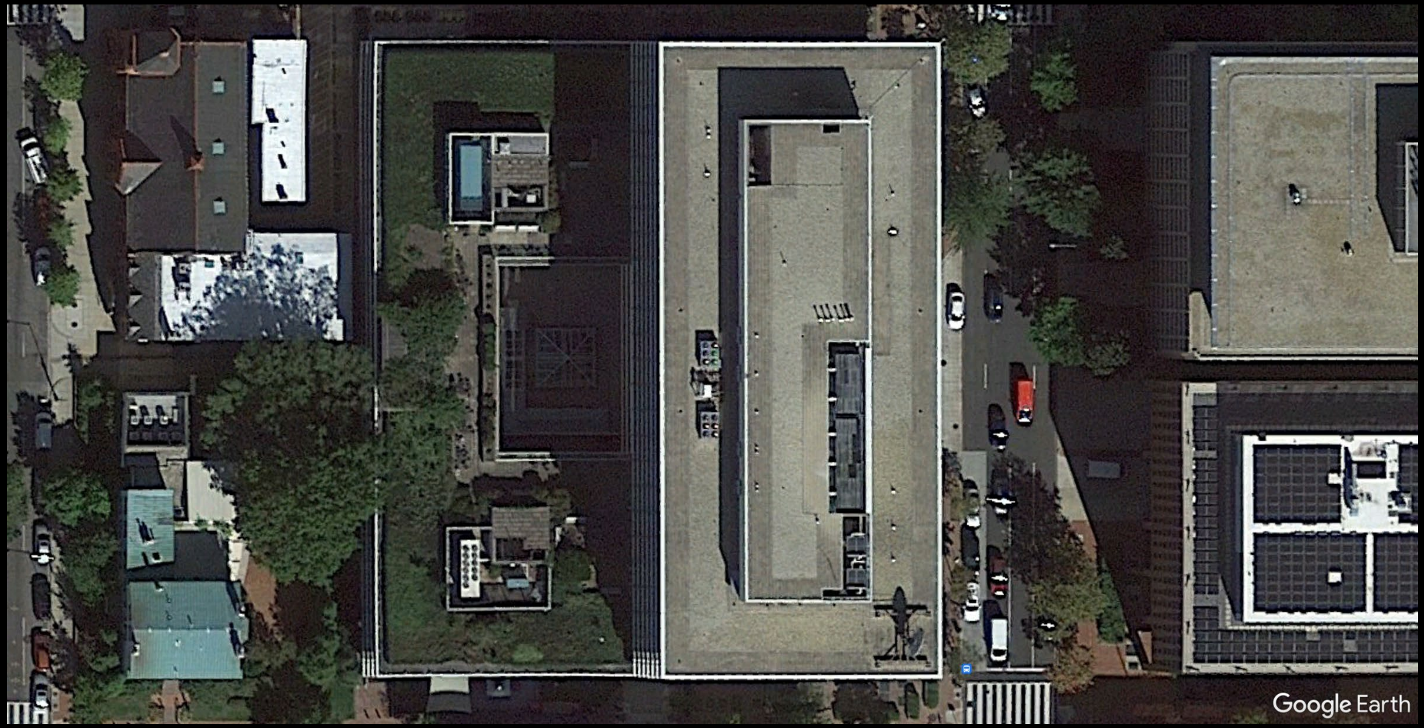
Filtered Water to Heat Exchanger

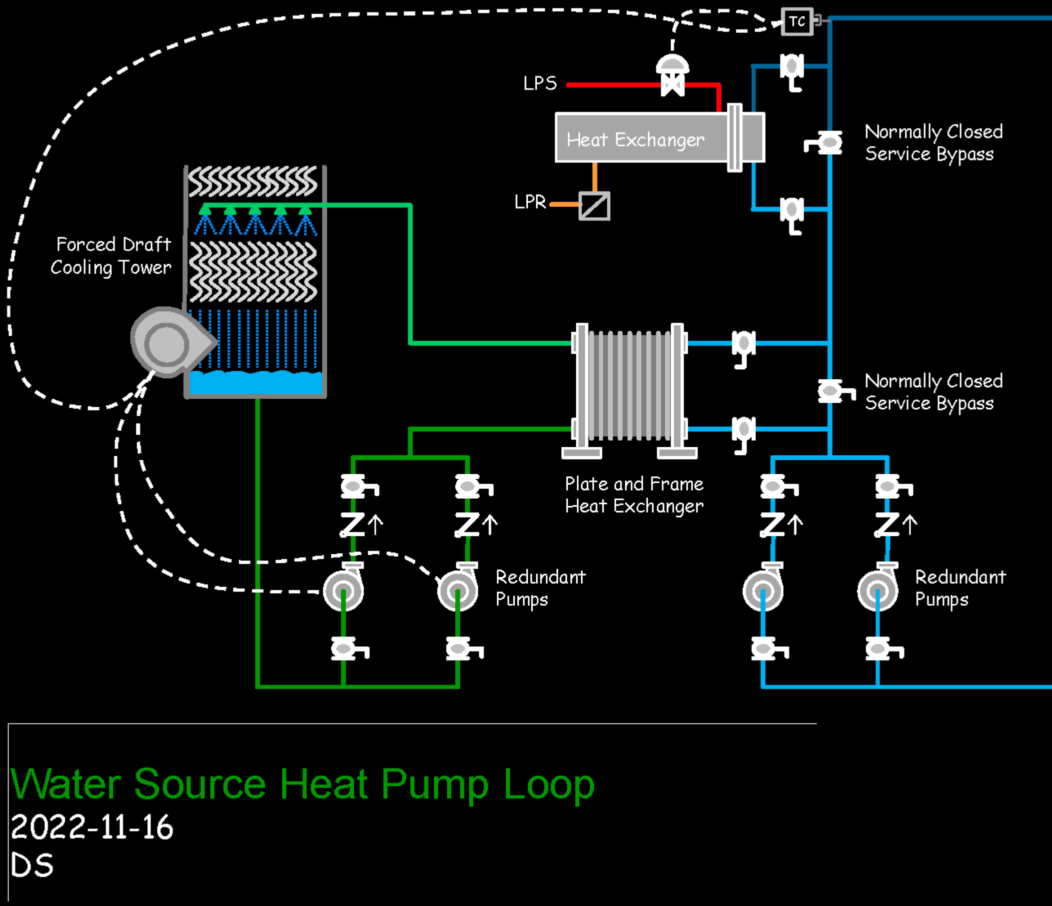


Closed Loop to the Heat Pump

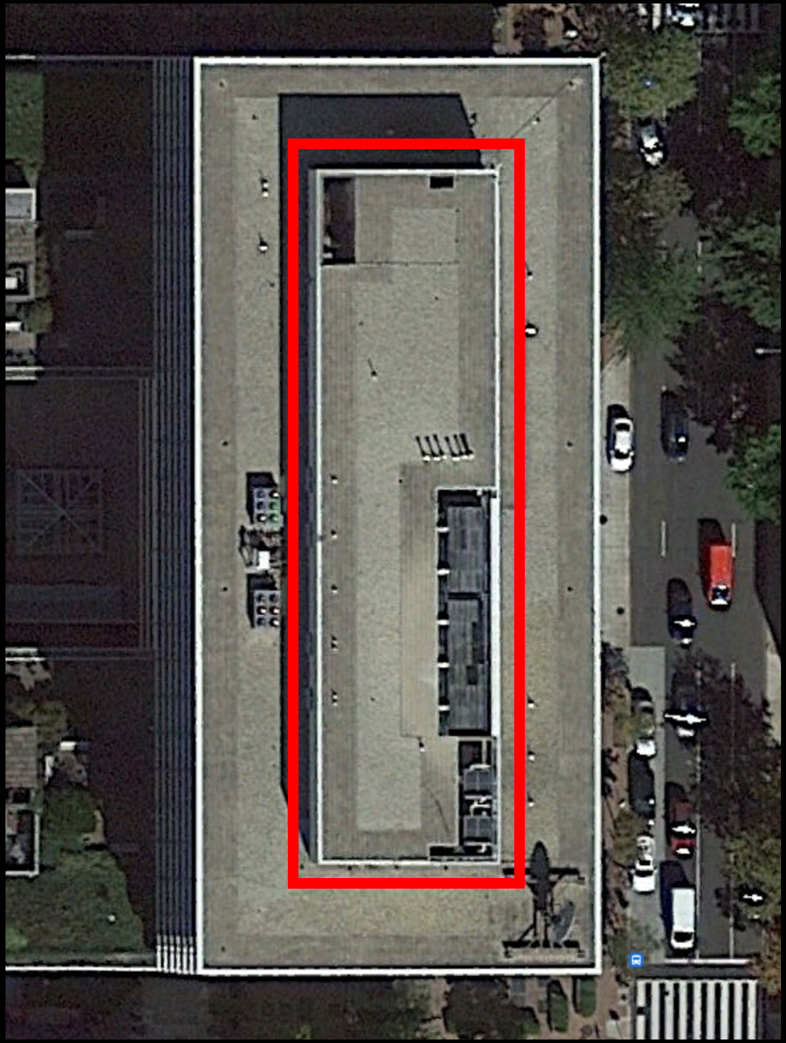
https://tinyurl.com/ExploratoriumSystem

Bottom Line; There Has to be Heat to Recover





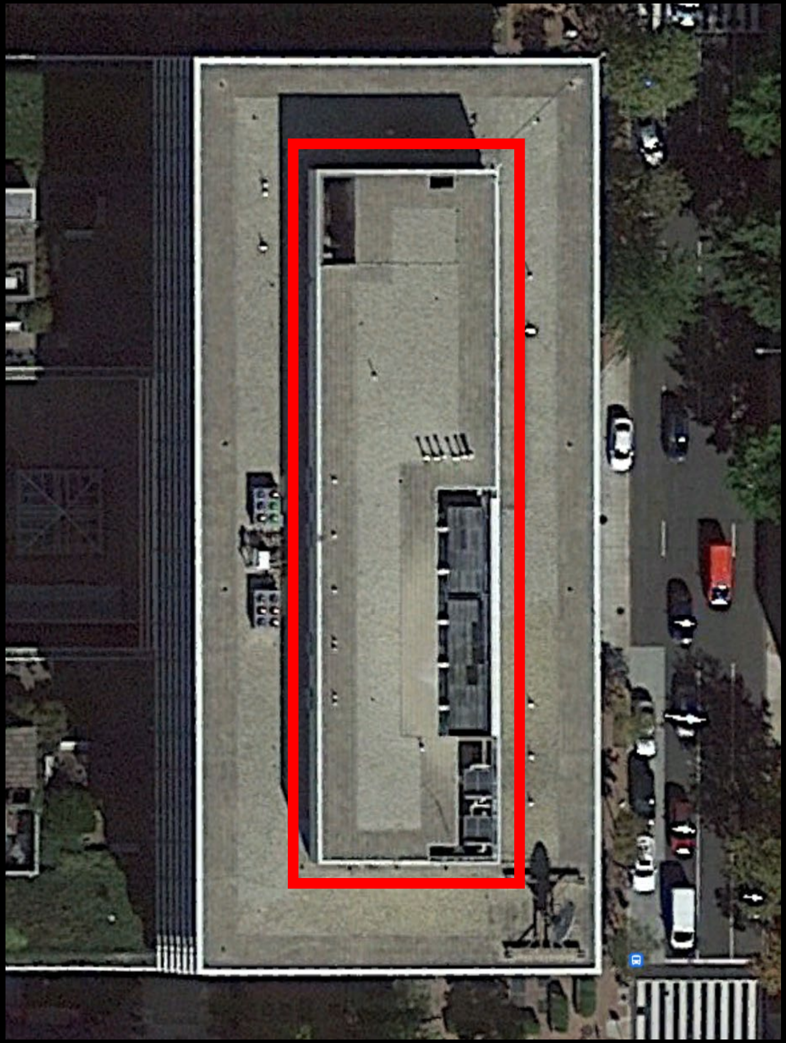
Consider This Washington DC Site



Water source heat pump loop serving the penthouse of a historic building

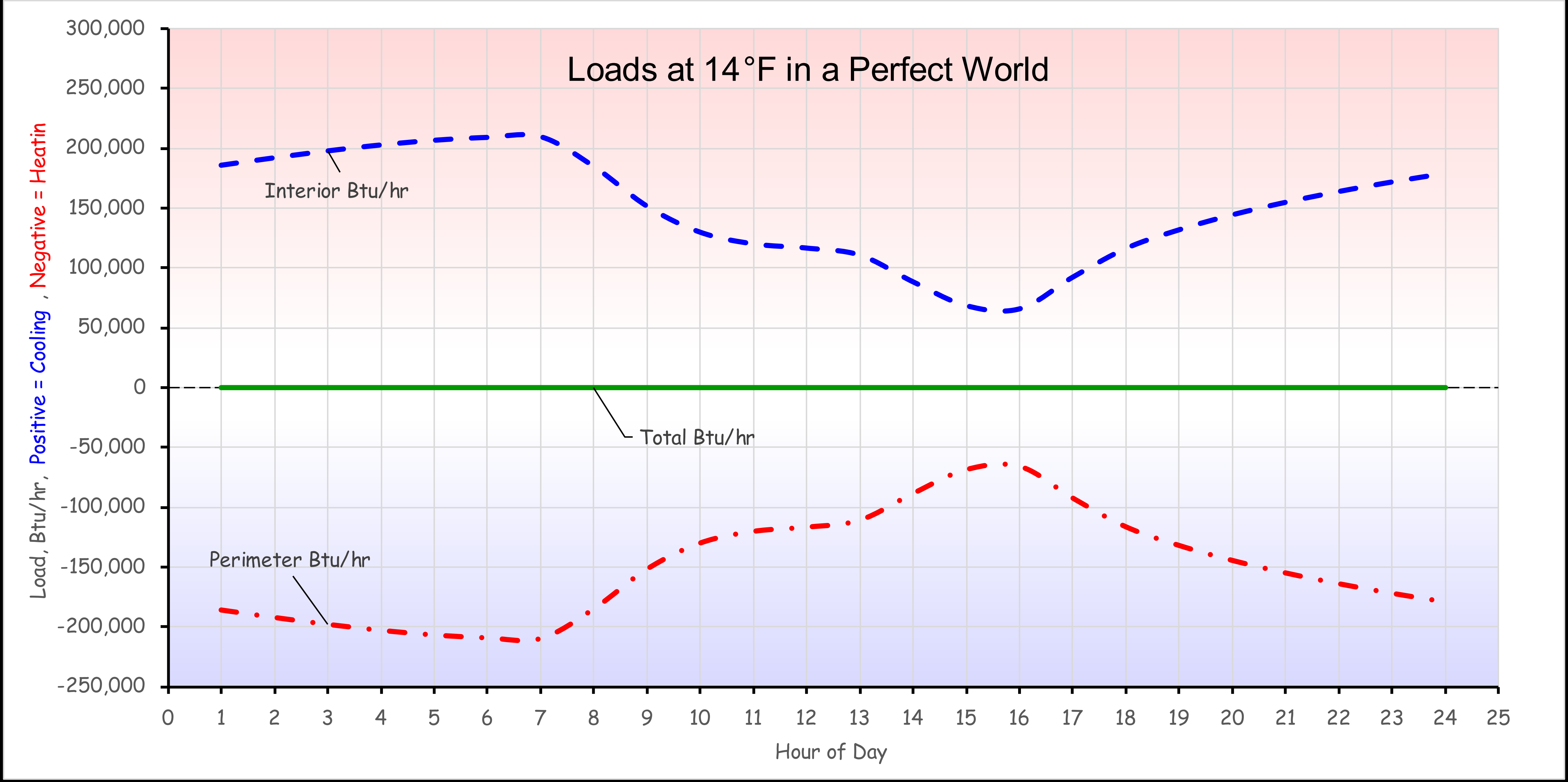
- Long, thin aspect ratio
- Large, single pane, double hung windows

Consider This Washington DC Site

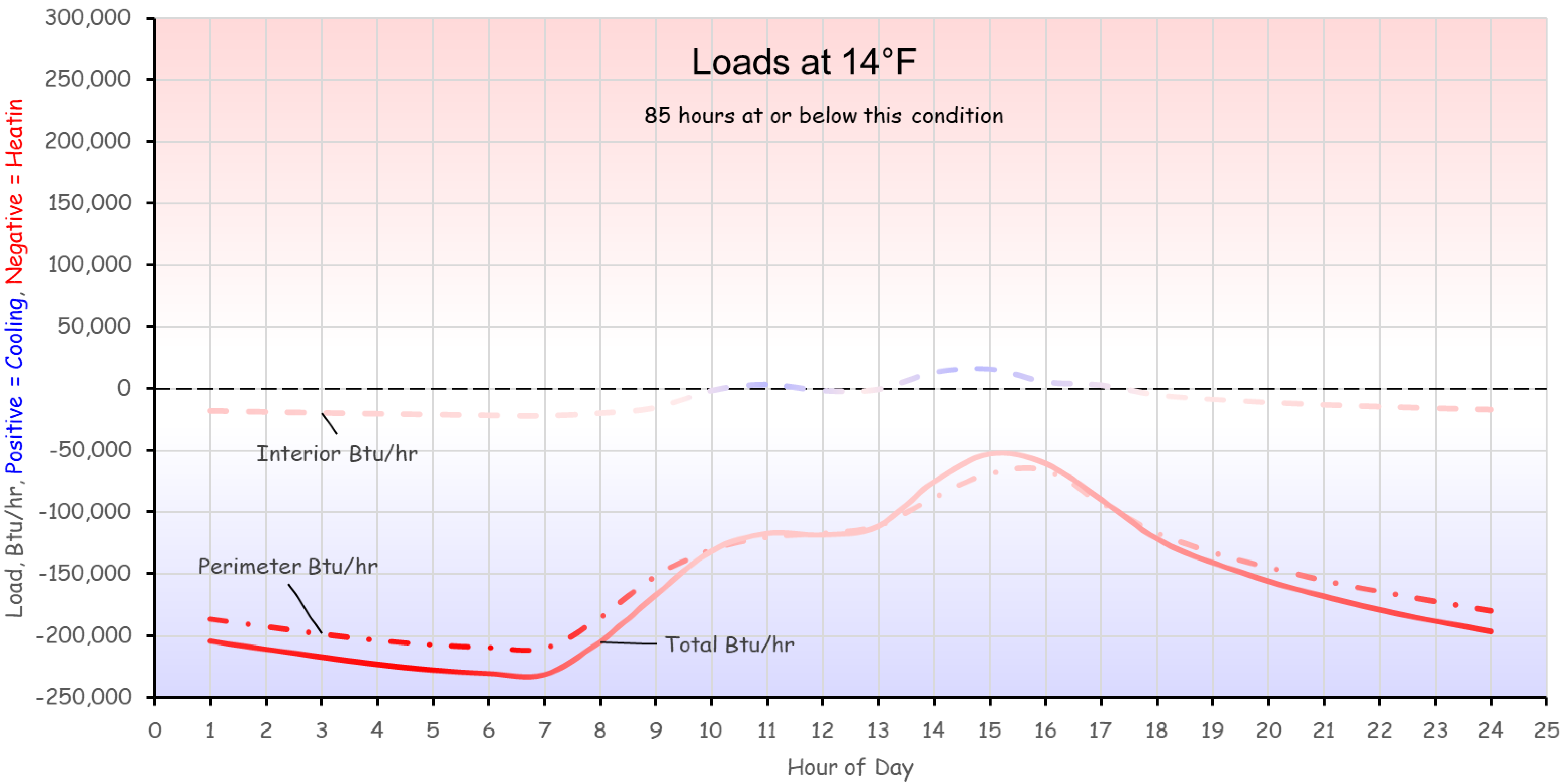


Open office concept

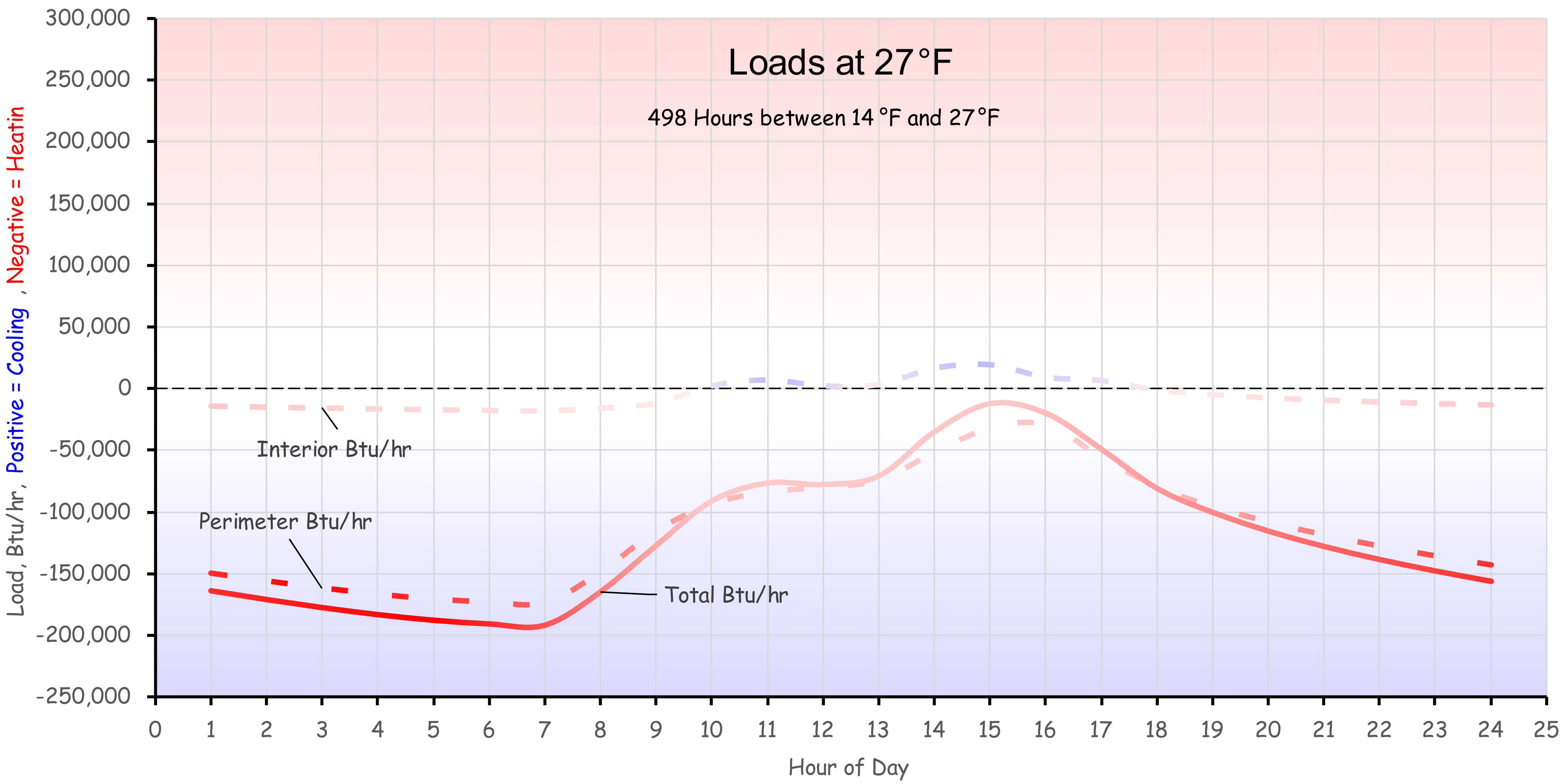
- Design intent is for flexible zoning to accommodate “churn”
- 2-3 enclosed conference spaces
- DOAS system provides ventilation to an under floor plenum
- Heat pumps located in the under floor plenum and ducted to outlets at the window sills



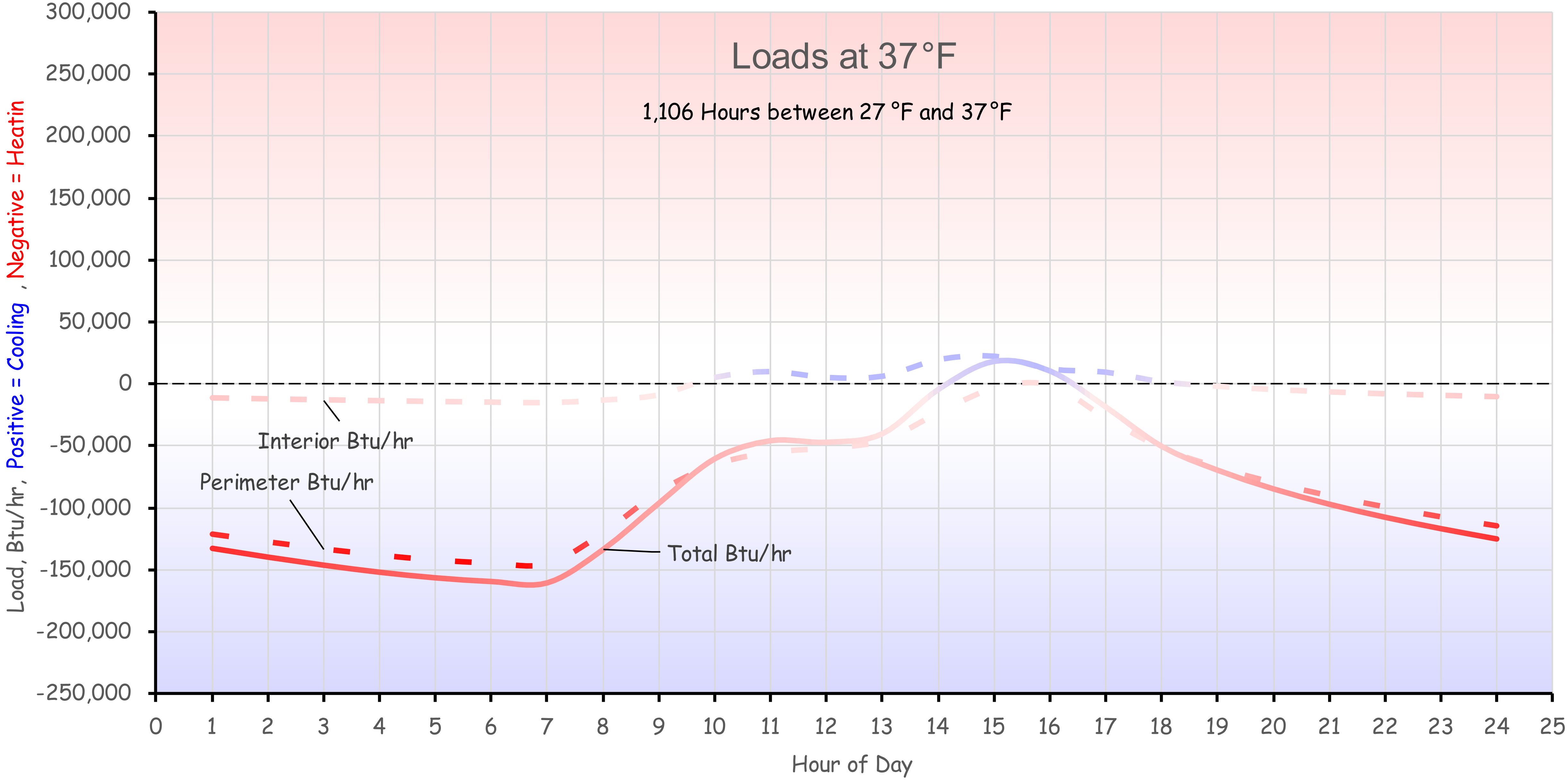
Loads at 14°F in a Perfect World
Interior Btu/hr
Total Btu/hr
Perimeter Btu/hr
Load, Btu/hr, Positive = Cooling , Negative = Heatin
Hour of Day
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25



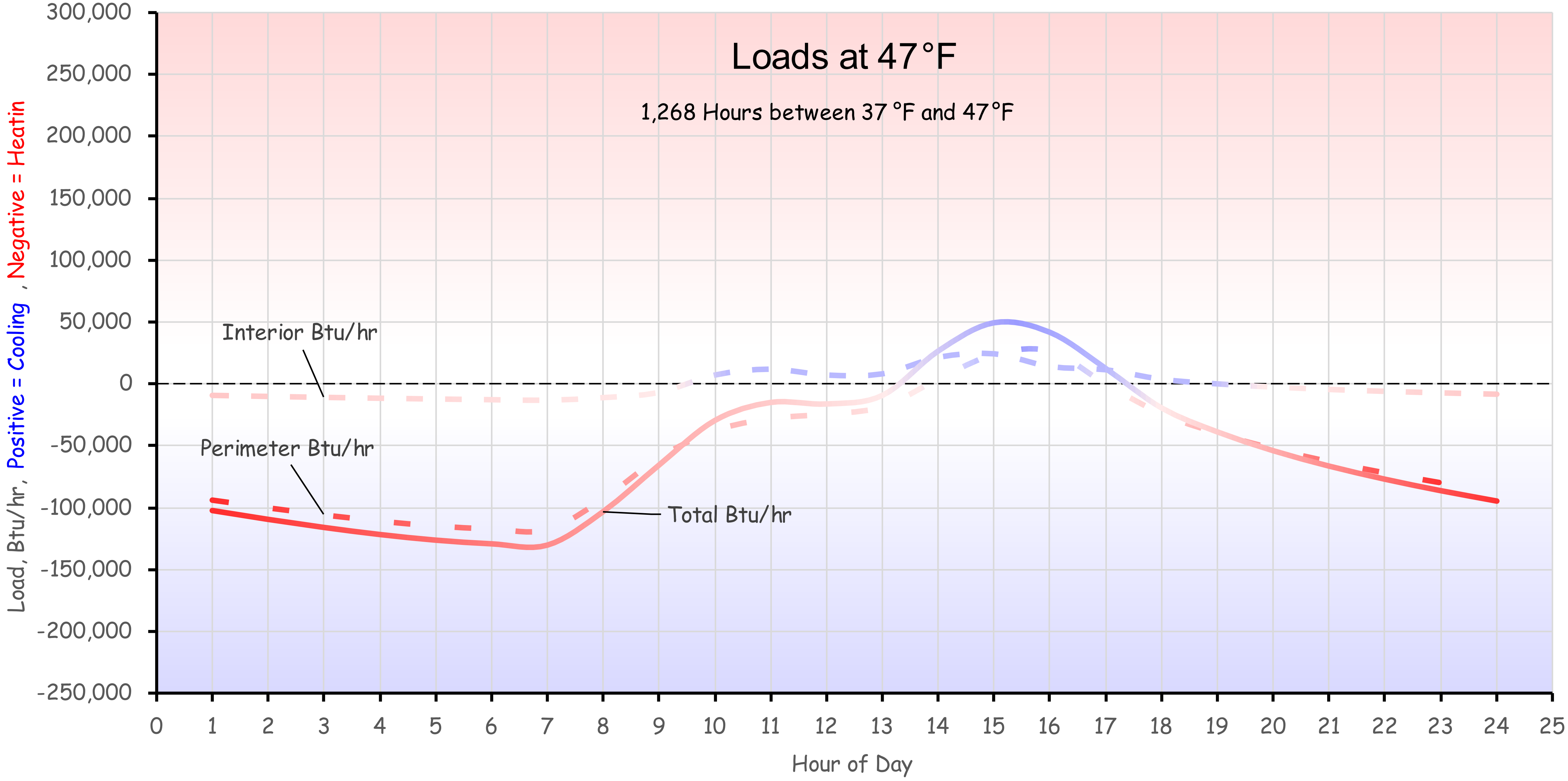
Loads at 14°F
85 hours at or below this condition
Interior Btu/hr
Perimeter Btu/hr
Total Btu/hr
Load, Btu/hr, Positive = Cooling, Negative = Heatin
Hour of Day
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25



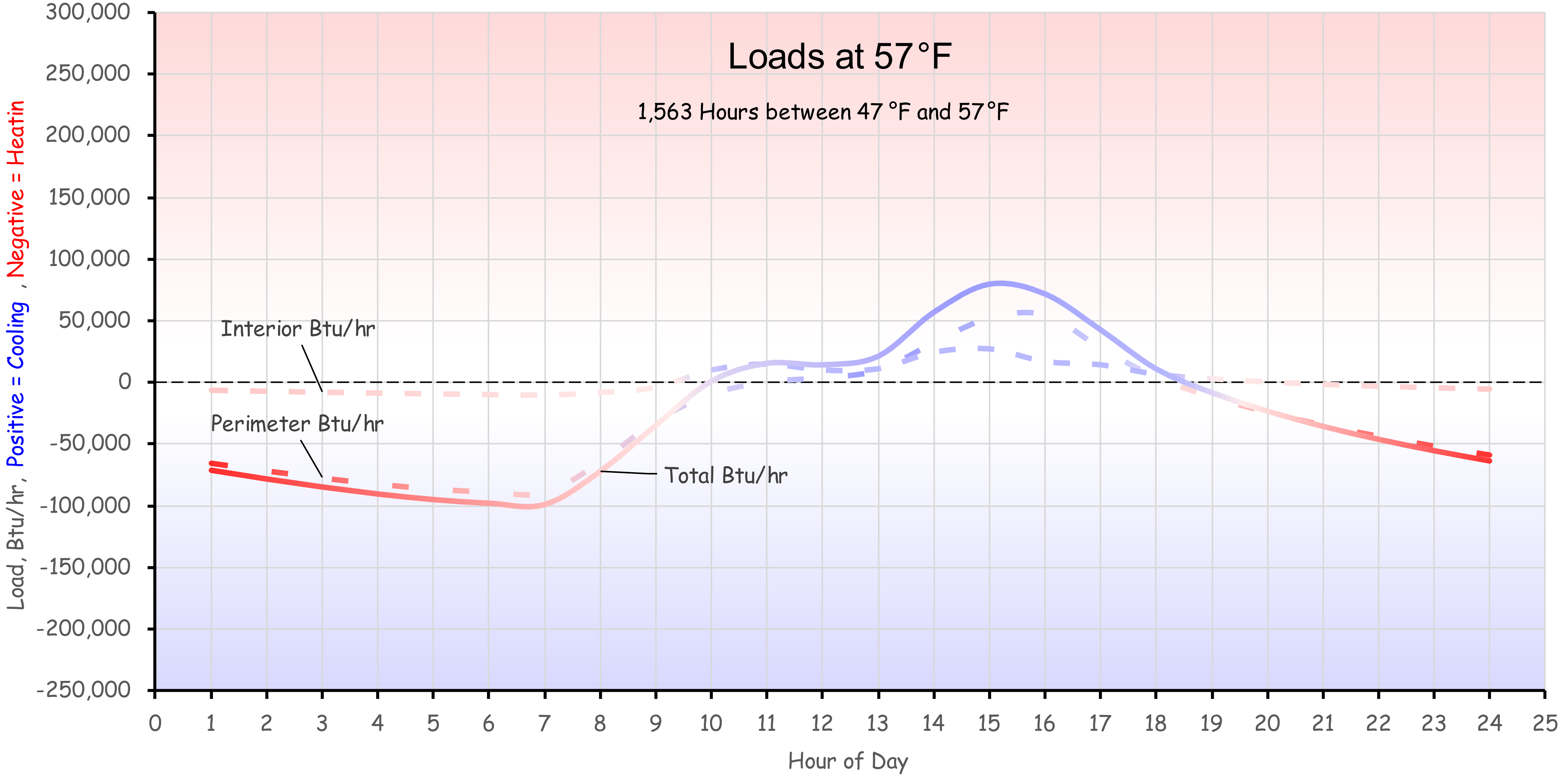
Loads at 27°F
498 Hours between 14°F and 27°F
Interior Btu/hr
Perimeter Btu/hr
Total Btu/hr
Load, Btu/hr, Positive = Cooling, Negative = Heatin
Hour of Day
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25



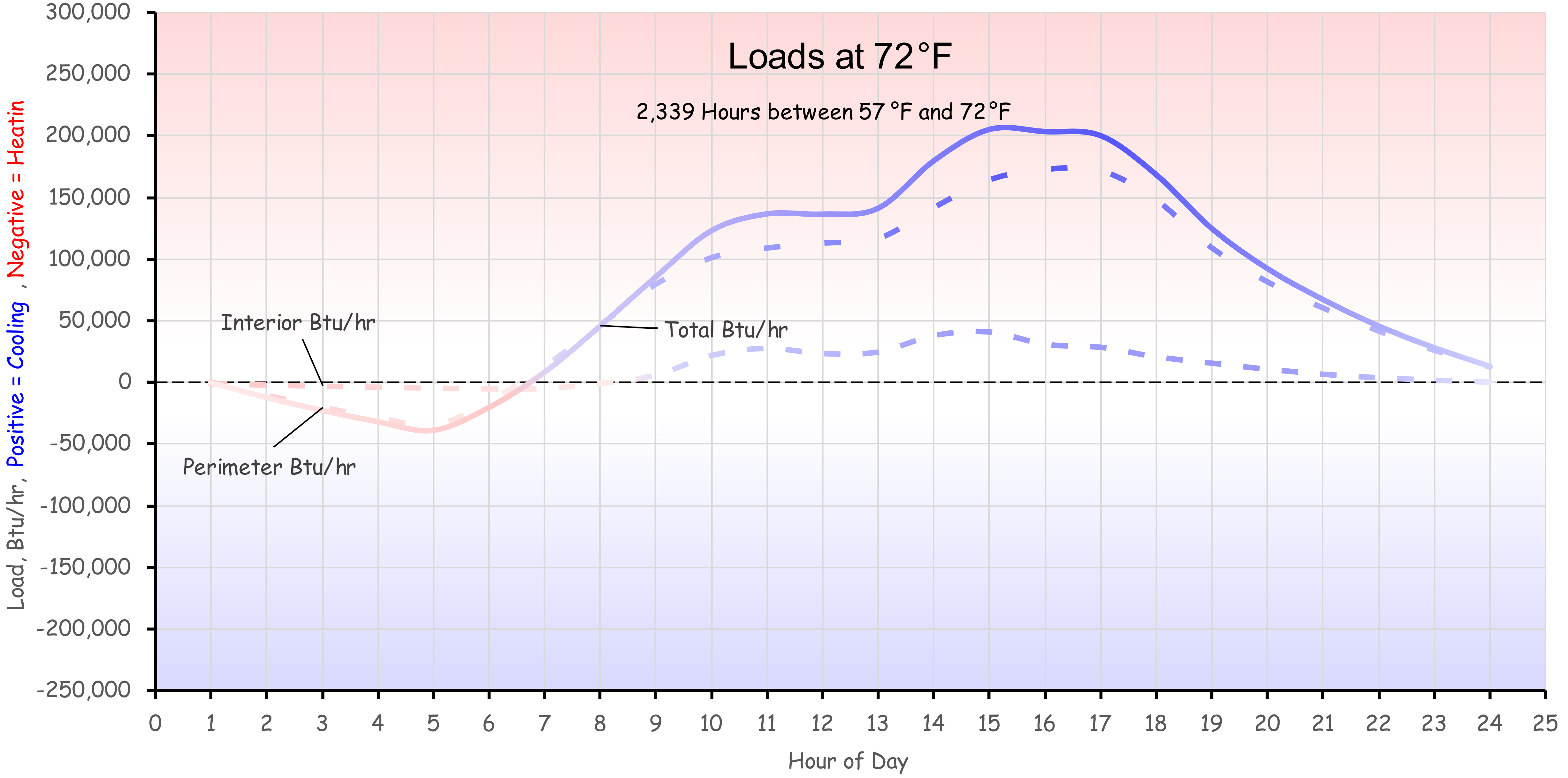
Loads at 37°F
1,106 Hours between 27 °F and 37°F
Load, Btu/hr , Positive = Cooling , Negative = Heatin
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
Interior Btu/hr
Perimeter Btu/hr
Total Btu/hr
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Hour of Day



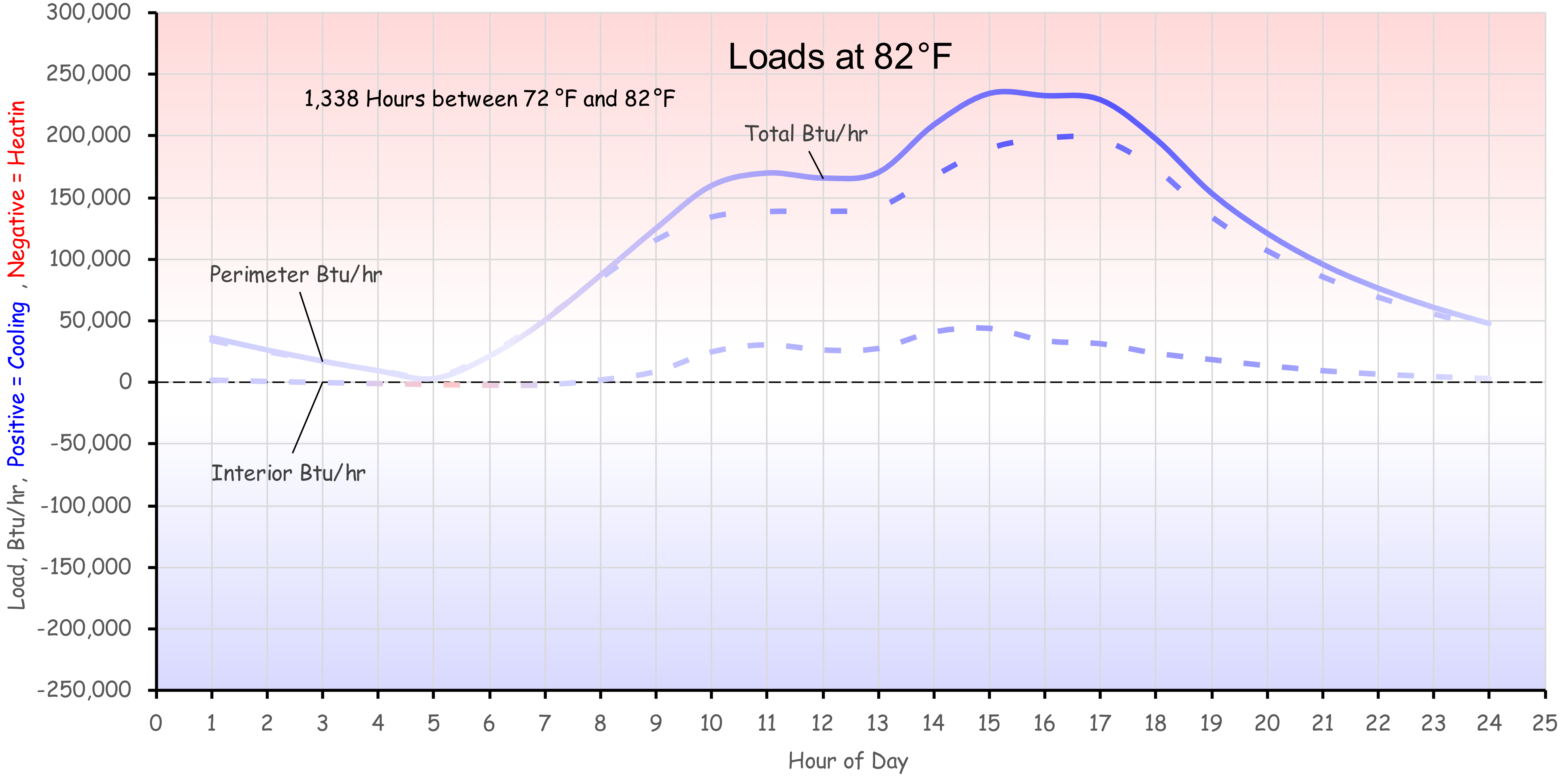
Loads at 47°F
1,268 Hours between 37 °F and 47°F
Interior Btu/hr
Perimeter Btu/hr
Total Btu/hr
Load, Btu/hr, Positive = Cooling , Negative = Heatin
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Hour of Day



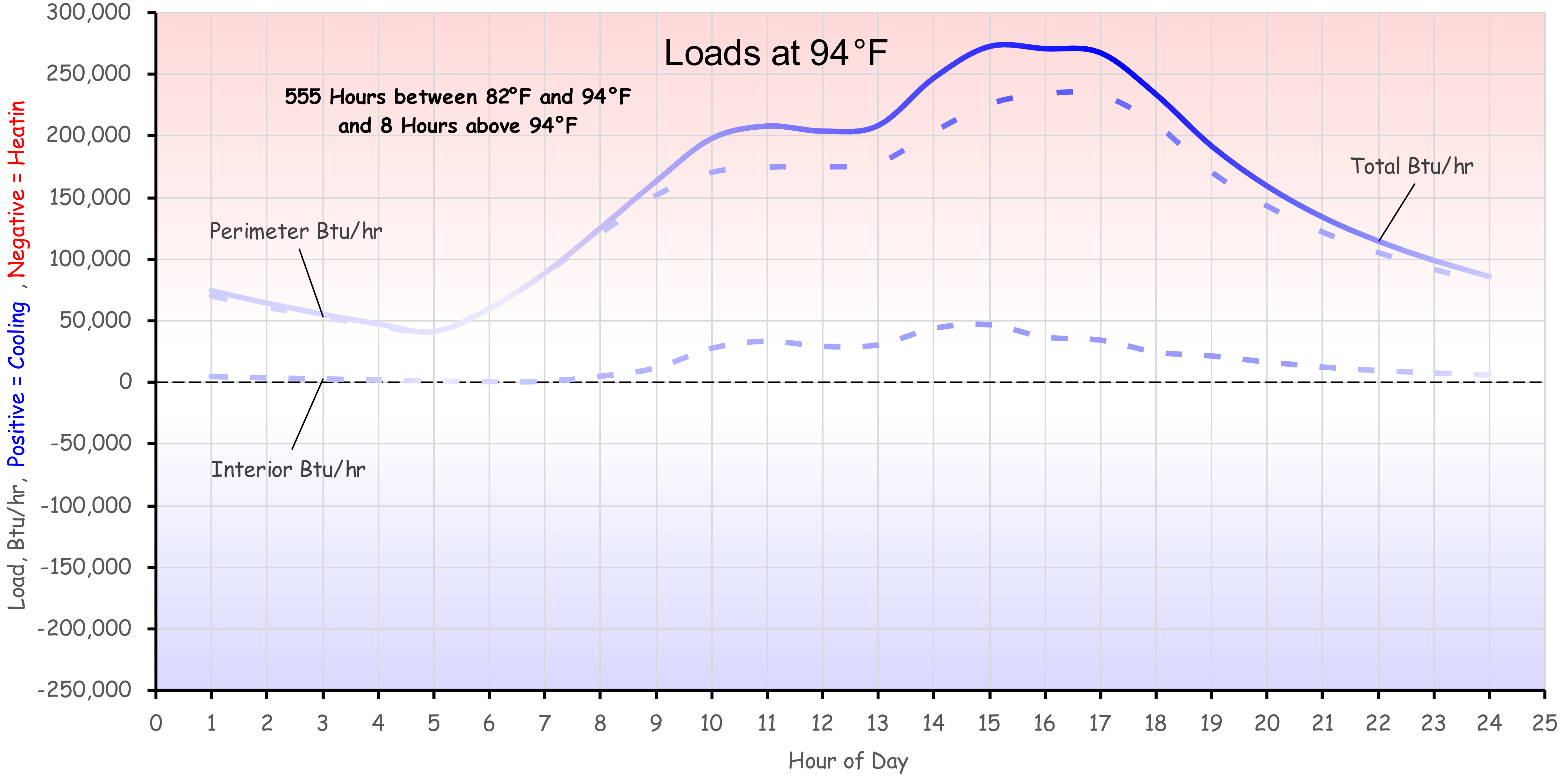
Loads at 57°F
1,563 Hours between 47 °F and 57°F
Interior Btu/hr
Perimeter Btu/hr
Total Btu/hr
Load, Btu/hr, Positive = Cooling , Negative = Heatin
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Hour of Day



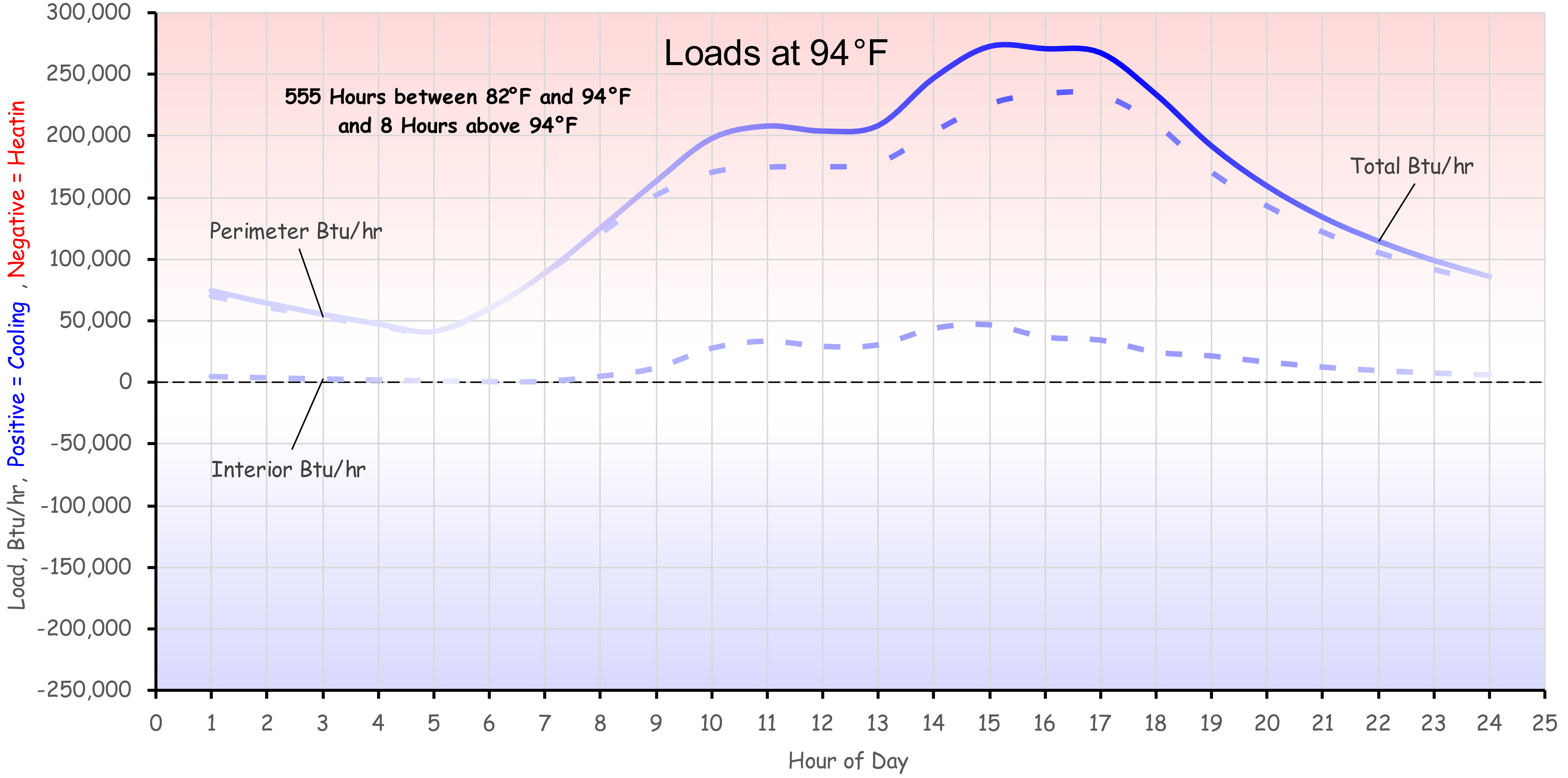
Loads at 72°F
2,339 Hours between 57 °F and 72 °F
Interior Btu/hr
Total Btu/hr
Perimeter Btu/hr
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Hour of Day
Load, Btu/hr , Positive = Cooling , Negative = Heatin



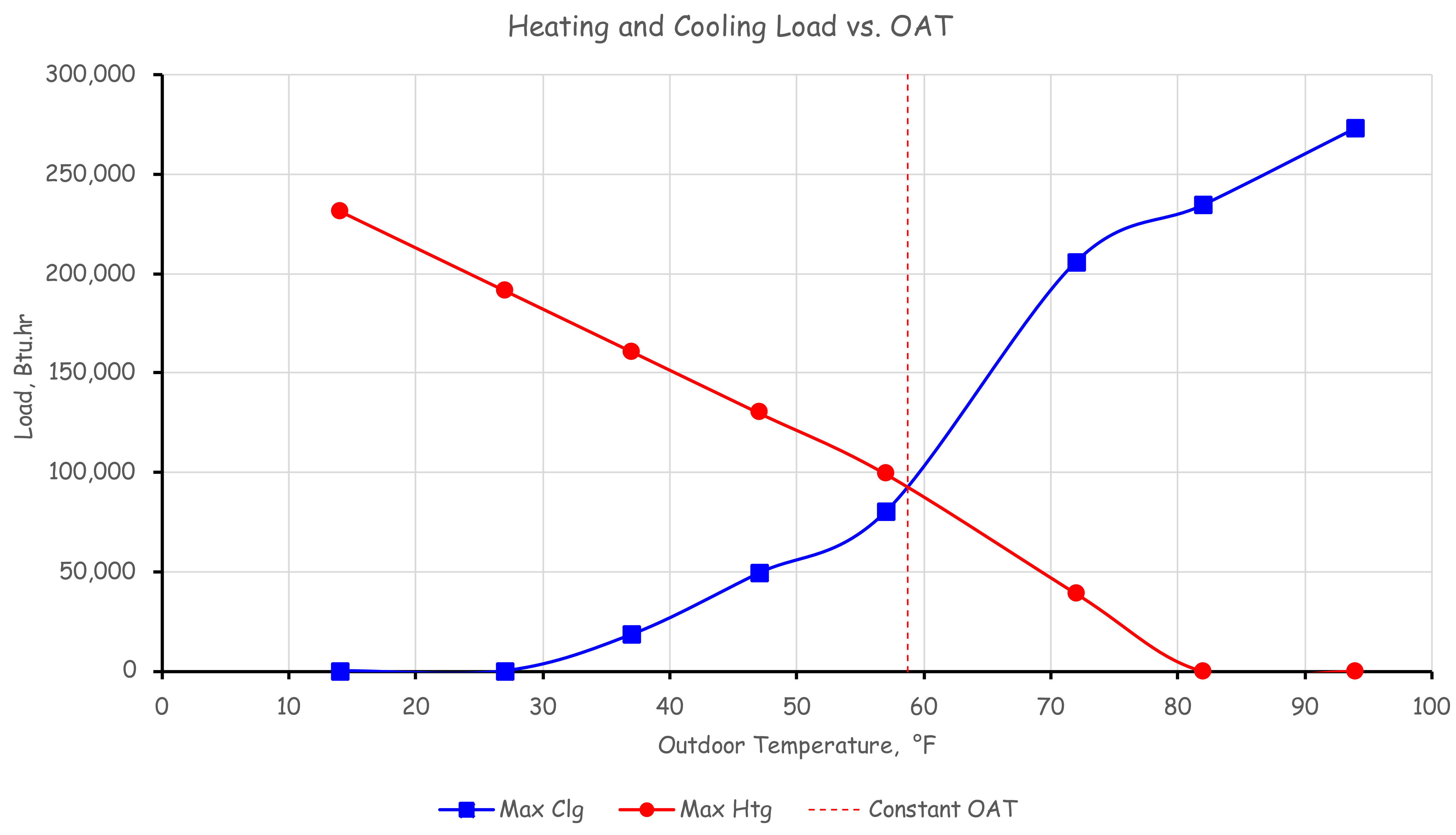
Loads at 82°F
1,338 Hours between 72 °F and 82°F
Total Btu/hr
Perimeter Btu/hr
Interior Btu/hr
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Hour of Day
Load, Btu/hr, Positive = Cooling , Negative = Heatin



Loads at 94°F
555 Hours between 82°F and 94°F
and 8 Hours above 94°F
Total Btu/hr
Perimeter Btu/hr
Interior Btu/hr
Load, Btu/hr, Positive = Cooling , Negative = Heatin
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Hour of Day



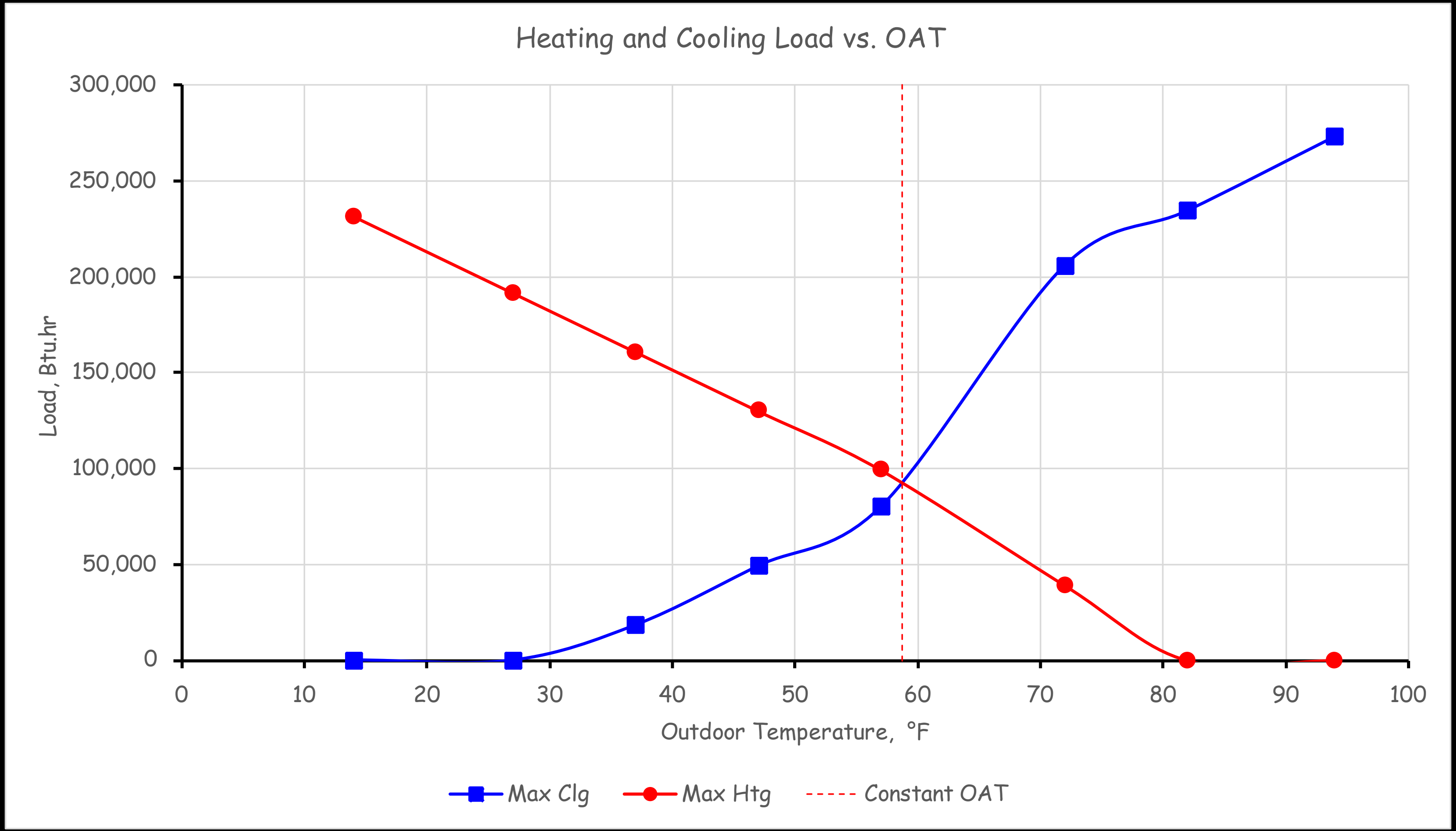
Loads at 94°F
555 Hours between 82°F and 94°F
and 8 Hours above 94°F
Total Btu/hr
Perimeter Btu/hr
Interior Btu/hr
Load, Btu/hr, Positive = Cooling, Negative = Heatin
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Hour of Day



Heating and Cooling Load vs. OAT
300,000
250,000
200,000
150,000
100,000
50,000
0
Load, Btu.hr
0
10
20
30
40
50
60
70
80
90
100
Outdoor Temperature, °F
Max Clg
Max Htg
Constant OAT

Bottom Line

There has to be heat to pump for a heat pump to recover energy



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

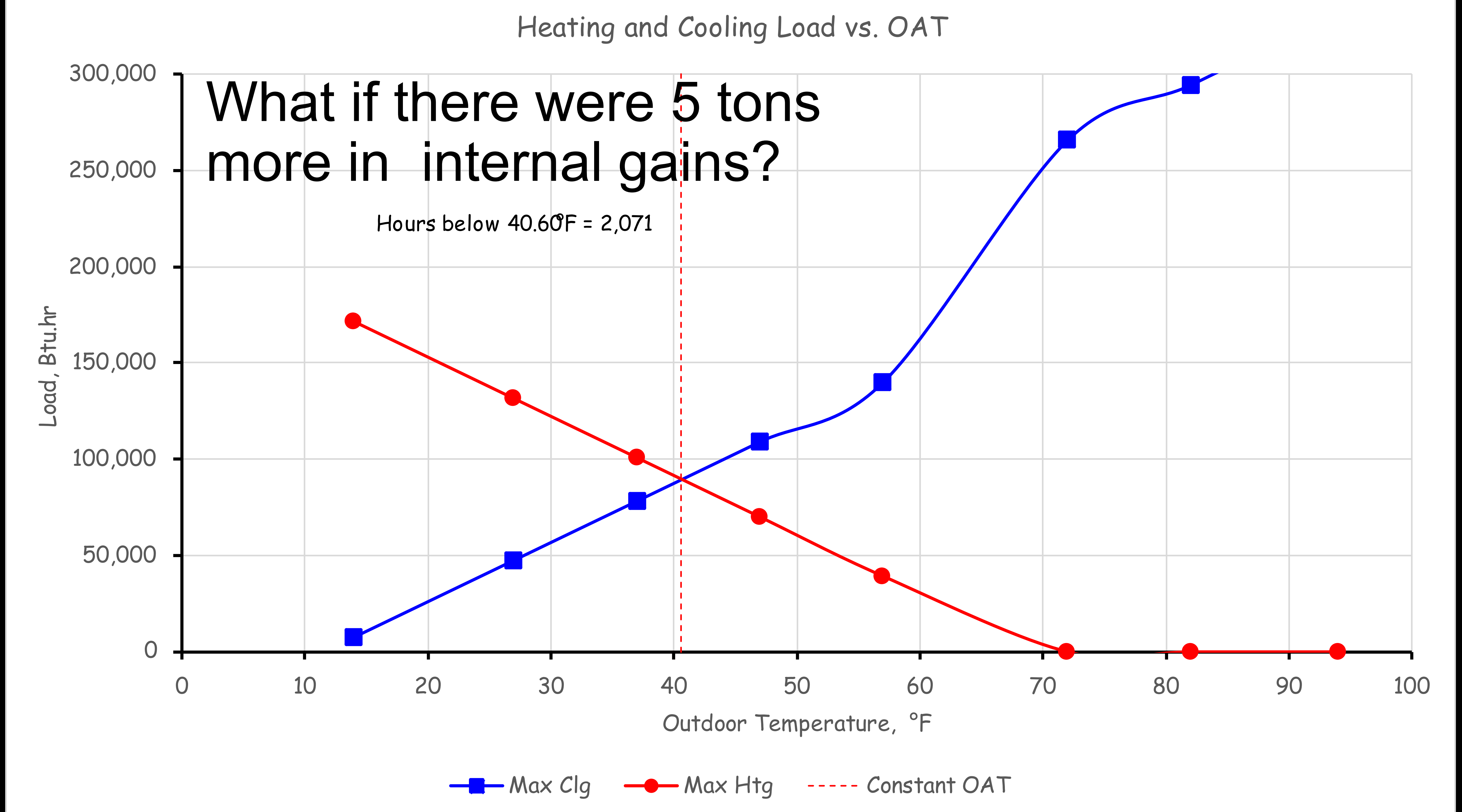
Loads that can Use Low Grade Heat

Heat Pump Application Checklist

Energy Available to Recover ✗

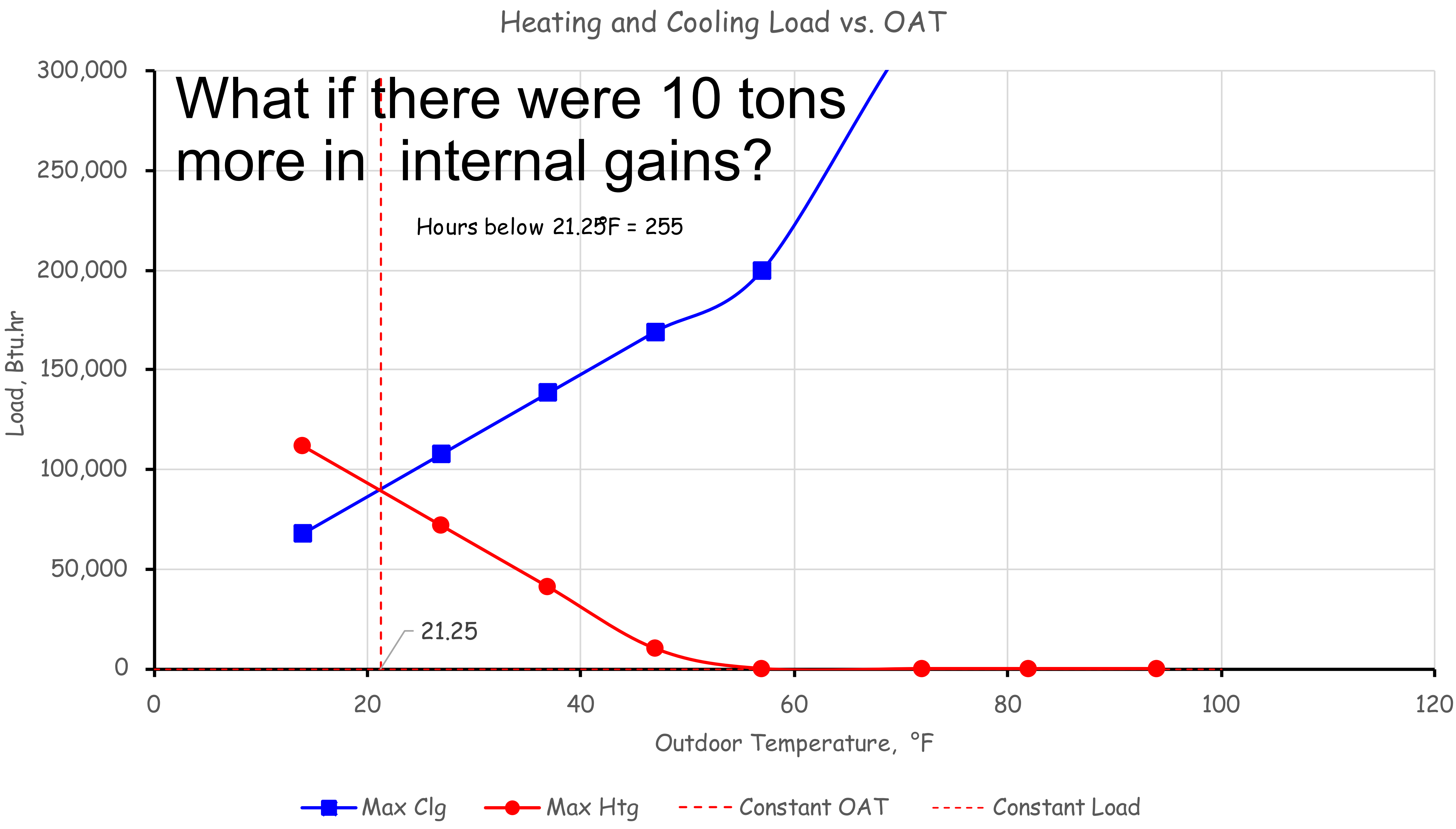
Warm Alternative Energy Source ✓

Loads that can Use Low Grade Heat ✓



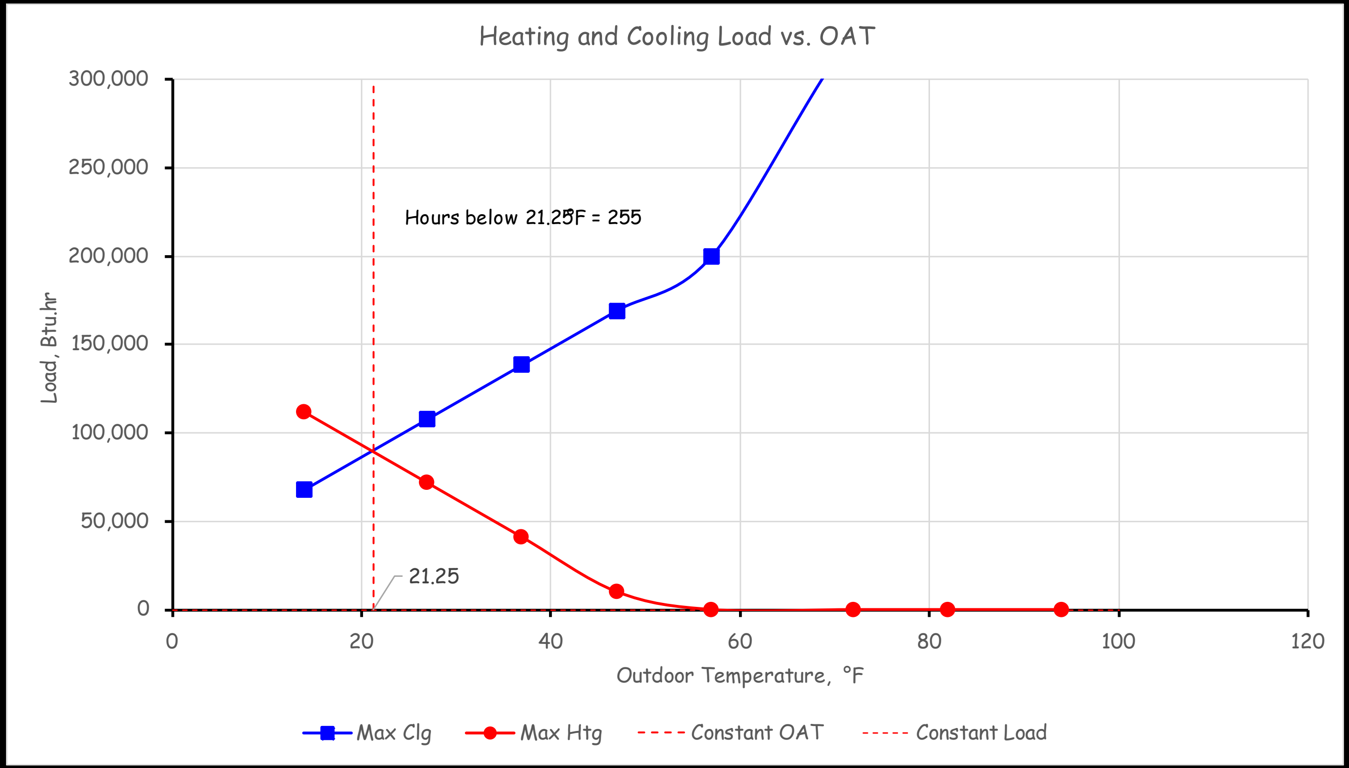
Heating and Cooling Load vs. OAT
What if there were 5 tons more in internal gains?
Hours below 40.60°F = 2,071
Load, Btu.hr
Outdoor Temperature, °F
300,000
250,000
200,000
150,000
100,000
50,000
0
0
10
20
30
40
50
60
70
80
90
100
Max Clg
Max Htg
Constant OAT

What if there were 10 tons more in internal gains?



A Question For You

https://tinyurl.com/HeatPumpD3WSLoopQ2

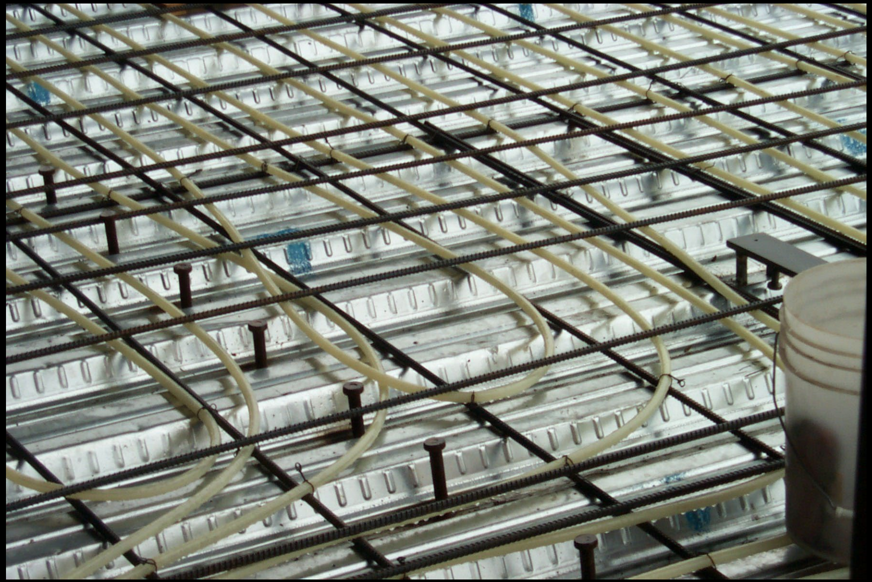


Methods for Serving Heating Loads

Radiation and Convection

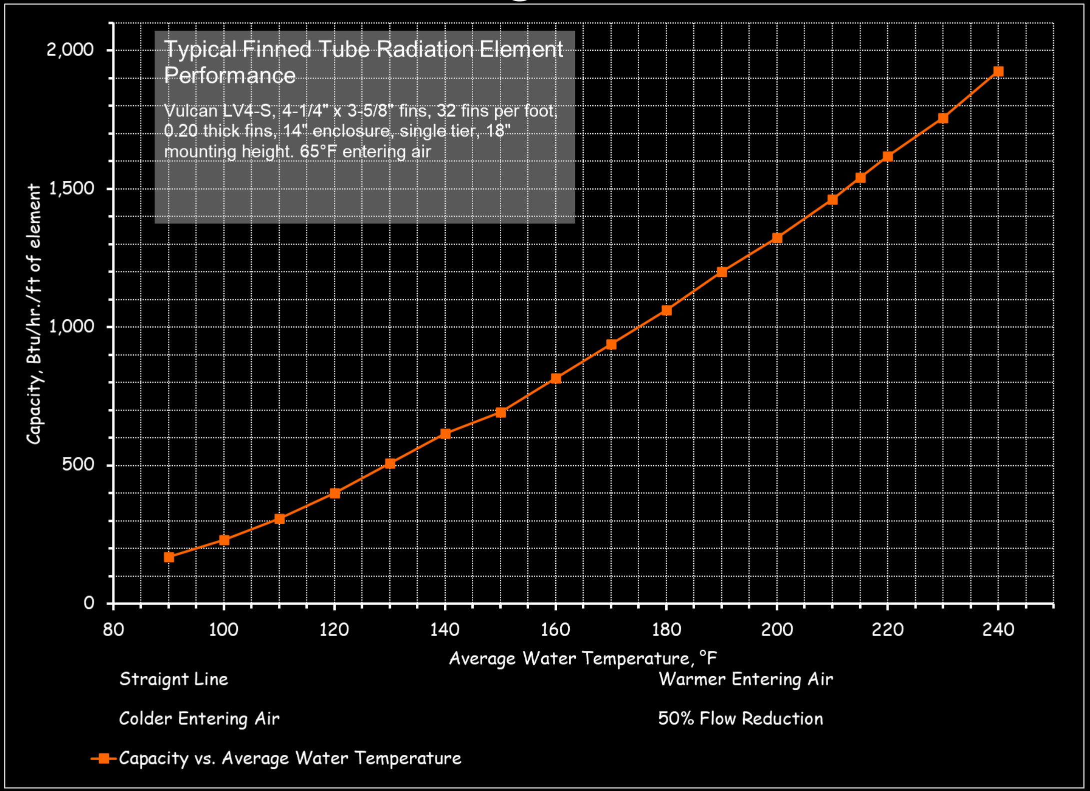
Use Coils to Heat Air

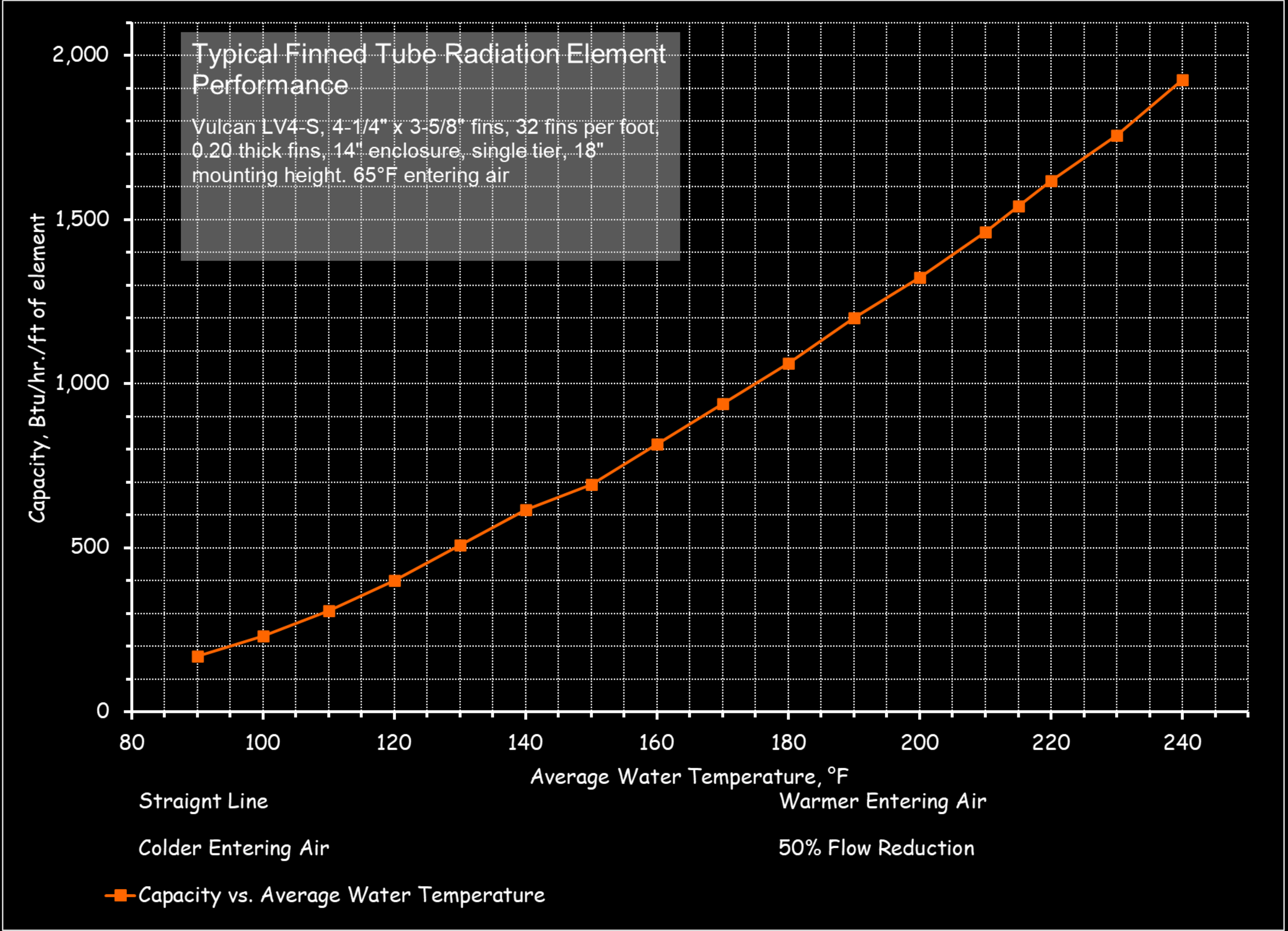
Pure Radiation



Radiation and Convection

Fluid in the element needs to be significantly warmer than the desired space temperature to deliver meaningful heat





Typical Finned Tube Radiation Element Performance
Vulcan LV4-S, 4-1/4" x 3-5/8" fins, 32 fins per foot, 0.20 thick fins, 14" enclosure, single tier, 18" mounting height. 65°F entering air
Capacity, Btu/hr./ft of element
2,000
1,500
1,000
500
0
80
100
120
140
160
180
200
220
240
Average Water Temperature, °F
Straight Line
Warmer Entering Air
Colder Entering Air
50% Flow Reduction
Capacity vs. Average Water Temperature

Radiation and Convection

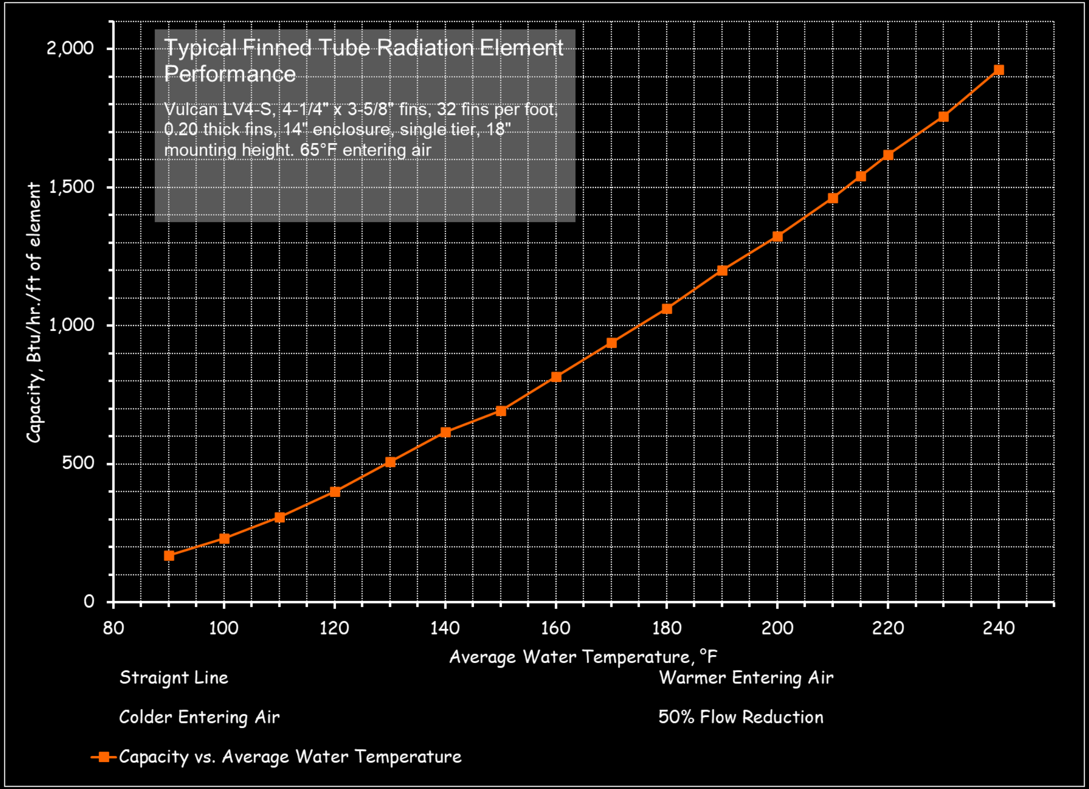
Heat Pump Application Checklist

Energy Available to Recover

Warm Alternative Energy Source

Loads that can Use Low Grade Heat ✘

Fluid in the element needs to be significantly warmer than the desired space temperature to deliver meaningful heat



Using Coils to Heat Air

Recall the Definition of Heating

- A process that adds energy
  - For a space, this is often accomplished by circulating air through it at a temperature above the required set point
  - For a fluid stream, this is often accomplished by passing it over a surface that is above the required supply temperature

Using Coils to Heat Air

Recall the Definition of Preheat

- A process that heats a fluid stream to prepare it for a subsequent HVAC process
- In air handling systems, this process is used to raise subfreezing air above freezing to protect water filled elements down stream from damage due to freezing

Using Coils to Heat Air

Recall the Definition of Reheat

- A process that uses heat to warm air being delivered to a zone to prevent over cooling
- The temperature of the air was set by the need to hit a dehumidification target, or
- By the requirements of another zone
- Thus, it can not be raised at the central system
- The volume can not be reduced because it has been set to assure proper ventilation (contaminant control)

Using Coils to Heat Air

Fluid in the coil needs to be warmer than the desired air temperature

- Typical preheat coil leaving air temperature requirements – 45 – 65°F

Using Coils to Heat Air

Coil Performance at Different Entering Water Temperatures

Item	Preheat	
	Warm Up	Preheat, 50% OA
Air flow (SCFM)	22306	22306
Total capacity (MBH)	585.1	399.0
Entering dry bulb (°F)	62.0	34.0
Leaving dry bulb (°F)	86.2	50.5
Face velocity (ft/min)	465	465
Entering fluid temp. (°F)	170.0	110.0
Leaving fluid temp. (°F)	130.0	83.0
Fluid flow rate (GPM)	29.8	29.8
Fluid velocity (ft/s)	2.71	2.71
Fluid pressure drop (ft of water)	4.4	4.7
Tube Diameter	5/8	5/8
Fin height (in)	72.0	72.0
Fin length (in)	96.0	96.0
Face area (ft^2)	48.00	48.00
Rows	1	1
Fin spacing (fins/in)	9	9

Fluid in the coil needs to be warmer than the desired air temperature

- Typical preheat coil leaving air temperature requirements – 45 – 65°F

Using Coils to Heat Air

Fluid in the coil needs to be warmer than the desired air temperature

- Typical preheat coil leaving air temperature requirements – 45 – 65°F

Heat Pump Application Checklist

Energy Available to Recover

Warm Alternative Energy Source

Loads that can Use Low Grade Heat ✓

Using Coils to Heat Air

Fluid in the coil needs to be warmer than the desired air temperature

- Typical preheat coil leaving air temperature requirements – 45 – 65°F
- Typical reheat coil leaving air temperature requirements – 55 – 68°F for reheat

Using Coils to Heat Air

Coil Performance at Different Entering Water Temperatures		
Item		Reheat
	Design Condition	110°F 40°F Delta t
Air flow (SCFM)	1185	1185
Total capacity (MBH)	50.9	18.5
Entering dry bulb (°F)	53.0	53.0
Leaving dry bulb (°F)	92.7	67.4
Face velocity (ft/min)	249	249
Entering fluid temp. (°F)	170.0	110.0
Leaving fluid temp. (°F)	156.5	90.0
Fluid flow rate (GPM)	7.7	1.9
Fluid velocity (ft/s)	4.20	1.02
Fluid pressure drop (ft of water)	6.1	0.4
Tube Diameter	5/8	5/8
Fin height (in)	18.0	18.0
Fin length (in)	38.0	38.0
Face area (ft^2)	4.75	4.75
Rows	1	1
Fin spacing (fins/in)	9	9

Fluid in the coil needs to be warmer than the desired air temperature

- Typical preheat coil leaving air temperature requirements – 45 – 65°F
- Typical reheat coil leaving air temperature requirements – 55 – 68°F for reheat

Using Coils to Heat Air

Coil Performance at Different Entering Water Temperatures

Item	Reheat	
	Design Condition	110°F, Design gpm
Air flow (SCFM)	1185	1185
Total capacity (MBH)	50.9	24.6
Entering dry bulb (°F)	53.0	53.0
Leaving dry bulb (°F)	92.7	72.1
Face velocity (ft/min)	249	249
Entering fluid temp. (°F)	170.0	110.0
Leaving fluid temp. (°F)	156.5	103.6
Fluid flow rate (GPM)	7.7	7.7
Fluid velocity (ft/s)	4.20	4.20
Fluid pressure drop (ft of water)	6.1	6.6
Tube Diameter	5/8	5/8
Fin height (in)	18.0	18.0
Fin length (in)	38.0	38.0
Face area (ft^2)	4.75	4.75
Rows	1	1
Fin spacing (fins/in)	9	9

Fluid in the coil needs to be warmer than the desired air temperature

- Typical preheat coil leaving air temperature requirements – 45 – 65°F
- Typical reheat coil leaving air temperature requirements – 55 – 68°F for reheat

Using Coils to Heat Air

Fluid in the coil needs to be warmer than the desired air temperature

- Typical preheat coil leaving air temperature requirements – 45 – 65°F
- Typical reheat coil leaving air temperature requirements – 55 – 68°F for reheat

Heat Pump Application Checklist

Energy Available to Recover

Warm Alternative Energy Source

Loads that can Use Low Grade Heat ✓

Using Coils to Heat Air

Fluid in the coil needs to be warmer than the desired air temperature

- Typical preheat coil leaving air temperature requirements – 45 – 65°F
- Typical reheat coil leaving air temperature requirements – 55 – 68°F for reheat
- Typical reheat coil leaving air temperature requirements – 95 – 115°F for space heat

Using Coils to Heat Air

Coil Performance at Different Entering Water Temperatures

Item	Design Condition	Reheat 110°F 40°F Delta t
Air flow (SCFM)	1185	1185
Total capacity (MBH)	50.9	18.5
Entering dry bulb (°F)	53.0	53.0
Leaving dry bulb (°F)	92.7	67.4
Face velocity (ft/min)	249	249
Entering fluid temp. (°F)	170.0	110.0
Leaving fluid temp. (°F)	156.5	90.0
Fluid flow rate (GPM)	7.7	1.9
Fluid velocity (ft/s)	4.20	1.02
Fluid pressure drop (ft of water)	6.1	0.4
Tube Diameter	5/8	5/8
Fin height (in)	18.0	18.0
Fin length (in)	38.0	38.0
Face area (ft^2)	4.75	4.75
Rows	1	1
Fin spacing (fins/in)	9	9

Fluid in the coil needs to be warmer than the desired air temperature

- Typical preheat coil leaving air temperature requirements – 45 – 65°F
- Typical reheat coil leaving air temperature requirements – 55 – 68°F for reheat
- Typical reheat coil leaving air temperature requirements – 95 – 115°F for space heat

Using Coils to Heat Air

Heat Pump Application Checklist

Energy Available to Recover

Warm Alternative Energy Source

Loads that can Use Low Grade Heat ✘

Fluid in the coil needs to be warmer than the desired air temperature

- Typical preheat coil leaving air temperature requirements – 45 – 65°F
- Typical reheat coil leaving air temperature requirements – 55 – 68°F for reheat
- Typical reheat coil leaving air temperature requirements – 95 – 115°F for space heat

Pure Radiation

Radiant slabs typically need to be held at 85°F or less

- Warmer temperatures cause comfort problems
- Warmer temperatures can cause issues with floor coverings and finishes

Pure Radiation

Heat Pump Application Checklist

Energy Available to Recover

Warm Alternative Energy Source

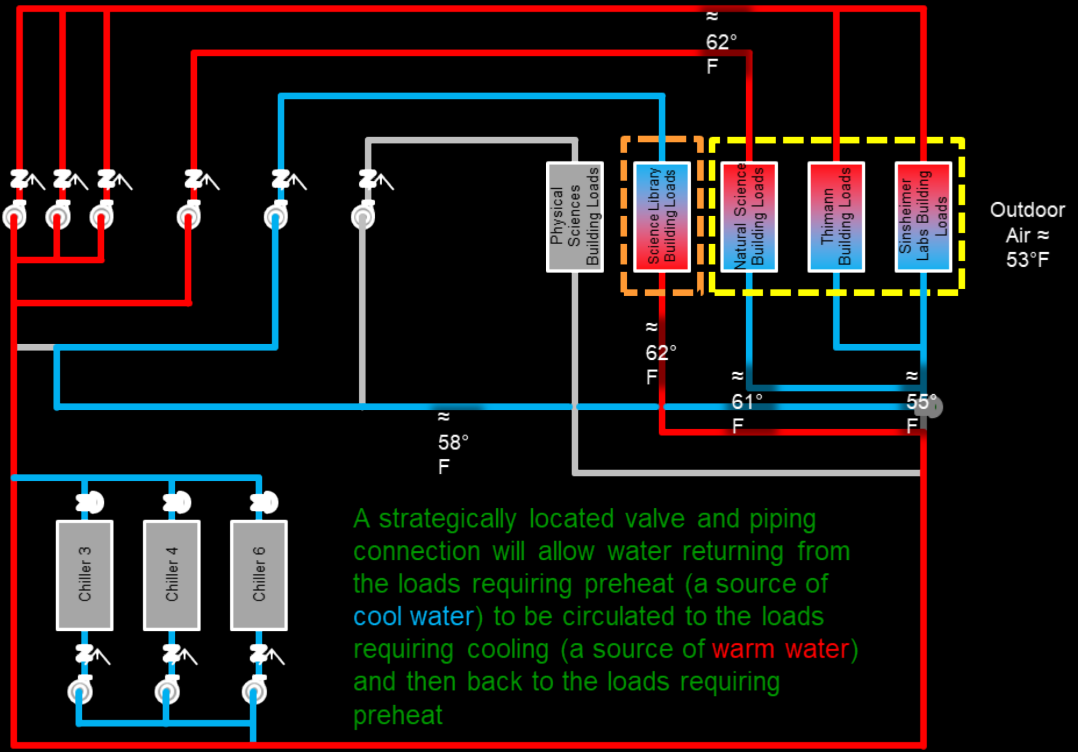
Loads that can Use Low Grade Heat ✓

Radiant slabs typically need to be held at 85°F or less

- Warmer temperatures cause comfort problems
- Warmer temperatures can cause issues with floor coverings and finishes

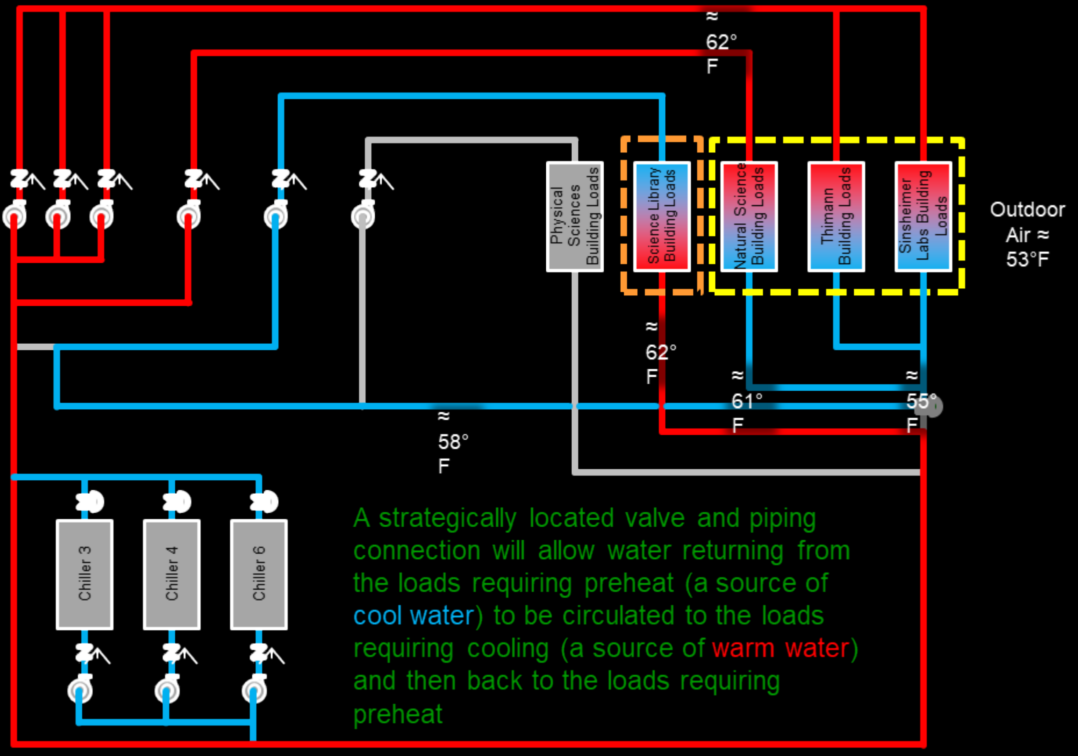
How Much Heat Can a Heat Pump Pump if a Heat Pump Could Pump Heat?

More Specifically, How Hot Can We Get?



62°F with some outside the box thinking and conventional pumps, pipes and loads

More Specifically, How Hot Can We Get?



62°F with some outside the box thinking and conventional pumps, pipes and loads

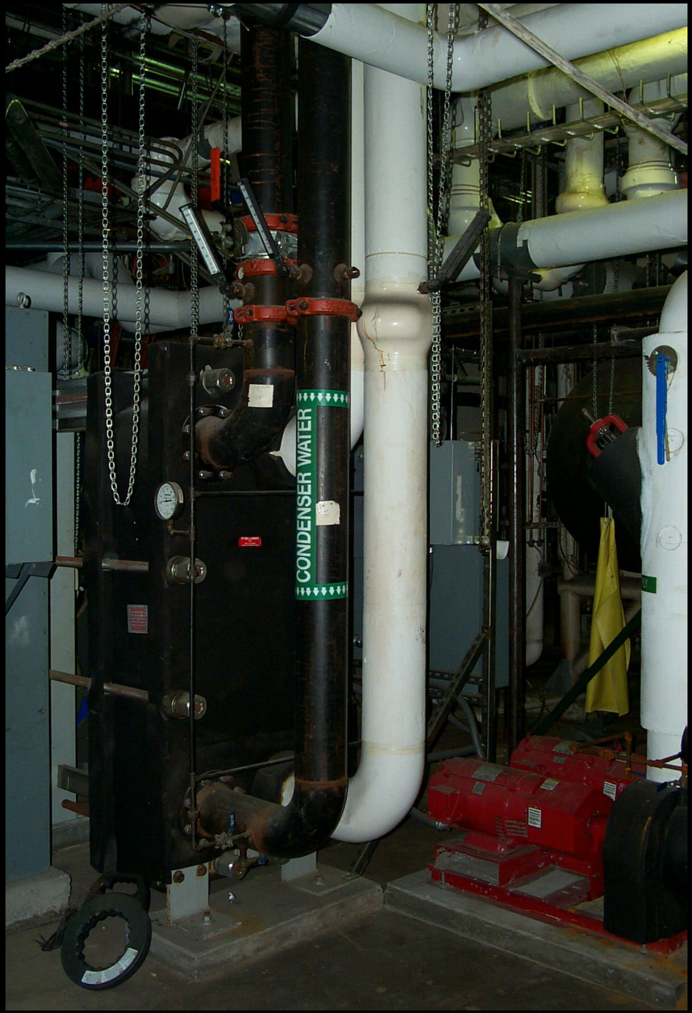
Heat Pump Application Checklist

Energy Available to Recover

Warm Alternative Energy Source ✓

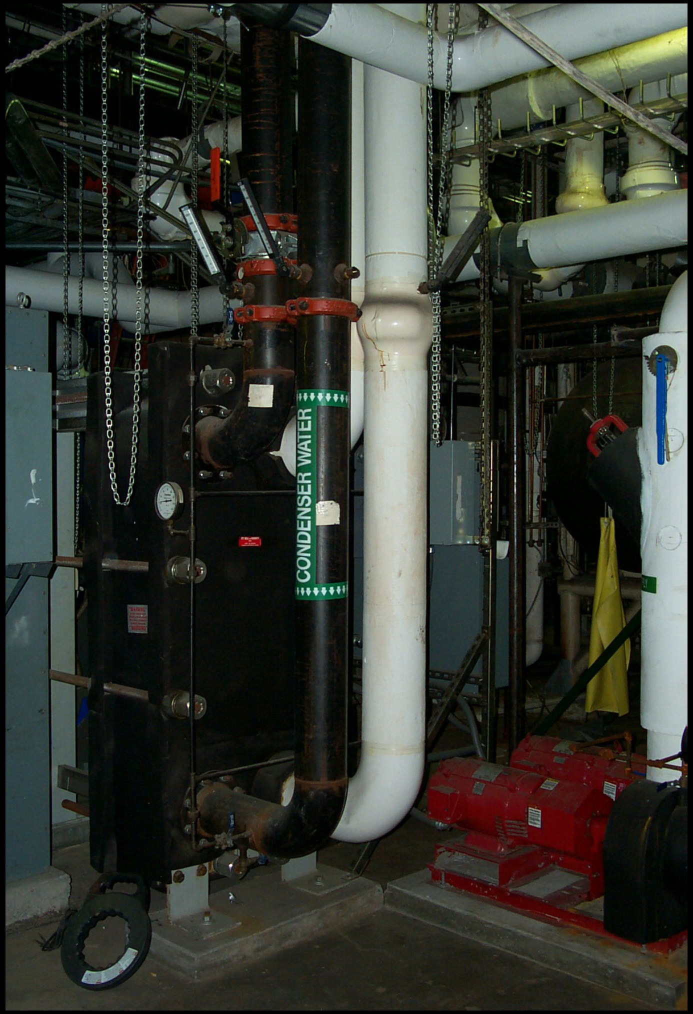
Loads that can Use Low Grade Heat

More Specifically, How Hot Can We Get?



90°F with plate and frame heat exchangers recovering heat from the condenser water system at conventional condenser water temperatures (85°F from the towers, 95°F to the towers)

More Specifically, How Hot Can We Get?

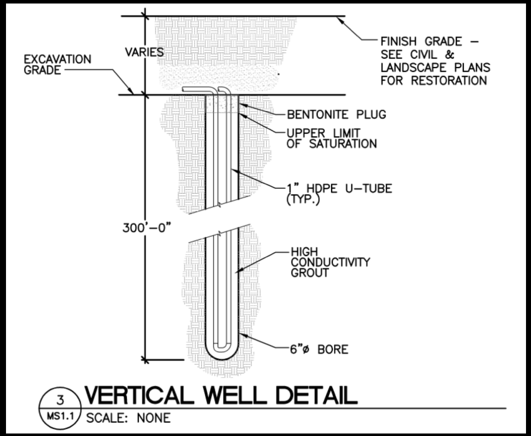


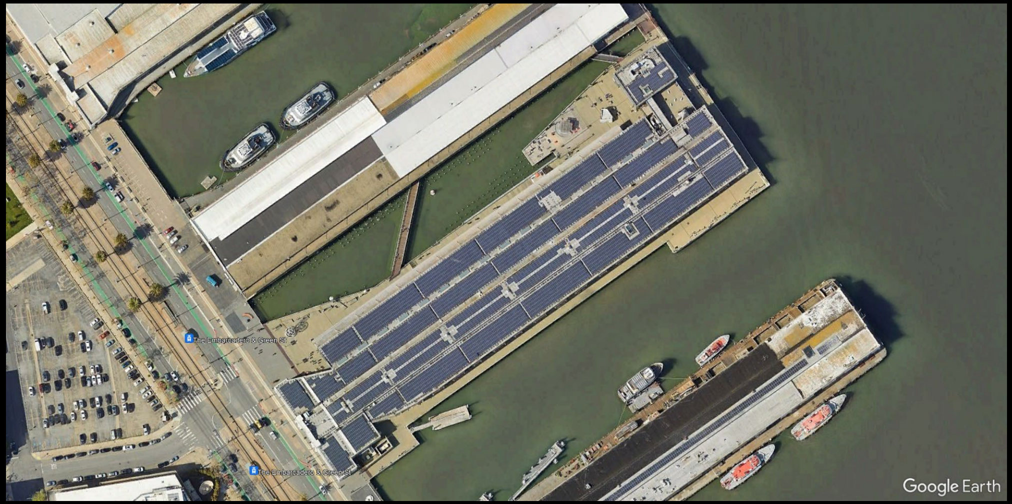
90°F with plate and frame heat exchangers recovering heat from the condenser water system at conventional condenser water temperatures (85°F from the towers, 95°F to the towers)

Heat Pump Application Checklist

- Energy Available to Recover
- Warm Alternative Energy Source ✓
- Loads that can Use Low Grade Heat

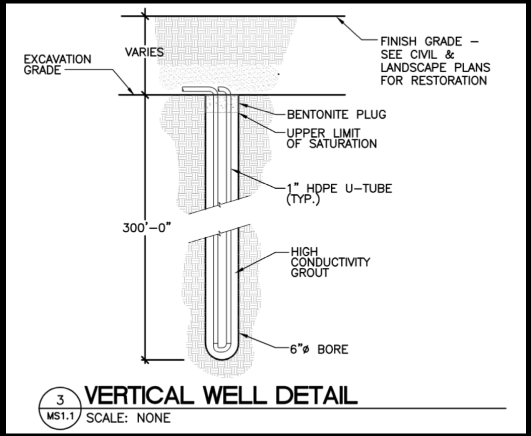
More Specifically, How Hot Can We Get?



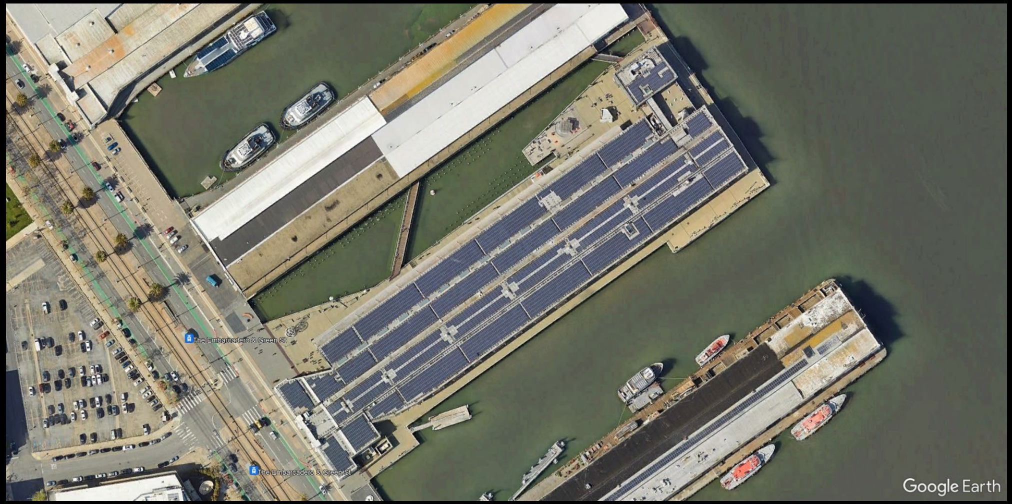


120 - 140°F with conventional water source heat pumps using ground water or a large body of water as the source

More Specifically, How Hot Can We Get?



120 - 140°F with conventional water source heat pumps using ground water or a large body of water as the source



Heat Pump Application Checklist

Energy Available to Recover

Warm Alternative Energy Source ✓

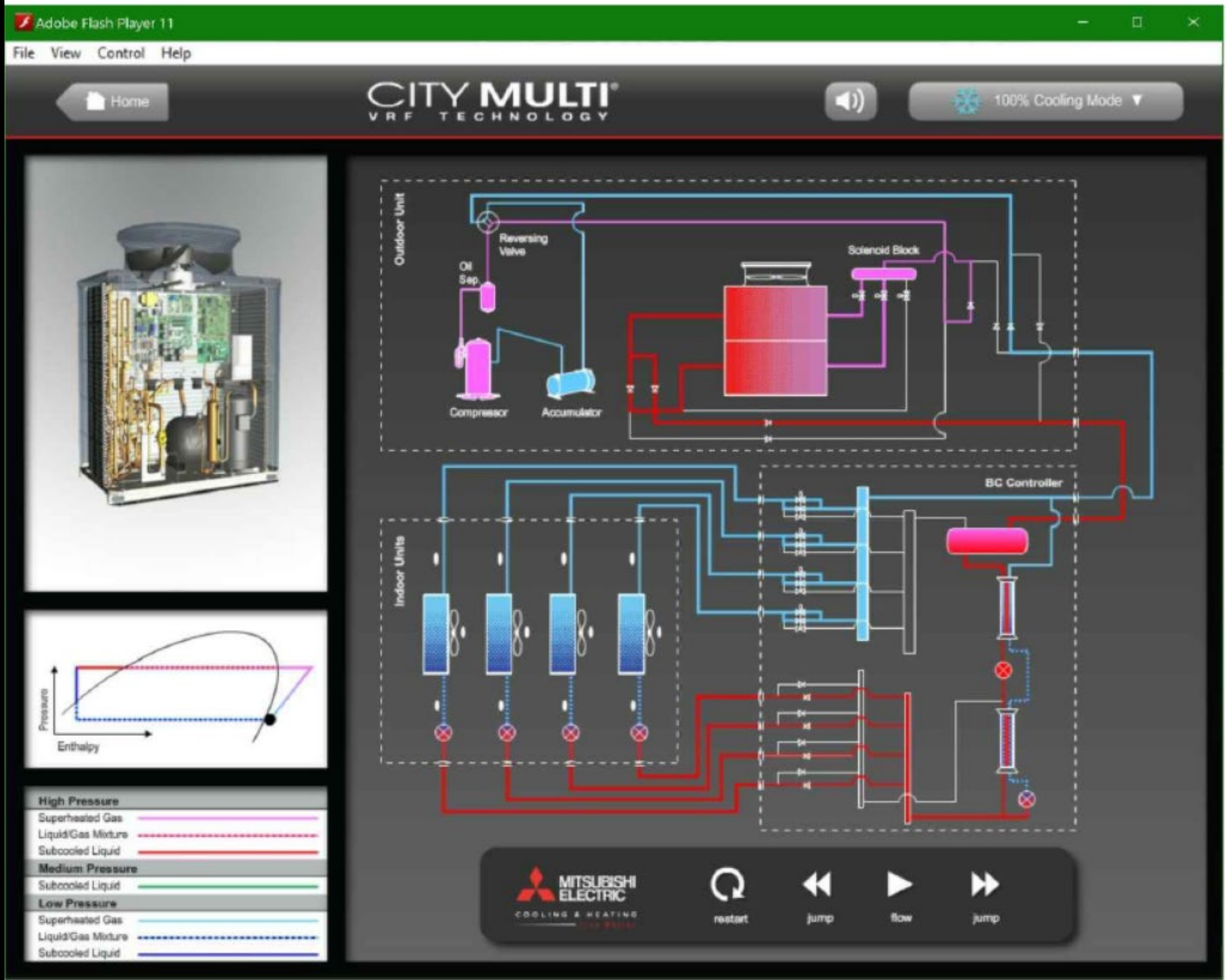
Loads that can Use Low Grade Heat

More Specifically, How Hot Can We Get?

95 - 115°F with air source Variable Refrigeration Flow (VRF) systems

Taking a Look at a VRF System

https://tinyurl.com/MitsubishiVRFFlow

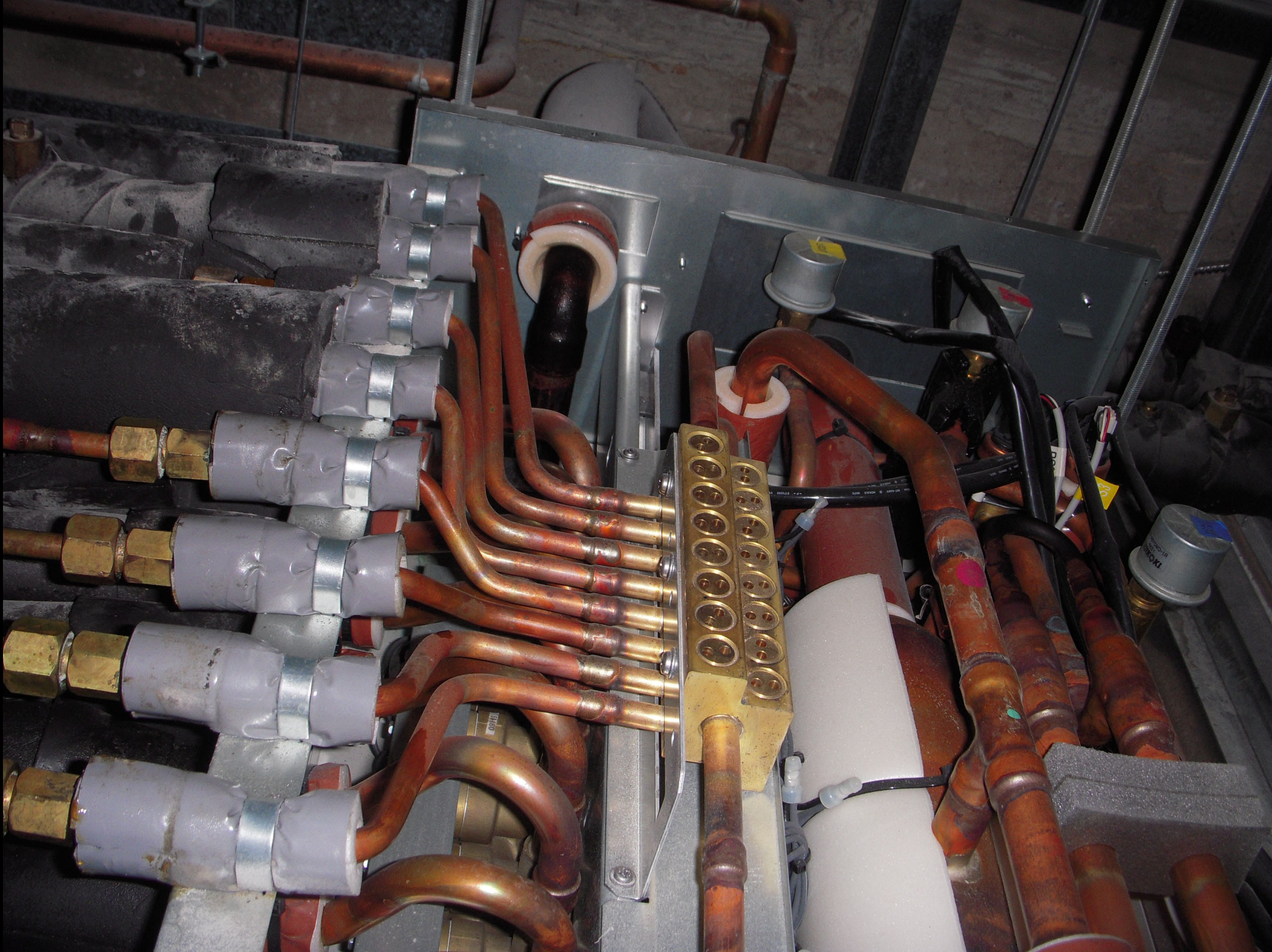


Typical Outdoor Unit

Typical Indoor Unit

Typical Branch Controller

Typical Branch Controller



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Heat Pump Application Checklist

Energy Available to Recover

Warm Alternative Energy Source ✗ ✓

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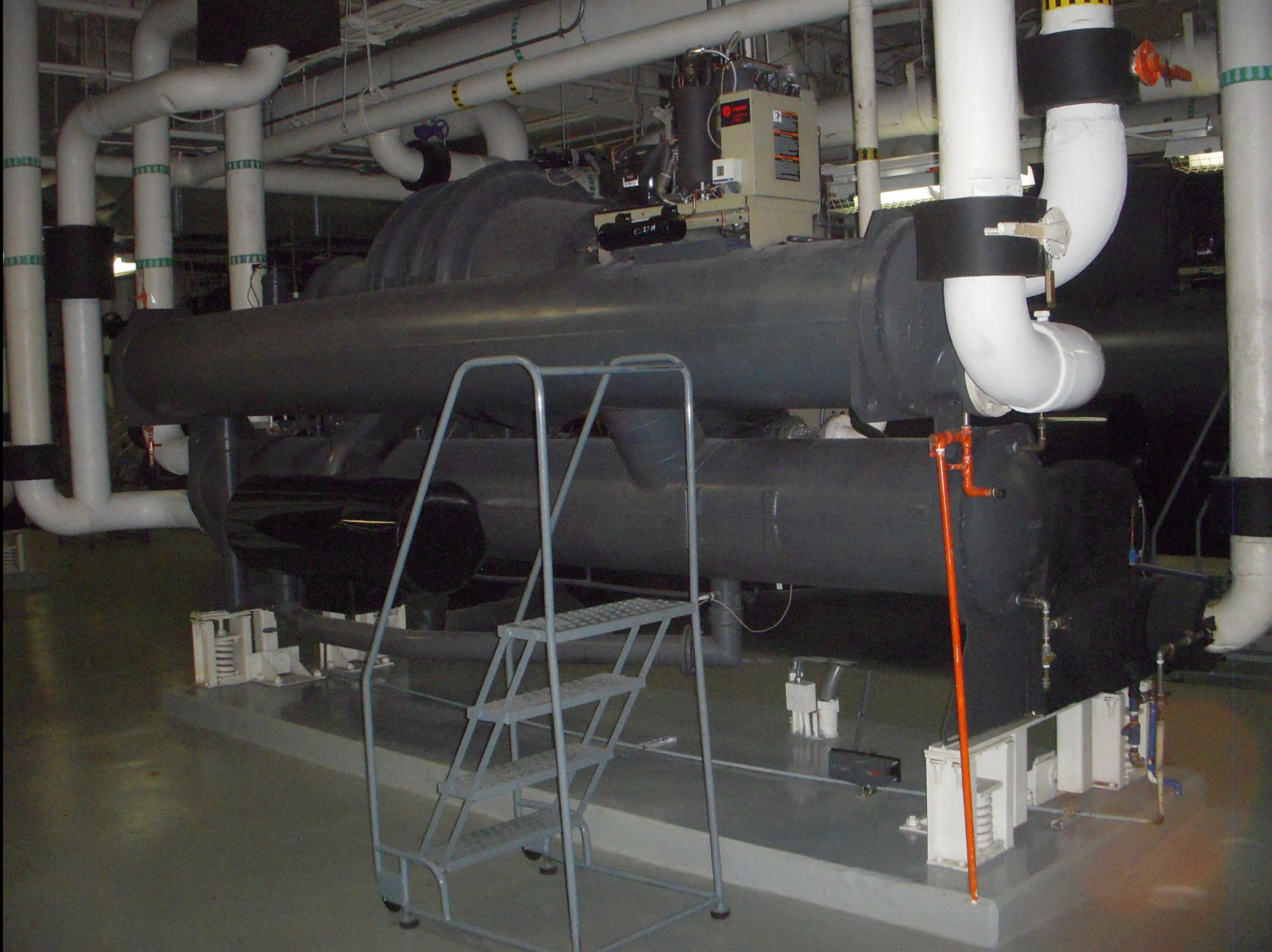
More Specifically, How Hot Can We Get?

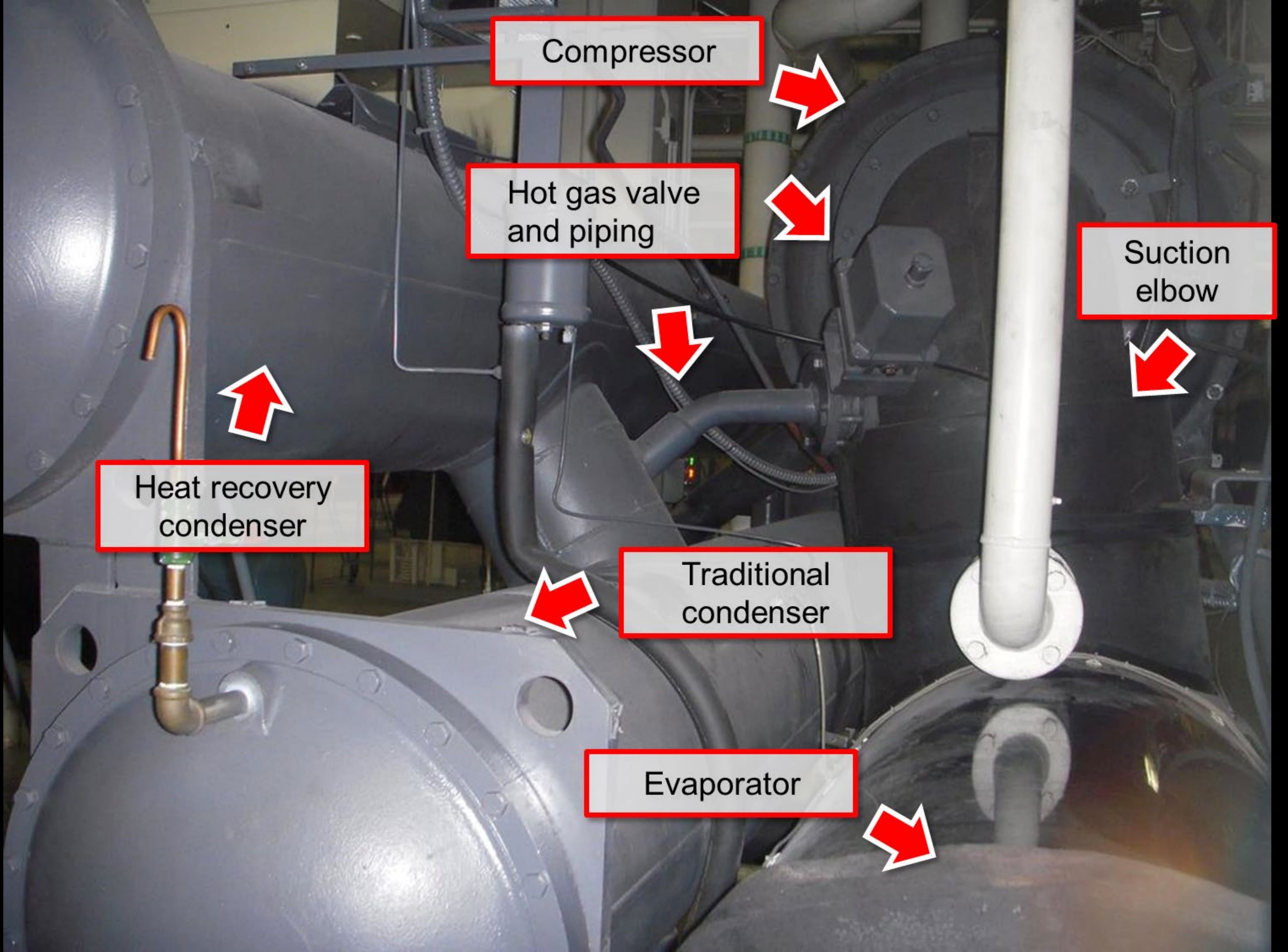
115 - 165 °F with a conventional heat recovery chiller

Taking a Look at a Heat Recover Chiller

Taking a Look at a Heat Recover Chiller



Taking a Look at a Heat Recover Chiller



More Specifically, How Hot Can We Get?

115 - 165 °F with a conventional heat recovery chiller

Heat Pump Application Checklist

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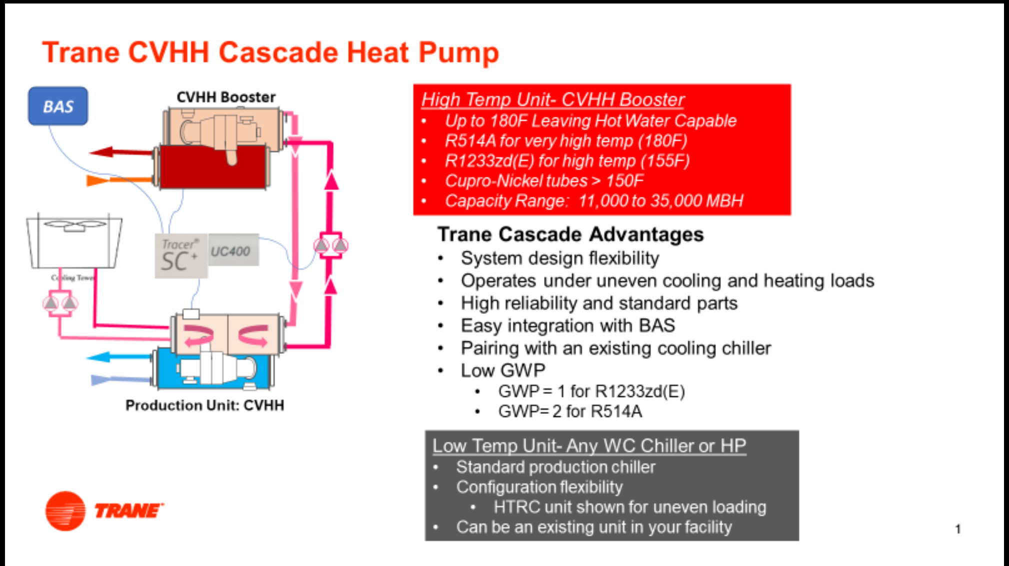
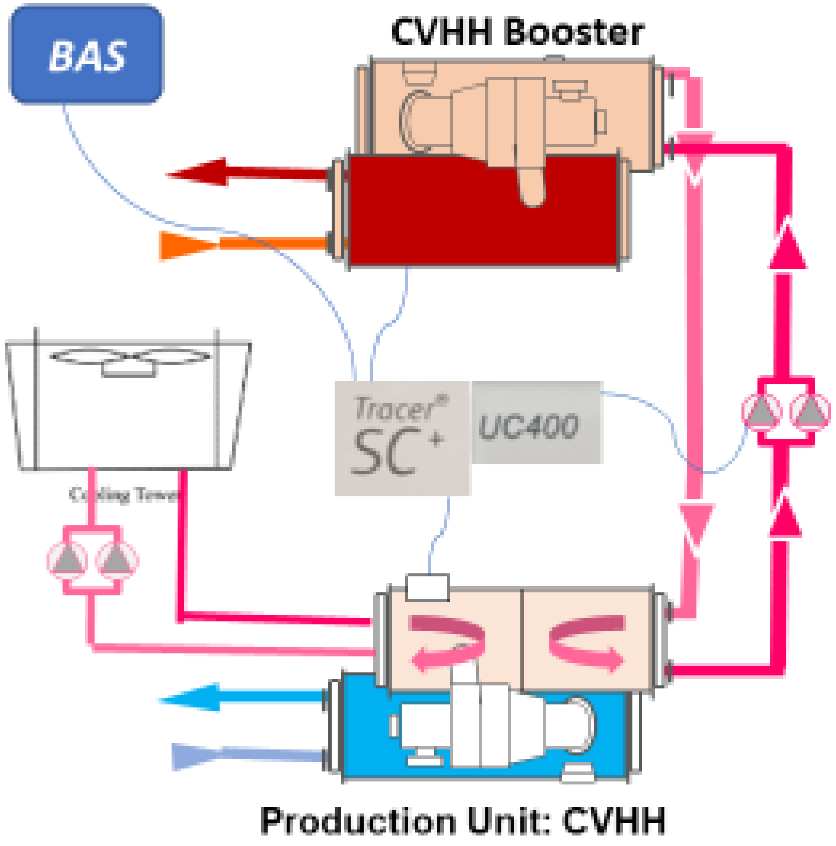
More Specifically, How Hot Can We Get?



180°F by cascading conventional chillers

(Image courtesy Dan Driver; DDriver@Trane,com)

Trane CVHH Cascade Heat Pump



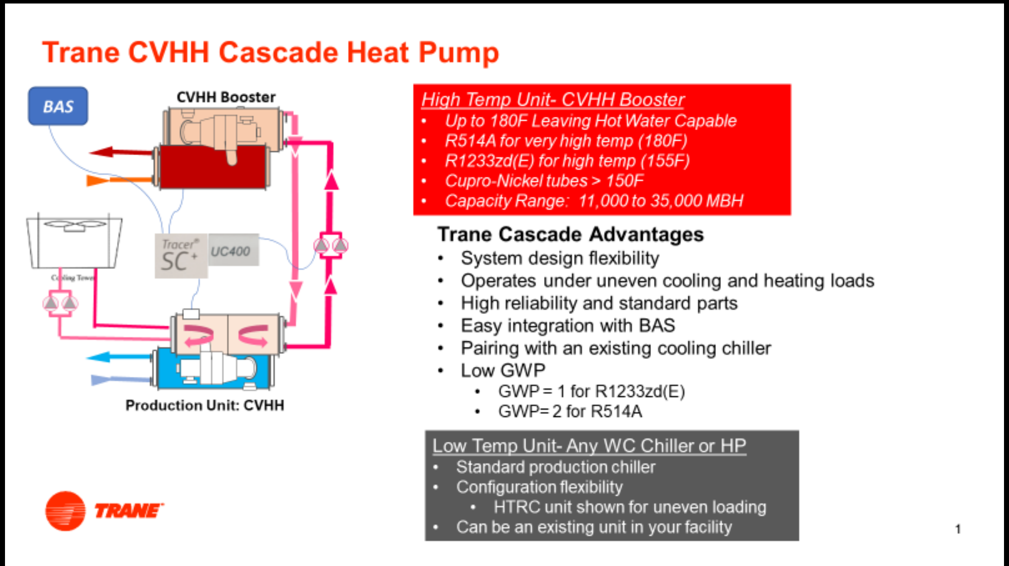
High Temp Unit- CVHH Booster
- *Up to 180F Leaving Hot Water Capable*
- *R514A for very high temp (180F)*
- *R1233zd(E) for high temp (155F)*
- *Cupro-Nickel tubes > 150F*
- *Capacity Range: 11,000 to 35,000 MBH*

Trane Cascade Advantages
- System design flexibility
- Operates under uneven cooling and heating loads
- High reliability and standard parts
- Easy integration with BAS
- Pairing with an existing cooling chiller
- Low GWP
  - GWP = 1 for R1233zd(E)
  - GWP= 2 for R514A

Low Temp Unit- Any WC Chiller or HP
- Standard production chiller
- Configuration flexibility
  - HTRC unit shown for uneven loading
- Can be an existing unit in your facility

TRANE

More Specifically, How Hot Can We Get?



180°F by cascading conventional chillers

Heat Pump Application Checklist

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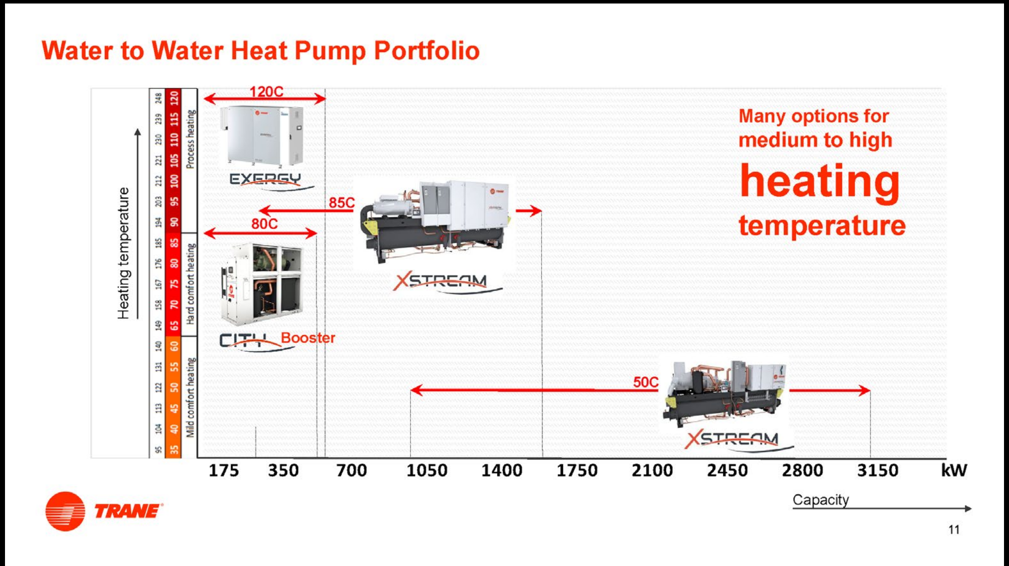
(Image courtesy Dan Driver; DDriver@Trane,com)

More Specifically, How Hot Can We Get?

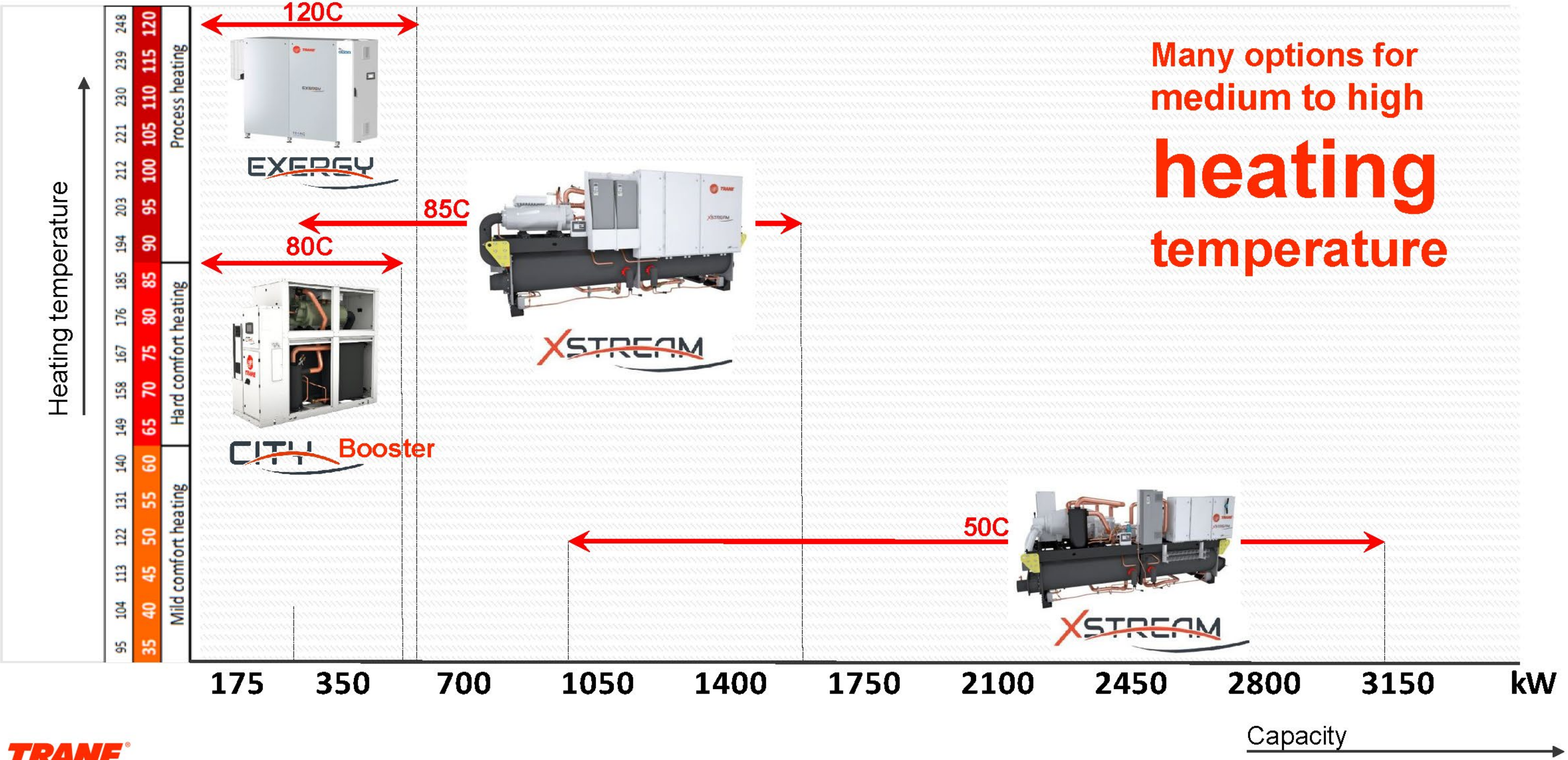


250°F with emerging technology

- Reciprocating chillers
- Approximately 150-200 ton capacity range

(Image courtesy Dan Driver; DDriver@Trane,com)

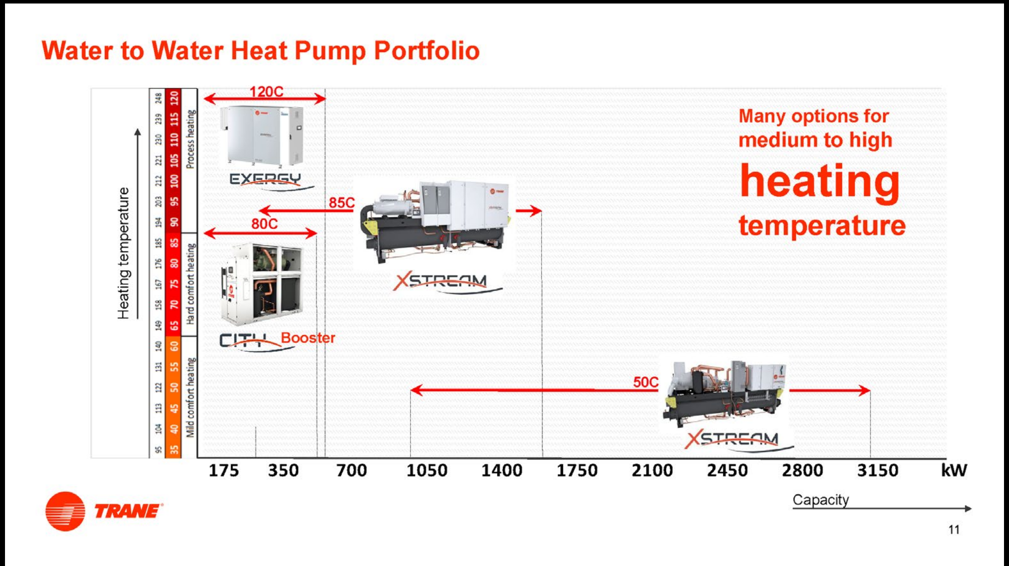
Water to Water Heat Pump Portfolio



Many options for medium to high **heating** temperature

TRANE

More Specifically, How Hot Can We Get?



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Heat Pump Application Checklist

Energy Available to Recover

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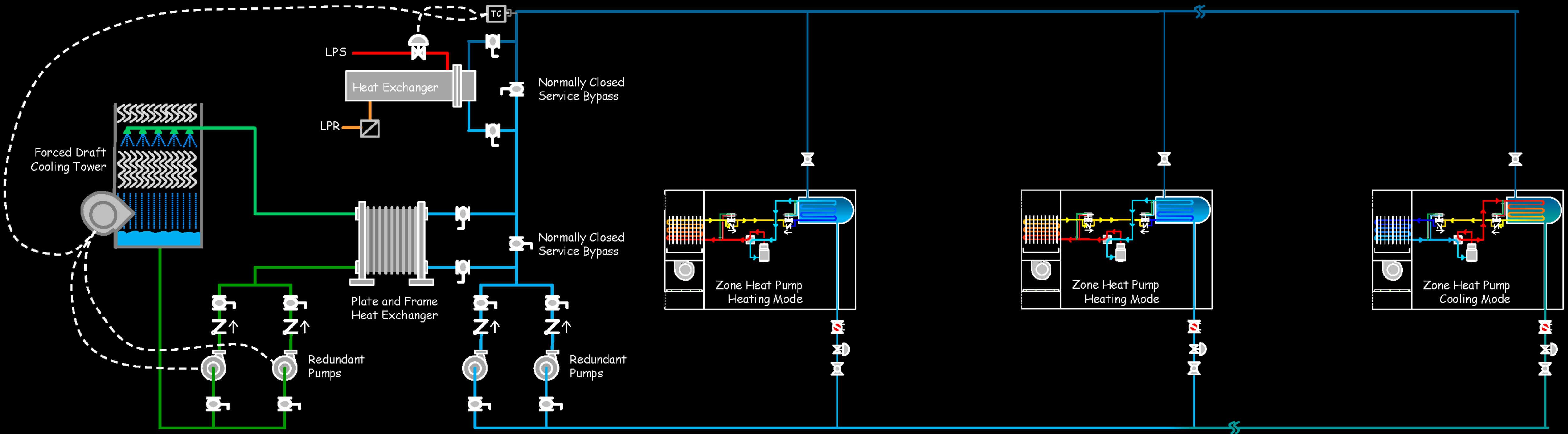
Loads that can Use Low Grade Heat

(Image courtesy Dan Driver; DDriver@Trane,com)

Another Question For You

https://tinyurl.com/HeatPumpD3WSLoopQ3-1



Water Source Heat Pump Loop
2022-11-16
DS

Point List

Point		System and Service	Sensor		Features											Notes
Name	Number		Type	Accuracy	Alarms				Trending							
					Limit		Warning		Samples	Commissioning[5]			Operating[5]			
					Hi	Lo	Hi	Lo		Time[2]	Local[3]	Archive	Time[2]	Local[3]	Archive[4]	
Analog Inputs																
Analog Outputs																
Digital Inputs																
Digital Outputs																
Safety Interlocks (Hardwired to shut down the system. Safeties shall funciton no matter what position the equipments Hand-Off-Auto, Inverter-Bypass, or other selector switches are in)																
Network Points																

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

There Can Be A Lot to Coordinate

IDU Remote Controller Features and Settings

Function Settings (Nt. 18) — 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)	Use Remote Controller Temperature: Use Remote Sensor	Use Remote Controller Temperature: Use Internal Sensor	Power Failure Recovery Mode: Automatically Restart	Power Failure Recovery Mode: Do not restart (Note 16)	External Static Pressure Setting, in.w.c. (Note 17)	User Password (Note 8)	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	Timer: Auto-Off	Display Format: Language	Display Format: Temperature Unit	Display Format: Show/hide Room Temp.	Display Format: Backlight Timeout	Sound/Contrast: Sound	Sound/Contrast: Contrast
BACnet Access									▶	X	X	X		X	X	X	N/A		N/A				N10								
Password Protected								▶	▶								N/A		N/A	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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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

HVAC System	Energy Savings Assistant – Mode Settings – Select 1 (Note 11): Non-Use	Thermo-off	Temp. Offset	Fan Spd. Down	On/Off	Operating Mode	Note 13: Offset Value	Auto-Away Time	Detection Level	Invalidate Item Setting: Date and Time	Light Sensor: Enable/Disable	Light Sensor: 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	Brightness: High	Brightness: Low	Color During Energy Savings	Occupany Detection Indication	Switch LED Brightness via Space Brightness: Enable/Disable	Light Detected	Dark Detected	Touch Panel Calibration
Password Protected	X												X																					X
DOAS 1																																		
IDU-1.2						X	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
IDU-1.3						X	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
DOAS 2																																		
IDU-1.14						X	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
IDU-1.15						X	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
IDU-2.1						X	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
IDU-2.2						X	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
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IDU-2.4B						X	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
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DOAS 3																																		
IDU-1.4	X						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
IDU-1.5	X						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
IDU-1.6	X						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
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IDU-2.9						X	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
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IDU-1.9	X						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
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HRV-1																																		
IDU-1.12	X						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
HRV-2																																		
IDU-1.13	X						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
HRV-3																																		
IDU-1.1	X						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

HVAC System	Lockable Remote Controller Functions Lock State: On/Off	Operating Mode	Set Temp.	Fan Speed	Air Direction	Lover Swing	LOSSNAY Speed	Hold	Sensor Threshold: Occupancy	Brightness Sensor: Light Threshold	Brightness Sensor: 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	Cool-Heat Display: Setback Mode	Override Control: Enable/Disable	Override Control: Operating Time	Temp. Sensor Offset	Humidity Sensor Offset	Auto Mode (Select 1): Single Setpoint	Auto Mode (Select 1): Dual Setpoint	Room Name	Telephone Number	LED Colors	Extra Occupancy Sensor, Note 1	Notes
Password Protected	X								X			X						X					X	X	X	X	X	X		X	X	X	X		X	X	X		
DOAS 1																																							
IDU-1.2	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	L	L	U	L	N/A	N/A	N/A	L	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	

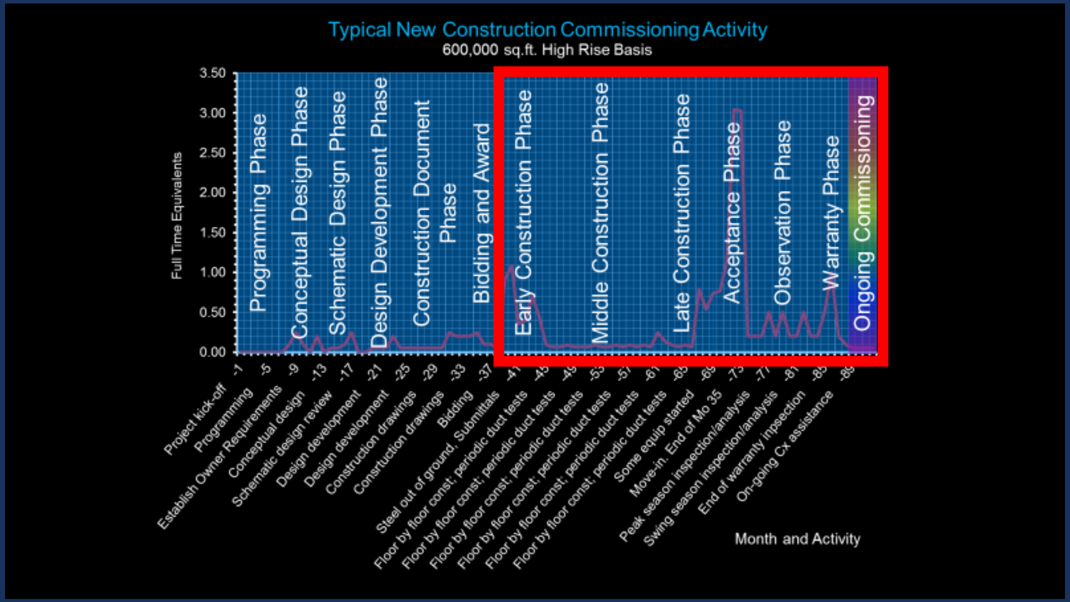
Notes

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.

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



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?

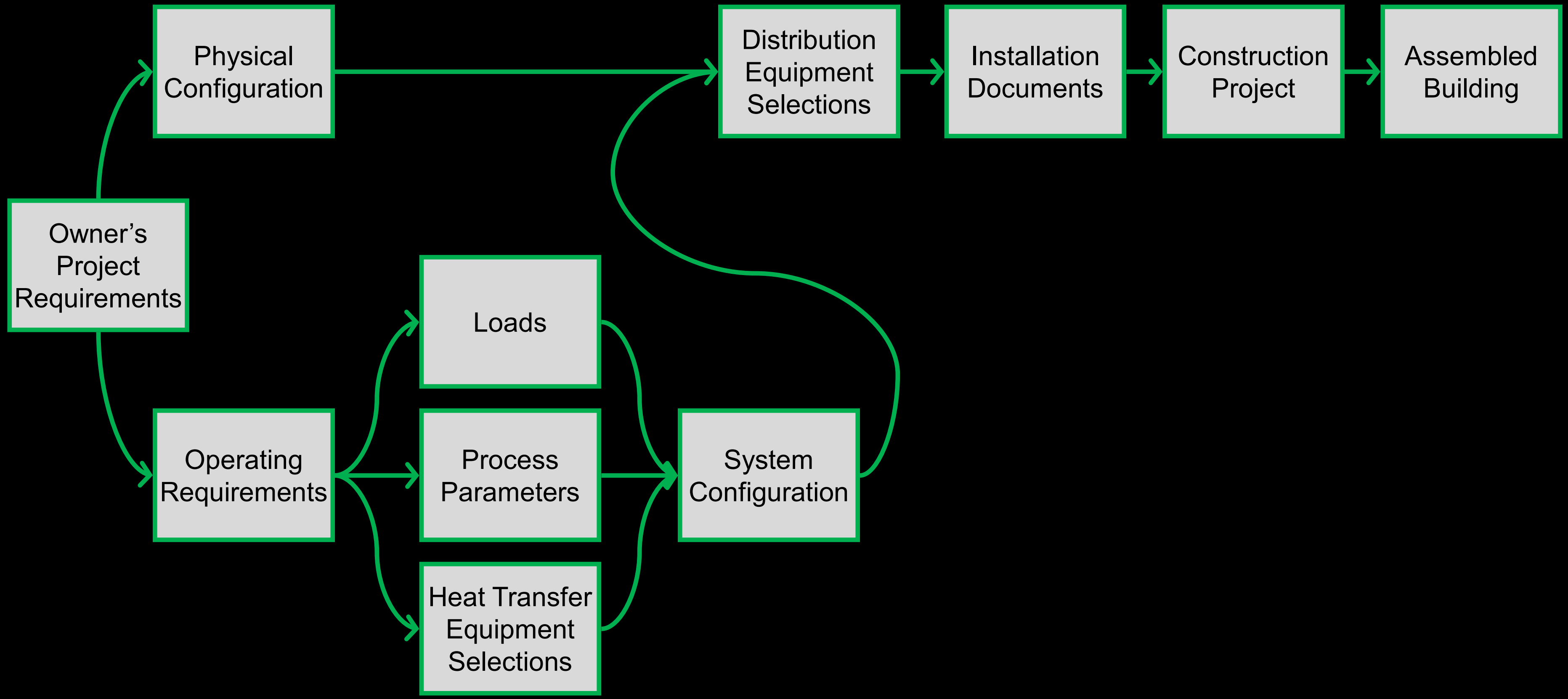
Functional Testing

- Core element of any commissioning process
- Validates machinery and systems for an EBCx Process
    - Why don’t they deliver?
    - Why aren’t they working well together
    - How big should it be?

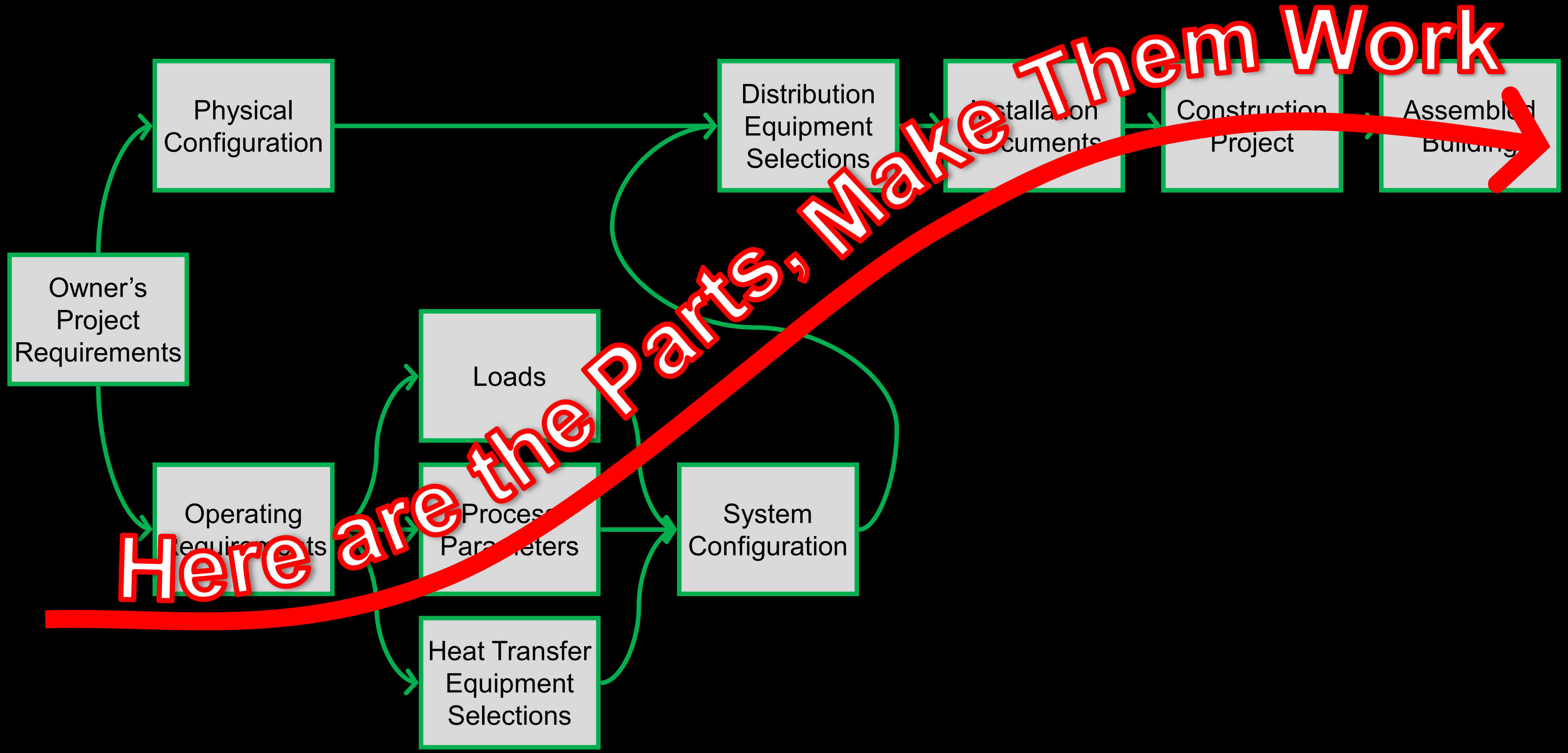
Functional Testing

- 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?

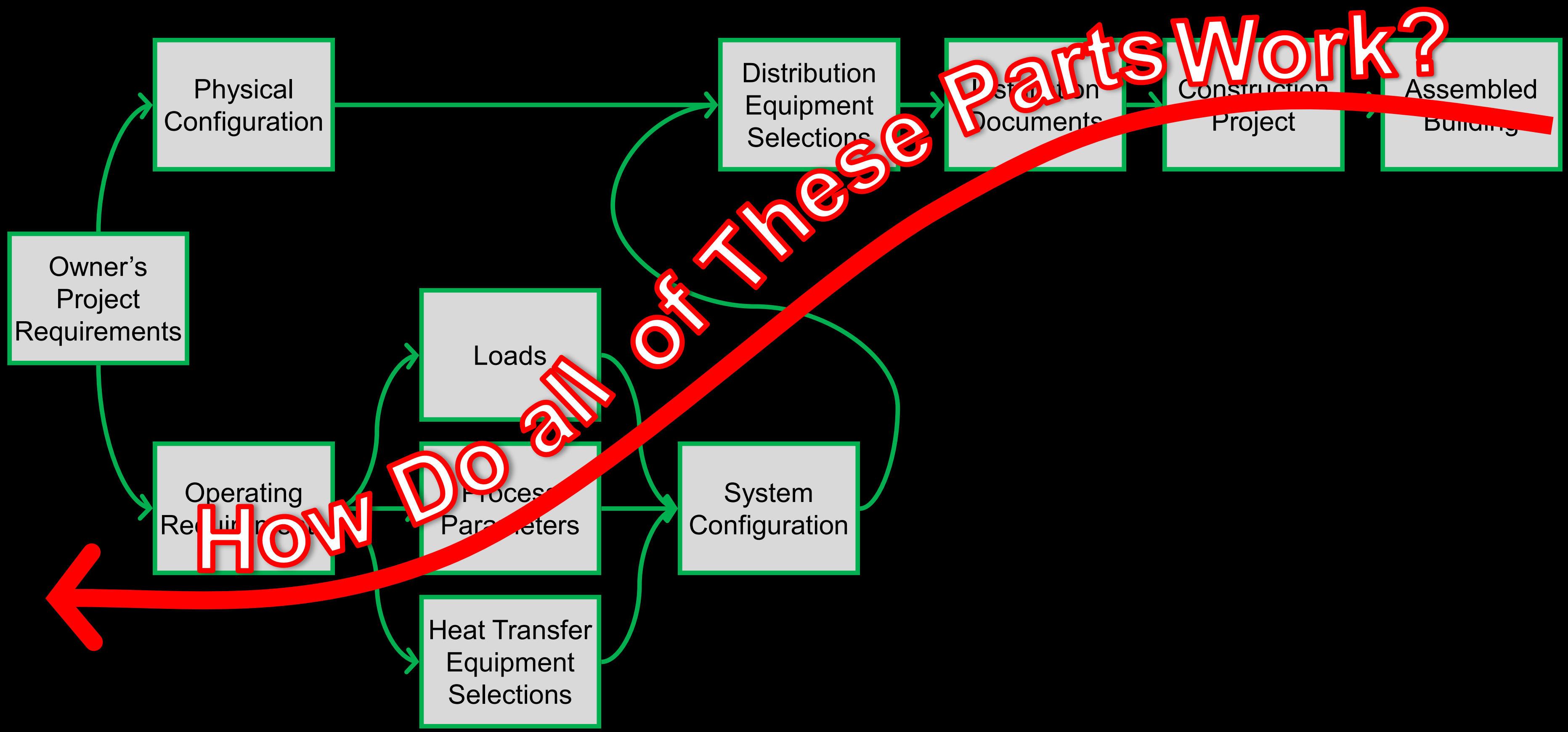
Functional Testing as it Relates to the Metrics of the Systems We Test



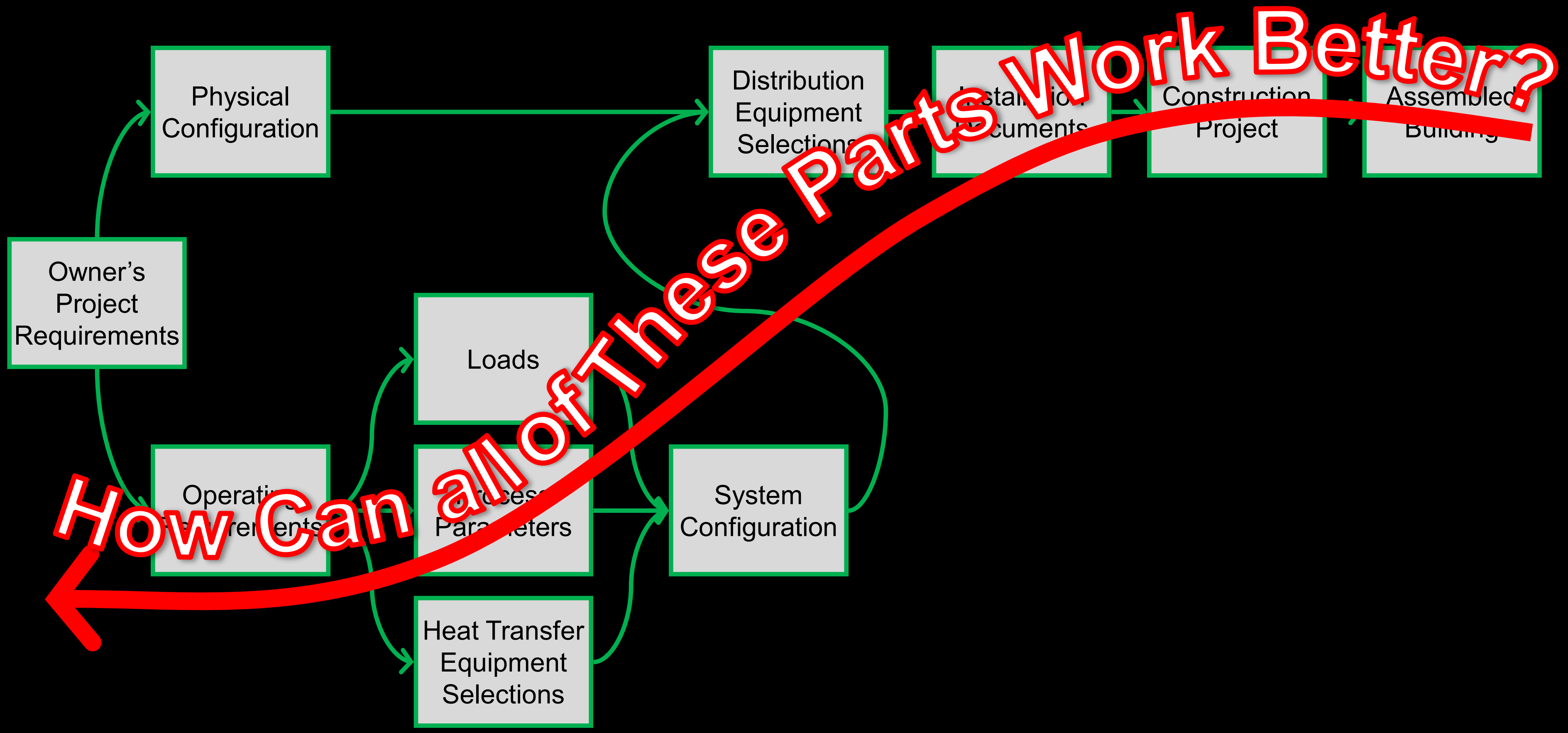
Functional Testing as it Relates to the Metrics of the Systems We Test – New Construction Perspective



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



New Construction versus EBCx Testing

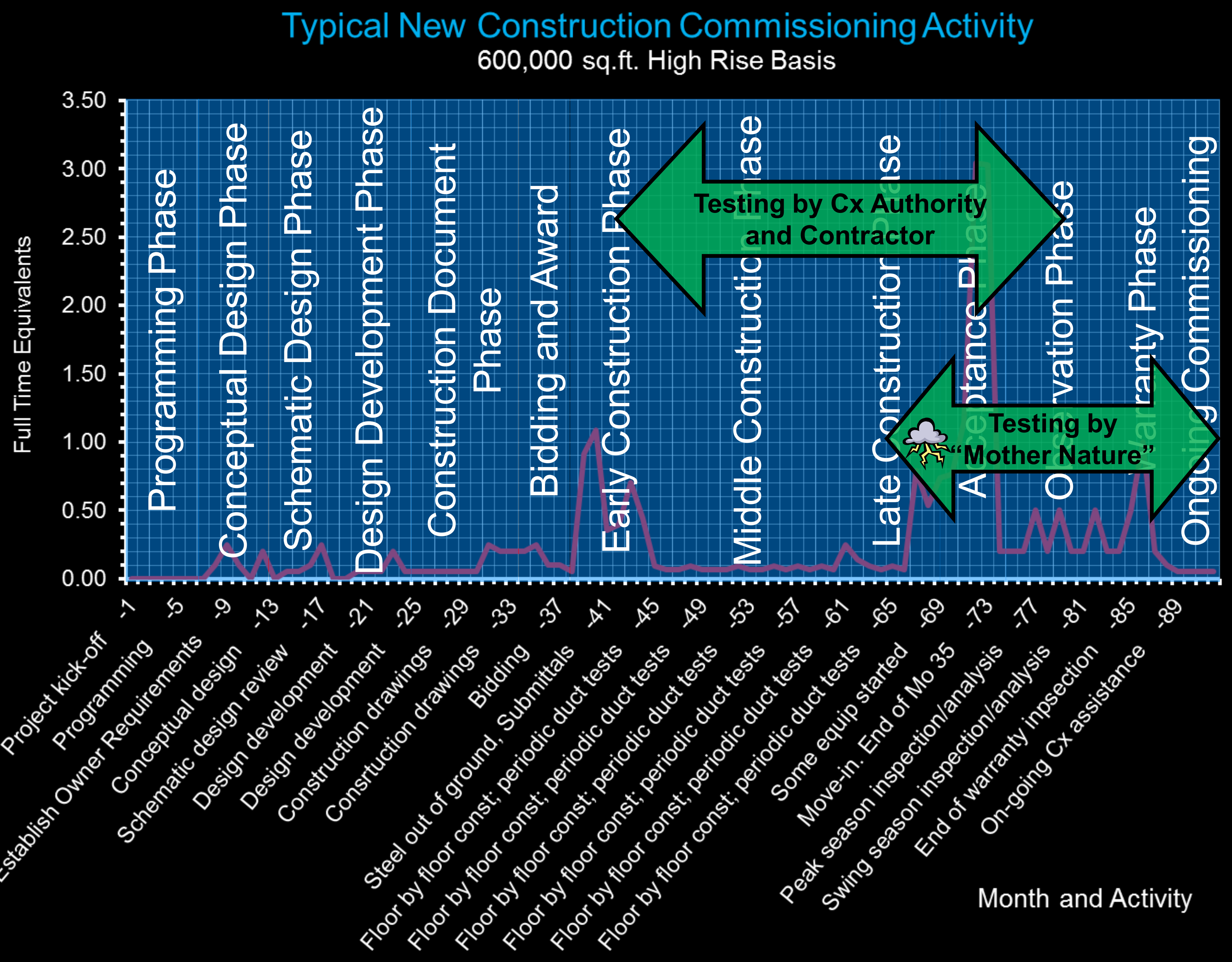
New Construction

- 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

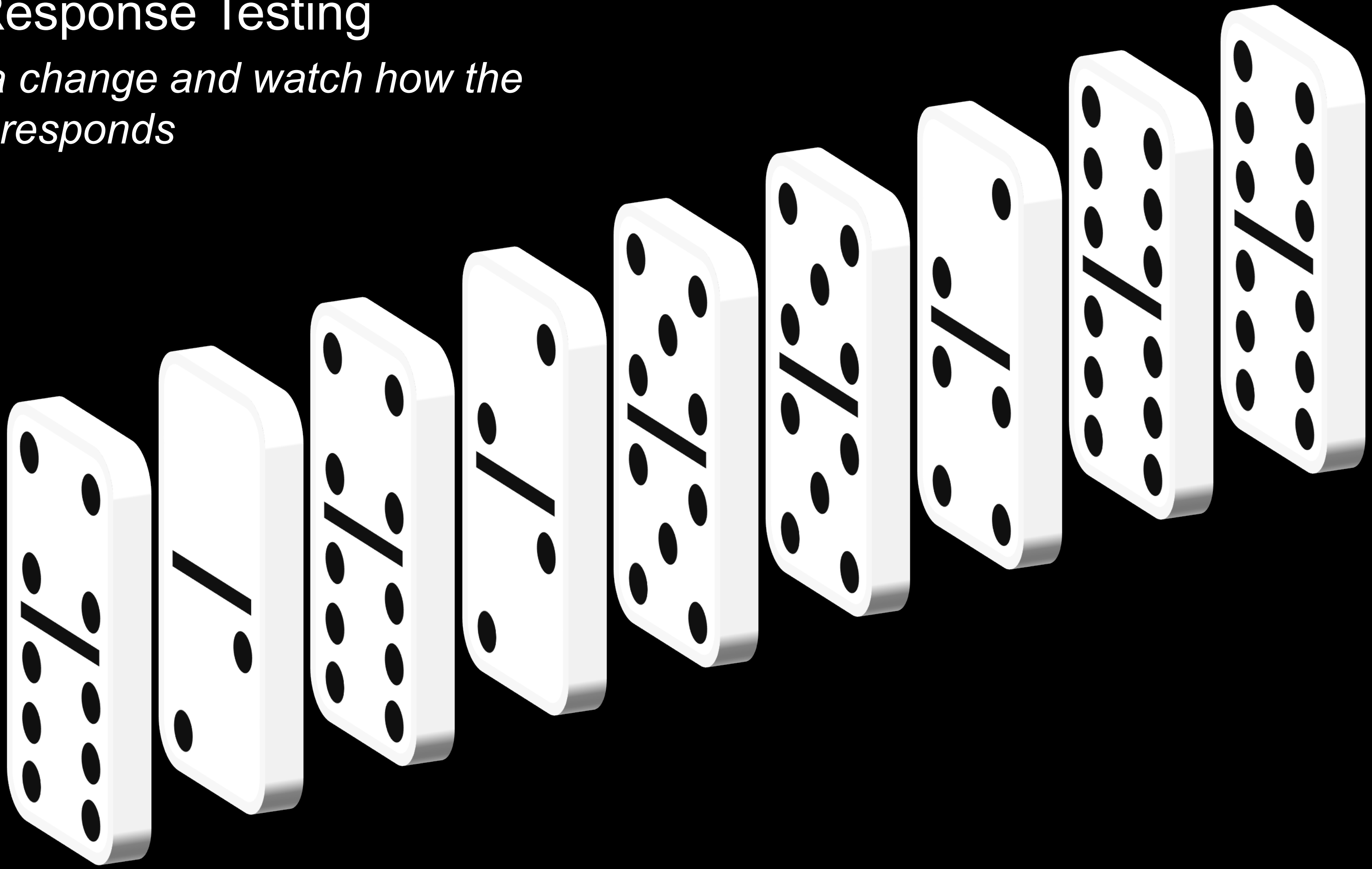
Functional Testing as it Relates to the Project Timeline


Typical New Construction Commissioning Activity
600,000 sq.ft. High Rise Basis
Full Time Equivalents
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Programming Phase
Conceptual Design Phase
Schematic Design Phase
Design Development Phase
Construction Document Phase
Bidding and Award
Early Construction Phase
Middle Construction Phase
Late Construction Phase
Acceptance Phase
Observation Phase
Warranty Phase
Ongoing Commissioning
Testing by Cx Authority and Contractor
Testing by "Mother Nature"
-1 -5 -9 -13 -17 -21 -25 -29 -33 -37 -41 -45 -49 -53 -57 -61 -65 -69 -73 -77 -81 -85 -89
Project kick-off
Programming
Establish Owner Requirements
Conceptual design
Schematic design review
Design development
Design development
Construction drawings
Consrtuction drawings
Bidding
Steel out of ground, Submittals
Floor by floor const; periodic duct tests
Floor by floor const; periodic duct tests
Floor by floor const; periodic duct tests
Floor by floor const; periodic duct tests
Floor by floor const; periodic duct tests
Floor by floor const; periodic duct tests
Some equip started
Move-in. End of Mo 35
Peak season inspection/analysis
Swing season inspection/analysis
End of warranty inpsection
On-going Cx assistance
Month and Activity

Forced vs. Natural Response Testing

Forced Response Testing

I force a change and watch how the system responds



Forced vs. Natural Response Testing

Forced Response Testing

I force a change and watch how the system responds

View the video on Youtube at http://tinyurl.com/MR-1-Launch

Natural Response Testing

I observe how a system responds to the normal course of events

What Happened

1. Two electrical cables provided power and telemetry up to launch
    - One carried control signals – design intent was that it would separate first
    - One carried power and grounding signals – design intent was that it would separate second

What Happened

2. Separation timing was controlled by cable length
3. A field modification was made to the military version of the control cable to shorten it so it would separate second as intended for manned flight
4. The modification failed at lift-off
5. The power cable separated first

What Happened

6. Lack of grounding triggered a power surge through the engine cut off relay
   - Intended to trigger normal engine cut off at the end of flight
   - Shuts the engine down
   - Sends a “normal engine cut off” signal to the capsule

What Happened

7. “Normal engine cutoff” should trigger two things
   - Jettison the escape tower
   - Trigger explosive bolts to separate the capsule when the system detects no acceleration after free-fall started

What Happened

8. Jettisoning the escape tower arms the parachute system
9. Since the altitude was below 10,000 feet, the parachute deployment sequence was triggered
10. Since there was no weight detected on the main parachute, the system assumed it had failed and the reserve parachute was deployed

Bottom Line; Sometimes Things Don't Go as Anticipated

That doesn't mean the test was a failure

- Some things did work as intended
- Issues were identified and could be corrected

An HVAC System Example

Forced Response Testing

- With it 50°F outside and
- the AHU near 100% OA,

I override the outdoor air sensor and manually enter 100°F as the outdoor temperature

I Observe That :

- Outdoor air dampers commanded to MOA
- Leaving air set point commanded to low end of reset range
- Chilled water valve opens

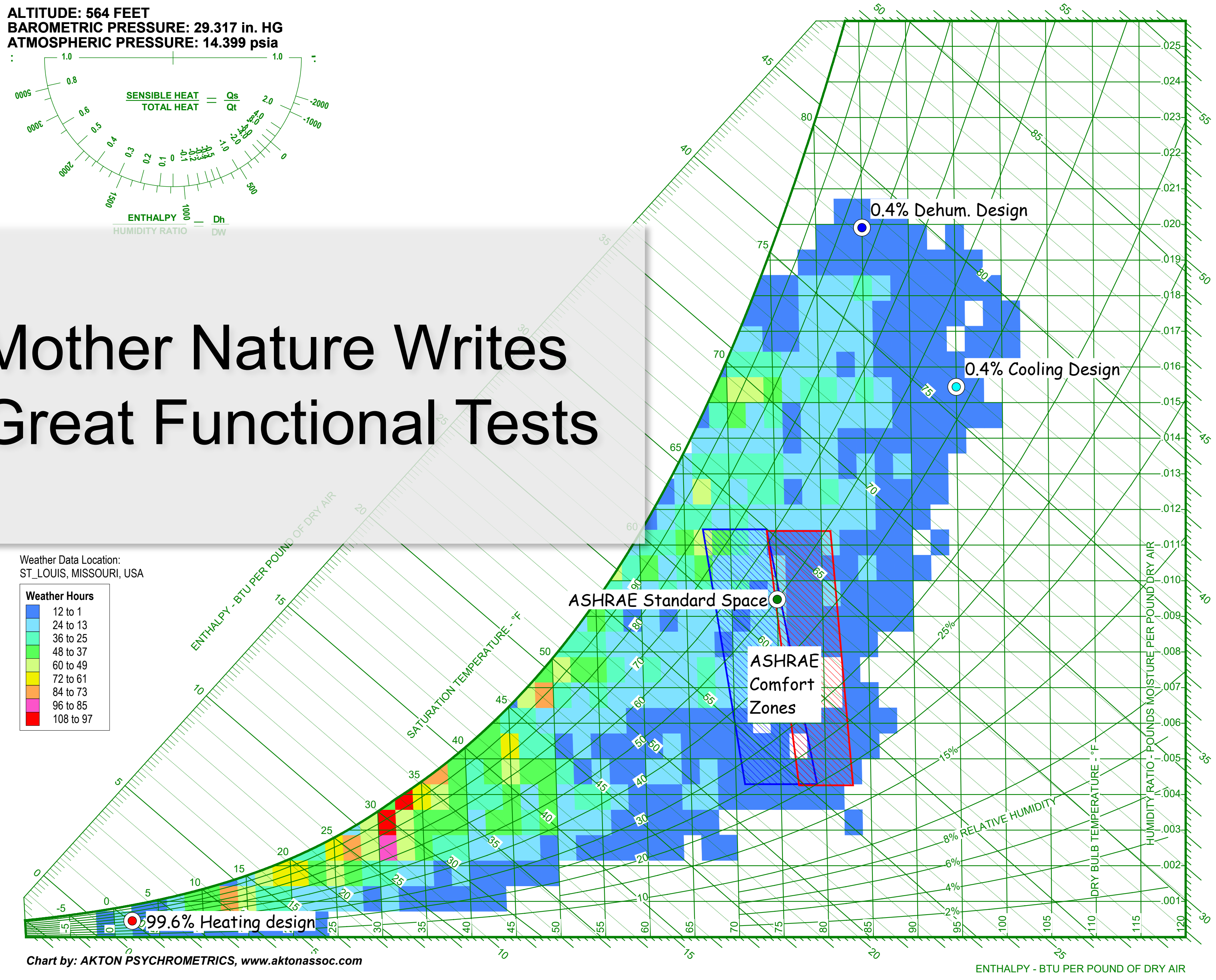
Natural Response Testing

- I pull trend data from the system for a day when the outdoor air temperature swung from 53 – 82°F

I Observe That

- Transition to and from economizer at appropriate temperatures
- Chilled water temperature instability during low outdoor air temperature periods
- Return fan tracking fails on minimum outdoor air

Mother Nature Writes Great Functional Tests



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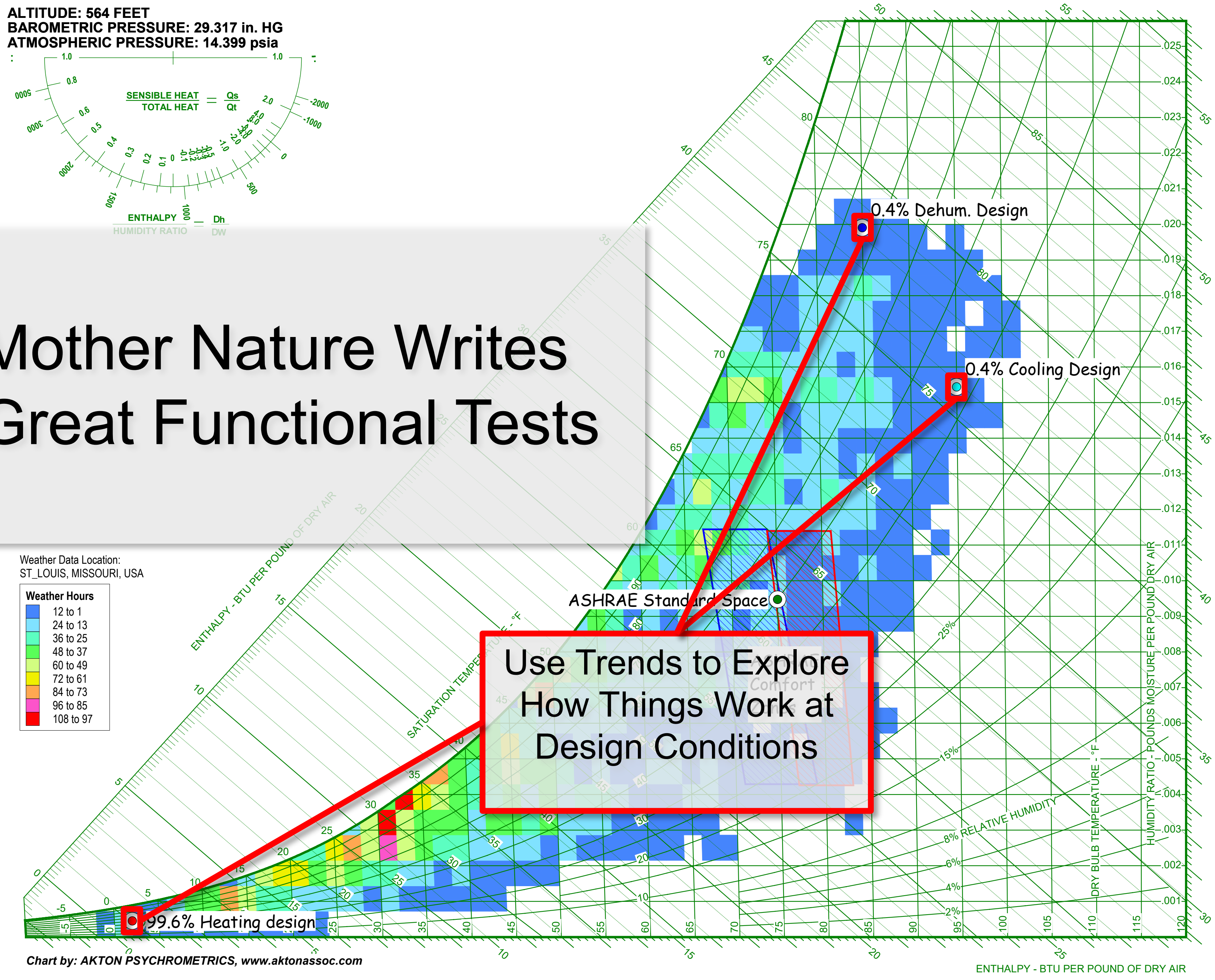

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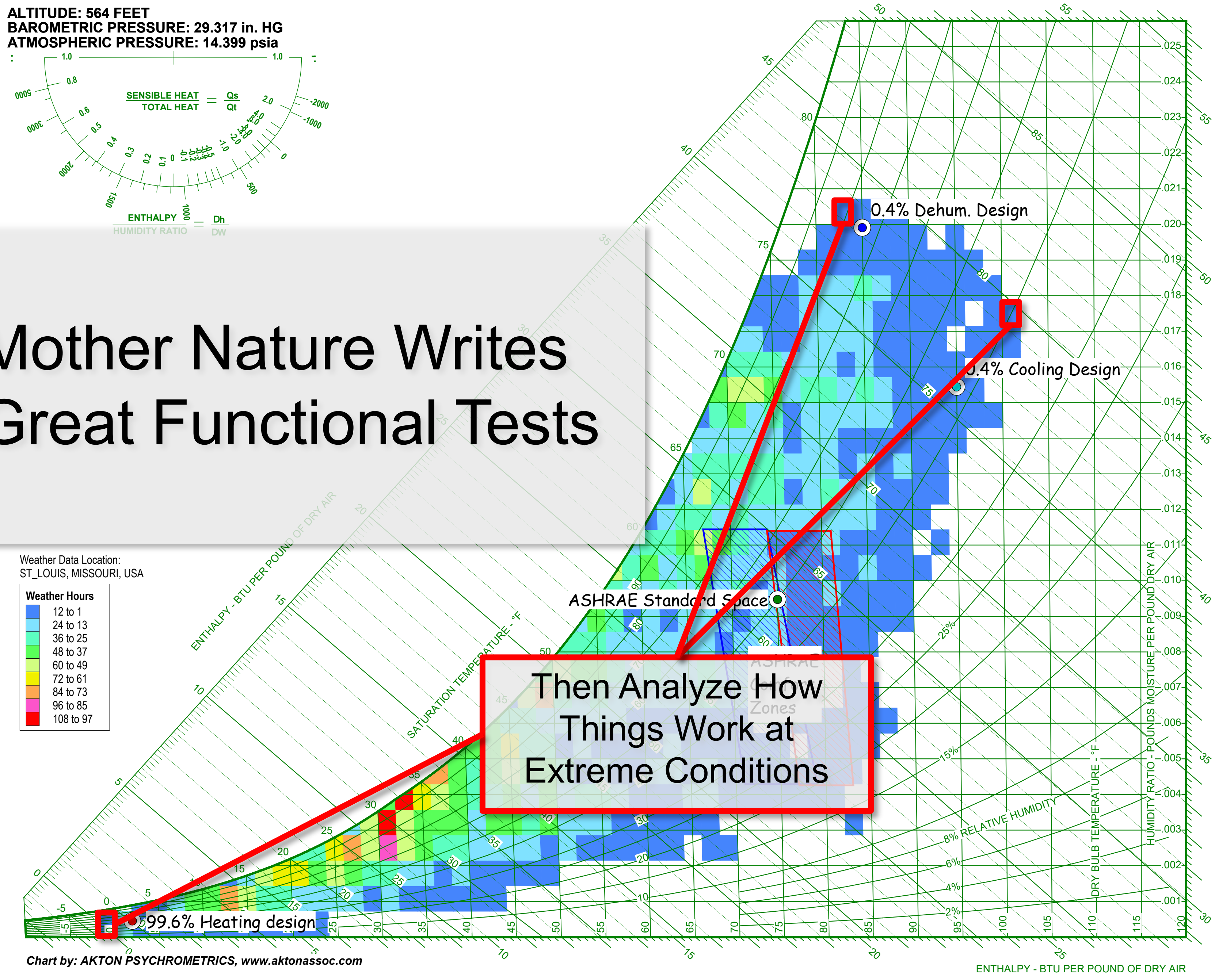

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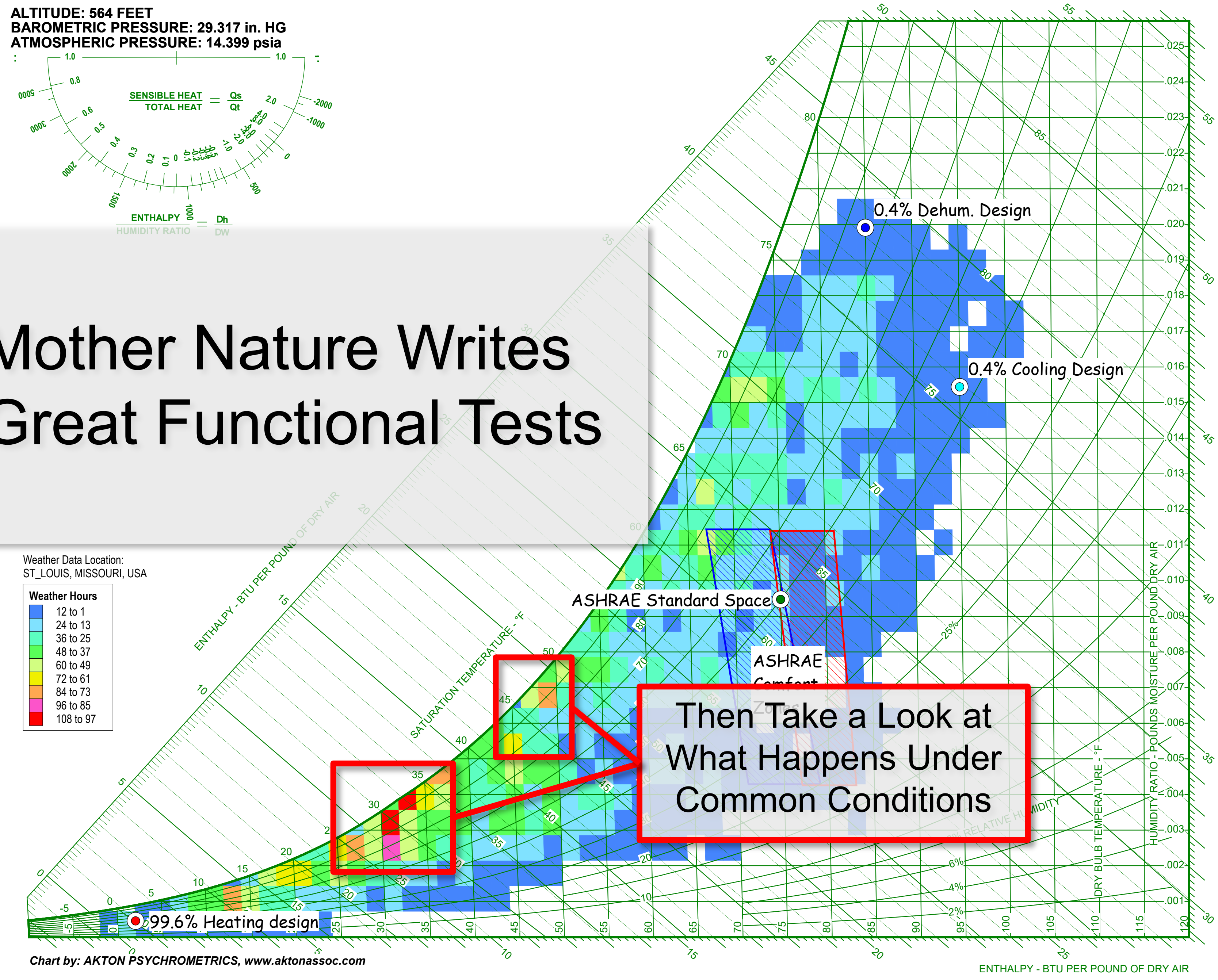
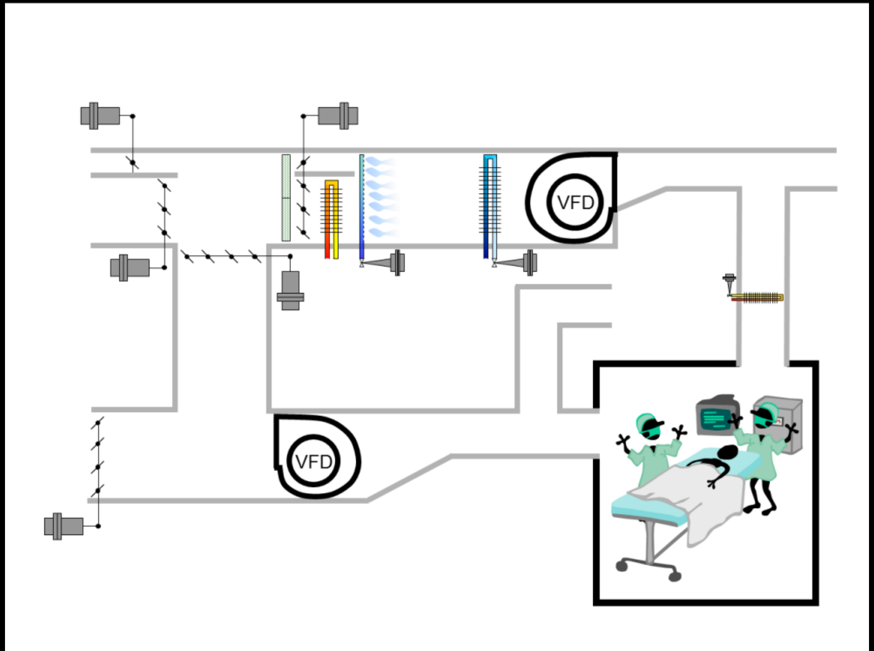
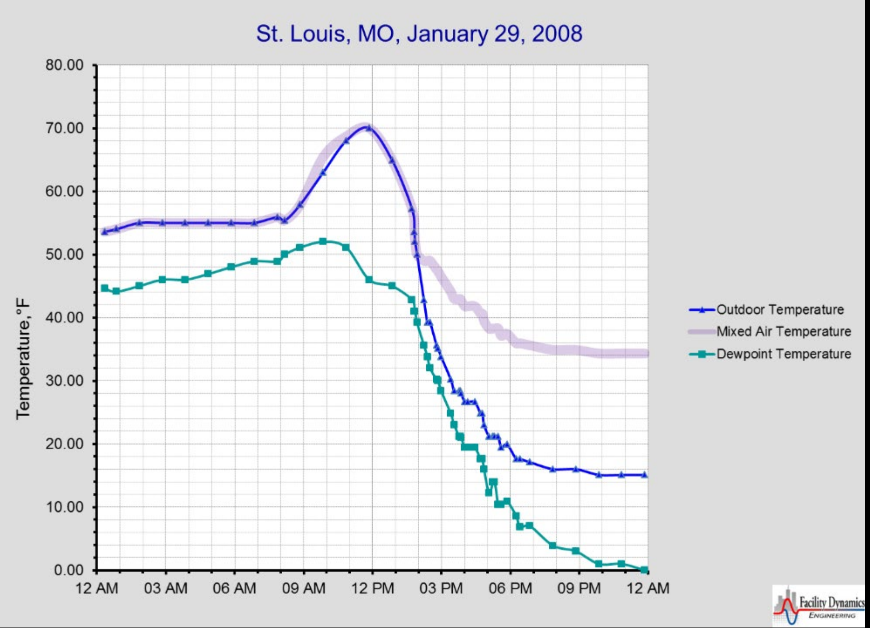


Then Take a Look at What Happens Under Common Conditions

Don't Forget to Consider a Day with an Extreme Diurnal Swing and its Impact on the Performance of Sensitive HVAC Processes

Mother Nature Writes Great Functional Tests





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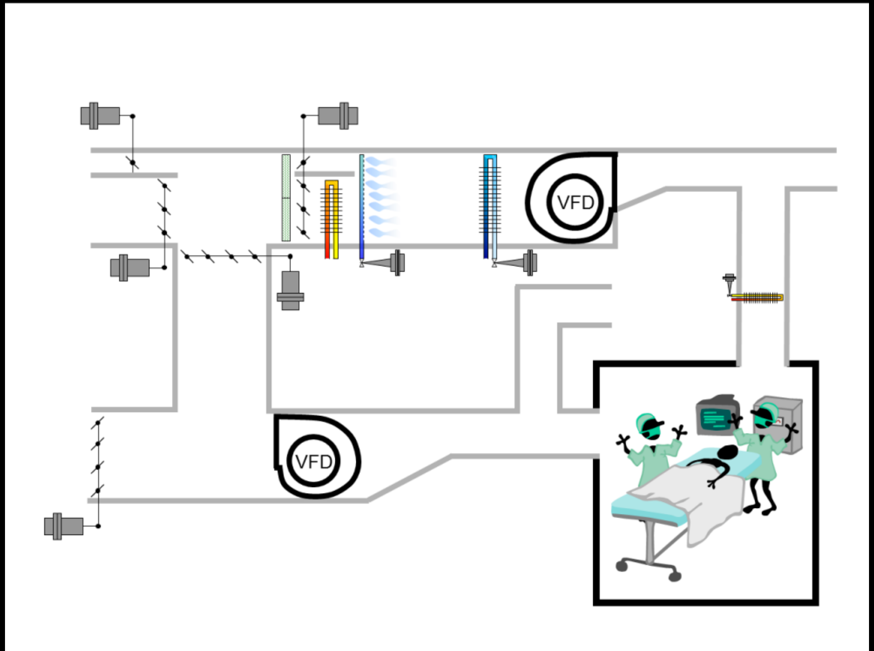
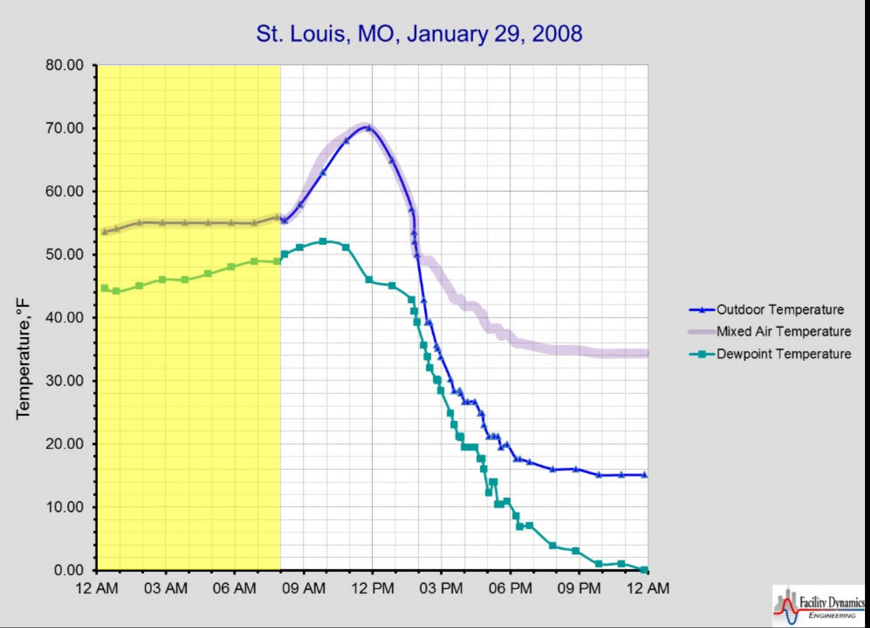


Mother Nature Writes Great Functional Tests

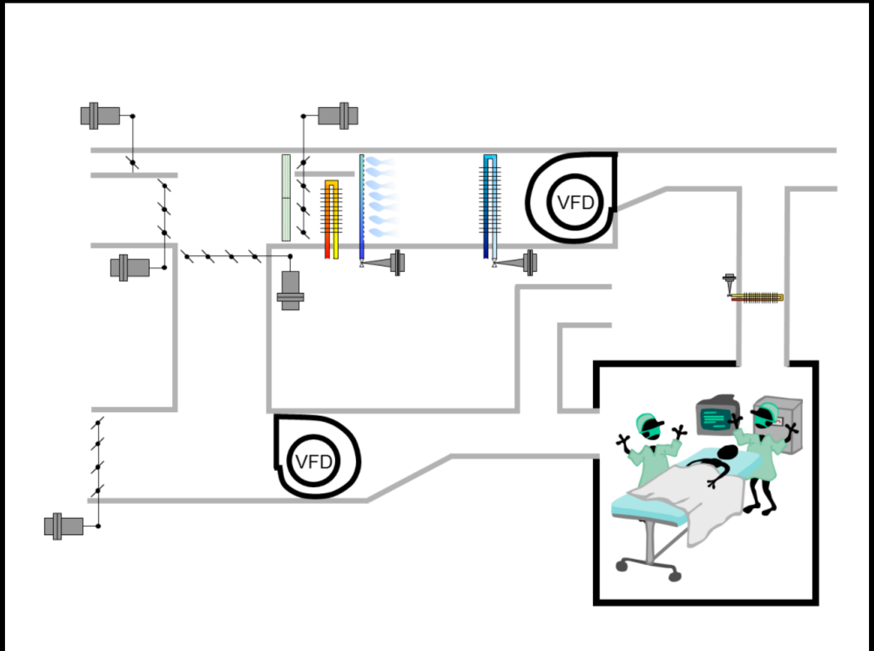
100% Outdoor Air with Humidification

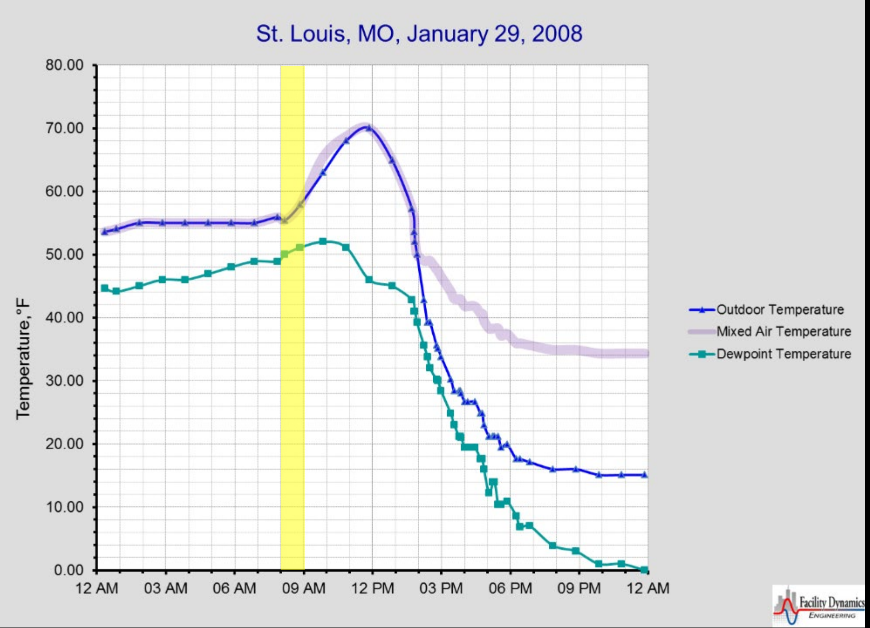


Don’t Forget to Consider a Day with an Extreme Diurnal Swing and its Impact on the Performance of Sensitive HVAC Processes

Mother Nature Writes Great Functional Tests

100% Outdoor Air





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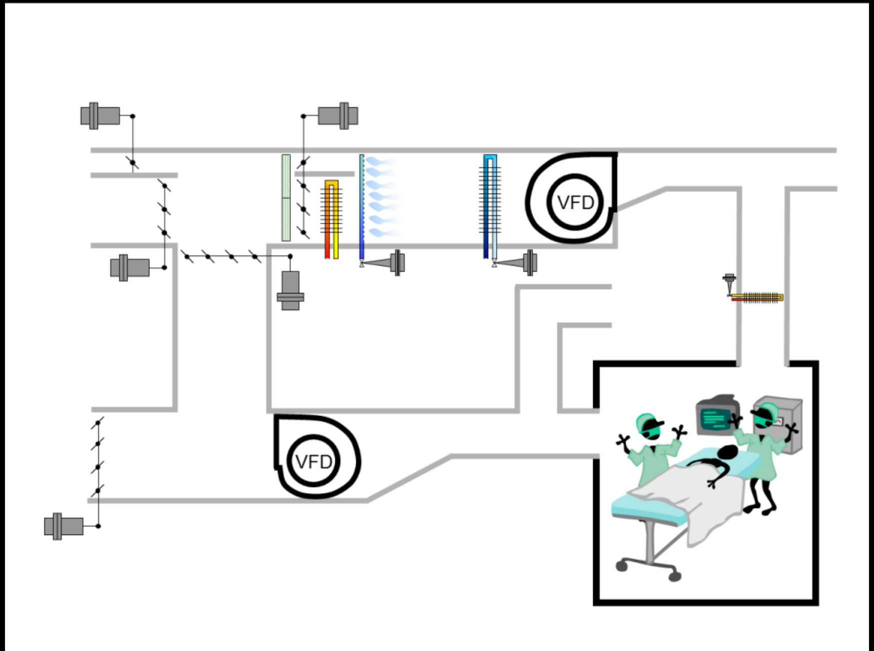
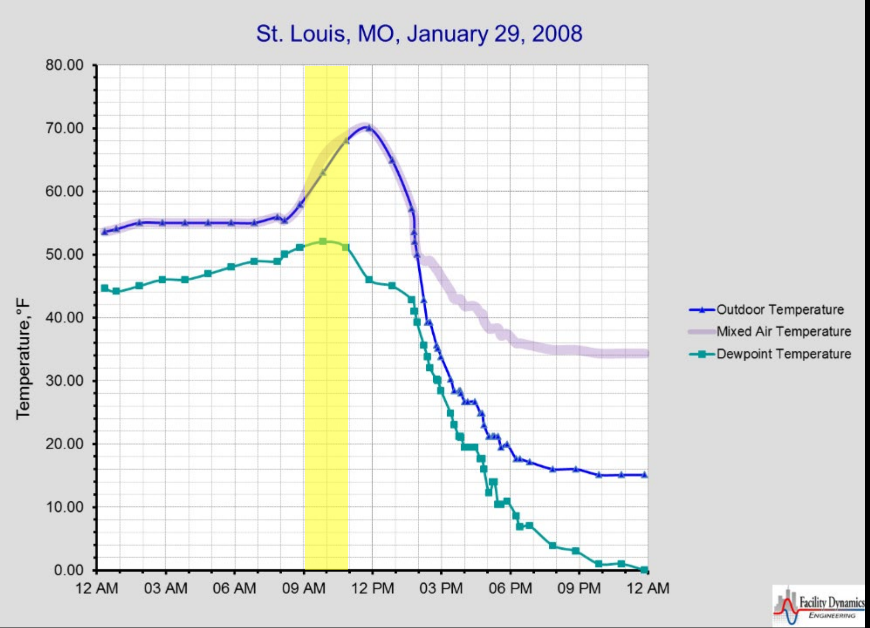
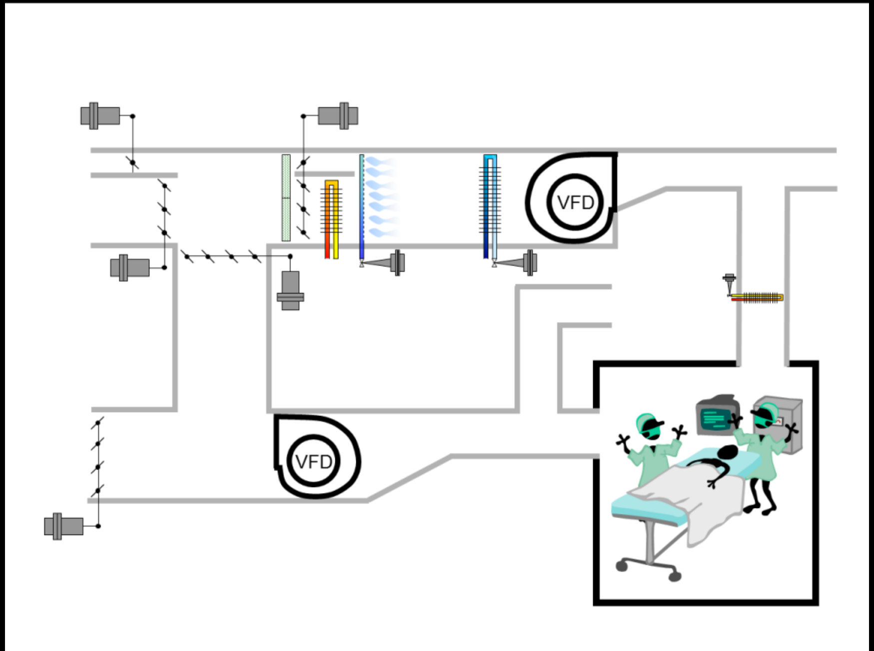


Mother Nature Writes Great Functional Tests

Enthalpy Driven Change-over to Minimum Outdoor Air

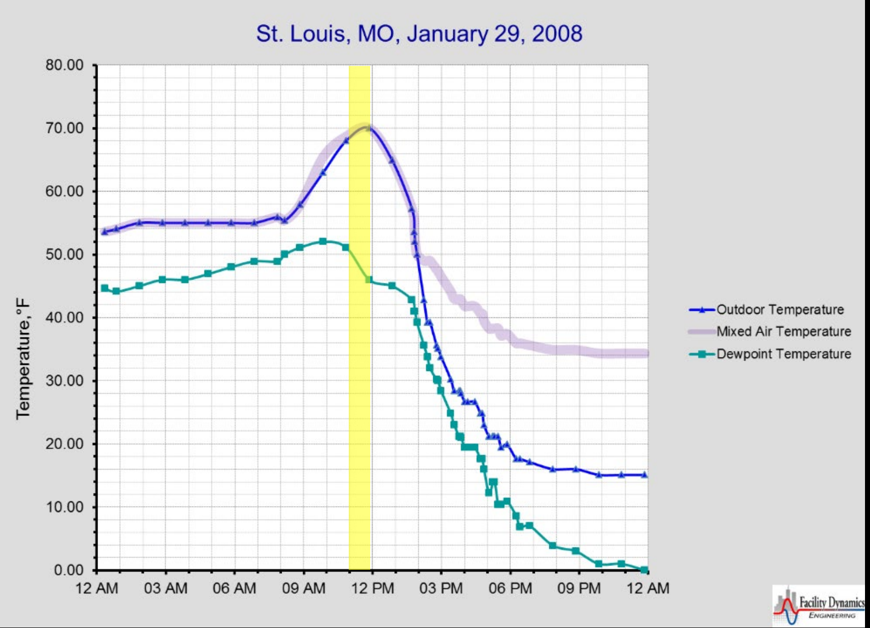


Don't Forget to Consider a Day with an Extreme Diurnal Swing and its Impact on the Performance of Sensitive HVAC Processes



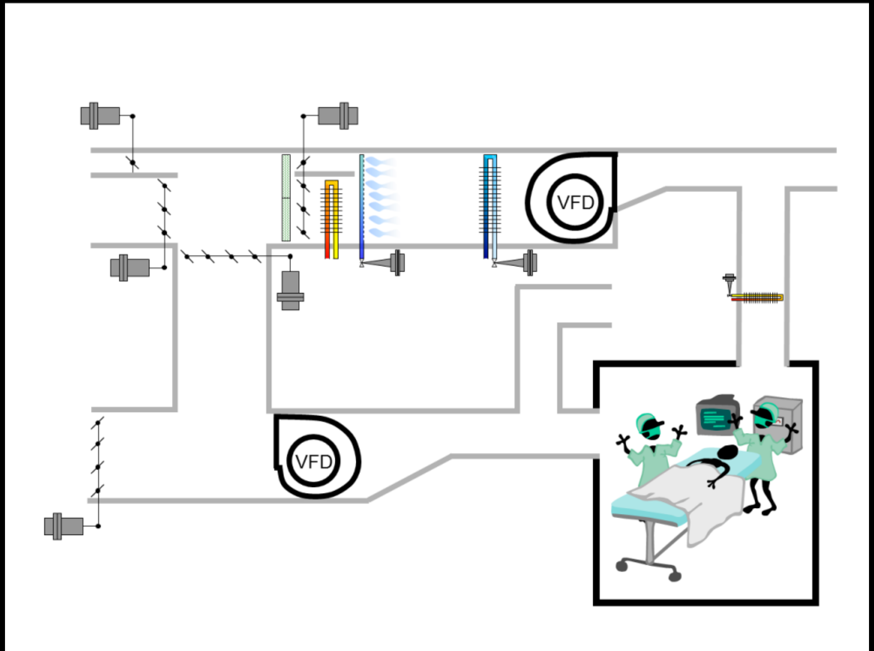
Mother Nature Writes Great Functional Tests

Minimum Outdoor Air with Humidification

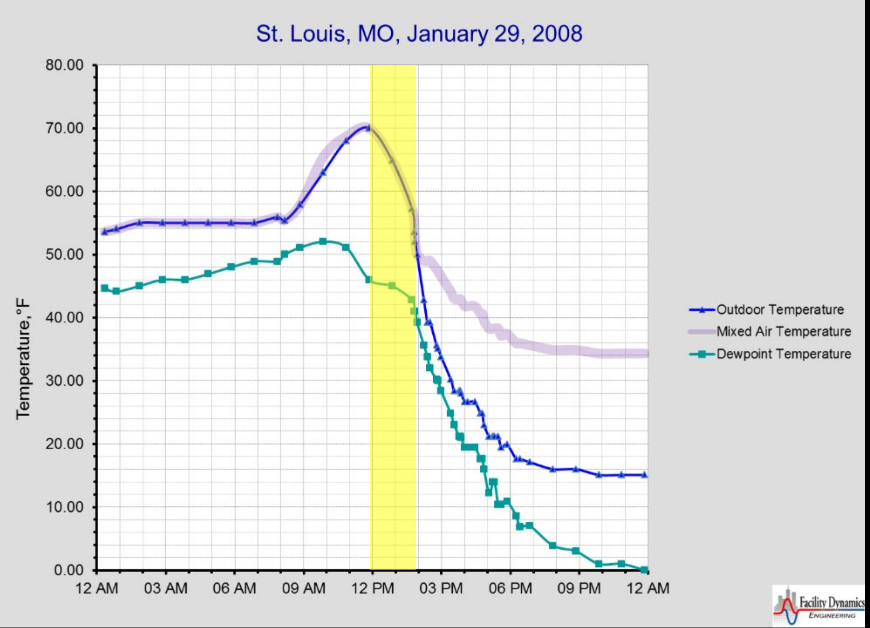


Don't Forget to Consider a Day with an Extreme Diurnal Swing and its Impact on the Performance of Sensitive HVAC Processes

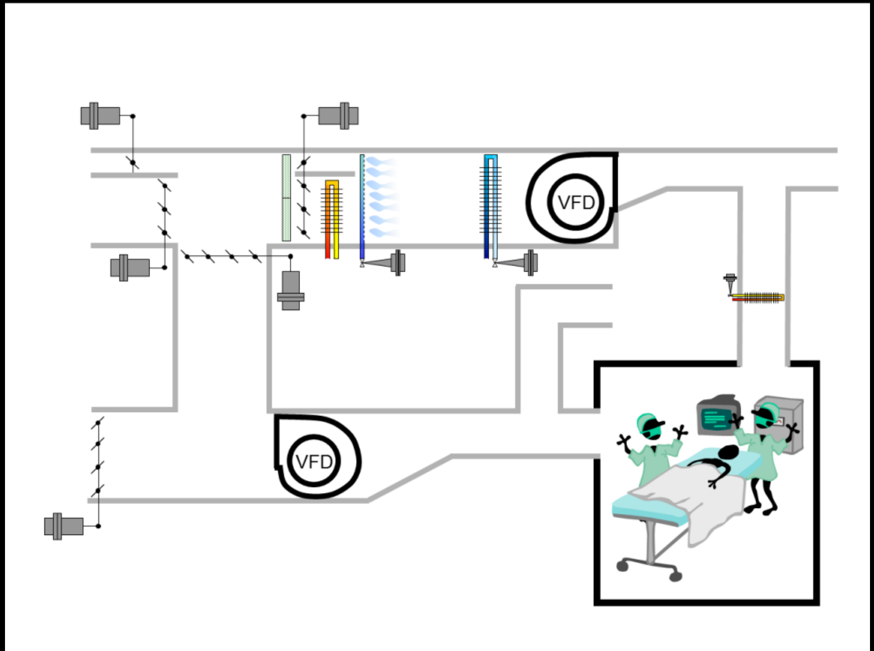
Mother Nature Writes Great Functional Tests



Enthalpy Driven Change-over to 100% Outdoor Air, Humidification

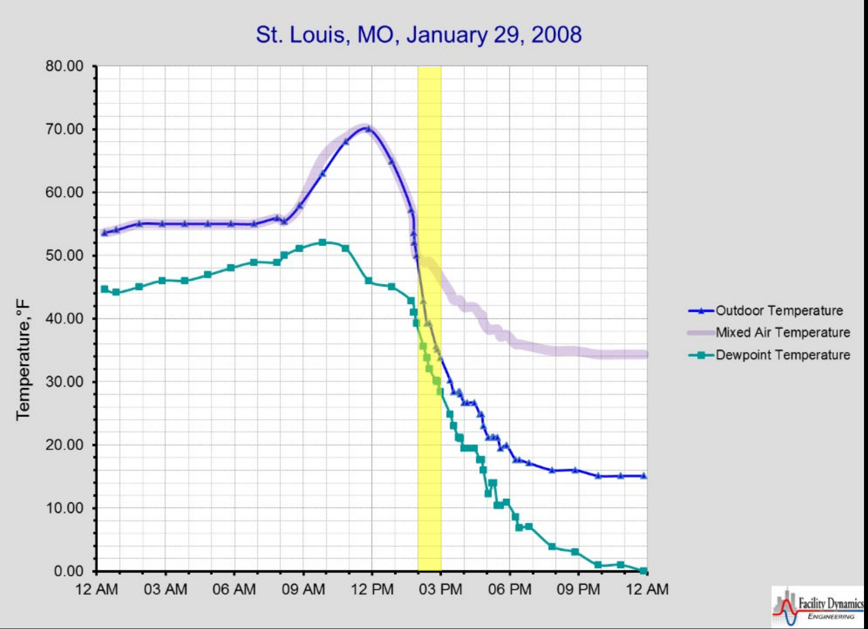


Don't Forget to Consider a Day with an Extreme Diurnal Swing and its Impact on the Performance of Sensitive HVAC Processes



Mother Nature Writes Great Functional Tests

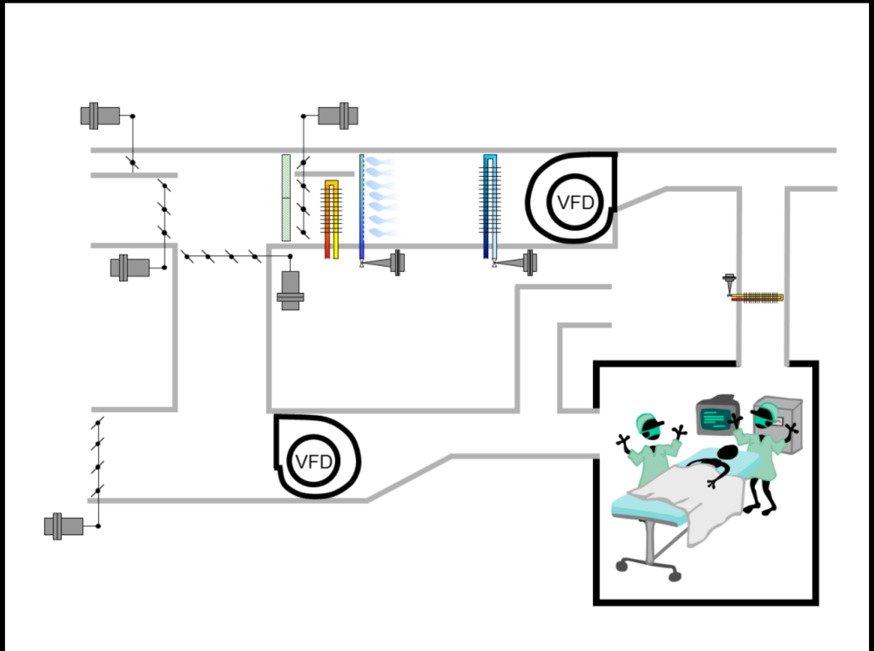
Economizer Modulates with Humidification

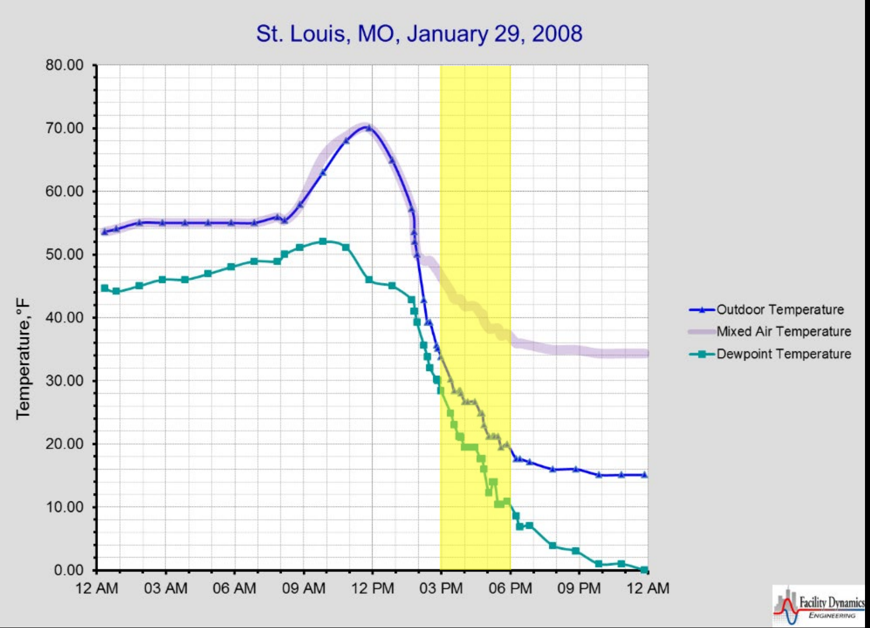


Don't Forget to Consider a Day with an Extreme Diurnal Swing and its Impact on the Performance of Sensitive HVAC Processes

Mother Nature Writes Great Functional Tests

Minimum Outdoor Air with Preheat and Humidification

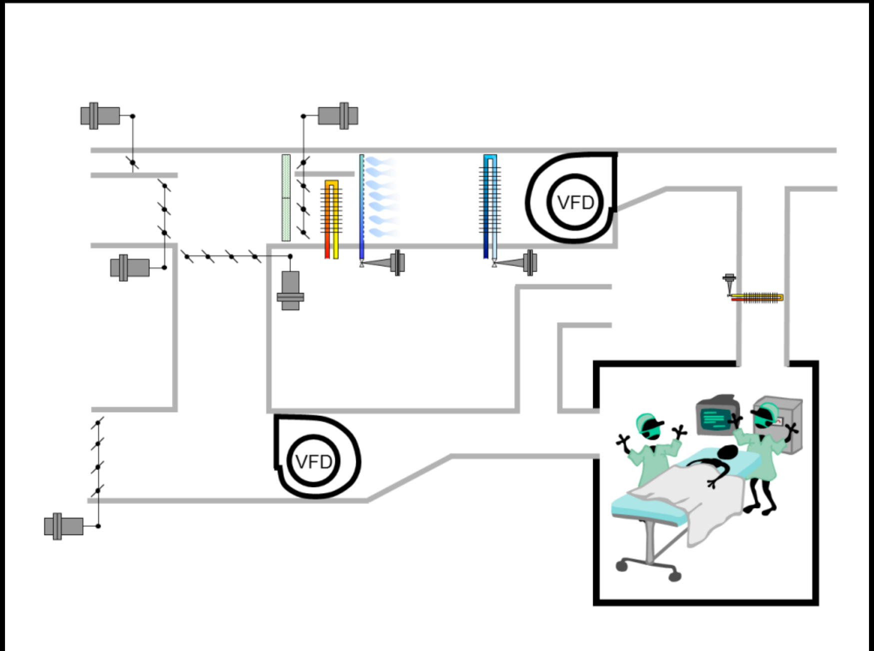


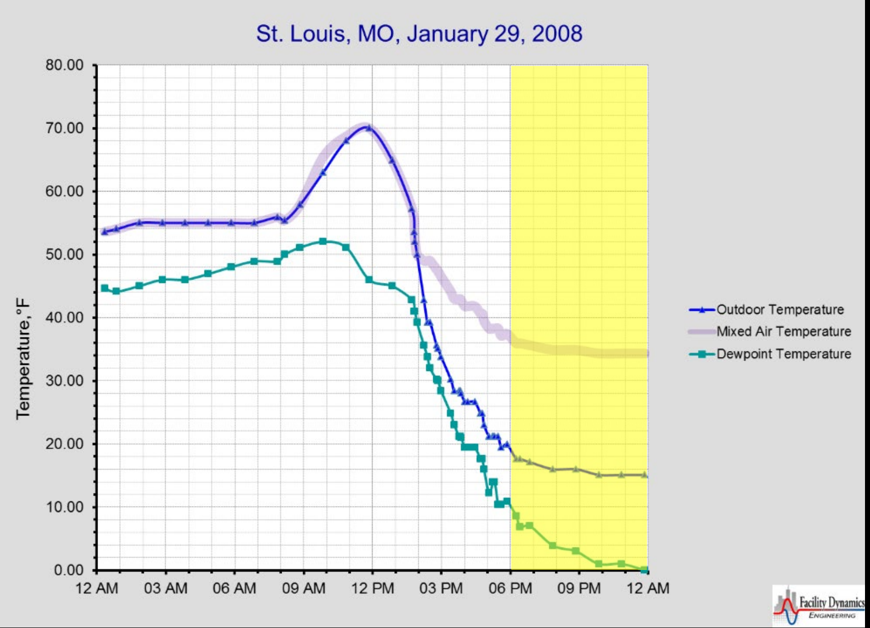


Don’t Forget to Consider a Day with an Extreme Diurnal Swing and its Impact on the Performance of Sensitive HVAC Processes

Mother Nature Writes Great Functional Tests

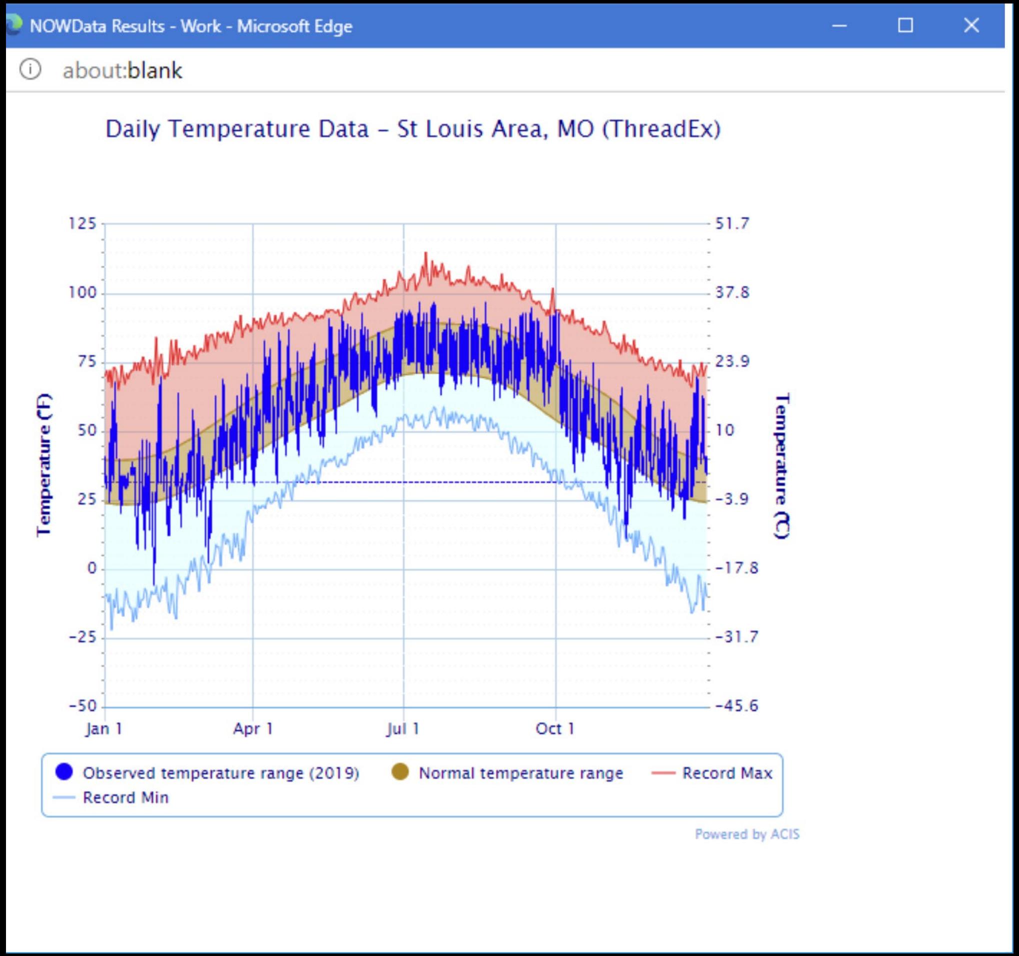
Minimum Outdoor Air with Preheat and Humidification; Freezestat trips if the Preheat Process Fails





Finding Those Days

https://tinyurl.com/NOWData



NOWData Results - Work - Microsoft Edge

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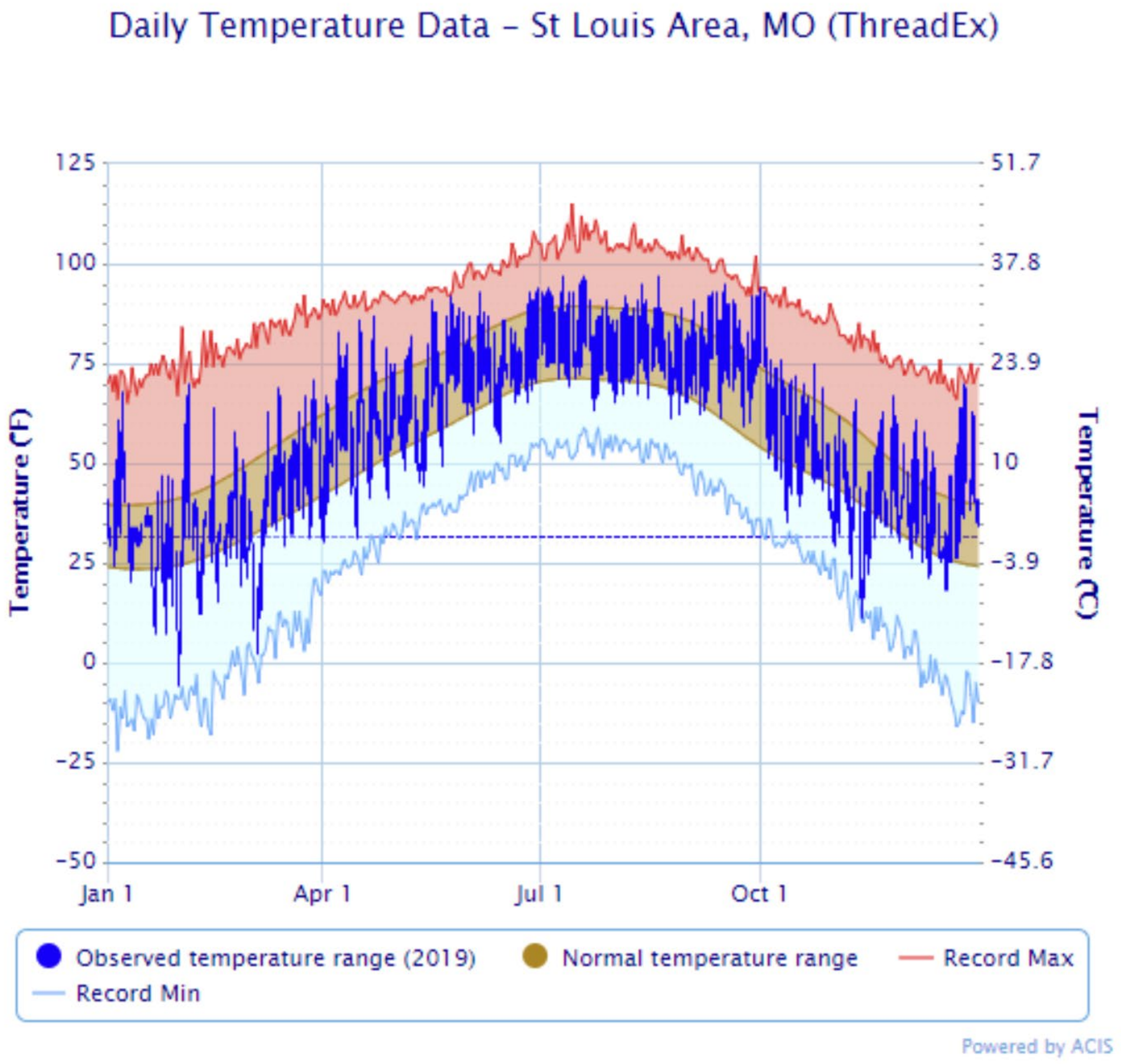
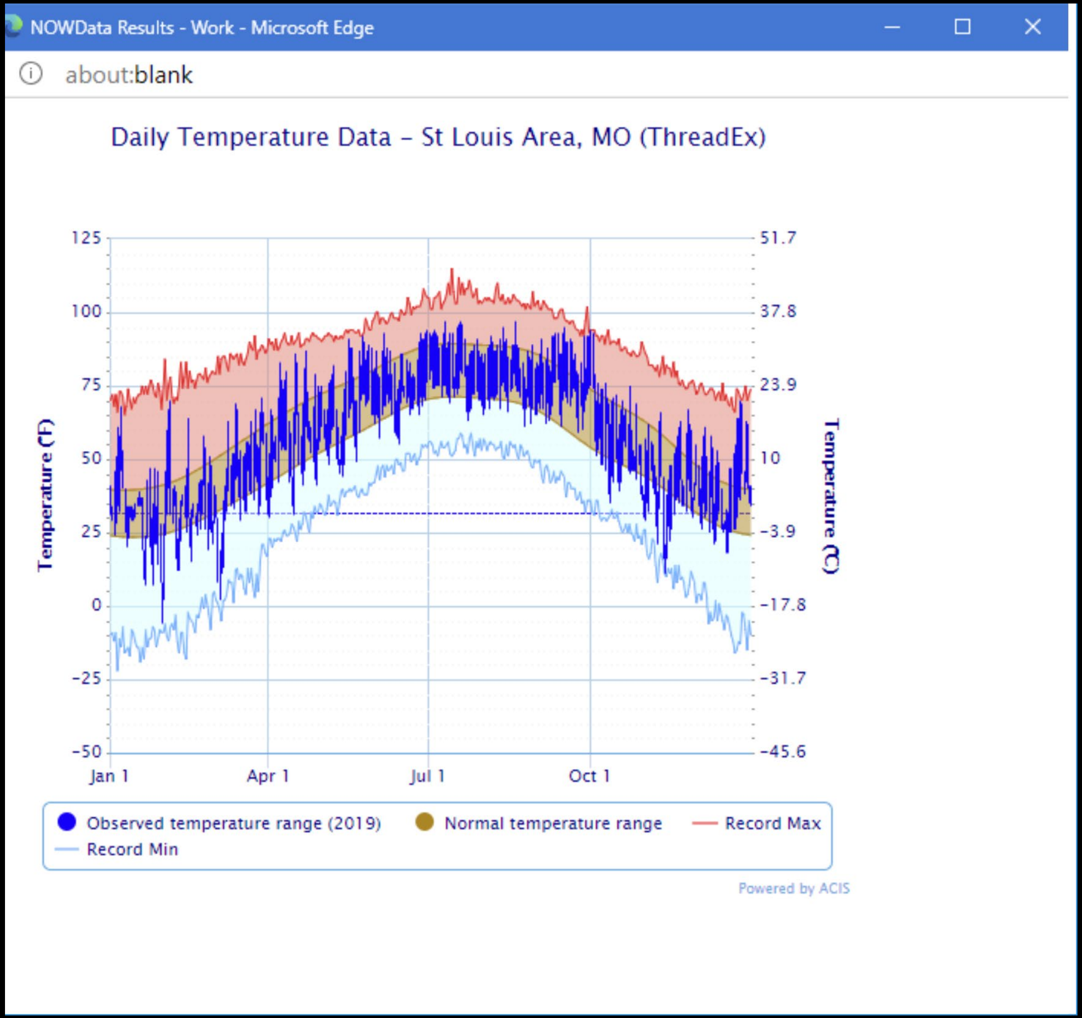
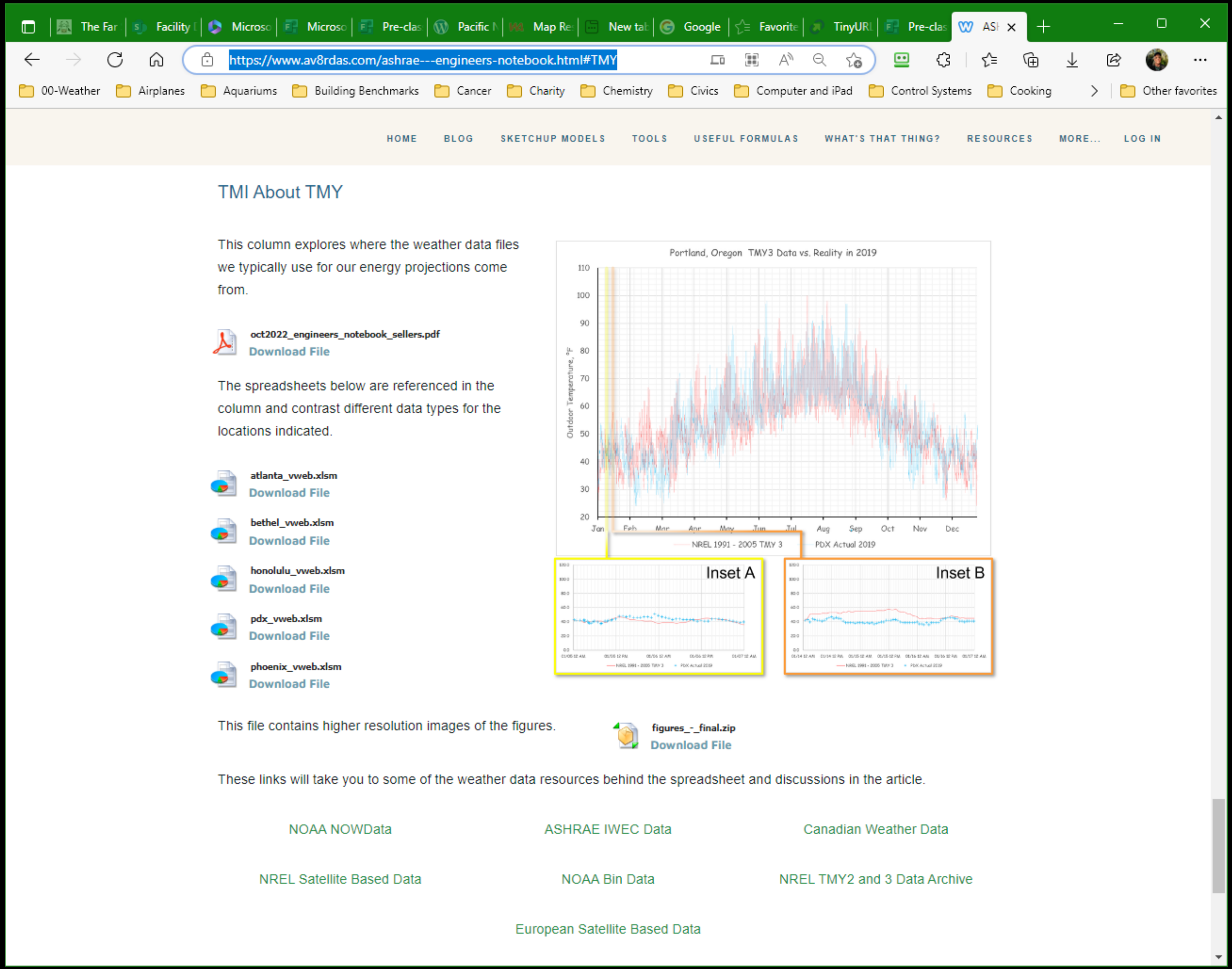


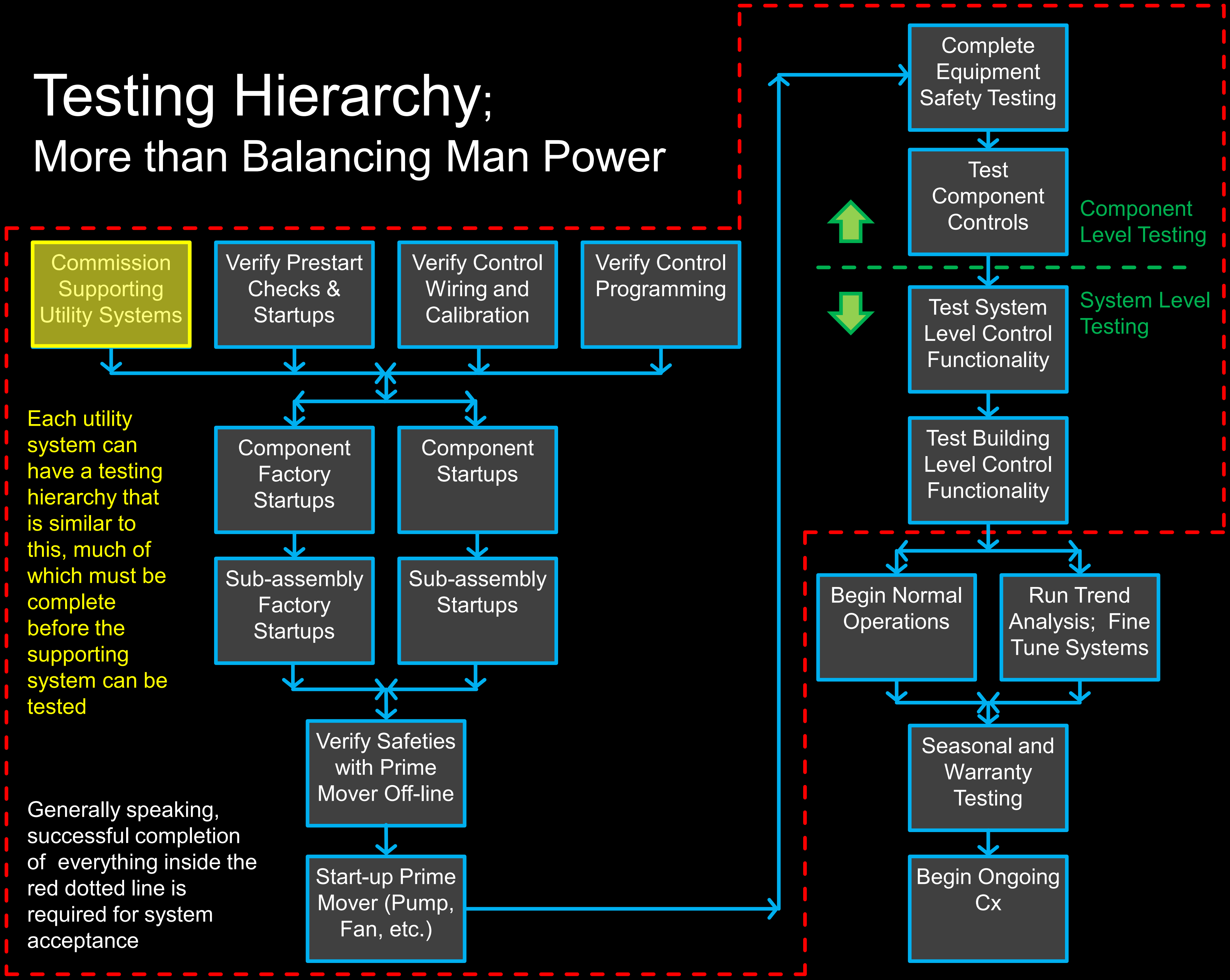
Another Climate Data Resource

https://tinyurl.com/TMIAboutTMY

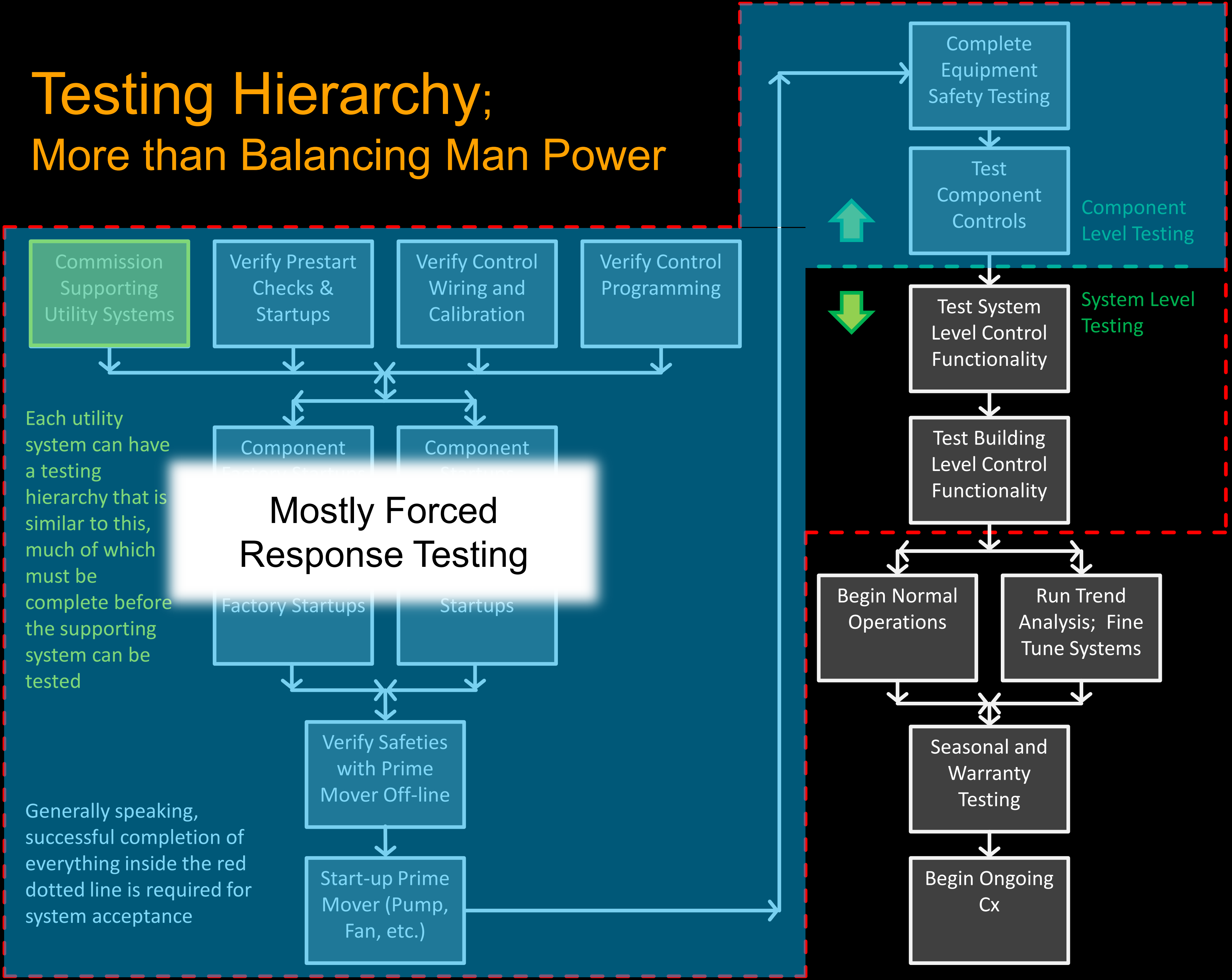




Testing Hierarchy;
More than Balancing Man Power



Testing Hierarchy;
More than Balancing Man Power



Testing Hierarchy;
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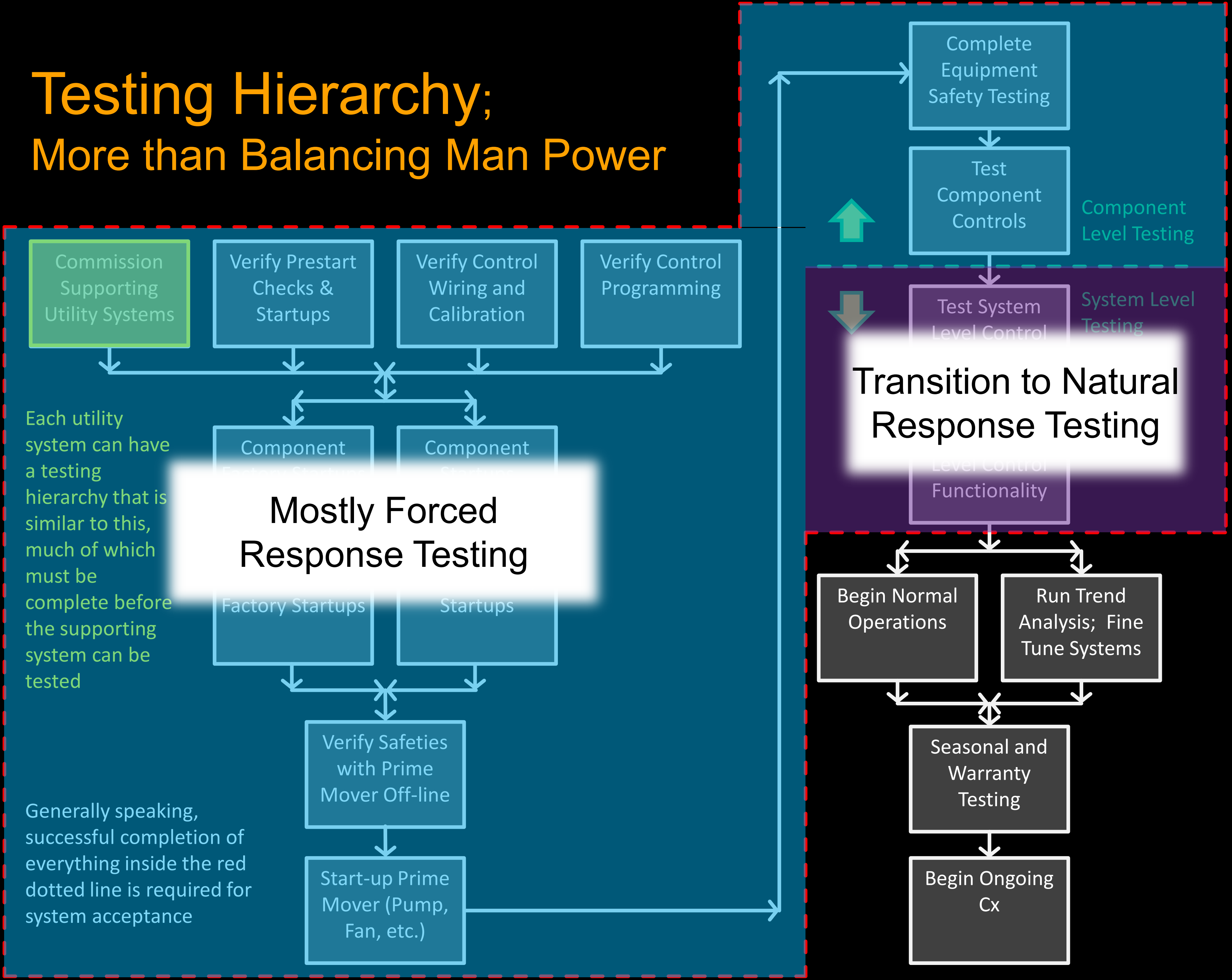

Testing Hierarchy;
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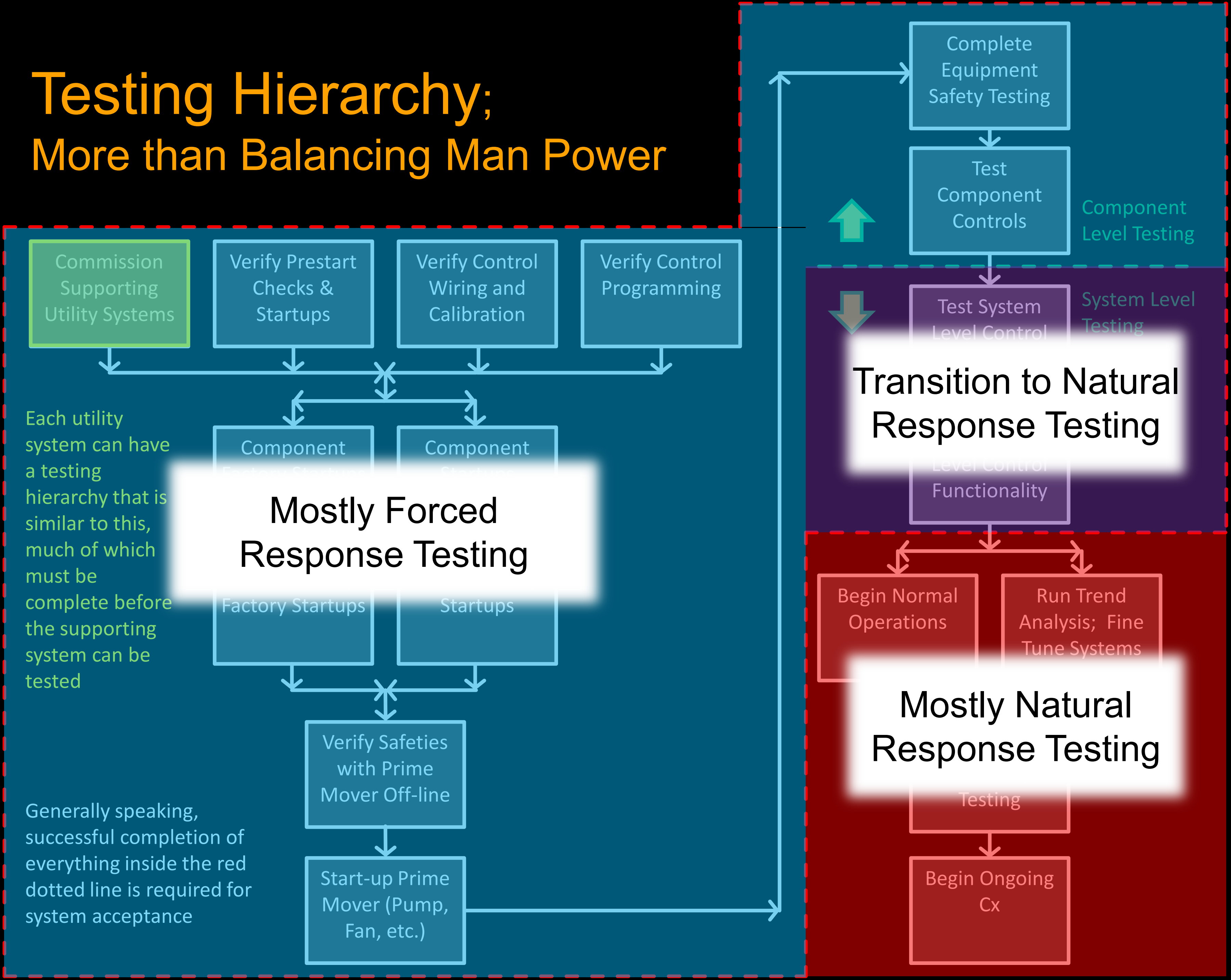


Functional Testing

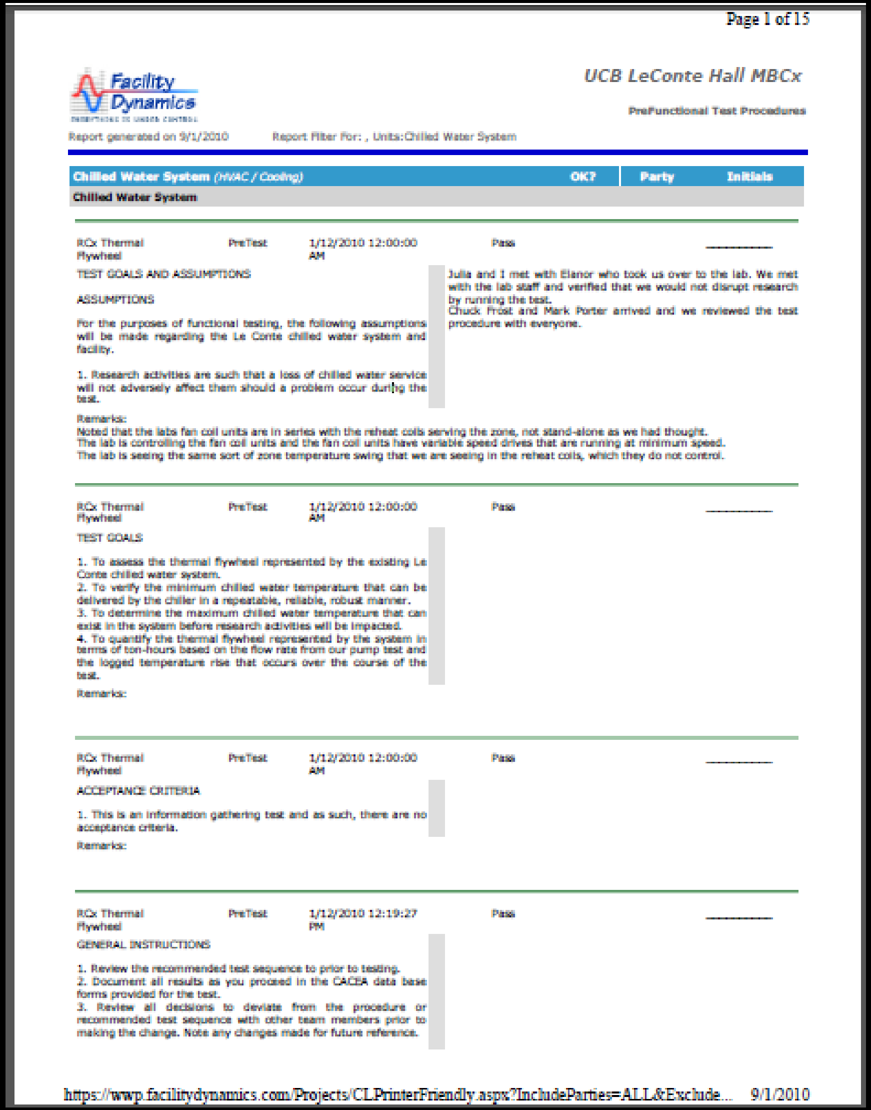
One of the ways we have a dialog with the building

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

The Real Trick

Figuring out what to ask

Figuring Out What to Ask for New Construction Projects

General Goal

Validate the machinery and systems

1. Do they deliver?
2. Do the work well together?
3. Was it big enough?

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

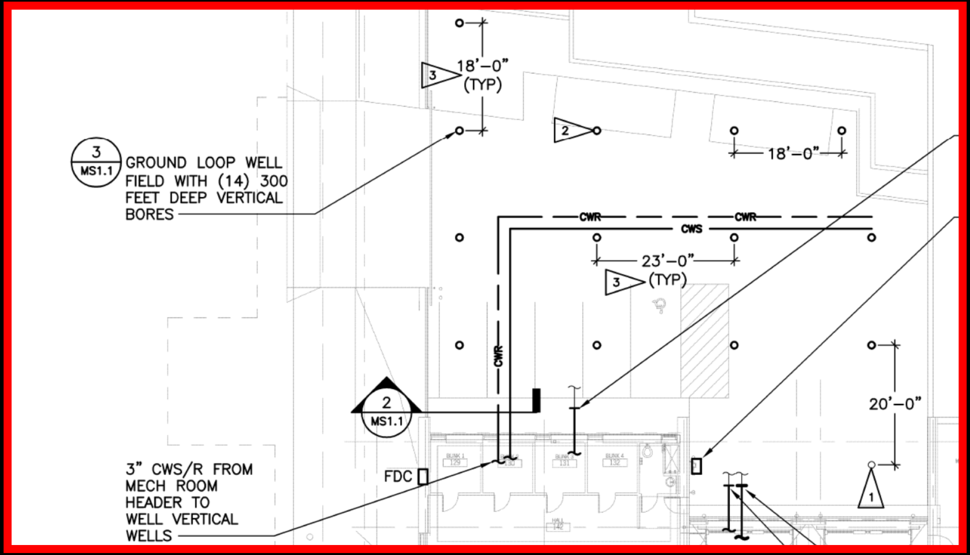
https://tinyurl.com/FunctionalTestingGuide

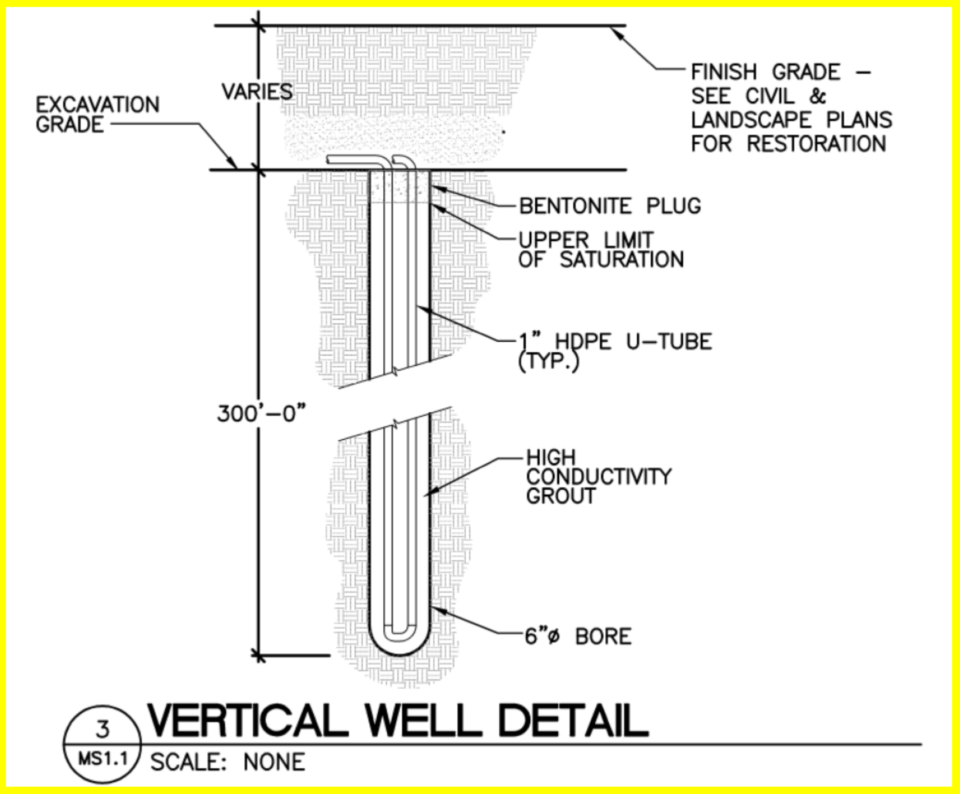
- Your knowledge and experience

This, That, and the Other Thing

A Question For You

https://tinyurl.com/HeatPumpD3Glycol





Freezing Point								
Ethylene Glycol Solution (% by volume)		**0**	**10**	**20**	**30**	**40**	**50**	**60**
Temperature	(° F)	32	25.9	17.8	7.3	-10.3	-34.2	-63
	(° C)	0	-3.4	-7.9	-13.7	-23.5	-36.8	-52.8

Dynamic Viscosity - μ - (centiPoise)								
Temperature		**Ethylene Glycol Solution (% by volume)**						
(° F)	**(° C)**	**25**	**30**	**40**	**50**	**60**	**65**	**100**
0	-17.8	1)	1)	15	22	35	45	310
40	4.4	3	3.5	4.8	6.5	9	10.2	48
80	26.7	1.5	1.7	2.2	2.8	3.8	4.5	14
120	48.9	0.9	1	1.3	1.5	2	2.4	7
160	71.1	0.65	0.7	0.8	0.95	1.3	1.5	3.8
200	93.3	0.48	0.5	0.6	0.7	0.88	0.98	1.4
240	115.6	2)	2)	2)	2)	2)	2)	1.8
280	137.8	2)	2)	2)	2)	2)	2)	1.4

1. below freezing point
2. above boiling point

Specific Gravity- *SG* -								
Temperature		Ethylene Glycol Solution (% by volume)						
(°F)	(°C)	25	30	40	50	60	65	100
-40	-40	1)	1)	1)	1)	1.12	1.13	1)
0	-17.8	1)	1)	1.08	1.1	1.11	1.12	1.16
40	4.4	1.048	1.057	1.07	1.088	1.1	1.11	1.145
80	26.7	1.04	1.048	1.06	1.077	1.09	1.095	1.13
120	48.9	1.03	1.038	1.05	1.064	1.077	1.082	1.115
160	71.1	1.018	1.025	1.038	1.05	1.062	1.068	1.1
200	93.3	1.005	1.013	1.026	1.038	1.049	1.054	1.084
240	115.6	2)	2)	2)	2)	2)	2)	1.067
280	137.8	2)	2)	2)	2)	2)	2)	1.05

1. below freezing point
2. above boiling point

Specific Heat Capacity of Ethylene Glycol based Water Solutions

Specific Heat - c_p - of ethylene glycol based water solutions at various temperatures are indicated below

Specific Heat - c_p - (Btu/lb.°F)								
Temperature		Ethylene Glycol Solution (% by volume)						
(°F)	(°C)	25	30	40	50	60	65	100
-40	-40	1)	1)	1)	1)	0.68	0.703	1)
0	-17.8	1)	1)	0.83	0.78	0.723	0.7	0.54
40	4.4	0.913	0.89	0.845	0.795	0.748	0.721	0.562
80	26.7	0.921	0.902	0.86	0.815	0.768	0.743	0.59
120	48.9	0.933	0.915	0.875	0.832	0.788	0.765	0.612
160	71.1	0.94	0.925	0.89	0.85	0.81	0.786	0.64
200	93.3	0.953	0.936	0.905	0.865	0.83	0.807	0.66
240	115.6	2)	2)	2)	2)	2)	0.828	0.689
280	137.8	2)	2)	2)	2)	2)	2)	0.71

1 Btu/(lb_m °F) = 4,186.8 J/(kg K) = 1 kcal/(kg °C)

1. below freezing point
2. above boiling point

Boiling Points Ethylene Glycol Solutions

Boiling Point												
Ethylene Glycol Solution (% by volume)		**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Temperature	(°F)	212	214	216	220	220	225	232	245	260	288	386
	(°C)	100	101.1	102.2	104.4	104.4	107.2	111.1	118	127	142	197

Increase in Flow required for a 50% Ethylene Glycol Solution

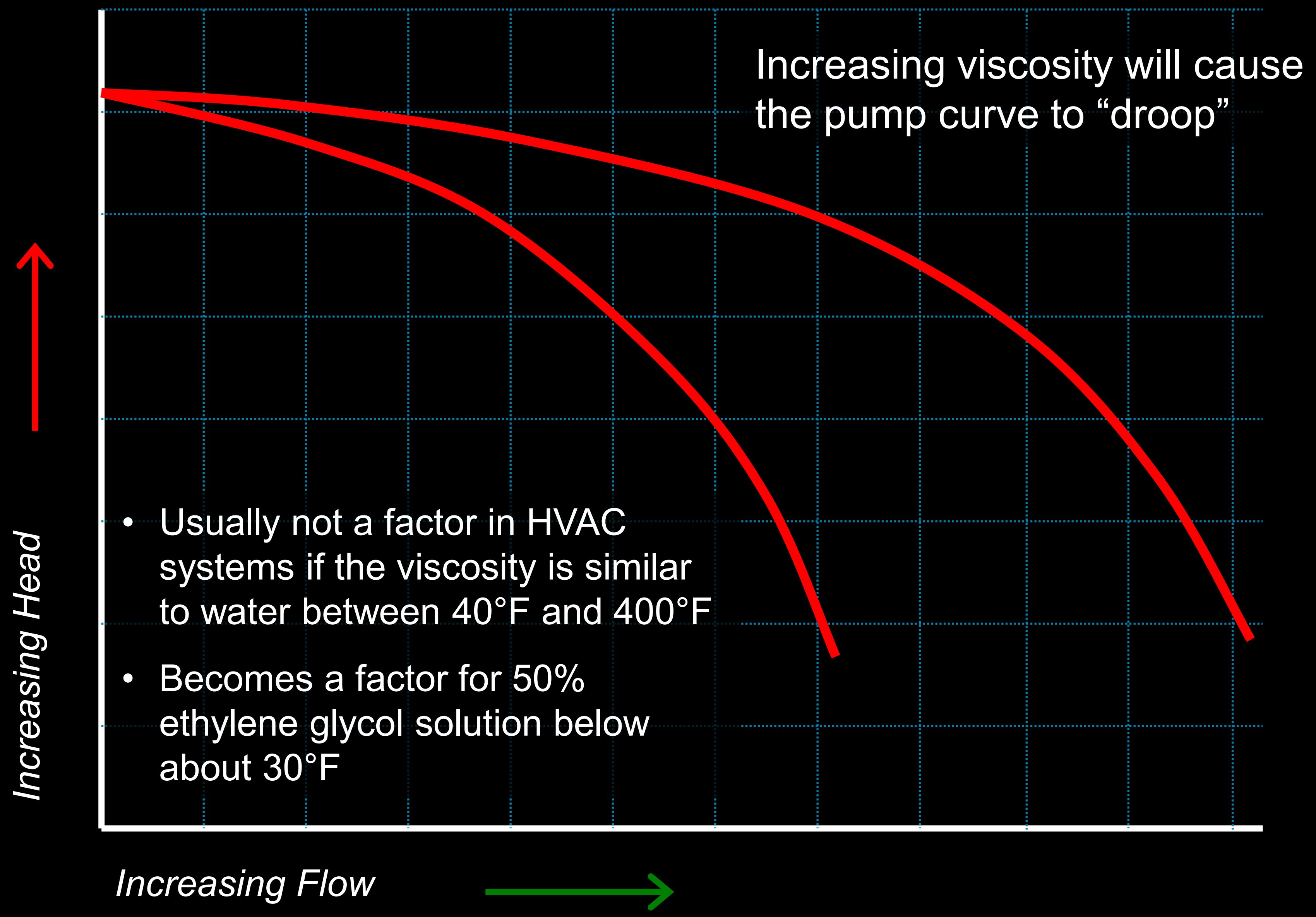
Increase in circulated flow for 50% ethylene glycol solutions compared with clean water are indicated in the table below

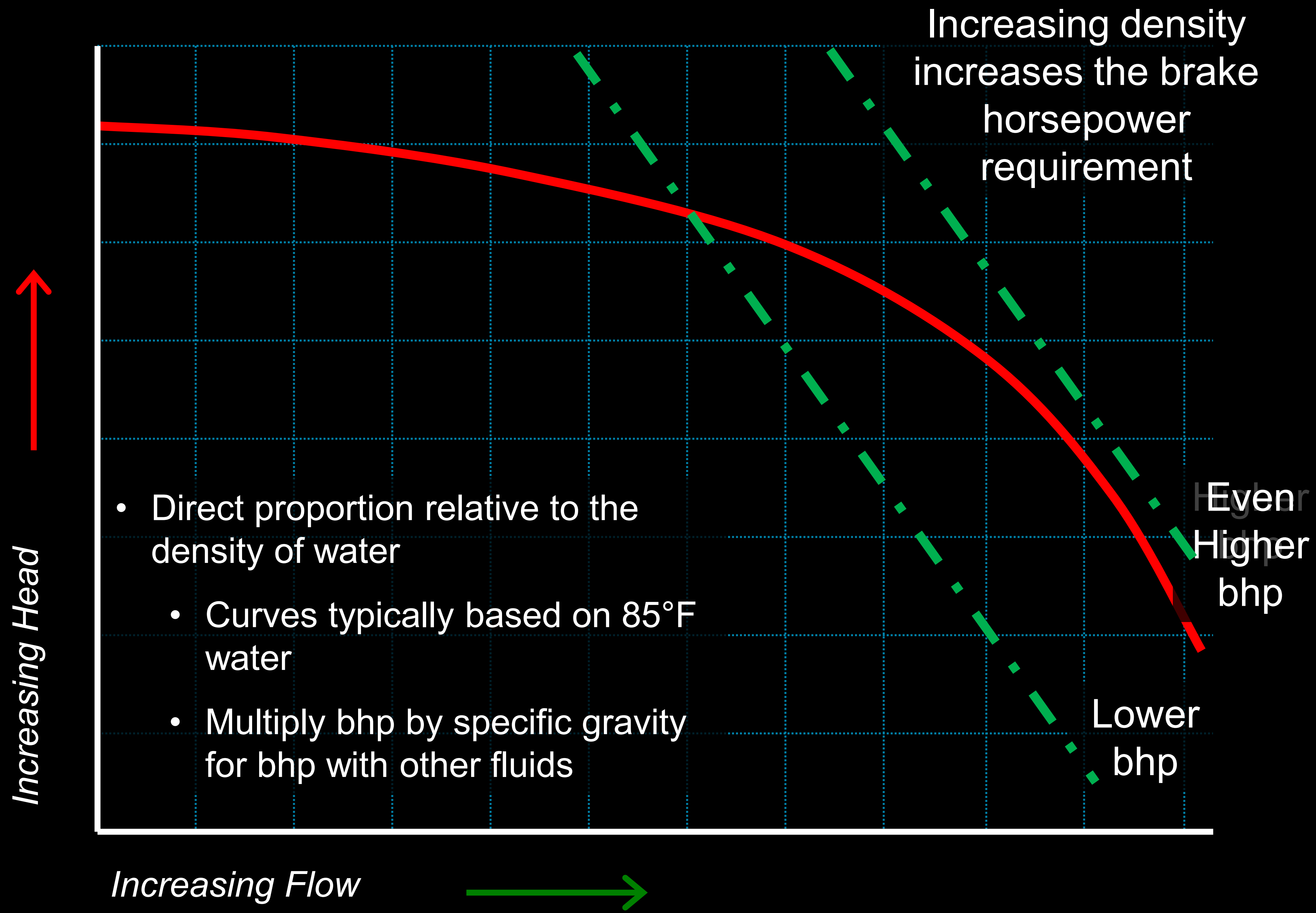
Fluid Temperature		**Flow Increase**
(°F)	**(°C)**	**(%)**
40	4.4	22
100	37.8	16
140	60	15
180	82.2	14
220	104.4	14

Pressure Drop Correction and Combined Pressure Drop and Volume Flow Correction for 50% Ethylene Glycol Solution

Pressure drop correction and combined pressure drop and flow increase correction for 50% ethylene glycol solutions compared with clean water are ed in the table below

Fluid Temperature		**Pressure Drop Correction with Flow Rates Equal**	**Combined Pressure Drop and Flow Rate Correction**
(°F)	**(°C)**	**(%)**	**(%)**
40	4.4	45	114
100	37.8	10	49
140	60	0	32
180	82.2	-6	23
220	104.4	-10	18


Increasing viscosity will cause the pump curve to “droop”
Usually not a factor in HVAC systems if the viscosity is similar to water between 40°F and 400°F
Becomes a factor for 50% ethylene glycol solution below about 30°F
Increasing Head
Increasing Flow

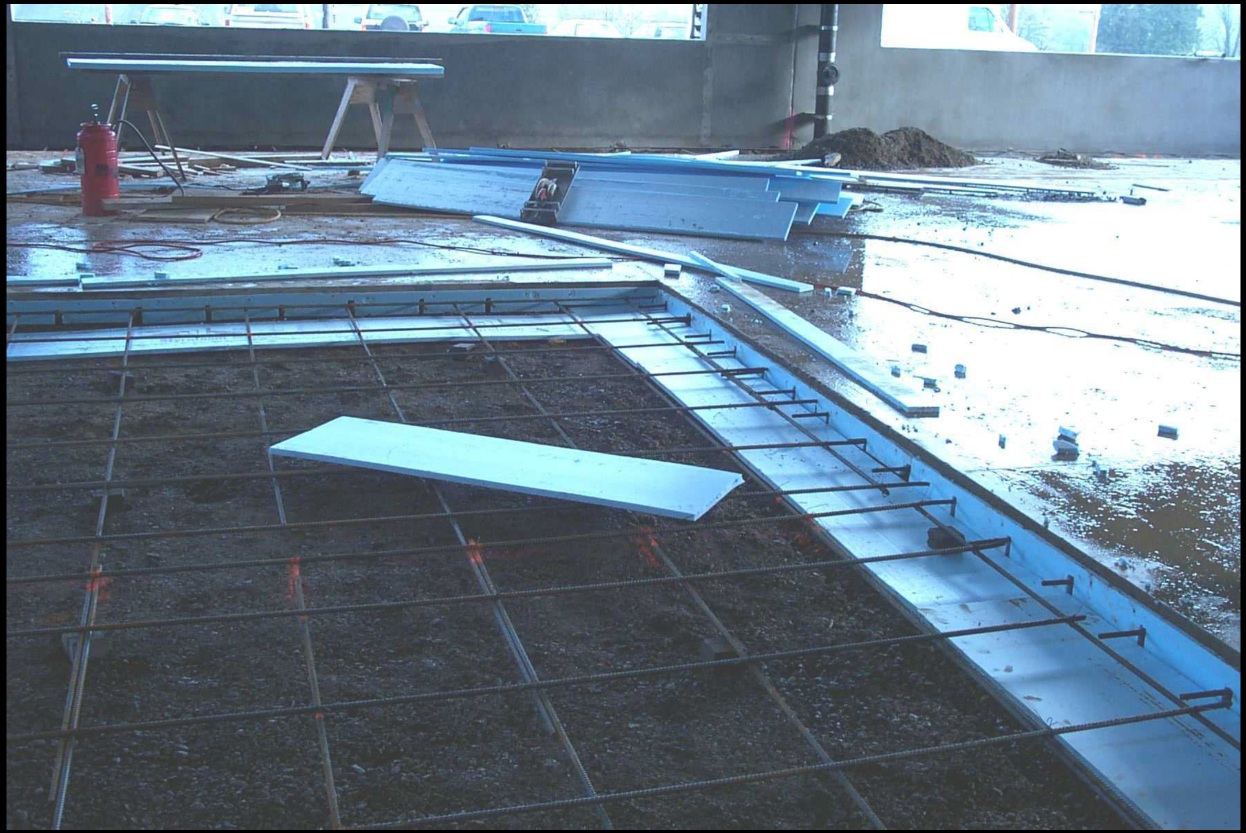


- Direct proportion relative to the density of water
  - Curves typically based on 85°F water
  - Multiply bhp by specific gravity for bhp with other fluids

A Few Words About Radiant Slabs

Radiant slabs give us an attractive way to serve space heating loads with low temperature water

A Few Words About Radiant Slabs

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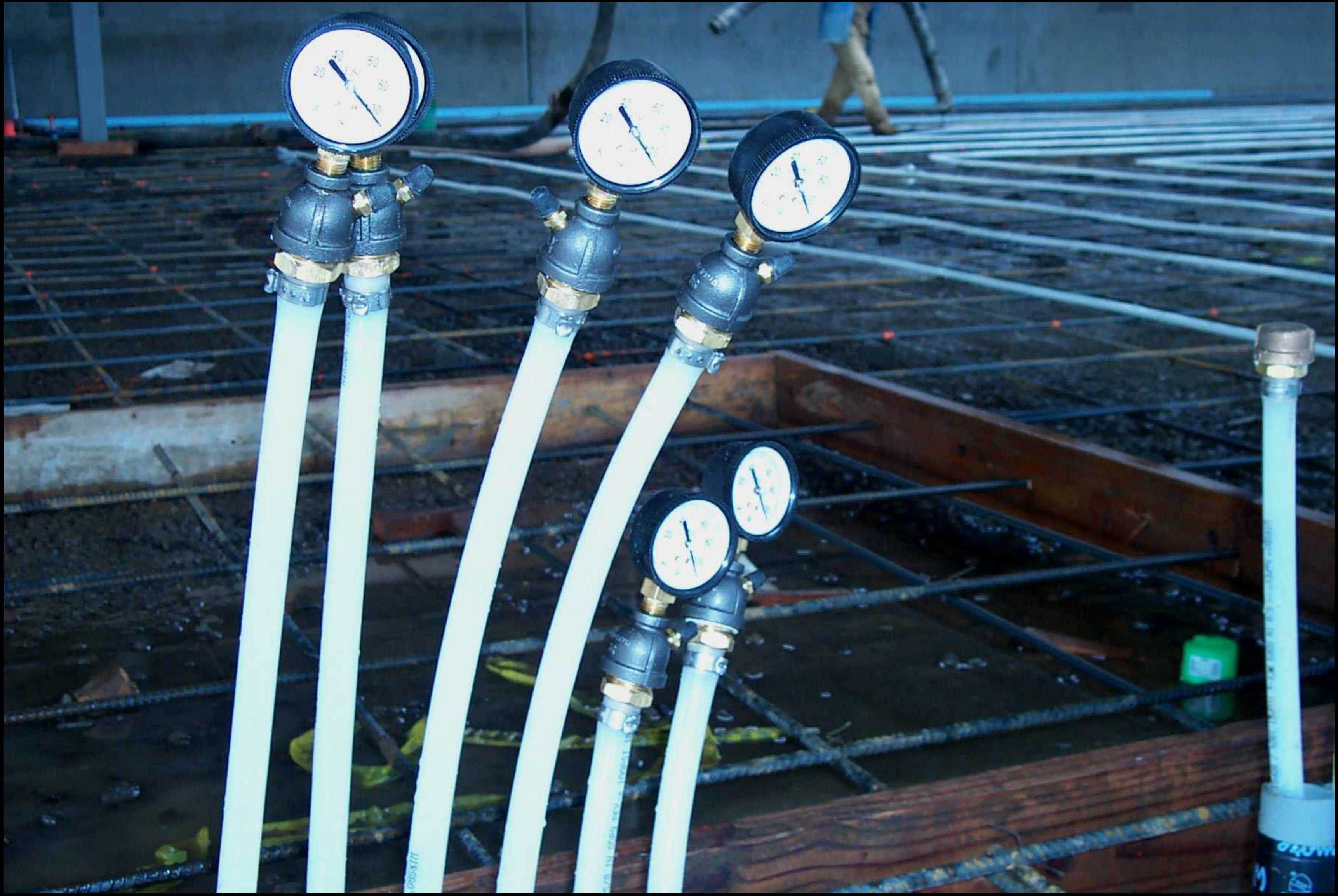
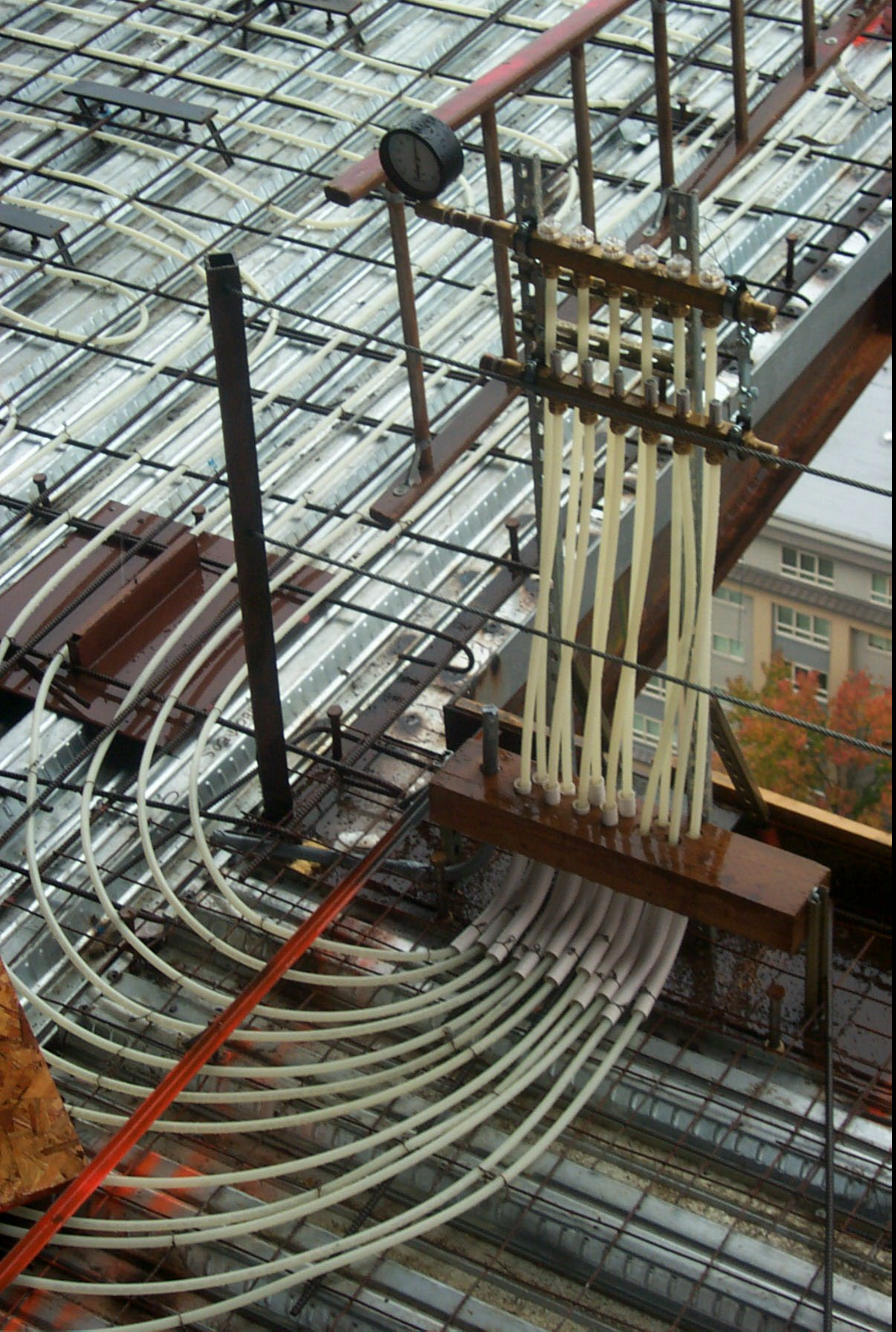
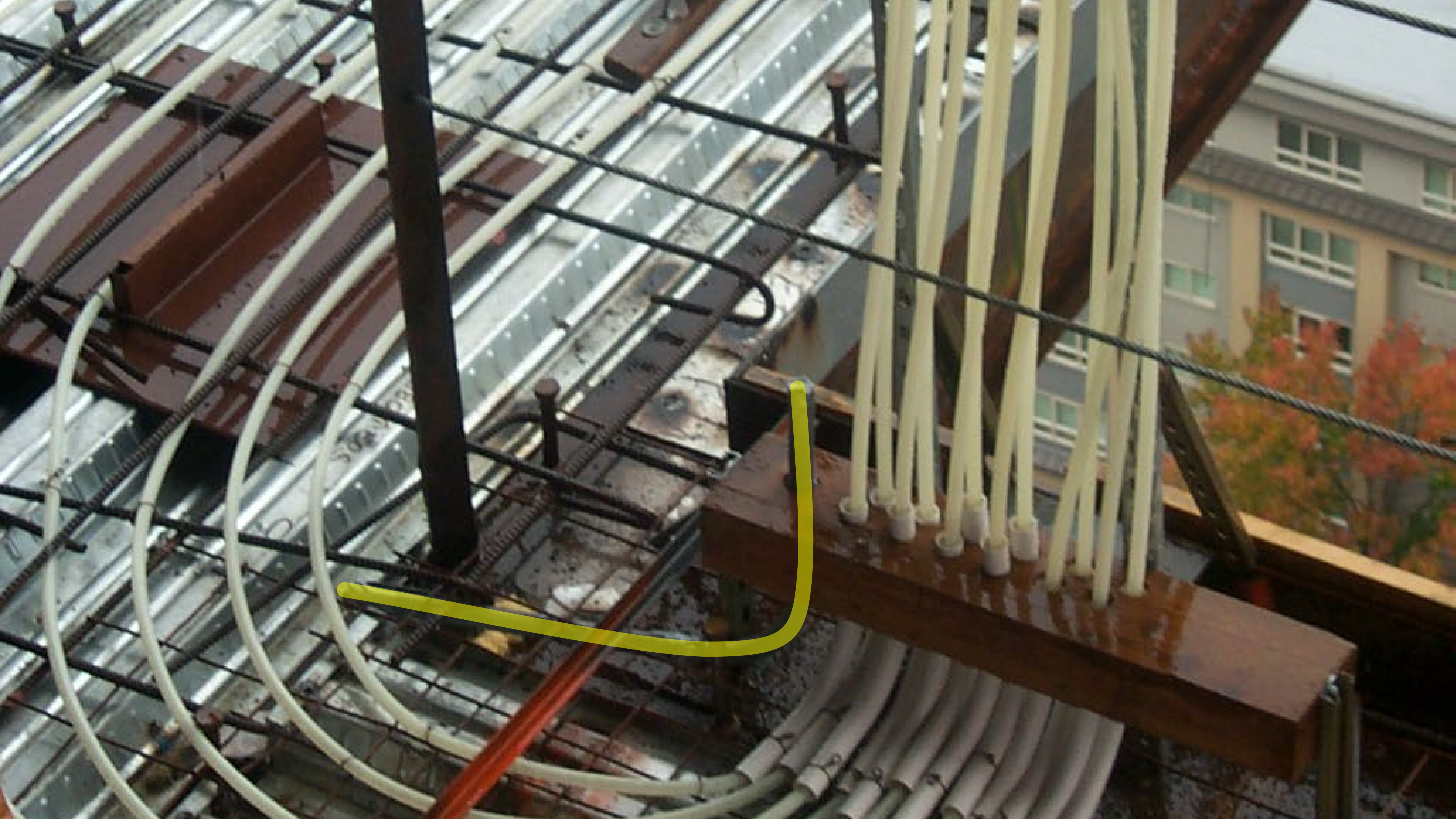
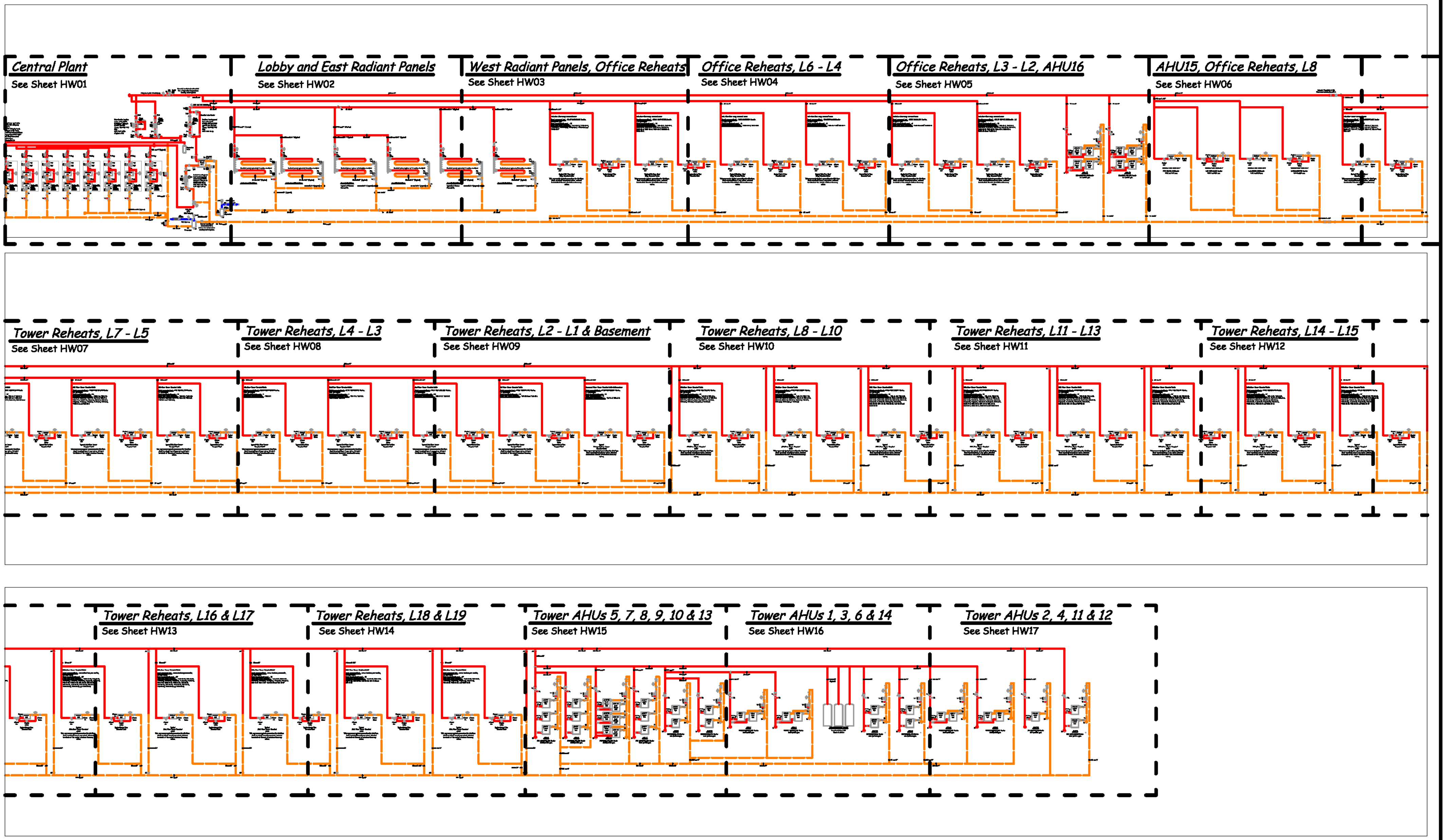







OWEN
CORNIN
1-FOC

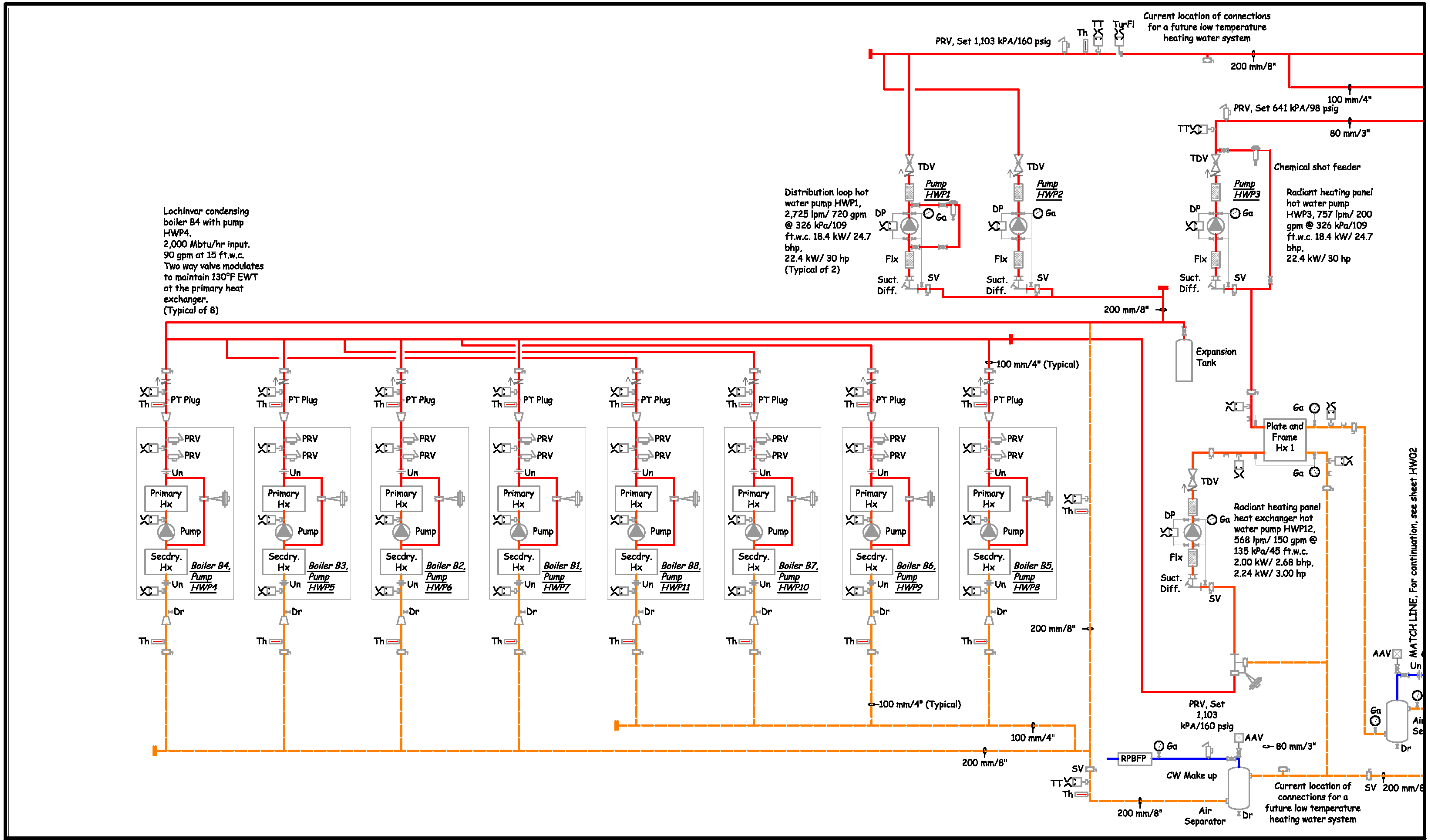

1-FOC



New Seattle Court House Heating Water System Flow Diagram

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

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



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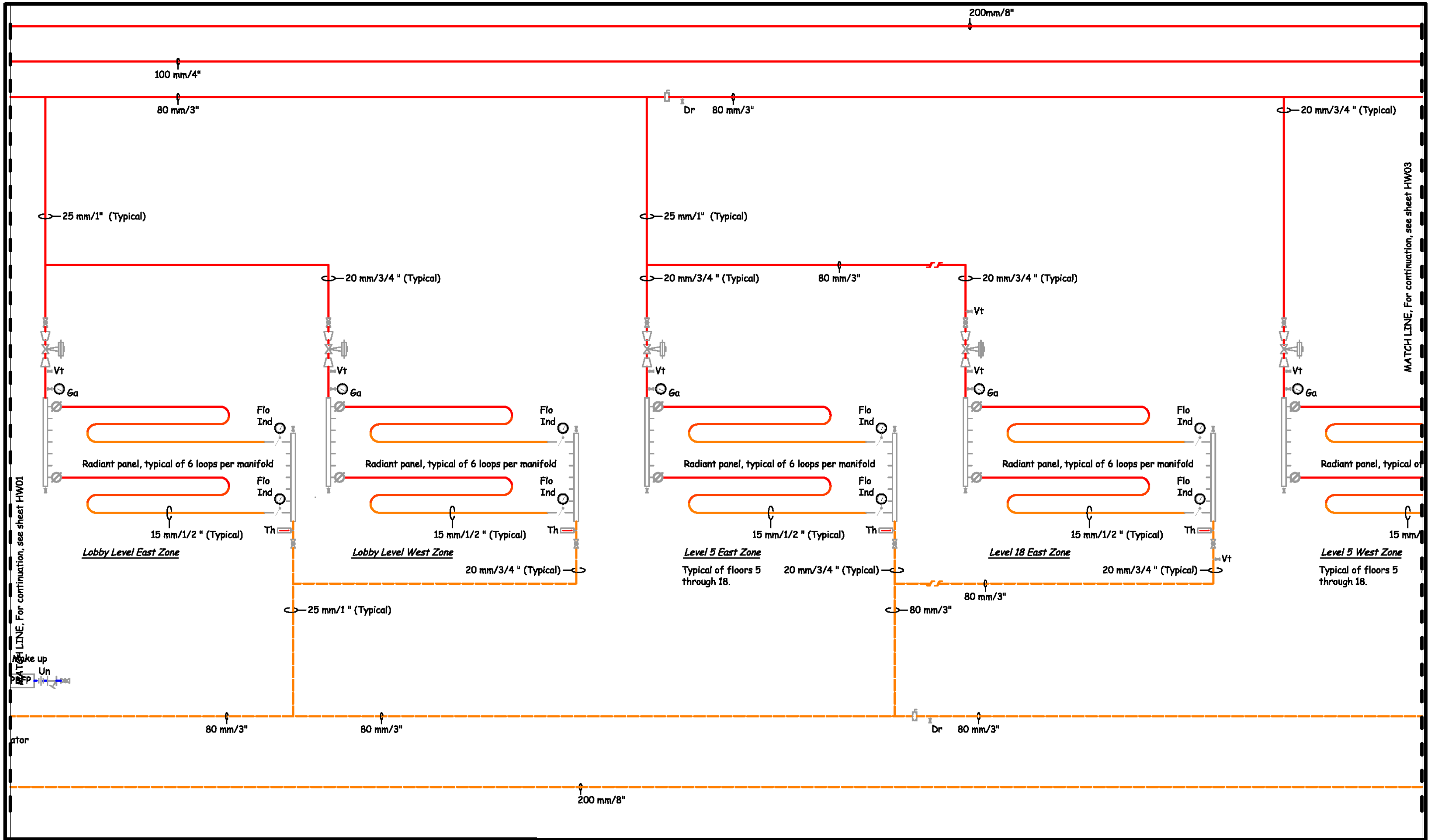
Revisions: 3 - 12-15-03 - Updated and detailed to include radiant panel heat exchanger and HP12.
Revisions: 4 - Release 3/23/04
Revisions: 5 - 7-6-04 - Revised radiant panel pump connections.
Revisions: 5.1 - 7-7-04 - Revised radiant panel connection to the boiler header.

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

HW01



C:\Documents and Settings\David Sellers\My Documents\Workspace\00 - FDD\Seattle Federal Courthouse\System Diagrams\Heating Water System Flow Diagram r7.2.dwg, HW02, 12/3/2007 11:23:38 AM, David Sellers, Facility Dynamics Engineering, Adobe PDF

New Seattle Court House Heating Water System Flow Diagram

Revisions: Release 3/23/04	Drawn by: DAS	Date: April 29, 2002	HW02
	Checked by:	Plot date: May 1, 2002	

A Low Temperature Hot Water Application Resource

https://tinyurl.com/ACEEELowTempHW

Making Energy Intensive HVAC Processes More Sustainable via Low Temperature Heat Recovery

David Sellers, Portland Energy Conservation Inc.
Tom Stewart, Memorial Hospital of Carbondale

ABSTRACT

This paper looks at low temperature hot water distribution and heat recovery as an approach that can be used in health care and laboratory applications to reduce the energy intensity of the HVAC reheat and preheat process. The concepts presented could easily be applied to reheat and preheat processes in other applications such as semiconductor and pharmaceutical clean rooms. The paper also looks at radiant slabs as an opportunity to use low temperature hot water for comfort heating applications in new construction. A case study of an application in a health care environment is included.

Introduction

Current air handling system configurations, such as Variable Air Volume (VAV) systems, have led to significant reductions in HVAC energy requirements in many applications. However, there are some applications that require precise control of the pressure relationships between adjacent spaces and precise control of the temperature and humidity at the load. These requirements often eliminate the VAV approach as an option and force designers to use a constant volume reheat system. Examples of such applications include surgical suites, laboratories, and clean rooms. The reheat process of these systems is typically very energy intensive since it often involves simultaneous heating and cooling. In addition, the large volumes of outdoor air required often result in significant preheat loads.

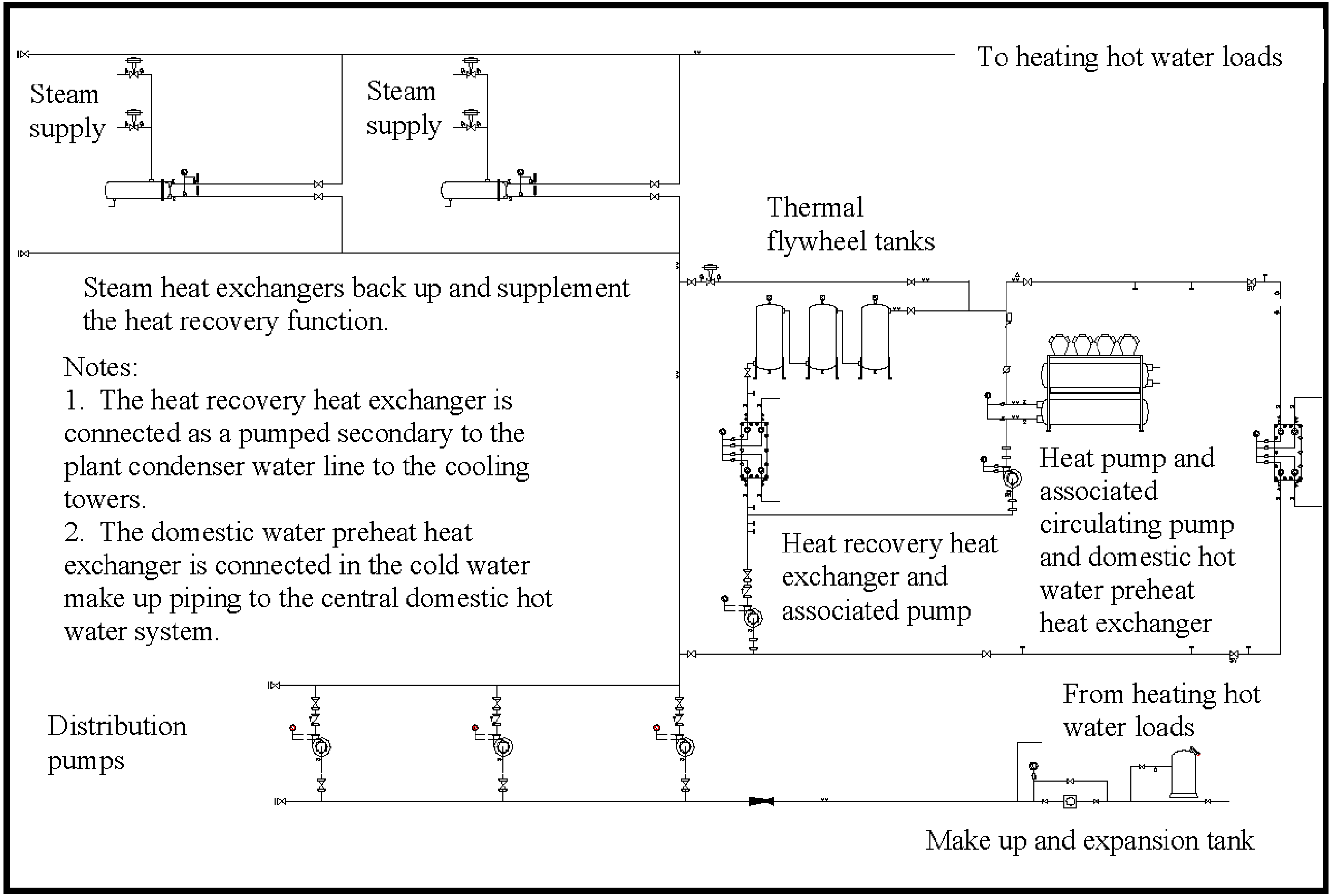
There are some characteristics of the preheat and reheat loads associated with these processes that make them ideal low heating water temperature loads. These characteristics are often complemented by the nature of the load served by the system since they typically represent very high internal gains, and are a source of recoverable heat. In new construction, radiant slabs can represent an opportunity to use this recovered energy for comfort heating in addition to the preheat and reheat processes.

The information presented in this paper is based on actual installations and experience with low temperature hot water systems in the context of a distribution and utilization strategy that is readily adaptable to recovered energy. An overview of technical considerations is followed by a case study of a low temperature hot water system at the Memorial Hospital of Carbondale, Illinois (MHC).

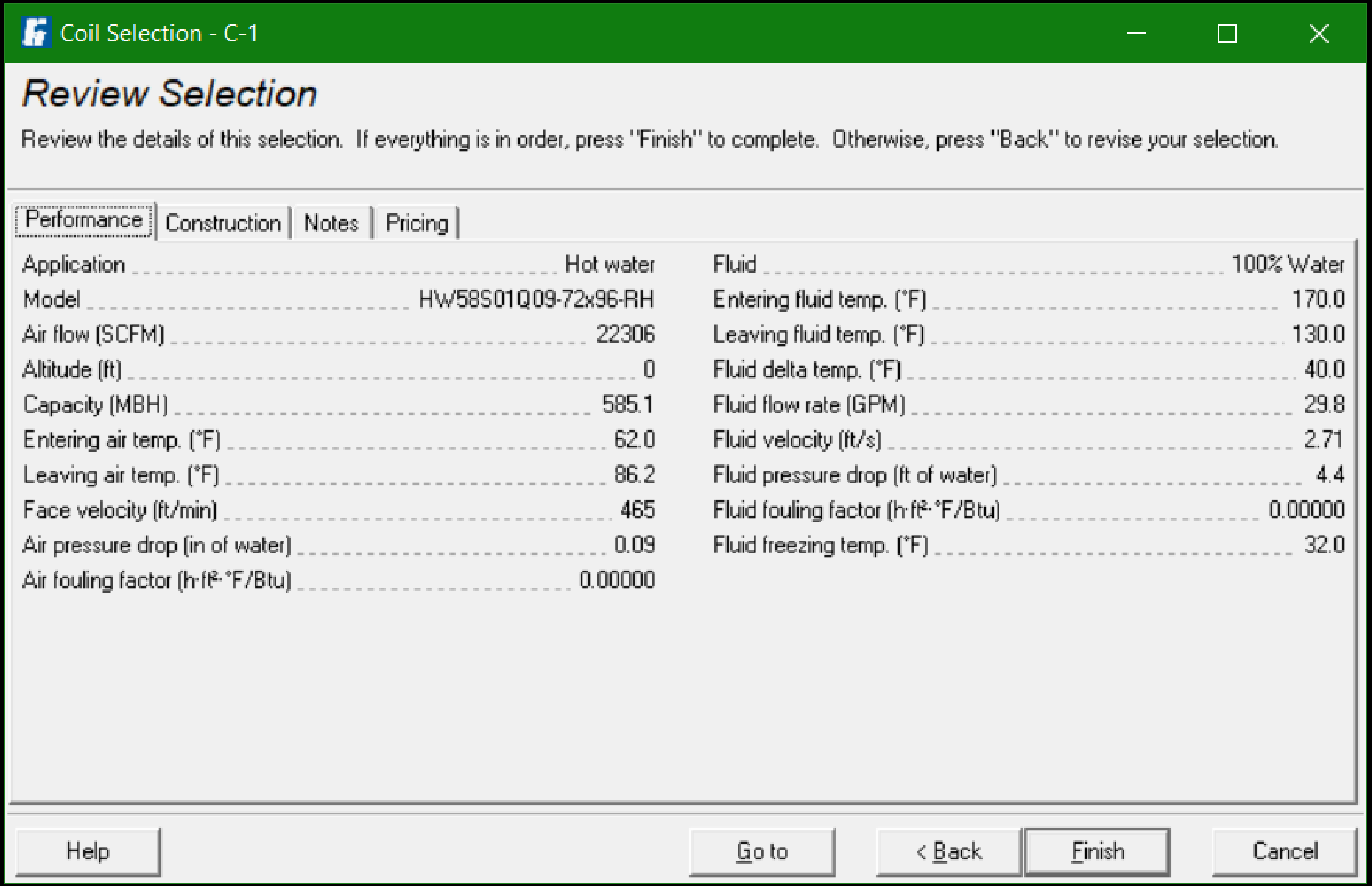
Technical Discussion

The following paragraphs explore some of the technical issues associated with low temperature hot water systems. Figure 1 illustrates a typical system configuration as extracted from schematic design documents for a project in the Northwest. The arrangement several important features:

Figure 2 - Final System Configuration at Memorial Hospital of Carbondale



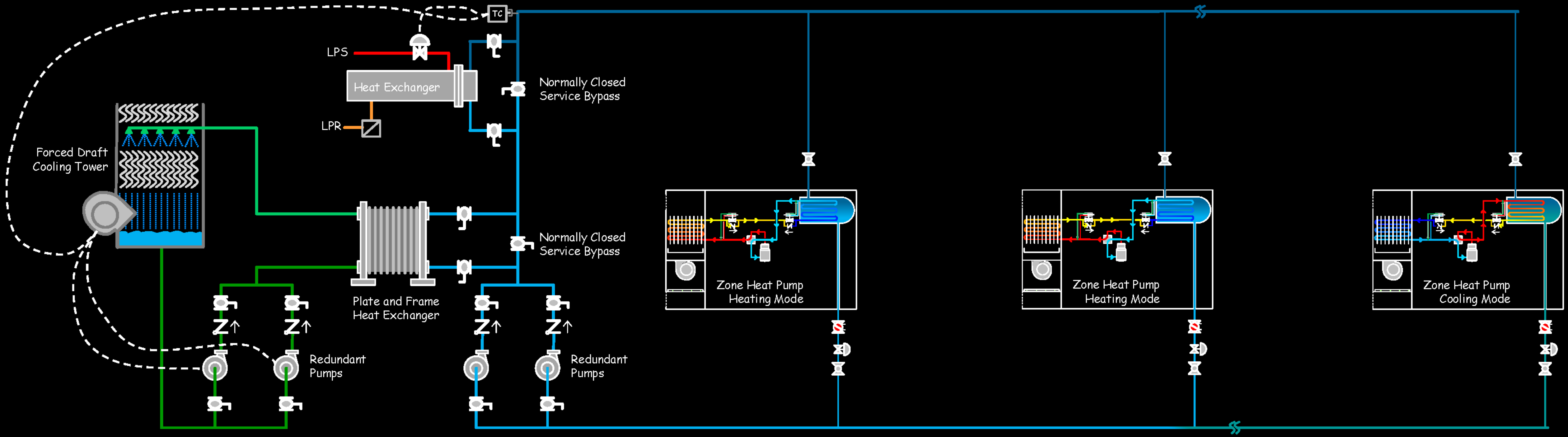
Taking a Look at Hot Water Coil Performance



Commissioning the Water Source Heat Pump Loop

A Question For You

https://tinyurl.com/HeatPumpD3WSLoopQ3



Water Source Heat Pump Loop

2022-11-16

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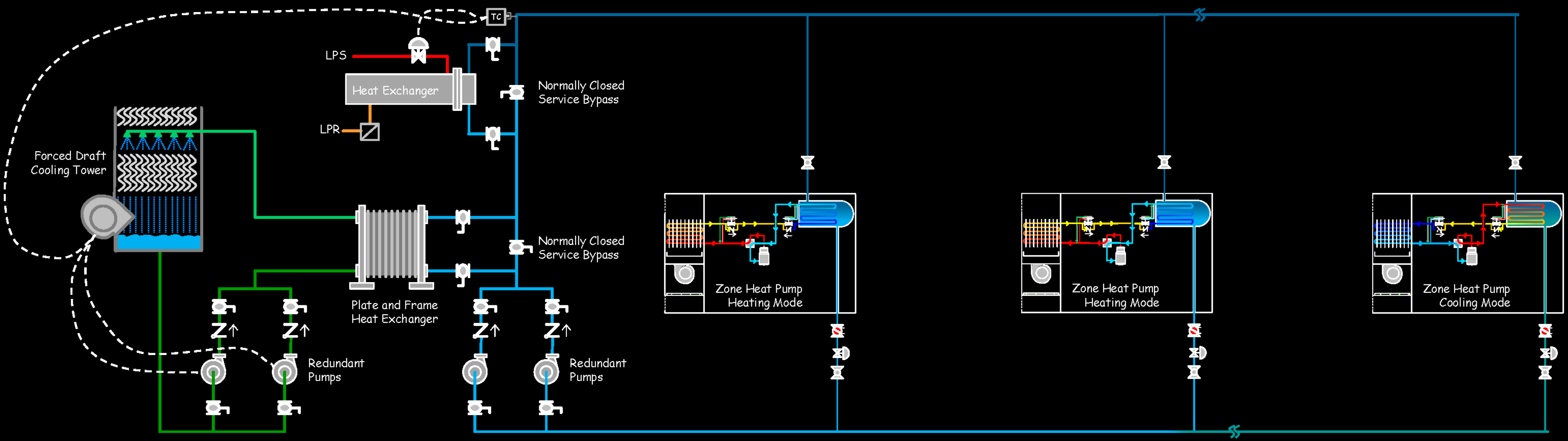
Yet Another Question For You

https://tinyurl.com/HeatPumpD3WSLoopQ4



Water Source Heat Pump Loop
2022-11-16
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Together, Building a Better California

Break Time

We will be back at ??:?? ?m Pacific Time

Together, Building
a Better California