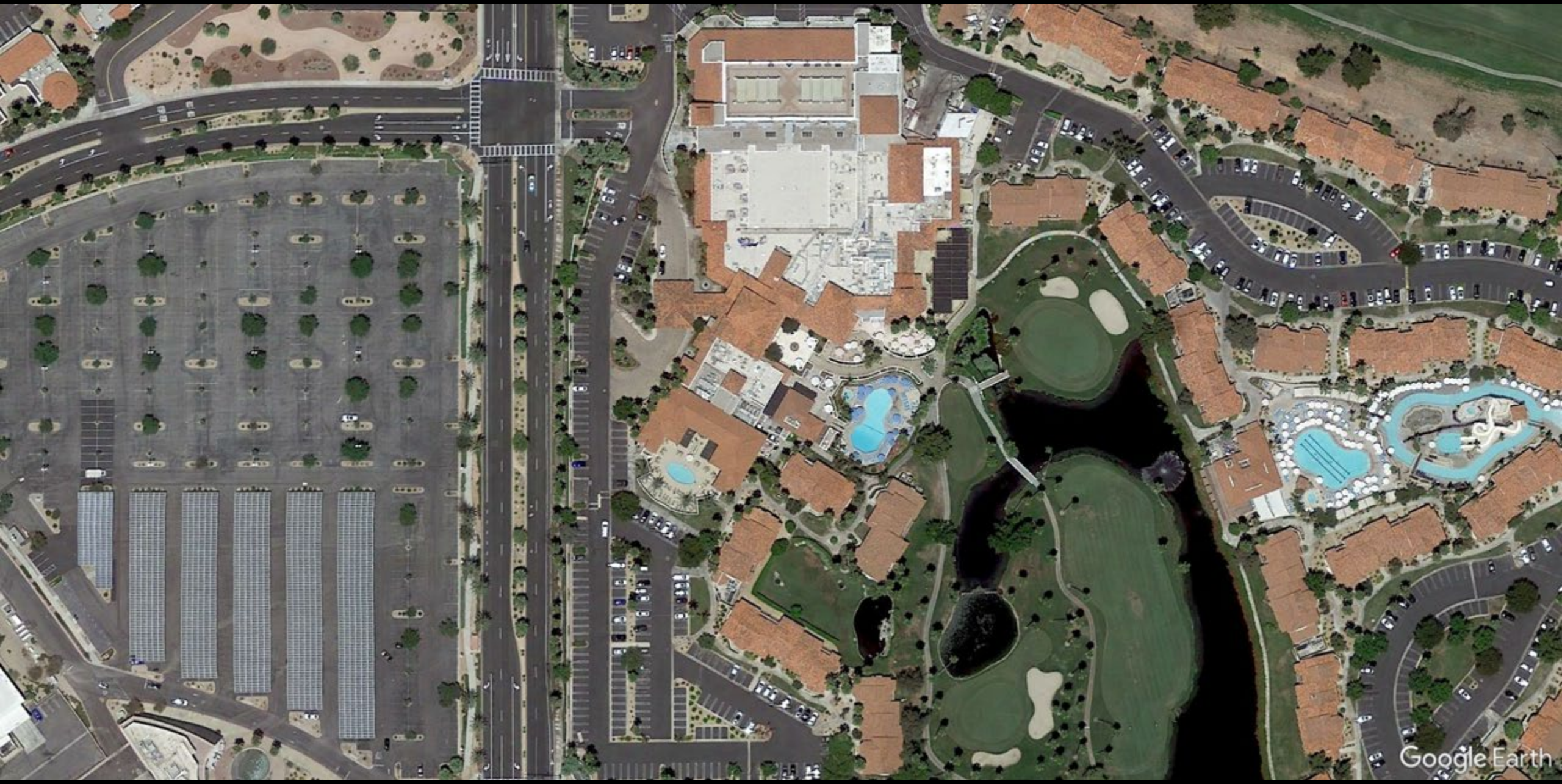
How Water and Steam Systems; Basic Principles, Ongoing Commissioning, Operation, and Optimization

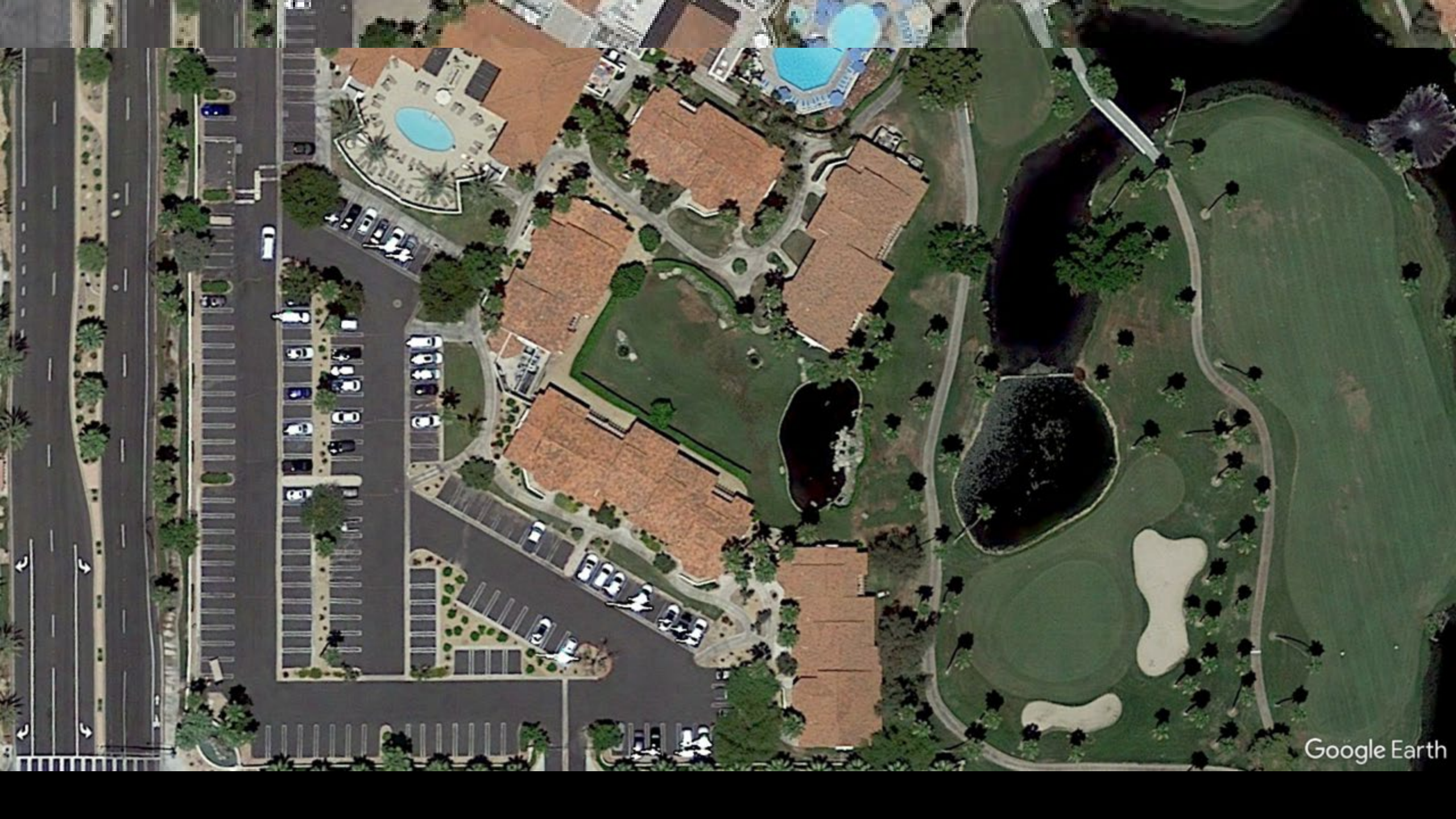
Water Source Heat Pump Loop Example

Presented By:
David Sellers
Senior Engineer, Facility Dynamics Engineering

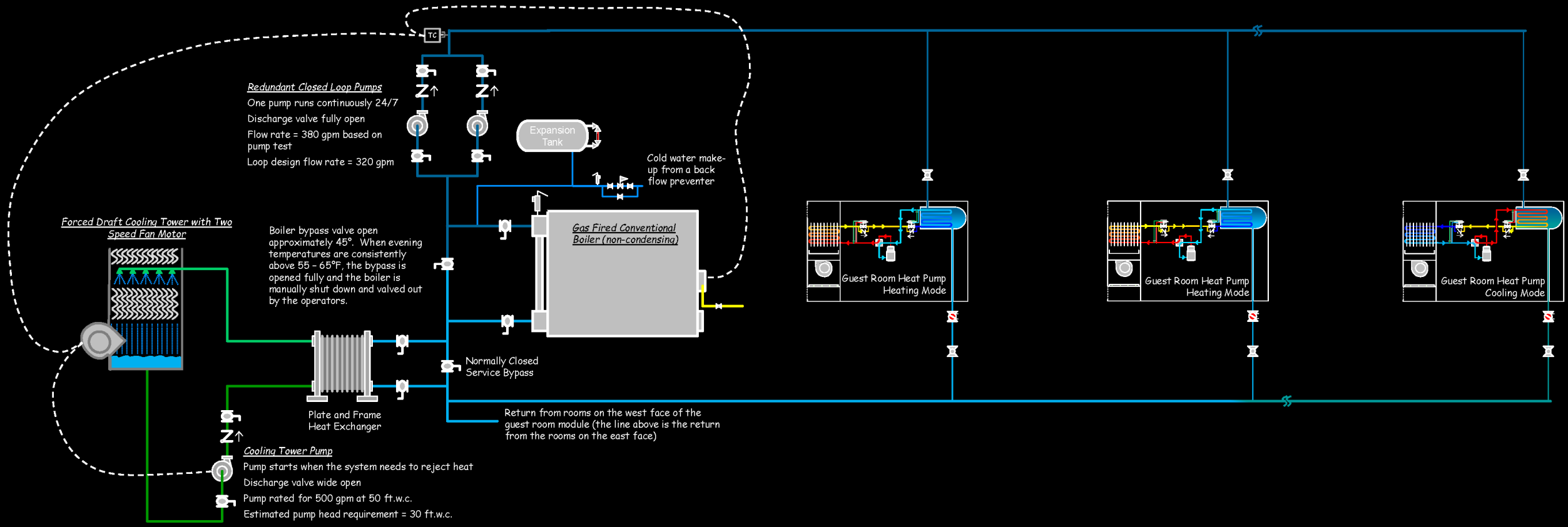
A Hospitality Industry Campus Style Location

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


Google Earth

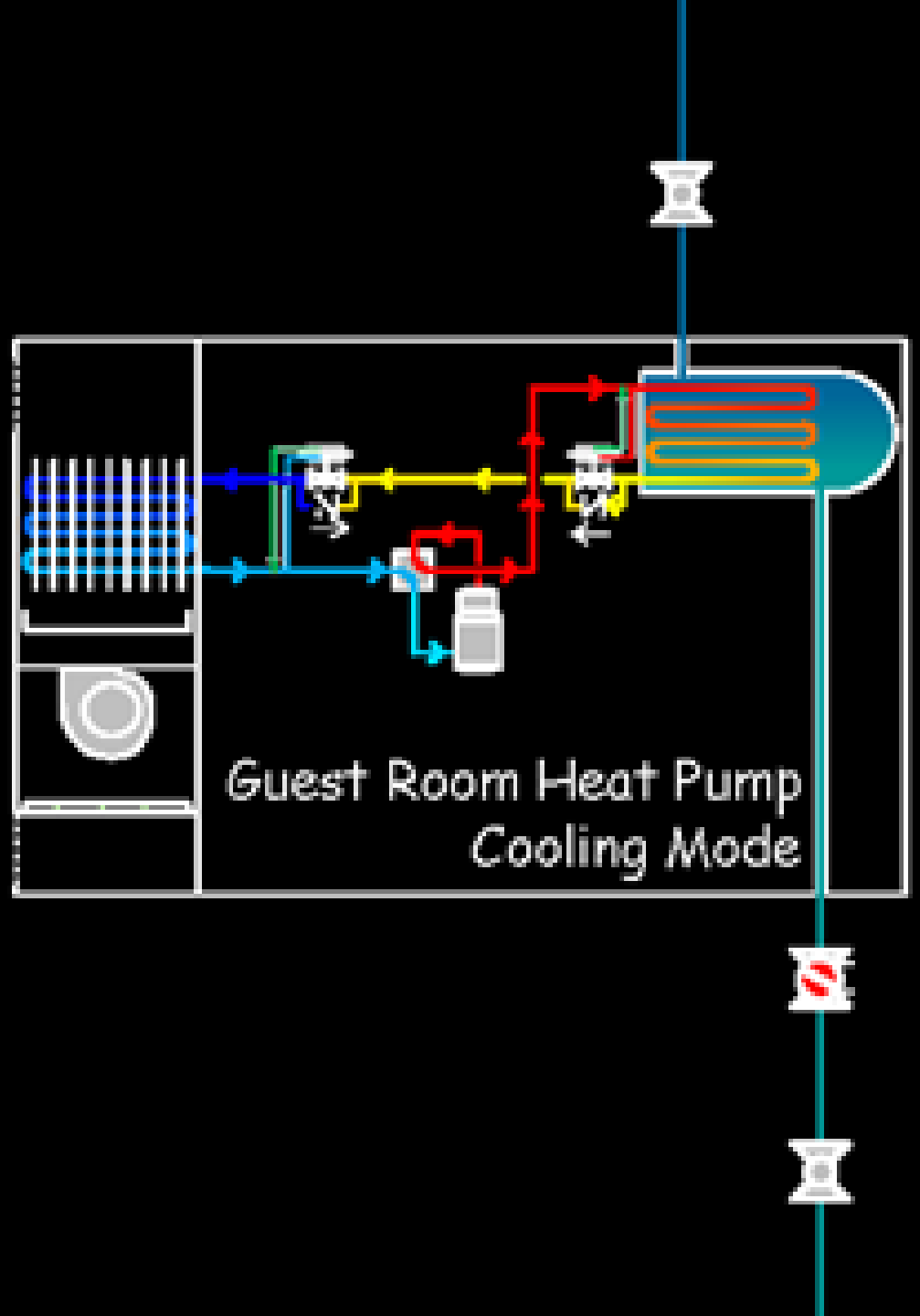

Google Earth

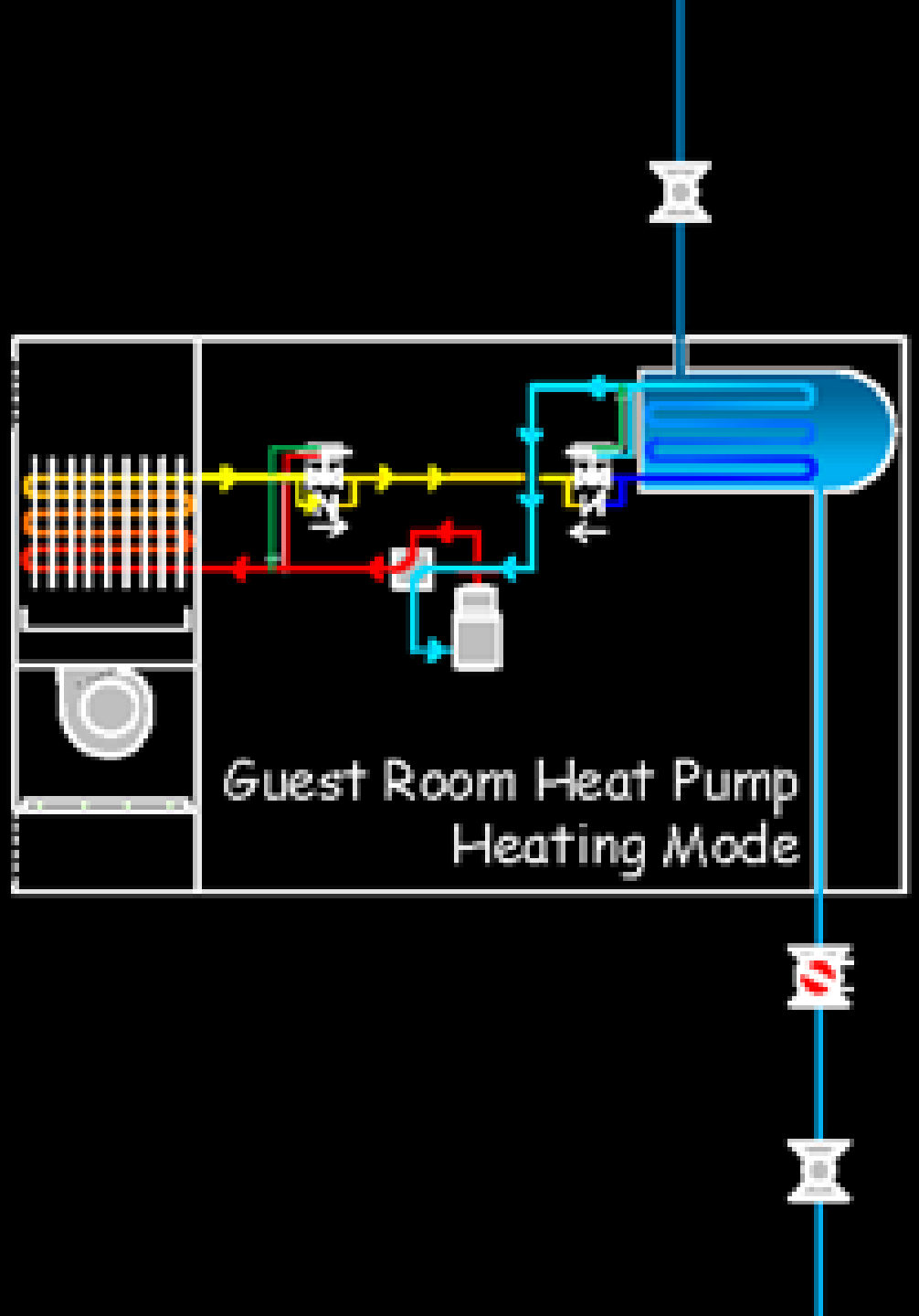
A Typical Guest Room Heat Pump Loop

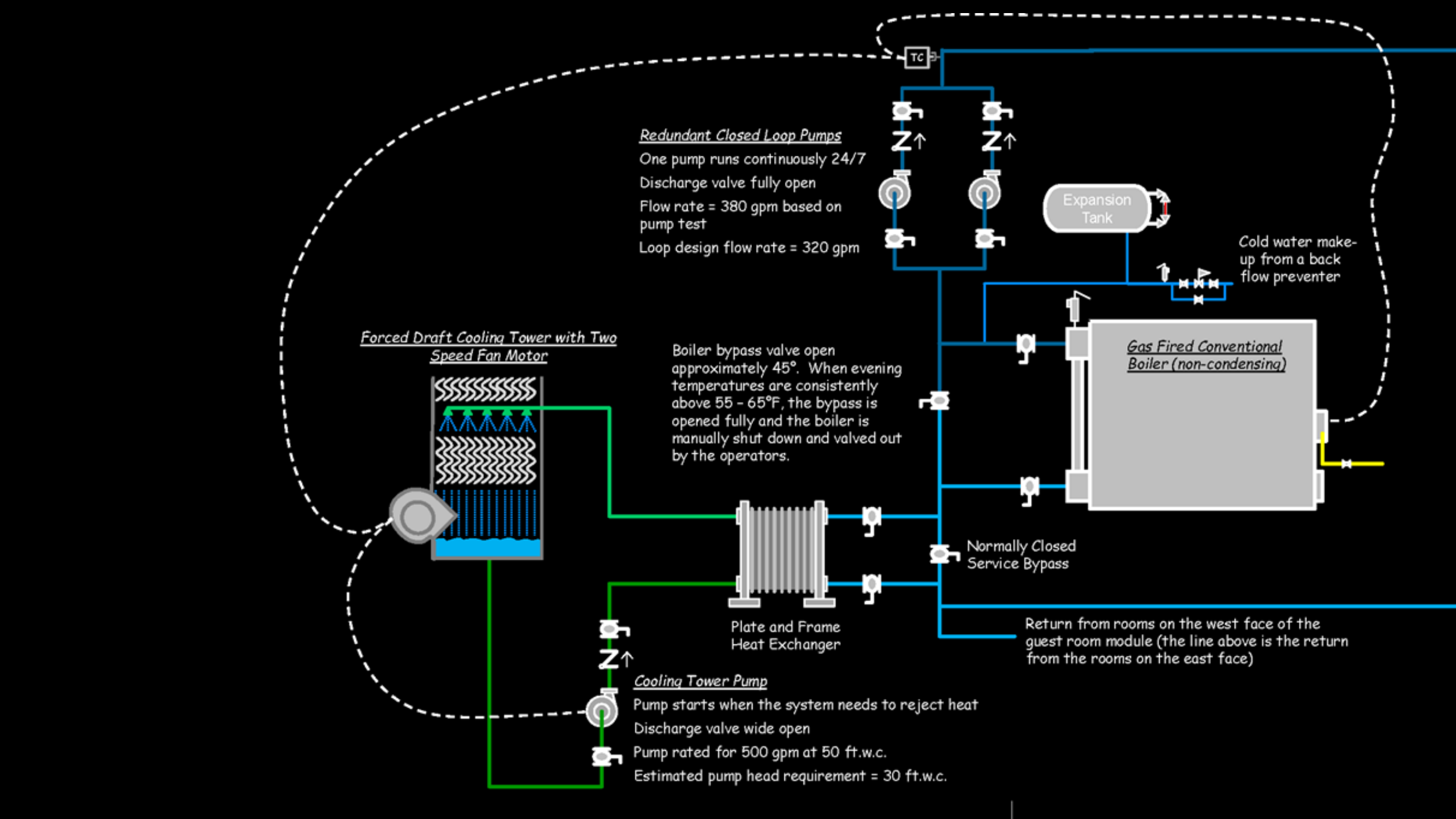


Water Source Heat Pump Loop

2022-11-16, DS

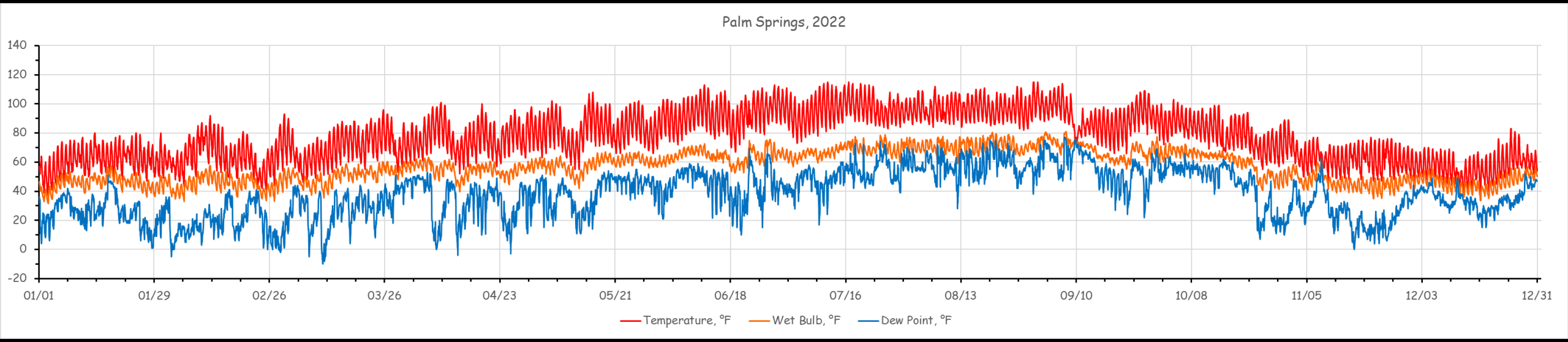

Guest Room Heat Pump
Cooling Mode


Guest Room Heat Pump
Heating Mode

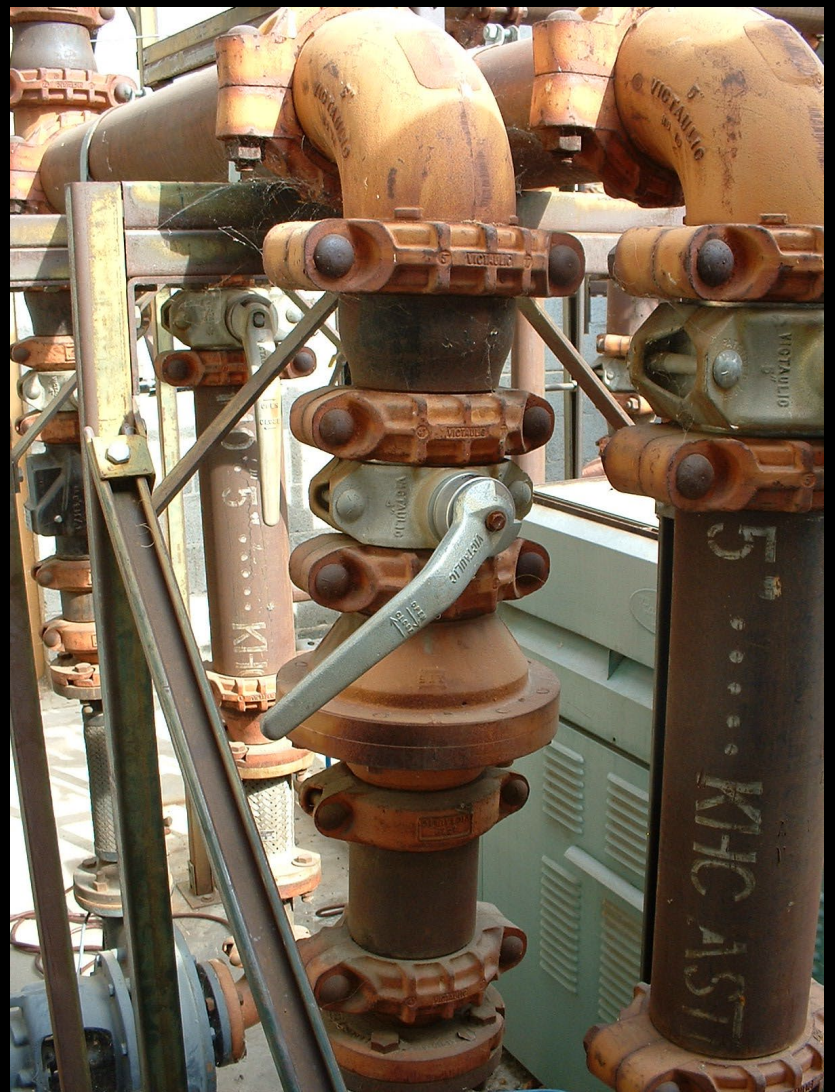

TC
Redundant Closed Loop Pumps
One pump runs continuously 24/7
Discharge valve fully open
Flow rate = 380 gpm based on pump test
Loop design flow rate = 320 gpm
Expansion Tank
Cold water make-up from a back flow preventer
Forced Draft Cooling Tower with Two Speed Fan Motor
Boiler bypass valve open approximately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

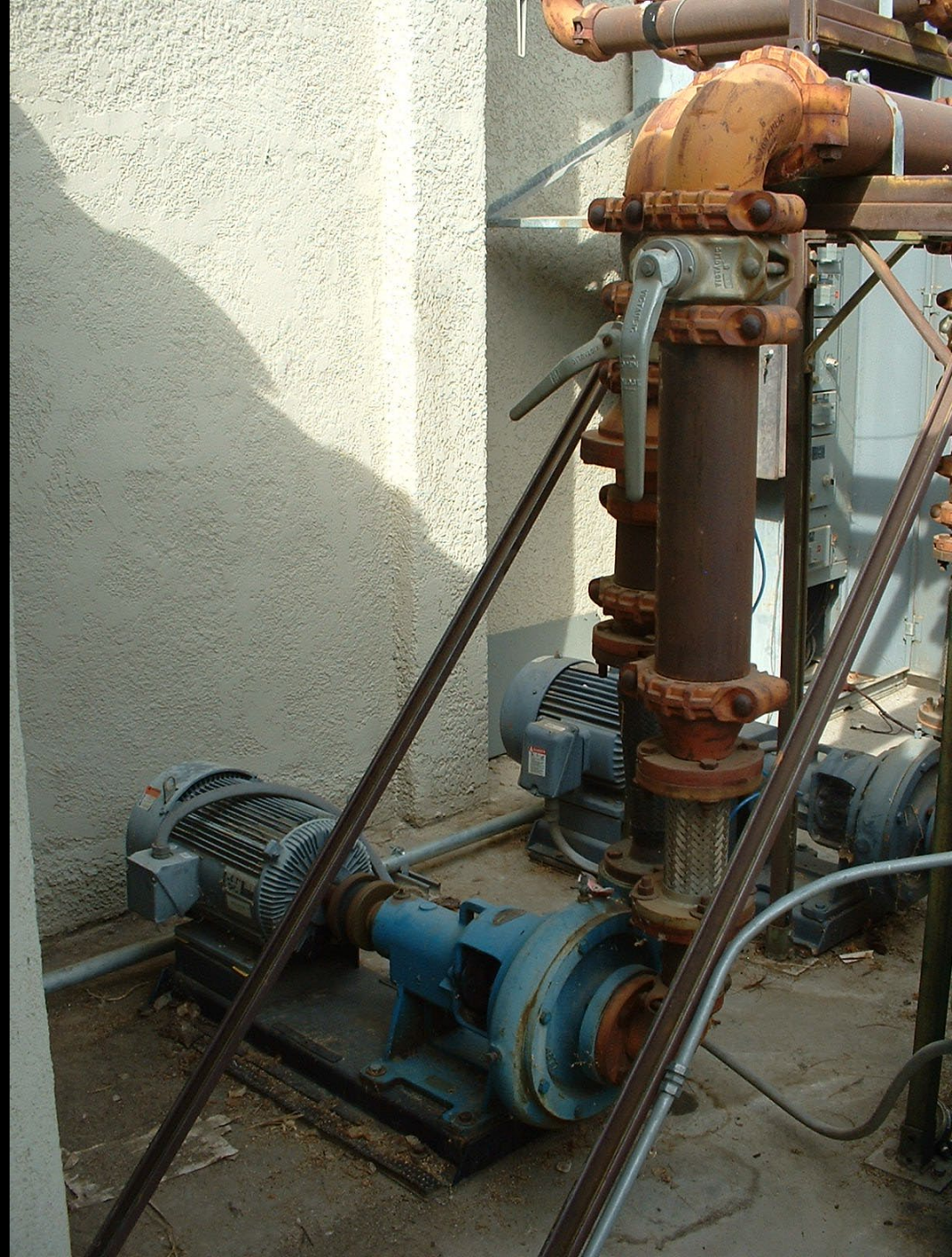
Do You Think There Is Much Heat to Pump?

Are There Other Benefits to the Water Source Heat Pump Loop?



The Loop Pumps

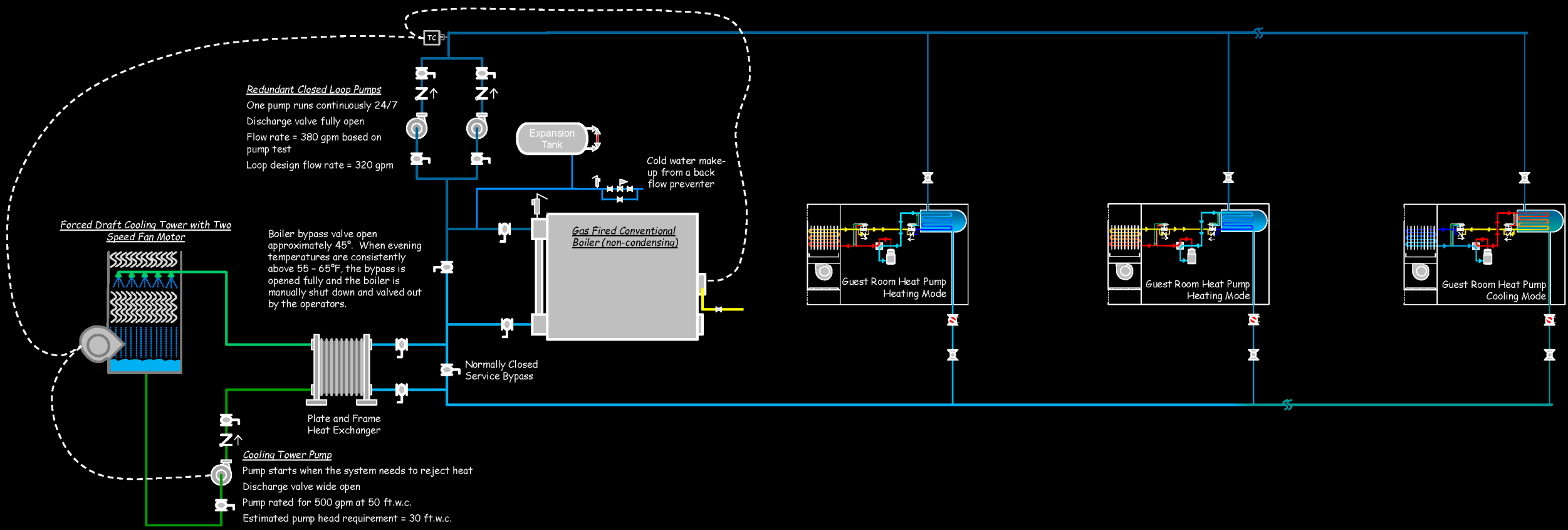




The Tower Pump

The Heat Exchanger and Boiler

Thinking About Monitoring



Water Source Heat Pump Loop

2022-11-16, DS

Monitoring Plan Targets

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

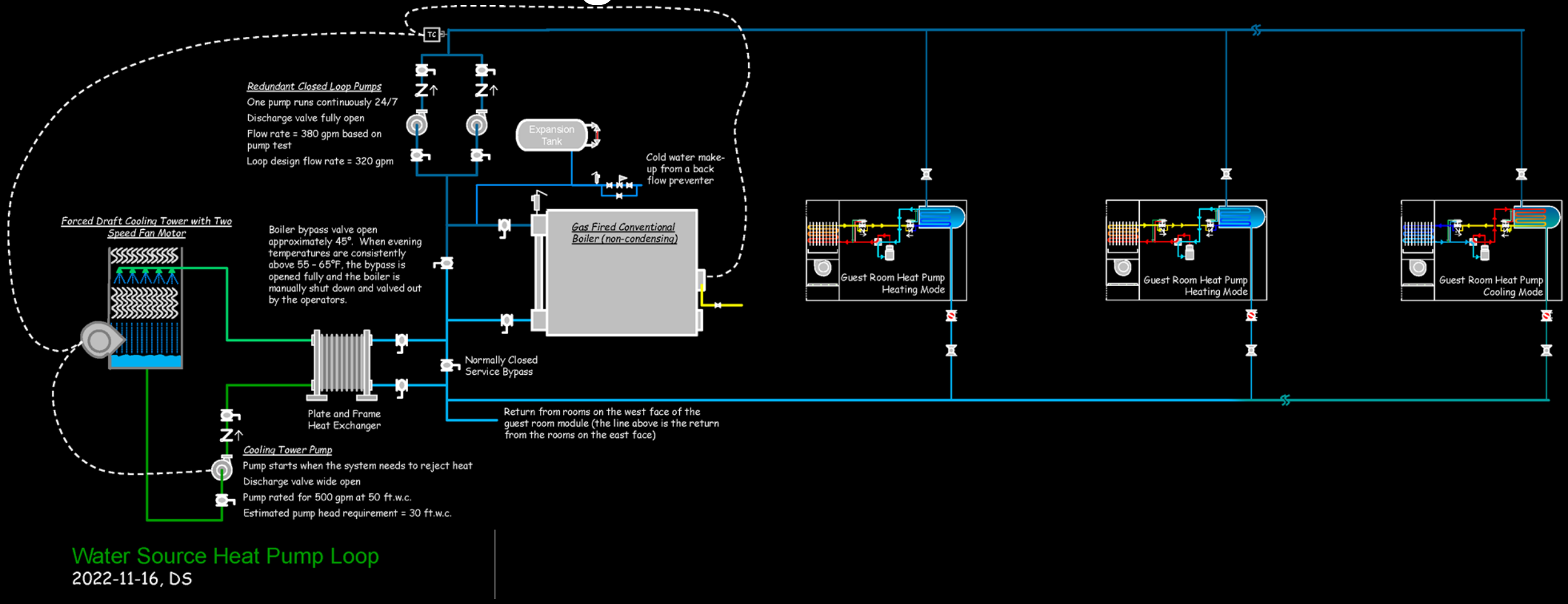
Logger Serial Number (EMS indicates control system trend)	System	Point (use full point name for EMS Points)	Sensor	Sampling Time	Sensor Location	Logger Location	Link to Screenshots of deployed location of sensors and Logger Link to Screenshot of Launch	Notes
10263770	Cooling Tower Cooling Tower Cooling Tower Cooling Tower	Cell 1 Hot Basin Temperature Cell 2 Hot Basin Temperature Cell 1 Cold Basin Temperature Cell 2 Cold Basin Temperature	TMC50-HD TMC50-HD TMC50-HD TMC50-HD	1 minute 1 minute 1 minute 1 minute	Hot basin of cell 1 Hot basin of cell 2 Hot basin of cell 1 Hot basin of cell 2	On magnet under the case	Sensor 1: Drainage Sensor 2: Logger location Sensor 3: Typical Basin Temperature Sensor Sensor 4: Logger: Screen shot of logger attached at launch	1. Put logger in a zip lock bag and then under something to protect it.
10263769	South Tower 4CC South Tower 4CC South Tower 4CC South Tower 4CC	Cooling tower 1 fan amps Cooling tower 2 fan amps CW Pump 1 amps CW Pump 2 amps	CTV-B (50 amp) CTV-B (50 amp) CTV-B (50 amp) CTV-B (50 amp)	1 minute 1 minute 1 minute 1 minute	CT 1 feed at MCC CT 2 feed at MCC CW Pump 1 feed at MCC CW Pump 2 feed at MCC	At 4CC	Sensor 1: Cooling Plant 4CC Sensor 2: Sensor 3: Sensor 4: Logger: Screen shot of logger 10263769	1. See general note 2
	South Tower CHW South Tower CHW	Chiller 1 Amps Chiller 2 Amps	CTV-D (500 amp) CTV-D (500 amp)	1 minute 1 minute	Chiller 1 main switch Chiller 2 main switch		Sensor 1: Sensor 2: Sensor 3: Sensor 4: Logger:	1. Could still obtain two 600 amp CTs for you if you want one.
10263774	South Tower CHW South Tower CHW South Tower CHW South Tower CHW	Chiller 1 EWT - Chilled Water Chiller 1 LWT - Chilled Water Chiller 1 EWT - Condenser Water Chiller 1 LWT - Condenser Water	TMC20-HD TMC20-HD TMC20-HD TMC20-HD	1 minute 1 minute 1 minute 1 minute	Thermometer well Thermometer well Thermometer well Thermometer well	At chiller	Sensor 1: Logger location Sensor 2: Sensors Sensor 3: Sensor detail Sensor 4: Logger: Logger 10263774 Launch	1. See general notes 1 and 3
10263767	South Tower CHW South Tower CHW South Tower CHW South Tower CHW	Chiller 2 EWT - Chilled Water Chiller 2 LWT - Chiller Water Chiller 2 EWT - Condenser Water Chiller 2 LWT - Condenser Water	TMC20-HD TMC20-HD TMC20-HD TMC20-HD	1 minute 1 minute 1 minute 1 minute	Thermometer well Thermometer well Thermometer well Thermometer well	At chiller	Sensor 1: Logger location Sensor 2: Sensors Sensor 3: Sensor 4: Logger: Screen shot with final sensor and fix	1. See general notes 1 and 3.
10263771	South Tower CHW South Tower CHW South Tower Domestic Water South Water Domestic Water	CHW Pump 1 Amps CHW Pump 2 Amps Pump 1 Amps Pump 2 Amps	CTV-D (200 amp) CTV-D (200 amp) CTV-A (20 amp) CTV-A (20 amp)	1 minute 1 minute 2 seconds 2 seconds	CT 1 feed at MCC CT 2 feed at MCC DW Pump 1 feed in MCC DW Pump 2 feed in MCC	At 4CC	Sensor 1: Cooling Plant 4CC Sensor 2: Sensor 3: Sensor 4: Logger: 10263771 deployment screenshot	1. See general note 2 2. I have assumed a 20 amp CT will be big enough for the domestic water pumps.
10352812 (Centre's logger)	ST By Rm. Conditions ST By Rm. Conditions ST By Rm. Conditions	ST By Rm. Temperature ST. By. Rm R H ST By Rm. Lighting Level	Internal Internal Internal	1 minute 1 minute 1 minute	On Top of DW Pump Room On Top of DW Pump Room On Top of DW Pump Room	At DW Pumps	Sensor 1: Logger not to overlap at Section 3.mp Sensor 2: Sensor 3: Sensor 4: Logger: Screen shot of 10352812 launch	1. Because one of Carlos's loggers with an internal lighting sensor.
10263768	NT Lobby 3b Unit NT Lobby 3b Unit NT Lobby 3b Unit NT Lobby 3b Unit	Supply fan amps Post cooling Air Temperature Cool Deck Temperature Hot Deck Temperature	CTV-D (50 amp) TMC20-HD TMC20-HD TMC20-HD	1 minute 1 minute 1 minute 1 minute	VFD incoming line Downstream of fan Downstream of coil Downstream of coil	Tie-wrapped to supply fan VFD	Sensor 1: Fan amps sensor Sensor 2: Post discharge sensor Sensor 3: Cool deck sensor Sensor 4: Hot deck sensor Logger: Screen shot of logger art launch	1. See general notes 1 and 4.
10264069	NT Lobby 3b Unit NT Lobby 3b Unit	Return temperature Return RH	Internal Internal	1 minute 1 minute	Exhaust duct Exhaust duct	Tie-wrapped to duct support in the return duct	Sensor 1: Data logger - Initial deployment Sensor 2: Sensor 3: Sensor 4: Logger: Screen shot of logger art launch Screen shot of logger redeployment	1. Try to get the sensor into the open area away from the door as the air swings around the door does not influence the logger too much.

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

Monitoring Plan Resources

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

What Points Would You Monitor and What Tests Might You Run?



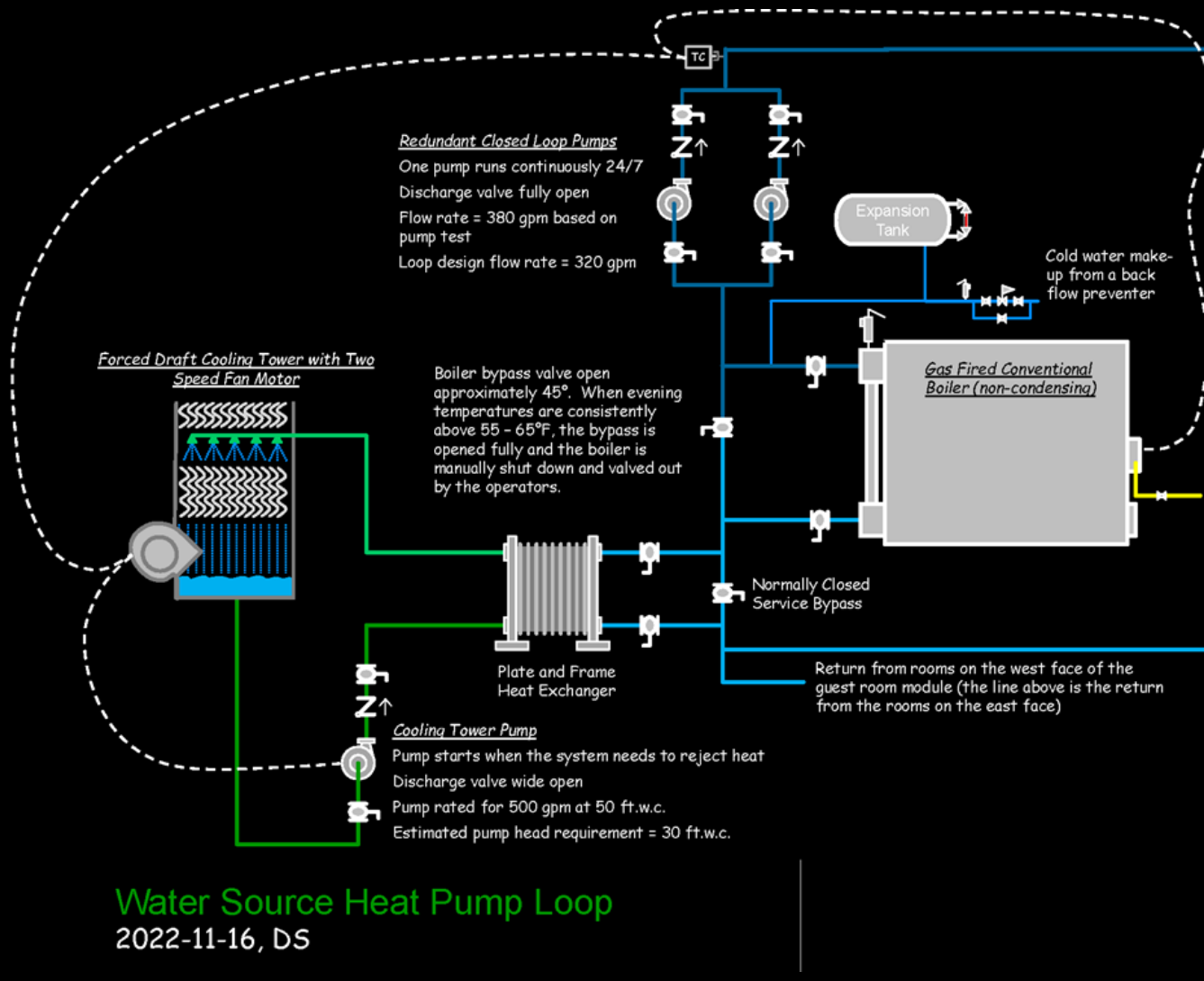
Water Source Heat Pump Loop
2022-11-16, DS

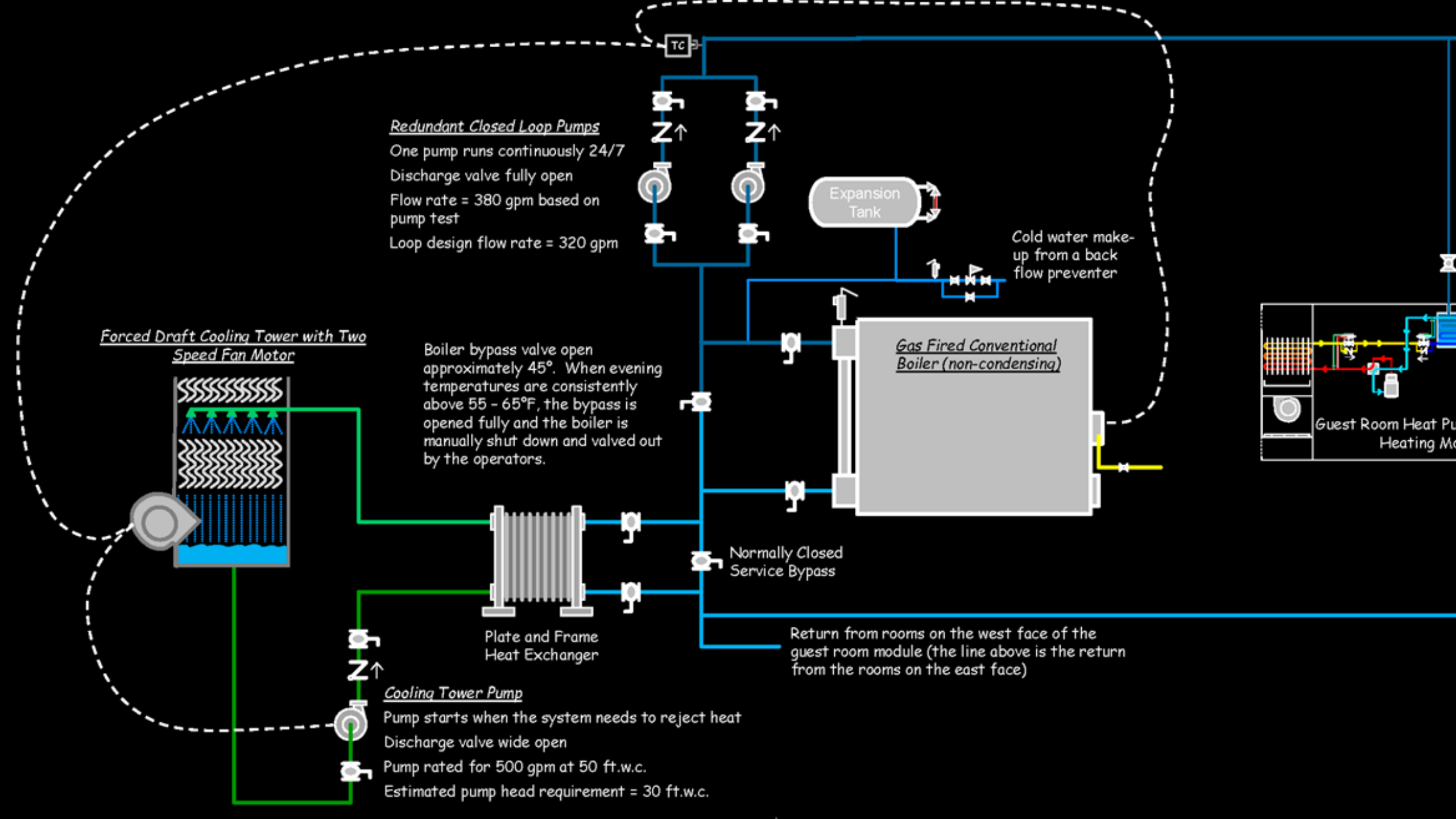
Adding Some Constraints

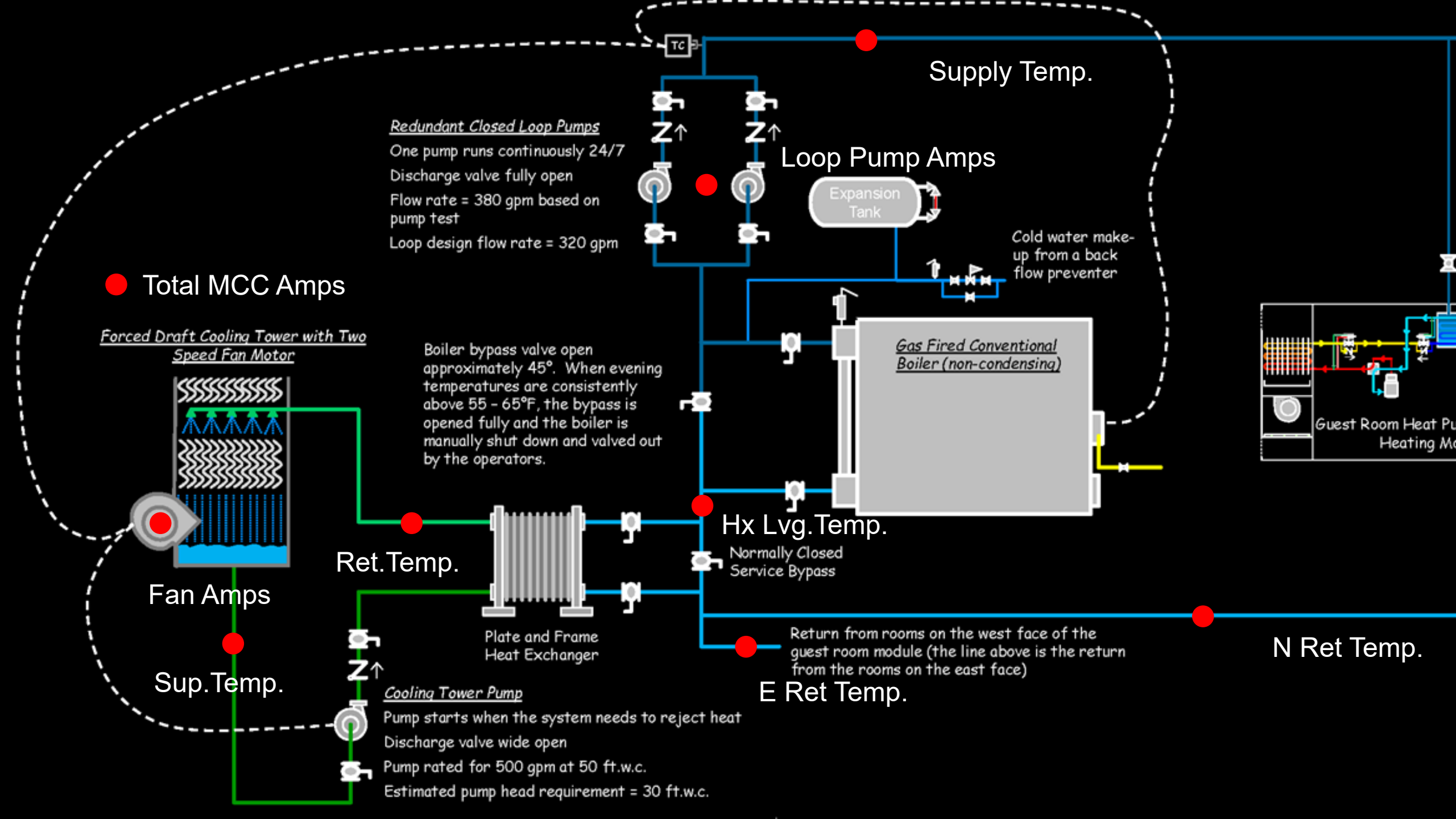
Your logger inventory

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

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




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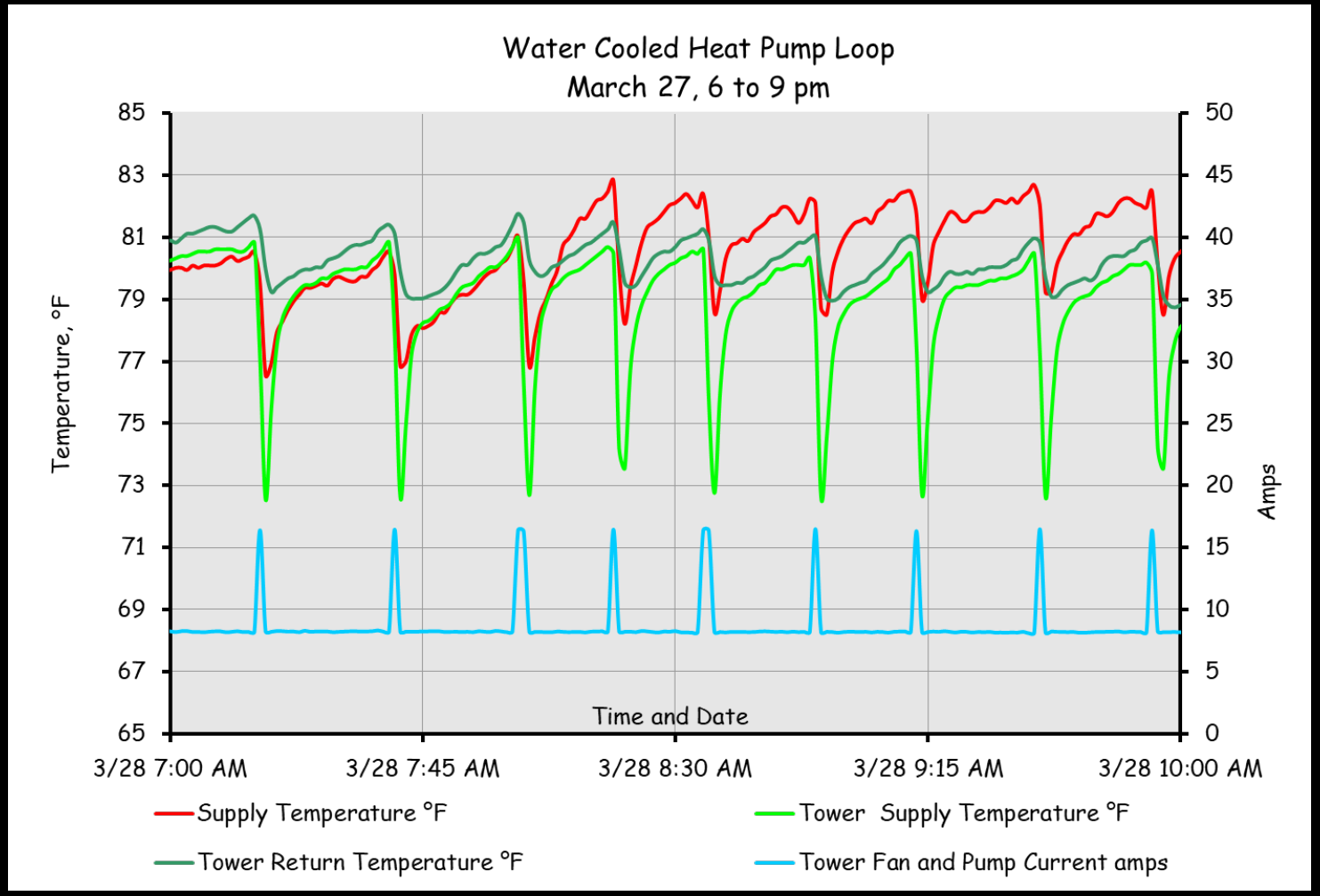
Estimated pump head requirement = 30 ft.w.c.

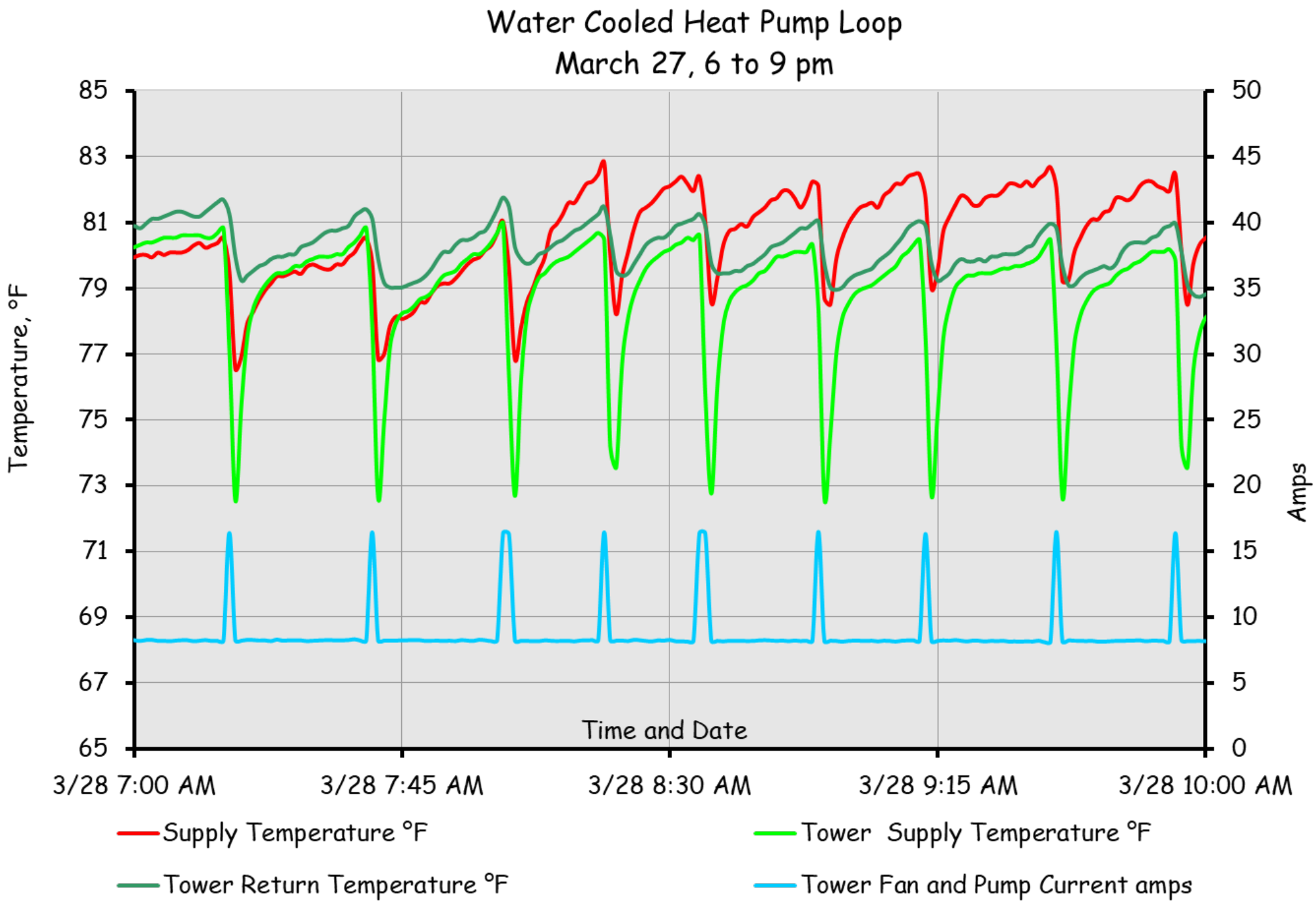
Let’s Look at Some Data

https://tinyurl.com/DataLoggingDecades

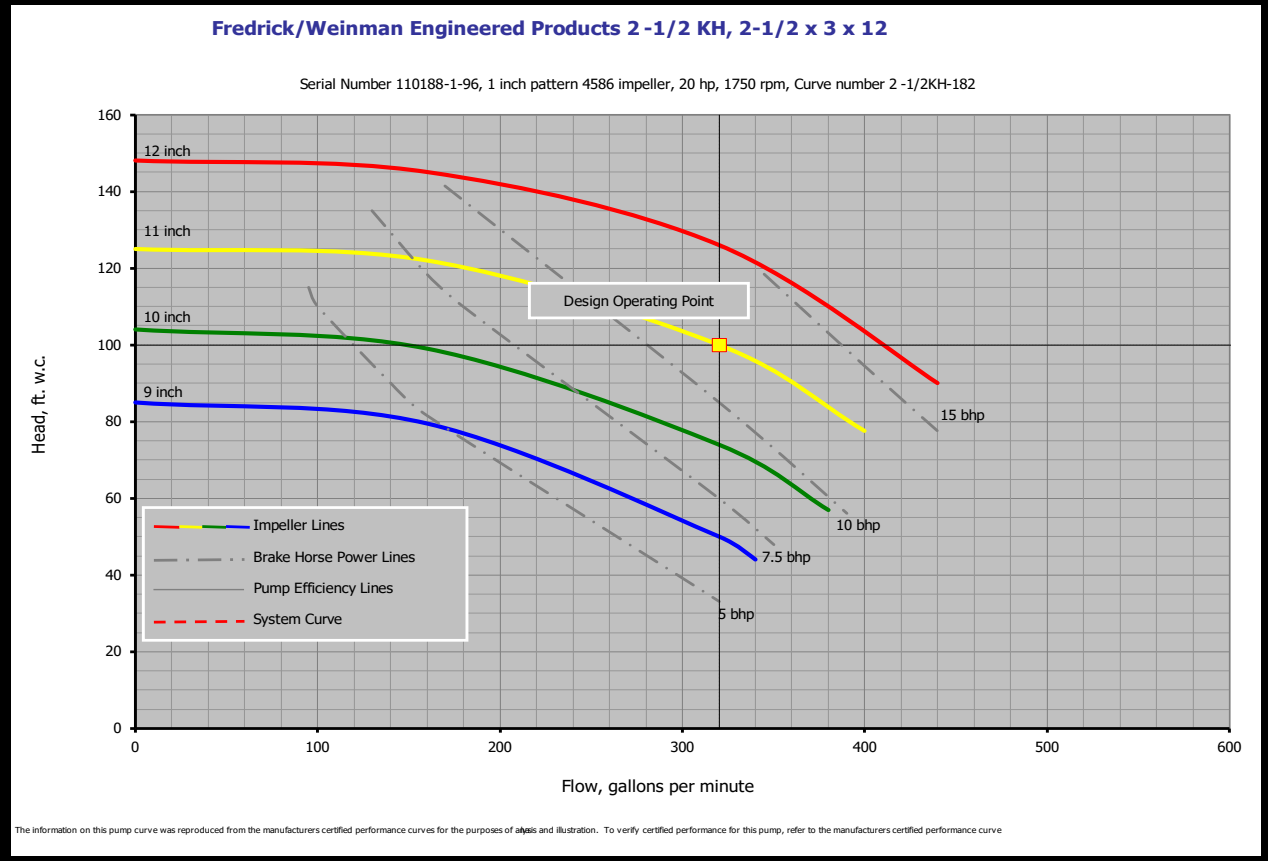

onset
CTV-D
HOBO 4-channel analog logger
StoP
HOBO data node
temp
HOBO MX CO2 logger
onset
HOBO
RH
Temp
2 x External
onset
HOBO U-Shuttle
esc
yes
no

What You Might Learn




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

What You Might Learn From the Pump

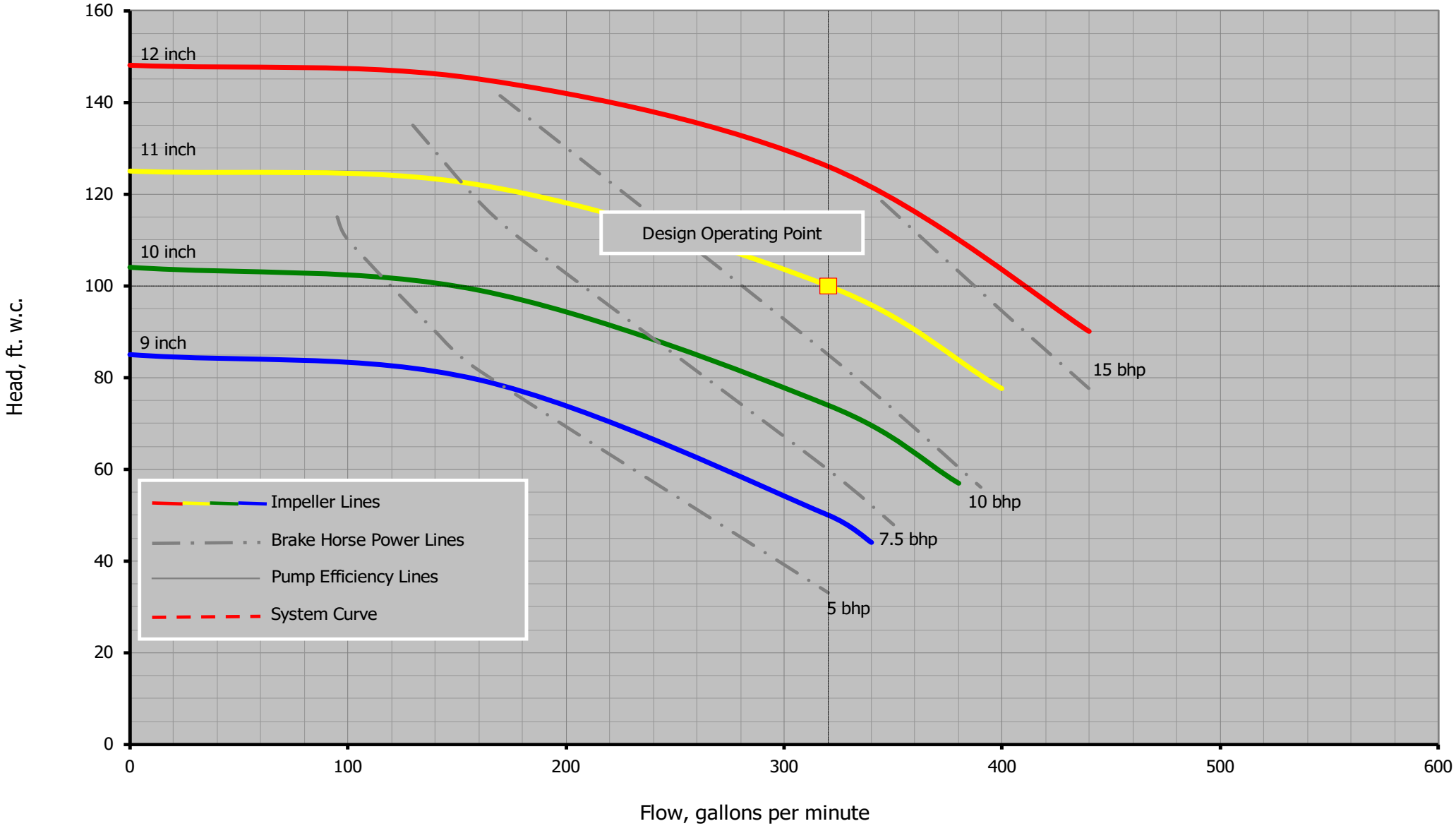


Design Condition

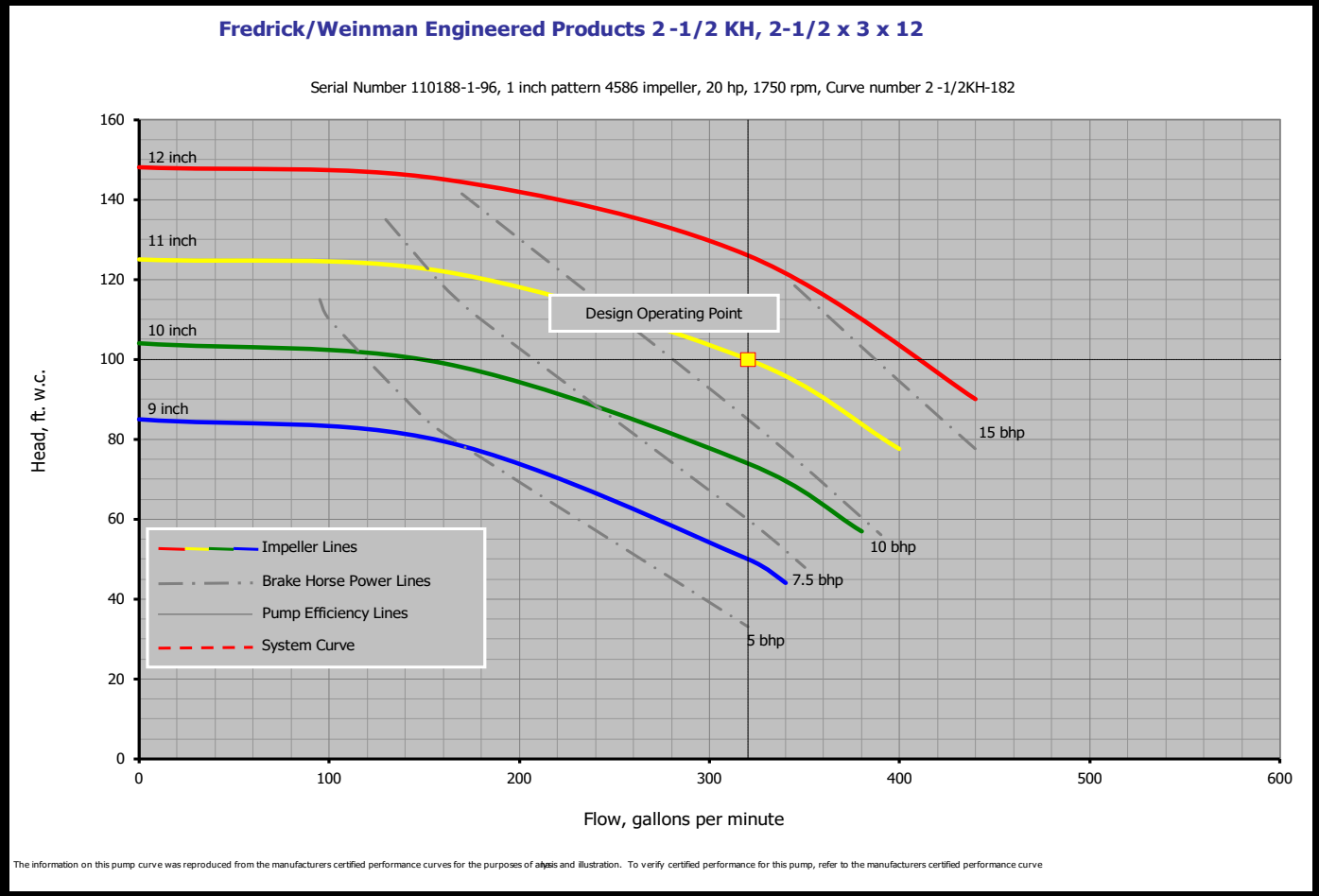
- 11 inch impeller
- Design Flow – 320 gpm
- Design Head – 100 ft.w.c.

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

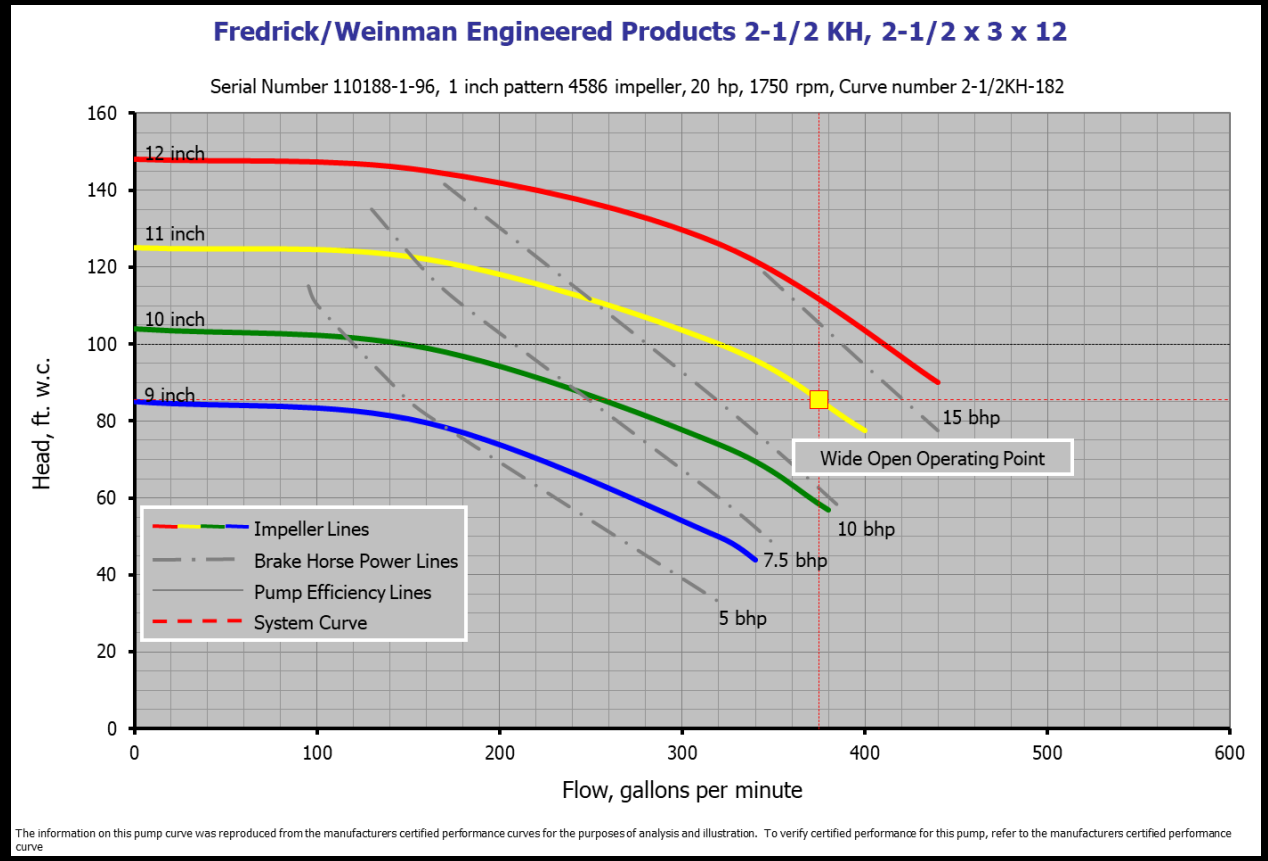
Serial Number 110188-1-96, 1 inch pattern 4586 impeller, 20 hp, 1750 rpm, Curve number 2 -1/2KH-182



Does the Pump Head Seem Reasonable?



What You Might Learn From the Pump

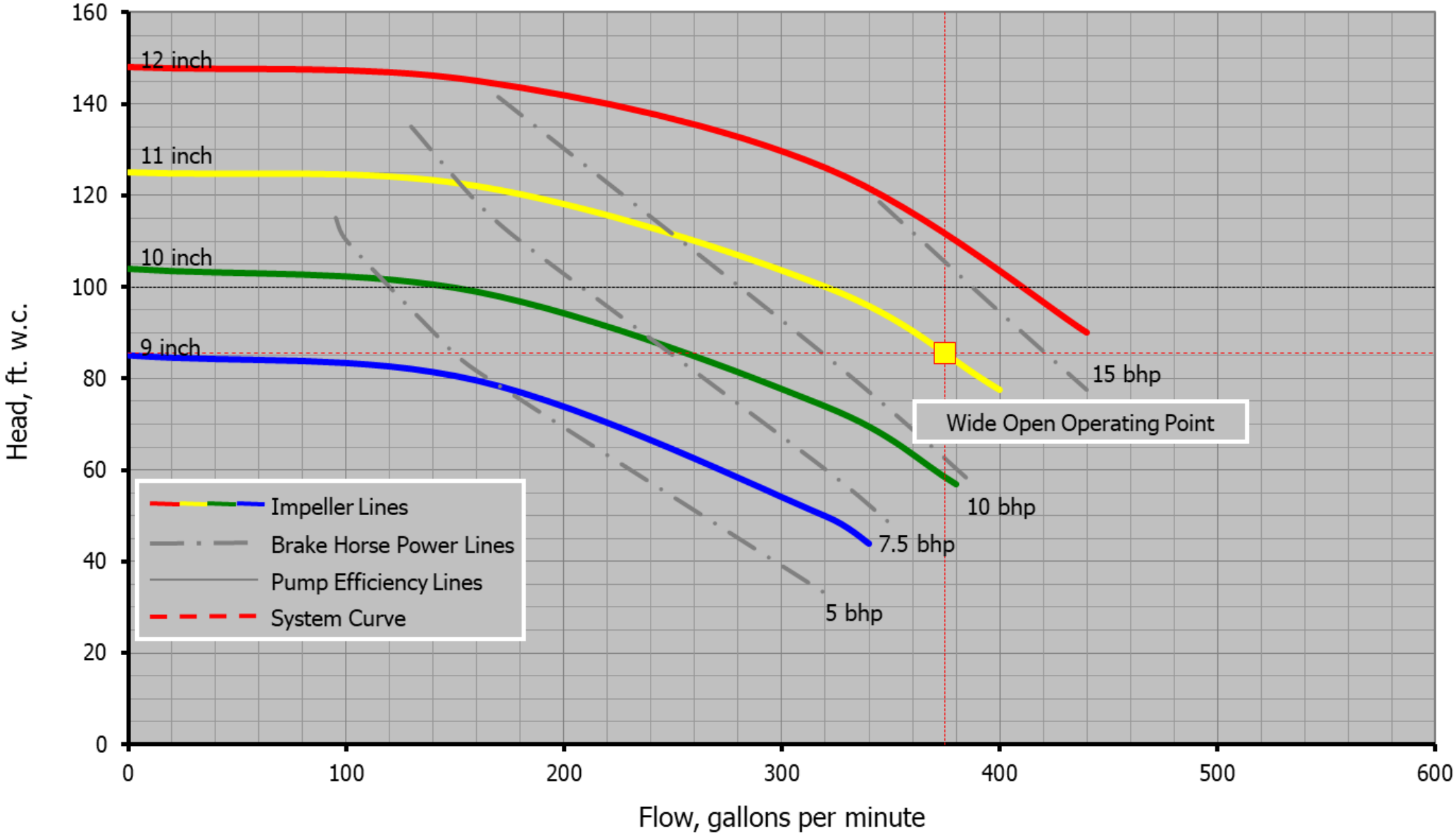


Pump Test Results

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

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

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



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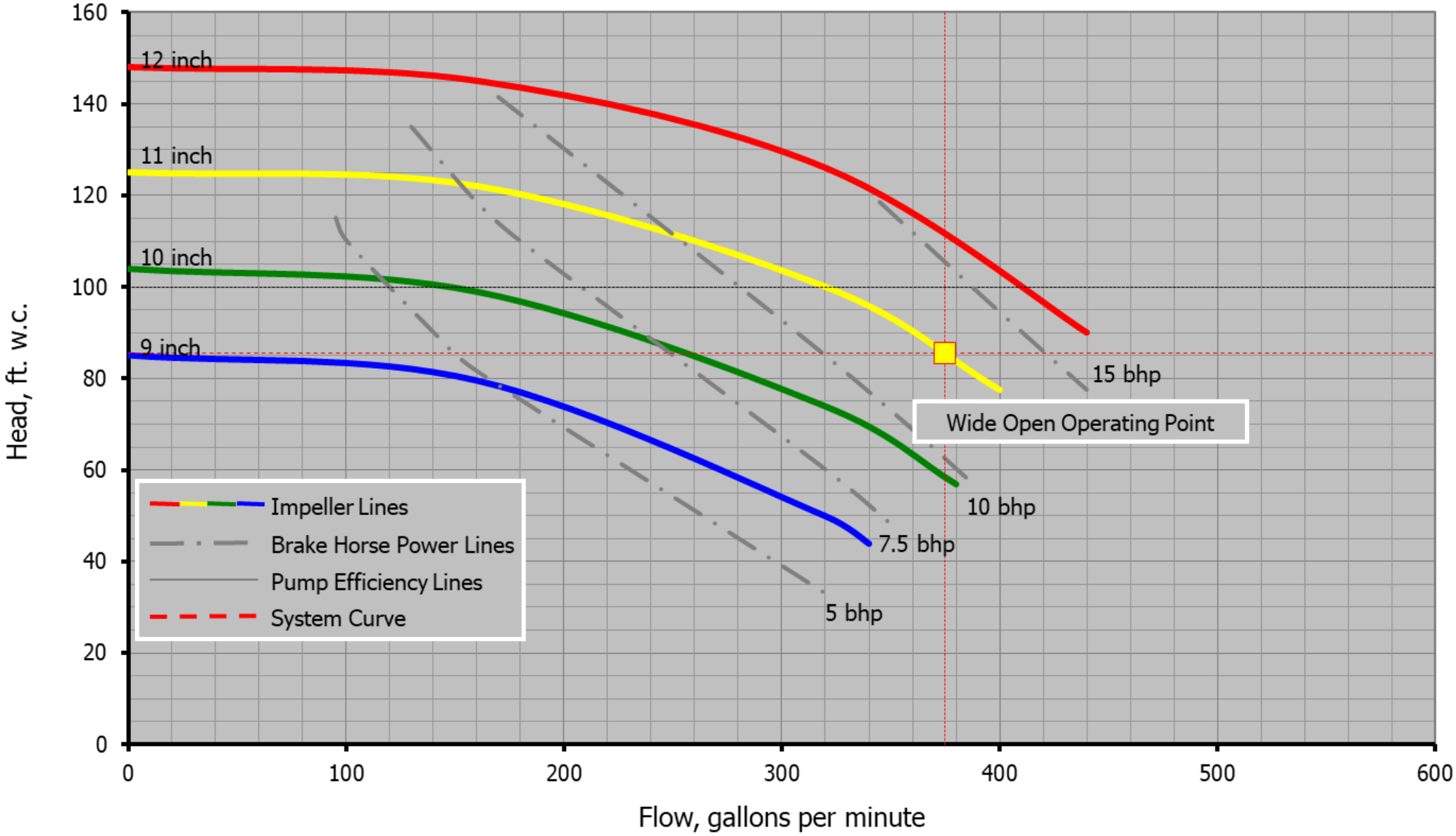

Fredrick/Weinman Engineered Products 2 -1/2 KH, 2-1/2 x 3 x 12

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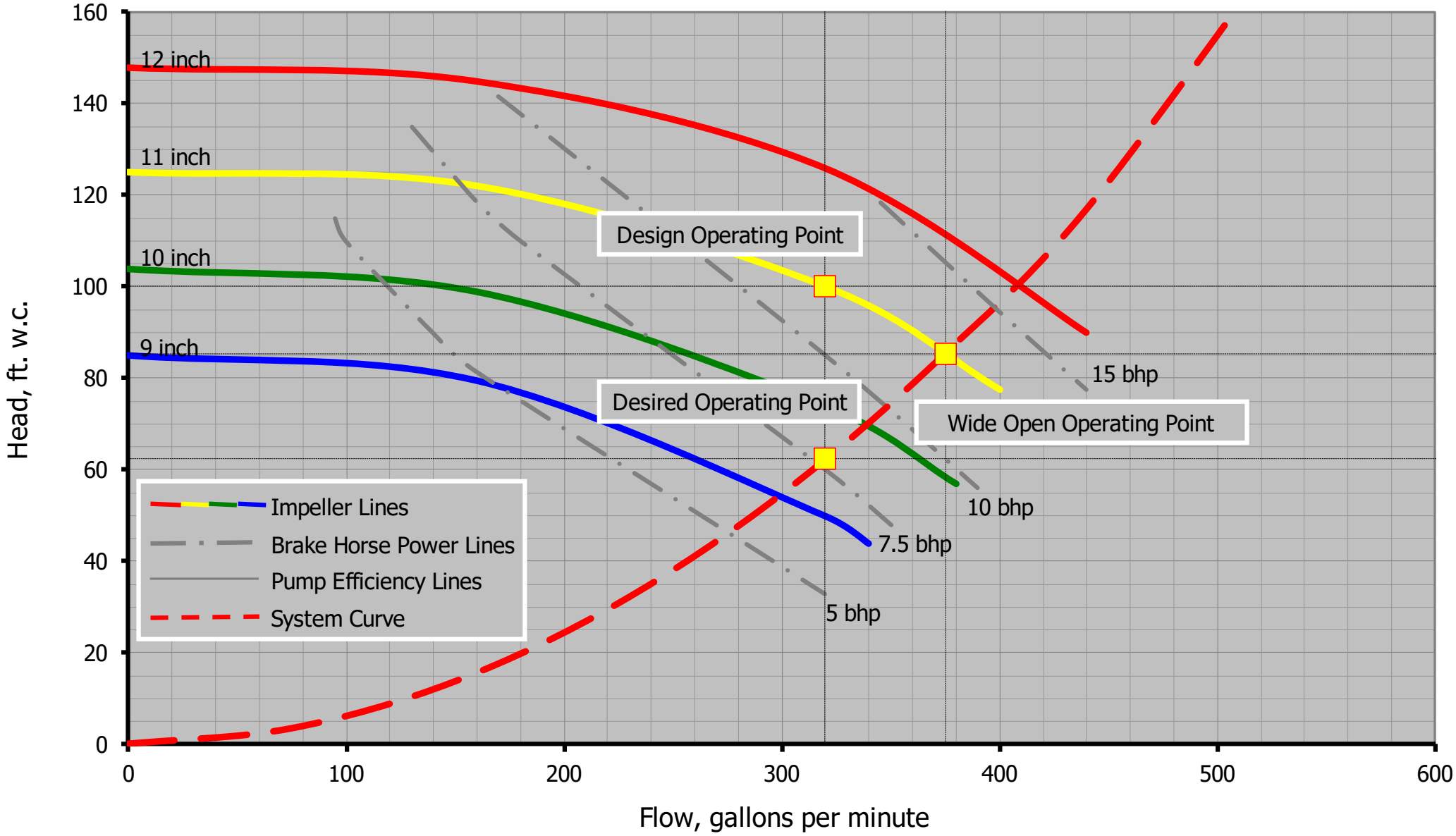
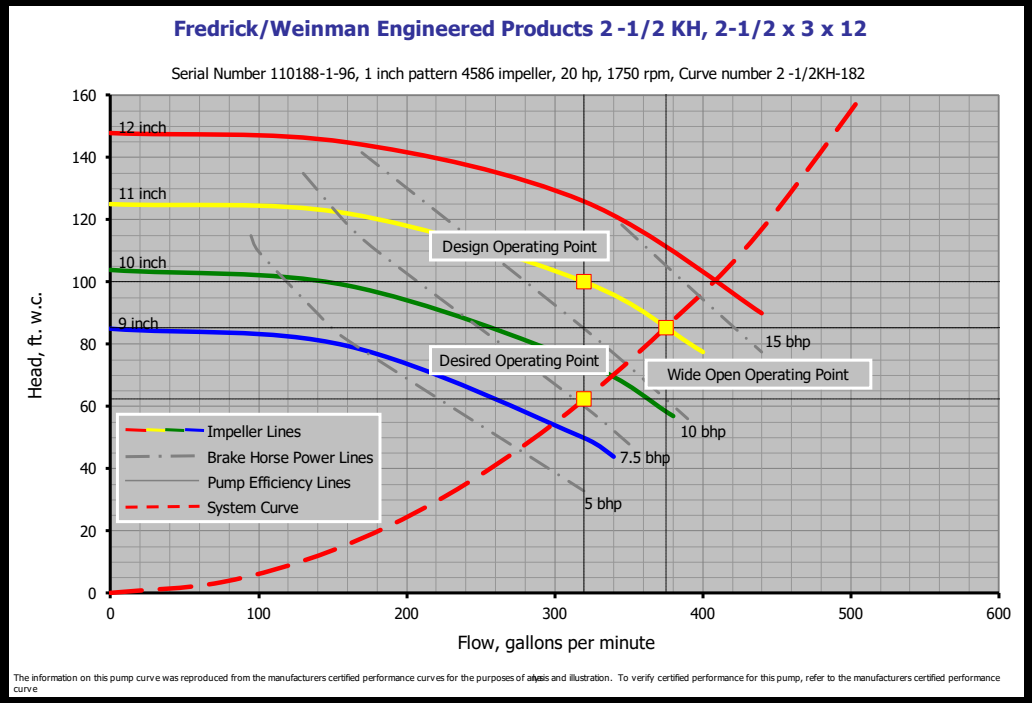
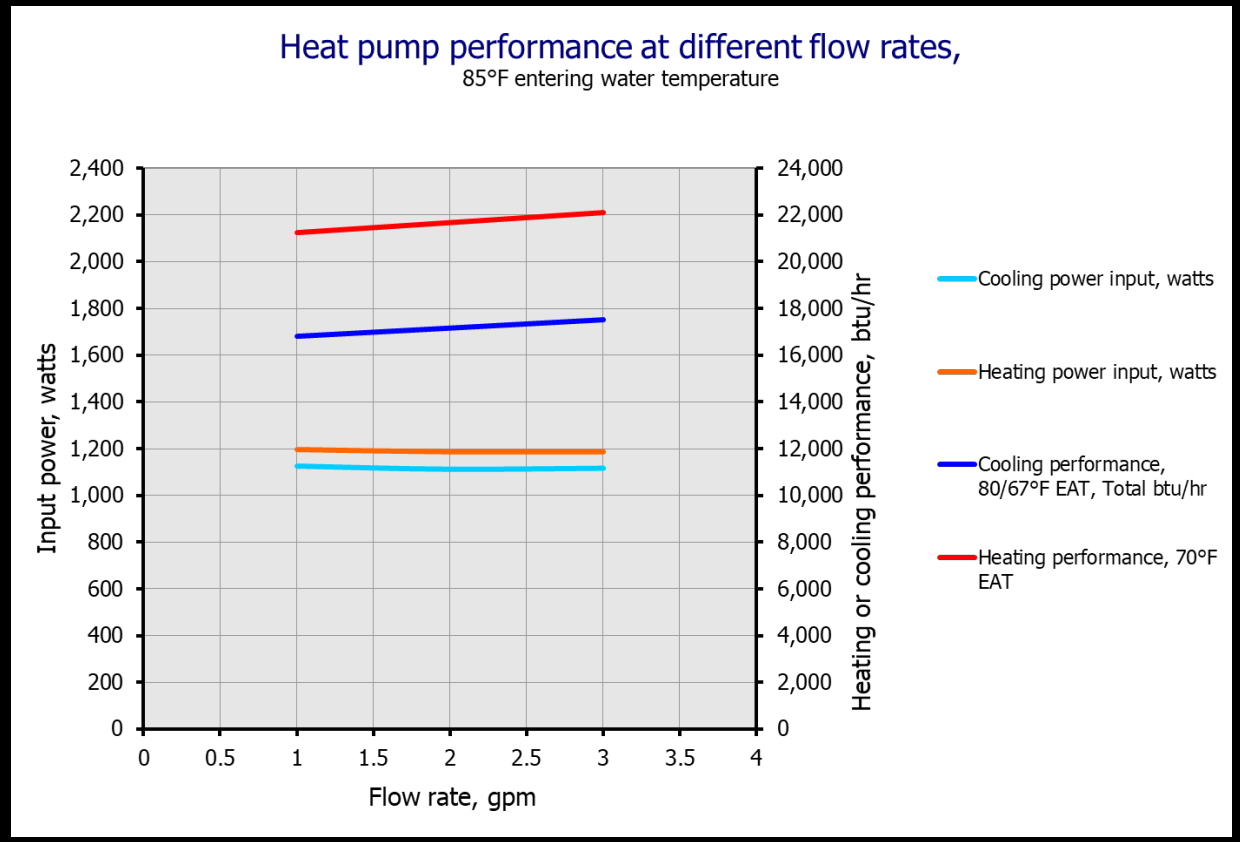


Considering Heat Pump Interactions

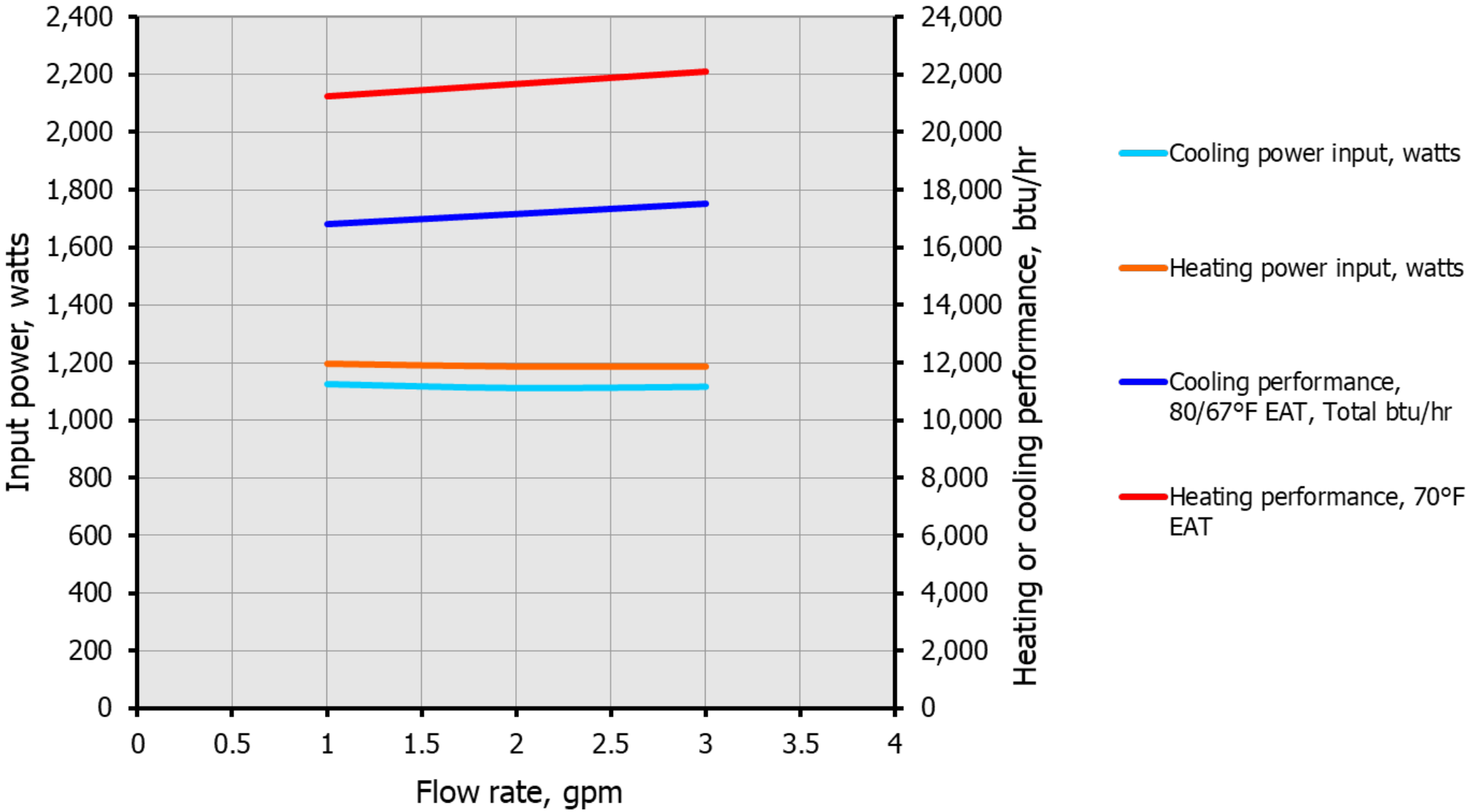
Heat pump performance can be impacted by the flows and temperatures in the system



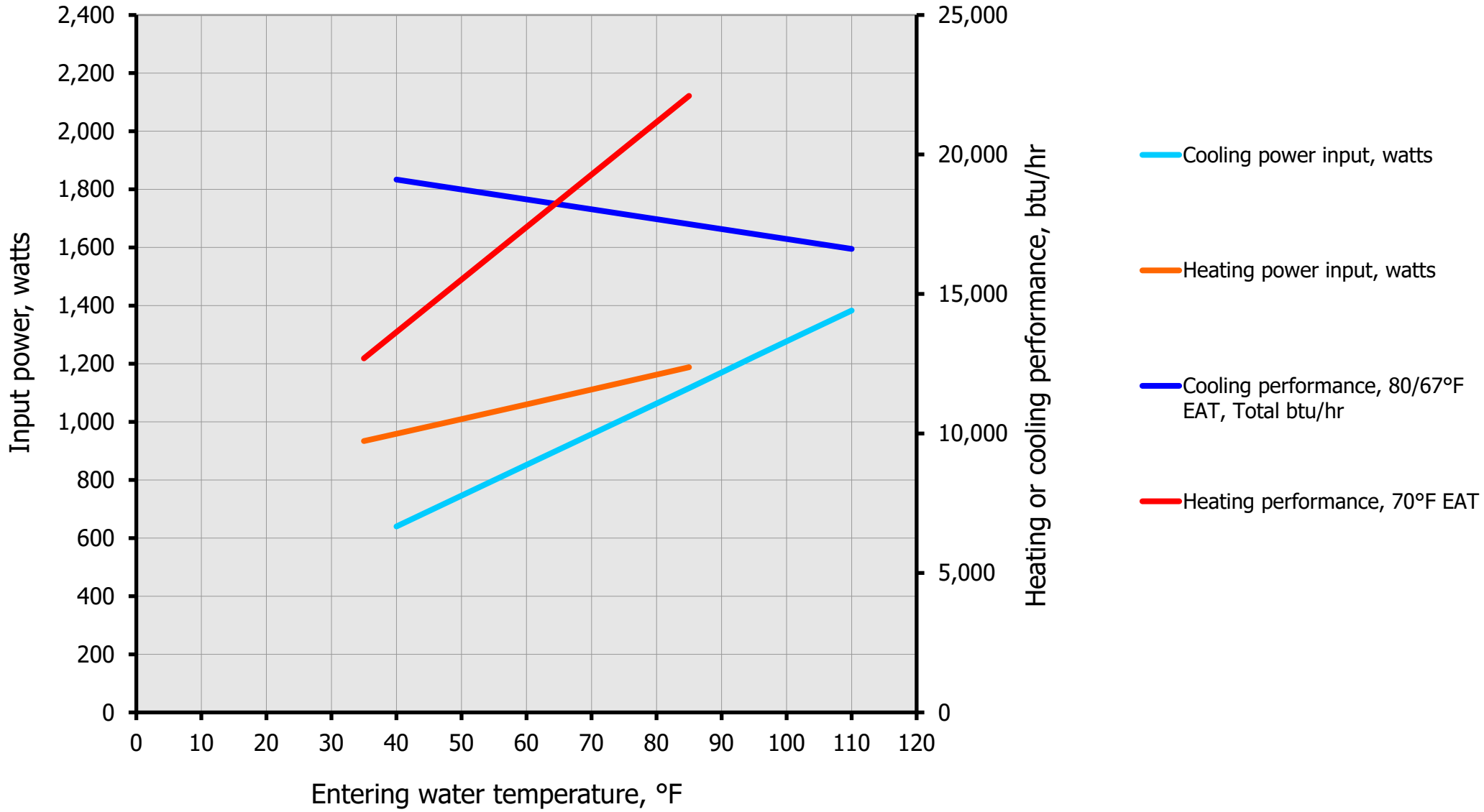


Heat pump performance at different flow rates,

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 stag	0	$0	0	$0	$0	$0	0.0	N/A	Note 1
3	GHL8 - Bypassing Flow around Heat Exchang	0	$0	0	$0	$0	$0	0.0	No	
4	GHL5 - Trim Cooling Tower Pump	40,396	$4,040	0	$0	$4,040	$9,000	2.2	Yes	
5	GHL1, GHL3 - Optimize closed loop	277,192	$27,719	48,094	$37,513	$65,232	$140,199	2.1	Yes	
Total for Guest Housing Heat Pump Loops		**359,127**	**$35,913**	**48,094**	**37,513**	**$73,426**	**$171,903**	**2.3**		

Notes
1. This finding has already been implemented by the operating staff
2 The simple payback for this finding could be as low as 4 years. The energy savings is a conservative estimate.
3 Further investigation is needed to estimate beneifts and cost for this measure.
4 Energy savings possible is a conservative estimate. The actual savings could be double from the amount listed

Bottom Lines

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

Findings Summary Table — $0.10 per kWh — $0.78 per therm

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Questions?

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Break Time

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

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