WELCOME

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Commissioning Heat Pump Systems: The Already All Electric Building (and a Potpourri of Topics)

May 29, 2024

PG&E

Facility Dynamics ENGINEERING

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Cover
Hold

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& Pack Go-Bag

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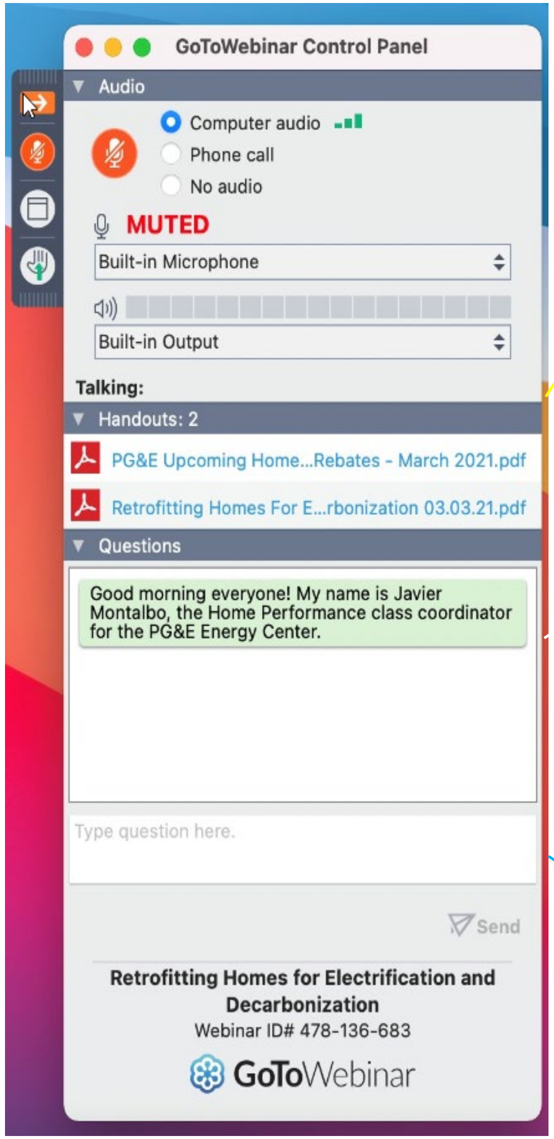

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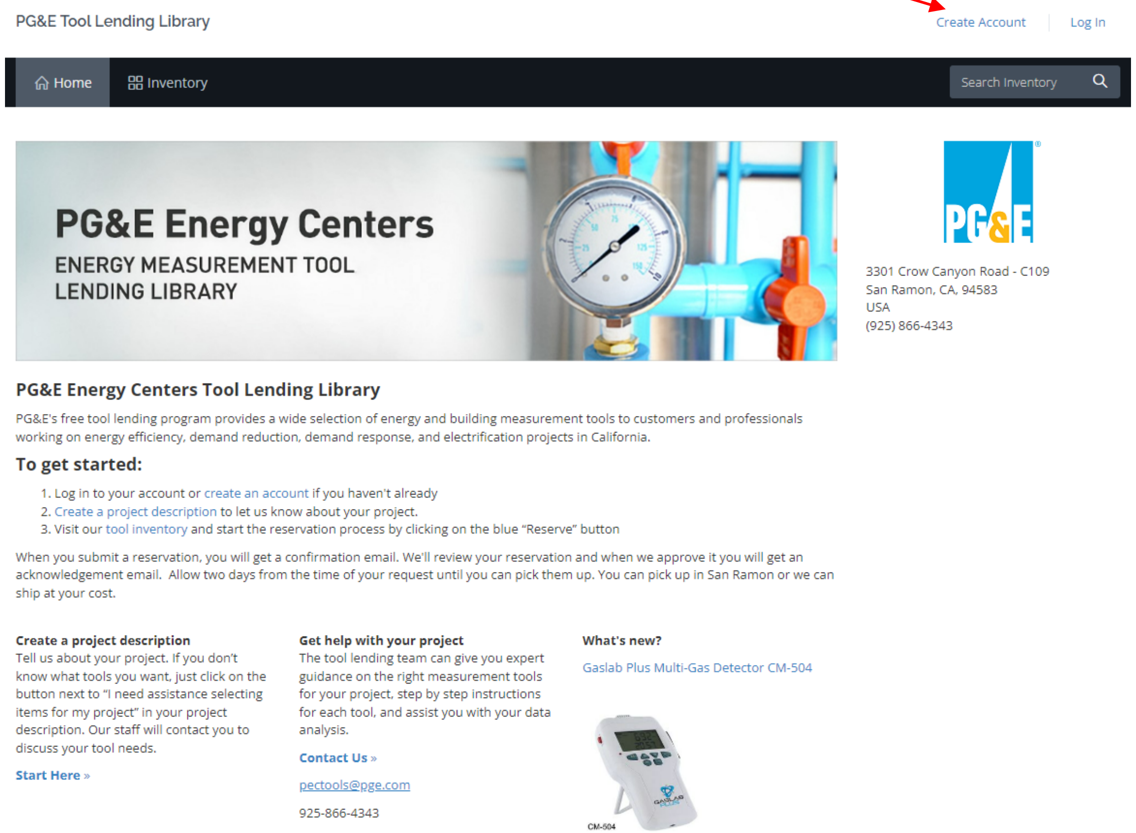

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- Infiltration and duct leakage assessments

Introduction

Today’s Agenda

1. Introduction
2. Conclusion of EBCx effort on the Palm Springs water source heat pump loop.
3. A common VRF system EBCx issue.
4. Introduce the concept of electrification and the all electric building.
5. A closer look at how buildings use heat in the context of the climate they are in.
6. A closer look at coil performance in the context of using recovered energy.
7. A look at the power of an ongoing commissioning process, a dedication to energy efficiency, and creative thinking.
8. All electric building case studies.

A Bit About Me

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

A Senior Engineer for Facility Dynamics Engineering Focusing On:

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

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

Resources
(See Module 1 for Details)

The Far Side C | Facility Dynami | Microsoft Forn | (8) Calendar | | Pacific Northw | Map Results | | New tab | Google | Favorites | Google Forms | Home

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What's New?

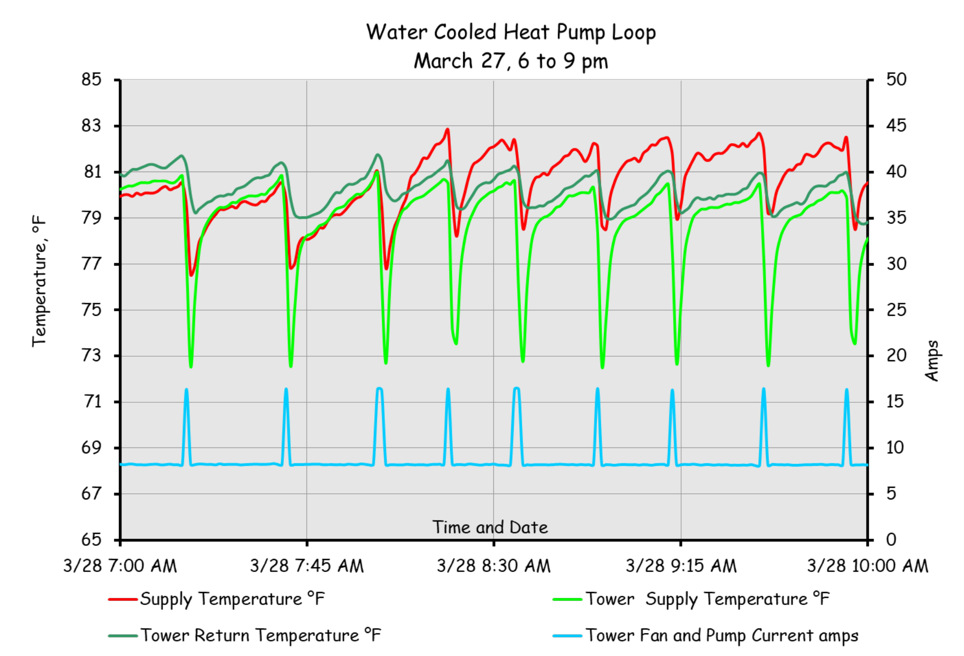
Search

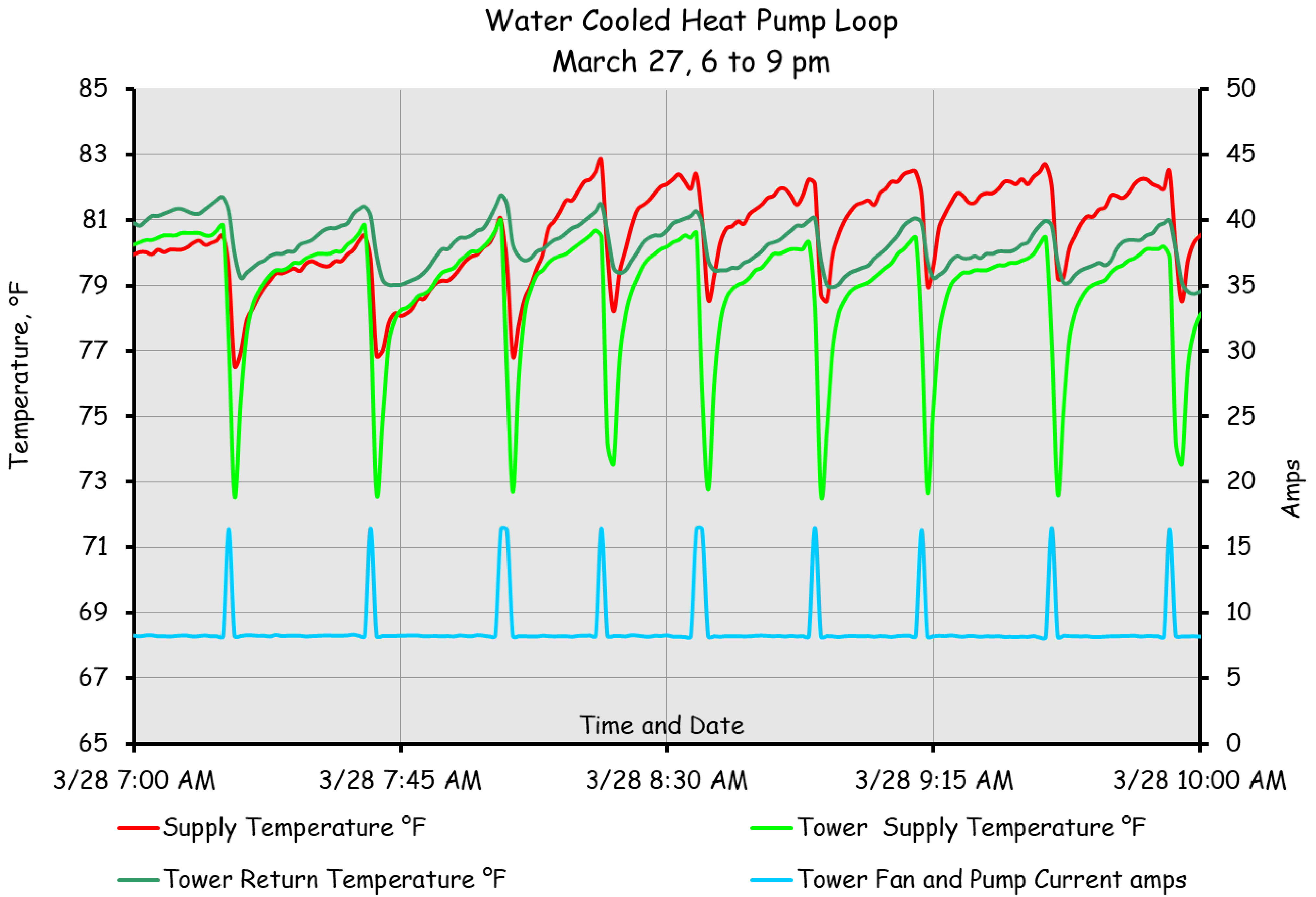
Buildings are Talking to Us

We Just Need to Learn How to Listen

My Goal

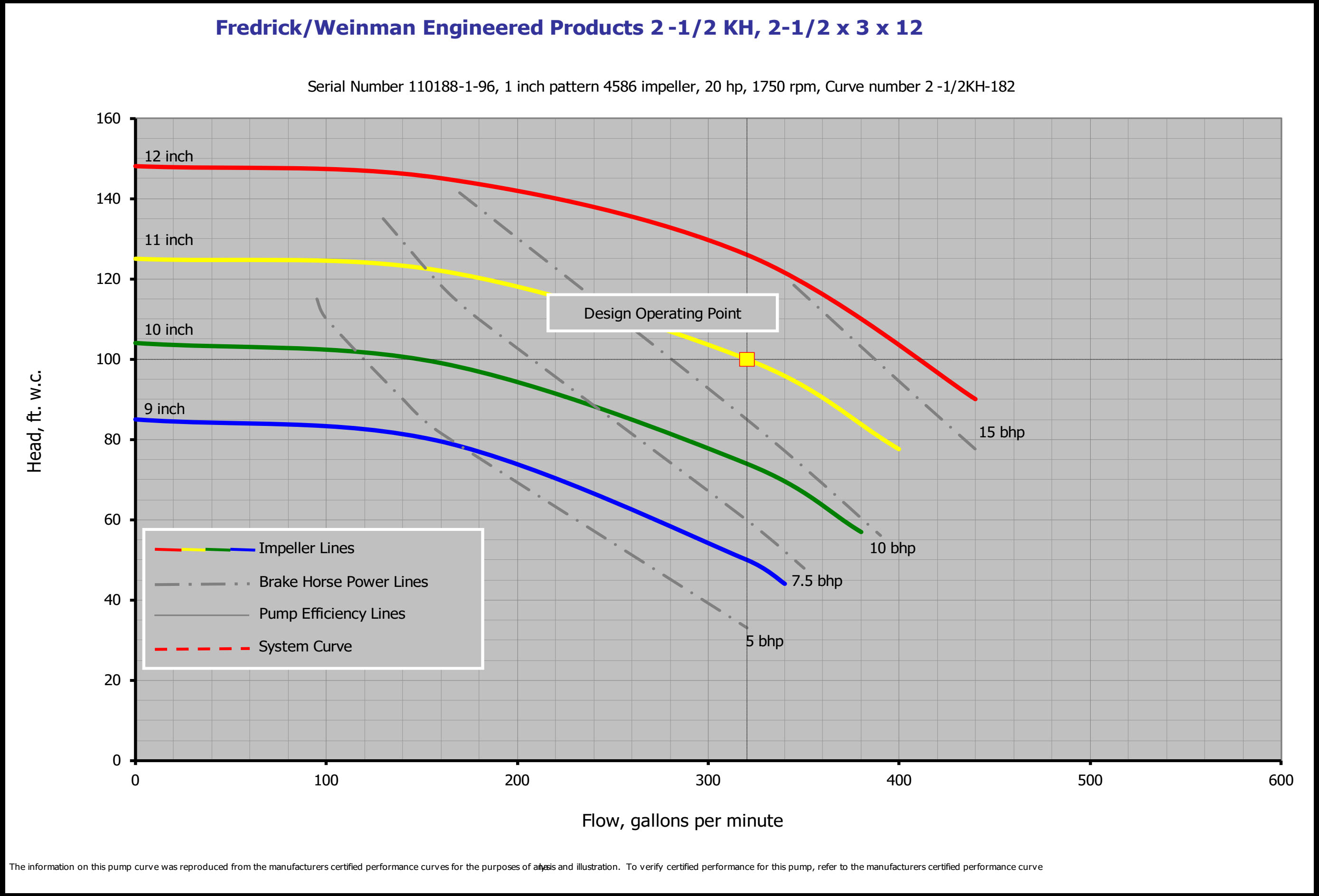
Previously on *Commissioning Heat Pump Systems*



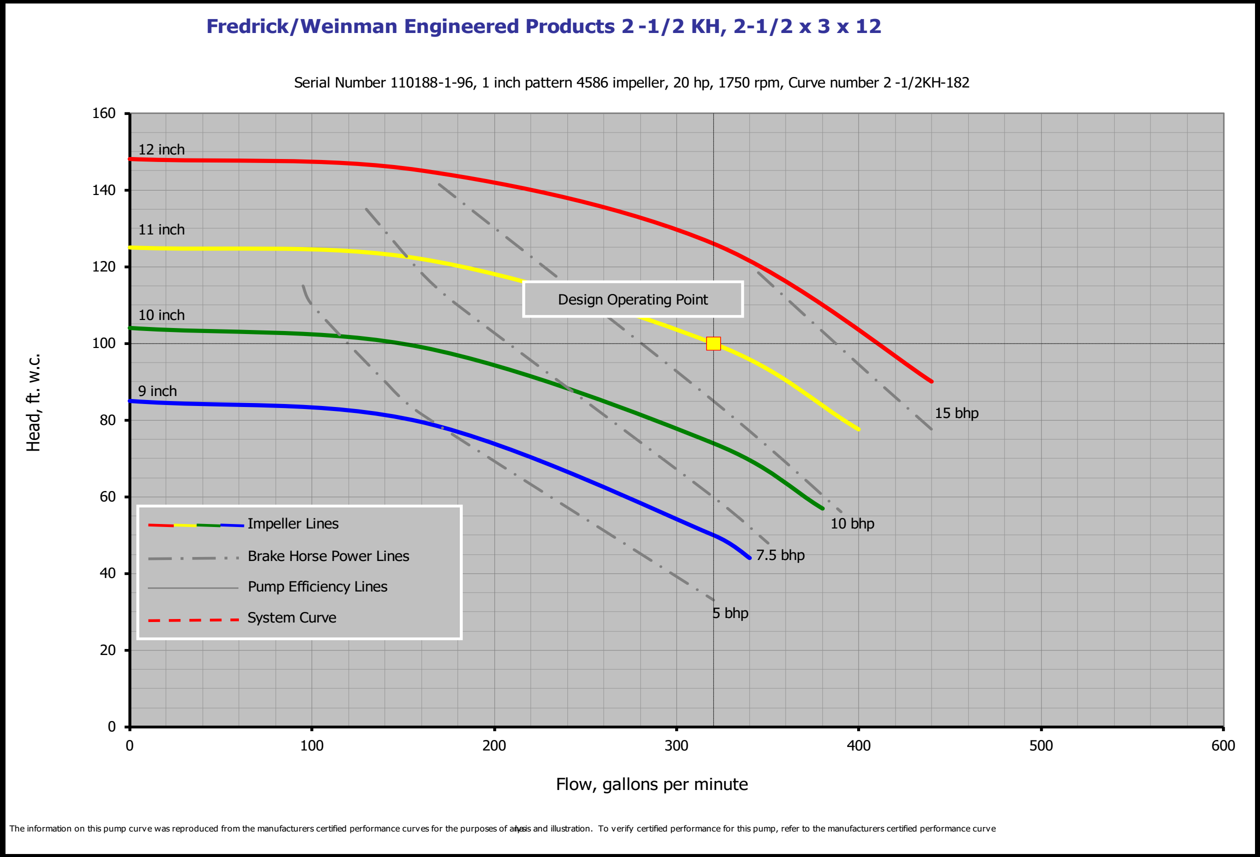


Water Cooled Heat Pump Loop
March 27, 6 to 9 pm
Temperature, °F
Amps
85
83
81
79
77
75
73
71
69
67
65
50
45
40
35
30
25
20
15
10
5
0
Time and Date
3/28 7:00 AM
3/28 7:45 AM
3/28 8:30 AM
3/28 9:15 AM
3/28 10:00 AM
Supply Temperature °F
Tower Supply Temperature °F
Tower Return Temperature °F
Tower Fan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

Does the Pump Head Seem Reasonable?



What You Might Learn From the Pump

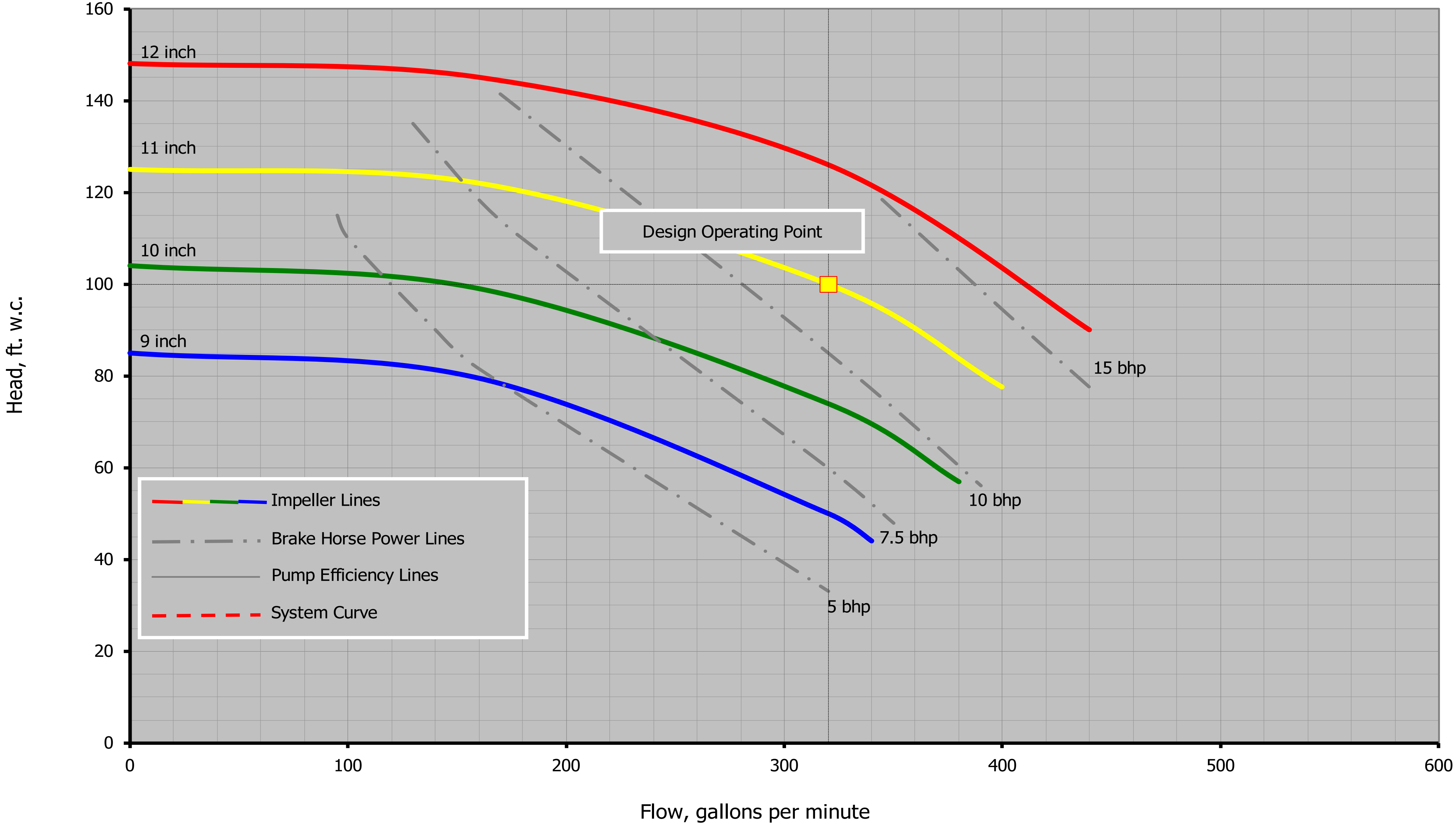


Design Condition

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

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

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



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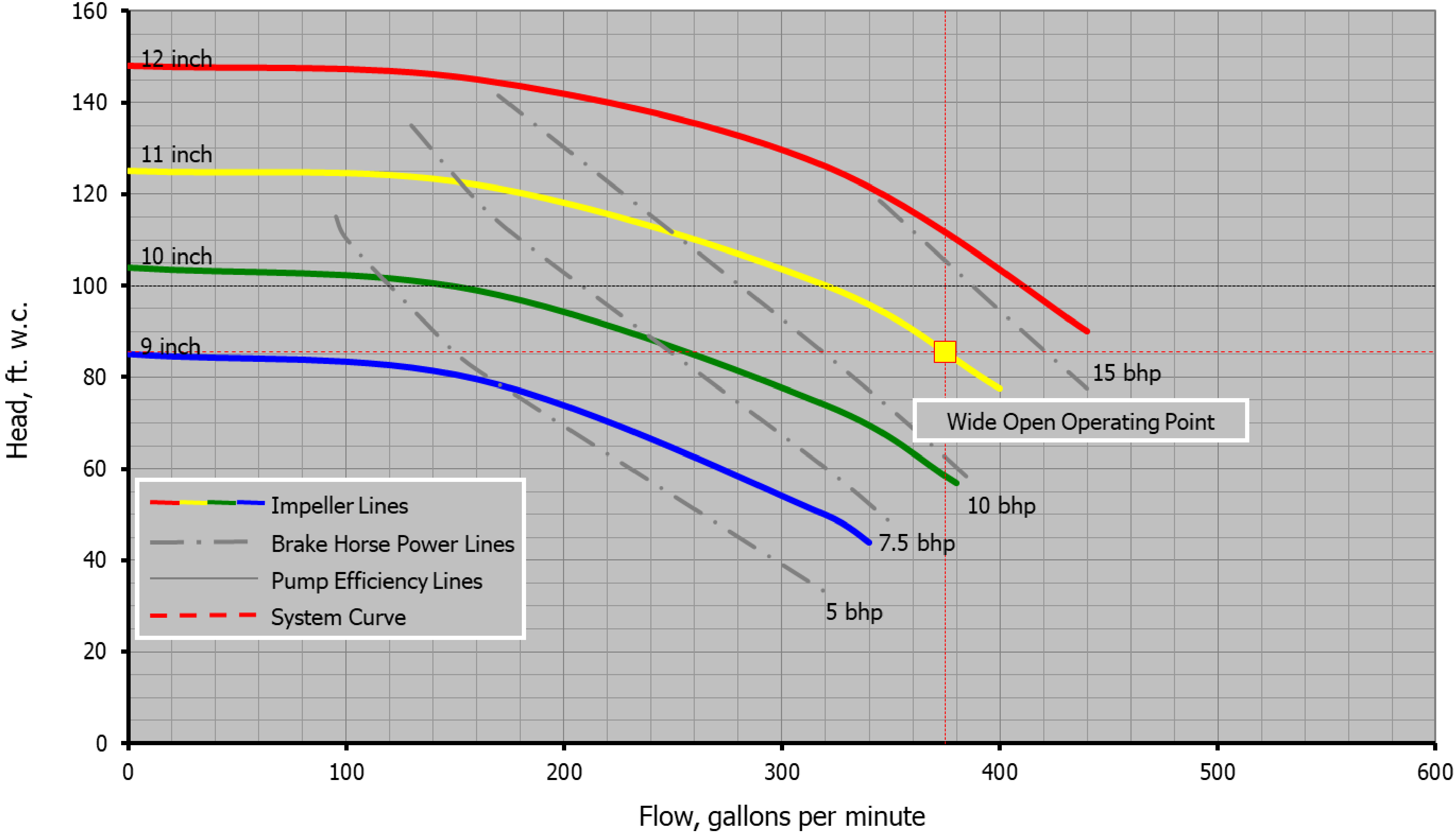
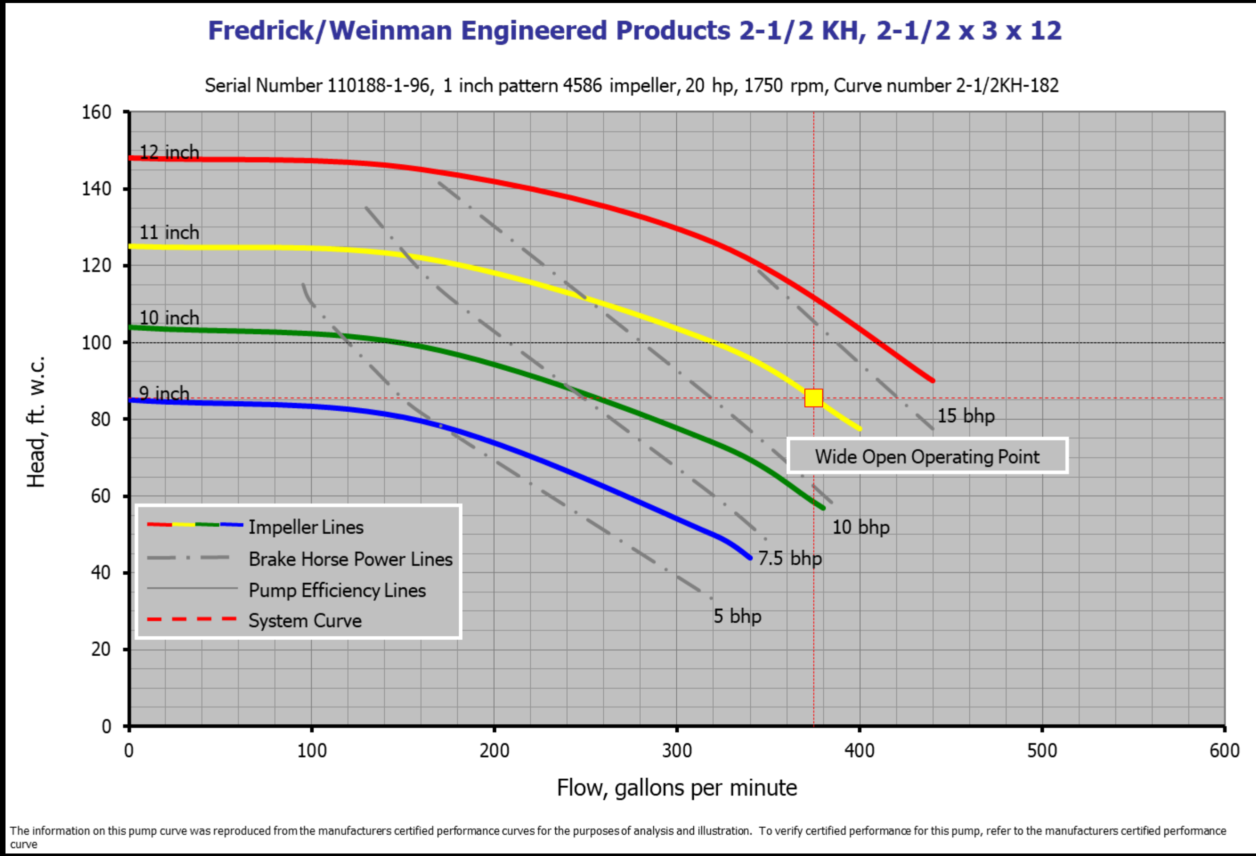


The information on this pump curve was reproduced from the manufacturers certified performance curves for the purposes of analysis and illustration. To verify certified performance for this pump, refer to the manufacturers certified performance curve

What Did You Learn?

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



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

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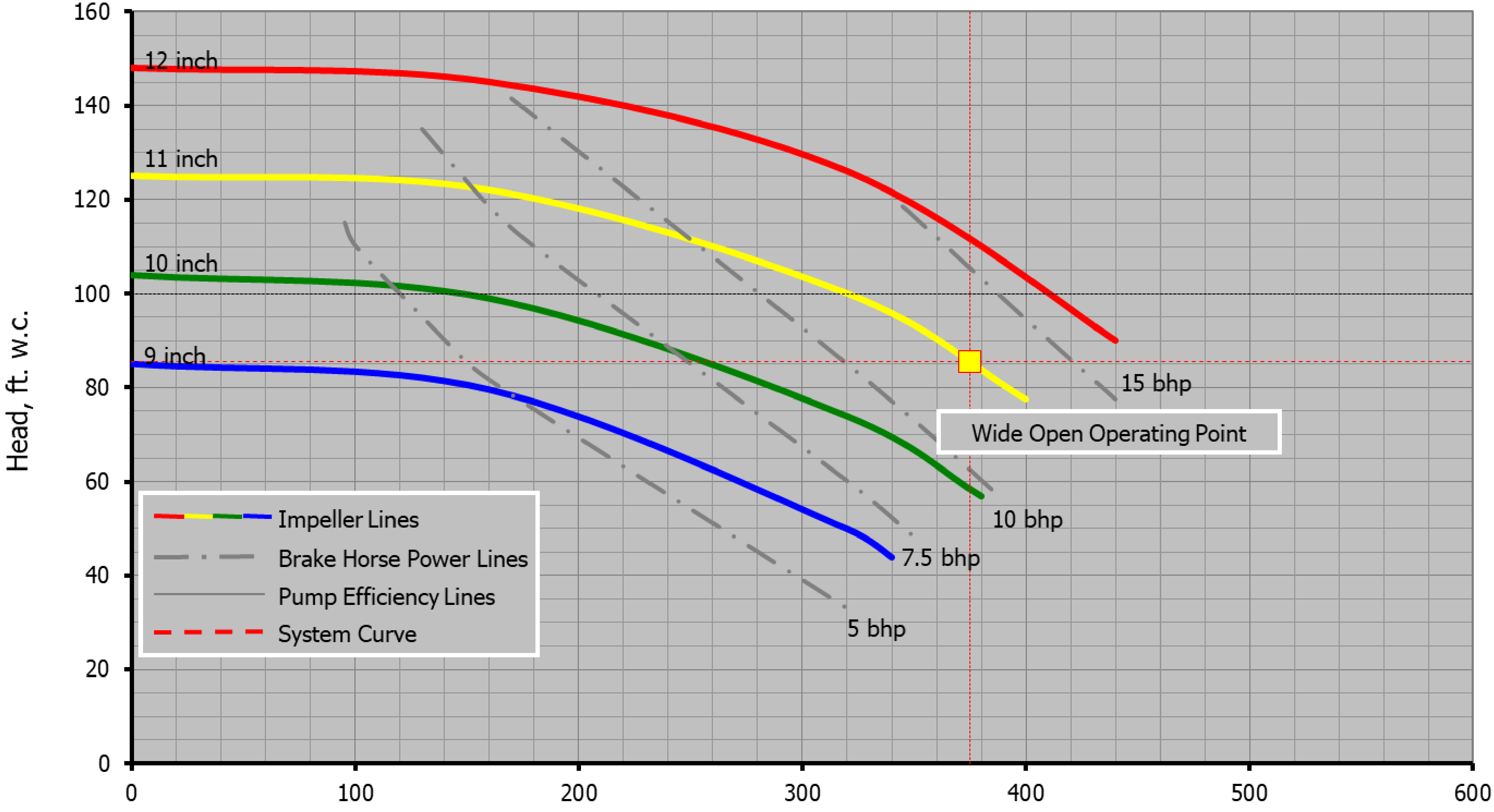

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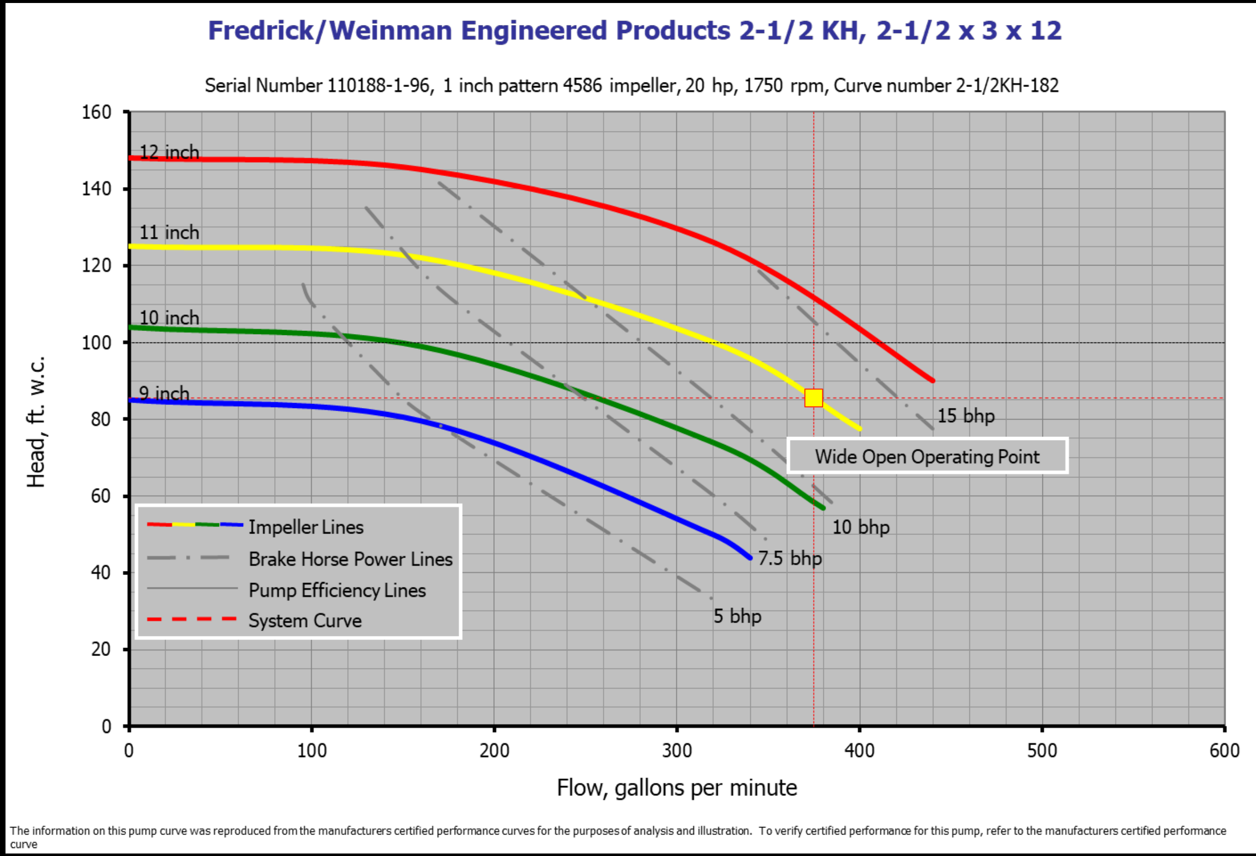
What Did You Learn?

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



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

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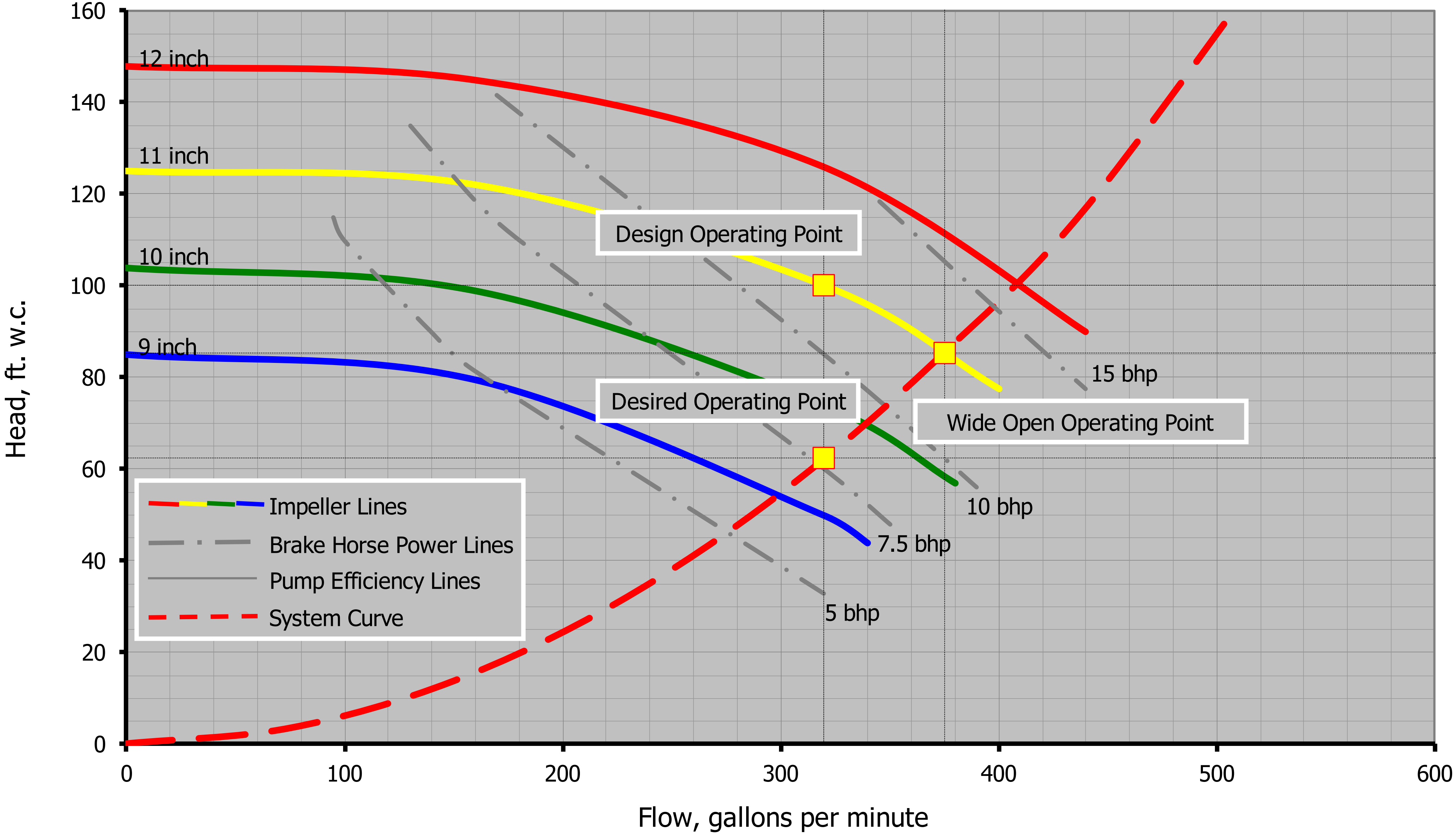

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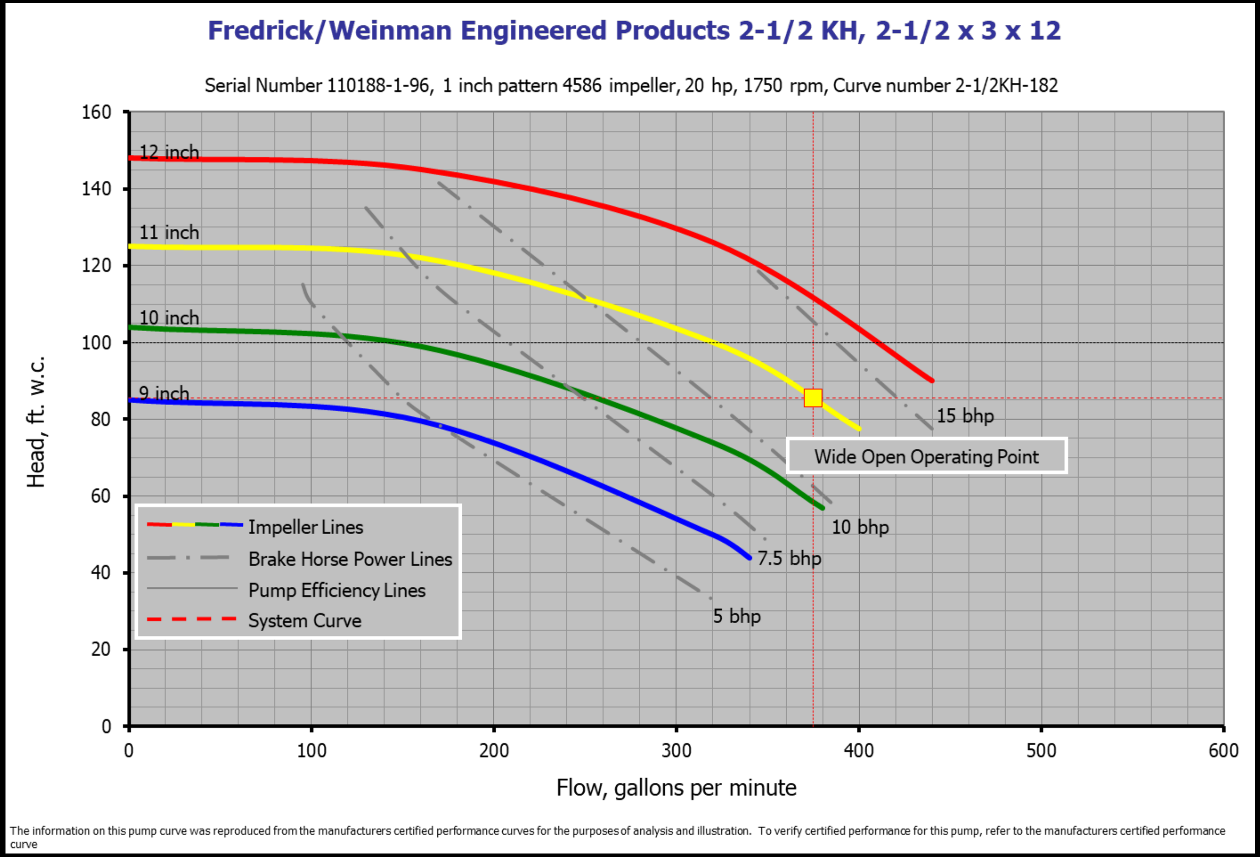
What Did You Learn?

What are the options for optimizing the pump?



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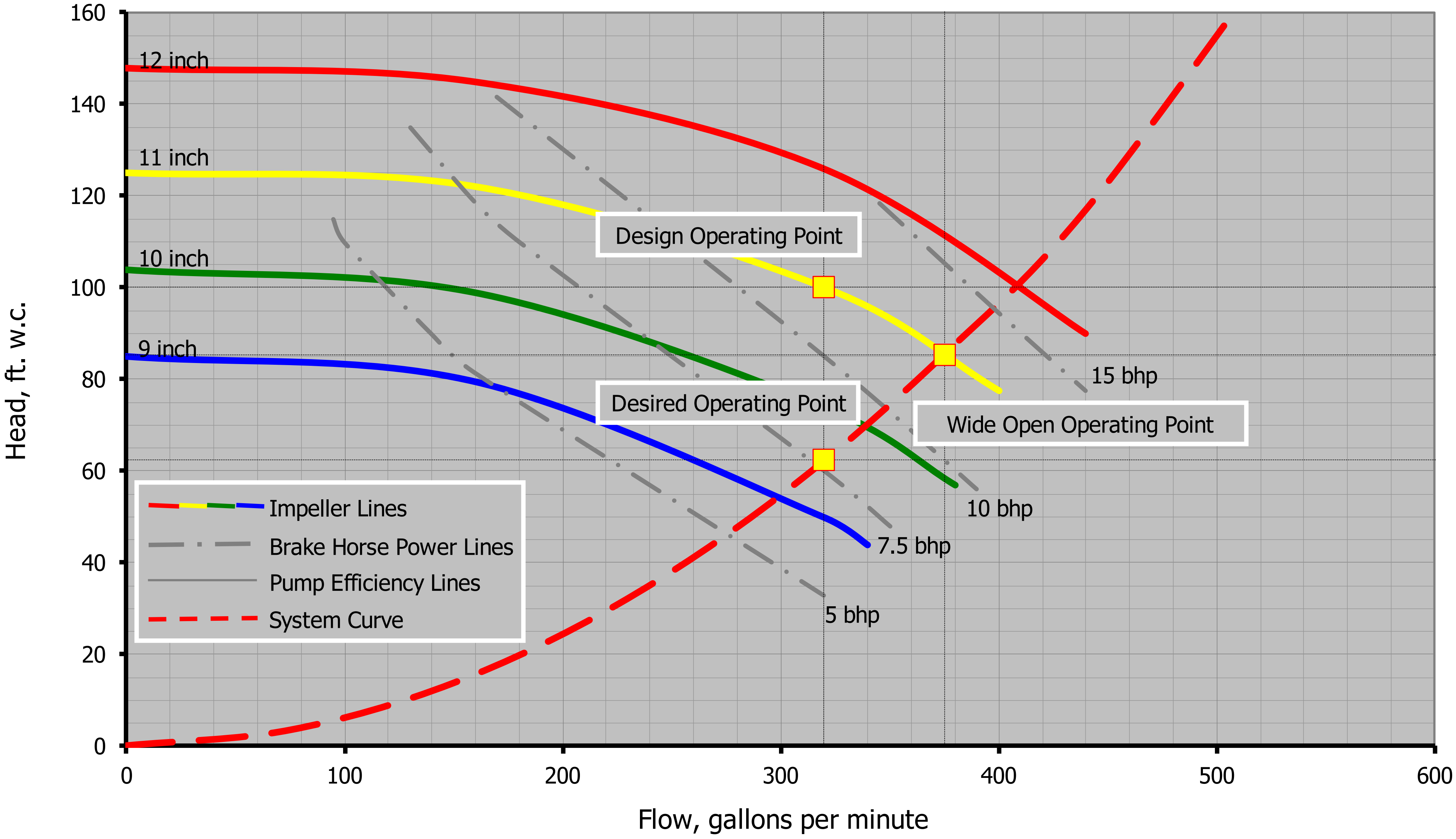

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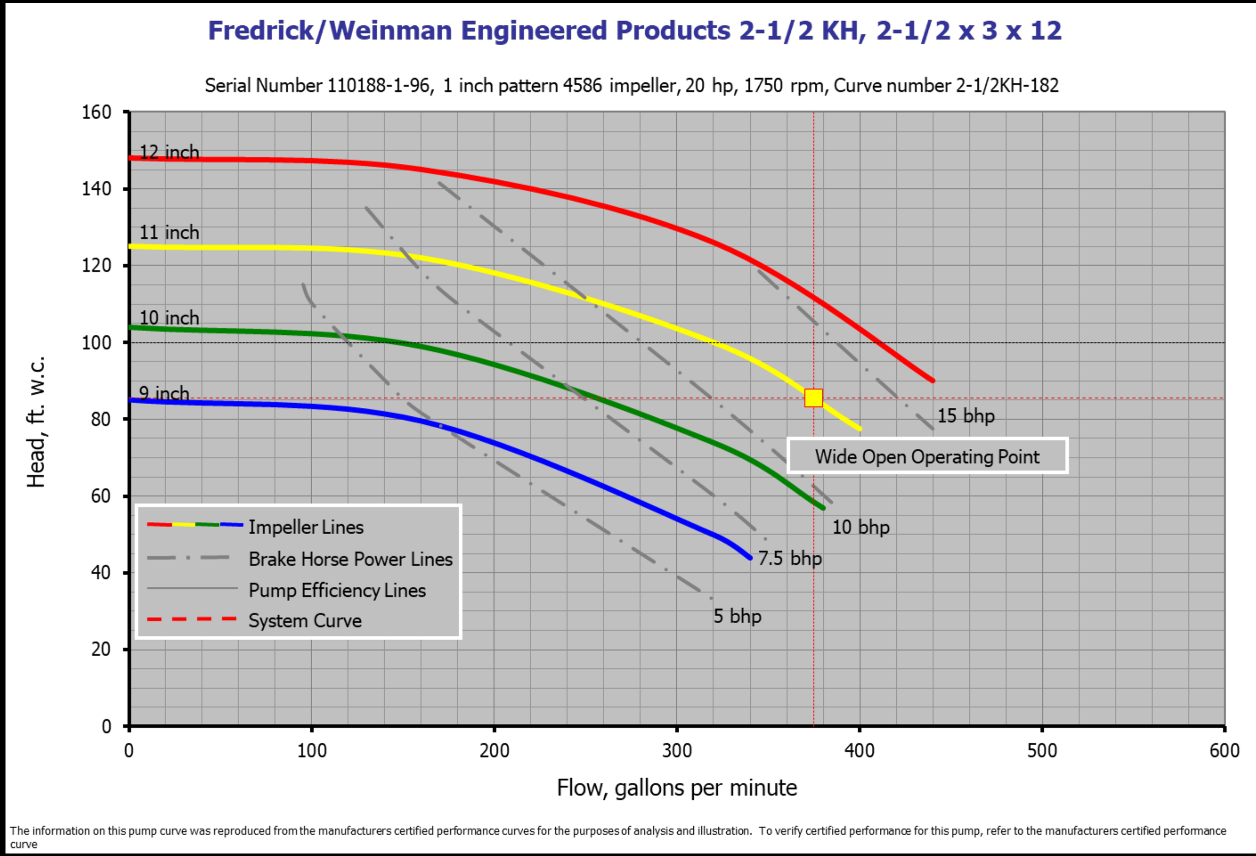
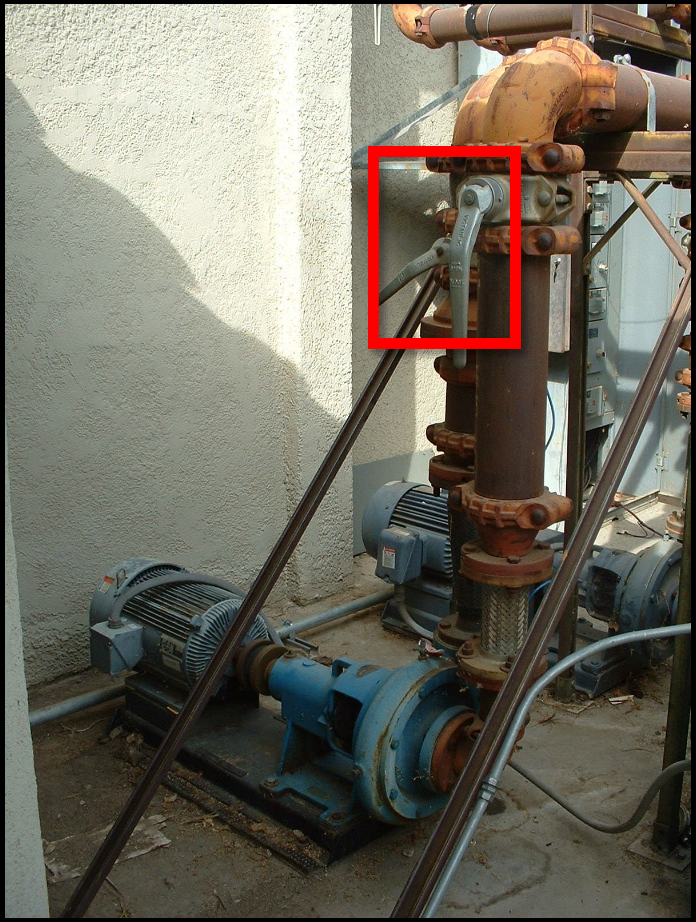
What Did You Learn?

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



A Pump In A Different Loop Also Has Something to Say



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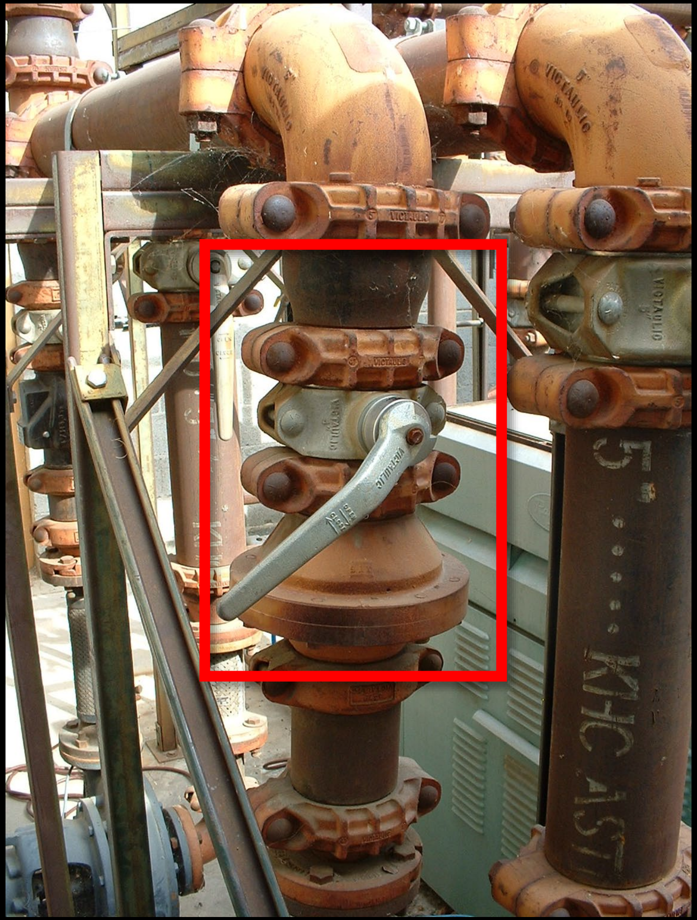


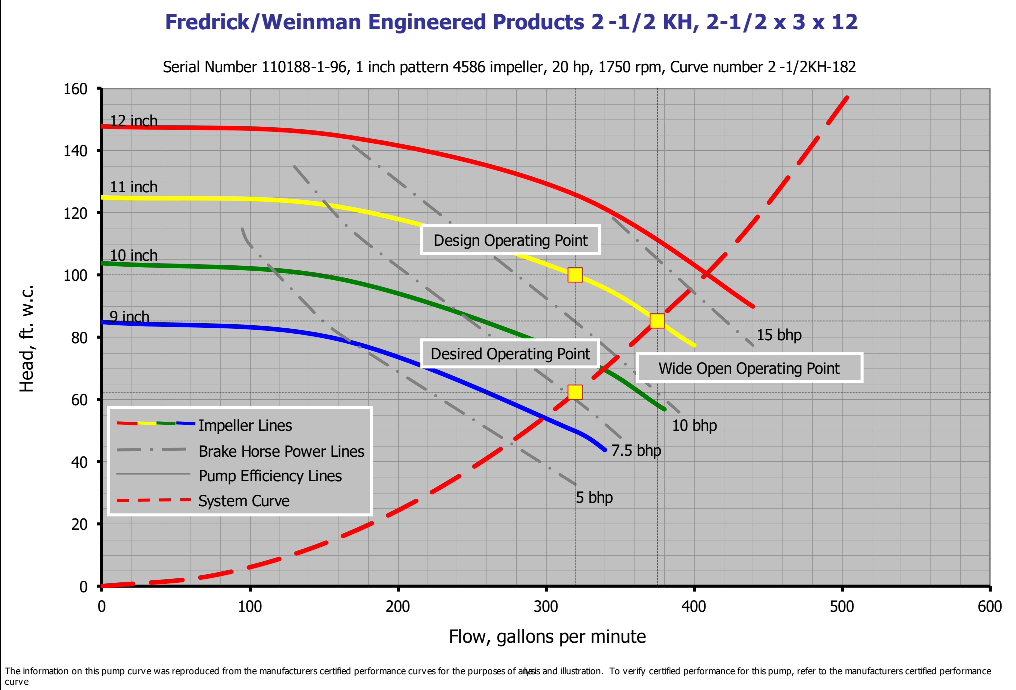
It's saying …

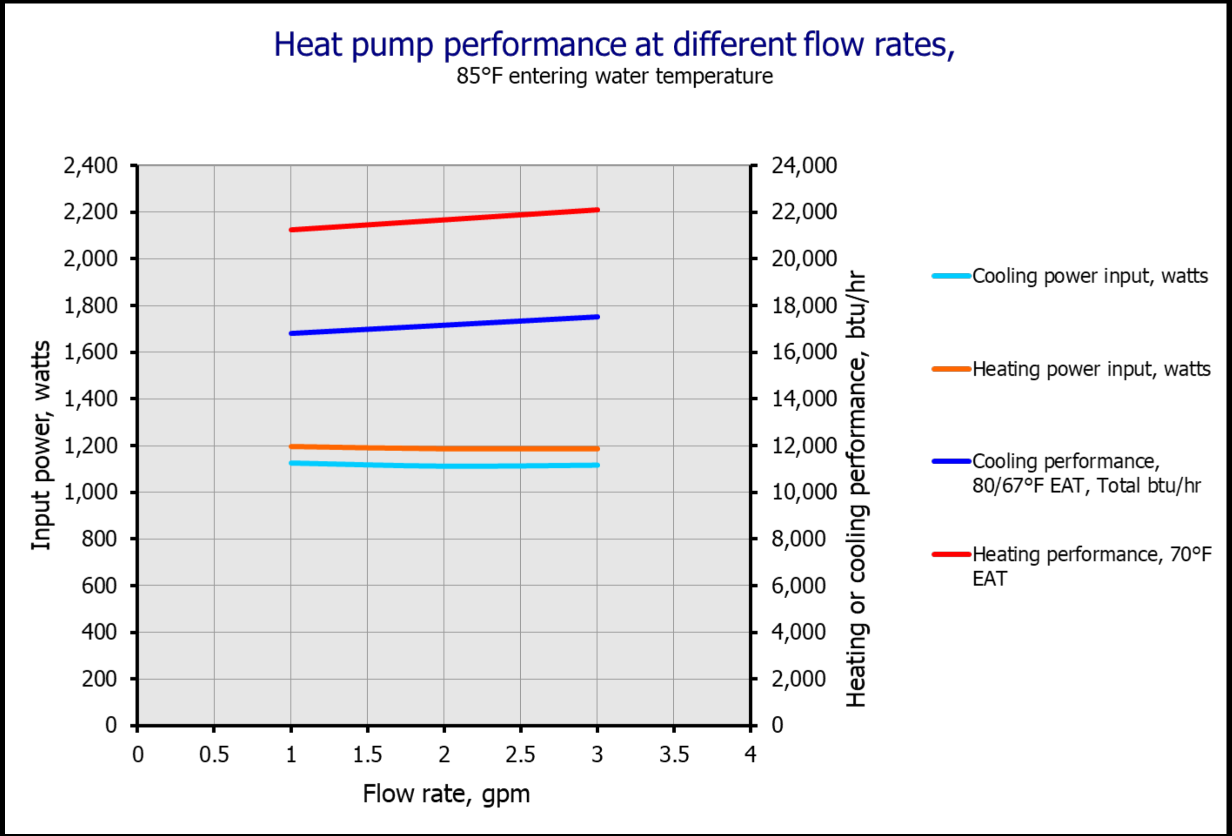
Help! Help! I'm oversized!

… just in a different way

Considering Heat Pump Interactions

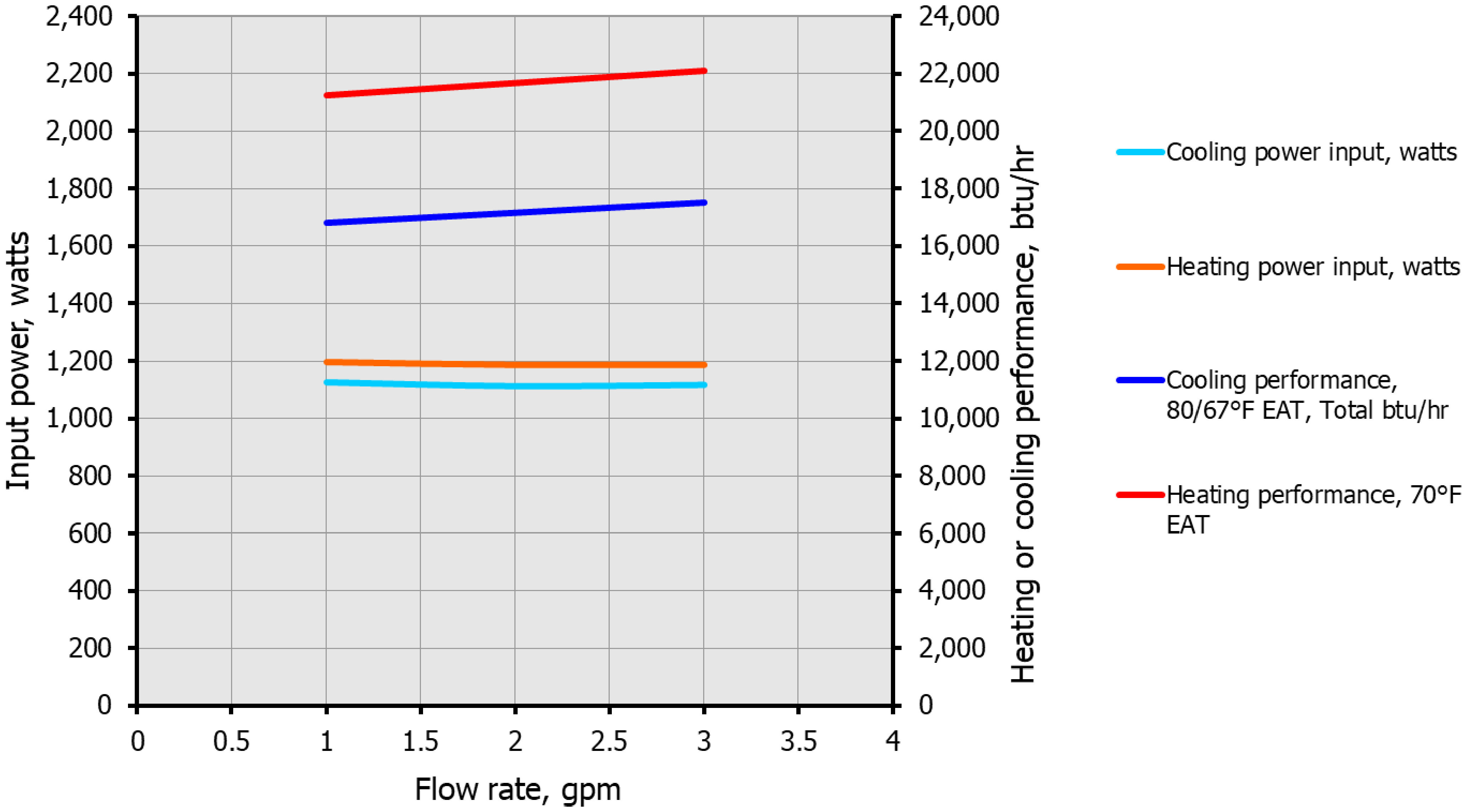
Heat pump performance can be impacted by the flows and temperatures in the system



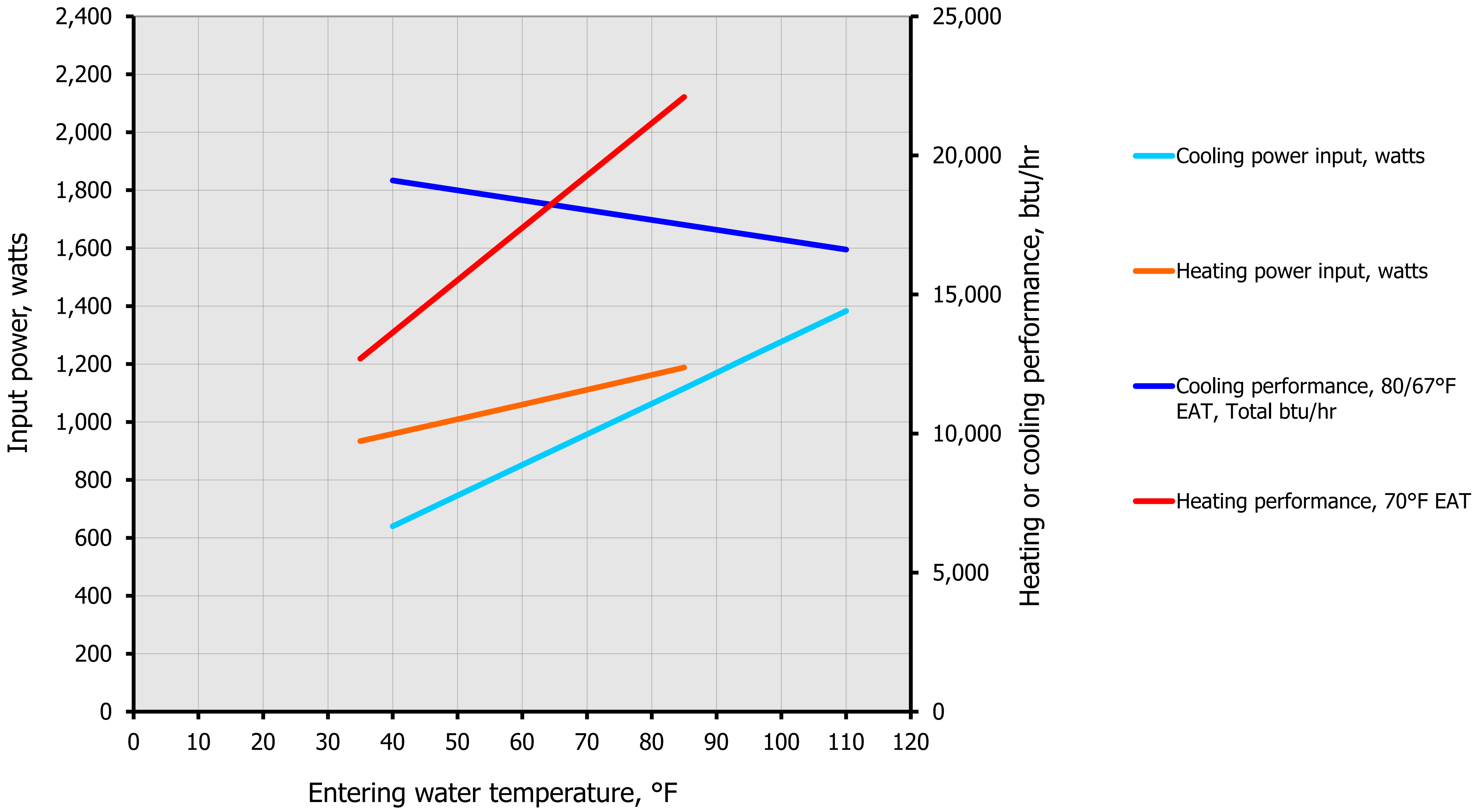


Heat pump performance at different flow rates,

85°F entering water temperature



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



Bottom Lines

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

Bottom Lines

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

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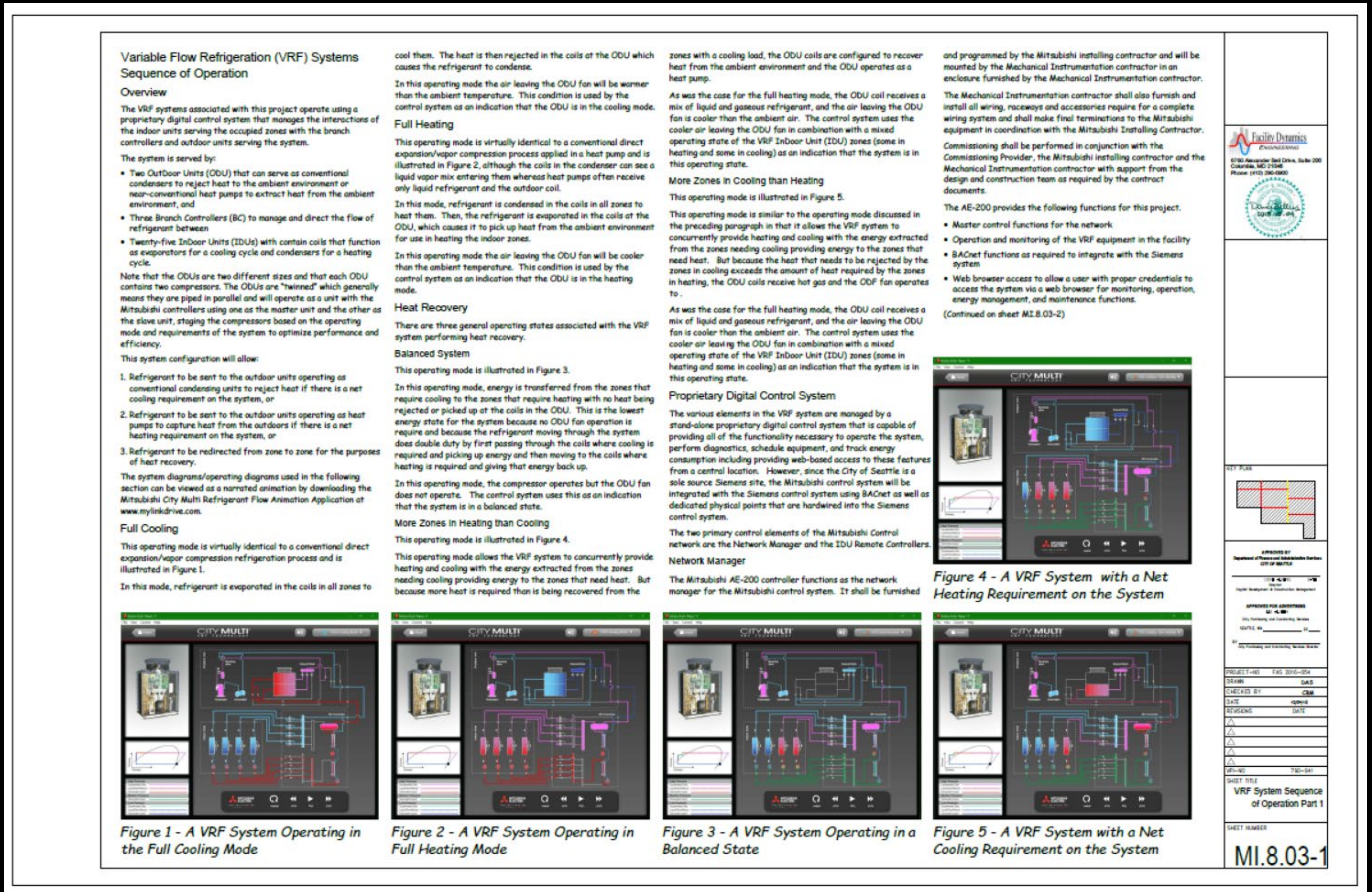
VRF Systems (Again)

Variable Refrigerant Flow Systems

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

VRF Systems



Variable Flow Refrigeration (VRF) Systems Sequence of Operation

Overview

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

The system is served by:

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

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

This system configuration will allow:

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

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

Full Cooling

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

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

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

Full Heating

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

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

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

Heat Recovery

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

Balanced System

This operating mode is illustrated in Figure 3.

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

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

More Zones in Heating than Cooling

This operating mode is illustrated in Figure 4.

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

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

More Zones in Cooling than Heating

This operating mode is illustrated in Figure 5.

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

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

Proprietary Digital Control System

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

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

Network Manager

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

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

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

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

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

(Continued on sheet MI.8.03-2)

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

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

Figure 2 - A VRF System Operating in Full Heating Mode

Figure 3 - A VRF System Operating in a Balanced State

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

VRF System Sequence of Operation Part 1

MI.8.03-1

Taking a closer look at the details

Turn-Down Limitations

VRF systems are often considered to be capable of infinite turn down

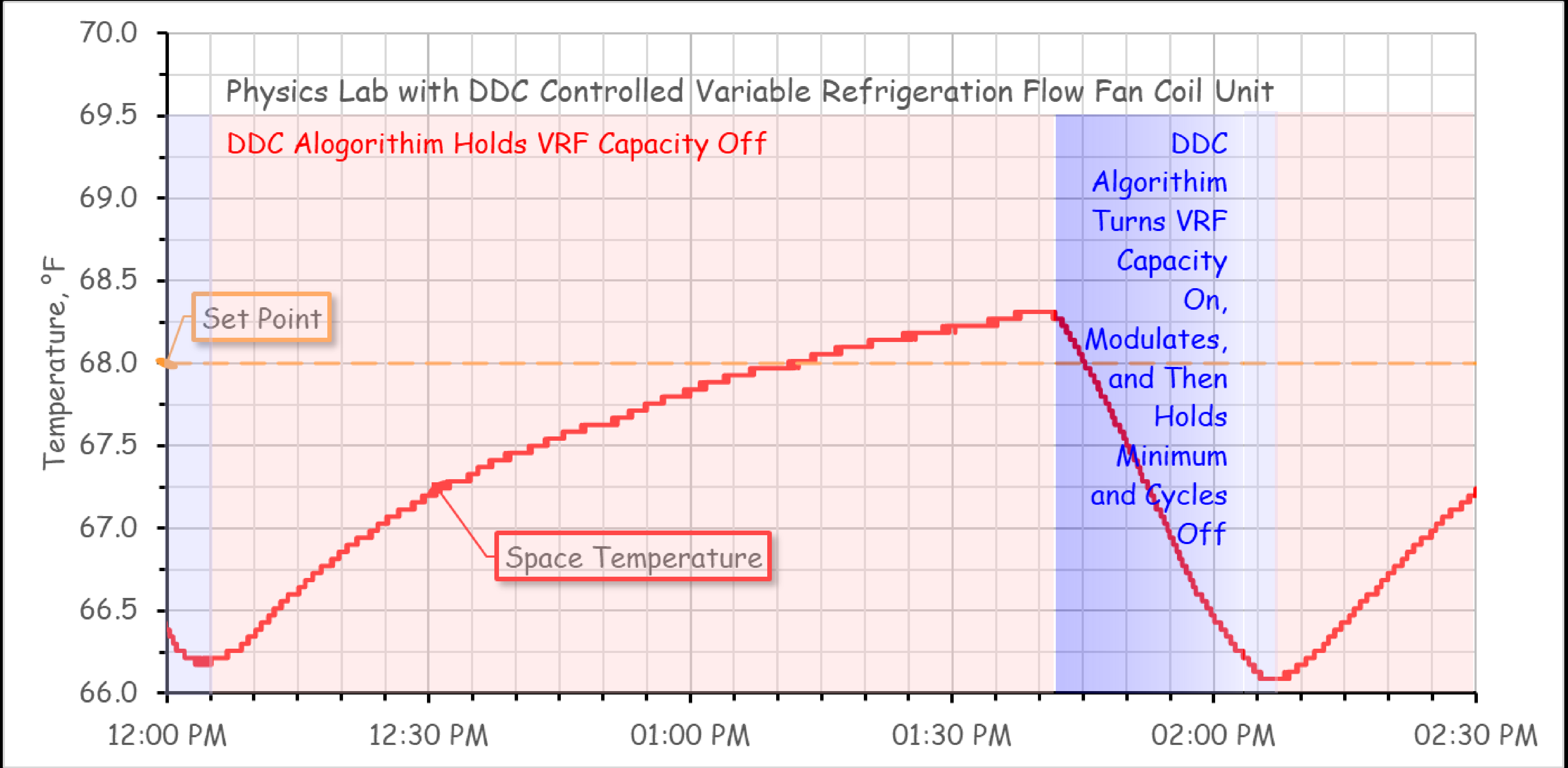
- What we take that to mean (would like it to mean)

  subject to no limitation or external determination

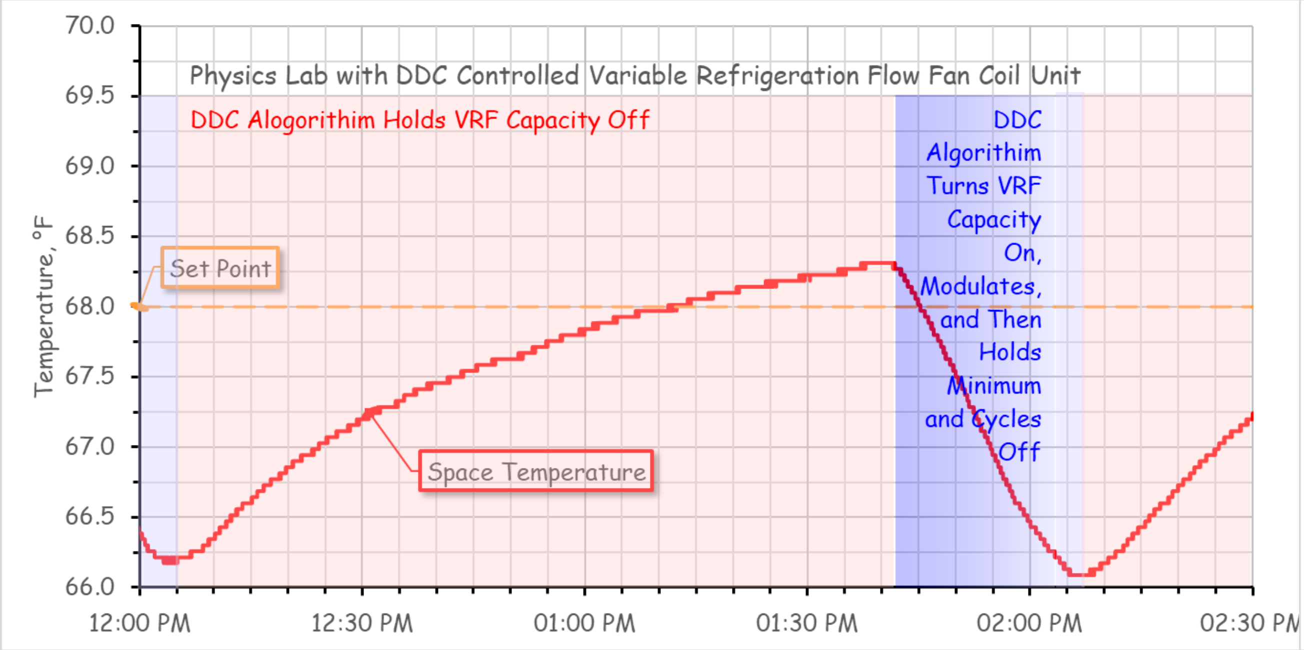
  www.merriam-webster.com

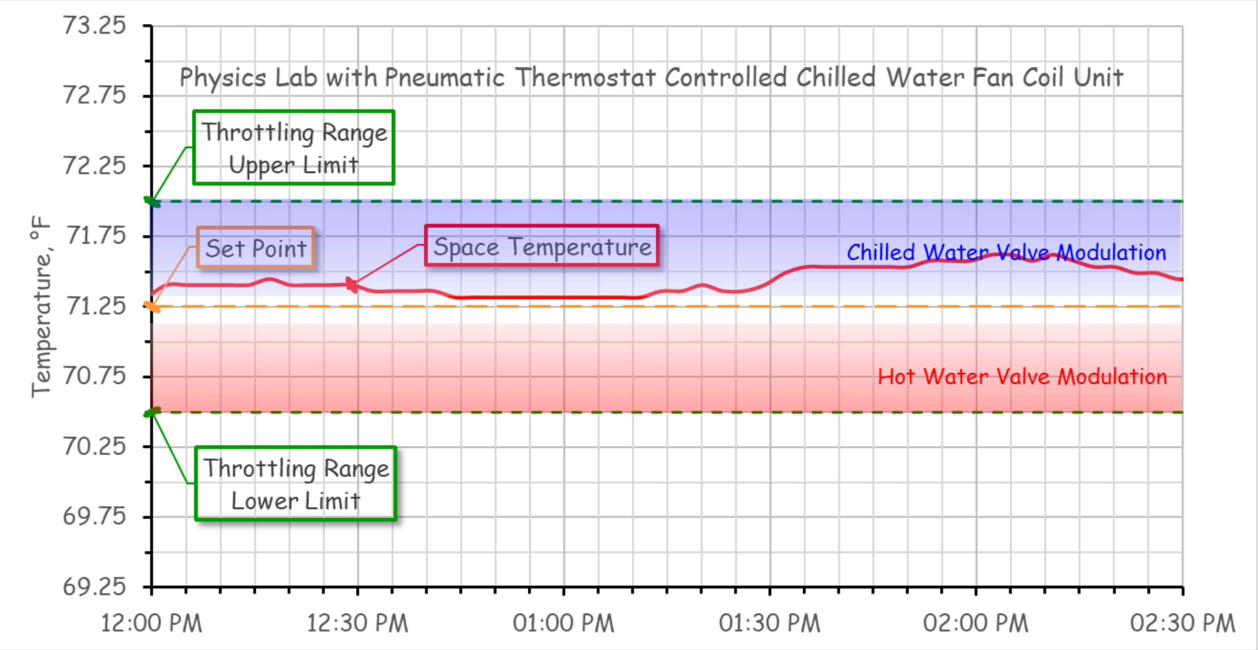
- Based on vendor discussions “infinite” means
  - 15-20% of rated capacity for the indoor units
  - 19-25% of rated capacity for the outdoor units

Turn-Down Limitations

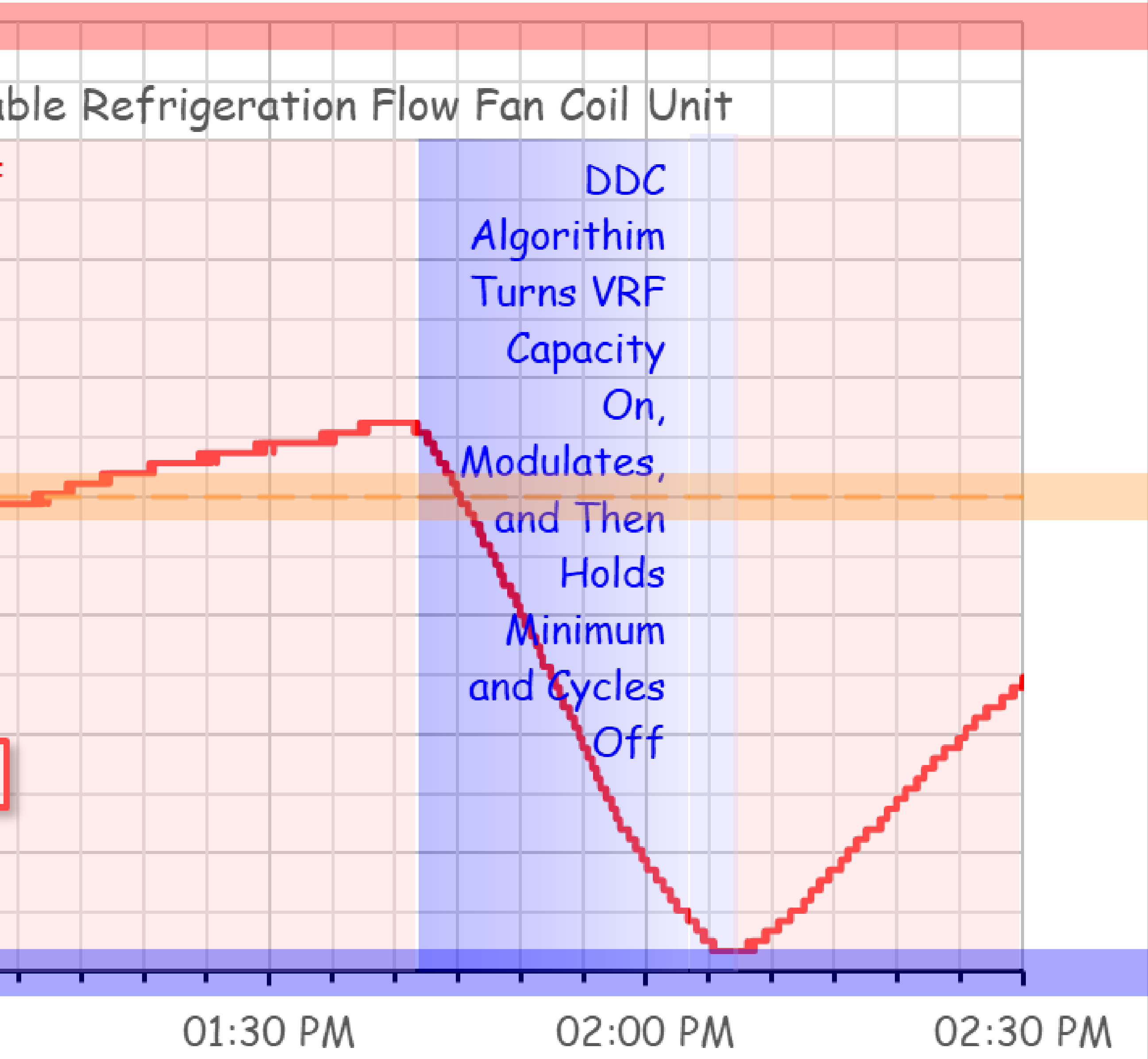


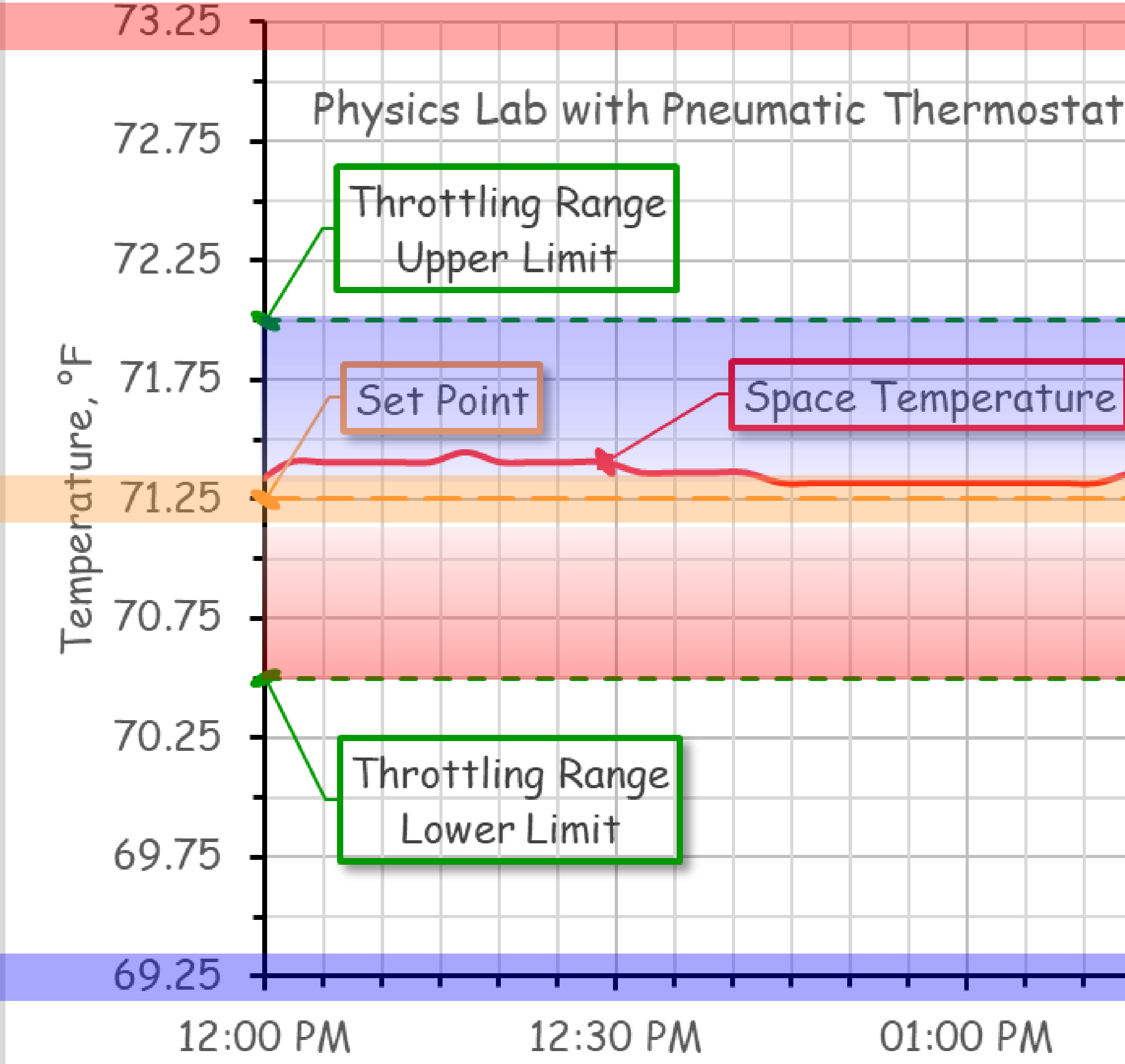
Turn-Down Limitations



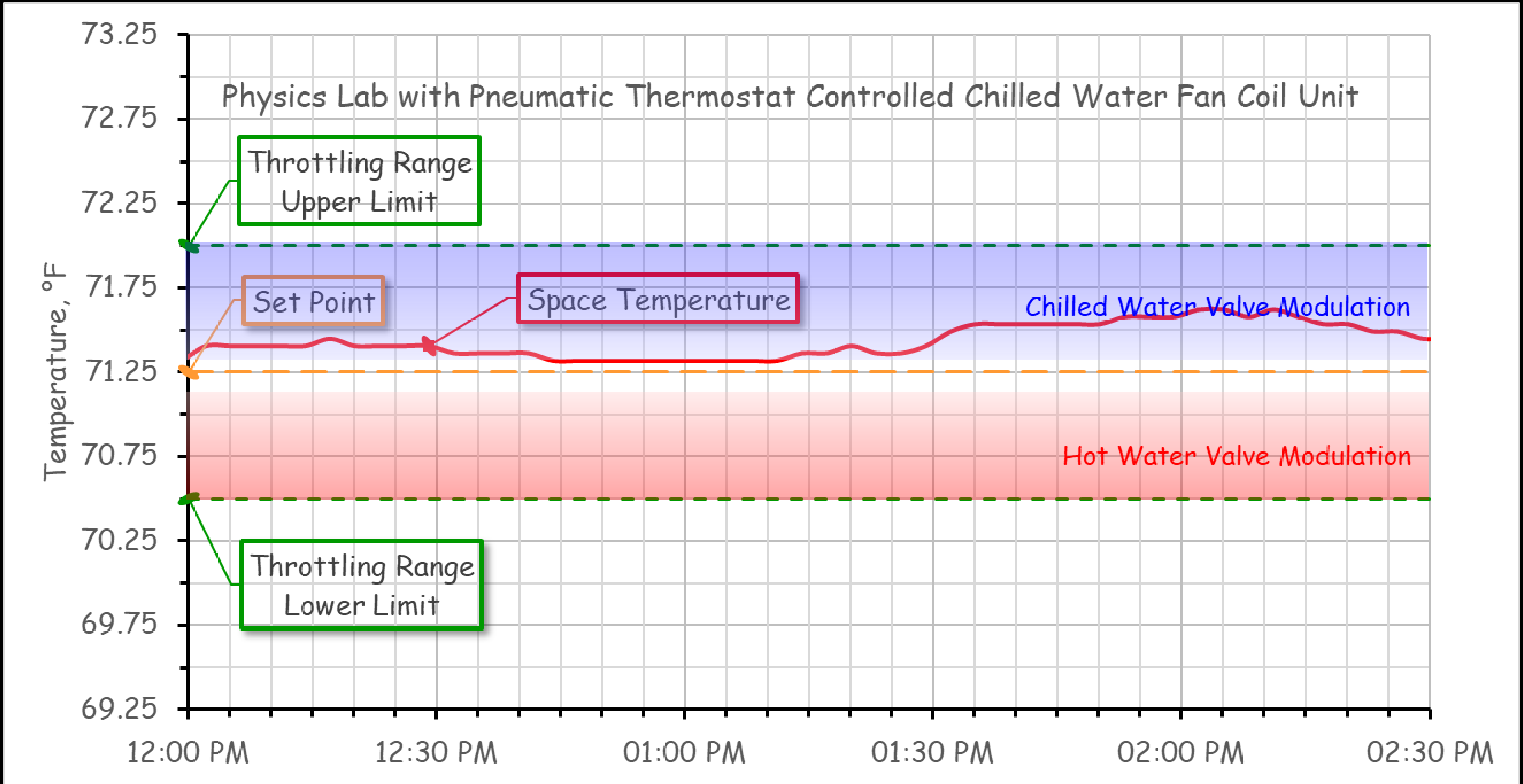


Turn-Down Limitations

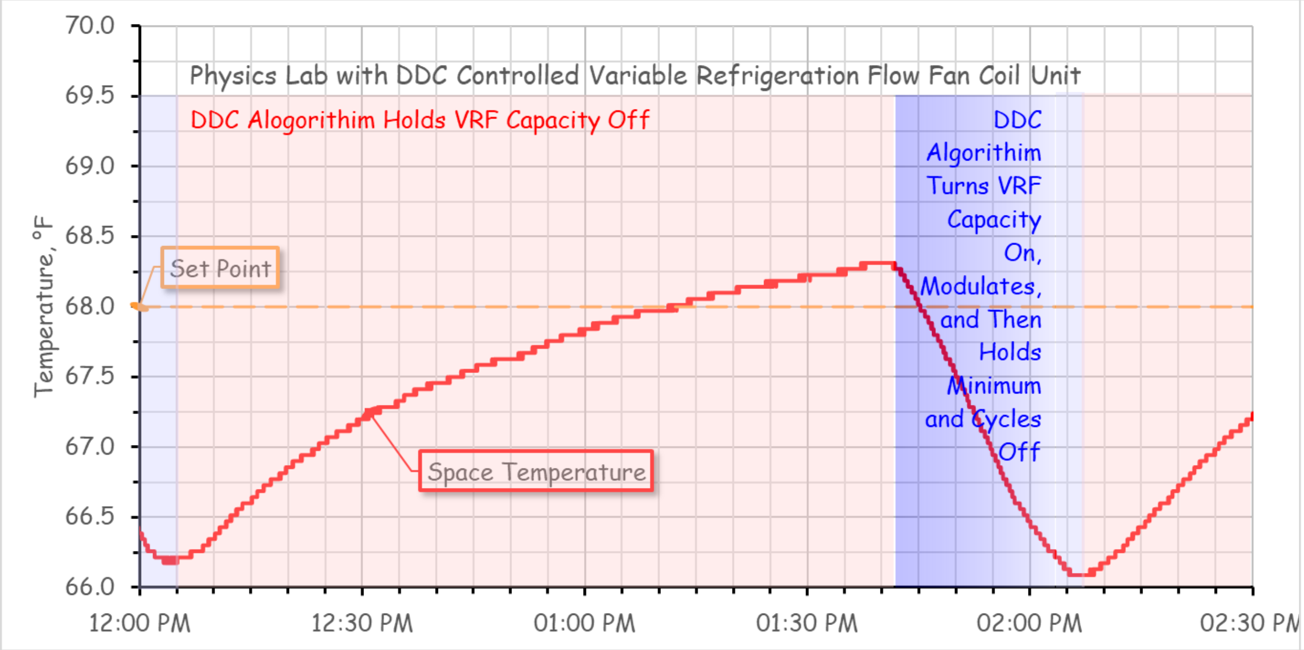


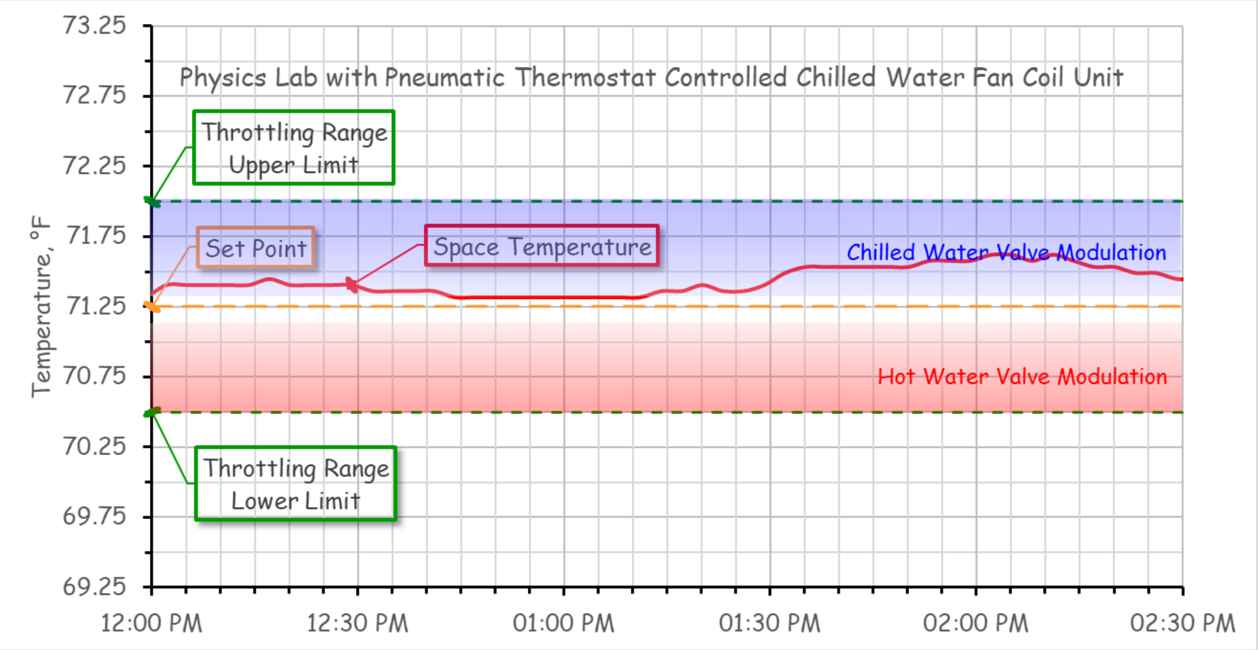


Turn-Down Limitations

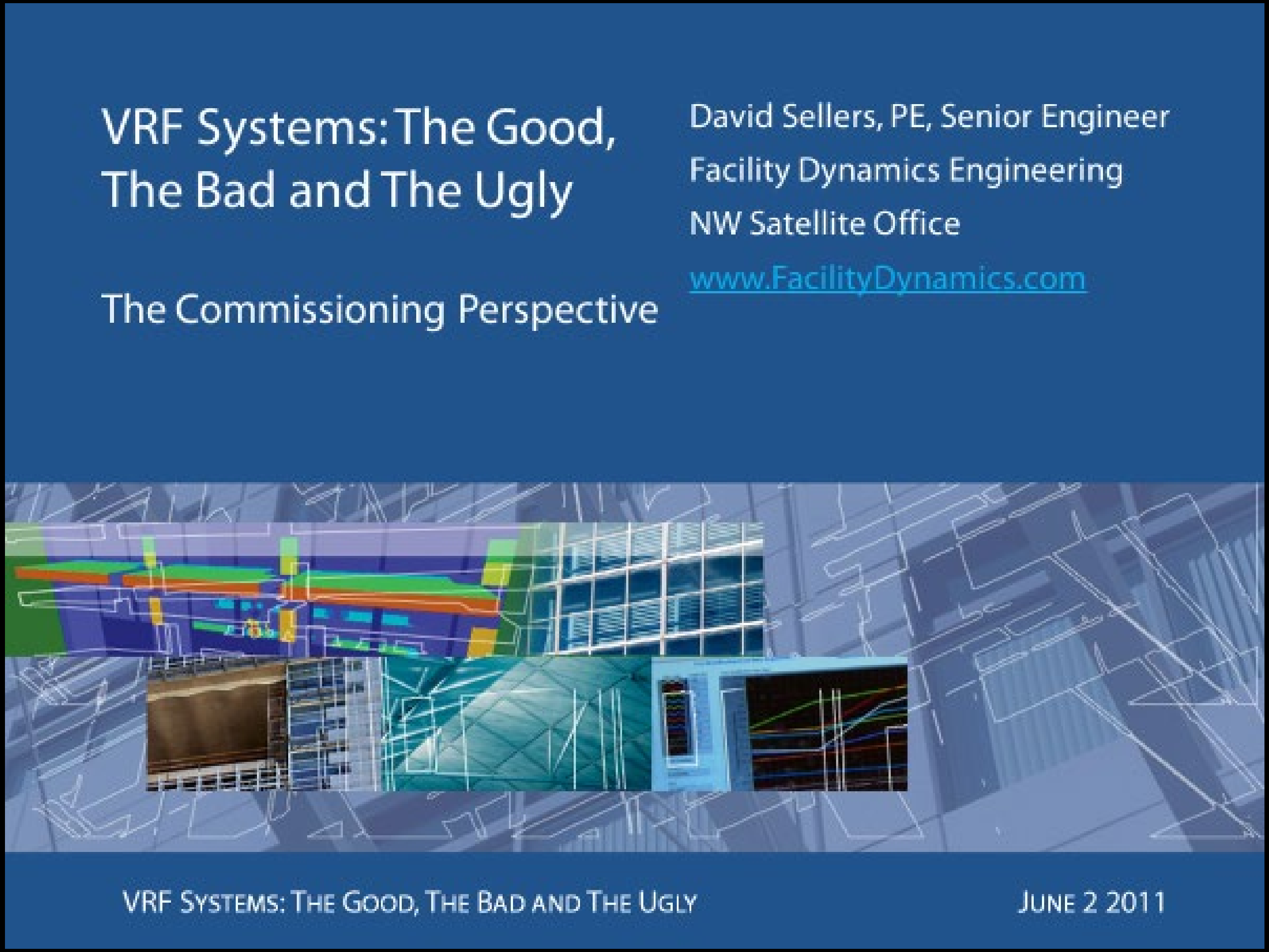


Turn-Down Limitations





VRF Systems



https://tinyurl.com/VRFMemo

Electrification and the Already All-Electric Building

Electrification and the Already All-Electric Building

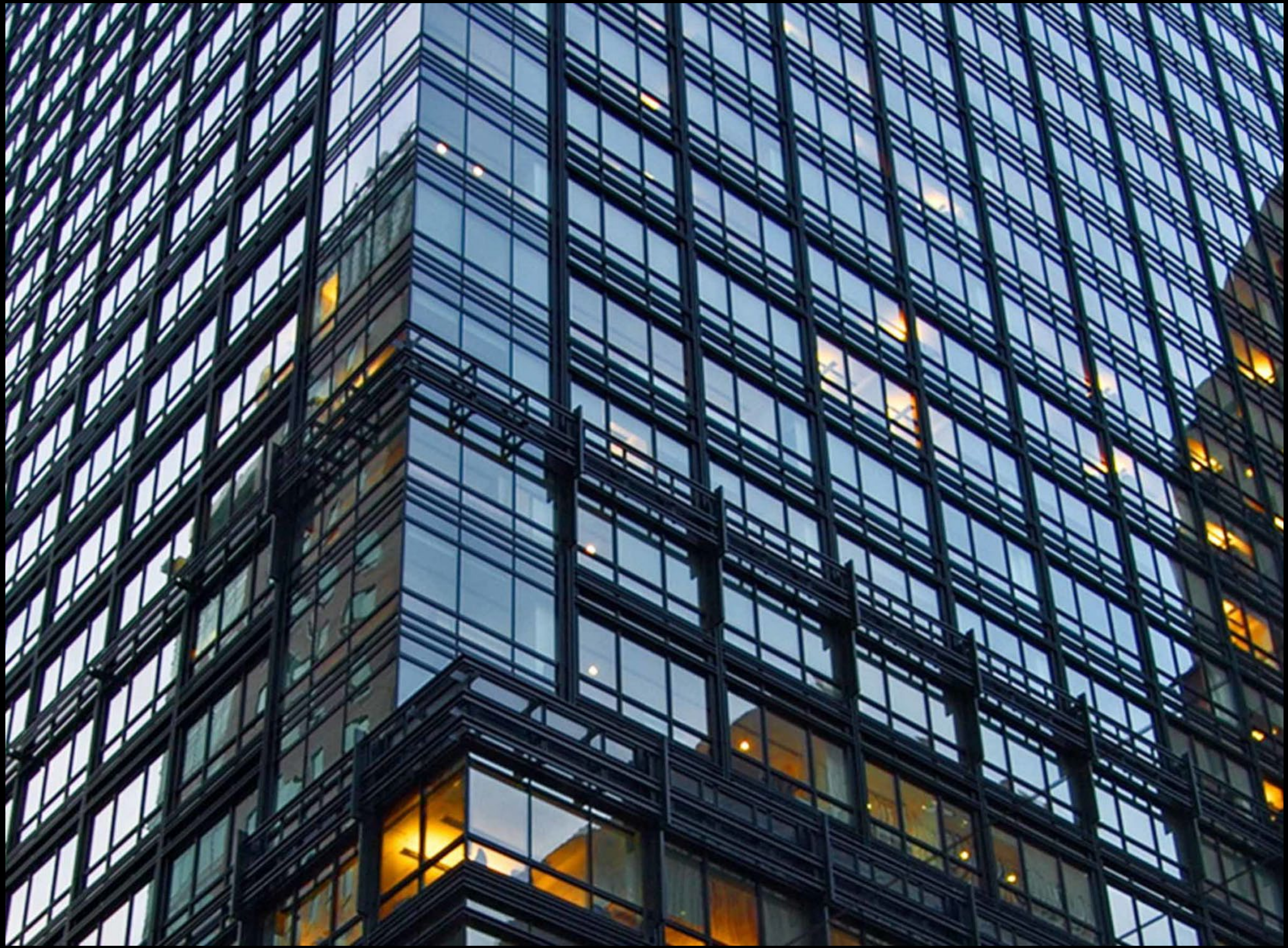
560 Mission Street

- 2002
- 31 Floors
- 665,000 sq.ft.
- LEED Platinum
- All Electric
  - *in anticipation of being net-zero and carbon free*

Electrification and the Already All-Electric Building

I have 300 kW of electric resistance heat, and the energy it uses is a major portion of our utility bills. And yet the building is cold!

Gary Walters, Chief Engineer



Carbon vs. Time vs. Efficiency

Carbon vs. Time vs. Efficiency

We expect our energy mix to be 70% carbon free by 2040 based on current commitments and mandates, and we're working to deliver the right resources and technologies to make that happen

Energy Strategy; www.portlandgeneral.com

Carbon vs. Time vs. Efficiency

The Current Carbon Impact of Burning Fuel to Make Heat

CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered by Boilers						
		Boiler Efficiency						
		95%	90%	85%	80%	75%	70%	65%
Natural Gas	117	123	130	137	146	156	167	179
Propane	139	146	154	163	173	185	198	213
Oil	163	172	182	192	204	218	234	251
Coal	212	223	235	249	265	282	303	326

Emmissions Factor Source - https://www.eia.gov/environment/emissions/co2_vol_mass.php

Heat Rate Source - "Heat Rates" tab of this spreadsheet

* This is the average value for the various fossil fuel power plants listed in the "Heat Rates" tab

Carbon vs. Time vs. Efficiency

The Goal

CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered by Boilers							lb CO_2 per Million Btu Delivered Renewable Resources or Nuclear Power
		Boiler Efficiency							
		95%	90%	85%	80%	75%	70%	65%	
Natural Gas	117	123	130	137	146	156	167	179	0
Propane	139	146	154	163	173	185	198	213	
Oil	163	172	182	192	204	218	234	251	
Coal	212	223	235	249	265	282	303	326	

Emmissions Factor Source - https://www.eia.gov/environment/emissions/co2_vol_mass.php

Heat Rate Source - "Heat Rates" tab of this spreadsheet

* This is the average value for the various fossil fuel power plants listed in the "Heat Rates" tab

Carbon vs. Time vs. Efficiency

The Current Reality

CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered by Boilers — Boiler Efficiency							lb CO_2 per Million Btu Delivered Renewable Resources or Nuclear Power
		95%	90%	85%	80%	75%	70%	65%	
Natural Gas	117	123	130	137	146	156	167	179	0
Propane	139	146	154	163	173	185	198	213	
Oil	163	172	182	192	204	218	234	251	
Coal	212	223	235	249	265	282	303	326	

Emmissions Factor Source - https://www.eia.gov/environment/emissions/co2_vol_mass.php

Heat Rate Source - "Heat Rates" tab of this spreadsheet

* This is the average value for the various fossil fuel power plants listed in the "Heat Rates" tab

State	% of Total Electric Power Generation — Non-Renewable — Combustion Processes: Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Renewable — Combustion Processes: Biomass	Renewable — Non-Combustion Processes: Hydro	Wind	Solar	Geothermal	Nuclear	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	62.4%	37.6%

Source - eGRID 2020, Table 4

Carbon vs. Time vs. Efficiency

The Current Reality

CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered by Boilers							lb CO_2 per Million Btu Delivered Renewable Resources or Nuclear Power
		Boiler Efficiency							
		95%	90%	85%	80%	75%	70%	65%	
Natural Gas	117	123	130	137	146	156	167	179	0
Propane	139	146	154	163	173	185	198	213	
Oil	163	172	182	192	204	218	234	251	
Coal	212	223	235	249	265	282	303	326	

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Heat Rate Source - "Heat Rates" tab of this spreadsheet

* This is the average value for the various fossil fuel power plants listed in the "Heat Rates" tab

Heat Rates for Different Types of Power Plants

Generating Station Type	Typical Heat Rate			
	Minimum		Maximum	
	Btu/kWh	Efficiency	Btu/kWh	Efficiency
Natural Gas with Cogeneration	5,000	68%	6,500	53%
Natural Gas Combined Cycle	6,200	55%	8,000	43%
Natural Gas Reciprocating Engine	7,500	46%	8,500	40%
Natural Gas Combustion Turbine	8,000	43%	10,000	34%
Coal Steam Turbine	9,000	38%	11,000	31%
Natural Gas Steam Turbine	10,000	34%	12,000	28%
Nuclear Power Plant	10,446	33%	10,459	33%

Heat Rate Source - https://energyknowledgebase.com/topics/heat-rate.asp

Emmissions Factor Source - https://www.eia.gov/environment/emissions/co2_vol_mass.php

Carbon vs. Time vs. Efficiency

The Current Reality

CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered by Boilers							lb CO_2 per Million Btu Delivered Renewable Resources or Nuclear Power	lb CO_2 per Million Btu Delivered as Electric Resistance Heat *
		Boiler Efficiency								
		95%	90%	85%	80%	75%	70%	65%		
Natural Gas	117	123	130	137	146	156	167	179	0	214
Propane	139	146	154	163	173	185	198	213		
Oil	163	172	182	192	204	218	234	251		
Coal	212	223	235	249	265	282	303	326		

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Carbon vs. Time vs. Efficiency

The Current Reality

CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered by Boilers							lb CO_2 per Million Btu Delivered Renewable Resources or Nuclear Power	lb CO_2 per Million Btu Delivered as Electric Resistance Heat *	lb CO_2 per Million Btu Delivered by a Heat Pump with a COP of 3.7*
		Boiler Efficiency									
		95%	90%	85%	80%	75%	70%	65%			
Natural Gas	117	123	130	137	146	156	167	179	0	214	91
Propane	139	146	154	163	173	185	198	213			
Oil	163	172	182	192	204	218	234	251			
Coal	212	223	235	249	265	282	303	326			

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Carbon vs. Time vs. Efficiency

The Current Reality

CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered by Boilers							lb CO_2 per Million Btu Delivered Renewable Resources or Nuclear Power	lb CO_2 per Million Btu Delivered as Electric Resistance Heat *	lb CO_2 per Million Btu Delivered by a Heat Pump with a COP of 3.7*
		Boiler Efficiency									
		95%	90%	85%	80%	75%	70%	65%			
Natural Gas	117	123	130	137	146	156	167	179	0	214	91
Propane	139	146	154	163	173	185	198	213			
Oil	163	172	182	192	204	218	234	251			
Coal	212	223	235	249	265	282	303	326			

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Heat Rate Source - "Heat Rates" tab of this spreadsheet

* This is the average value for the various fossil fuel power plants listed in the "Heat Rates" tab

In the transition, burning fossil fuel efficiently to make heat may be better than burning it to make power to make heat

Don’t loose sight of energy efficiency

- Just because it’s free doesn’t mean we can be careless with it
- Don’t loose sight of the power of commissioning
- Deliver better new buildings and improve existing buildings

Encourage creative thinking

Revisiting How Buildings Use Heat

How Buildings Use Heat

How Buildings Use Heat

How Buildings Use Heat

- Preheat Ventilation Air
- Reheat
- Space Heat
  - Radiant slabs
  - Air
  - Finned tube radiation
- Drive Processes
  - Humidification
  - Cooling
  - Sterilization
- Power Generation

How Buildings Use Heat

- Preheat Ventilation Air
- Reheat
- Space Heat
  - Radiant slabs
  - Air
  - Finned tube radiation
- Drive Processes
  - Humidification
  - Cooling
  - Sterilization

How Buildings Use Heat

- Preheat Ventilation Air 50°F - 75°F
- Reheat
- Space Heat
  - Radiant slabs
  - Air
  - Finned tube radiation
- Drive Processes
  - Humidification
  - Cooling
  - Sterilization

How Buildings Use Heat

- Preheat Ventilation Air 50°F - 75°F
- Reheat 50°F - 75°F
- Space Heat
  - Radiant slabs
  - Air
  - Finned tube radiation
- Drive Processes
  - Humidification
  - Cooling
  - Sterilization

How Buildings Use Heat

• Preheat Ventilation Air	50°F - 75°F
• Reheat	50°F - 75°F
• Space Heat	
• Radiant slabs	80°F - 85°F
• Air	95°F - 110°F
• Finned tube radiation	120°F – 220°F
• Drive Processes	
• Humidification	
• Cooling	
• Sterilization	

How Buildings Use Heat

• Preheat Ventilation Air	50°F - 75°F
• Reheat	50°F - 75°F
• Space Heat	
• Radiant slabs	80°F - 85°F
• Air	95°F - 110°F
• Finned tube radiation	120°F – 220°F
• Drive Processes	
• Humidification	212°F or higher
• Cooling	212°F or higher; hotter is better
• Sterilization	300°F or higher

How Buildings Use Heat

Low Grade

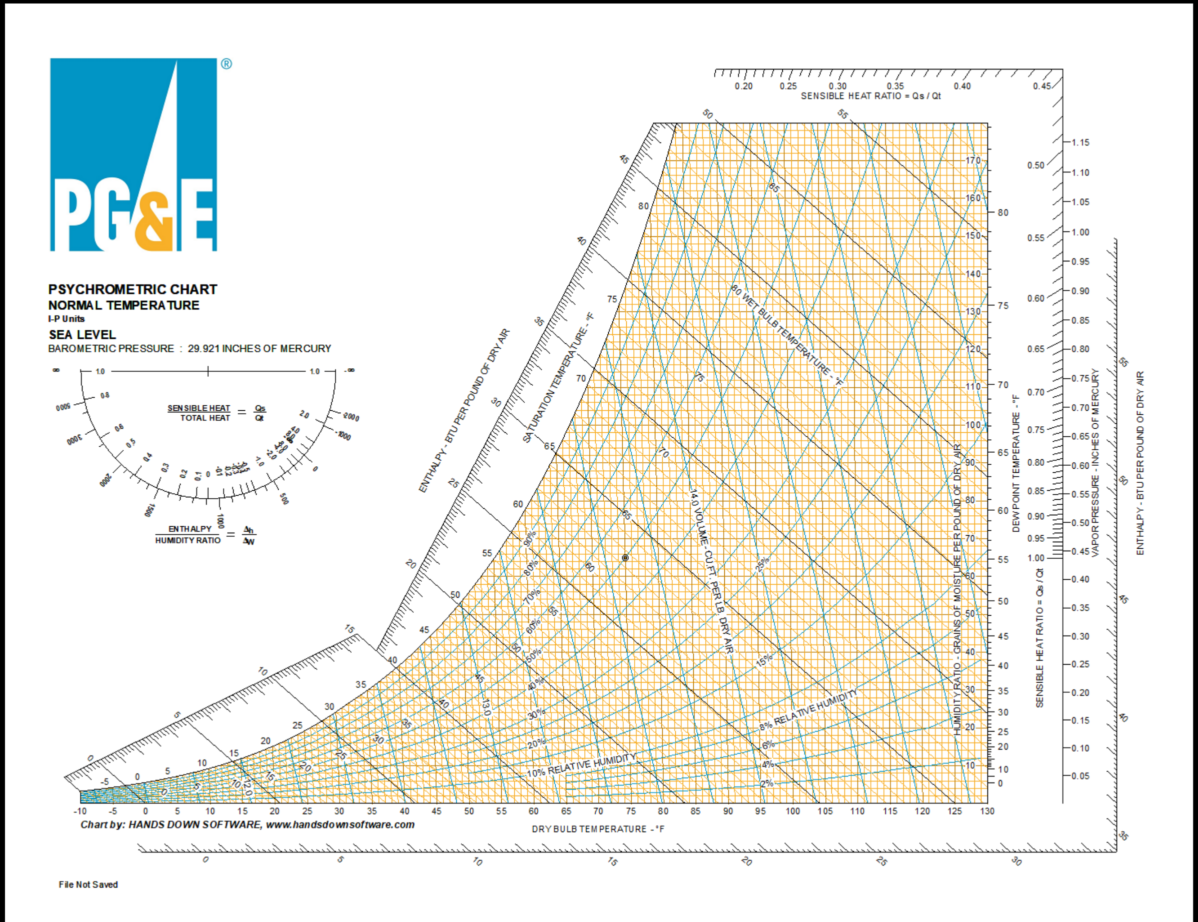
- Preheat Ventilation Air — 50°F - 75°F
- Reheat — 50°F - 75°F
- Space Heat
  - Radiant slabs — 80°F - 85°F
  - Air — 95°F - 110°F
  - Finned tube radiation — 120°F – 220°F
- Drive Processes
  - Humidification — 212°F or higher
  - Cooling — 212°F or higher; hotter is better
  - Sterilization — 300°F or higher

High Grade

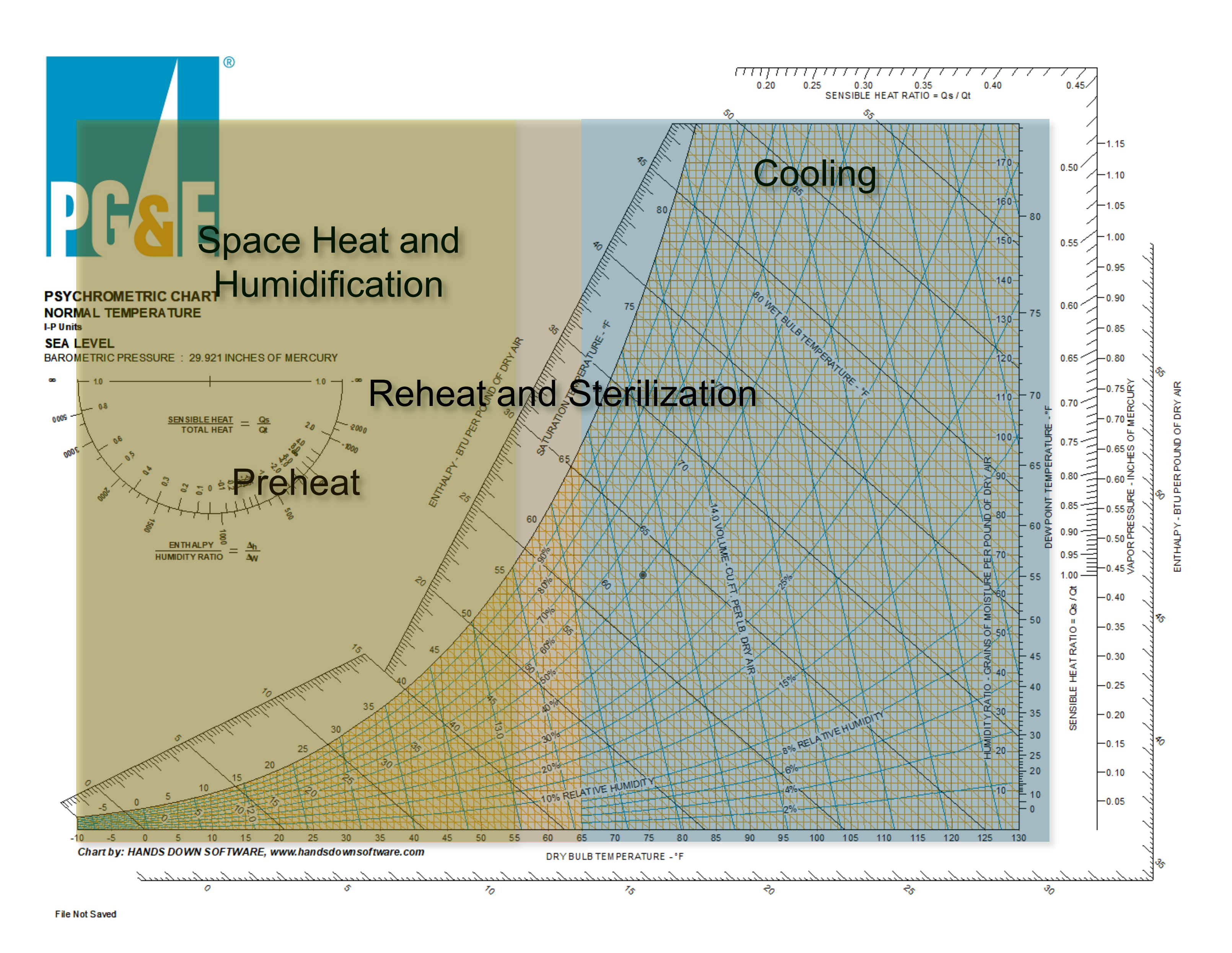
How Buildings Use Heat in the Context of Climate

A Free Electronic Psych Chart

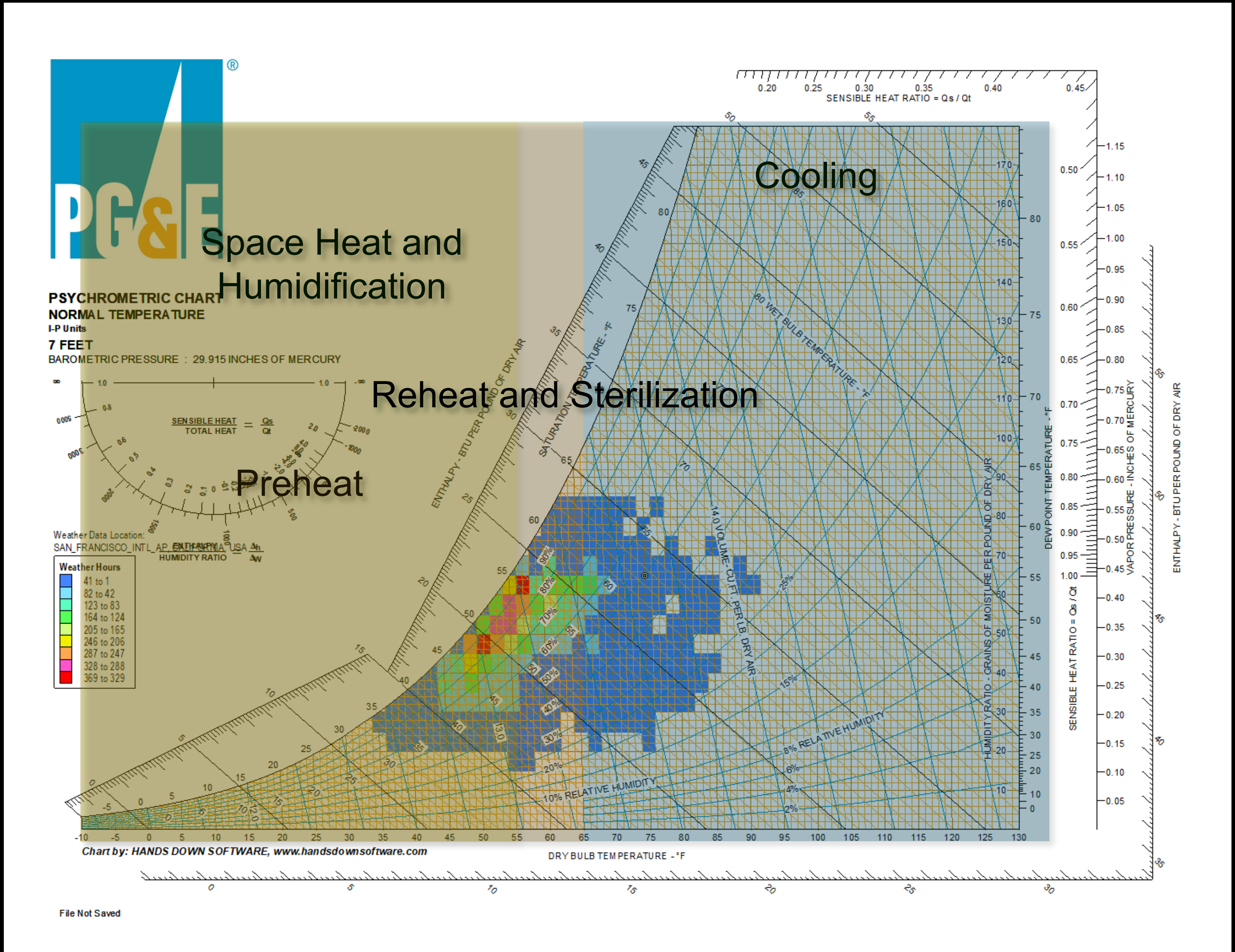
https://tinyurl.com/FreePsychChart



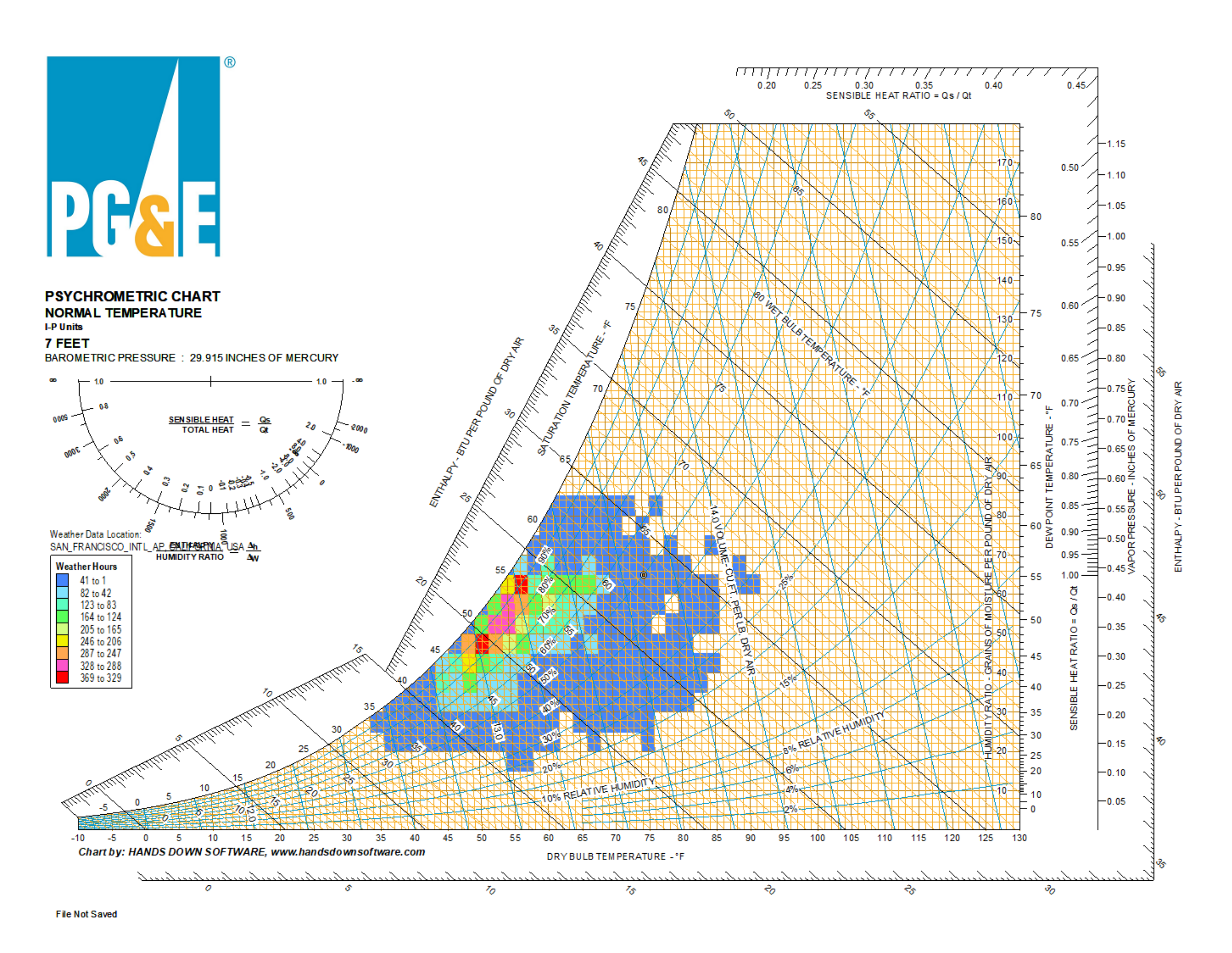
How Buildings Use Heat in the Context of Climate

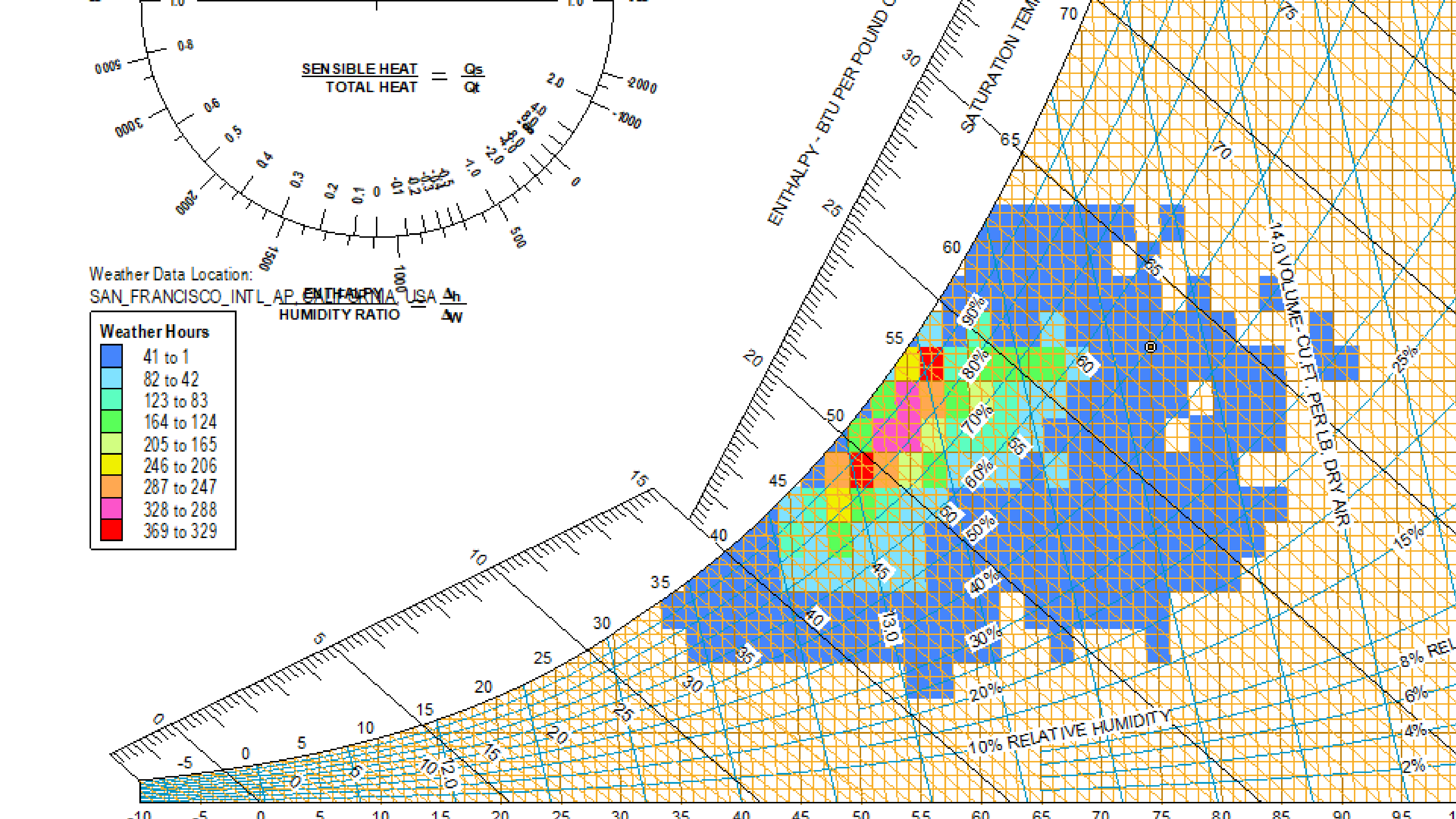


How Buildings Use Heat in the Context of Climate



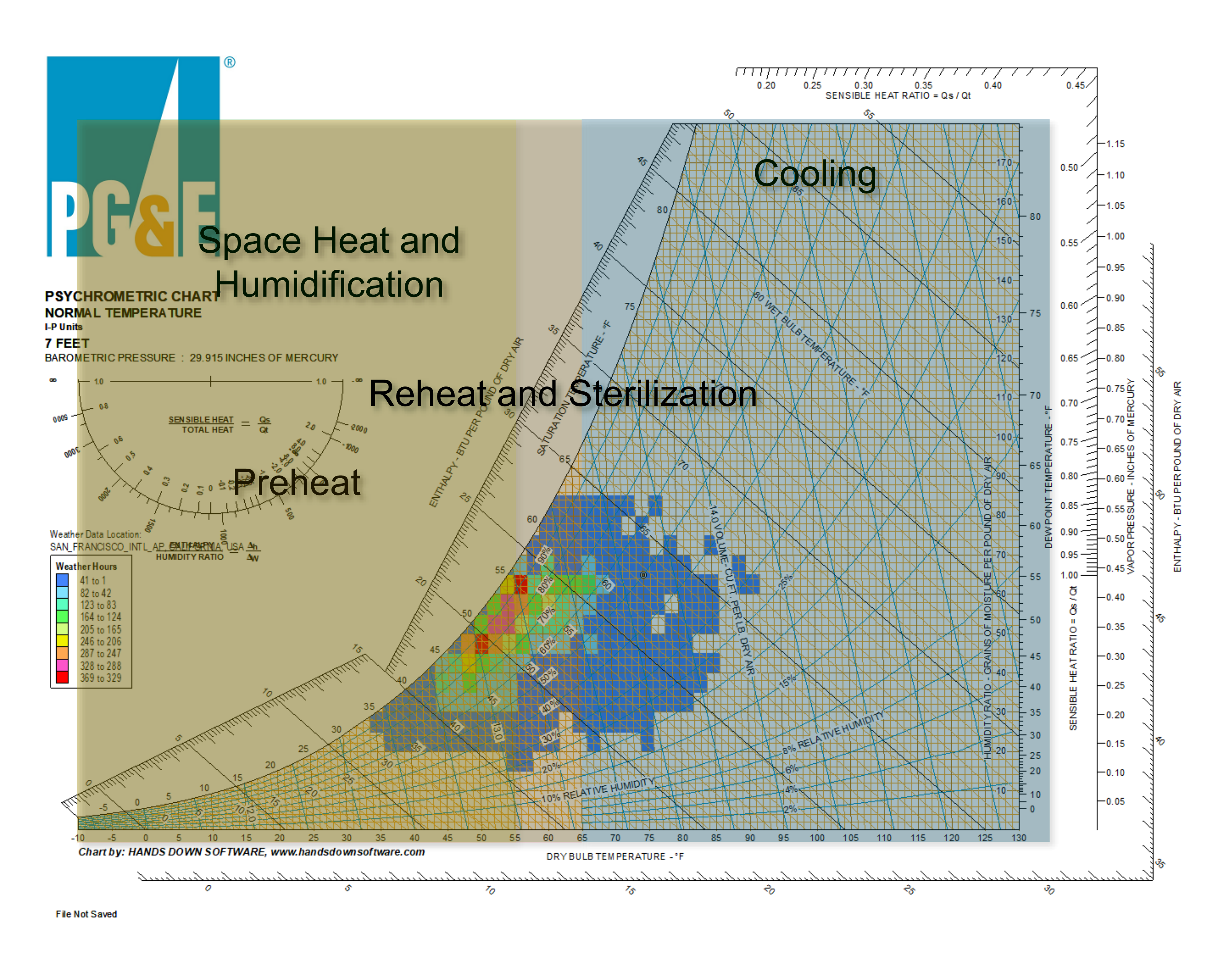
How Buildings Use Heat in the Context of Climate



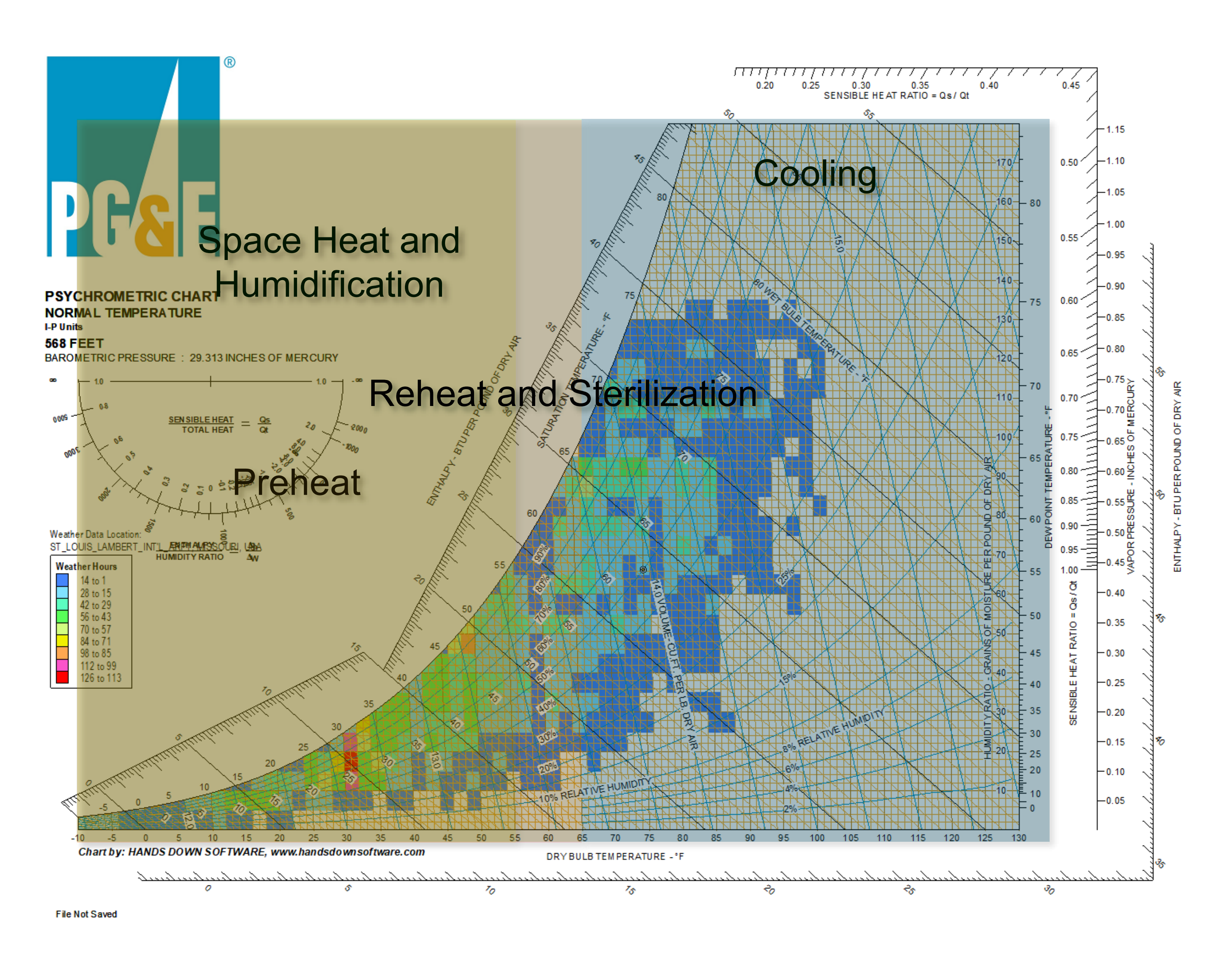


SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
Weather Data Location:
SAN_FRANCISCO_INTL_AP, CALIFORNIA, USA
Weather Hours
41 to 1
82 to 42
123 to 83
164 to 124
205 to 165
246 to 206
287 to 247
328 to 288
369 to 329
ENTHALPY - BTU PER POUND
SATURATION
14.0 VOLUME-CU.FT. PER LB. DRY AIR
13.0
12.0
10% RELATIVE HUMIDITY
90%
80%
70%
60%
50%
40%
30%
20%
25%
15%
8%
6%
4%
2%

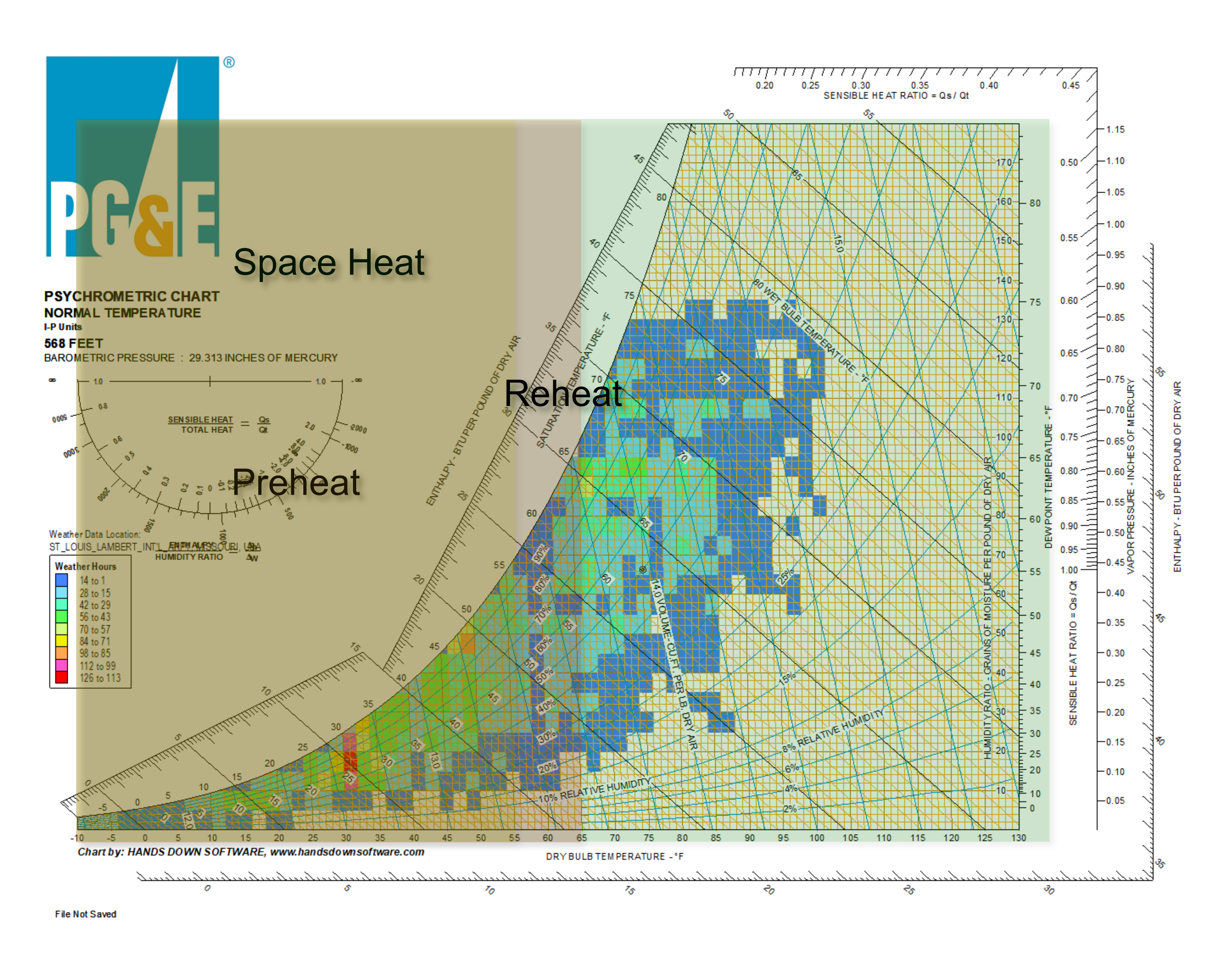
How Buildings Use Heat in the Context of Climate



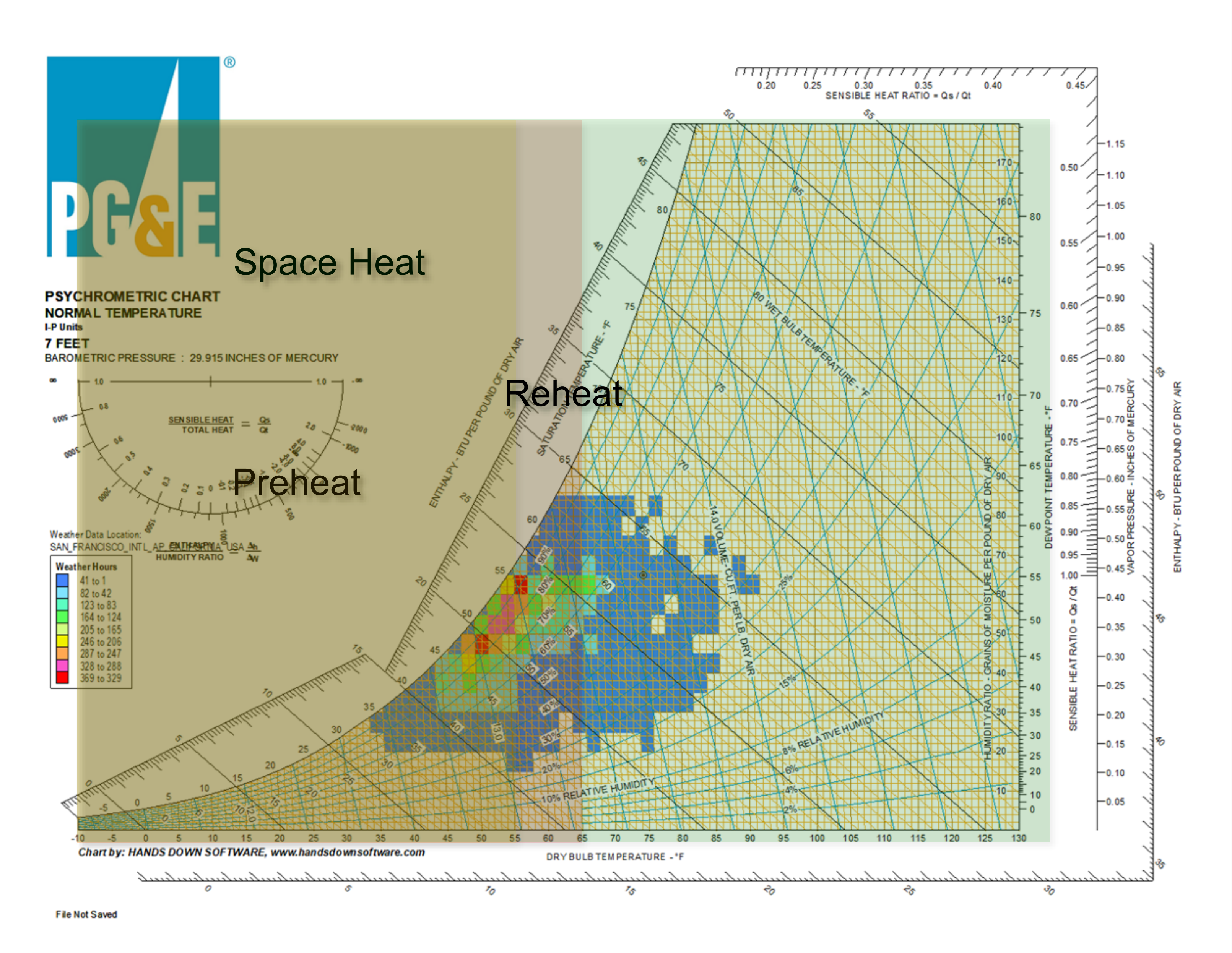
How Buildings Use Heat in the Context of Climate



How Buildings Use Heat in the Context of Climate

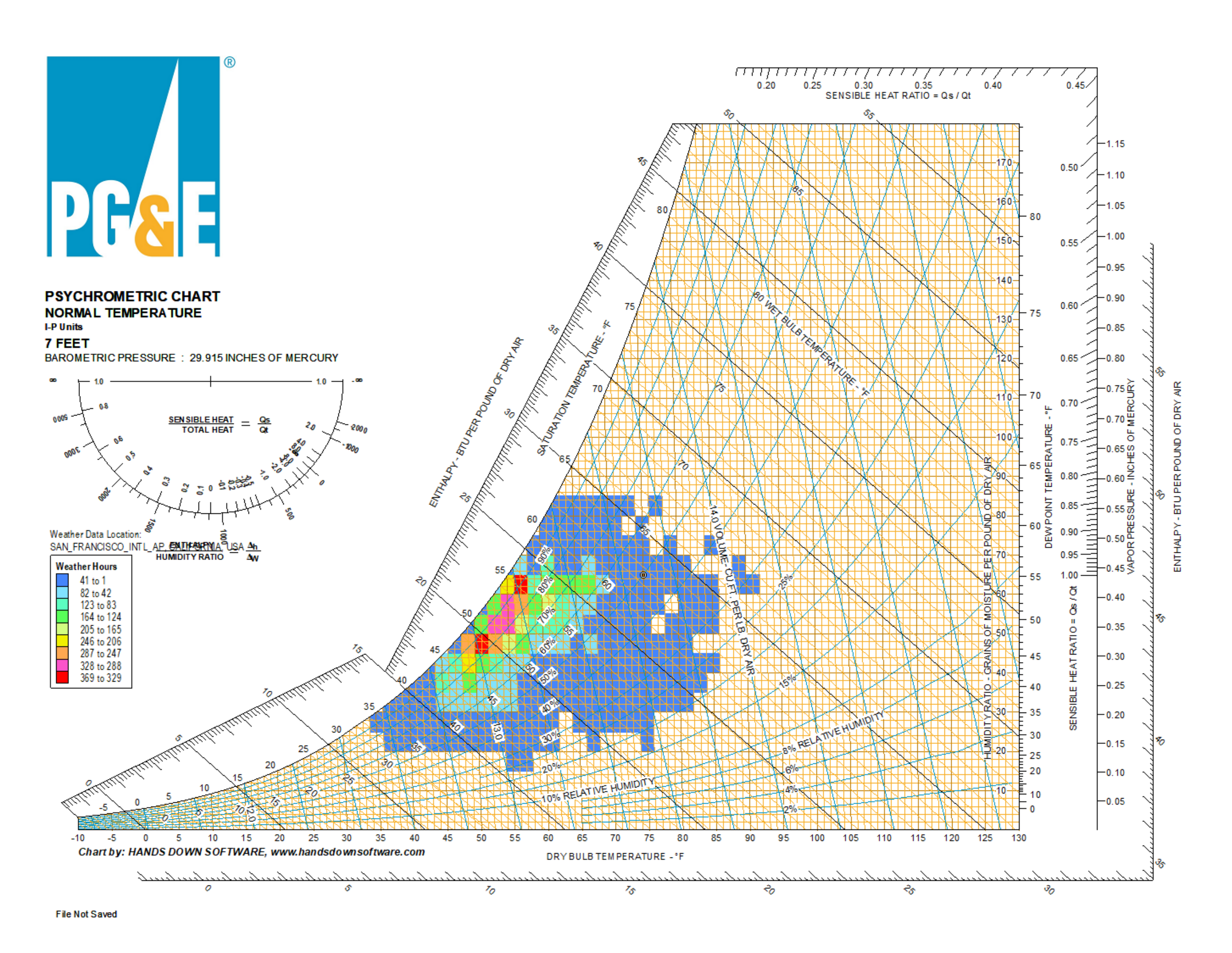


How Buildings Use Heat in the Context of Climate



Quantifying the Hours with Different Requirements

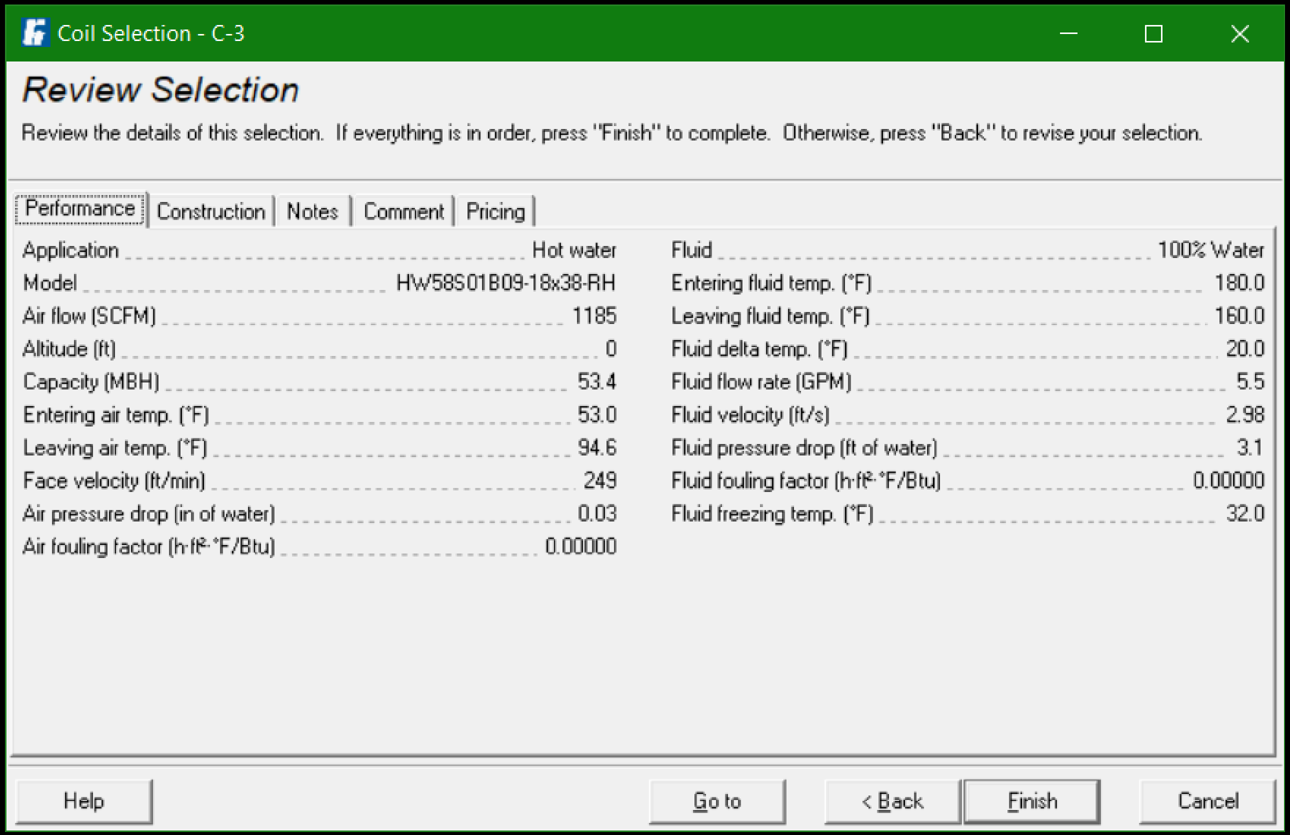
Quantifying the Hours with Different Requirements



Exploring Coil Performance

Recall That a Reheat Coil Selected for Space Heating Can Do Reheat With Much Cooler Water (i.e. Lower Grade Heat)

https://tinyurl.com/GreenheckCoilSelection


Coil Selection - C-3

Review Selection

Review the details of this selection. If everything is in order, press "Finish" to complete. Otherwise, press "Back" to revise your selection.

Performance | Construction | Notes | Comment | Pricing

Application	Hot water	Fluid	100% Water
Model	HW58S01B09-18x38-RH	Entering fluid temp. (°F)	180.0
Air flow (SCFM)	1185	Leaving fluid temp. (°F)	160.0
Altitude (ft)	0	Fluid delta temp. (°F)	20.0
Capacity (MBH)	53.4	Fluid flow rate (GPM)	5.5
Entering air temp. (°F)	53.0	Fluid velocity (ft/s)	2.98
Leaving air temp. (°F)	94.6	Fluid pressure drop (ft of water)	3.1
Face velocity (ft/min)	249	Fluid fouling factor (h·ft²·°F/Btu)	0.00000
Air pressure drop (in of water)	0.03	Fluid freezing temp. (°F)	32.0
Air fouling factor (h·ft²·°F/Btu)	0.00000		

Help | Go to | < Back | Finish | Cancel

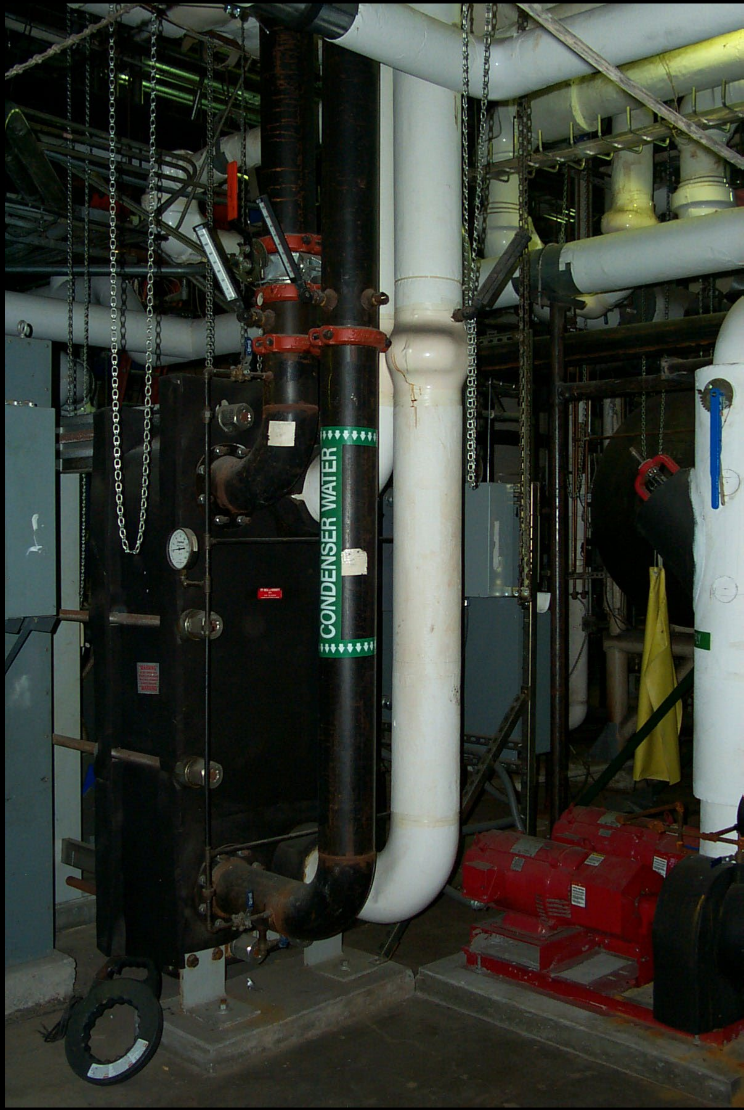
The Power of Ongoing Cx

(With Heat Pumps)

The Power of Ongoing Cx

Another Question

In the context of applying a heat pump is there a benefit to a central plant?

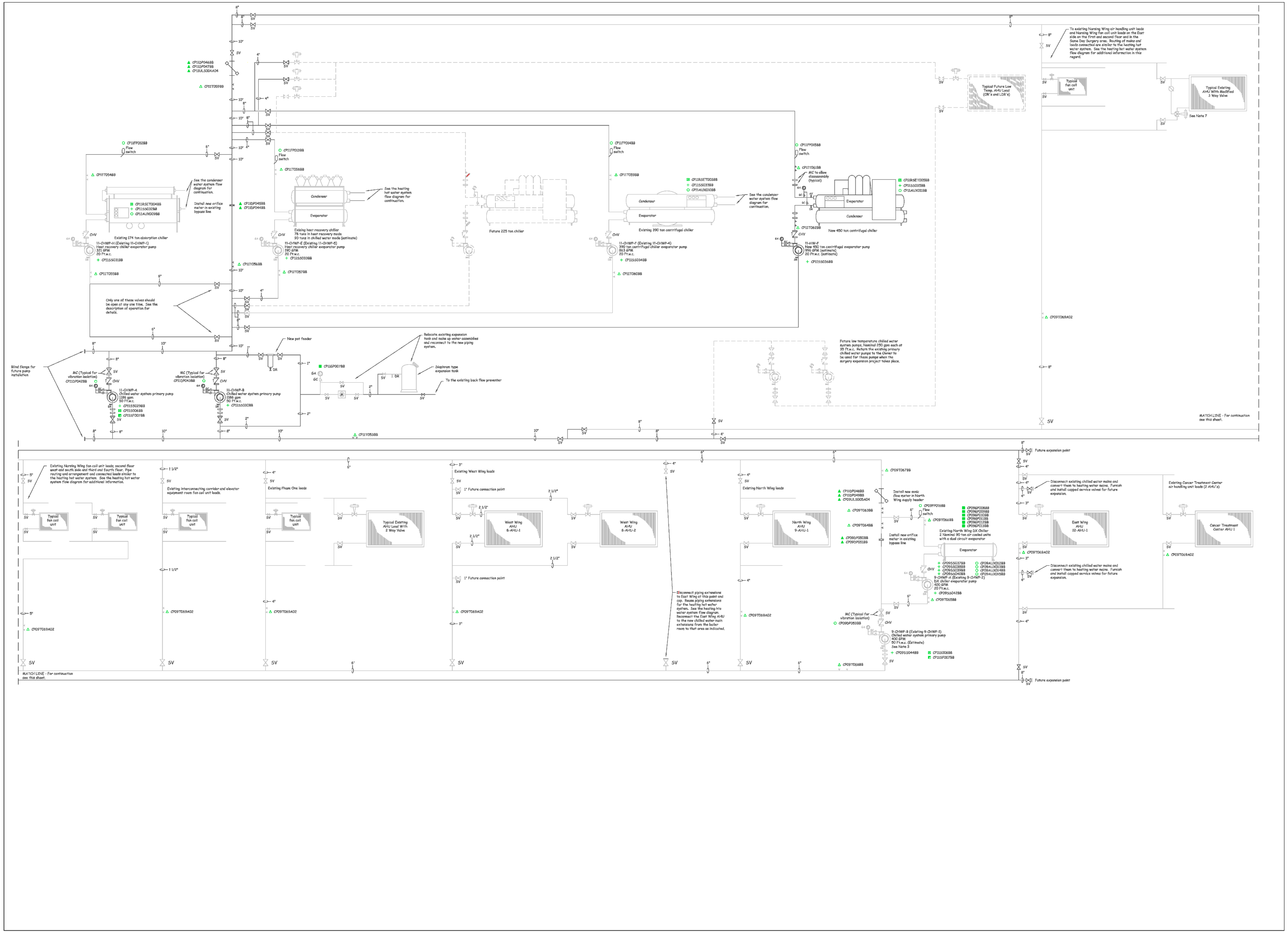


Central Plant Applications

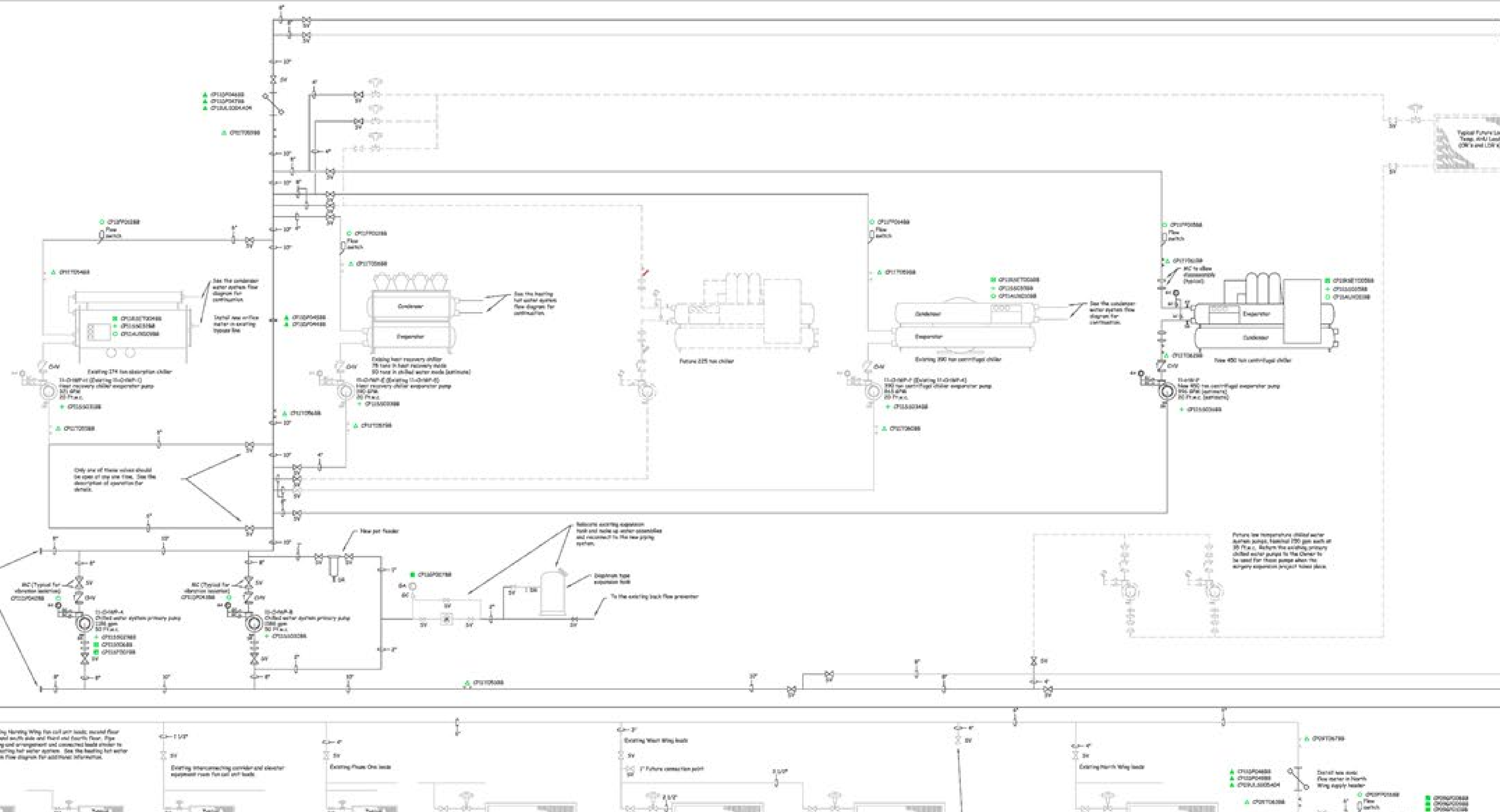
Opening the door to recovering energy we have been tossing away all of these years

Tracing Energy Through a Facility

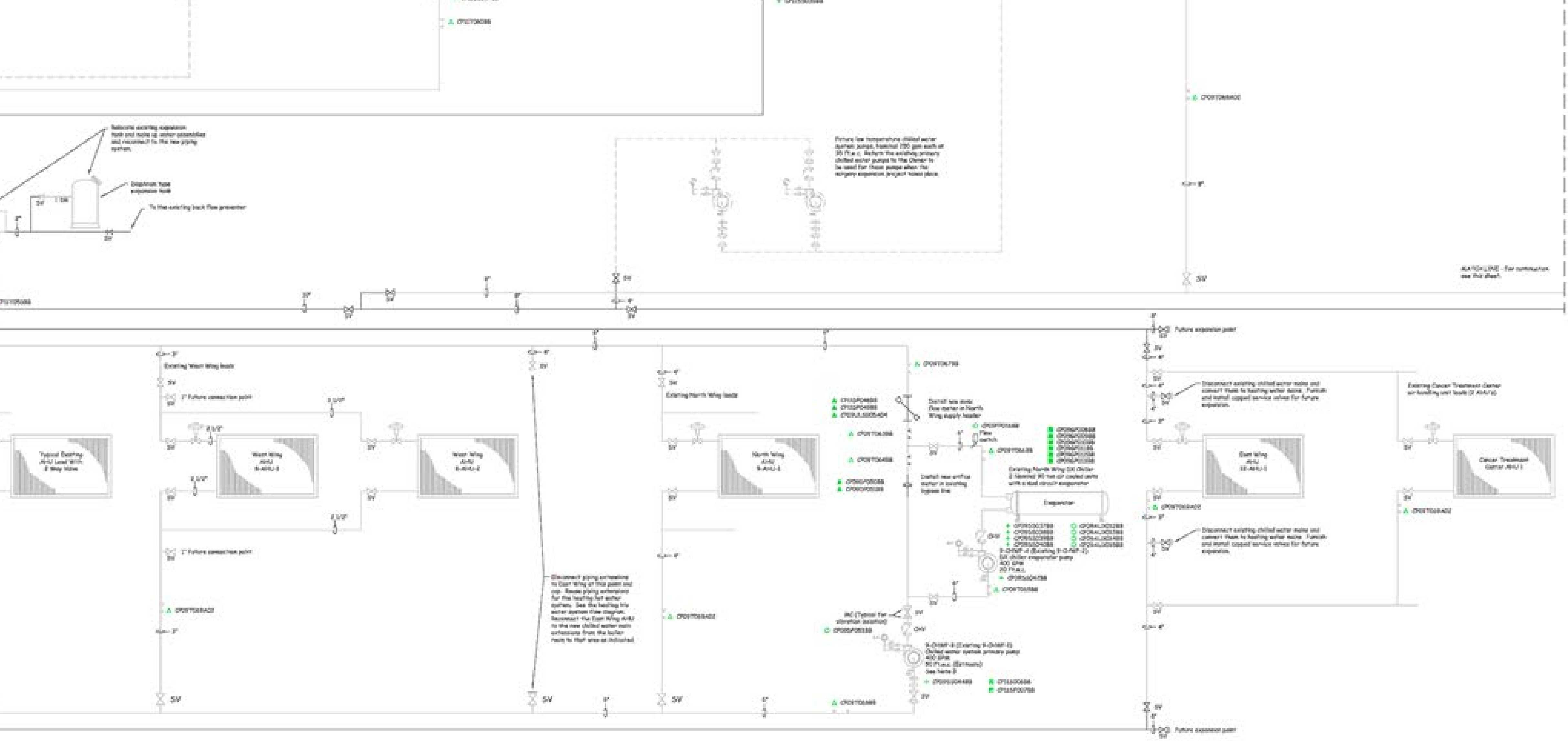

Google Earth



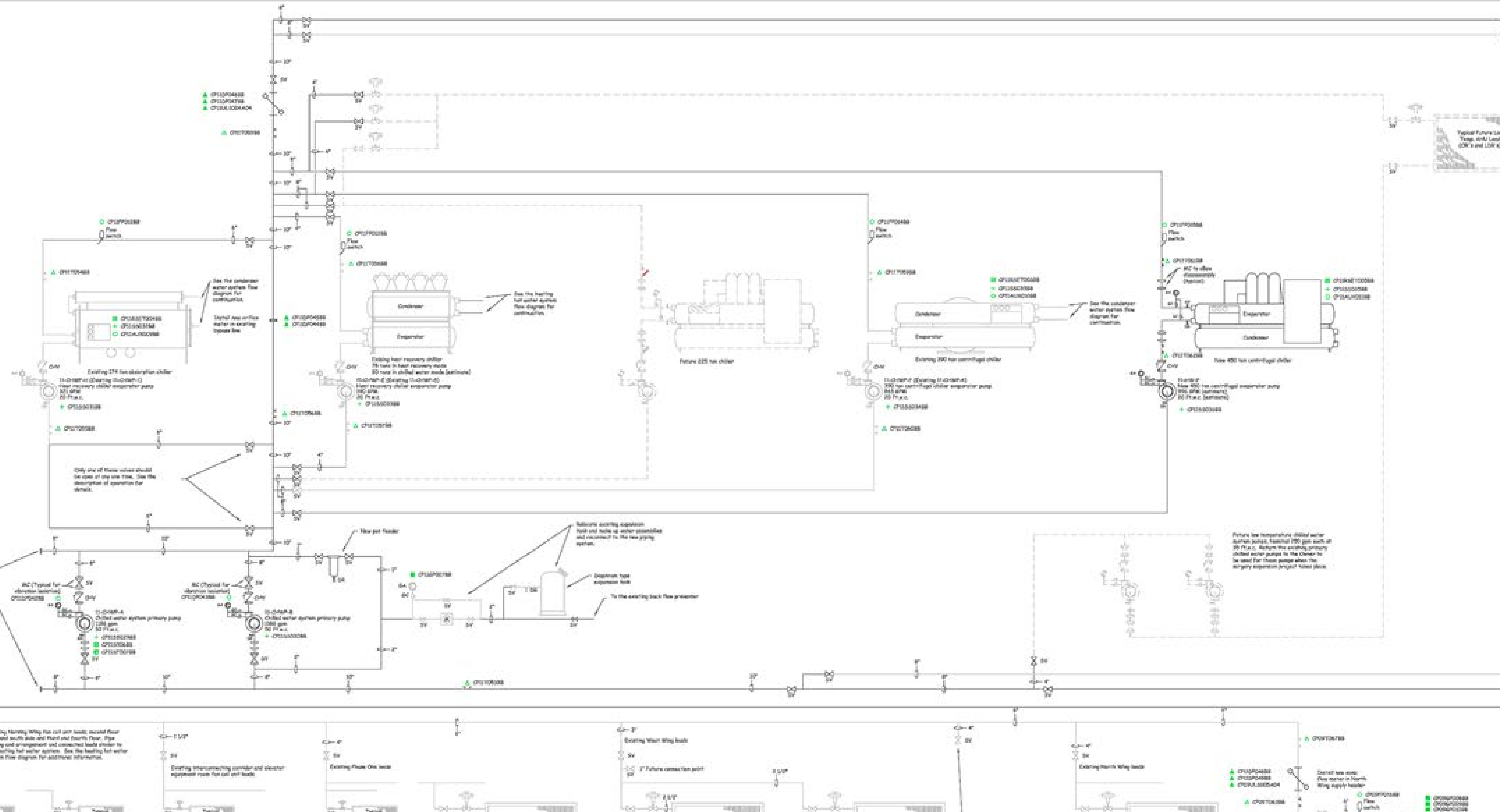
Existing 174 ton absorption chiller
Existing heat recovery chiller
Condenser
Evaporator
Future 225 ton chiller
Existing 390 ton centrifugal chiller
New 450 ton centrifugal chiller
Flow switch
New pot feeder
Diaphragm type expansion tank
To the existing back flow preventer
Blind flange for future pump installation
Typical Future Low Temp. AHU Load (OR's and LDR's)
Typical fan coil unit
Typical Existing AHU With Modified 3 Way Valve
See Note 7
MATCH LINE - For continuation see this sheet.
Existing Nursing Wing fan coil unit loads
Existing interconnecting corridor and elevator equipment room fan coil unit loads.
Existing Phase One loads
Typical Existing AHU Load With 2 Way Valve
Existing West Wing loads
1" Future connection point
West Wing AHU 6-AHU-1
West Wing AHU 6-AHU-2
Existing North Wing loads
North Wing AHU 9-AHU-1
Install new sonic flow meter in North Wing supply header
Existing North Wing DX Chiller
Evaporator
Future expansion point
East Wing AHU 12-AHU-1
Existing Cancer Treatment Center air handling unit loads (2 AHU's)
Cancer Treatment Center AHU 1
MATCH LINE - For continuation see this sheet.



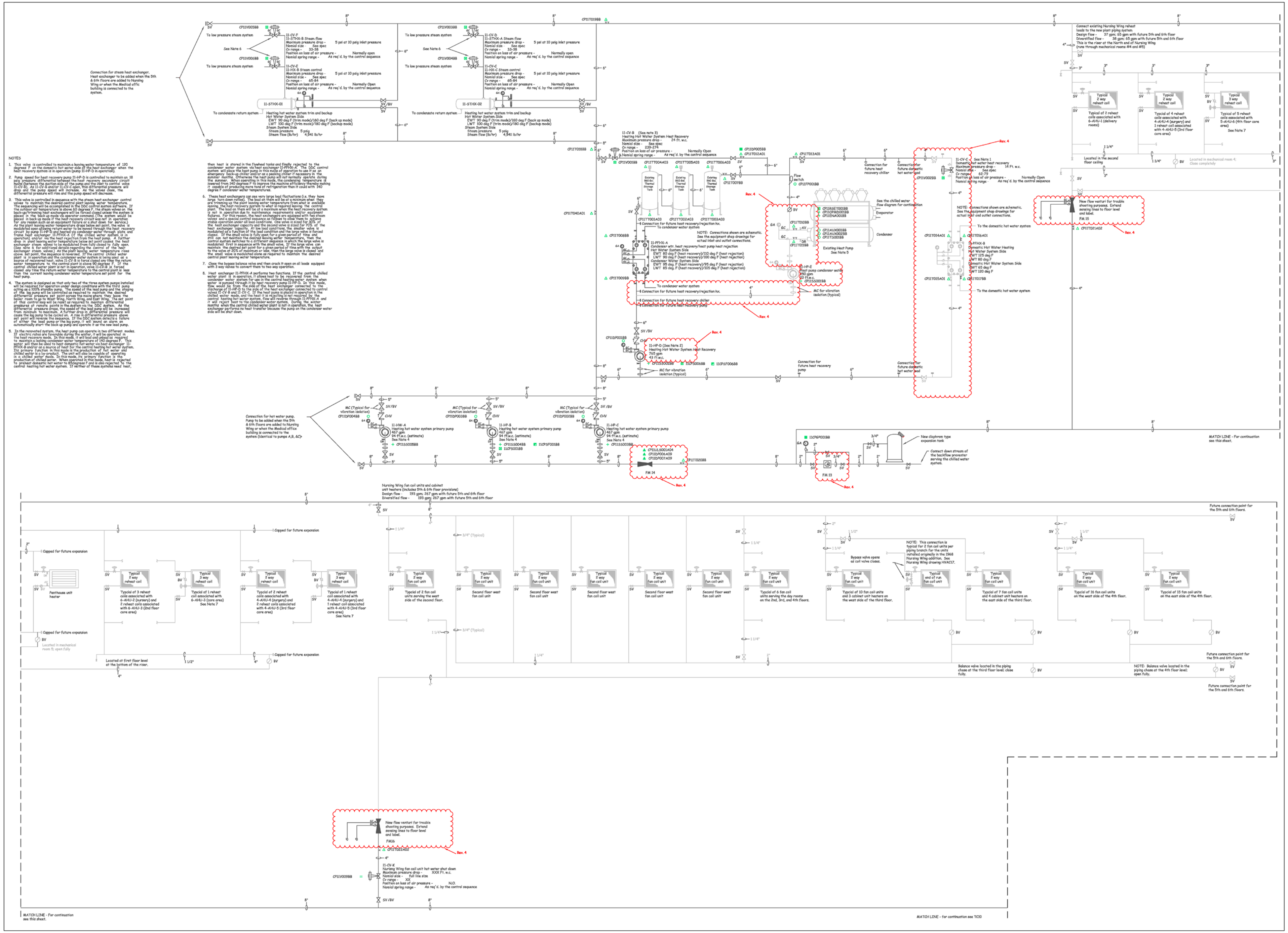
Condenser
Evaporator
Future 225 ton chiller
Existing 390 ton centrifugal chiller
New 450 ton centrifugal chiller
New pot feeder
Diaphragm type expansion tank
To the existing back flow preventer
Existing West Wing loads
Existing Phase One loads
Existing North Wing loads



Diaphragm type expansion tank
To the existing back flow preventer
Existing West Wing loads
1" Future connection point
Typical Existing AHU Load With 2 Way Valve
West Wing AHU
Existing North Wing loads
North Wing AHU
Evaporator
CHV
Future expansion point
East Wing AHU
Cancer Treatment Center AHU 1
SV



Condenser
Evaporator
Existing heat recovery chiller
Future 225 ton chiller
Existing 390 ton centrifugal chiller
New 450 ton centrifugal chiller
Flow switch
Only one of these valves should be open at any one time. See the description of operation for details.
New pot feeder
Diaphragm type expansion tank
To the existing back flow preventer
Existing West Wing loads
Existing Phase One loads
Existing North Wing loads



NOTES

1. This valve is controlled to maintain a leaving water temperature of 120 degrees F on the domestic hot water side of the heat exchanger when the heat recovery system is in operation (pump 11-HP-D in operation).

2. Pump speed for heat recovery pump 11-HP-D is controlled to maintain an 18 psig pressure differential between the heat recovery secondary circuit mains (between the suction side of the pump and the inlet to control valve 11-CV-B). As 11-CV-B and/or 11-CV-C open, this differential pressure will drop and the pump speed will increase. As the valves close, the differential pressure will rise and the pump speed will decrease.

3. This valve is controlled in sequence with the steam heat exchanger control valves to maintain the desired central plant leaving water temperature. The sequencing will be accomplished in the DDC control system software. If the outdoor air temperature is above 60 degrees F, the steam valves on the back-up/trimming heat exchangers will be forced closed unless the system is placed in the back up mode via operator command. (The system would be placed in back up mode if the heat recovery circuit was not in operation for any reason such as an equipment failure or a shut down for service.) As the plant leaving water temperature drops below set point, the valve is modulated open allowing return water to be moved through the heat recovery circuit by pump 11-HP-D and heated via condenser water through plate and frame heat exchanger 11-PFHX-A (if the chilled water system is in operation) and/or via the heat rejection from the heat pump. A further drop in plant leaving water temperature below set point causes the heat exchanger steam valves to be modulated from fully closed to fully open. (See note 6 for additional details regarding the control of the heat exchanger steam valves.) As the plant leaving water temperature rises above set point, the sequence is reversed. If the central chilled water plant is in operation and the condenser water system is being used as a source of recovered heat, valve 11-CV-B is force closed any time the return water temperature to the central plant is above 90 degrees F. If the central chilled water plant is not in operation, valve 11-CV-B is forced closed any time the return water temperature to the central plant is less than the current leaving condenser water temperature set point for the heat pump.

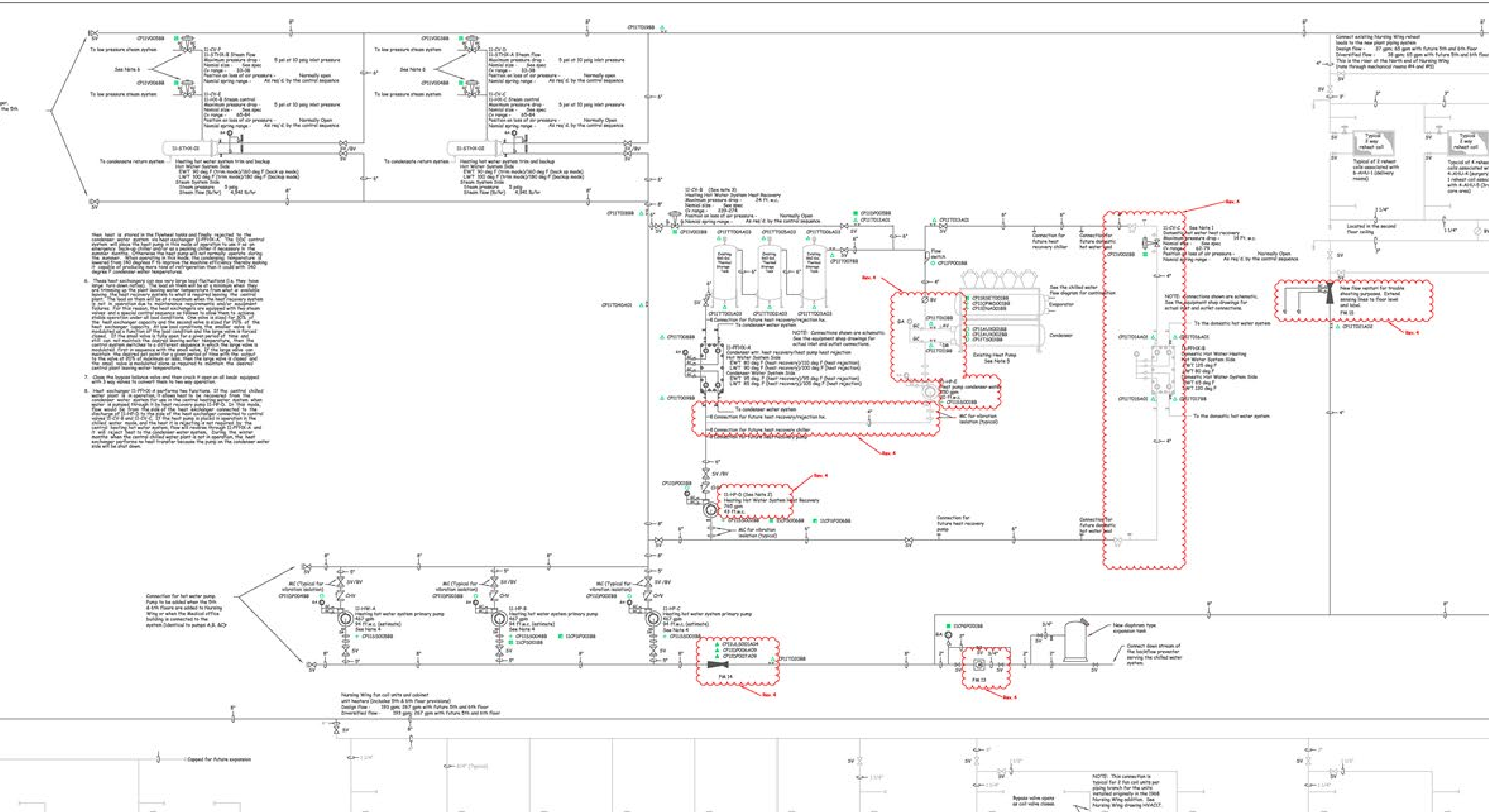
4. The system is designed so that only two of the three system pumps installed will be required for operation under design conditions with the third pump acting as a 100% standby pump. The speed of the lead pump and the staging of the lag pump will be controlled as required to maintain the desired differential pressure set point across the mains where they leave the boiler room to go to West Wing, North Wing, and East Wing. The set point of this control loop will be reset as required to maintain differential pressures at remote points in the system via the DDC system. As the differential pressure drops, the speed of the lead pump will be increased from minimum to maximum. A further drop in differential pressure will cause the lag pump to be cycled on. A rise in differential pressure above set point will reverse the sequence. If the DDC system detects a failure of either the lead pump or the lag pump, it will sound an alarm an automatically start the back up pump and operate it as the new lead pump.

5. In the renovated system, the heat pump can operate in two different modes. If electric rates are favorable during the winter, it will be operated in the heat recovery mode. In this mode, it will load and unload as required to maintain a leaving condenser water temperature of 140 degrees F. This water will then be used to heat domestic hot water via heat exchanger 11-PFHX-B and/or as a source of heat for the central heating hot water system. Its primary function in this mode is the production of hot water and chilled water is a by-product. The unit will also be capable of operating in a chilled water mode. In this mode, its primary function is the production of chilled water. When operated in this mode, heat is rejected to preheat domestic hot water to 85degrees F and is also rejected to the central heating hot water system. If neither of these systems need heat, then heat is stored in the flywheel tanks and finally rejected to the condenser water system via heat exchanger 11-PFHX-A. The DDC control system will place the heat pump in this mode of operation to use it as an emergency back-up chiller and/or as a peaking chiller if necessary in the summer months. Otherwise the heat pump will not normally operate during the summer. When operating in this mode, the condensing temperature is lowered from 140 degrees F to improve the machine efficiency thereby making it capable of producing more tons of refrigeration than it could with 140 degree F condenser water temperatures.

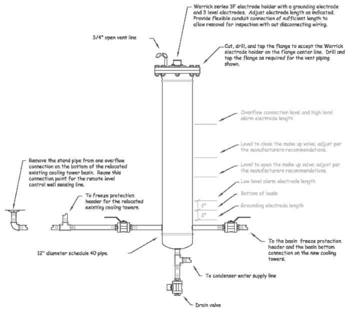
6. These heat exchangers can see very large load fluctuations (i.e. they have large turn down ratios). The load on them will be at a minimum when they are trimming up the plant leaving water temperature from what is available leaving the heat recovery system to what is required leaving the central plant. The load on them will be at a maximum when the heat recovery system is not in operation due to maintenance requirements and/or equipment failures. For this reason, the heat exchangers are equipped with two steam valves and a special control sequence as follows to allow them to achieve stable operation under all load conditions. One valve is sized for 30% of the heat exchanger capacity and the second valve is sized for 70% of the heat exchanger capacity. At low load conditions, the smaller valve is modulated as a function of the load condition and the large valve is forced closed. If the small valve is fully open for a given period of time and still can not maintain the desired leaving water temperature, then the control system switches to a different sequence in which the large valve is modulated first in sequence with the small valve. If the large valve can maintain the desired set point for a given period of time with the output to the valve at 20% of maximum or less, then the large valve is closed and the small valve is modulated alone as required to maintain the desired central plant leaving water temperature.

7. Close the bypass balance valve and then crack it open on all loads equipped with 3 way valves to convert them to two way operation.

8. Heat exchanger 11-PFHX-A performs two functions. If the central chilled water plant is in operation, it allows heat to be recovered from the condenser water system for use in the central heating water system when water is pumped through it by heat recovery pump 11-HP-D. In this mode, flow would be from the side of the heat exchanger connected to the discharge of 11-HP-D to the side of the heat exchanger connected to control valves 11-CV-B and 11-CV-C. If the heat pump is placed in operation in the chilled water mode, and the heat it is rejecting is not required by the central heating hot water system, flow will reverse through 11-PFHX-A and it will reject heat to the condenser water system. During the winter months when the central chilled water plant is not in operation, the heat exchanger performs no heat transfer because the pump on the condenser water side will be shut down.

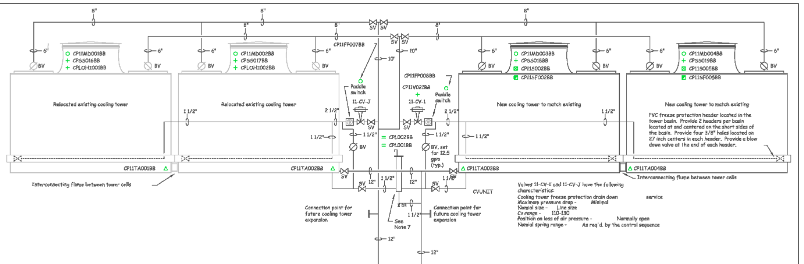


To low pressure steam system
To condensate return system
Heating hot water system trim and backup
Existing Heat Pump
See Note 5
Evaporator
Condenser
To the domestic hot water system
New diaphragm type expansion tank
Capped for future expansion
Rev. 4



COOLING TOWER LEVEL CONTROL WELL DETAIL

NO SCALE



Design data for each cooling tower cell is as follows:

- Cell flow rate (gpm) - 1770
- Cell entering water temperature (deg. F) - 96.5
- Cell leaving water temperature (deg. F) - 86.5
- Design wet bulb temperature (deg. F) - 78.0
- Cell fan diamter (ft.) - 7.0
- Cell fan flow rate (cfm) - 83,170
- Cell fan speed (rpm) - 426
- Cell fan blades - 6
- Cell motor horse power - 15
- Cell motor speed (rpm) - 1750
- Cell motor volts/phase - 460/3

NOTES:

1. The balance valves are to be adjusted to that with the largest condenser water pump in operation, the pump head is just enough to begin to lift water over the tower with the bypass valve fully open; i.e. all of the flow is through the bypass. Proceed as follows:

   a. Place the largest condenser water pump on the system in operation.

   b. Open the bypass valve fully.

   c. Gradually close the two balance valves until water just begins to flow over the tower.

   Note that there are two balance valves simply because they were already there from the previous system configuration. It may be possible to totally close one valve and make all adjustments with the remaining valve. If not, then both valves should be adjusted an equal amount.

2. Cut new steel tees with service valves into the existing piping as indicated during the first available cold weather. This will allow the existing system to be refilled and returned to service as required while the new system and new tower cells are installed on the Nursing Wing roof. When the new system is ready for operation, valve out the existing tower cells and valve in the new tower cells. Operate the existing chiller plant off of the new towers while the existing towers are moved. Cap the valves in the boiler room where the existing piping connected to the existing towers for use as the connection point for the future chiller that will be added if the medical office building is built to the East of the hospital. This valving arrangement also allows the fiberglass piping system to be isolated from the steel piping system so that in the event of some sort of failure in the fiberglass system a portion of the condenser water system is still available for operation while any repairs are made.

3. Tower fans and the bypass valve are sequenced based on the entering water temperature to the chillers in the boiler room header down stream of the bypass valve connection. Due to the location of the bypass connection point in the header, the sensor(s) used for this function are selected based on which of the chillers are in operation. The set point of this loop is reset based on the average basin water temperature (at the cooling towers) to help compensate for transportation delays associated with the time it takes the tower water to flow through the basins and down to the boiler room. This time delay will be in excess of 10 minutes with just the absorption chiller in operation and will be at least 2 minutes with all chillers in the plant in operation (including the future 250 ton unit associated with the potential medical building expansion). With the two centrifugal units associated with this project in operation the delay will be something like 3 to 4 minutes. Note that if two of the basins are taken out of service and drained for cleaning, it will be necessary to somehow compensate for the sensors located in the drained basins to maintain the desired cooling tower set point. Toward this end, the software will be arranged to eliminate either the sensors in the North basins or the South basins from the calculation based on the status of a manually controlled variable. The operators should set this variable appropriately when they are draining the tower basins for service.

   As the supply temperature to the chillers in the boiler room header begins to deviate from set point, the output of the control loop begins to increase. An increasing control loop output causes the following events to occur in sequence.

   The bypass valve modulates from fully open to fully closed.

   The lead variable speed tower fan comes on and modulates from minimum speed to 50% speed.

   The lag variable speed tower fan comes on and modulates with the lead fan from minimum speed to 50% speed.

   The lead two speed tower fan cycles from off to low speed.

   The lag two speed tower fan cycles from off to low speed.

   The lead and lag variable speed tower fans modulate together from 50% speed to 100% speed.

   The lead two speed tower fan cycles from low speed to high speed.

   The lag two speed tower fan cycles from low speed to high speed.

   As the deviation from set point decreases, the sequence is reversed.

   The tower fans, bypass valve, and water treatment system are all interlocked with the operation of the chiller condenser water pumps. If none of the condenser water pumps are in operation, then the tower fans are shut down, the water treatment system is shut down, and the bypass valve is fully opened. Lead and lag tower fans are rotated based on accumulated hours of operation.

4. The freeze protection system is provided so that it is not necessary to drain the cooling towers during cold weather, thereby making the system more readily available for immediate operation when the weather turns warm and saving on water treatment costs. The system is designed to hold the basin water temperatures at 40 degrees F on with an outdoor temperature of -30 degrees F and a 15 mile per hour wind. The system is arranged to operate any time the condenser water pumps are off and the outdoor air temperature is below 40 degrees F. Under these conditions, the hot basin header drain down valves at the tower open and the circulator pump is started. The heat exchanger steam valve is controlled to maintain the tower basin temperature at 40 degrees F. Water circulates from the circulating pump, through the heat exchanger and up to the tower via the normal piping mains. The open drain down valves prevent water from circulating over the top of the tower. Instead, the water circulates through the open valves into the distribution header in the tower basin, flows through the basin, and then flows back to the inlet of the circulating pump via the normal return piping system. Blow down valves are provided at the end of the headers. By opening these valves during normal maintenance, any debris in the header can be blown out into the basin for removal.

   It is important to note that this freeze protection system is intended to keep the towers in a standby state during subfreezing weather. It is not designed or intended to provide for cooling tower operation under these conditions. Any attempt to operate the current system under these conditions will more than likely result in poor performance and severe damage to the cooling towers.

5. The system is arranged to allow two of the tower cells to be valved out while the other two cells are in operation for maintenance and service work. Blow down switches are provided at the tower hot basin header drain down valves to allow the valves to be opened while the basin is drained to flush out the freeze protection header.

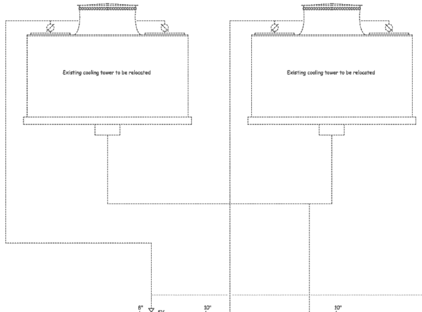
6. The physical arrangement of the piping incorporates the following design features.

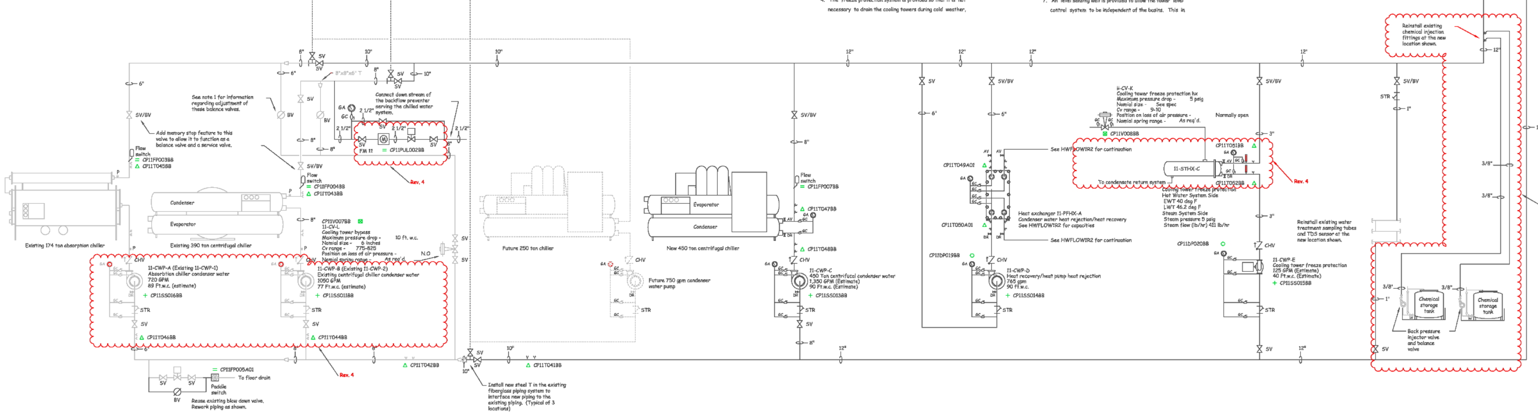
   Headers are sized at for minimal pressure drop at full flow.

   Distribution and collection piping to each tower is symetrically arranged so that the pressure drop from the header to each hot basin and from the sumps to the header is nearly identical.

   These features are intended to maintain uniform flow over all cells regardless of the number of pumps in operation once the system has been balanced out.

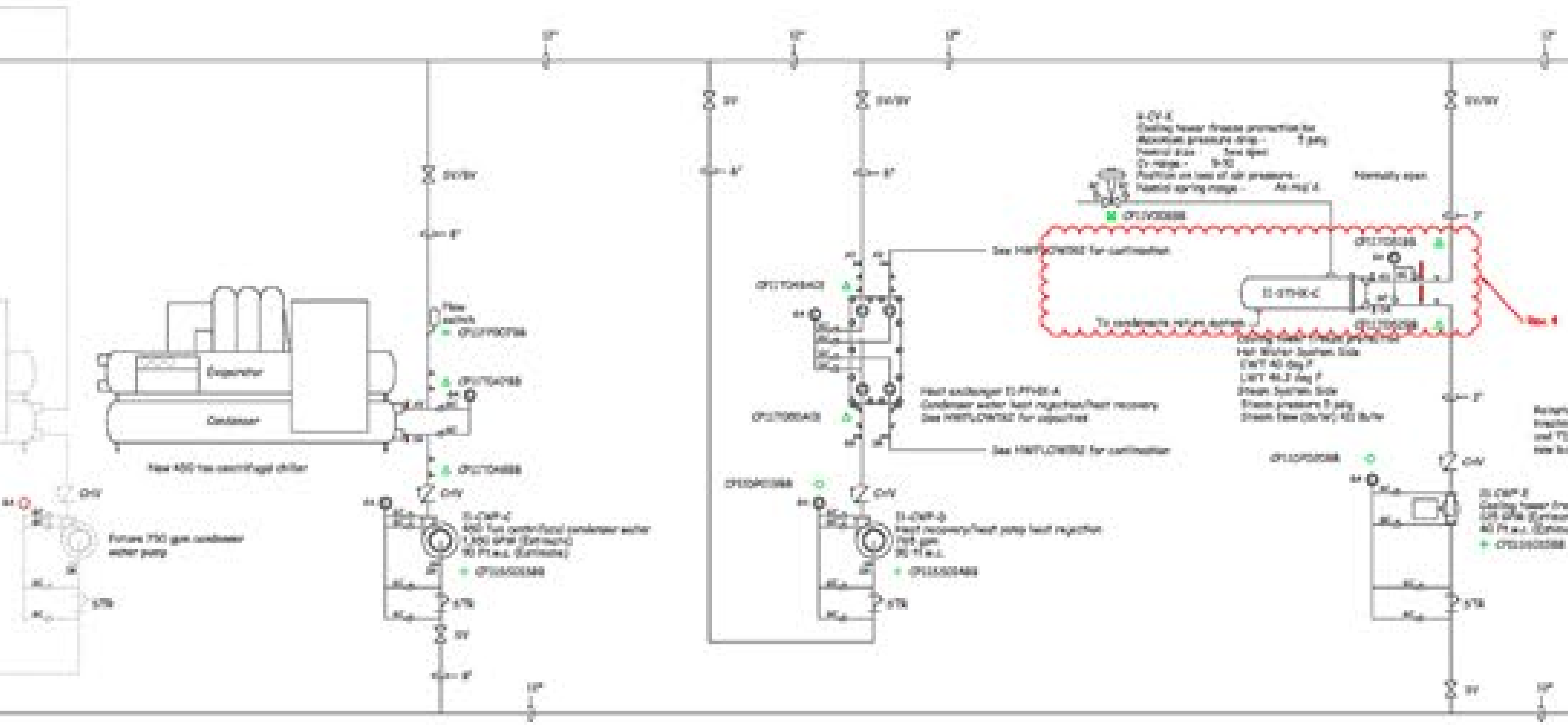
7. An level sensing well is provided to allow the tower level control system to be independent of the basins. This in turn allows either tower basin to be valved out for servicing while the other tower cells are in operation with out disrupting the operation of the level ocntrol system. See the detail for information regarding the construction of this well. During service operations, the side of the level control piping loop that is connected to the tower to be drained should be valved out.





necessary to drain the cooling towers during cold weather.

control system to be independent of the boiler. This is



A Few Central Plant Bottom Lines

Chilled water is required for surgery when the outdoor temperature reaches 45 - 50°F

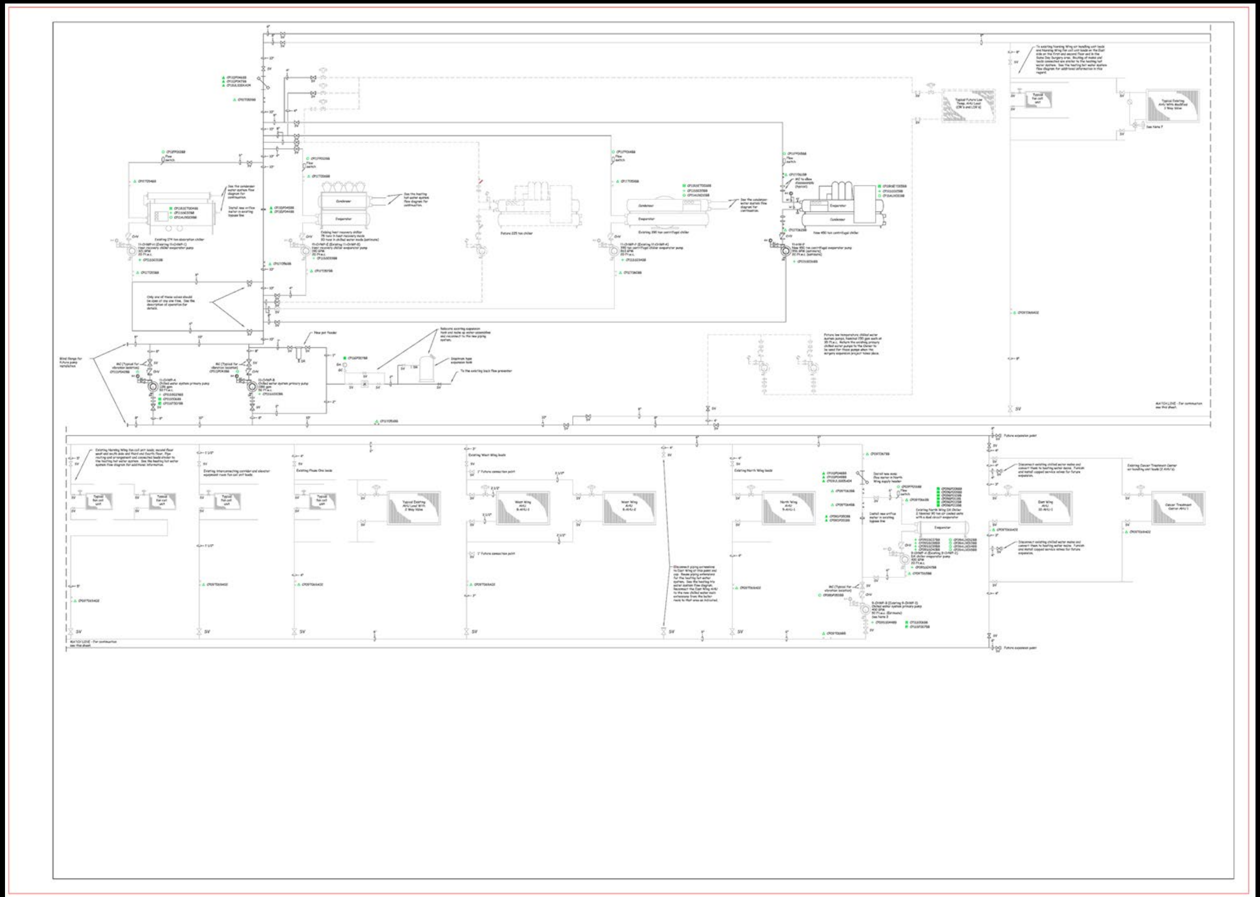
- Served by the North Wing Air Cooled Chiller

Chilled water is required by the remainder of the facility when outdoor temperatures exceed 52 – 58°F

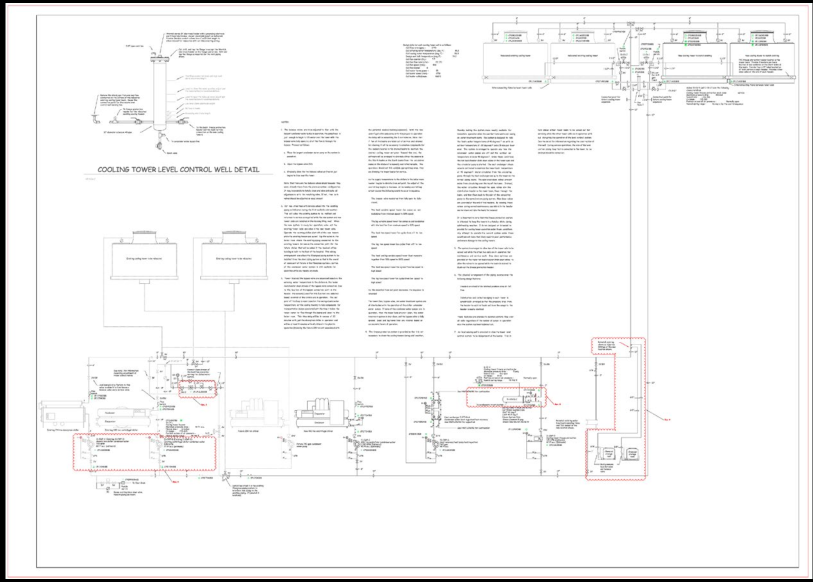
- Humidity dependent
- Transition to the Nursing Wing Central Plant

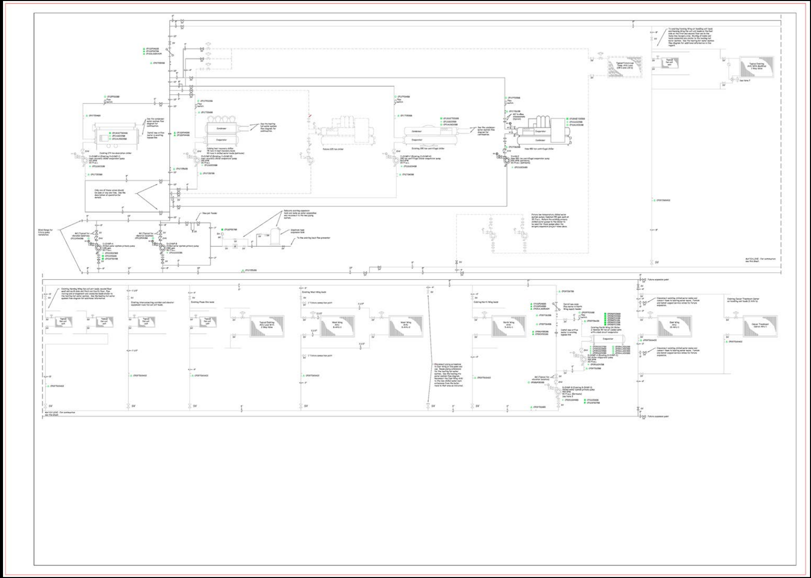
Heat is required year round

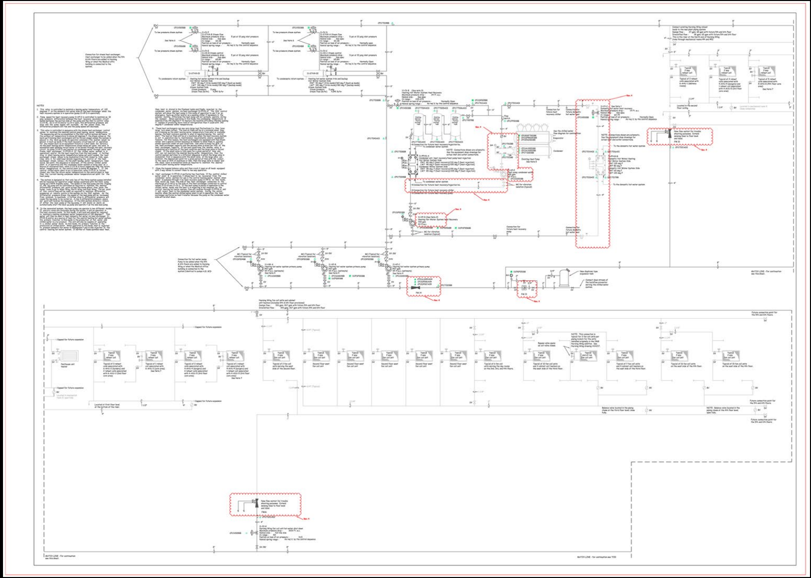
- 80 - 90°F works above 65-70°F
- 160 – 180°F required during extreme weather
- 120 – 140°F works during mild weather



Tracing Energy Through a Facility

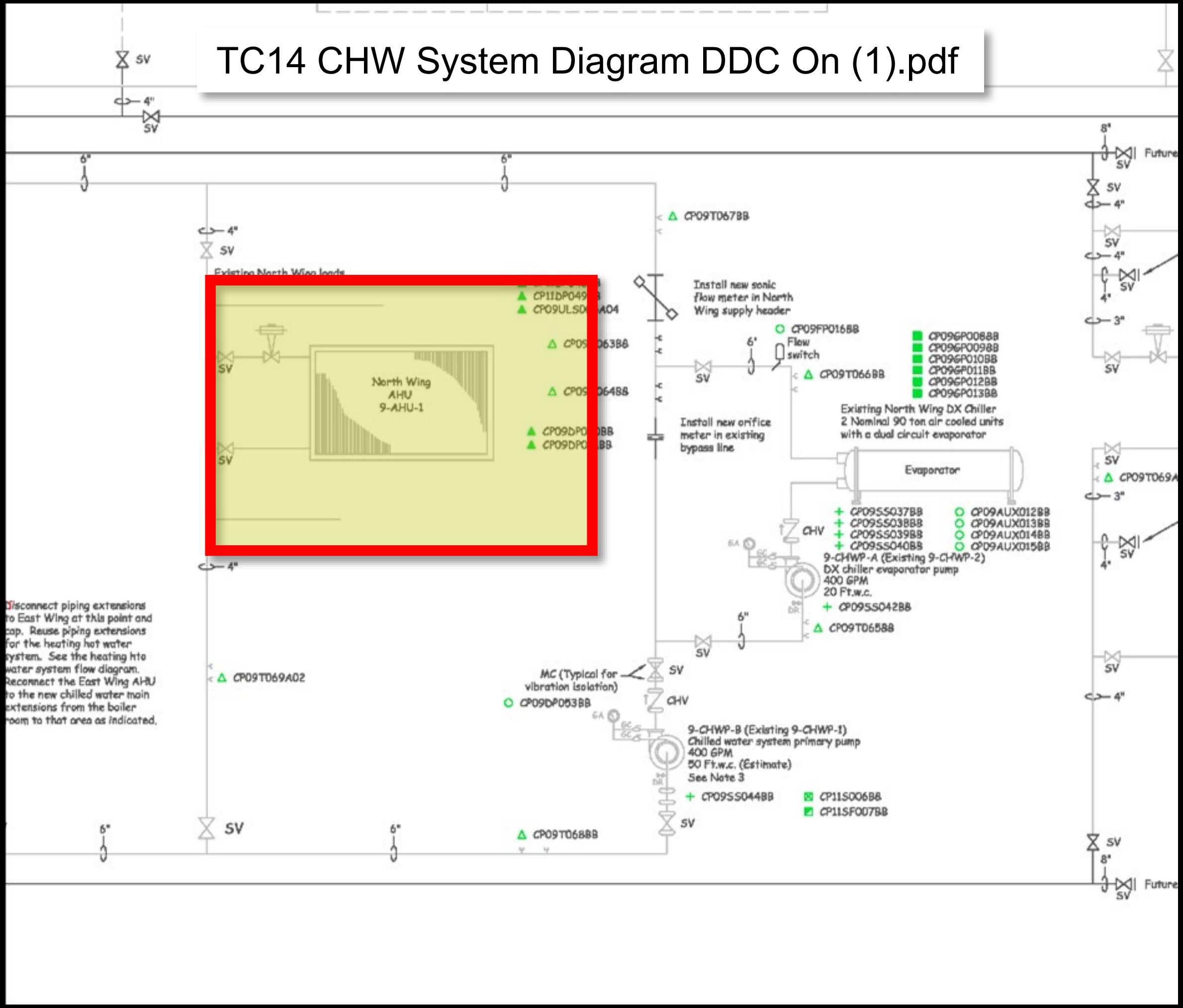






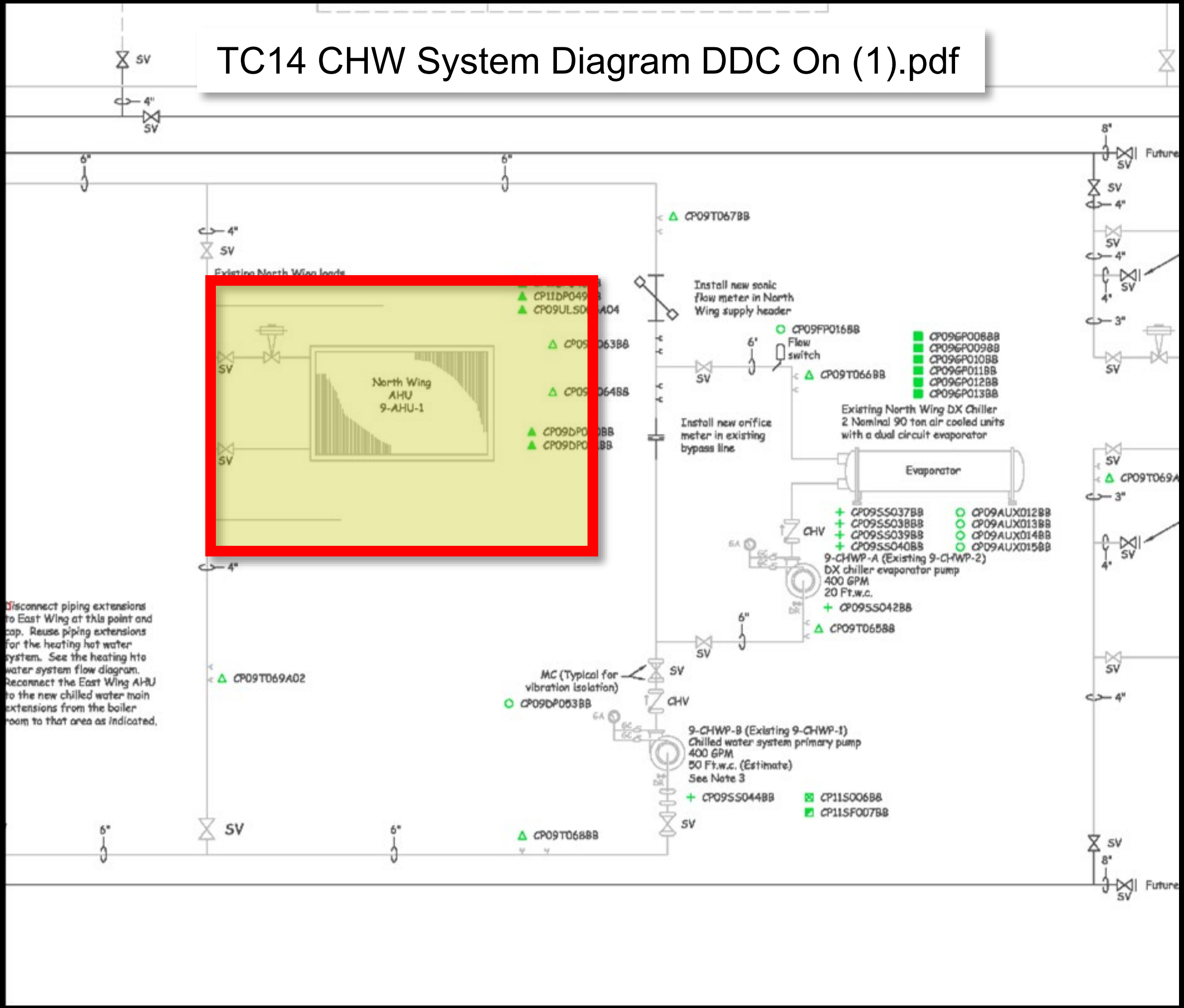
Tracing Energy Through a Facility

1. Start with the North Wing AHU Chilled Water Coil



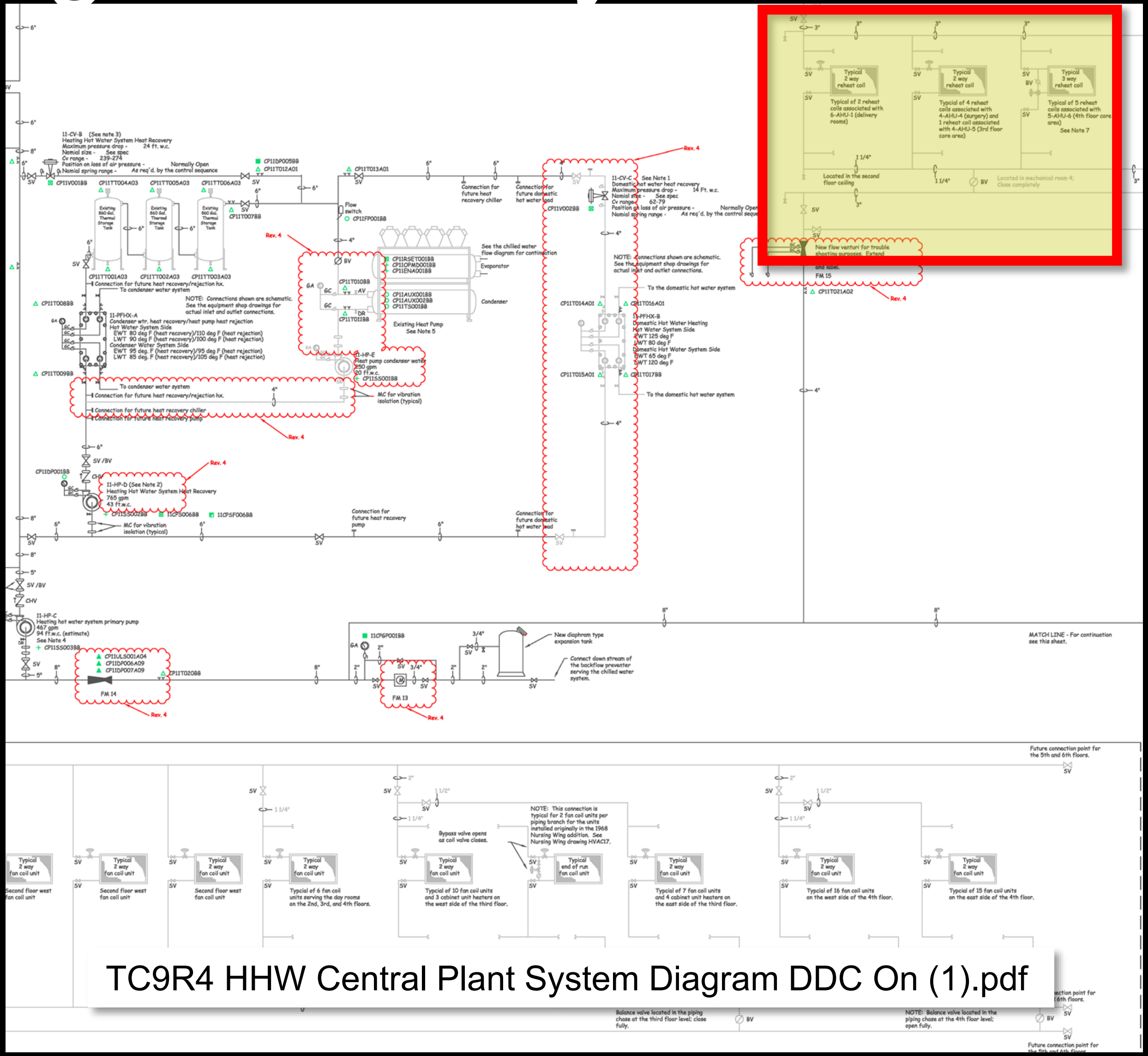
Tracing Energy Through a Facility

1. Start with the North Wing AHU Chilled Water Coil
2. Pretend you are a Btu that was picked up from the airstream and are now in the chilled water



Tracing Energy Through a Facility

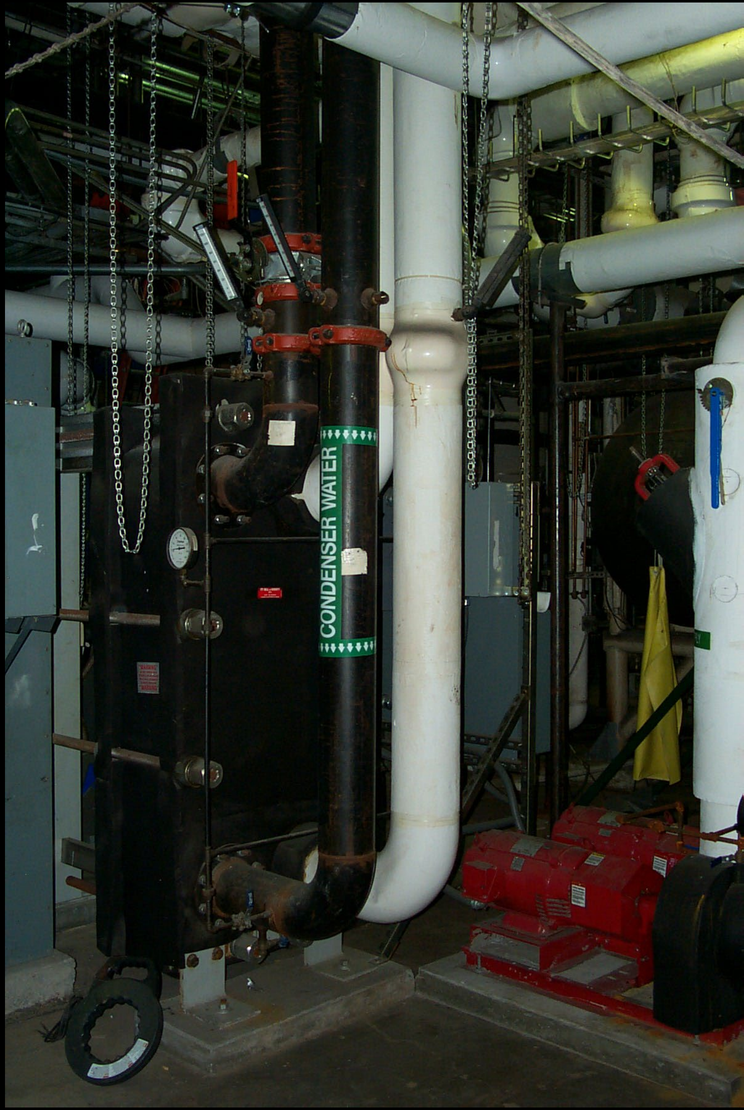
1. Start with the North Wing AHU Chilled Water Coil
2. Pretend you are a Btu that was picked up from the airstream and are now in the chilled water
3. See if you can get yourself into the heating water system and on your way to a reheat coil



TC9R4 HHW Central Plant System Diagram DDC On (1).pdf

Another Question

What would you need to do to the North Wing AHU control logic to allow heat to be recovered from it by the central plant during cool weather?

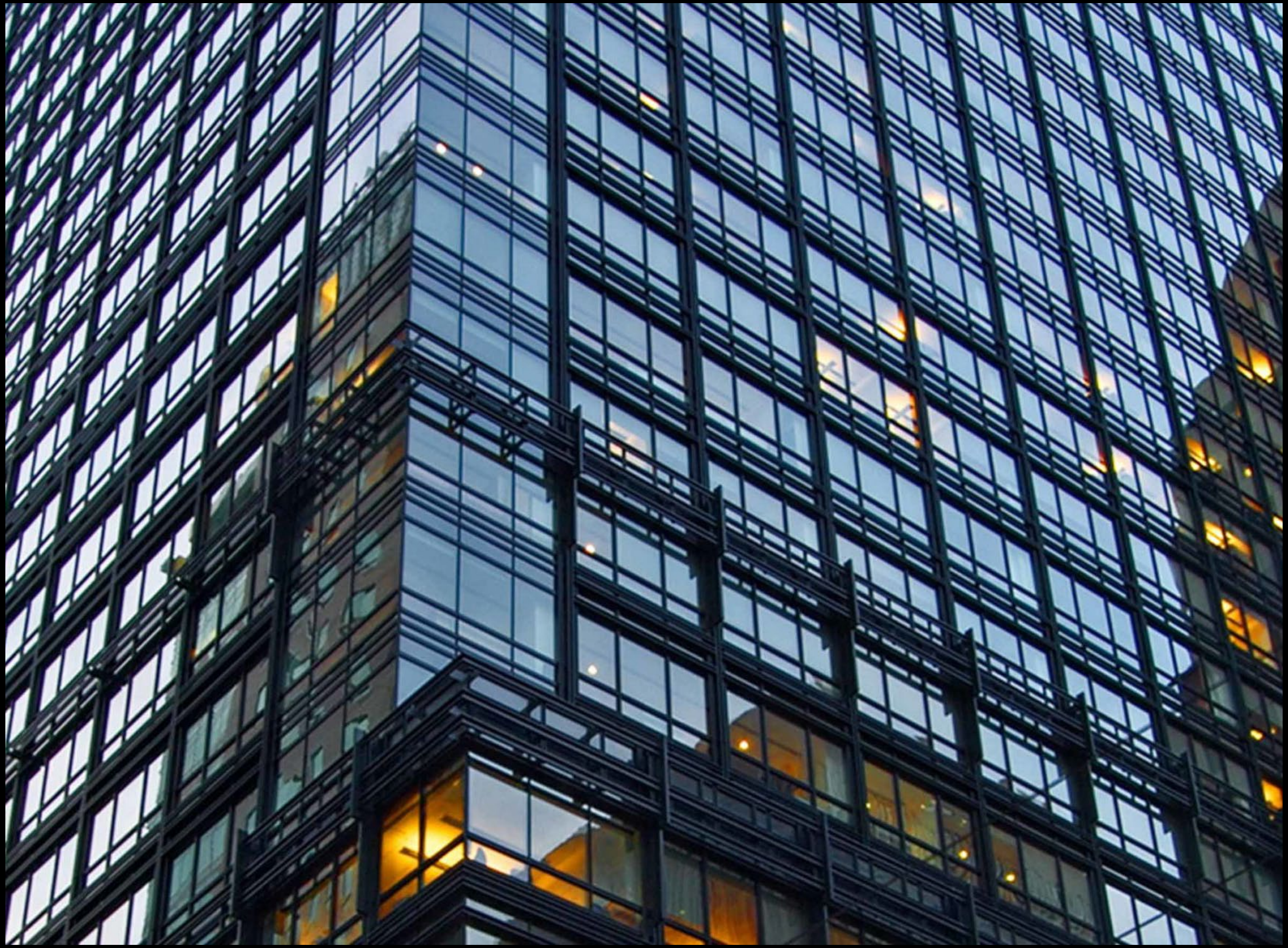


Getting Back to 560 Mission Street

Why Is This?

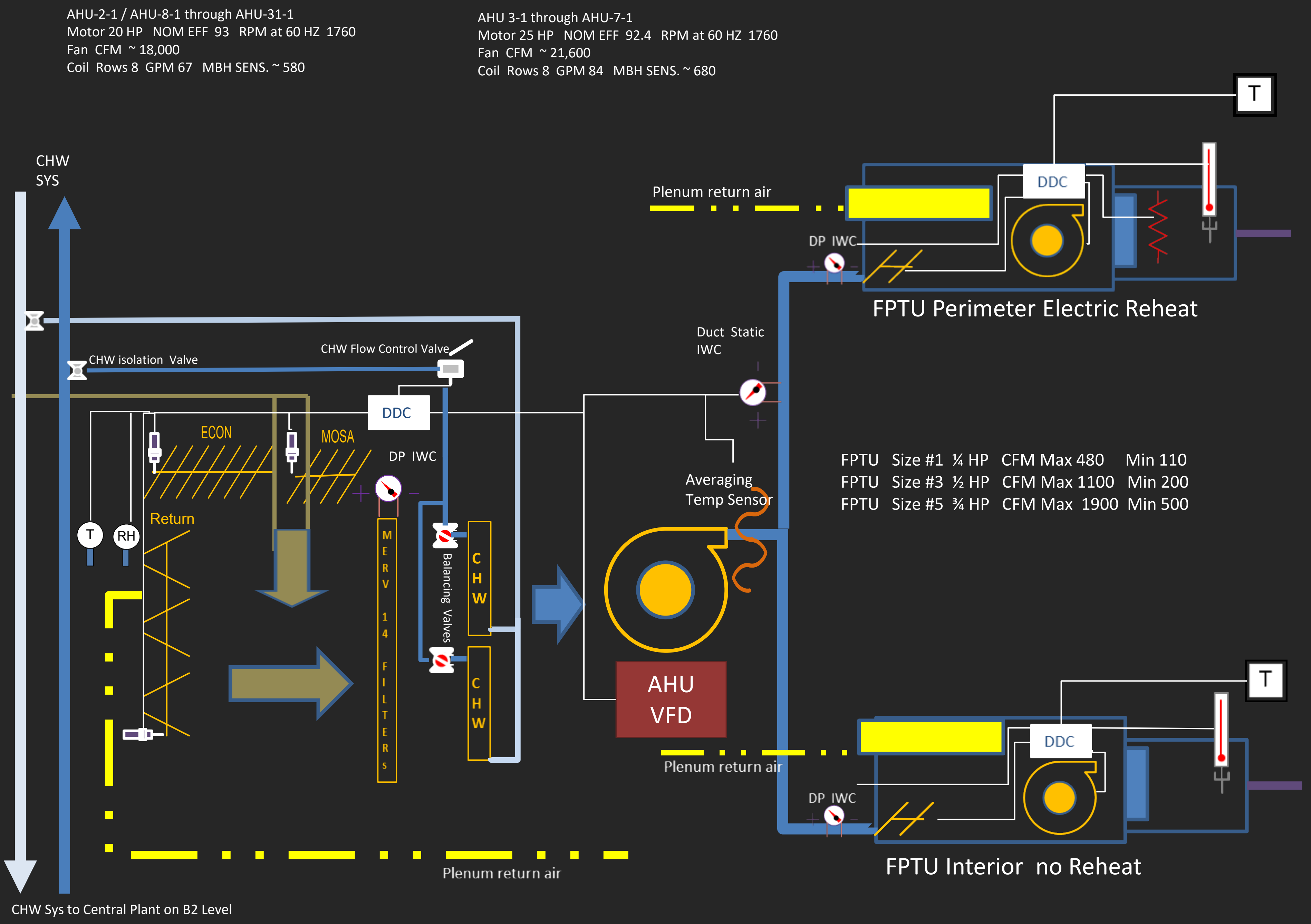
I have 300 kW of electric resistance heat, and the energy it uses is a major portion of our utility bills. And yet the building is cold!

Gary Walters, Chief Engineer

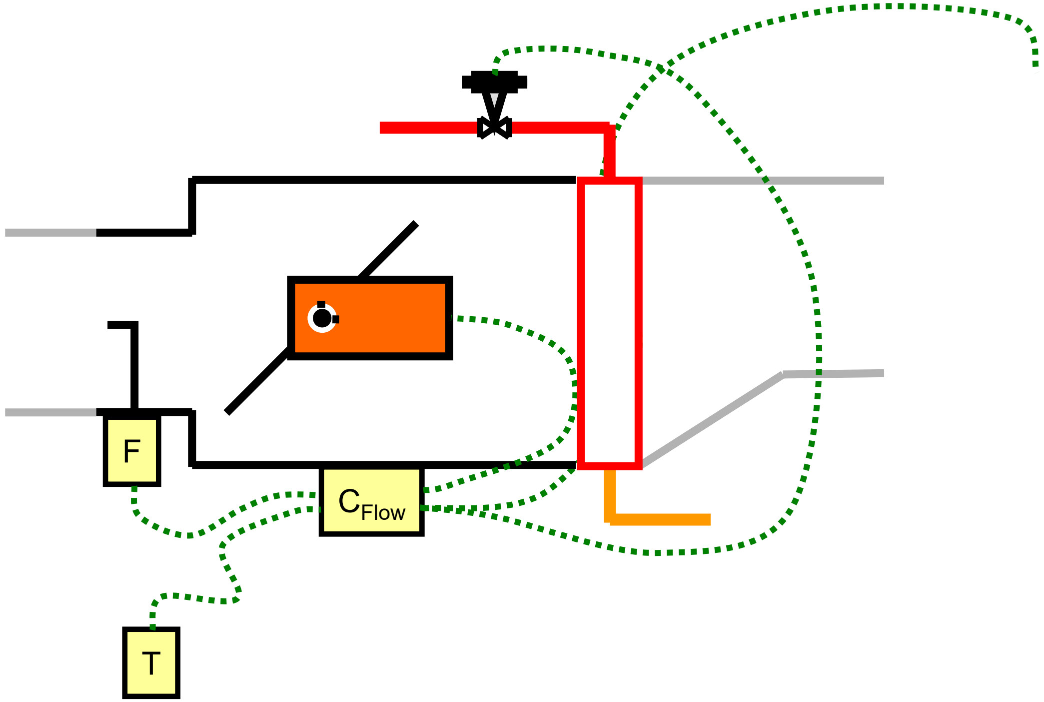


Fan Powered Terminal Units

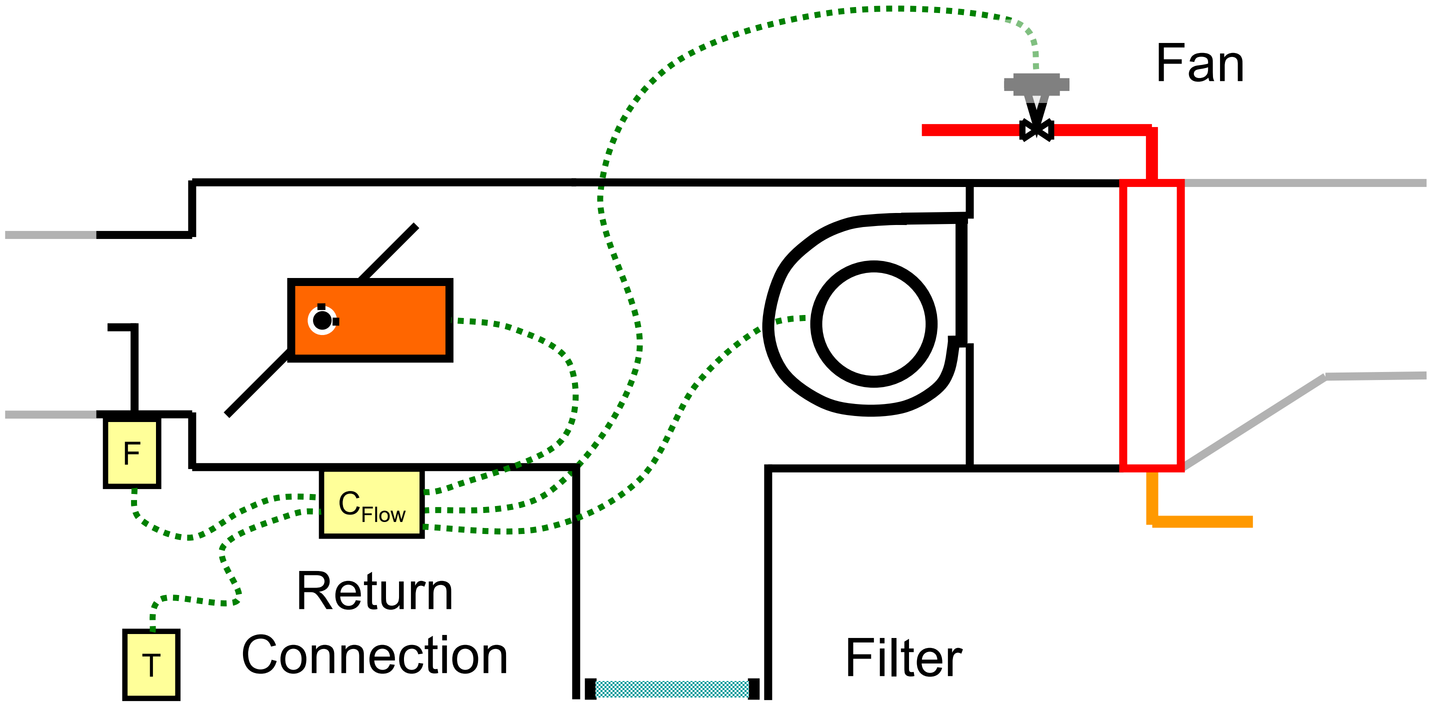
Gary's AHU System Diagram



Recovering Heat to Reheat
Series Fan Powered Box



Recovering Heat to Reheat
Series Fan Powered Box



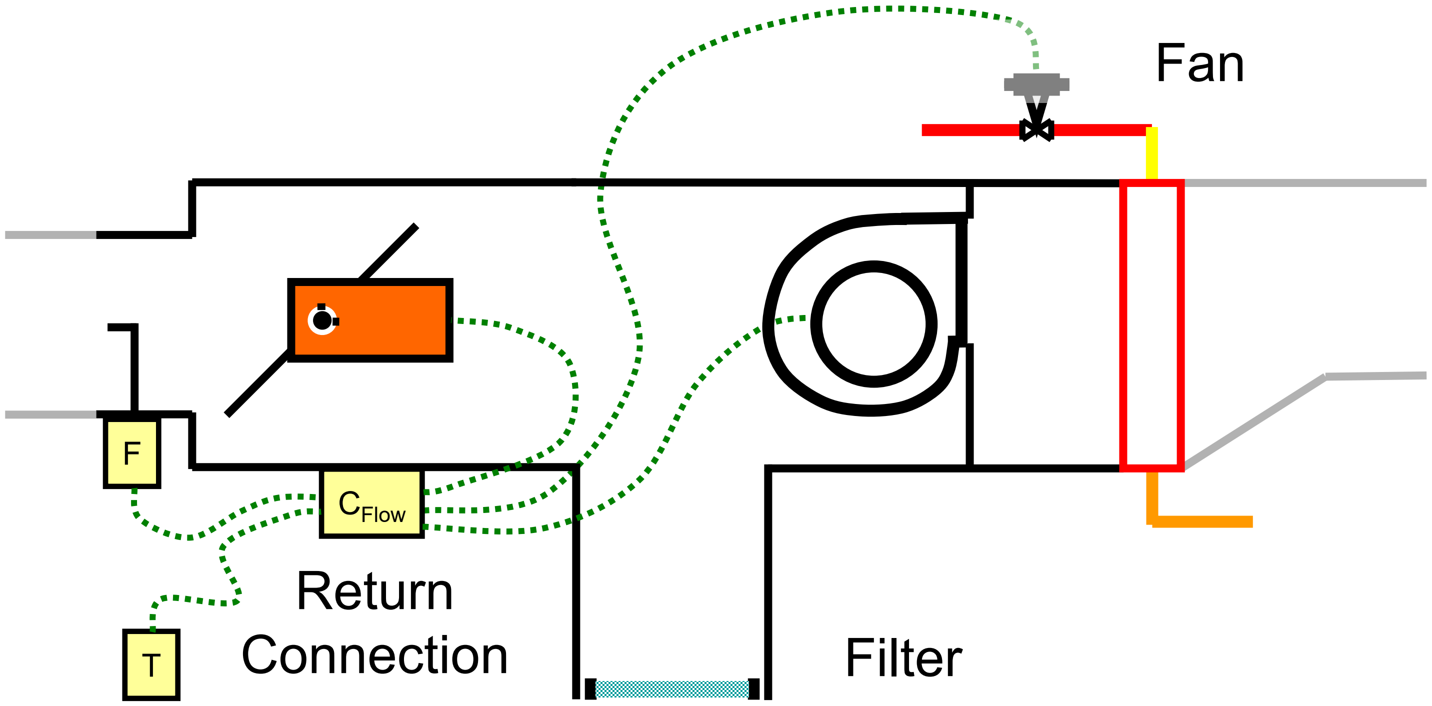
Fan runs continuously when the zone is occupied

- Tends to be constant volume

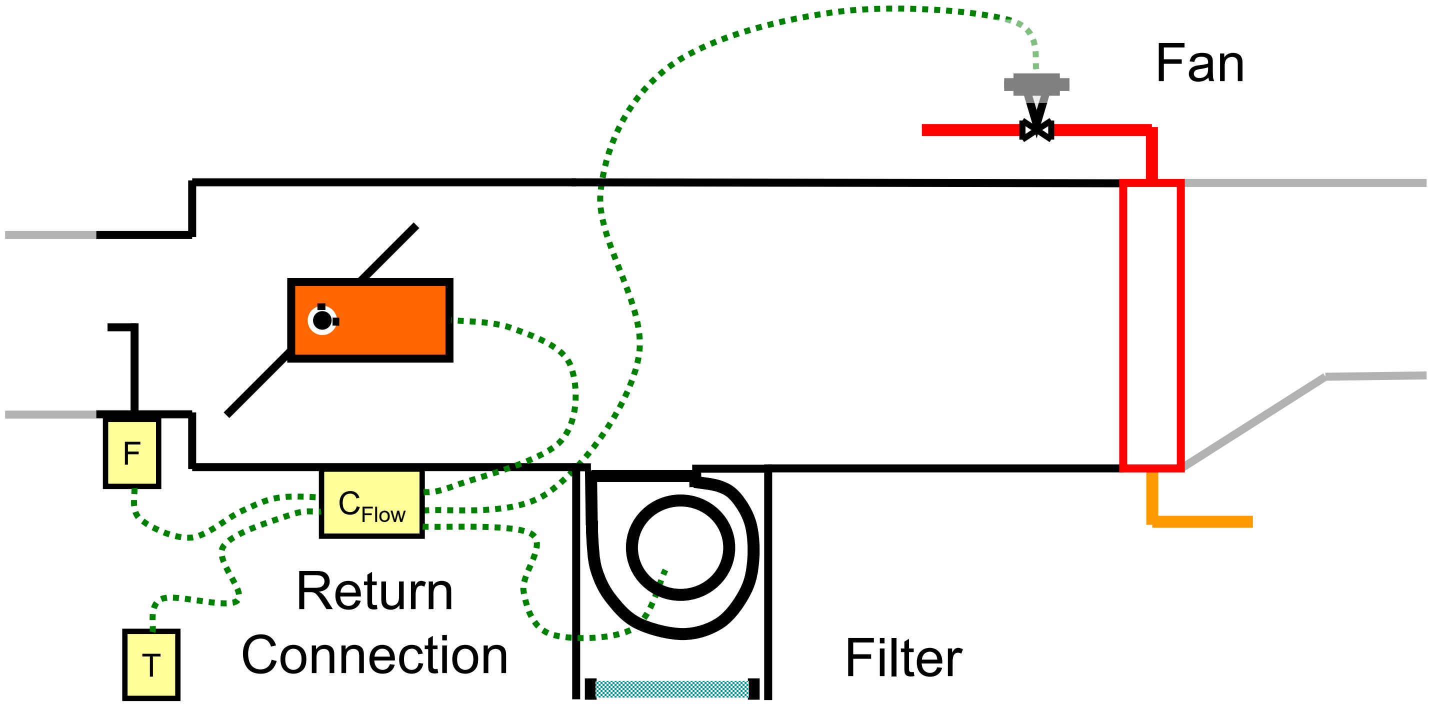
Reduction in primary flow (cooling air) is compensated for by increased return flow

- First stage of reheat
- Coil provides second stage

Recovering Heat to Reheat
Series Fan Powered Box



Recovering Heat to Reheat
Parallel Fan Powered Box



Fan runs intermittently when the zone is occupied

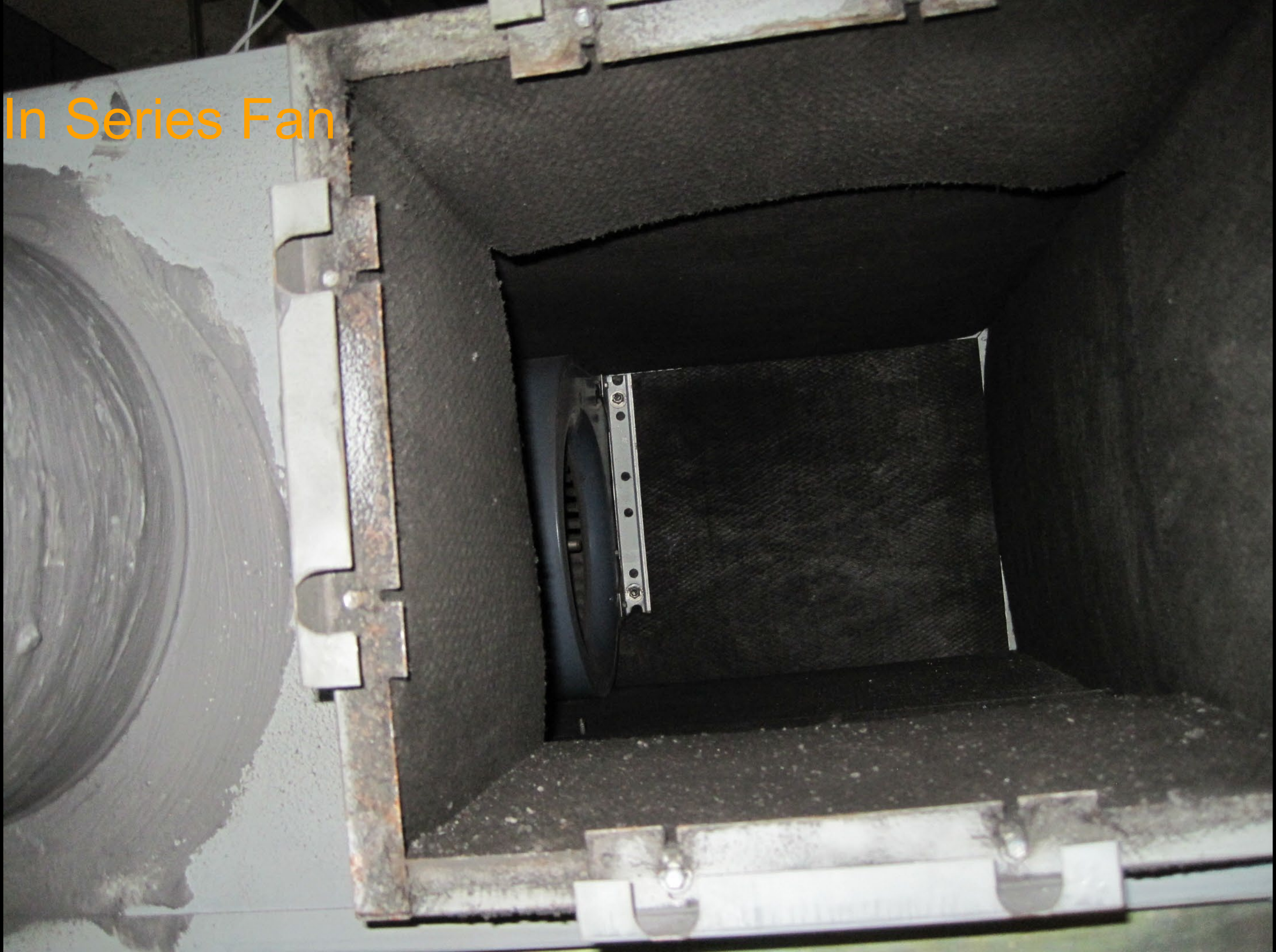
- Tends to be constant volume *when the fan runs*

Zone sees some reduction in flow until the fan starts

- First stage of reheat
- Coil provides second stage


A Typical Fan Powered Box

The In Series Fan



The In Series Fan

Electric Reheat Coils

Electric Reheat Coils

- Staged control can cause comfort issues
- Silicon Controlled Rectifiers (SCRs) allow modulation

Electric Reheat Coils

Interaction with other system components needs to be considered

- Fire dampers in line of sight can be a problem
- Temperature sensors in line of sight can be a problem

Electric Reheat Coils

Safeties can Cause Issues

- Air flow interlock switch may set the minimum flow rate instead of ventilation requirements

Electric Reheat Coils

Safeties can Cause Issues

- Air flow interlock switch may set the minimum flow rate instead of ventilation requirements
- Residual heat can trip high limit safeties after shut down

Electric Reheat Coils

Sustainability Implications

- 100% efficient at the coil!
- Run on electricity

Electric Reheat Coils

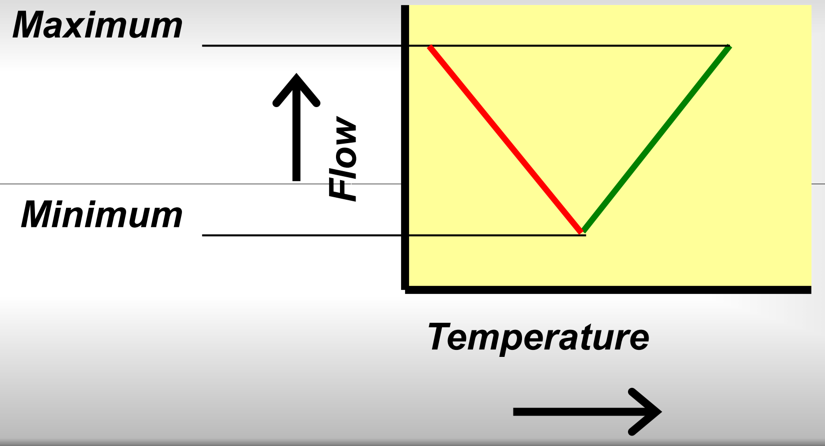
Sustainability Implications

- 100% efficient at the coil!
- Run on electricity
- 30-40% efficient from a source energy standpoint with a fossil fuel fired power plant
- Even with a renewable grid, there will be distribution system losses

A Paradox

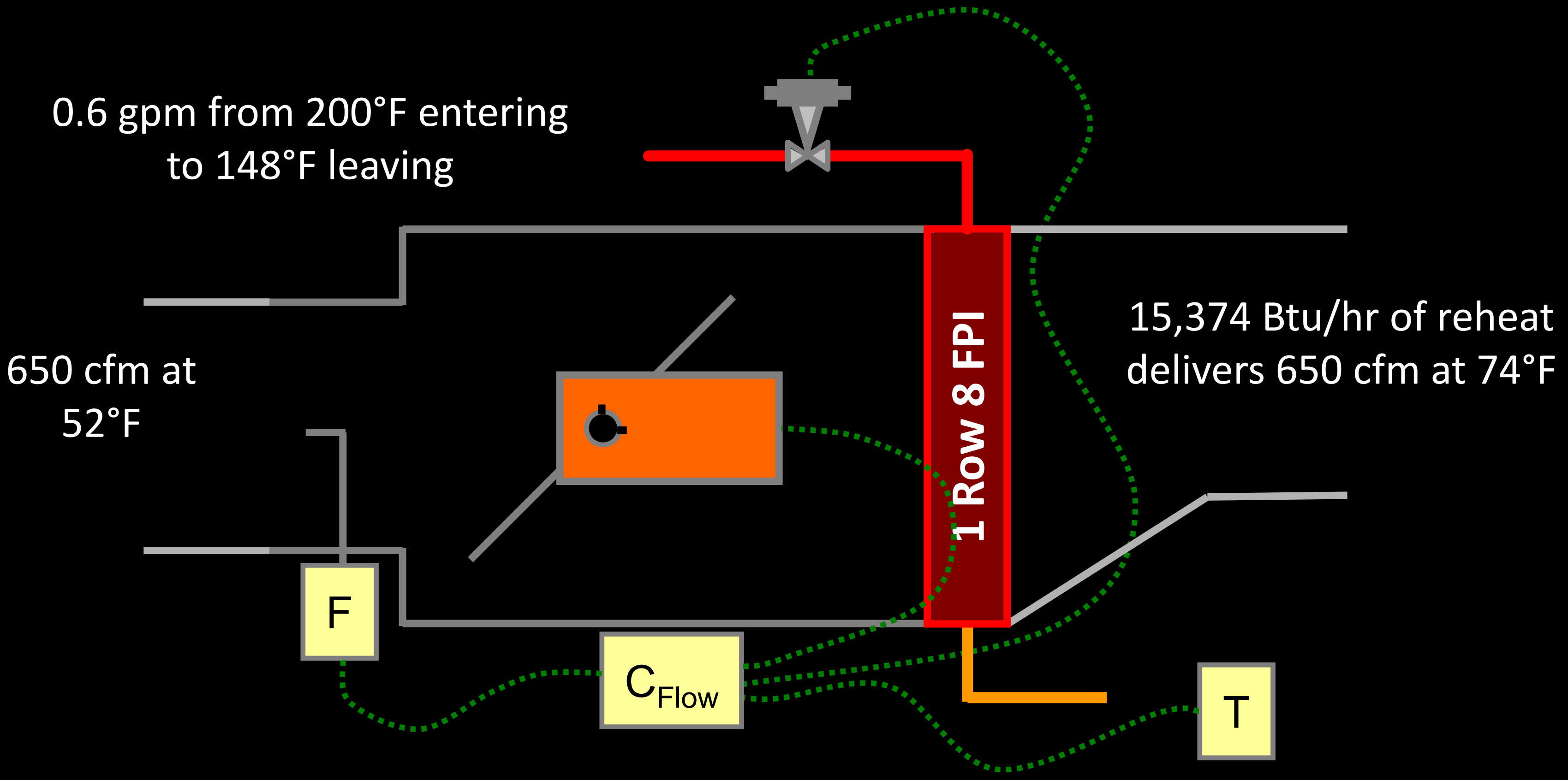
More Flow ≠ More Heating

What happens with this terminal unit control strategy if the minimum flow rate delivers more cooling than the space requires under most of the load conditions it might see?



More Flow ≠ More Heating

Flow, cfm	Space Temperature, °F	Entering Air, °F	Leaving Air, °F	Capacity, Btu/hr	Simultaneous Heating and Cooling		Heat Available to Offset Losses	
					Btu/hr	% of Total	Btu/hr	% of Total
650	72	52	74	15,374	14,321	93%	1,053	7%



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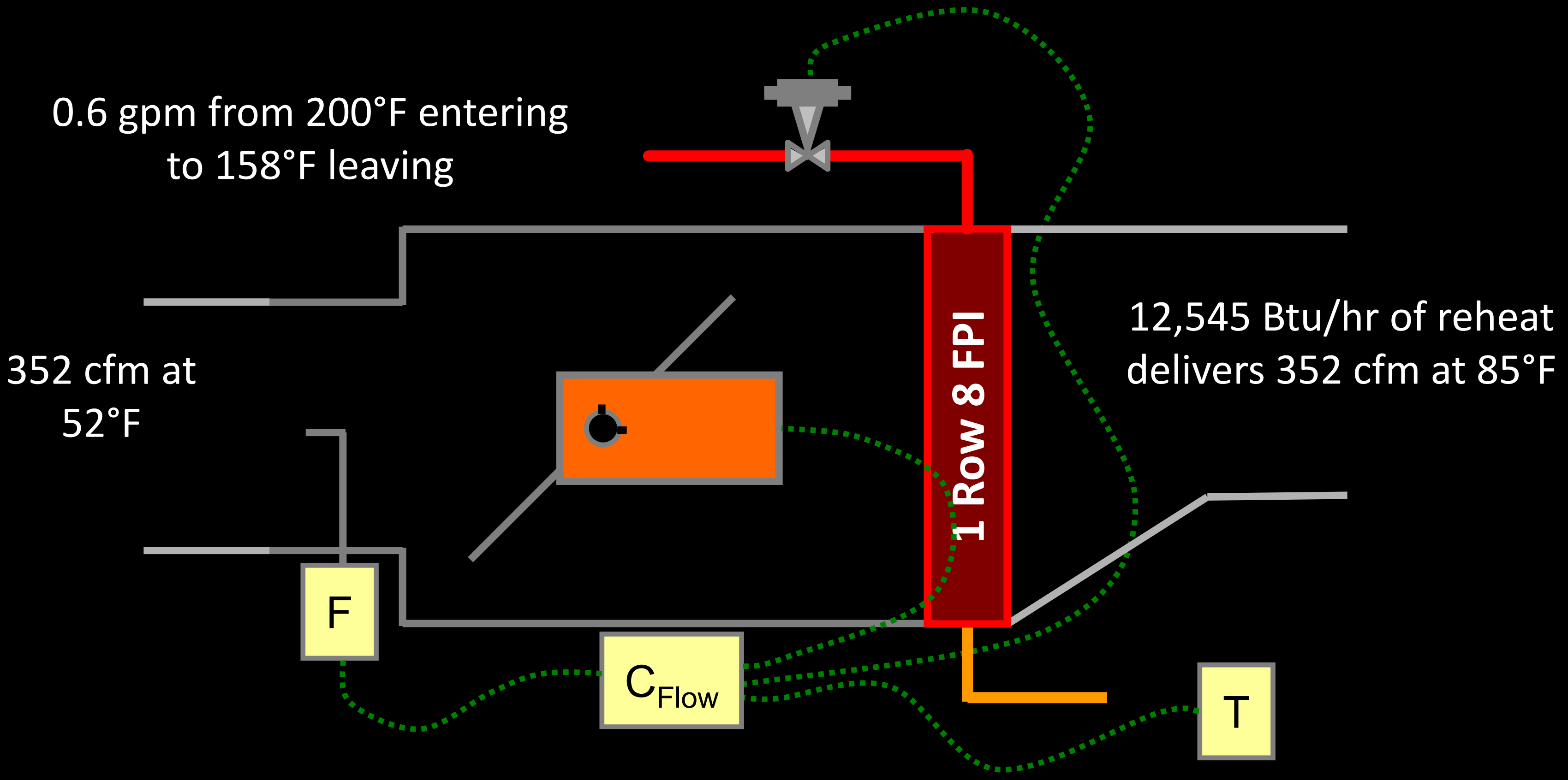
650	72	52	74	15,374	14,321	93%	1,053	7%
352	72	52	85	12,545	7,755	62%	4,790	38%



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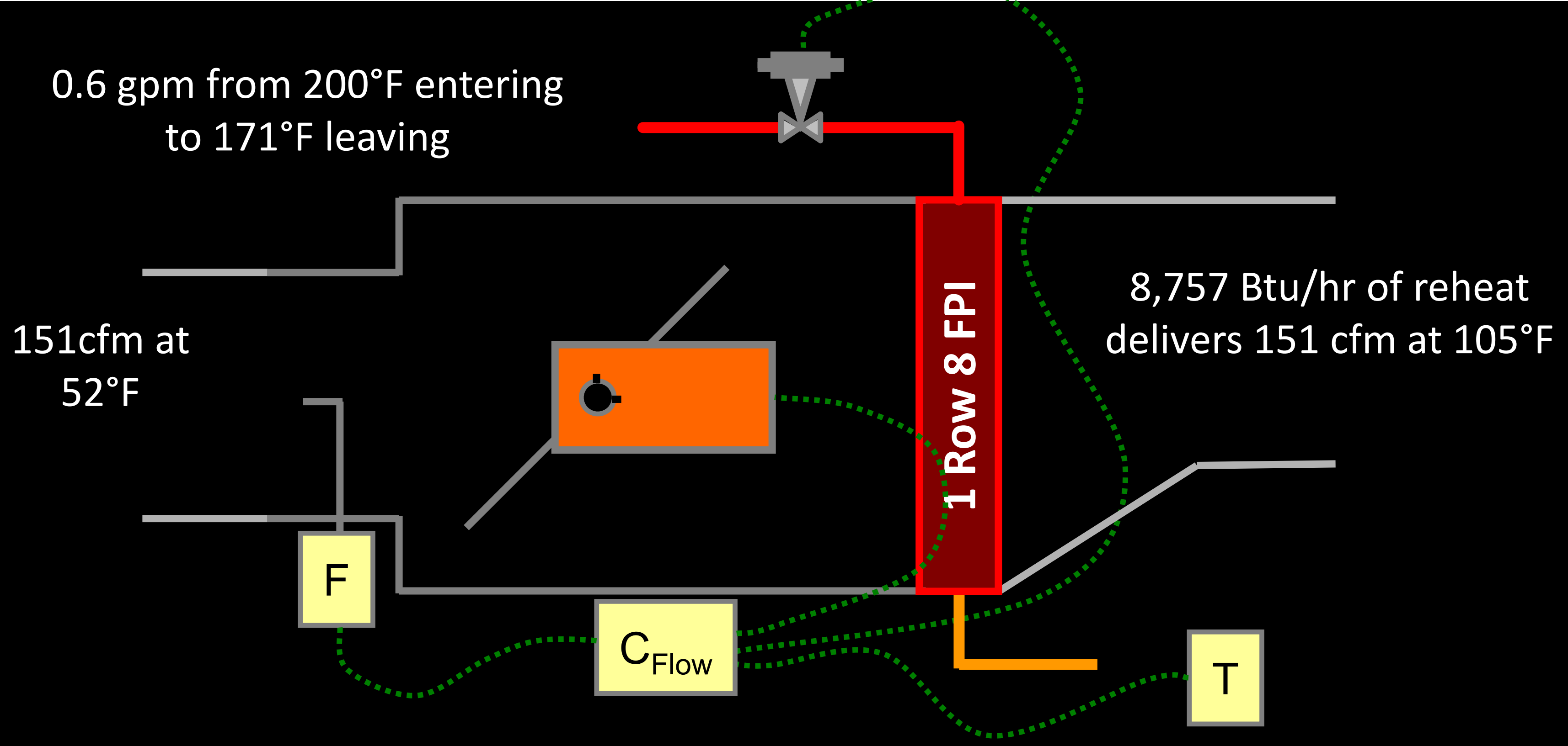
650	72	52	74	15,374	14,321	93%	1,053	7%
352	72	52	85	12,545	7,755	62%	4,790	38%
151	72	52	105	8,757	3,327	38%	5,431	62%



Air Distribution Considerations

Diffusers and Flow Variation

- Need to be designed for the full range of supply flow
- Performance with hot air different from performance with cold air
- Lower average velocity at lower flow rates
  - Less throw
  - Less mixing
  - “Dumping”

What Does All of This Mean?

What Does All of This Mean?

All Electric *<u>does not</u>* mean All Done in terms of opportunities to improve efficiency and performance and reduce atmospheric impact

What Does All of This Mean?

With a “clean sheet of paper” there may have been some better options

- Electrically fired hot water heat
  - Direct heat recovery from condenser water
  - Heat recovery chillers if higher grade heat is needed
  - Condensing boiler initially for peaking
  - Upgrade to electric boiler in the future

What Does All of This Mean?

For an existing facility, a commitment to ongoing commissioning along with creative thinking and long-term planning can make a difference

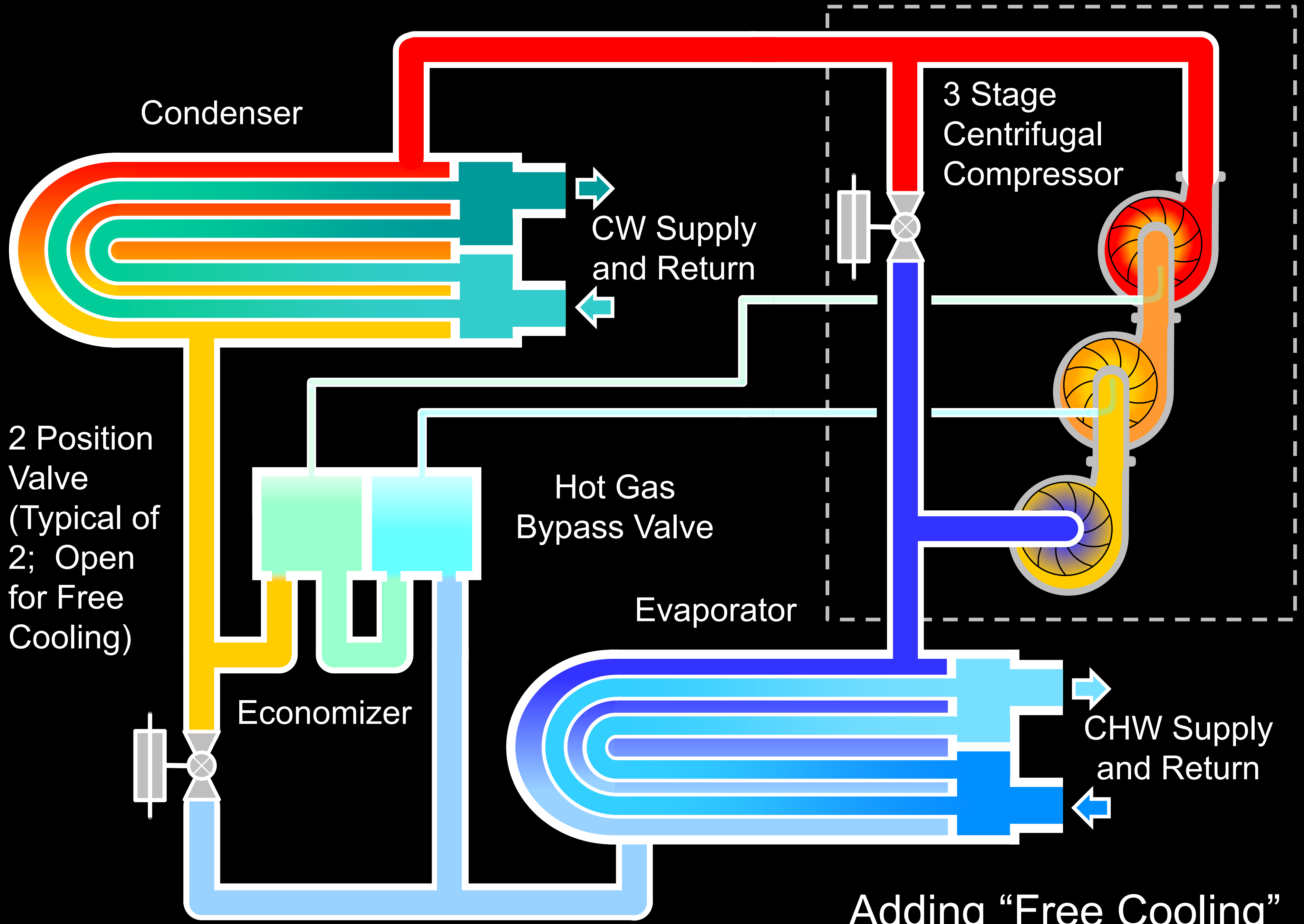
- Electrically fired hot water heat may be an upgrade path in a facility with a long life cycle

What Does All of This Mean?

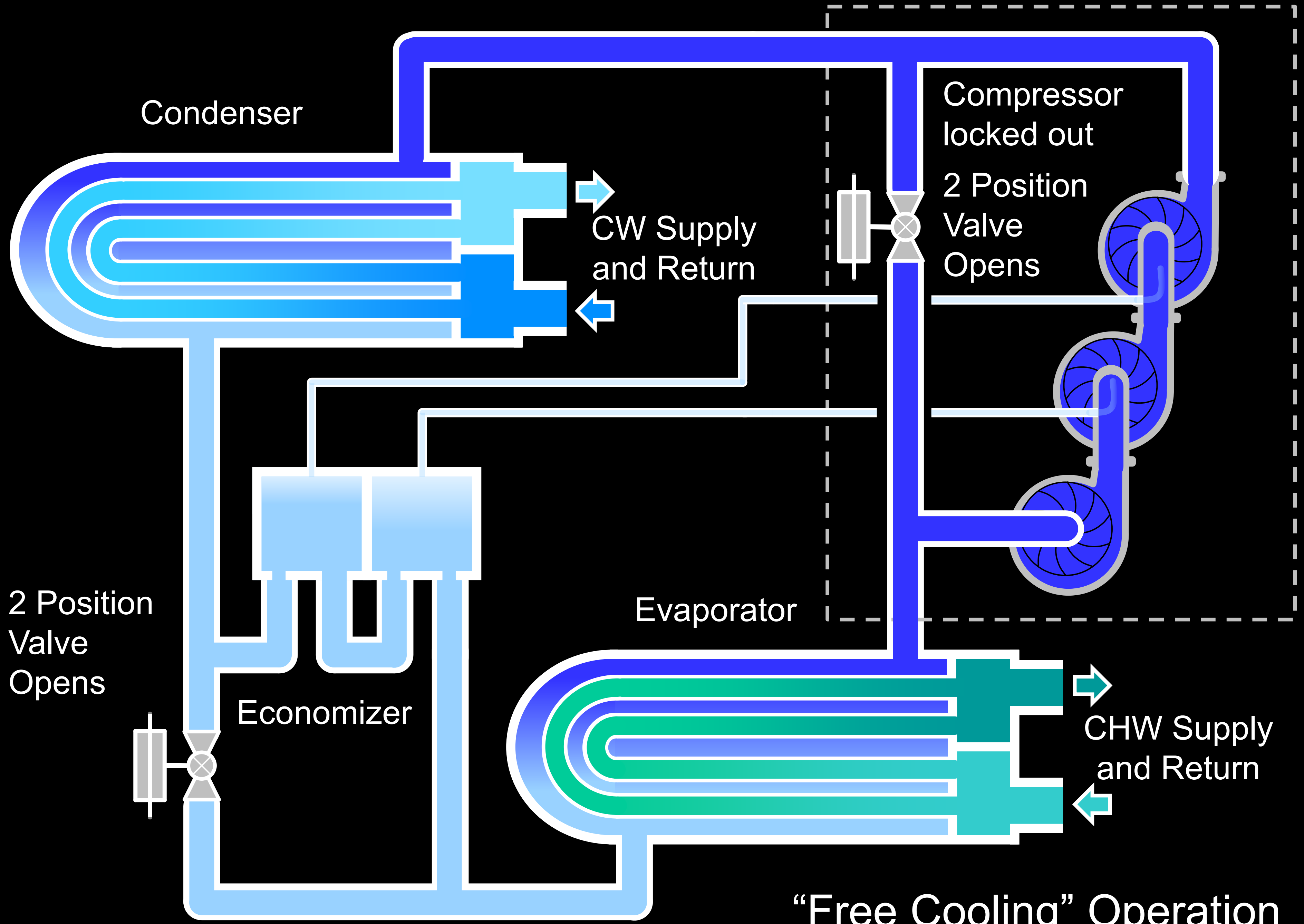
For an existing facility, a commitment to ongoing commissioning along with creative thinking and long-term planning can make a difference

- Electrically fired hot water heat may be an upgrade path in a facility with a long life cycle
- Creative thinking can start moving you in the right direction meanwhile

A Chiller Based Free Cooling Cycle

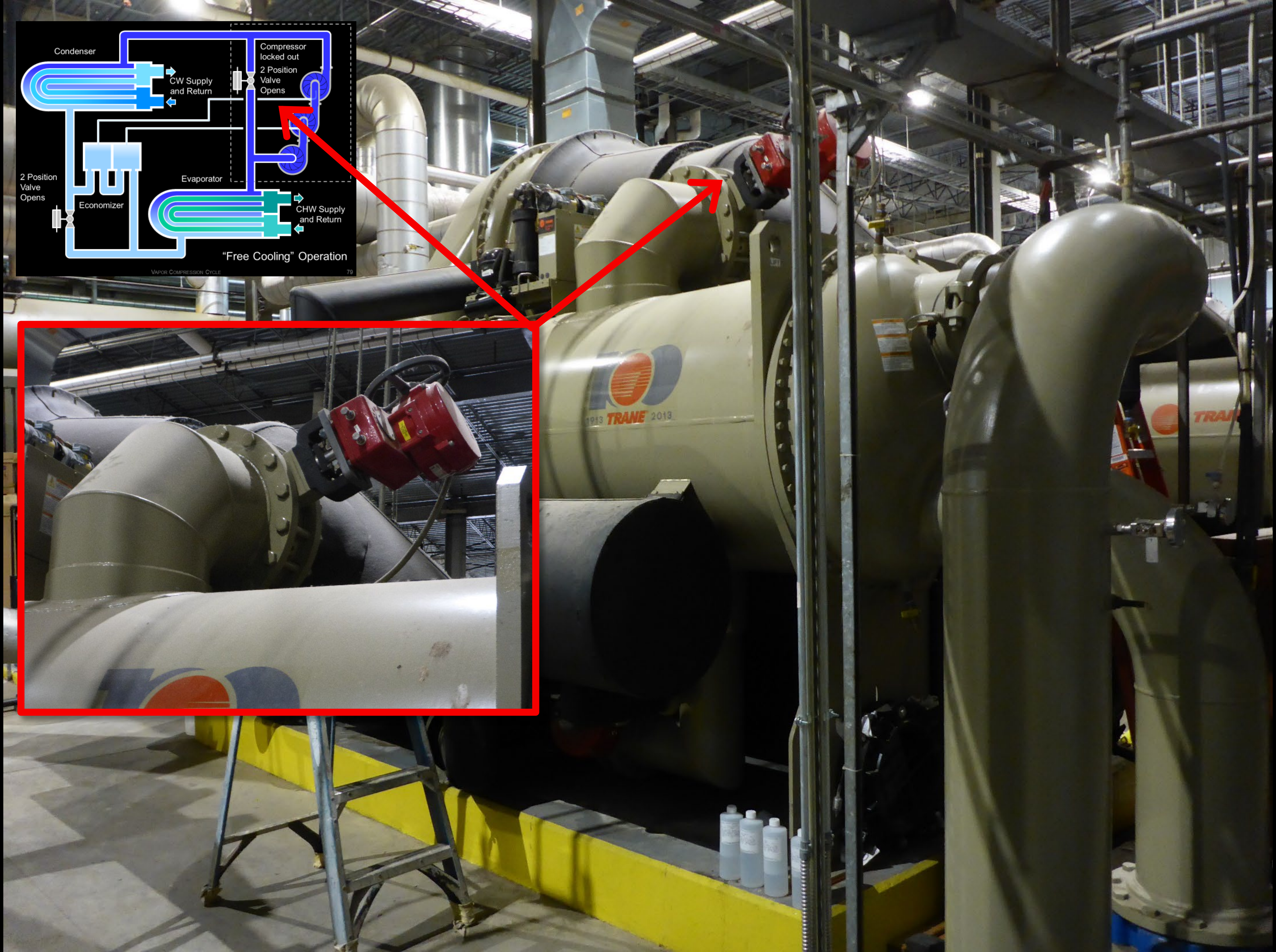


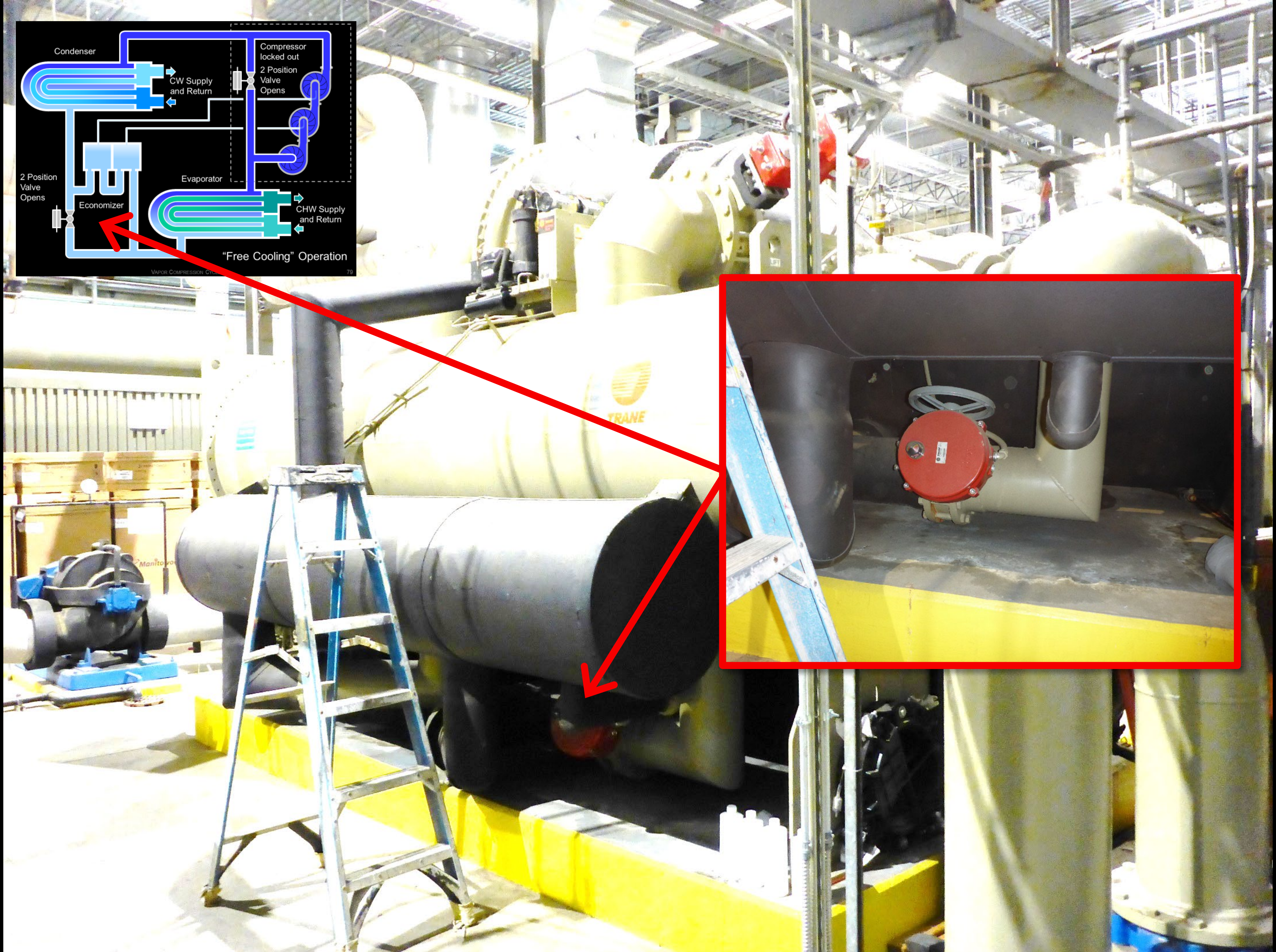
Adding “Free Cooling”



“Free Cooling” Operation

Condenser
Compressor locked out
2 Position Valve Opens
CW Supply and Return
2 Position Valve Opens
Evaporator
Economizer
CHW Supply and Return
"Free Cooling" Operation
Vapor Compression Cycle
79
1913 TRANE 2013


Condenser
CW Supply
and Return
Compressor
locked out
2 Position
Valve
Opens
2 Position
Valve
Opens
Economizer
Evaporator
CHW Supply
and Return
"Free Cooling" Operation
Vapor Compression Cycle
79
1913 TRANE 2013


Condenser
CW Supply and Return
Compressor locked out
2 Position Valve Opens
2 Position Valve Opens
Evaporator
Economizer
CHW Supply and Return
"Free Cooling" Operation
TRANE

Gary’s Chillers can Do This

… and he is using that feature to help solve his heating problem

The “Trick”

Understanding what “Cooling” and “Heating” Mean in the context of the loads in the facility

Data Center

“Cooling” means keeping the data center at 80°F

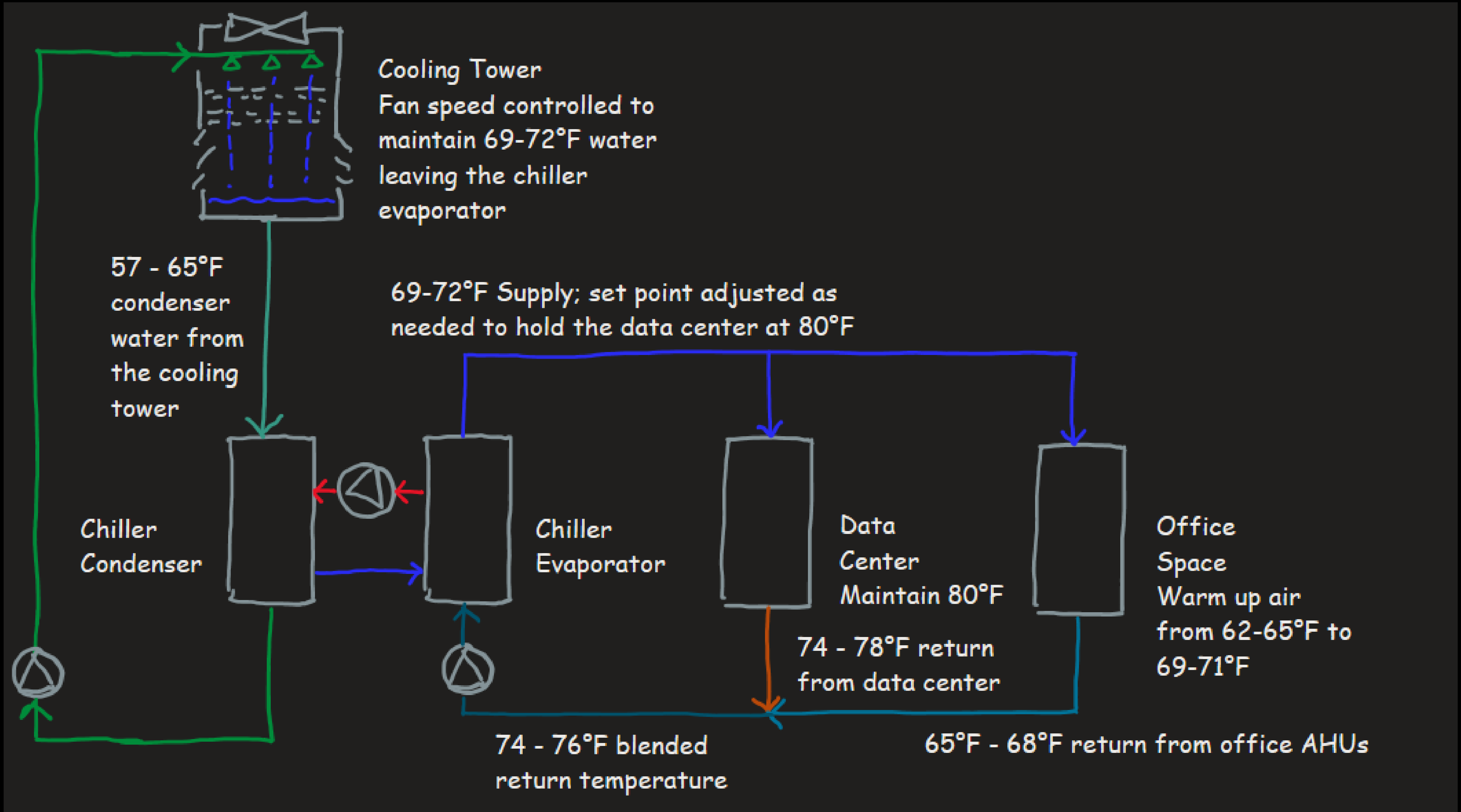
- Can be achieved using 69°F - 72°F “chilled” water
- Resulting return temperatures are in the 74°F – 78°F range

Office Spaces

“Heating” means warming up spaces that are around 62-65°F

- Can be achieved using 69°F – 72°F “hot water”
- Resulting leaving air temperatures are in the 69°F – 71°F range

The "Trick"



Cooling Tower
Fan speed controlled to maintain 69-72°F water leaving the chiller evaporator
57 - 65°F condenser water from the cooling tower
69-72°F Supply; set point adjusted as needed to hold the data center at 80°F
Chiller Condenser
Chiller Evaporator
Data Center Maintain 80°F
Office Space Warm up air from 62-65°F to 69-71°F
74 - 78°F return from data center
74 - 76°F blended return temperature
65°F - 68°F return from office AHUs

Thank You

Together, Building
a Better California

Class Survey

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

Here's how to participate:

- Click the provided link: https://www.surveymonkey.com/r/EWB20240529CHP
- Scan the QR code with your phone's camera

Break Time
We will be back at 11:00 am Pacific Time

PG&E Together, Building a Better California