Design Review for New Construction Commissioning and Beyond

Day 2 of 2

Presented By:

- David Sellers, Facility Dynamics Engineering
- Senior Engineer

Reviewing the Assignment

Given the Pump Schedule

PUMP SCHEDULE									
PLAN MARK	MANUFACTURER & MODEL	LOCATION & SERVICE	GPM	FT. HD.	[1] IMPELLER SIZE	MOTOR SPEED RPM	MOTOR		NOTES
							HP	VOLTS / Φ	
MP-D12	B&G HSC-6X8X17M	'D' LEVEL - HEATING WATER	1380	193	15	1750	100	460/3Φ	[2] [3]
MP-D13	B&G HSC-6X8X17M	'D' LEVEL - HEATING WATER	1380	193	15	1750	100	460/3Φ	[2] [3]
MP-D14	GRUNDFOSS #CR16-30U	'D' LEVEL - BOILER FEED	83	140		3500	7 1/2	460/3Φ	[5]
MP-D15	GRUNDFOSS #CR16-30U	'D' LEVEL - BOILER FEED	83	140		3500	7 1/2	460/3Φ	[5]
MP-G1	B&G 60-2 AA	GD.FL.-AHU-G1	50	20	4 3/4	1750	3/4	460/3Φ	
MP-3B	B&G 60-1 1/2 AA	3rd FL.- AHU-3B	40	18	4 3/4	1750	1/2	460/3Φ	
MP-3D	B&G 60-1 1/2 AA	3rd FL.- AHU-3D	40	18	4 3/4	1750	1/2	460/3Φ	
MP-3G	B&G 80-2 1/2 X 2 1/2 X 7	3rd FL.- AHU-3G	120	25	6	1750	1 1/2	460/3Φ	
MP-3-1	B&G 80-3×3×8½	3rd FL.- TOWER WATER	220	66	8½	1750	7½	460/3Φ	[4] [6]
MP-3-2	B&G 1510-3 BB	3rd FL.- LOOP WATER	220	80	9	1750	10	460/3Φ	
MP-G3	B&G 60-2AA	GRD FL MEZZ-AHU-G3	50	21	4 3/4	1750	3/4	"	[4]

[2] 400 PSIG WORKING PRESSURE.

[3] PROVIDE WITH VARIABLE SPEED PUMPING SYSTEM - SEE SPEC.

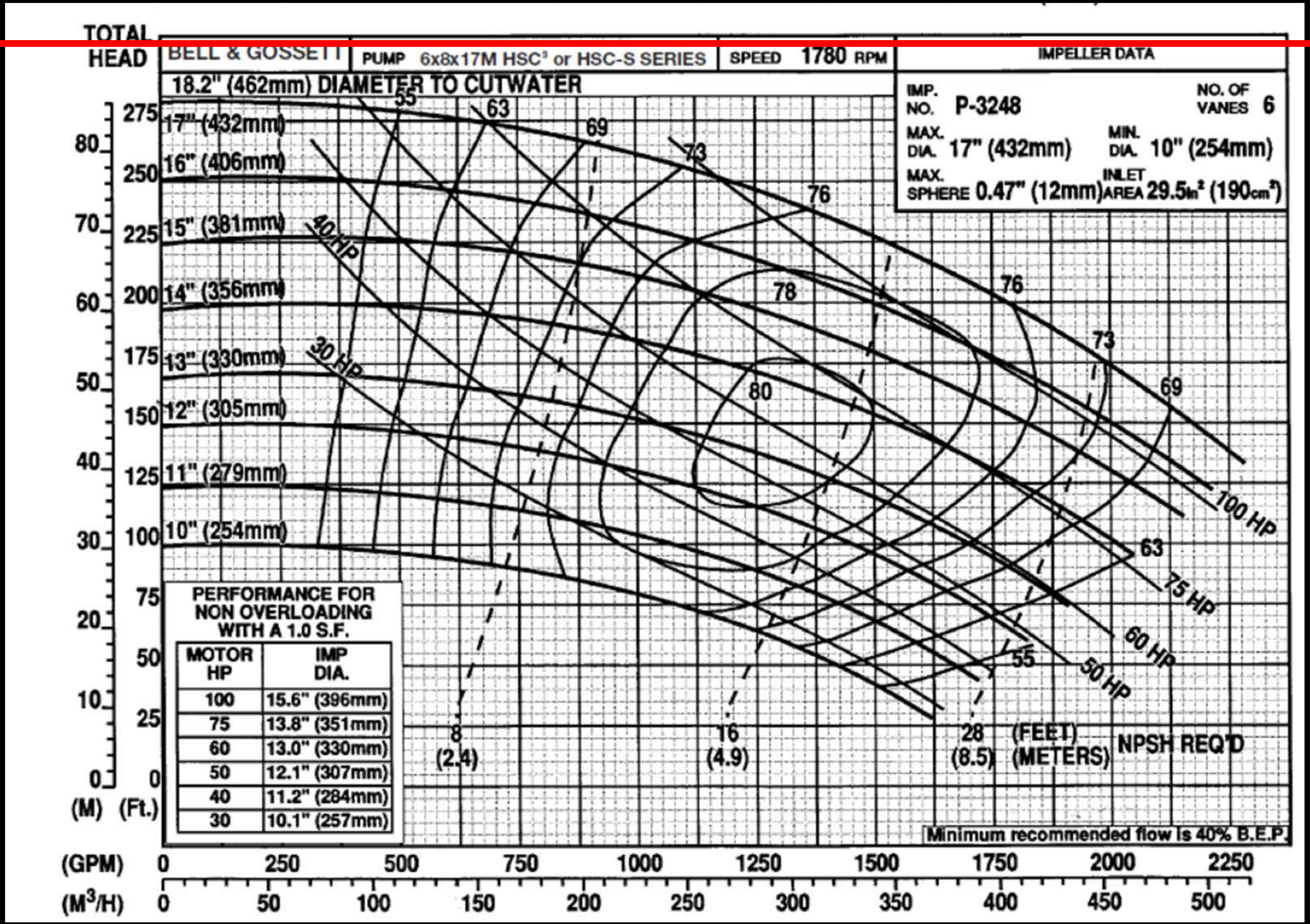
[4] 250 PSIG WORKING PRESSURE.

[5] CONTROL CABINET, C/W STARTERS, CIRCUIT BREAKERS, PILOT LIGHT AND HOA SELECTOR SWITCHES.

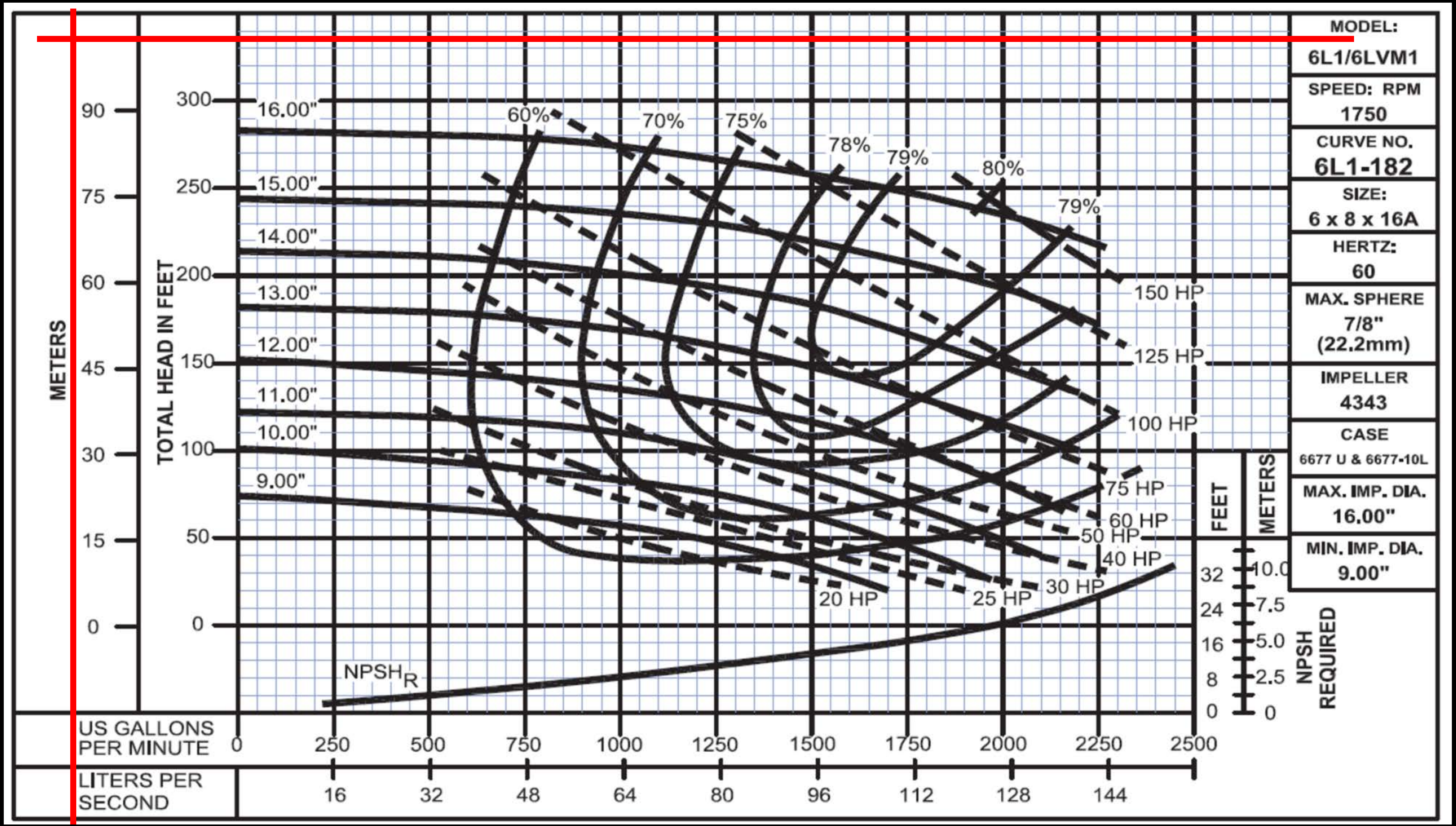
[6] HORIZONTAL MOUNT

[1] PROVIDE FULL SIZE IMPELLER, TRIMMED/SHAVED IMPELLER IS NOT ACCEPTABLE

Given the Basis of Design Pump Curve

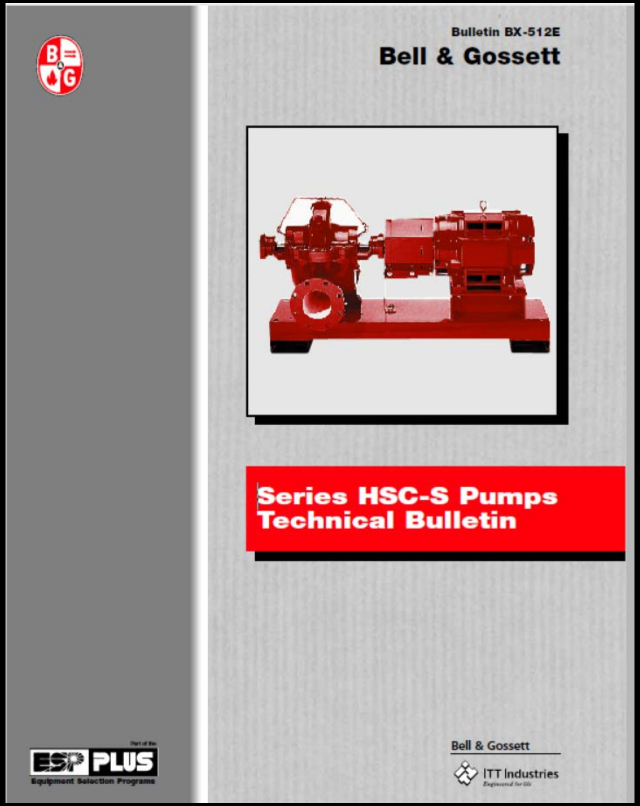


Given Submittal Pump Curve



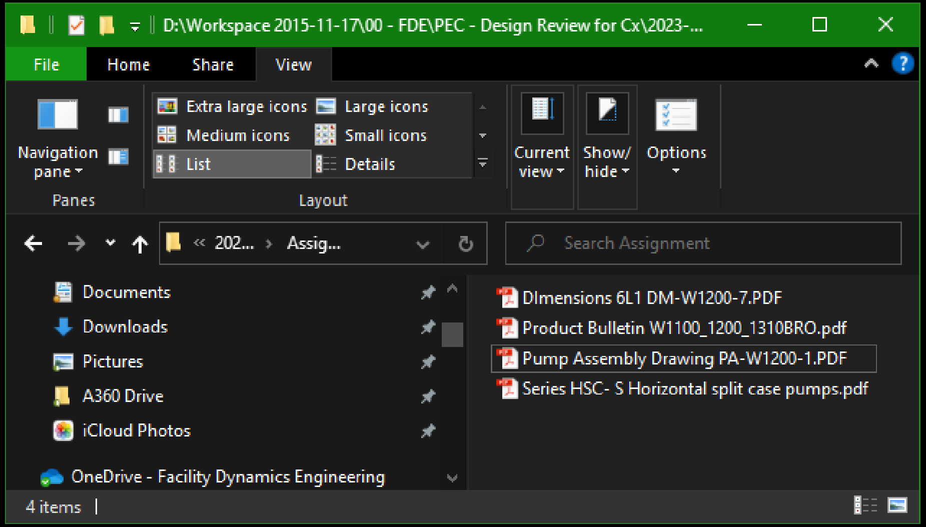
Given the Manufacturers Catalog Data

Basis of Design



Submitted

These files in the class materials



Would You Approve the Substitution?

- Why or why not?
- What other things might you comment on?

Post your answers here:

https://tinyurl.com/PECDesRevAssignment

Fire Damper Cost Benefit

For Hijend Hotel Ball Room Branch Duct to Reheat Coils				
	V Groove	Fabricated Airfoil	Extruded Airfoil	
Flow -	10,000	10,000	10,000	cfm
Duct Area -	6.86	6.86	6.86	sq.ft.
Velocity -	1,457	1,457	1,457	fpm
Static -	0.16	0.11	0.06	in.w.c.
Motor efficiency -	92.4%	92.4%	92.4%	
Belt efficiency -	97.0%	97.0%	97.0%	
VSD efficiency -	97.0%	97.0%	97.0%	
kW -	0.21	0.15	0.08	
Operating Hours -	5,000	5,000	5,000	
kWh -	1,052	740	394	
Savings -	Base Case	312	658	
Cost of electricity -	$0.19	$0.19	$0.19	
		$59	$125	
Damper cost -	$1,026		$1,213	
Difference -			$187	
Simple payback -			1.49	years

At a Higher Velocity

	V Groove	Fabricated Airfoil	Extruded Airfoil	
Flow -	10,000	10,000	10,000	cfm
Duct Area -	5.00	5.00	5.00	sq.ft.
Velocity -	2,000	2,000	2,000	fpm
Static -	0.29	0.21	0.11	in.w.c.
Motor efficiency -	92.4%	92.4%	92.4%	
Belt efficiency -	97.0%	97.0%	97.0%	
VSD efficiency -	97.0%	97.0%	97.0%	
kW -	0.39	0.29	0.15	
Operating Hours -	5,000	5,000	5,000	
kWh -	1,963	1,439	743	
Savings -	Base Case	523	1,220	
Cost of electricity -	$0.19	$0.19	$0.19	
		$99	$232	
Damper cost -	$748		$884	
Difference -			$136	
Simple payback -			0.59	years

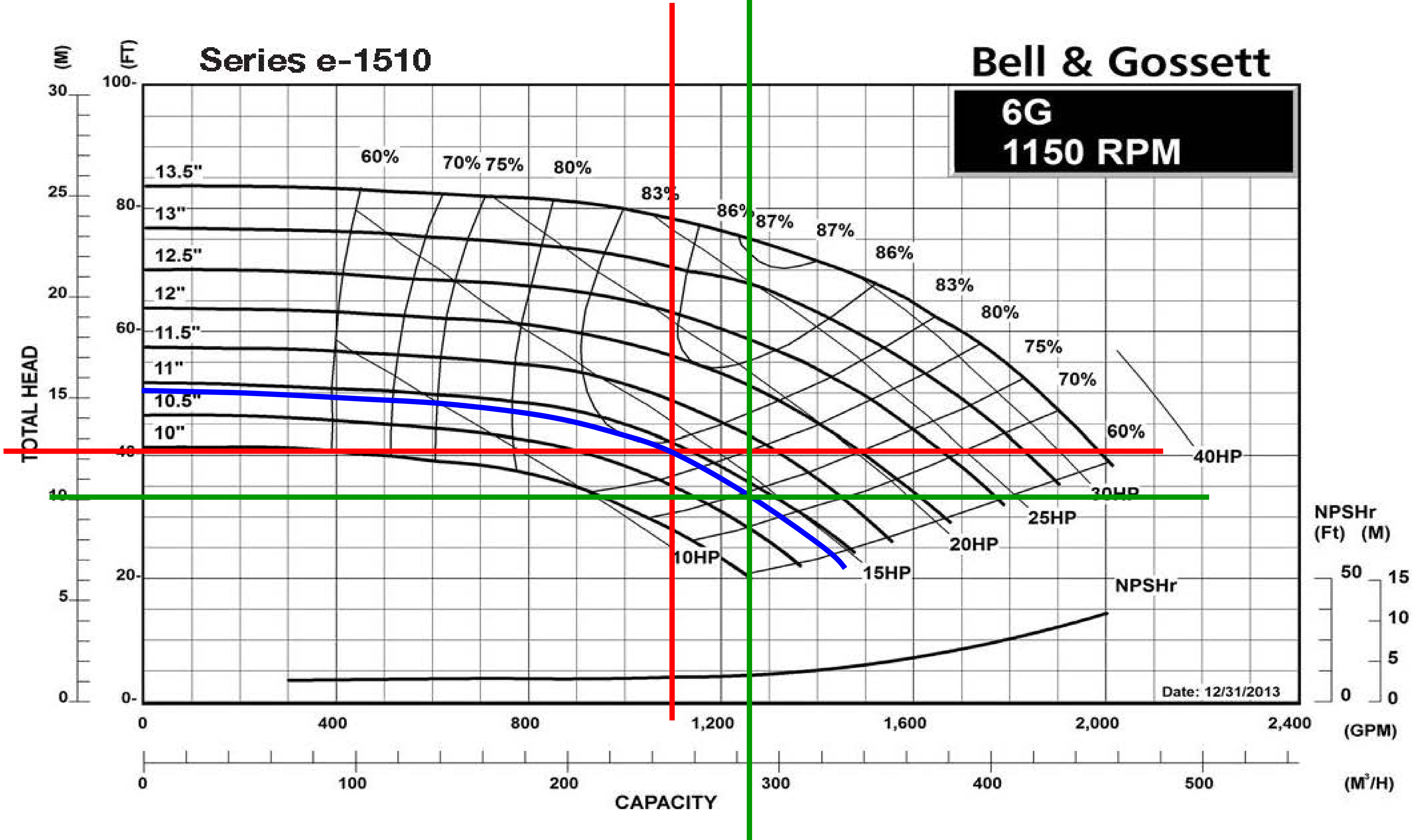
24/7 Operation	V Groove	Fabricated Airfoil	Extruded Airfoil	
Flow -	10,000	10,000	10,000	cfm
Duct Area -	5.00	5.00	5.00	sq.ft.
Velocity -	2,000	2,000	2,000	fpm
Static -	0.29	0.21	0.11	in.w.c.
Motor efficiency -	92.4%	92.4%	92.4%	
Belt efficiency -	97.0%	97.0%	97.0%	
VSD efficiency -	97.0%	97.0%	97.0%	
kW -	0.39	0.29	0.15	
Operating Hours -	8,760	8,760	8,760	
kWh -	3,438	2,521	1,301	
Savings -	Base Case	917	2,137	
Cost of electricity -	$0.19	$0.19	$0.19	
		$174	$406	
Damper cost -	$748		$884	
Difference -			$136	
Simple payback -			0.33	years

Estimating Pump Head

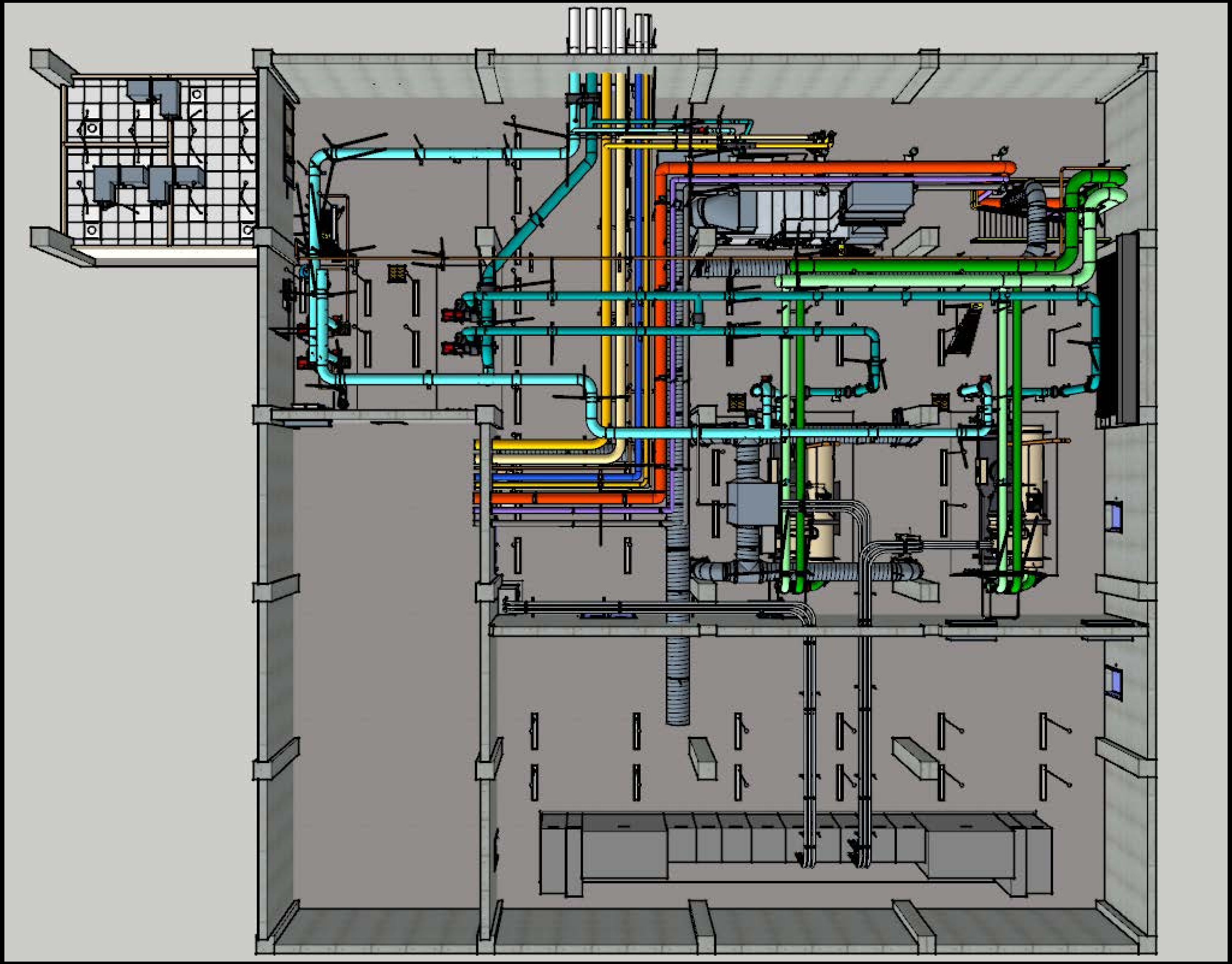
A Few Closing Thoughts

SERIES e-1510

1200 RPM SYNCHRONOUS SPEED



Ripple Effects



Looking at Diversity

The cooling coil portion of the equipment schedule

Cooling Coil Schedule

Coil Number	Unit or System Served	Flow, cfm	Maximum Fins per Inch	Rows	Minimum Face Area, sq.ft.	Airside Performance						Waterside Performance					Comments
						Entering Air		Leaving Air		Face Velocity, fpm	Pressure Drop, in.w.c.	Entering Water Temperature, °F	Leaving Water Temperature, °F	Flow Rate, gpm	Pressure Drop, ft.w.c.	Tons	
						Dry bulb, °F	Wet bulb, °F	Dry bulb, °F	Wet bulb, °F								
CC-1	AHU1 - Hotel Lobby and Administration	26,000	8	6	52.0	81.0	63.8	51.0	50.5	433	0.63	42.0	56.0	141.0	8.6	82.2	Note 3
CC-2	Main Ball Room	20,000	9	6	40.0	86.6	66.1	51.4	50.9	500	0.82	42.0	54.0	148.7	11.0	74.4	Note 3
CC-3	Junior Ball Room	15,000	8	6	30.0	80.2	63.5	51.7	51.1	500	0.74	42.0	54.0	88.7	9.2	44.3	Note 3
CC-4	Meeting Rooms	15,000	9	6	30.0	90.3	67.6	52.2	51.6	500	0.83	42.0	54.0	120.1	9.1	60.1	3-way valve, Notes 1, 4
CC-5	Corridor Make-up Air	23,775	8	6	47.6	90.3	67.6	53.7	52.9	495	0.74	42.0	54.0	177.0	4.9	88.5	Note 4
CC-6	Corridor Make-up Air	23,775	8	6	47.6	90.3	67.6	53.7	52.9	495	0.74	42.0	54.0	177.0	4.9	88.5	Note 4
CC-7	Laundry	10,000	8	6	20.0	81.3	65.0	53.9	53.3	500	0.75	42.0	54.0	57.9	3.1	29.0	Note 3
CC-8	Breakfast/Lunch Café	6,500	8	6	13.0	82.7	64.5	50.9	50.4	406	0.56	42.0	54.0	43.9	7.8	21.9	3-way valve, Notes 1,3
CC-9	Restaurant and Lounge	11,500	8	6	23.0	82.7	64.5	51.8	51.2	479	0.70	42.0	54.0	73.7	9.3	36.9	Note 3
CC-10	Main Kitchen	19,000	8	6	38.0	88.5	67.6	51.5	51.0	396	0.56	42.0	54.0	157.2	9.2	78.6	Note3
VF-1	Electrical Room	8,200	8	3	16.4	83.7	67.6	60.7	57.9	410	0.35	42.0	54.0	42.5	9.8	21.2	Note 3
CC-GR01	Typcial North Exposure Guest Room (294 thus)	300	14	3	1.4	72.0	60.0	49.4	49.0	214	0.15	42.0	48.6	2.7	3.5	0.7	Note 2
CC-GR02	Typcial East Exposure Guest Room (22 thus)	400	14	3	1.4	72.0	60.0	51.2	50.5	285	0.22	42.0	49.4	2.8	3.7	0.9	Note 2
CC-GR03	Typcial South Exposure Guest Room (292 thus)	600	14	3	2.2	72.0	60.0	50.4	49.8	275	0.21	42.0	50.1	4.1	9.7	1.4	Note 2
CC-GR04	Typcial West Exposure Guest Room (22 thus)	400	14	3	1.4	72.0	60.0	51.2	50.5	285	0.22	42.0	49.4	2.8	3.7	0.9	Note 2
CC-CR05	Typcial Luxury Guest Room (4 thus)	1,000	14	3	3.2	72.0	60.0	51.2	50.4	313	0.26	42.0	50.3	6.3	8.9	2.2	0

Note 1 Bypass balanced to 5 gpm with the valve positioned to full bypass

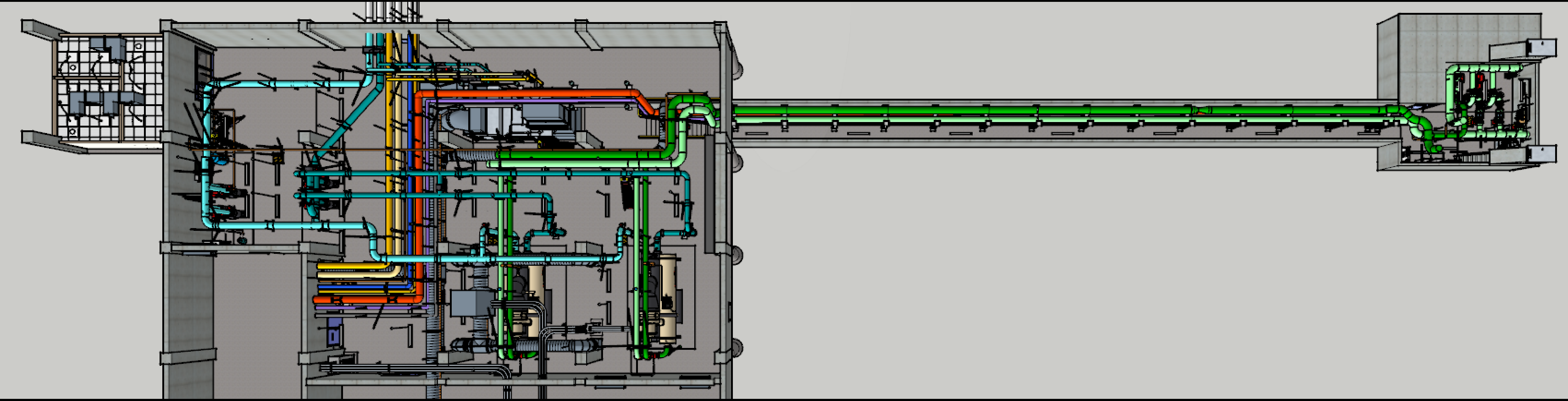
Note 2 One fan coil at the top of each riser to have a three way valve with the bypass balanced to the fan coil design flow rate when the valve in full bypass

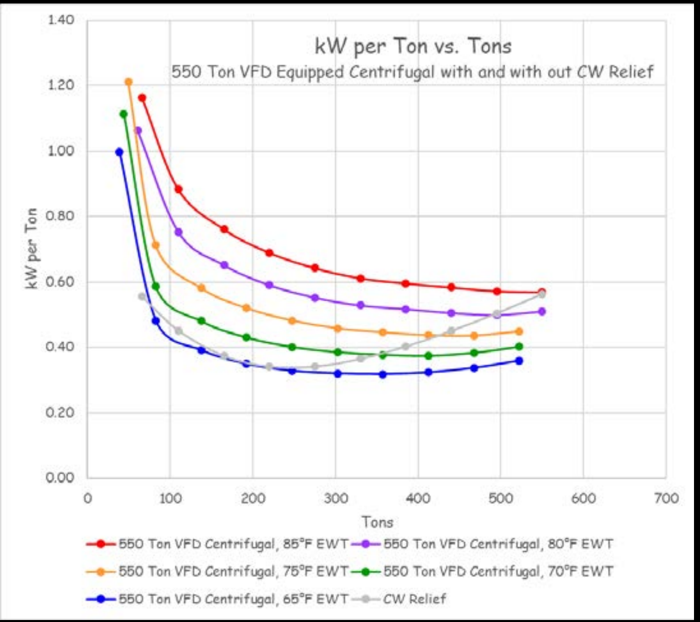
Note 3 Integrated economizer equipped

Note 4 100% outdoor air

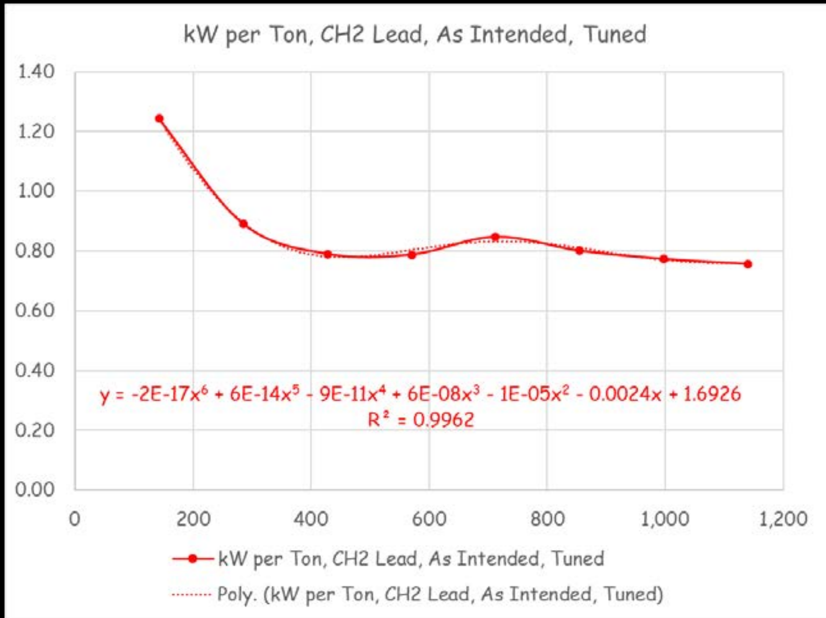
Matching a Plant to the Load Profile and Optimizing Chiller Staging

The Load and kW per Ton Profile



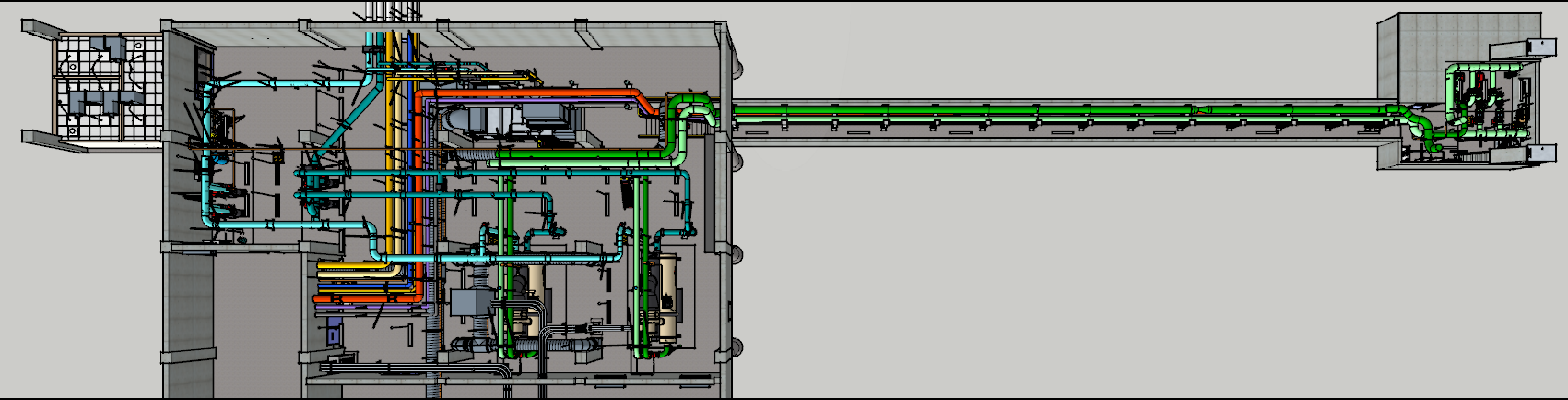


Item	12.5% 143 tons	25.0% 285 tons	37.5% 428 tons	50.0% 570 tons	62.5% 713 tons	75.0% 855 tons	87.5% 998 tons	100.0% 1,140 tons
Chiller 1	0.0	0.0	0.0	0.0	319.7	319.7	319.7	319.7
CHWP-1	0.0	0.0	0.0	0.0	14.6	14.6	14.6	14.6
CWP-1	0.0	0.0	0.0	0.0	43.8	43.8	43.8	43.8
CT-1	0.0	0.0	0.0	0.0	11.0	11.0	11.0	11.0
Chiller 2	113.1	181.2	252.7	347.5	113.1	181.2	252.7	324.9
CHWP-2	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
CWP-2	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8
CT-2	0.2	1.4	4.6	11.0	0.2	1.4	4.6	11.0
CHWP-3	2.7	6.6	11.2	16.3	21.8	27.6	33.7	40.1
CHWP-4	2.7	6.6	11.2	16.3	21.8	27.6	33.7	40.1
Total kW	177.1	254.2	338.2	449.5	604.5	685.4	772.3	863.7
kW per Ton	1.24	0.89	0.79	0.79	0.85	0.80	0.77	0.76



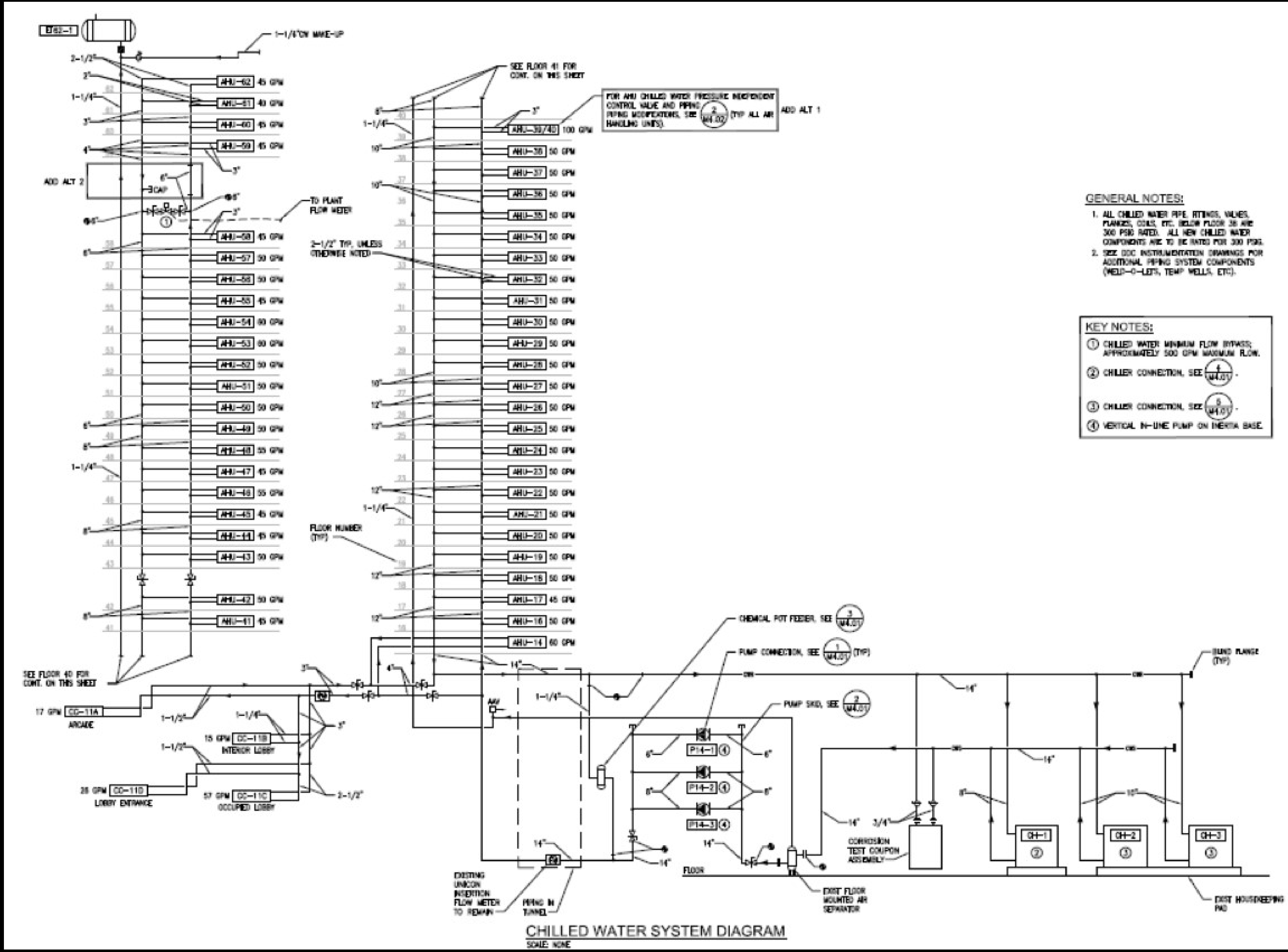
Given

The kW per Ton Concept



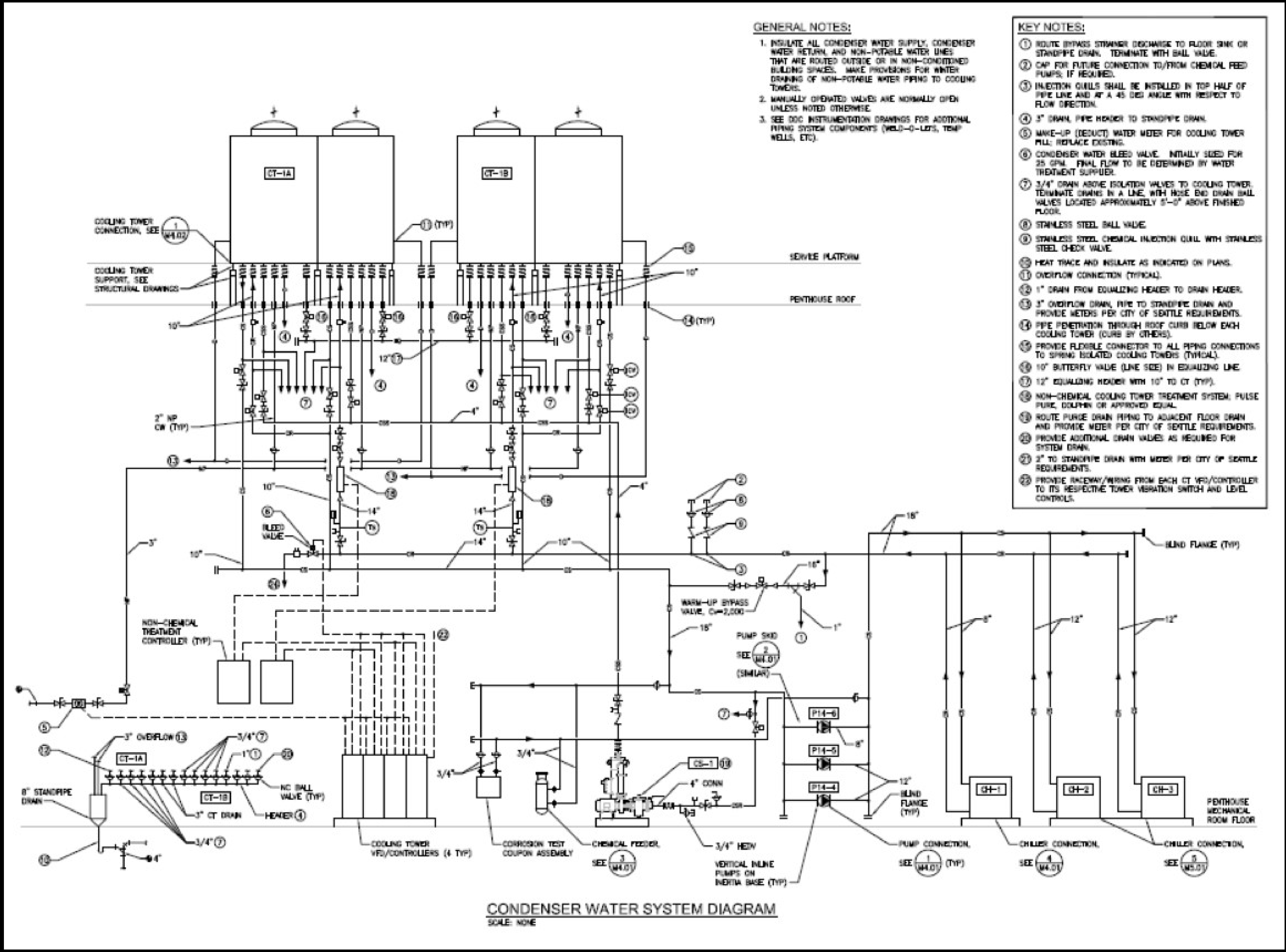
Given

Proposed CHW Schematic



Given

Proposed CW Schematic



Given

Proposed chiller performance

CHILLERS - WATER COOLED

MARK		CH-1	CH-2	CH-3
LOCATION		MECH RM	MECH RM	MECH RM
SERVES		CLG WATER	CLG WATER	CLG WATER
CAPACITY	TONS	300.0	1,000.0	1,000.0
	KW/TON	0.554	0.470	0.470
	COP			
COMPRESSOR	TYPE	CNTFGL	CNTFGL	CNTFGL
	QUANTITY: NO	2	3	3
EVAPORATOR	FLOW: GPM	450	1,500	1,500
	EWT: F	59	59	59
	LWT: F	43	43	43
	PD: FT HD	11	18	18
	FOULING FACTOR	0.00010	0.00010	0.00010
CONDENSER	FLOW: GPM	850	2,800	2,800
	EWT: F	86	86	86
	LWT: F	76	76	76
	PD: FT HD	15	16	16
	FOULING FACTOR	0.00025	0.00025	0.00025
REFRIGERANT	TYPE	R-134A	R-134A	R-134A
	CHARGE: LBS	895	2851	2851
ELECTRICAL	VOLT/PHASE	460/3	460/3	460/3
	TOTAL KW	163.3	470.4	470.4
	MCA	261	518 [3]	518 [3]
	MOP	350	724 [3]	724 [3]
	SCCR: AMPS	100,000	100,000	100,000
OPER WEIGHT	WEIGHT: LBS	10,000	35,000	35,000
BASIS OF DESIGN	MANUFACTURER	SMARDT	SMARDT	SMARDT
	MODEL	WA095.2H	WV400.3U	WV400.3U
	NOTES	[1, 2, 4, 6]	[1, 2, 4, 6]	[1, 2, 4, 6]

PROVIDE ALL CHILLERS FROM ONE MANUFACTURER.

NOTES:

1. SINGLE POINT CONNECTION, REFER TO ELECTRICAL DRAWINGS.
2. MAGNETIC BEARING, OIL-LESS COMPRESSORS.
3. RATINGS PER COMPRESSOR.
4. PROVIDE ONE SPARE COMPRESSOR FOR EACH SIZE USED IN THE NOMINAL 300 TON AND 1000 TON CHILLERS. DELIVER AT END OF WARRANTY PERIOD – ALTERNATE BID ITEM.
5. PROVIDE 5 YEAR WARRANTY – ALTERNATE BID ITEM.
6. PROVIDE MARINE BOXES AT ENDS WITH PIPING CONNECTIONS (300 LB PRESSURE CLASS ON EVAPORATOR) AND HINGED ACCESS AT ALL ENDS.

Given

Proposed pump performance

PUMPS - HYDRONIC

MARK		P14-1	P14-2	P14-3	P14-4	P14-5	P14-6
LOCATION		MECH RM	MECH RM	MECH RM	MECH RM	MECH RM	MECH RM
SERVES		CHILLED WTR	CHILLED WTR	CHILLED WTR	COND WTR	COND WTR	COND WTR
CAPACITY	FLOW: GPM	500	1,500	1,500	900	3,500	3,500
	TDH: FT	120	160	160	60	60	60
	EFFICIENCY: %	75	79	79	67	74	74
TYPE	DESCRIPTION	VIL	VIL	VIL	VIL	VIL	VIL
	MOTOR RPM	1,800	1,800	1,800	1,800	1,800	1,800
	MAX BHP	27.00	87.00	87.00	21.00	70.00	70.00
	SUCT CONN: IN	6	8	8	8	12	12
	DISCH CONN: IN	6	8	8	8	12	12
	IMP DIA: IN	11.20	13.26	13.26	8.34	10.00	10.00
ELECTRICAL	VOLT/PHASE	460/3	460/3	460/3	460/3	460/3	460/3
	MOTOR HP	40	100	100	25	75	75
	SCCR: AMPS	35,000	65,000	65,000	14,000	35,000	35,000
OPER WEIGHT	WEIGHT: LBS	1,050	2,150	2,150	950	2,600	2,600
BASIS OF DESIGN	MANUFACTURER	PACO	PACO	PACO	PACO	PACO	PACO
	MODEL	VLS 6x6x11.5	VLS 8X8X15	VLS 8X8X15	VLS 6x6x11.5	VLS 12x12x13	VLS 12x12x13
	NOTES	[1, 2, 3, 4]	[1, 2, 3, 4]	[1, 2, 3, 4]	[1, 2, 3, 4]	[1, 2, 3, 4]	[1, 2, 3, 4]

PROVIDE ALL PUMPS FROM ONE MANUFACTURER.

NOTES:

1. REFER TO ELECTRICAL DRAWINGS FOR DISCONNECT SWITCH.
2. PROVIDE WITH VARIABLE FREQUENCY DRIVE AND SUCTION DIFFUSER.
3. MOUNT PUMP ON SPRING ISOLATED CONCRETE INERTIA BASE; OPER WEIGHT DOES NOT INCLUDE INERTIA BASE.
4. PROVIDE ALL PUMPS WITH SUCTION DIFFUSERS; 300 LB PRESSURE CLASS ON CHILLED WATER PUMPS.

Given

Proposed cooling tower performance

COOLING TOWERS

MARK		CT-1A	CT-1B
LOCATION		ROOF	ROOF
SERVES		CHILLERS	CHILLERS
TYPE	AIRFLOW CONFIG	IND DRAFT	IND DRAFT
	DISCHARGE	VERTICAL	VERTICAL
	CELLS	2	2
CAPACITY [1]	HEAT REJ: TONS	1,185	1,185
	FLOW: GPM	3,450	3,450
	AMBIENT WB: F	66	66
	EWT: F	86	86
	LWT: F	76	76
	PD: FT HD	12	12
FAN	TYPE	SILENT PROP	SILENT PROP
	FANS: NO	2	2
	AIRFLOW: CFM	268,800	268,800
	ESP: IN WG	–	–
	TOTAL MOTOR HP	60	60
	PONY MOTOR HP	–	–
	VOLT/PHASE	460/3	460/3
BASIN HEATER	HEATERS	–	–
	CAPACITY: KW	–	–
	VOLT/PHASE	460/3	460/3
ELECTRICAL	SCCR: AMPS	14,000	14,000
OPER WEIGHT	WEIGHT: LBS	43,780	43,780
BASIS OF DESIGN	MANUFACTURER	EVAPCO	EVAPCO
	MODEL	UT–224–418	UT–224–418
	NOTES	[2–7]	[2–7]

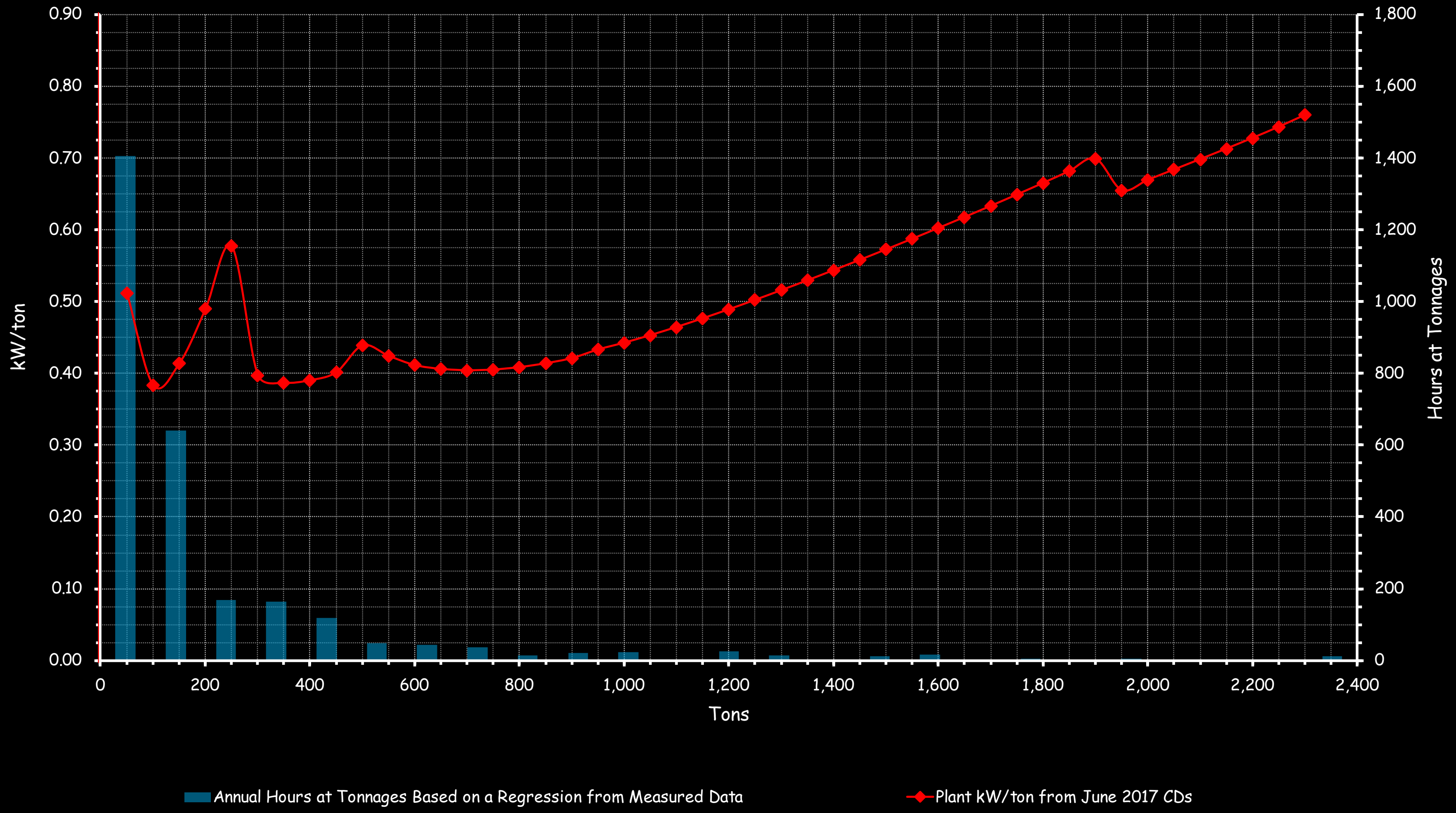
PROVIDE ALL COOLING TOWERS FROM ONE MANUFACTURER.

NOTES:

1. CAPACITIES BASED ON WATER.
2. REFER TO ELECTRICAL DRAWINGS FOR MOTOR STARTER AND DISCONNECT SWITCH.
3. PROVIDE WITH VIBRATION CUTOUT SWITCH.
4. PROVIDE WITH VARIABLE SPEED DRIVE AND FAN MOTORS.
5. PROVIDE WITH VORTEX ELIMINATOR AND BOTTOM PIPING CONNECTIONS.
6. PROVIDE STAINLESS STEEL PAN AND SUMP SWEEP PIPING/NOZZLES.
7. PROVIDE WITH REMOVABLE MOTOR LIFTING DAVIT PER 2–CELL TOWER, AND LIFTING DAVIT MOUNTING CHANNEL ON EACH TOWER CELL.

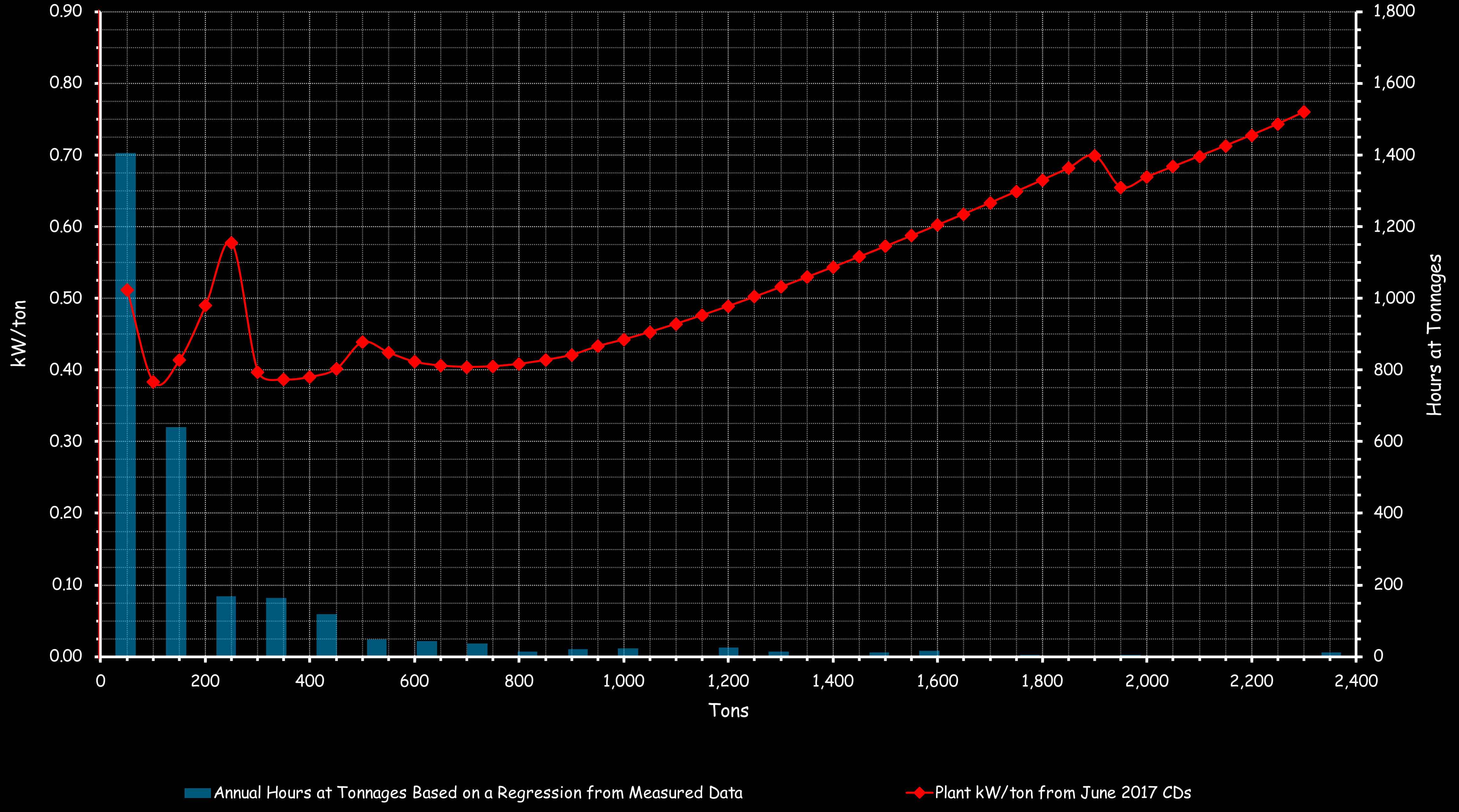
Given

Proposed kW per ton profile



A Question For You

https://tinyurl.com/PECDesRevkWPerTon


kW/ton
Hours at Tonnages
Tons
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
Annual Hours at Tonnages Based on a Regression from Measured Data
Plant kW/ton from June 2017 CDs

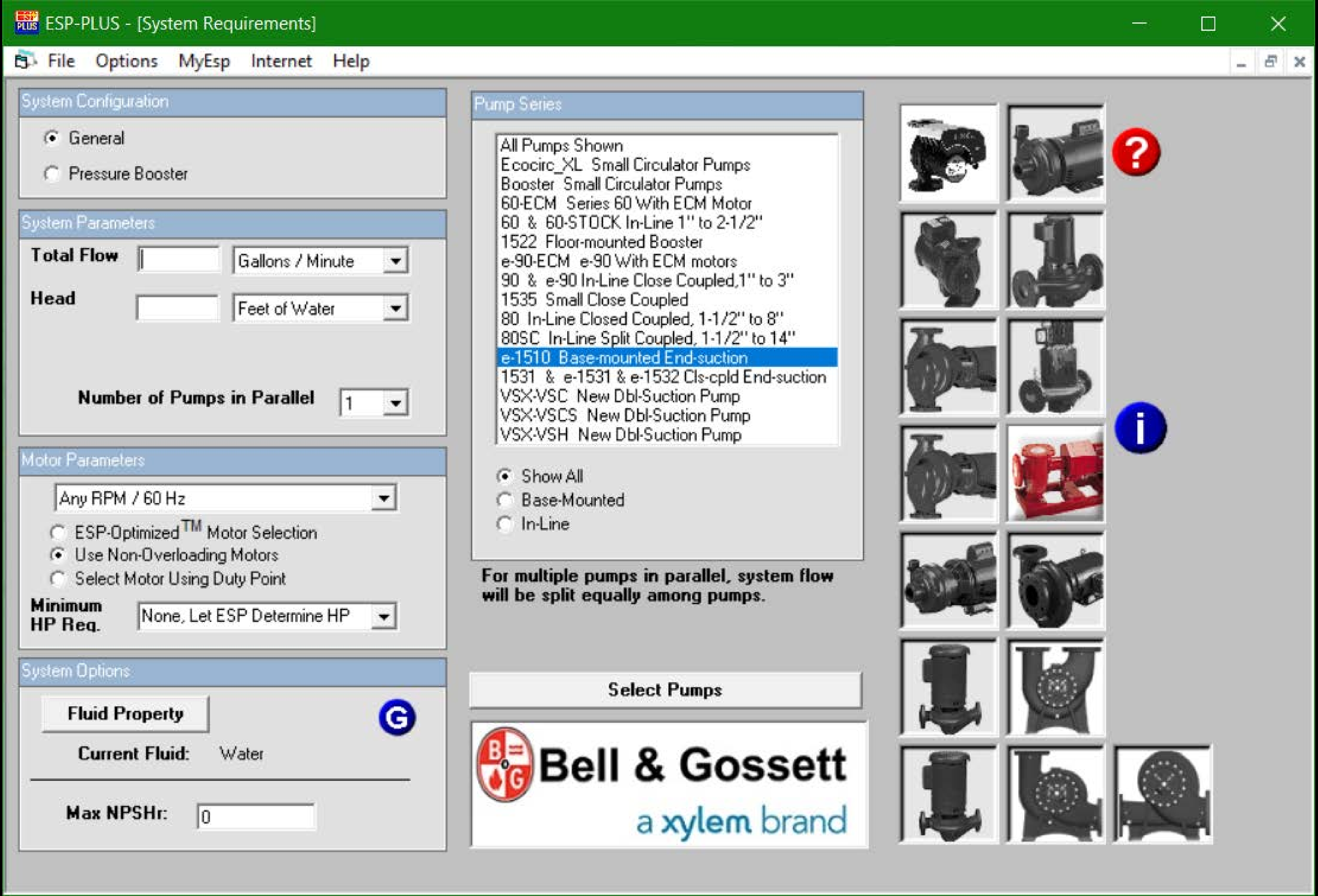
Pump Power Relationship

$$bhp = \left(\frac{Flow \times Head}{3{,}960 \times Efficiency_{Pump}} \right)$$

Where:

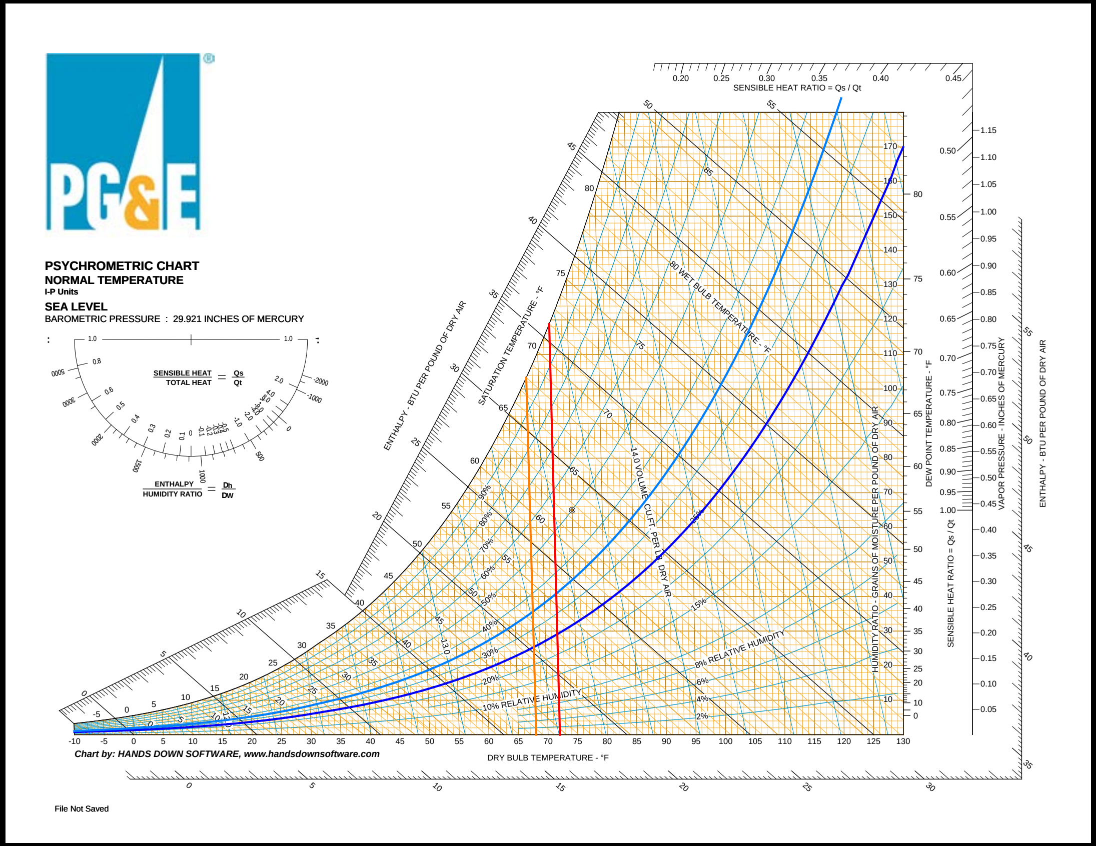
$Flow$	$=$	Flow produced by the pump in gpm
$Head$	$=$	Head produced by the pump in feet water column
3,960	=	A units conversion constant that will work for water at the temperatures and pressures typically encountered in HVAC systems.
$Efficiency_{Pump}$	$=$	Pump efficiency, read from the pump curve or estimated from past experience; .40 - .70 for small (under 500 gpm) pumps, .70 - .85 for large pumps

$$kW = \left(\frac{Flow_{gpm} \times Head_{ft.w.c.}}{3{,}960 \times \eta_{Pump} \times \eta_{Motor} \times \eta_{VSD}} \right) \times .746$$


ESP-PLUS - [System Requirements]
File Options MyEsp Internet Help
System Configuration
General
Pressure Booster
System Parameters
Total Flow
Gallons / Minute
Head
Feet of Water
Number of Pumps in Parallel
1
Motor Parameters
Any RPM / 60 Hz
ESP-Optimized TM Motor Selection
Use Non-Overloading Motors
Select Motor Using Duty Point
Minimum HP Req.
None, Let ESP Determine HP
System Options
Fluid Property
Current Fluid: Water
Max NPSHr: 0
Pump Series
All Pumps Shown
Ecocirc_XL Small Circulator Pumps
Booster Small Circulator Pumps
60-ECM Series 60 With ECM Motor
60 & 60-STOCK In-Line 1" to 2-1/2"
1522 Floor-mounted Booster
e-90-ECM e-90 With ECM motors
90 & e-90 In-Line Close Coupled,1" to 3"
1535 Small Close Coupled
80 In-Line Closed Coupled, 1-1/2" to 8"
80SC In-Line Split Coupled, 1-1/2" to 14"
e-1510 Base-mounted End-suction
1531 & e-1531 & e-1532 Cls-cpld End-suction
VSX-VSC New Dbl-Suction Pump
VSX-VSCS New Dbl-Suction Pump
VSX-VSH New Dbl-Suction Pump
Show All
Base-Mounted
In-Line
For multiple pumps in parallel, system flow will be split equally among pumps.
Select Pumps
Bell & Gossett
a xylem brand

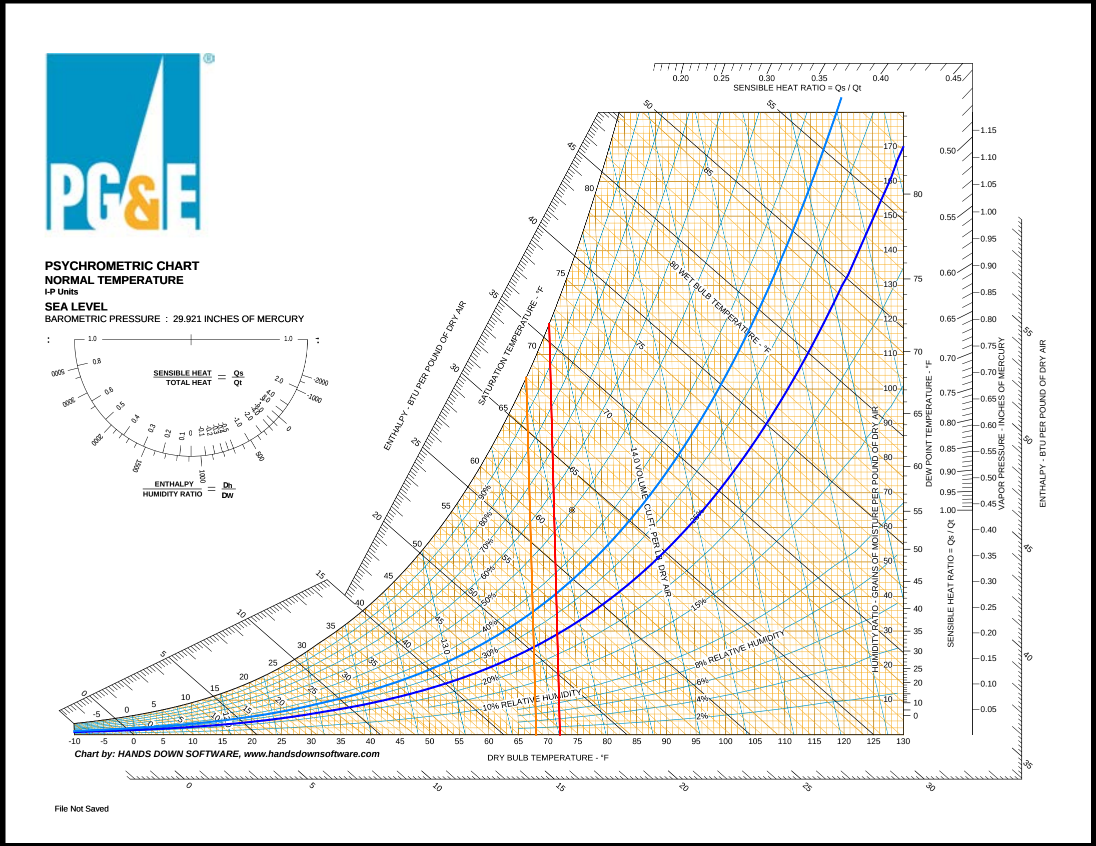
Considering the Climate vs. Owner Design Targets vs. Cost/Benefit

Given an Owners Requirement



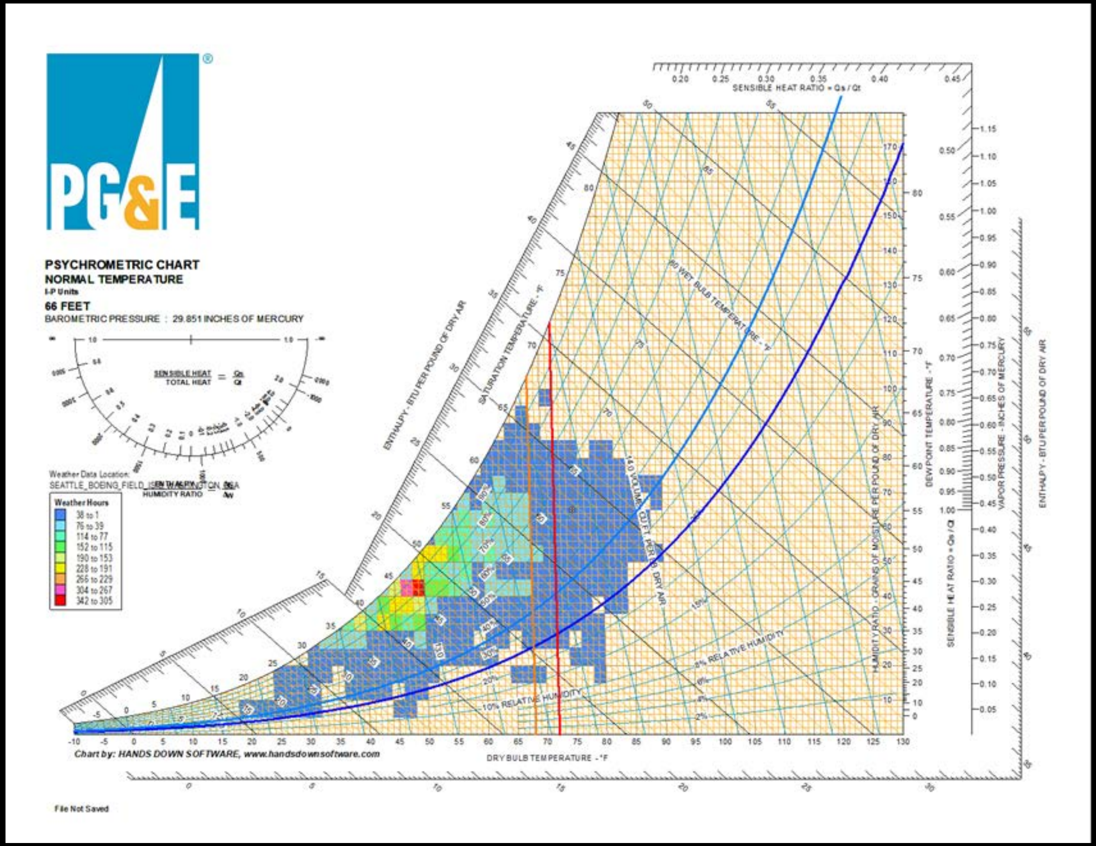
- Winter Indoor Dry Bulb Temperature Target – 68°F – 72°F
- Winter Indoor Relative Humidity Target – 25% - 35%

An Early Design Development Meeting

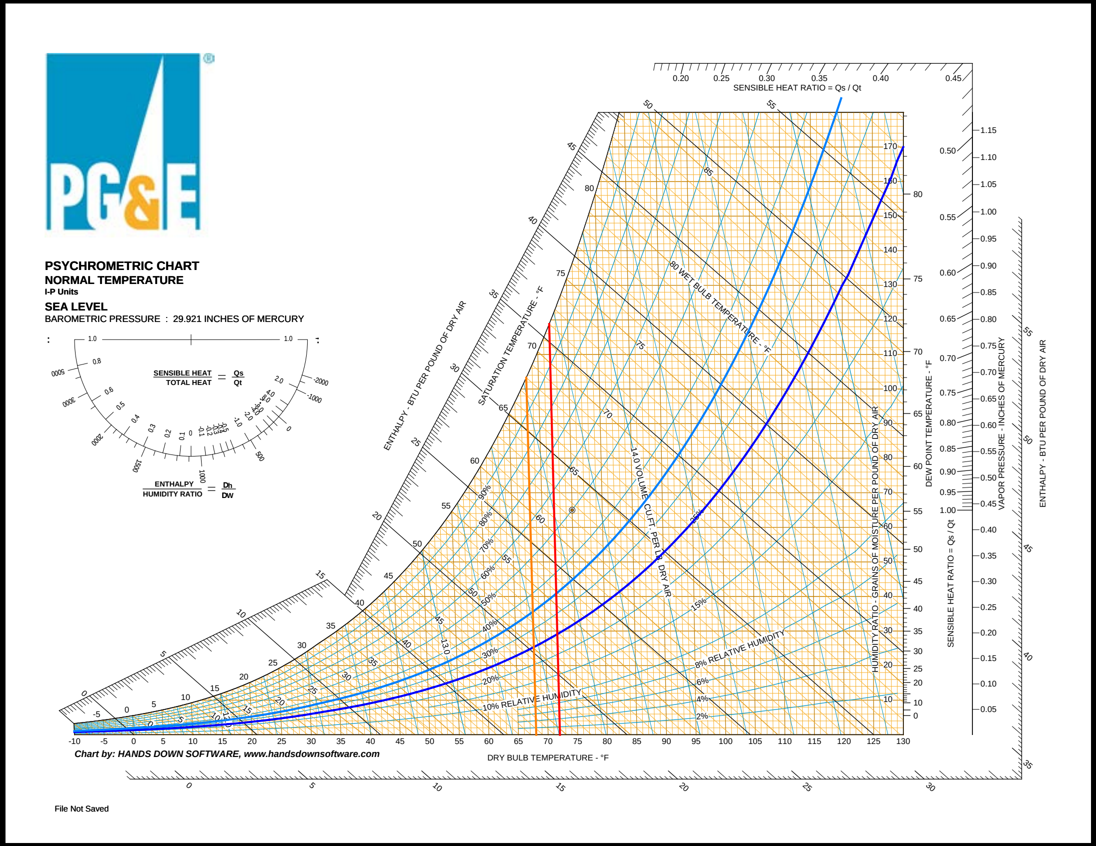


- The project is projecting to be over budget
- It may be necessary to eliminate commissioning from the project

The Pacific NW Climate



Is There Something We Can Do to Keep Commissioning in the Project



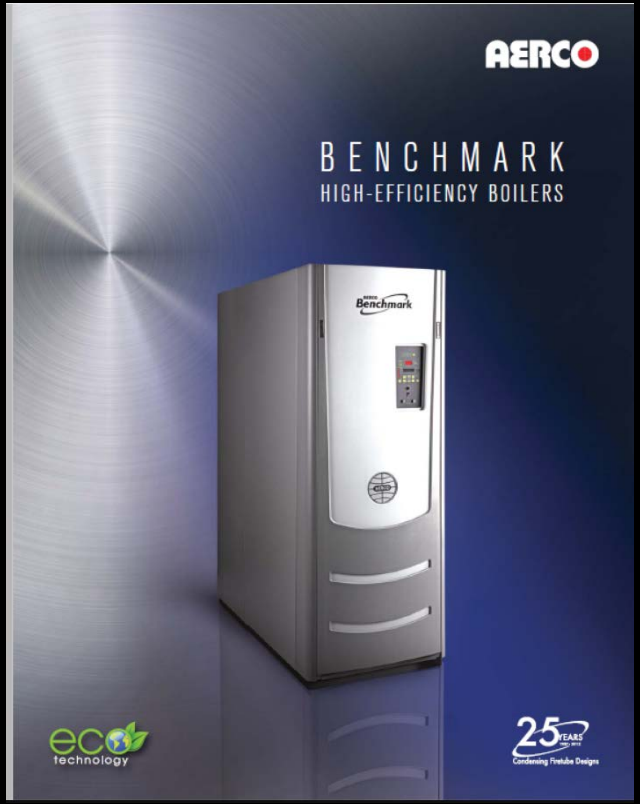
Some psychrometric resources

- https://tinyurl.com/FreePsychChart
- https://tinyurl.com/OlivieriChapters
- https://tinyurl.com/SlfSLoadsPsych

Proposed Substitution Equivalency to the Basis of Design

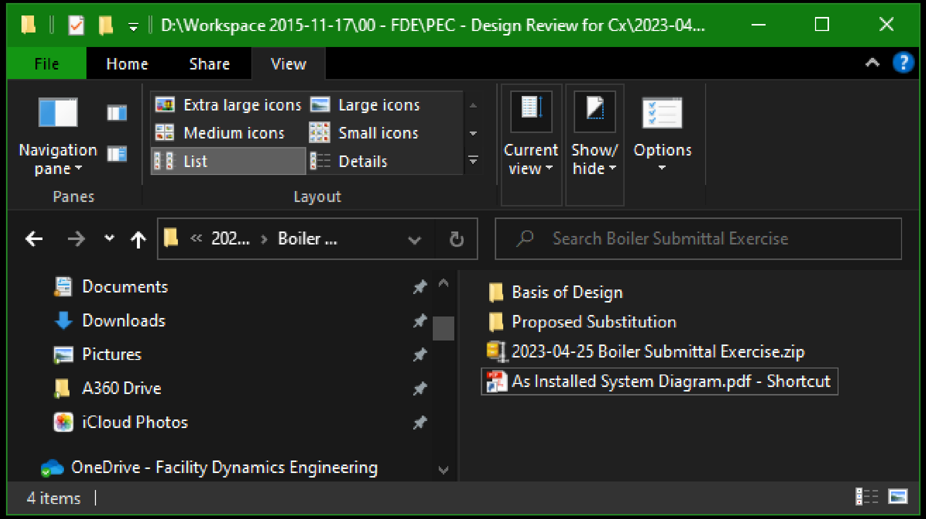
Given Submittal Data

Basis of Design



Submitted

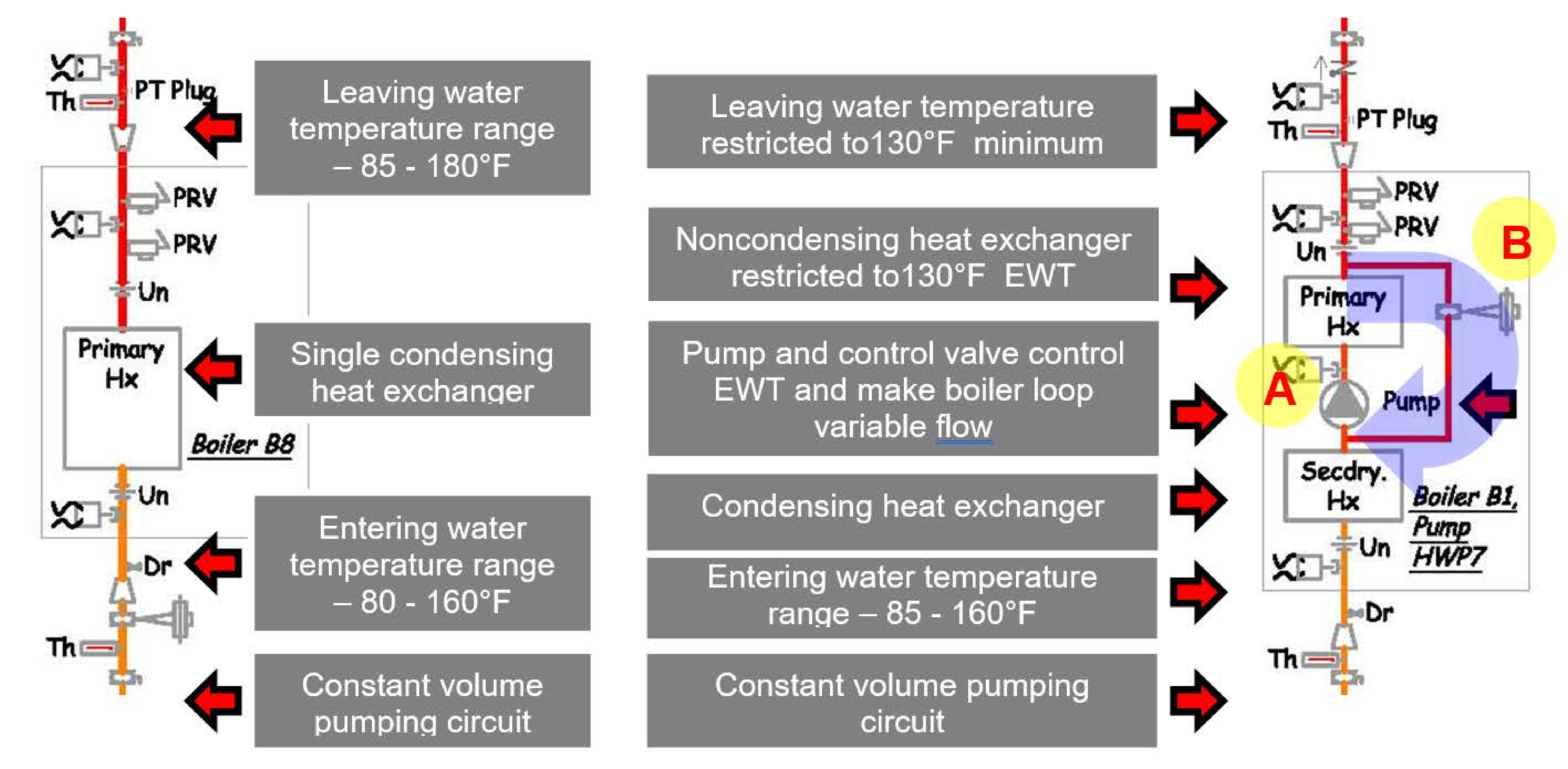
These files in the class materials



Answer the Questions at This Link

https://tinyurl.com/PECDesRevBoiler

Comparing the Boilers



Comparing the Boilers

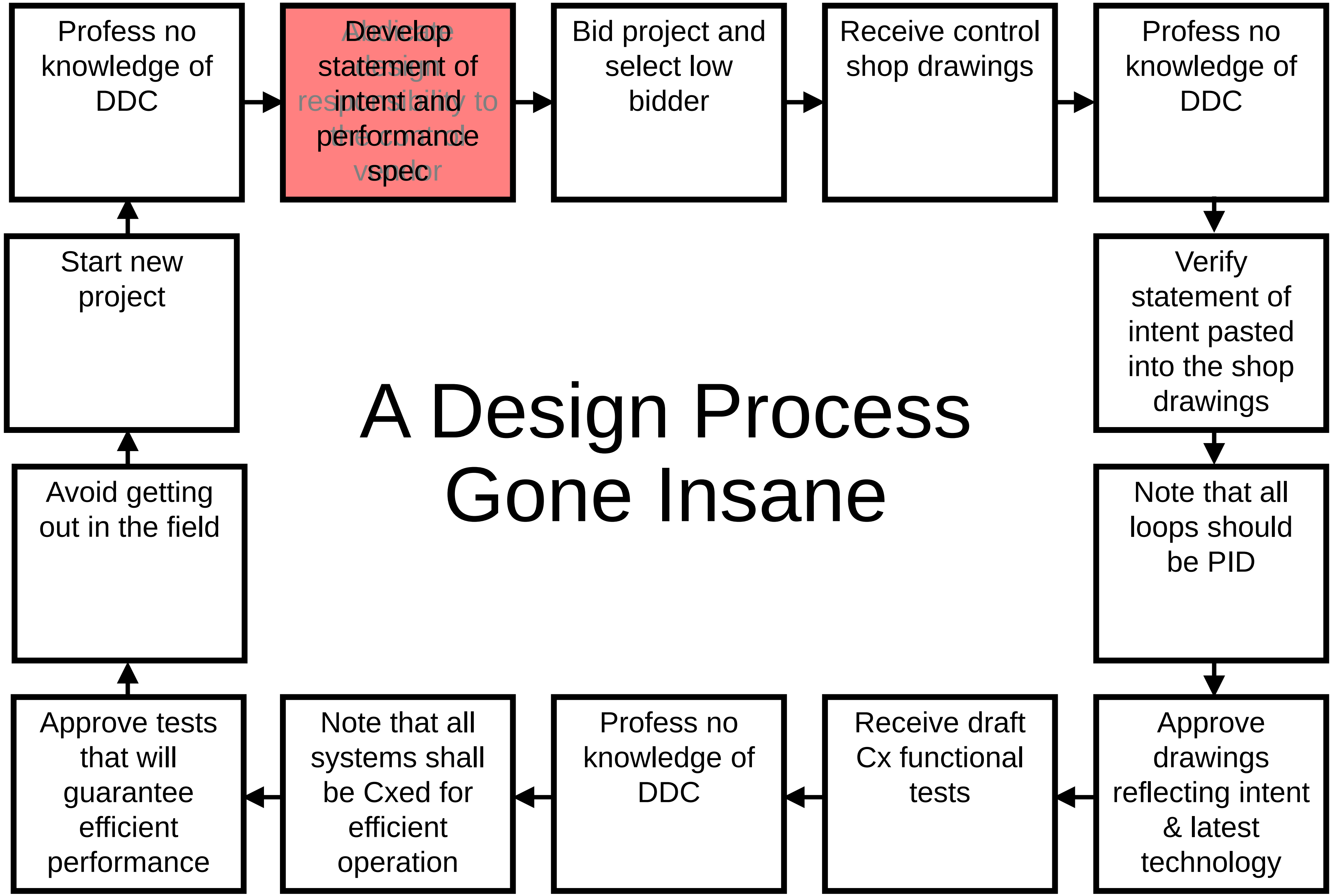
The primary difference between the Aerco Benchmark BMK2.0 boilers (left illustration) that were the basis of design and the Lochinvar Intellifin IBM2000 boilers (right illustration) that were actually furnished is that the Aerco units employ a single heat exchanger, rated and designed for condensing operation. In contrast, the Lochinvar units employ two heat exchangers, one of which (termed the secondary heat exchanger) is rated and designed for condensing operation and one of which (termed the primary heat exchanger) is not. To protect the primary heat exchanger from damage do to the corrosive by-products associated with condensing operation, the Lochinvar boilers incorporate a circulating pump (A) and a control valve (B), arranged to ensure that the entering water temperature to the primary heat exchanger never drops below 130°F. This is accomplished by recirculating water from the boiler's discharge to the inlet side of the primary heat exchanger as indicated by the blue shaded arrow in the right illustration. For this approach to work, the boiler must be controlled so that the leaving water temperature from the primary heat exchanger is never below 130°F. As a result, a system that employs the Lochinvar units and must directly control for supply water temperatures below 130°F need to incorporate some other mechanism for achieving the supply temperature requirement while protecting the boilers. One common approach for accomplishing this is to provide the system with a three-way valve that allows water from the boiler loop to be mixed with return water from the system to achieve the required supply temperature. Since the Aerco boilers are rated to control directly for any set point from 50-190°F, the basis of design system did not in incorporate such a feature. As a result, when the Lochinvar boilers are applied in the basis of design system configuration, there is no direct method for controlling supply temperature to a set point of 130°F. Rather, the master controller charged with cycling the boilers to maintain a desired system supply temperature must try to find a combination of boiler settings that indirectly produces the desired result by forcing the distribution system into an over-flow condition (distribution flow exceeds boiler loop flow) while the individual boiler controllers work to prevent the entering water temperature to their primary heat exchangers from dropping below 130°F. This is a complex hydraulics problem at best and may be impossible to achieve under some operating conditions with out considerable operator intervention.

Other Issues Identified During Construction Observation

Other Issues Identified During Construction Observation


OWEN
CORNIN
I-FOC

Design Review and Control System Cx


A Design Process Gone Insane
Profess no knowledge of DDC
Develop statement of intent and performance spec
Bid project and select low bidder
Receive control shop drawings
Profess no knowledge of DDC
Verify statement of intent pasted into the shop drawings
Note that all loops should be PID
Approve drawings reflecting intent & latest technology
Receive draft Cx functional tests
Profess no knowledge of DDC
Note that all systems shall be Cxed for efficient operation
Approve tests that will guarantee efficient performance
Avoid getting out in the field
Start new project

Solving the Problem: Own the Control Design and Commissioning Process

- Not as Hard as You Might Think
  - You ***DON'T*** need to have:
    - Intimate knowledge of computers
    - Intimate knowledge of networks
    - Intimate knowledge of sensing and actuating technologies
    - Intimate knowledge off differential calculus

Solving the Problem: Own the Control Design and Commissioning Process

- Not as Hard as You Might Think
  - You ***DO*** need to:
    - Understand your mechanical design and the related design targets
    - Apply sound physical principles in the development of your design
    - Communicate clearly
    - Think logically
    - Address the load profile
    - Recognize that all control systems are not created equal out of the box
    - Enforce your requirements

Solving the Problem: Own the Control Design and Commissioning Process

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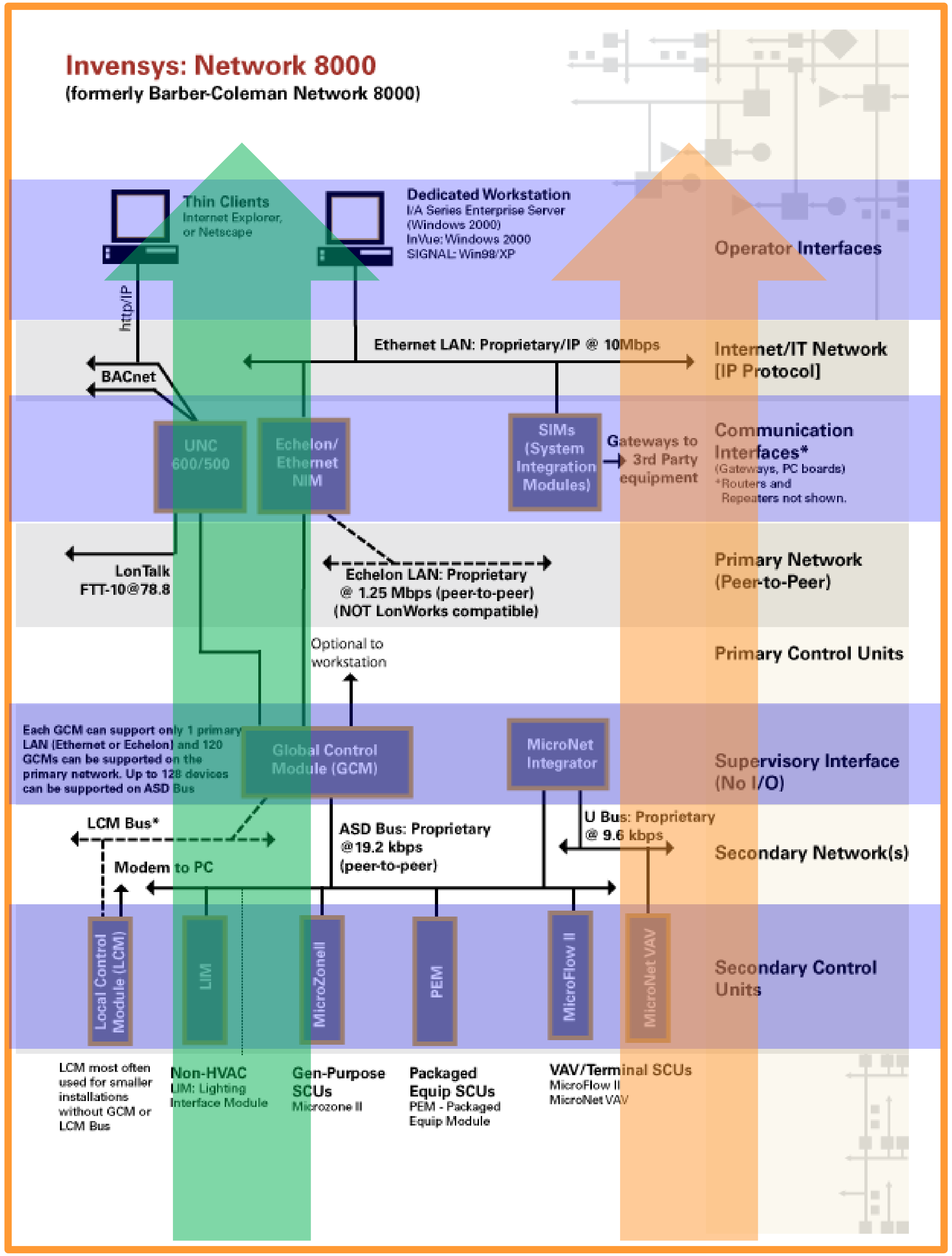
    - Think logically
    - Address the load profile
    - Recognize that all control systems are not created equal out of the box
    - Enforce your requirements

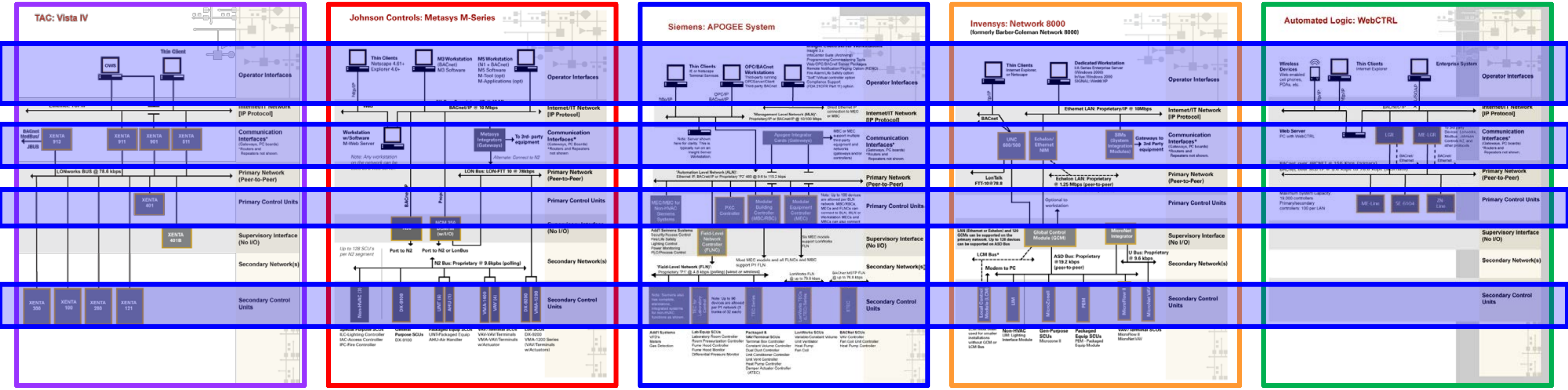
They're Not All Equal

- Different Network Levels
- Increasing Hardware Capability and Sophistication
- Increasing Network Speed and Protocol Sophistication



Images courtesy www.ddc-online.org

They’re Not All Equal

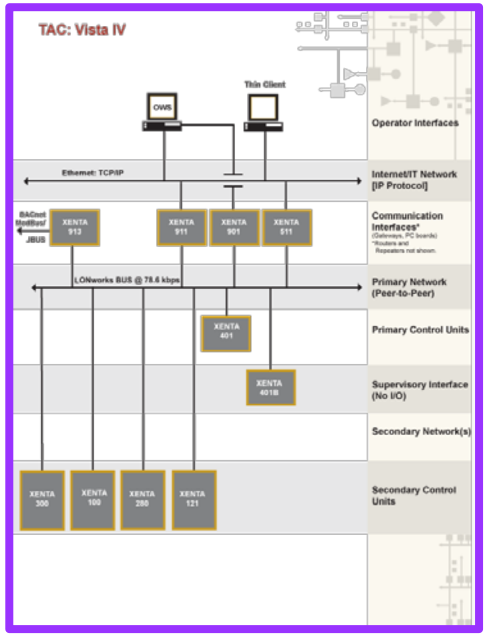


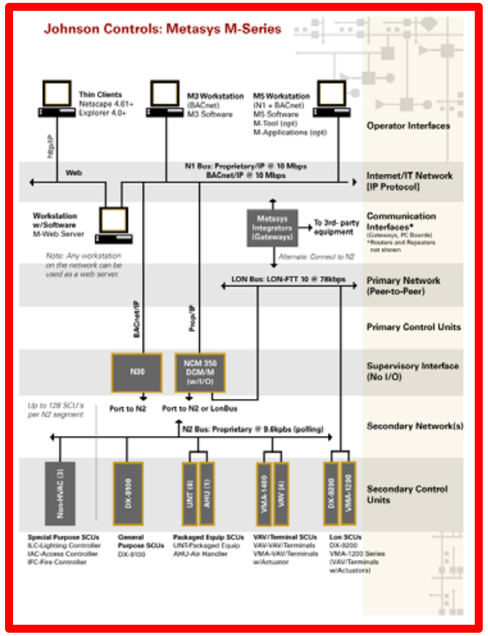
Images courtesy www.ddc-online.org

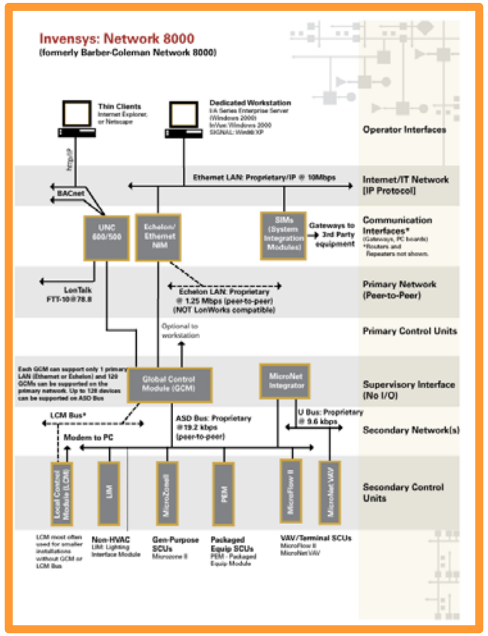
They’re Not All Equal

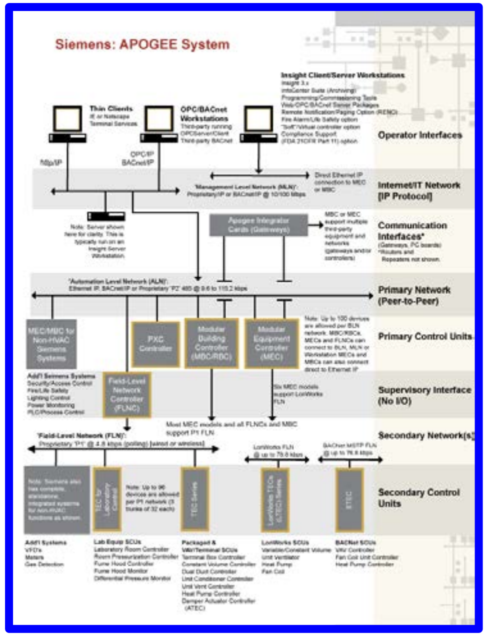
Network Architecture is Critical for Determining:

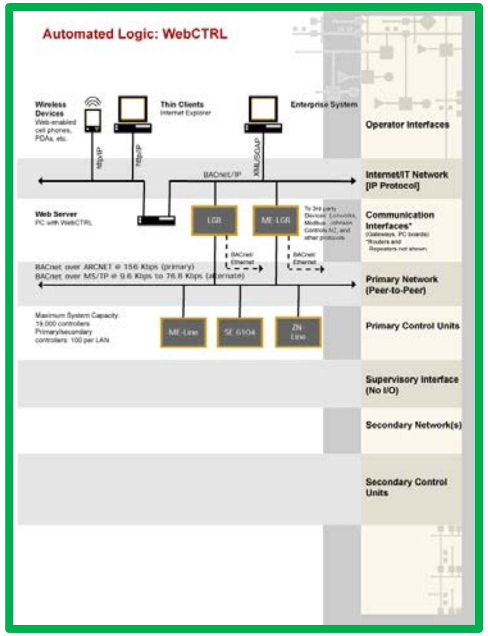
- Network speed
- Data handling capability
- Future flexibility
- Future expansion
- Interoperability







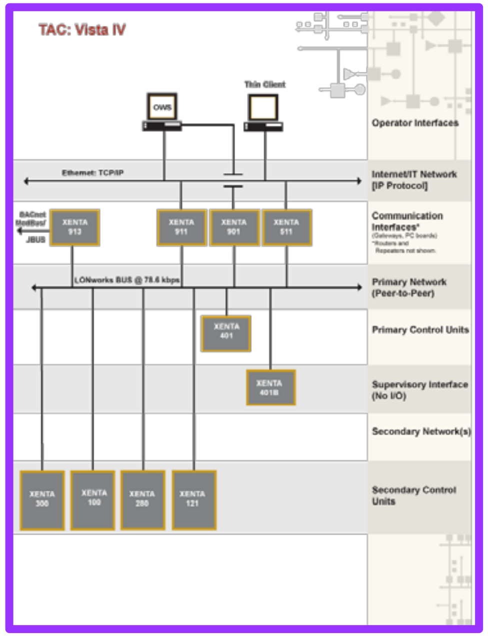


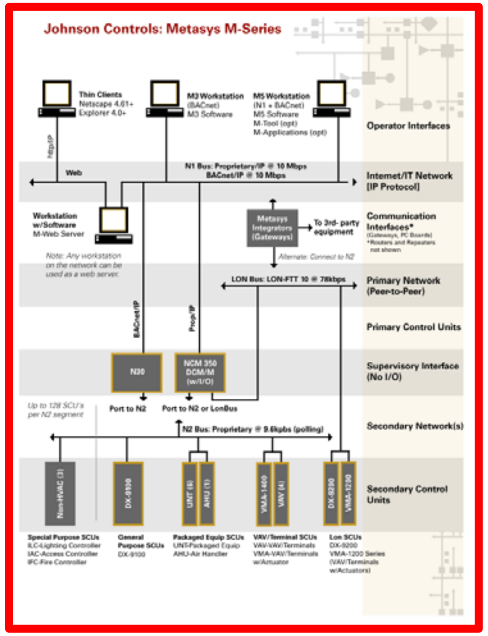


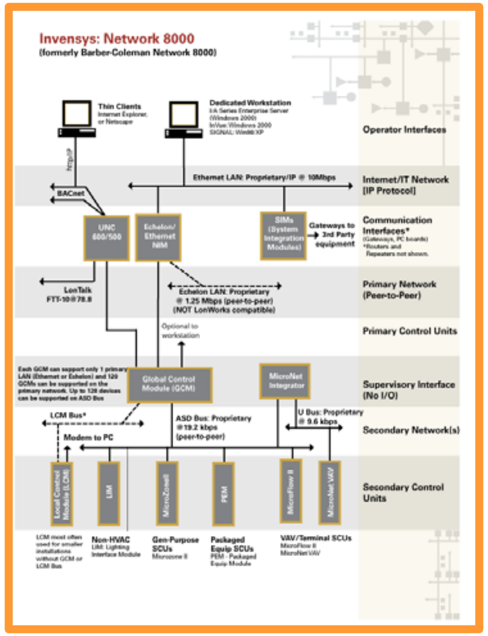
Images courtesy www.ddc-online.org

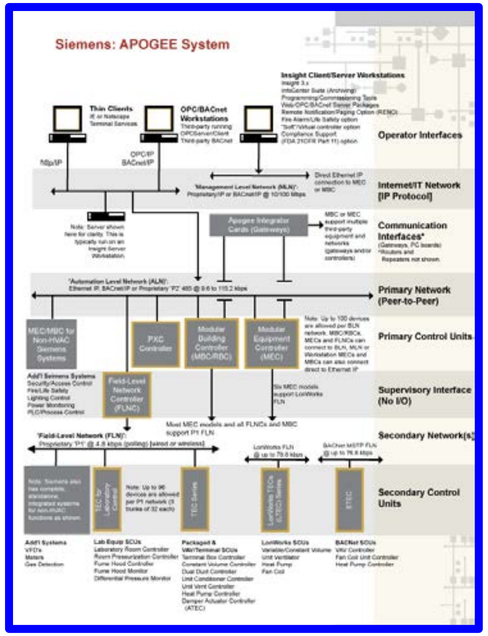
They’re Not All Equal

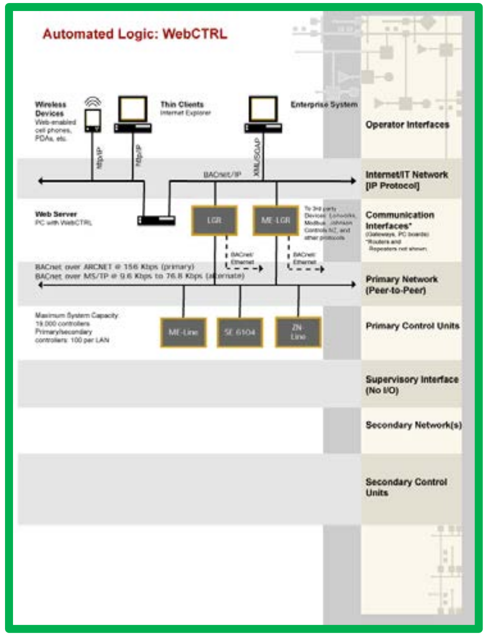
- Hardware Capabilities are Critical to Success







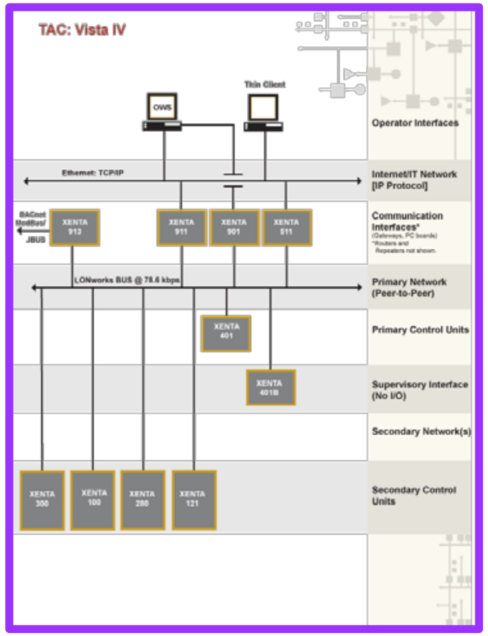


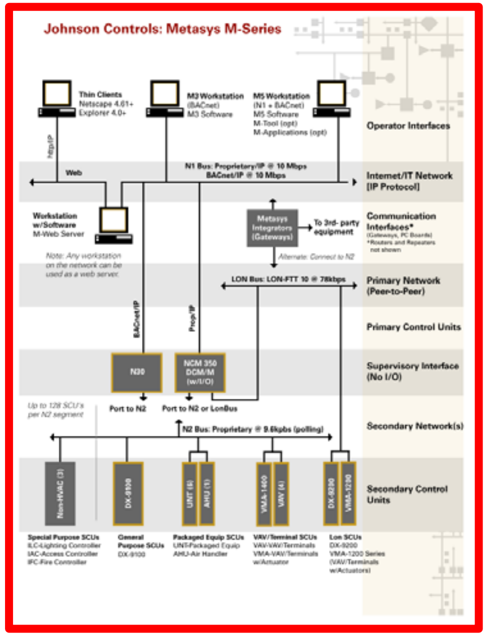


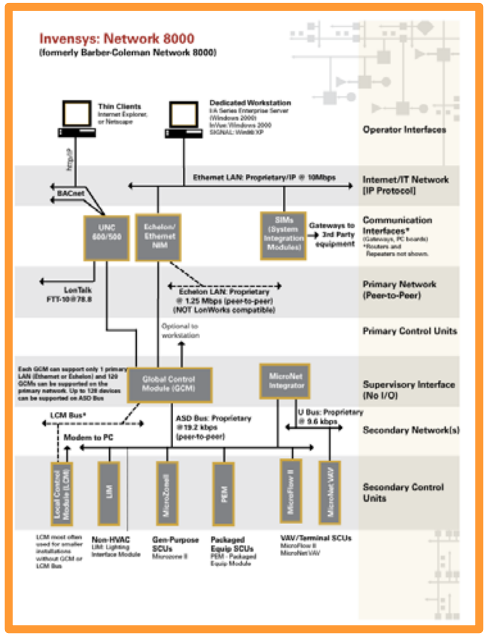
They’re Not All Equal

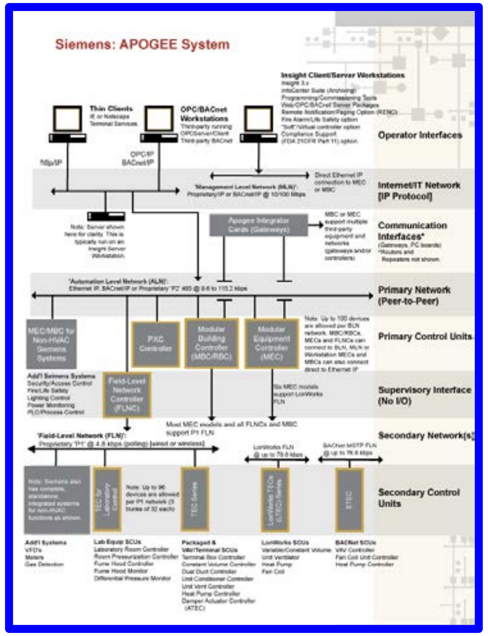
Specifications Can Define Critical Requirements

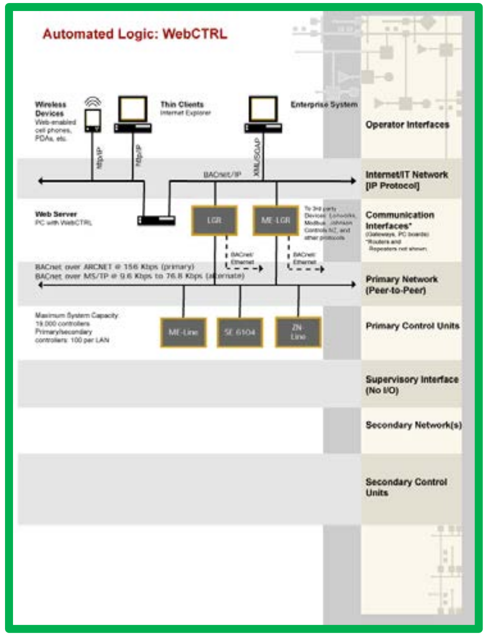
- Software
- Point capacity
- Global strategies
- A to D resolution
- Speed
- Network protocol
- Memory
- Real time clock
- Buffers
- Fully programmable
- Downloadable
- PC interface





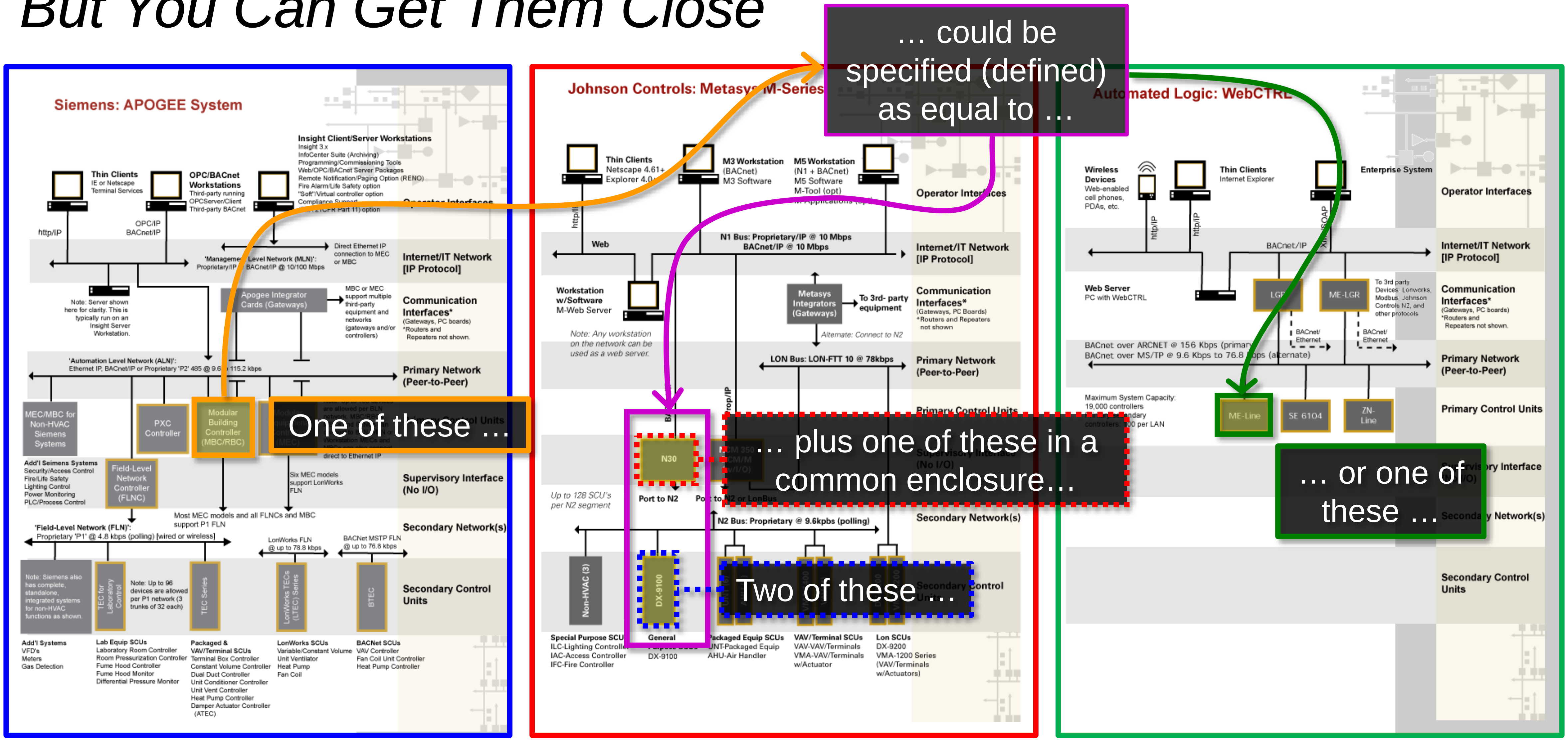






They're Not All Equal

But You Can Get Them Close



Must Have’s

- Point List

Bureacratic Affairs Building 1st Floor Hot Water System

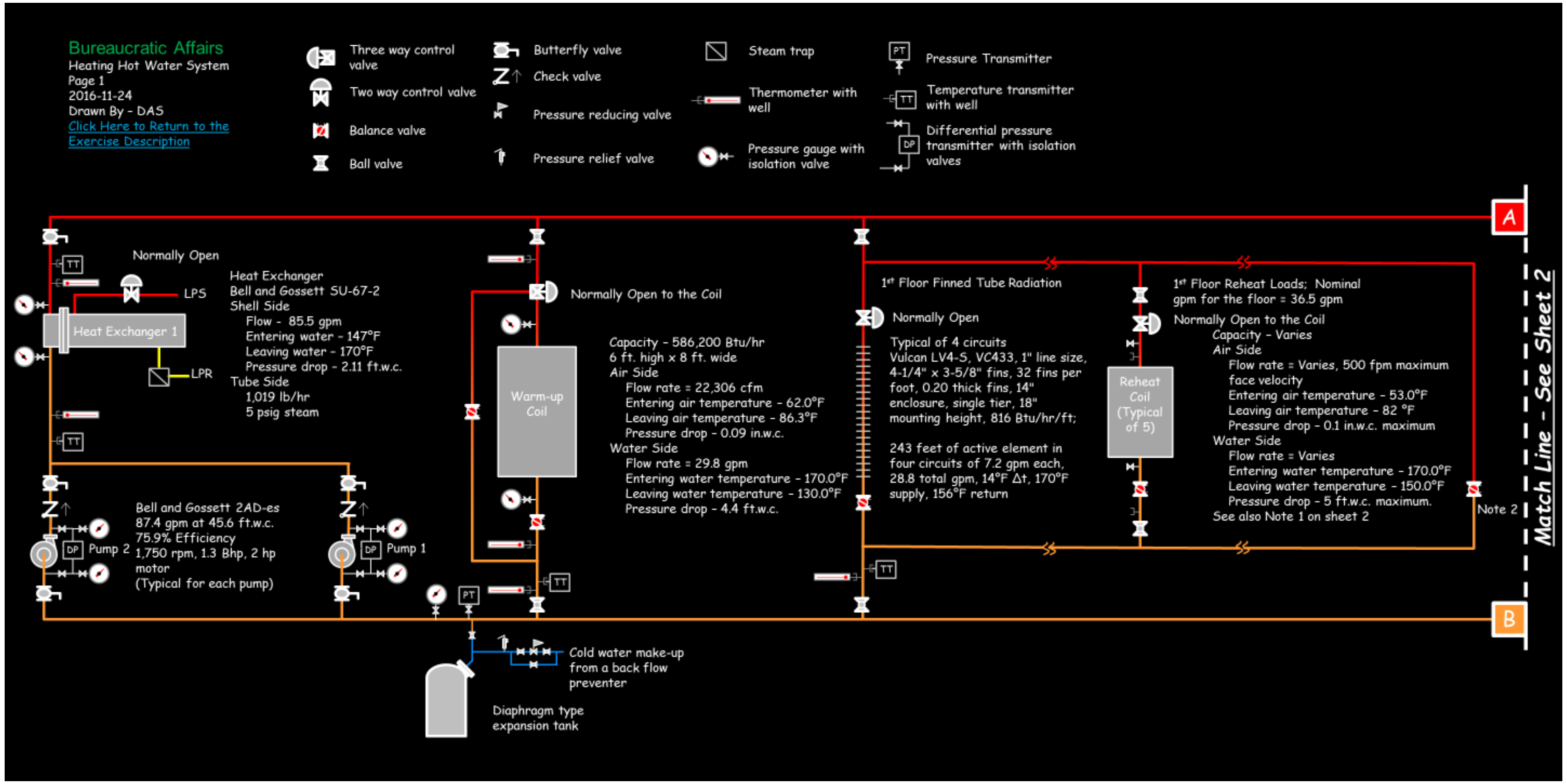
Point		Sensor			Features											Notes
Name (Note 6)	Description and Service	Type	Reference Spec Paragraph	Accuracy	Alarms				Trending							
					Limit		Warning		Samples[1]	Commissioning[5]			Operating[5]			
					Hi	Lo	Hi	Lo		Time[2]	Local[3]	Archive	Time[2]	Local[3]	Archive	
Analog Inputs																
STHX-1-LWT	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
SYSTM-OAT	System OAT	Single point 1,000 Ω Pt RTD with close coupled transmitter	25 35 00	0.75% of span for sensor + transmitter	None				12	5 min.	X	X	5 min.	X	X	
STHX-1-EWT	Shell and Tube Heat Exchanger -1 Ent. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
Analog Outputs (All analog outputs to include local override capability and status indication at the controller)																
STHX-1-STMVLV-CMD	Shell and Tube Heat Exchanger -1 Steam Valve Command	4-20 ma actuator	25 35 13	N/A	N/A	N/A	N/A	N/A	60	1 min.	X	X	1 min.	X	X	
Digital Inputs																
HWPMP-1-DPSW	Hot Water Pump -1 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X	
HWPMP-2-DPSW	Hot Water Pump -2 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X	
Virtual Points																
STHX-1-LWT-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-PG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Proportional Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-IG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Integral Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-DG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Derivative Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-OFF	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Loop Off Value	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	Note 9
STHX-1-OAT-RSTILO-SP	Shell and Tube Heat Exchanger -1 OAT Reset Lo Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-OAT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 OAT Reset Hi Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTILO-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Lo Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Hi Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-UNOCC-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Unoccupied Set Pn	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-CLS-SP	Shell and Tube Heat Exchanger -1 Close Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	

Notes:

1. Samples indicates the minimum number of data samples that must be held in the local controller if it is trending the point.
2. Time indicates the required sampling time for the trending function.
3. A check in the local column indicates that the trending only needs to be running in the local controller and the most recent value can write over the last value when the trend buffer fills up.
4. A check in the archive column indicates that the trend data must be archived to the system hard disc when trend buffer fills up so that a continuous trend record is maintained.
5. Commissioning trending requirements only need to be implemented during the start-up and warranty year. After the start-up and warranty process, the control contractor should set the trending parameters to the operating requirements listed if they differ from the commissioning requirements.
6. Point numbers are based on the Owner's point naming convention which is included in the specification. Point names will be verified during the submittal process in the control system integration and coordination meeting.
7. To be determined during the Control System Integration and Coordination Meeting
8. Furnish two wells for installation adjacent to each other by the mechanical contractor. One well is for the sensor and one is for calibration purposes. See the spec and detail.
9. The design intent is that the control loop is a PI loop with derivative added only if tuning in the field indicates that it is necessary to manage the response to a step change or reduce the settling time. Coordinate with the control system designer and Owner proir to adding derviative gain, but provide the point so it is there if needed.

Must Have’s

- Point List
- System Diagram



Must Have's

- Point List
- System Diagram
- Narrative Sequence

Bureaucratic Affairs Building Heat Exchanger Leaving Water Temperature Control

Overview

This sequence applies to the Bureaucratic Affairs Building hot water system steam heat exchanger. The heat exchanger serves finned tube radiation, reheat coils, and a warm-up coil. It is intended to be in operation any time either of the heating hot water pumps are in operation to deliver 170°F water to the loads.

Steam Valve Control

A temperature sensor located in the discharge piping from the heat exchanger serves as an input to a direct acting Proportional plus Integral (PI) control loop. The output of the control loop is used to modulate a normally open steam valve via a 4-20 ma signal that, in turn generates a 3-15 psi pneumatic signal via an electro-pneumatic signal convertor for valve actuation.

The set point of the loop is reset based on outdoor air temperature. The reset schedule set points shall be operator adjustable by an operator with administrator credentials. The initial set points are as follows:

- The hot water supply temperature is 170°F when the outdoor air temperature is 7.4°F. These values represent the design conditions.
- The hot water temperature is 102.5°F when the outdoor air temperature is 55°F. These values target matching the finned tube radiation performance to the perimeter heating load at 55°F outdoors with a 72°F indoor temperature.

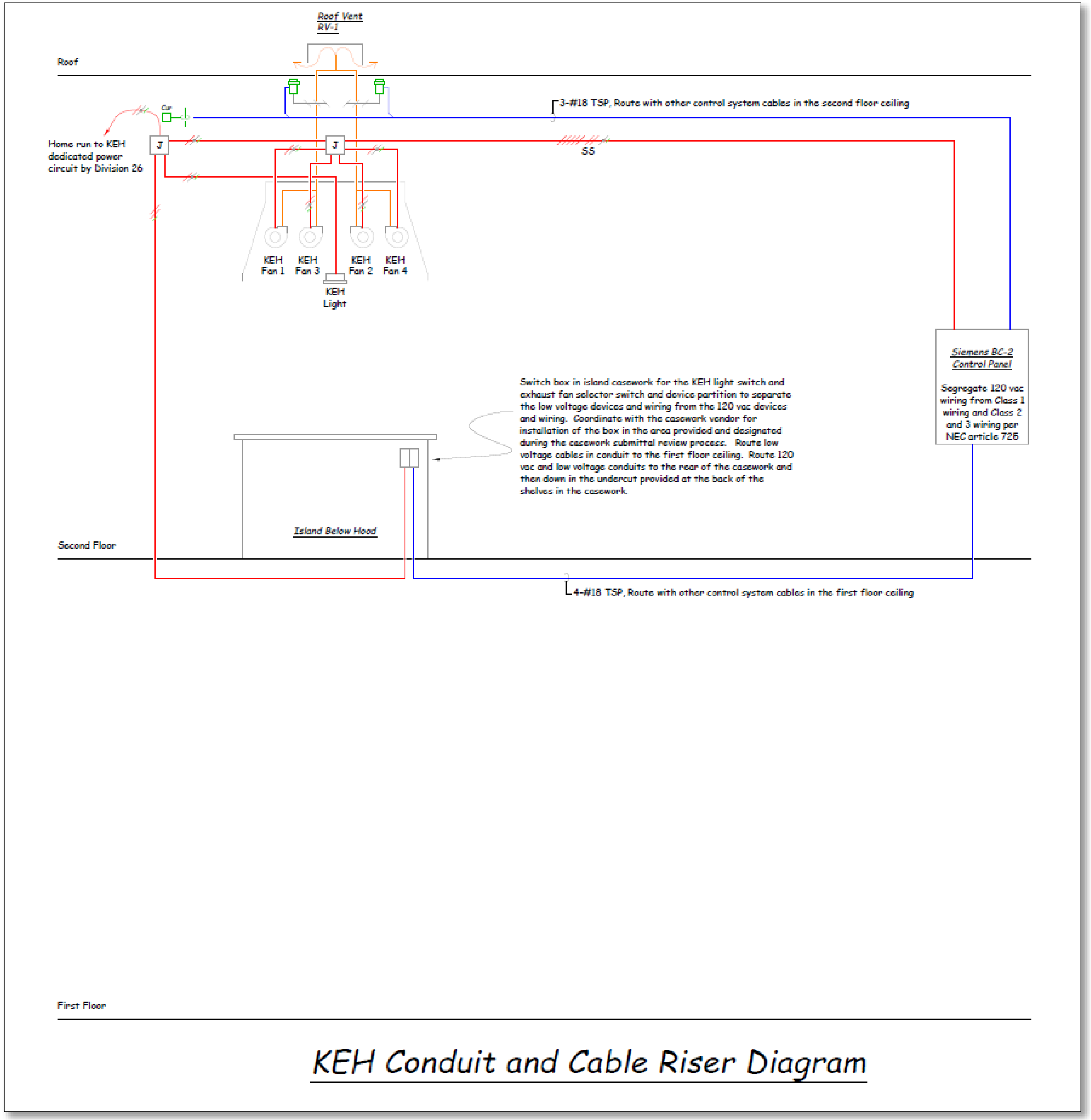
The set point is are limited to a maximum of 170°F and a minimum of 102.5°F, no matter what the output of the reset calculation is.

When the building is unoccupied, the hot water set point shall be maintained at 140°F to provide capacity for the night set back cycle when it is initiated.

As the supply temperature deviates above set point, the output of the control loop modulates from 4 ma towards 20 ma (3 psi towards 15 psi to the actuator), causing the normally open valve to modulate closed. As the supply temperature deviates below set point, the output of the control loop modulates from 20 ma towards 4 ma (15 psi towards 3 psi to the actuator), causing the normally open valve to modulate closed.

Must Have's

- Point List
- System Diagram
- Narrative Sequence
- Details



Must Have's

- Point List
- System Diagram
- Narrative Sequence
- Details
- Specifications

250800 - Integrated Automation - Commissioning

251116 - Integrated Automation - Network Hardware

251413 - Integrated Automation - Remote Control Panels

251516 - Integrated Automation - Software

253500 - Integrated Automation - Instrumentation and Terminal Devices

253513 - Integrated Automation - Actuators and Operators

253516 - Integrated Automation - Sensors and Transmitters

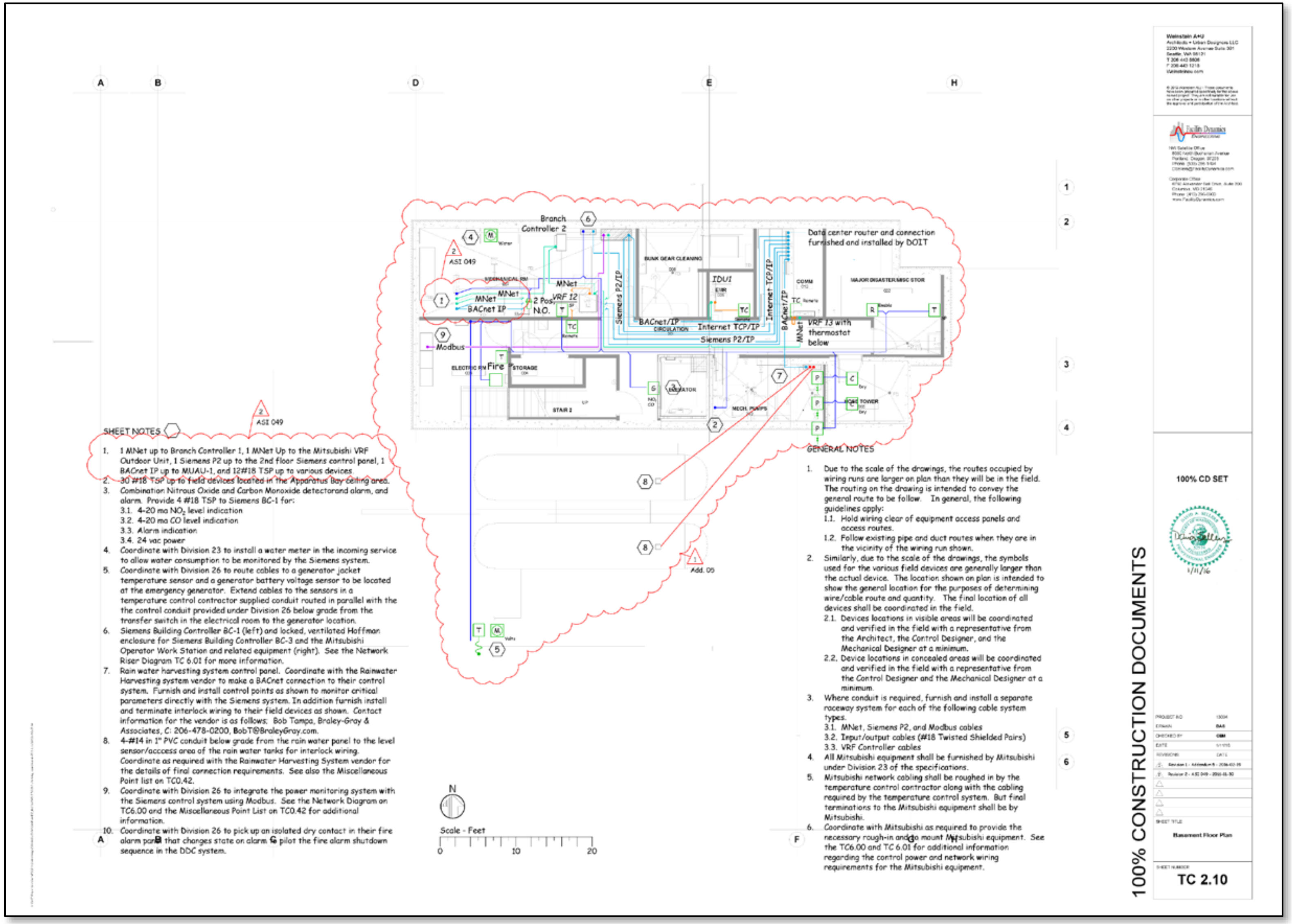
253519 - Integrated Automation - Control Valves

255500 - Integrated Automation - Control of HVAC

255500.13 - Integrated Automation - Control of HVAC-Object Naming Conventions

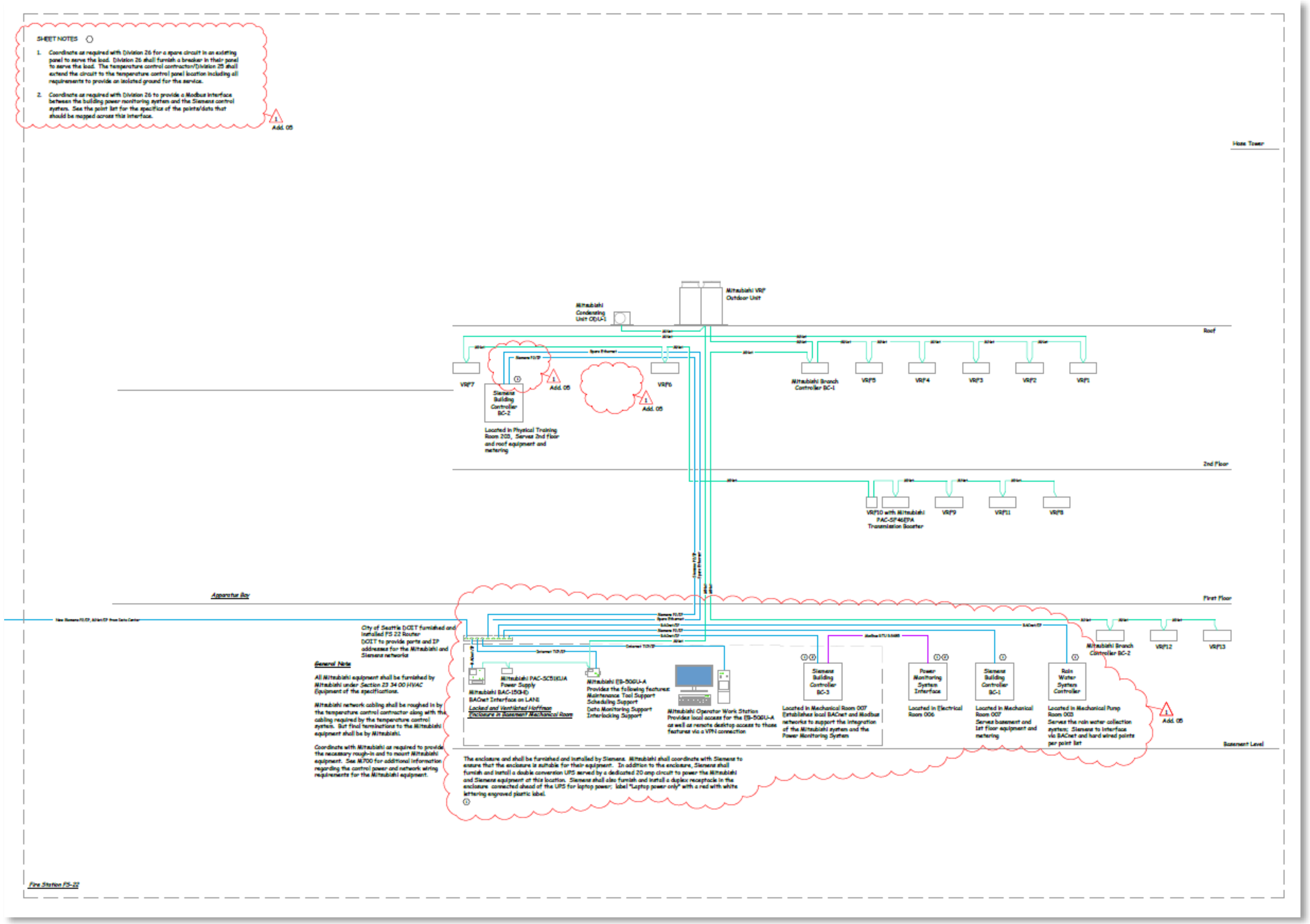
Nice Additions

- Floor Plans



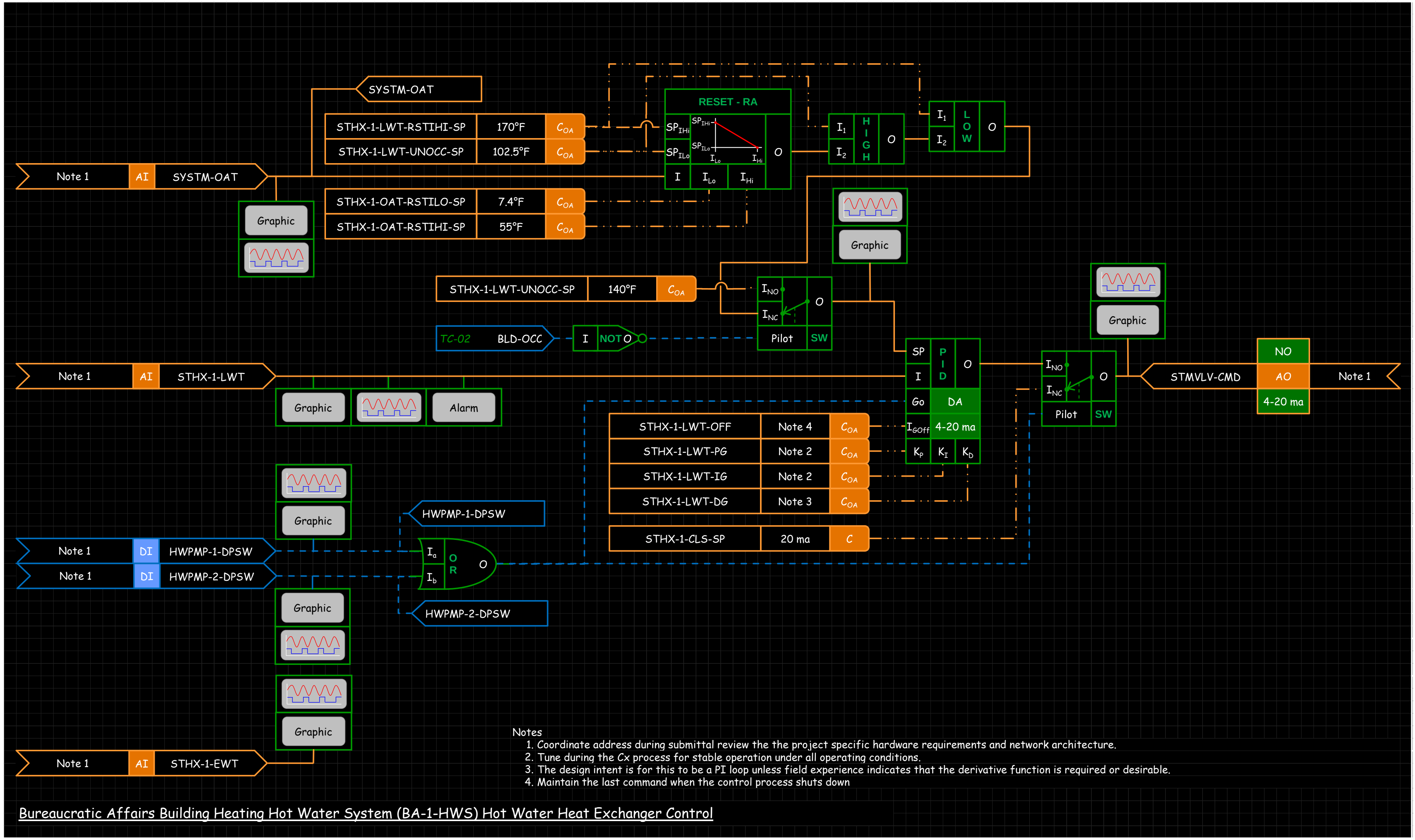
Nice Additions

- Floor Plans
- Network Diagrams



Nice Additions

- Floor Plans
- Network Diagrams
- Logic Diagrams



If Nothing Else, Make a Point List

Point Naming Conventions Establish Consistency

Point
Name (Note 6)
Analog Inputs
STHX-1-LWT
SYSTM-OAT
STHX-1-EWT
Analog Outputs (All analog outputs to include local

Bureacratic Affairs Building 1st Floor Hot Water System

Point Name (Note 6)	Description and Service	Sensor Type	Reference Spec Paragraph	Accuracy	Alarms Limit Hi	Alarms Limit Lo	Alarms Warning Hi	Alarms Warning Lo	Trending Samples[1]	Commissioning[5] Time[2]	Commissioning[5] Local[3]	Commissioning[5] Archive[4]	Operating[5] Time[2]	Operating[5] Local[3]	Operating[5] Archive[4]	Notes
Analog Inputs																
STHX-1-LWT	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
SYSTM-OAT	System OAT	Single point 1,000 Ω Pt RTD with close coupled transmitter	25 35 00	0.75% of span for sensor + transmitter	None				12	5 min.	X	X	5 min.	X	X	
STHX-1-EWT	Shell and Tube Heat Exchanger -1 Ent. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
Analog Outputs (All analog outputs to include local override capability and status indication at the controller)																
STHX-1-STMVLV-CMD	Shell and Tube Heat Exchanger -1 Steam Valve Command	4-20 ma actuator	25 35 13	N/A	N/A	N/A	N/A	N/A	60	1 min.	X	X	1 min.	X	X	
Digital Inputs																
HWPMP-1-DPSW	Hot Water Pump -1 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X	
HWPMP-2-DPSW	Hot Water Pump -2 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X	
Virtual Points																
STHX-1-LWT-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-PG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Proportional Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-IG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Integral Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-DG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Derivative Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-OFF	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Loop Off Value	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	Note 9
STHX-1-OAT-RSTILO-SP	Shell and Tube Heat Exchanger -1 OAT Reset Lo Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-OAT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 OAT Reset Hi Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTILO-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Lo Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Hi Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-UNOCC-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Unoccupied Set Pn	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-CLS-SP	Shell and Tube Heat Exchanger -1 Close Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	

Notes:

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If Nothing Else, Make a Point List

Description Conveys Intent

Description and Service

Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp.

System OAT

Shell and Tube Heat Exchanger -1 Ent. Wtr. Temp.

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Point		Sensor			Features											Notes
Name (Note 6)	Description and Service	Type	Reference Spec Paragraph	Accuracy	Alarms				Trending							
					Limit		Warning		Samples[1]	Commissioning[5]			Operating[5]			
					Hi	Lo	Hi	Lo		Time[2]	Local[3]	Archive[4]	Time[2]	Local[3]	Archive[4]	
Analog Inputs																
STHX-1-LWT	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
SYSTM-OAT	System OAT	Single point 1,000 Ω Pt RTD with close coupled transmitter	25 35 00	0.75% of span for sensor + transmitter	None				12	5 min.	X	X	5 min.	X	X	
STHX-1-EWT	Shell and Tube Heat Exchanger -1 Ent. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
Analog Outputs (All analog outputs to include local override capability and status indication at the controller)																
STHX-1-STMVLV-CMD	Shell and Tube Heat Exchanger -1 Steam Valve Command	4-20 ma actuator	25 35 13	N/A	N/A	N/A	N/A	N/A	60	1 min.	X	X	1 min.	X	X	
Digital Inputs																
HWPMP-1-DPSW	Hot Water Pump -1 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X	
HWPMP-2-DPSW	Hot Water Pump -2 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X	
Virtual Points																
STHX-1-LWT-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-PG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Proportional Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-IG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Integral Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-DG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Derivative Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-OFF	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Loop Off Value	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	Note 9
STHX-1-OAT-RSTILO-SP	Shell and Tube Heat Exchanger -1 OAT Reset Lo Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-OAT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 OAT Reset Hi Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTILO-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Lo Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Hi Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-UNOCC-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Unoccupied Set Pn	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-CLS-SP	Shell and Tube Heat Exchanger -1 Close Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	

Notes:

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If Nothing Else, Make a Point List

Sensor Type Establishes Performance Level Required

Sensor
Type
1,000 Ω Pt RTD with close coupled transmitter and thermometer well
Single point 1,000 Ω Pt RTD with close coupled transmitter
1,000 Ω Pt RTD with close coupled transmitter and thermometer well

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Point Name (Note 6)	Description and Service	Sensor Type	Reference Spec Paragraph	Accuracy	Features: Alarms Limit Hi	Alarms Limit Lo	Alarms Warning Hi	Alarms Warning Lo	Trending Samples[1]	Commissioning[5] Time[2]	Commissioning Local[3]	Commissioning Archive[4]	Operating[5] Time[2]	Operating Local[3]	Operating Archive[4]	Notes
Analog Inputs																
STHX-1-LWT	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
SYSTM-OAT	System OAT	Single point 1,000 Ω Pt RTD with close coupled transmitter	25 35 00	0.75% of span for sensor + transmitter	None				12	5 min.	X	X	5 min.	X	X	
STHX-1-EWT	Shell and Tube Heat Exchanger -1 Ent. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
Analog Outputs (All analog outputs to include local override capability and status indication at the controller)																
STHX-1-STMVLV-CMD	Shell and Tube Heat Exchanger -1 Steam Valve Command	4-20 ma actuator	25 35 13	N/A	N/A	N/A	N/A	N/A	60	1 min.	X	X	1 min.	X	X	
Digital Inputs																
HWPMP-1-DPSW	Hot Water Pump -1 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X	
HWPMP-2-DPSW	Hot Water Pump -2 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X	
Virtual Points																
STHX-1-LWT-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-PG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Proportional Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-IG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Integral Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-DG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Derivative Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-OFF	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Loop Off Value	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	Note 9
STHX-1-OAT-RSTILO-SP	Shell and Tube Heat Exchanger -1 OAT Reset Lo Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-OAT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 OAT Reset Hi Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTILO-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Lo Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Hi Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-UNOCC-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Unoccupied Set Pn	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-CLS-SP	Shell and Tube Heat Exchanger -1 Close Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	

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If Nothing Else, Make a Point List

Specification Reference and Accuracy Reinforce Performance Requirements

Reference Spec Paragraph	Accuracy
25 35 00	0.75% of span for sensor + transmitter
25 35 00	0.75% of span for sensor + transmitter
25 35 00	0.75% of span for sensor + transmitter

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Point Name (Note 6)	Description and Service	Sensor Type	Reference Spec Paragraph	Accuracy	Alarms Limit Hi	Alarms Limit Lo	Alarms Warning Hi	Alarms Warning Lo	Trending Samples[1]	Commissioning[5] Time[2]	Commissioning[5] Local[3]	Commissioning[5] Archive[4]	Operating[5] Time[2]	Operating[5] Local[3]	Operating[5] Archive[4]	Notes
Analog Inputs																
STHX-1-LWT	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
SYSTM-OAT	System OAT	Single point 1,000 Ω Pt RTD with close coupled transmitter	25 35 00	0.75% of span for sensor + transmitter	None				12	5 min.	X	X	5 min.	X	X	
STHX-1-EWT	Shell and Tube Heat Exchanger -1 Ent. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
Analog Outputs (All analog outputs to include local override capability and status indication at the controller)																
STHX-1-STMVLV-CMD	Shell and Tube Heat Exchanger -1 Steam Valve Command	4-20 ma actuator	25 35 13	N/A	N/A	N/A	N/A	N/A	60	1 min.	X	X	1 min.	X	X	
Digital Inputs																
HWPMP-1-DPSW	Hot Water Pump -1 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X	
HWPMP-2-DPSW	Hot Water Pump -2 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X	
Virtual Points																
STHX-1-LWT-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-PG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Proportional Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-IG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Integral Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-DG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Derivative Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-OFF	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Loop Off Value	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	Note 9
STHX-1-OAT-RSTILO-SP	Shell and Tube Heat Exchanger -1 OAT Reset Lo Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-OAT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 OAT Reset Hi Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTILO-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Lo Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Hi Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-UNOCC-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Unoccupied Set Pn	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-CLS-SP	Shell and Tube Heat Exchanger -1 Close Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	

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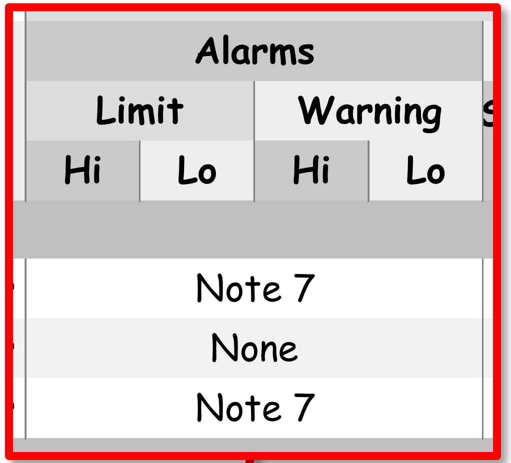
If Nothing Else, Make a Point List

Alarm Requirements Tailor the System to the Operator's Needs and Your Design Concerns



Bureacratic Affairs Building 1st Floor Hot Water System																
Point		Sensor			Features											Notes
Name (Note 6)	Description and Service	Type	Reference Spec Paragraph	Accuracy	Alarms				Trending							
					Limit		Warning		amples[1]	Commissioning[5]			Operating[5]			
					Hi	Lo	Hi	Lo		Time[2]	Local[3]	Archive	Time[2]	Local[3]	Archive	
Analog Inputs																
STHX-1-LWT	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitte	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
SYSTM-OAT	System OAT	Single point 1,000 Ω Pt RTD with close coupled transmitter	25 35 00	0.75% of span for sensor + transmitte	None				12	5 min.	X	X	5 min.	X	X	
STHX-1-EWT	Shell and Tube Heat Exchanger -1 Ent. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitte	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
Analog Outputs (All analog outputs to include local override capability and status indication at the controller)																
STHX-1-STMVLV-CMD	Shell and Tube Heat Exchanger -1 Steam Valve Command	4-20 ma actuator	25 35 13	N/A	N/A	N/A	N/A	N/A	60	1 min.	X	X	1 min.	X	X	
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Virtual Points																
STHX-1-LWT-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-PG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Proportional Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-IG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Integral Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-DG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Derivative Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-OFF	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Loop Off Value	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	Note 9
STHX-1-OAT-RSTILO-SP	Shell and Tube Heat Exchanger -1 OAT Reset Lo Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-OAT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 OAT Reset Hi Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTILO-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Lo Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Hi Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-UNOCC-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Unoccupied Set Pn	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-CLS-SP	Shell and Tube Heat Exchanger -1 Close Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	

Notes:

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If Nothing Else, Make a Point List

Trending Requirements Drive System Architecture and Memory and Support LEED

Trending						
Samples[1]	Commissioning[5]			Operating[5]		
	Time[2]	Local[3]	Archive[4]	Time[2]	Local[3]	Archive[4]
60	1 min.	X	X	1 min.	X	X
12	5 min.	X	X	5 min.	X	X
60	1 min.	X	X	1 min.	X	X

Bureacratic Affairs Building 1st Floor Hot Water System

Point		Sensor			Features												Notes
Name (Note 6)	Description and Service	Type	Reference Spec Paragraph	Accuracy	Alarms				Trending								
					Limit		Warning		Samples[1]	Commissioning[5]			Operating[5]				
					Hi	Lo	Hi	Lo		Time[2]	Local[3]	Archive[4]	Time[2]	Local[3]	Archive[4]		
Analog Inputs																	
STHX-1-LWT	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X		Note 8
SYSTM-OAT	System OAT	Single point 1,000 Ω Pt RTD with close coupled transmitter	25 35 00	0.75% of span for sensor + transmitter	None				12	5 min.	X	X	5 min.	X	X		
STHX-1-EWT	Shell and Tube Heat Exchanger -1 Ent. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X		Note 8
Analog Outputs (All analog outputs to include local override capability and status indication at the controller)																	
STHX-1-STMVLV-CMD	Shell and Tube Heat Exchanger -1 Steam Valve Command	4-20 ma actuator	25 35 13	N/A	N/A	N/A	N/A	N/A	60	1 min.	X	X	1 min.	X	X		
Digital Inputs																	
HWPMP-1-DPSW	Hot Water Pump -1 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X		
HWPMP-2-DPSW	Hot Water Pump -2 Differential Pressure Switch	Penn model P74FA-5 differential pressure switch	25 35 16 2.04	N/A	Note 7				10	COV	X	X	COV	X	X		
Virtual Points																	
STHX-1-LWT-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X		
STHX-1-LWT-PG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Proportional Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X		
STHX-1-LWT-IG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Integral Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X		
STHX-1-LWT-DG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Derivative Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X		
STHX-1-LWT-OFF	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Loop Off Value	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X		Note 9
STHX-1-OAT-RSTILO-SP	Shell and Tube Heat Exchanger -1 OAT Reset Lo Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X		
STHX-1-OAT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 OAT Reset Hi Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X		
STHX-1-LWT-RSTILO-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Lo Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X		
STHX-1-LWT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Hi Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X		
STHX-1-LWT-UNOCC-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Unoccupied Set Pn	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X		
STHX-1-CLS-SP	Shell and Tube Heat Exchanger -1 Close Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X		

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Notes

Note 8

Note 8

If Nothing Else, Make a Point List

Point Specific Notes Provide Additional Clarification if Needed

Bureacratic Affairs Building 1st Floor Hot Water System

Point		Sensor			Features											Notes
Name (Note 6)	Description and Service	Type	Reference Spec Paragraph	Accuracy	Alarms				Trending							
					Limit		Warning		Samples[1]	Commissioning[5]			Operating[5]			
					Hi	Lo	Hi	Lo		Time[2]	Local[3]	Archive[4]	Time[2]	Local[3]	Archive[4]	
Analog Inputs																
STHX-1-LWT	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
SYSTM-OAT	System OAT	Single point 1,000 Ω Pt RTD with close coupled transmitter	25 35 00	0.75% of span for sensor + transmitter	None				12	5 min.	X	X	5 min.	X	X	
STHX-1-EWT	Shell and Tube Heat Exchanger -1 Ent. Wtr. Temp.	1,000 Ω Pt RTD with close coupled transmitter and thermometer well	25 35 00	0.75% of span for sensor + transmitter	Note 7				60	1 min.	X	X	1 min.	X	X	Note 8
Analog Outputs (All analog outputs to include local override capability and status indication at the controller)																
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Digital Inputs																
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Virtual Points																
STHX-1-LWT-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-PG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Proportional Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-IG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Integral Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-DG	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Derivative Gain	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-OFF	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Loop Off Value	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	Note 9
STHX-1-OAT-RSTILO-SP	Shell and Tube Heat Exchanger -1 OAT Reset Lo Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-OAT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 OAT Reset Hi Lmt. Set Pnt.	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTILO-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Lo Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-RSTIHI-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Reset Hi Lmt. Set	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-LWT-UNOCC-SP	Shell and Tube Heat Exchanger -1 Lvg. Wtr. Temp. Unoccupied Set Pn	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	
STHX-1-CLS-SP	Shell and Tube Heat Exchanger -1 Close Set Pnt	N/A	25 35 00	N/A	Note 7				10	COV	X	X	COV	X	X	

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A Point List Tool

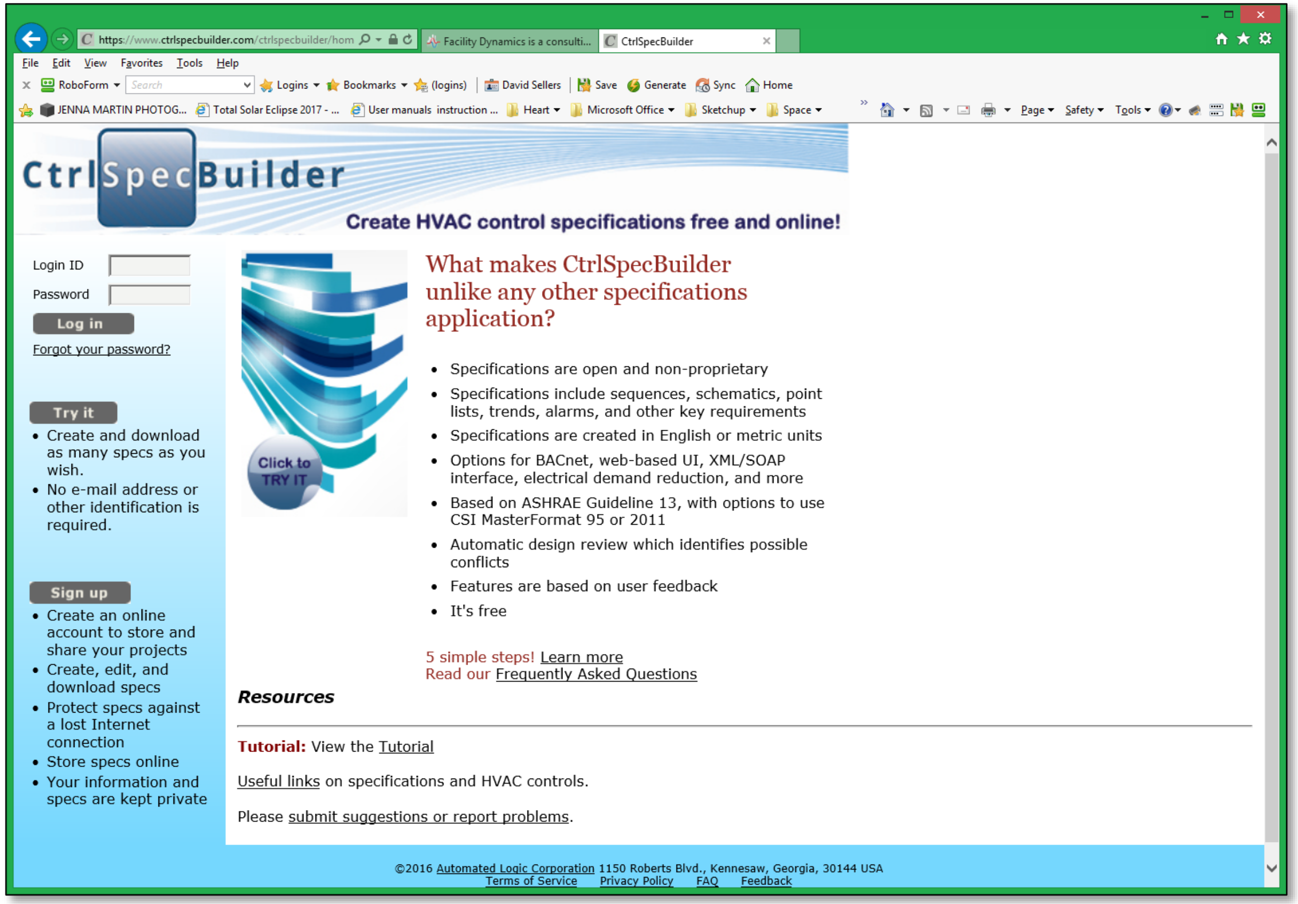
The Control Design Guide

- *Design process recommendations*
- *Sensor selection and application guidelines*
- *Point list tool*

A Specification Resource

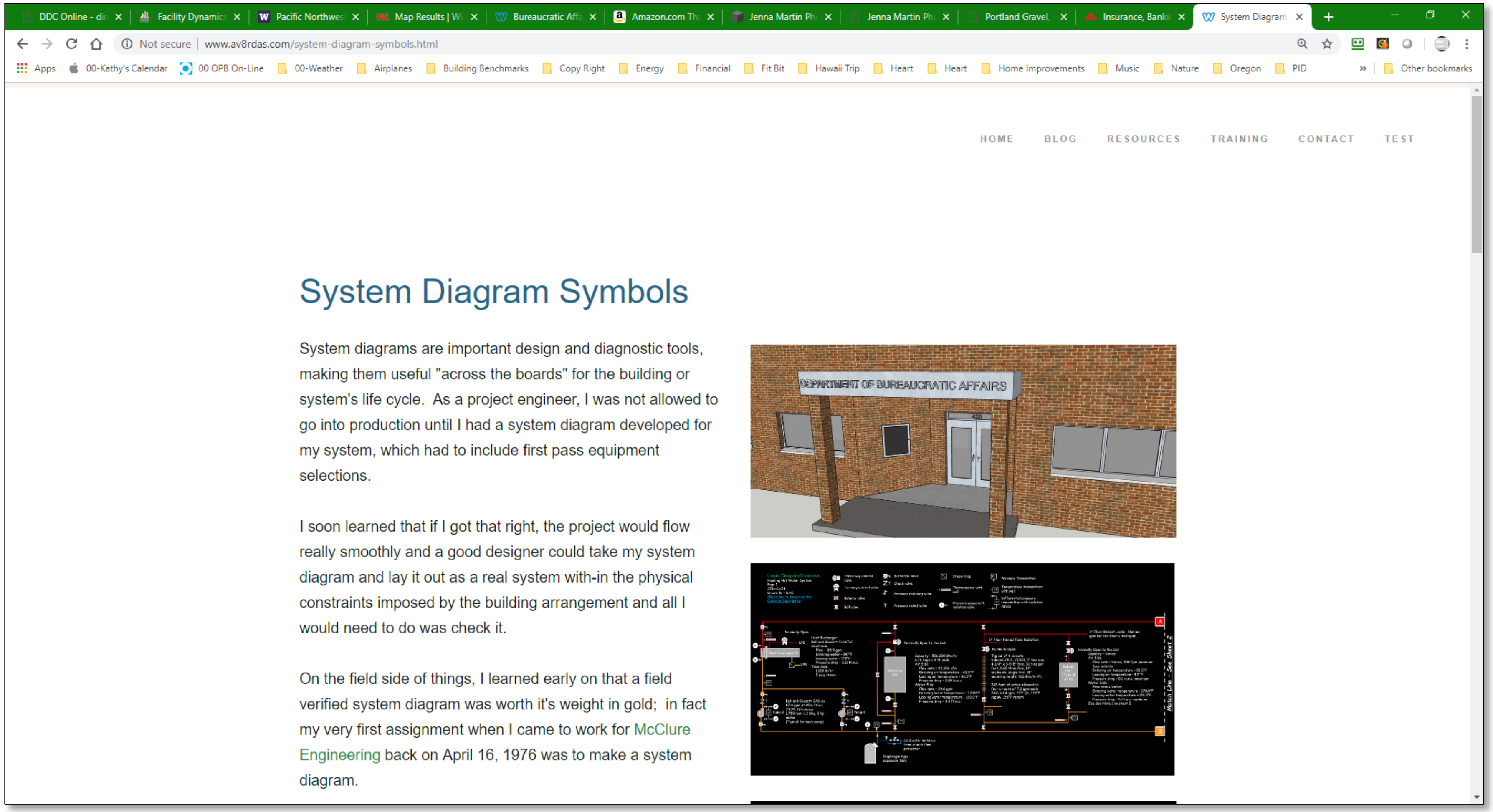
Control Spec Builder

- *Generic spec development in Word format*
- *Point list tool*
- *System diagram tool*
- *Sequence of operation tool*



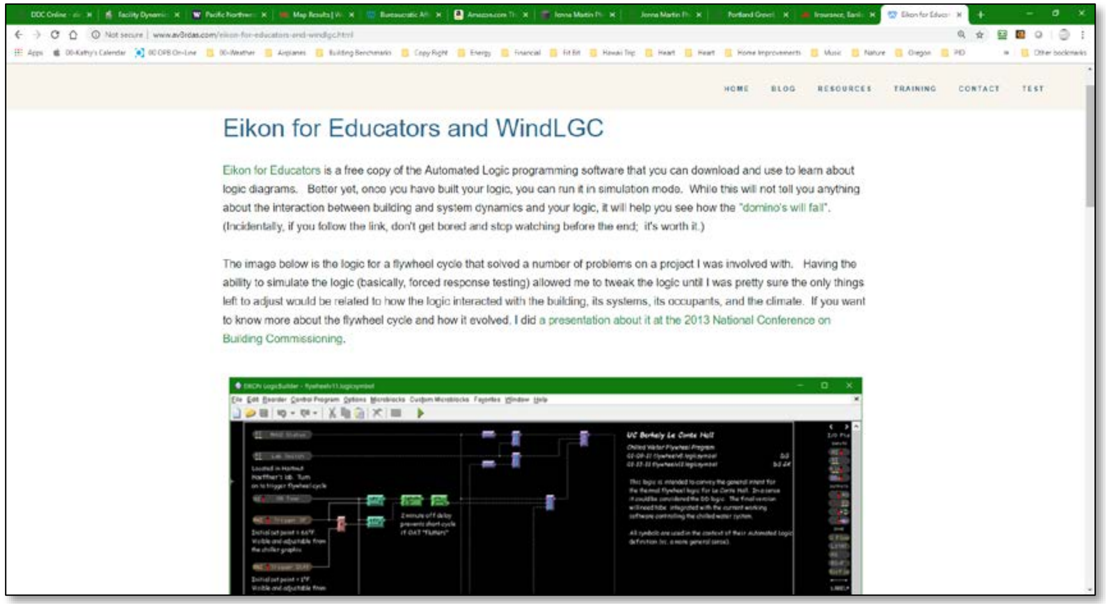
https://tinyurl.com/CntrlSpecTool

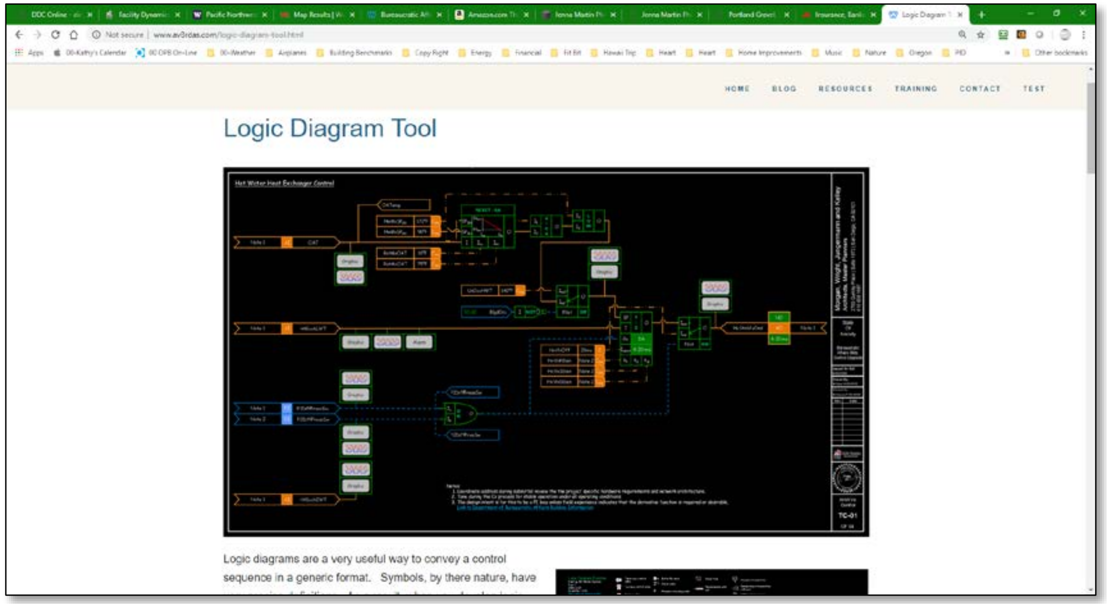
A System Diagram Tool



https://tinyurl.com/SystemDiagramTool

Logic Diagram Tools

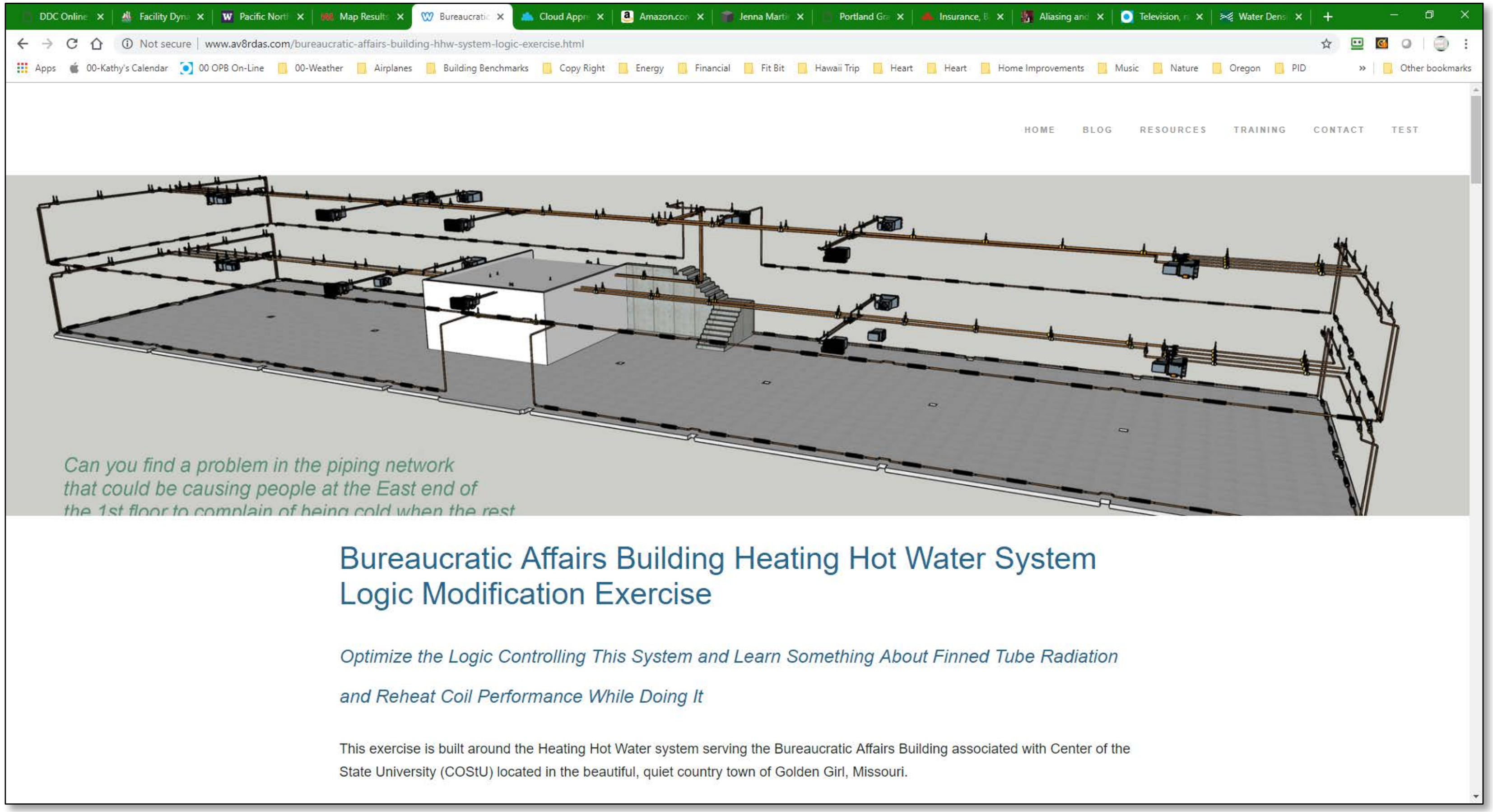




https://tinyurl.com/EikonWindLGC

https://tinyurl.com/LogicDiagramTool

A Logic Diagram Exercise



Blog Post Describing the Exercise

https://tinyurl.com/BABEasterEggHunt

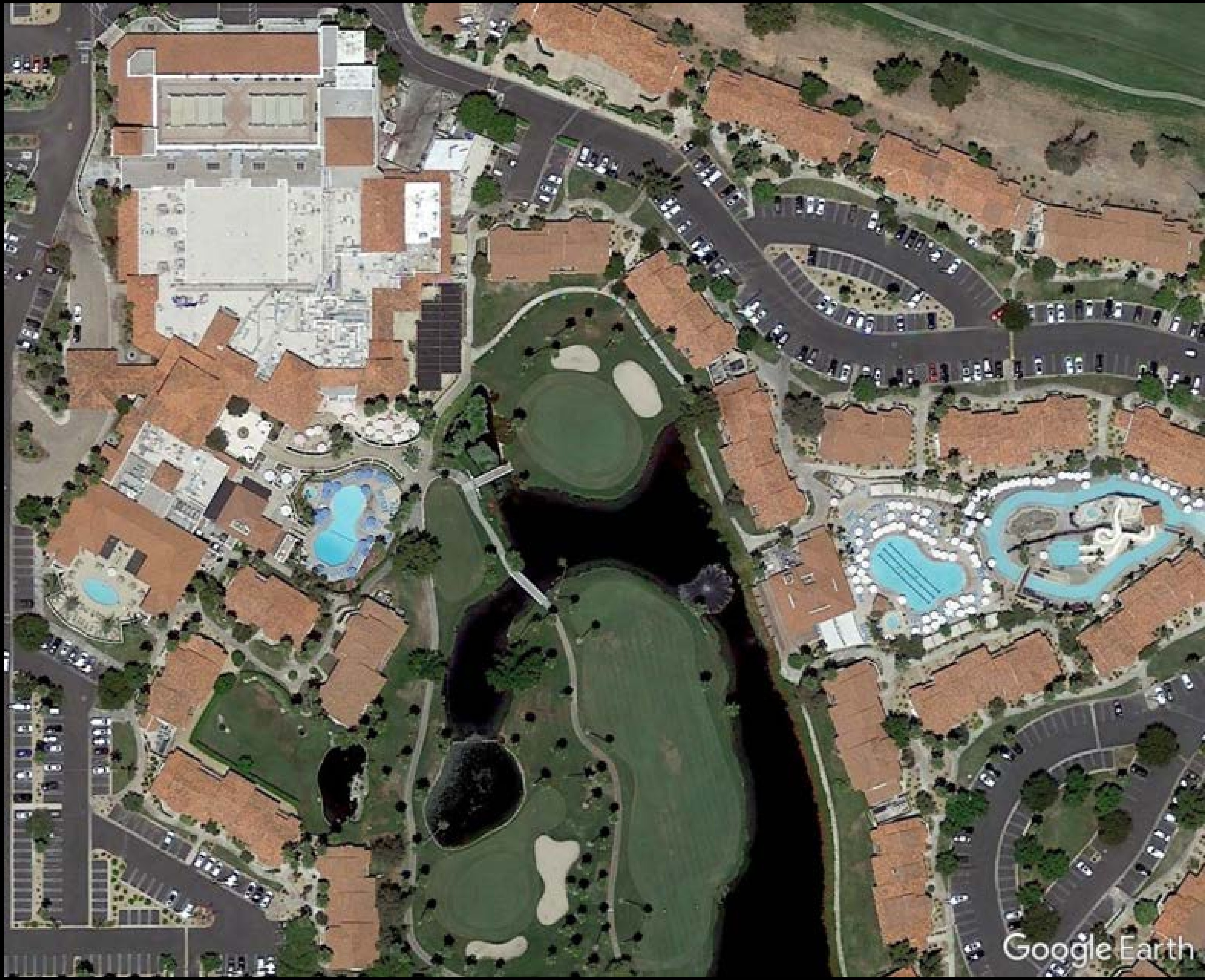
Exercise Set-up and Materials

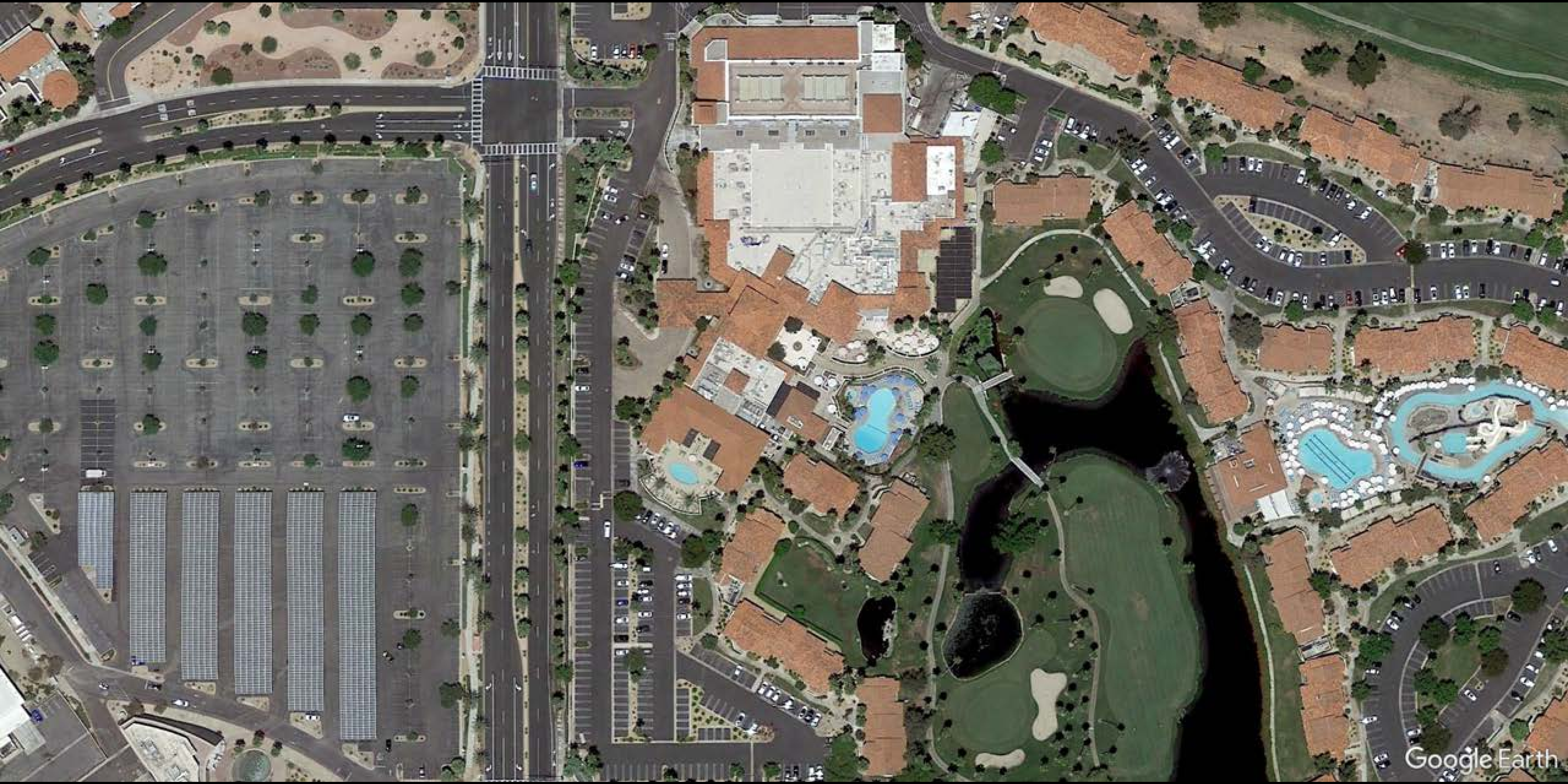
https://tinyurl.com/BABLogicEx

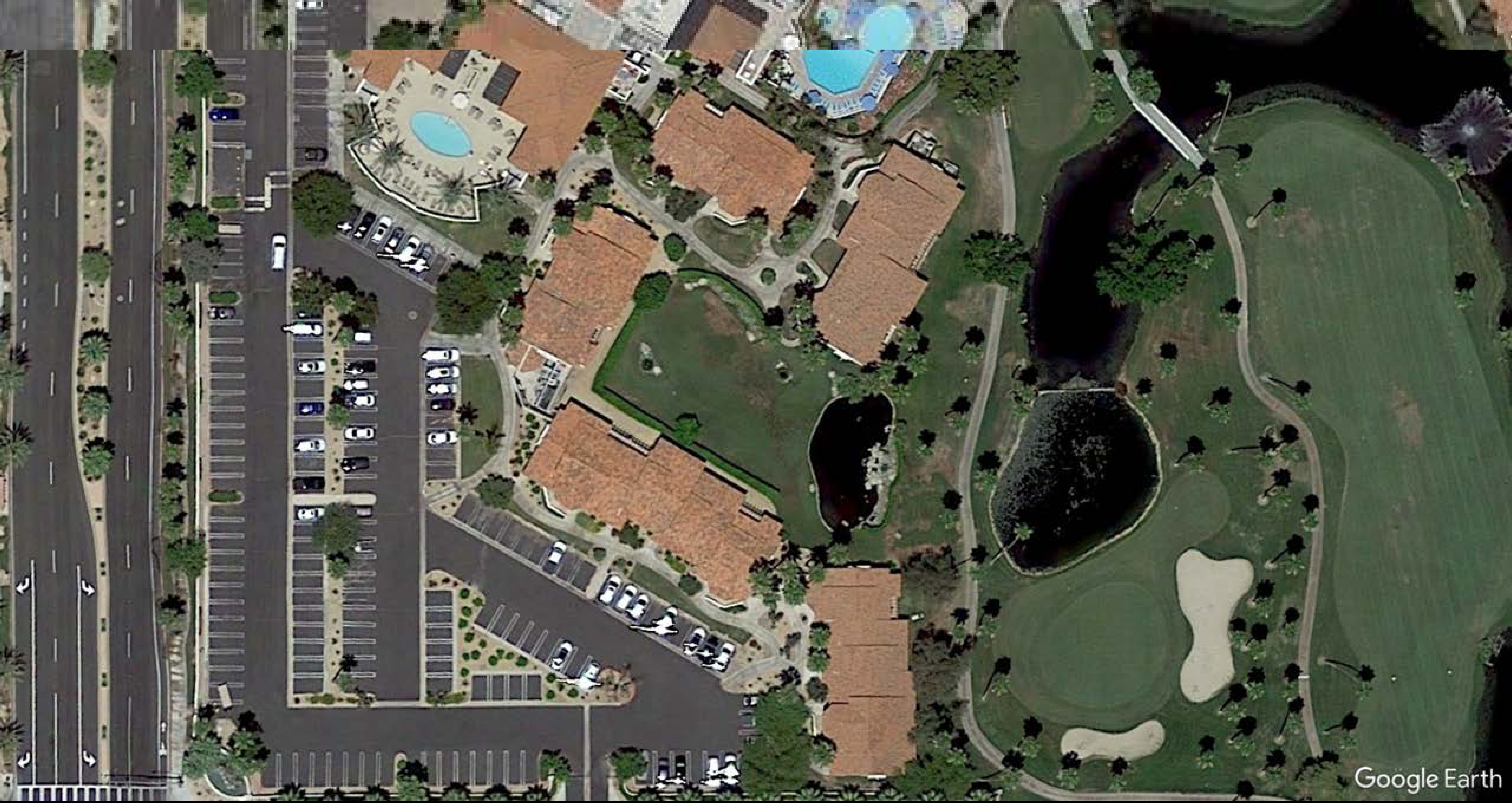
Applying the Concepts

A Hospitality Industry Campus Style Location

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

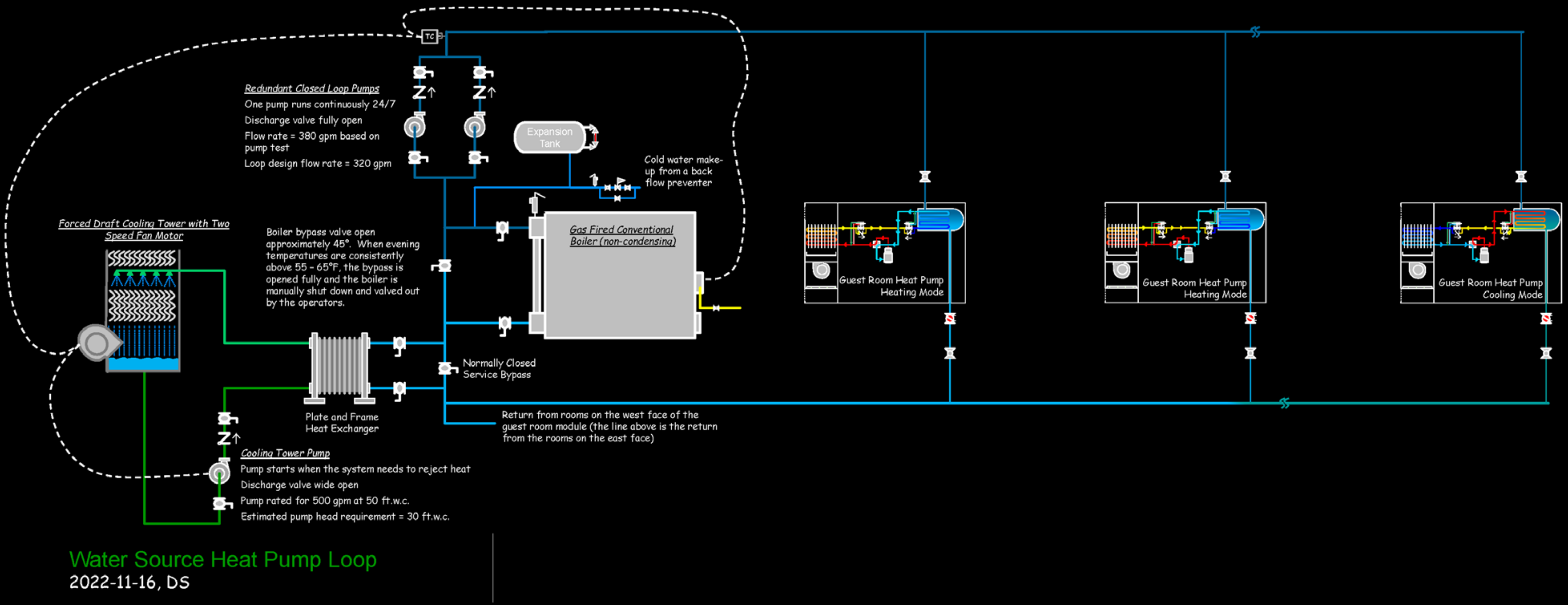


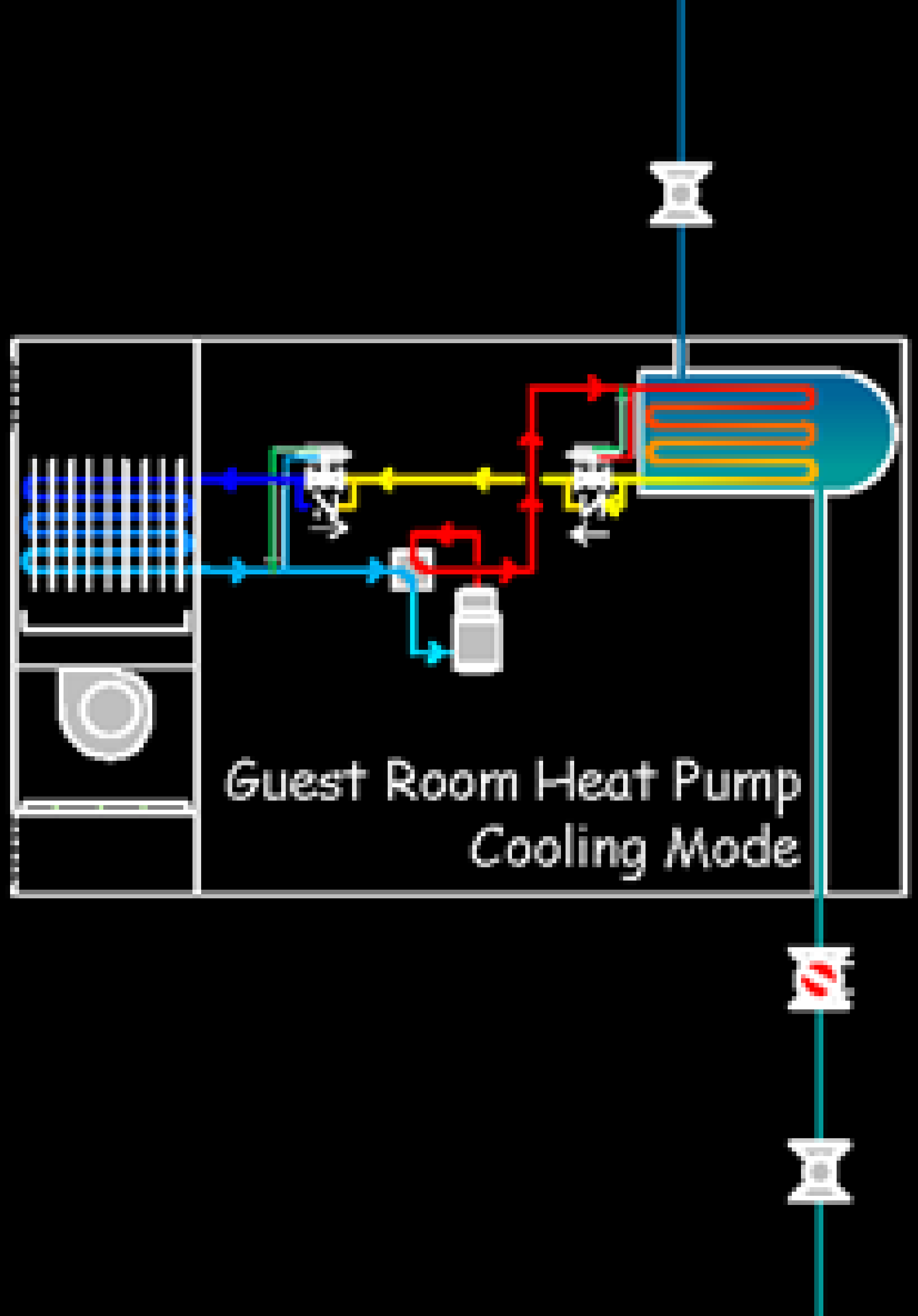

Google Earth

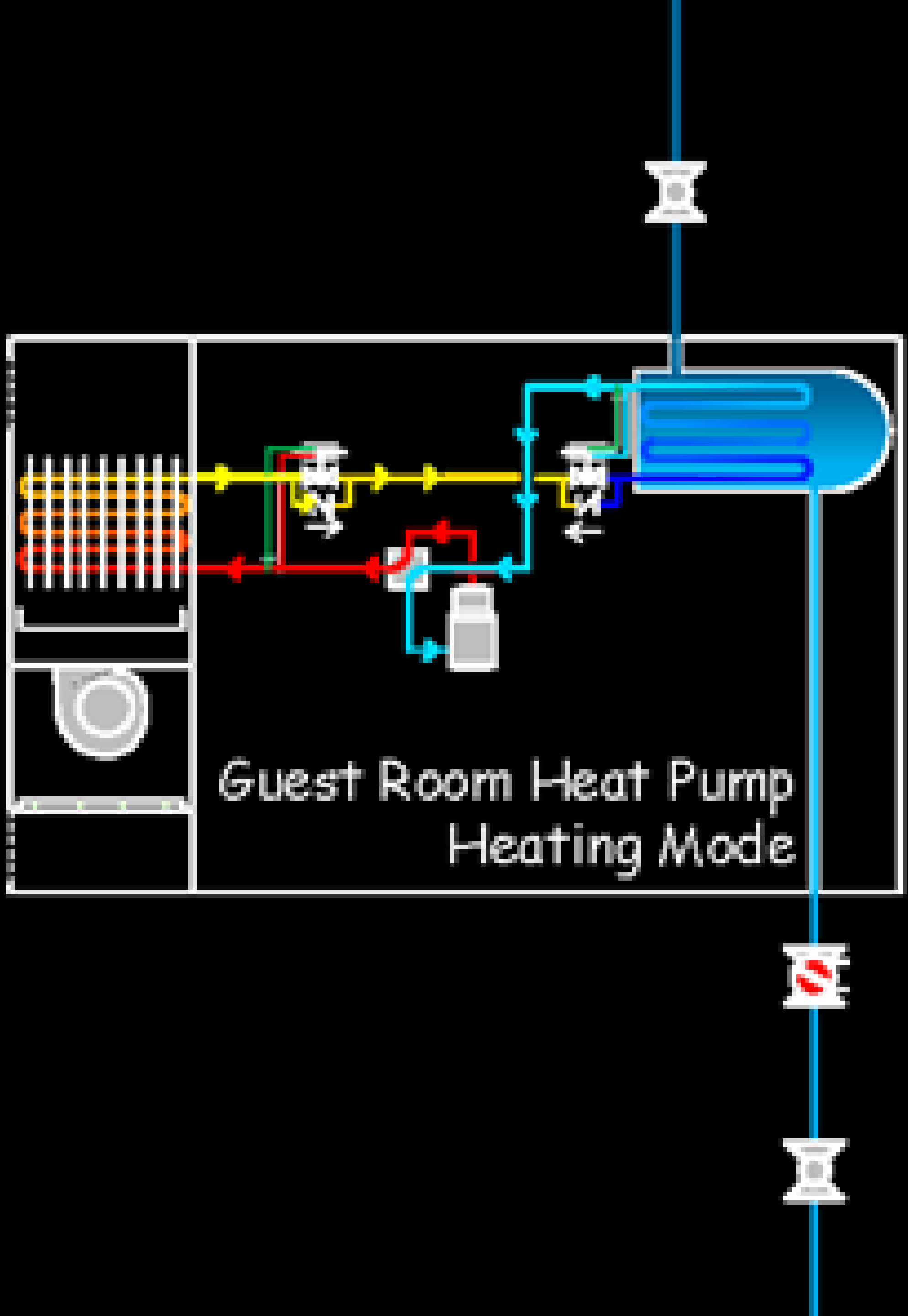

Google Earth

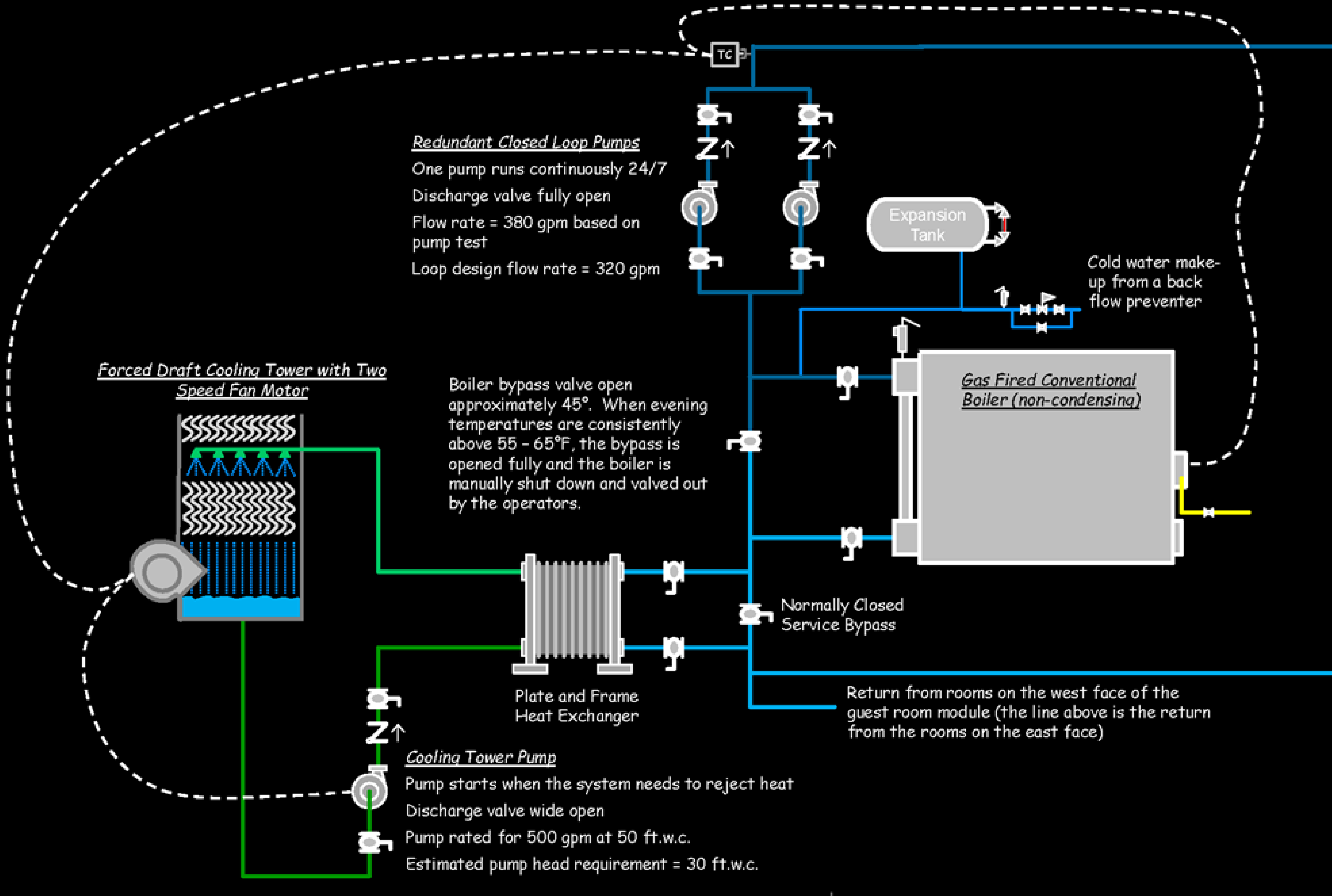



A Typical Guest Room Heat Pump Loop



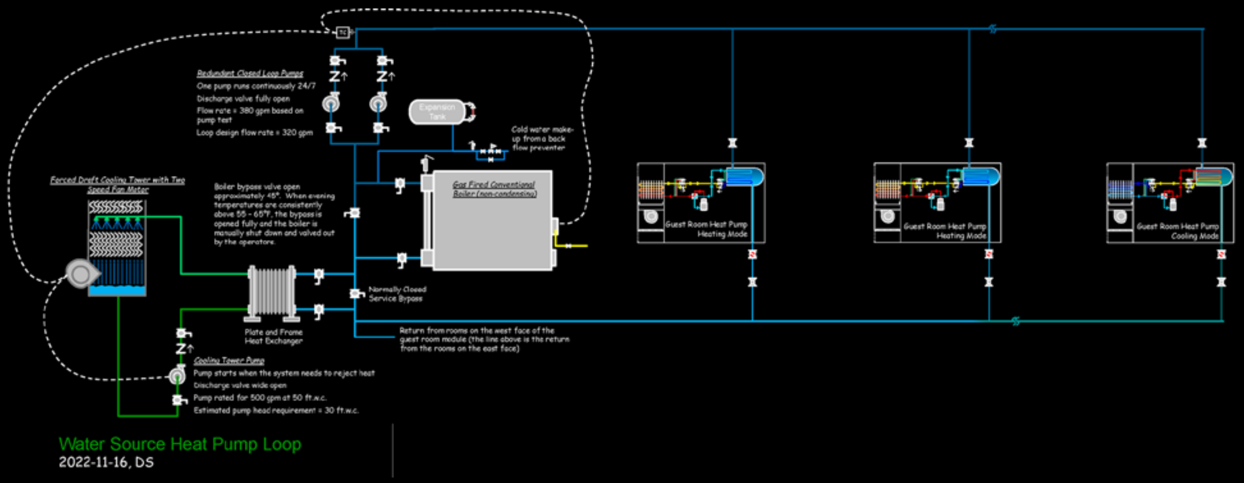

Guest Room Heat Pump
Cooling Mode


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.

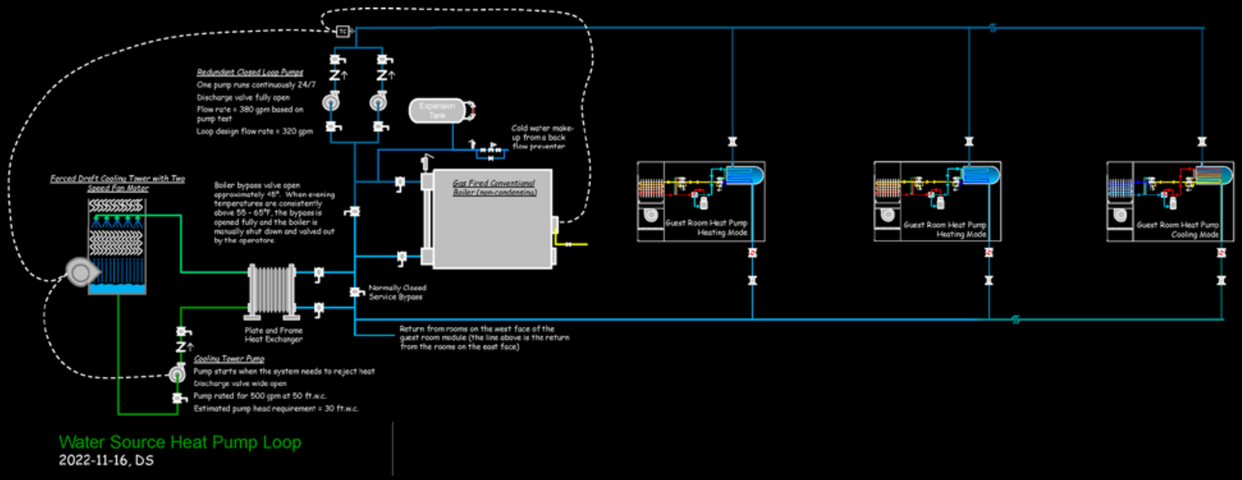
Given

- The water source heat pump system diagram
- Our discussions so far



Given

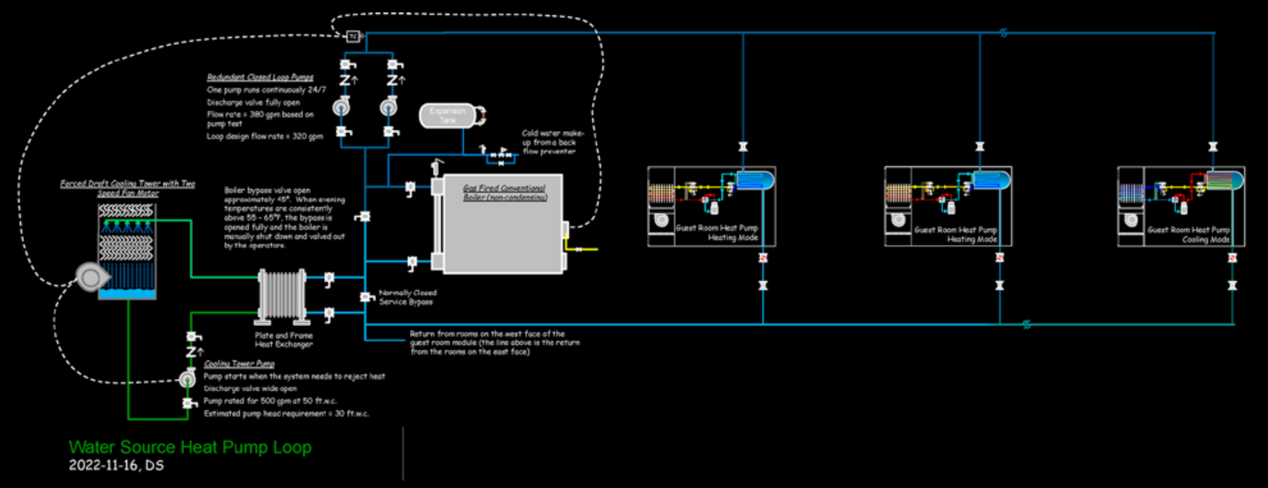
- The water source heat pump system diagram
- Our discussions so far
- The point list with the basic points required to control the system as shown on the design documents



Water Source Heat Pump Loop Points	
Point Name	System and Service
Analog Inputs	
System Supply Temperature	Guest Room Heat Pump Loop Supply Temperature
Digital Outputs	
Hot Water Boiler Enable	Auxilliary Heat Enable
Cooling Tower Fan Start/Stop	Cooling Tower Fan Control
Cooling Tower Pump Start/Stop	Cooling Tower Pump Control

Given

- The water source heat pump system diagram
- Our discussions so far
- The point list with the basic points required to control the system as shown on the design documents
- The basic point list loaded into the CDG Point List Template



Water Source Heat Pump Loop Points

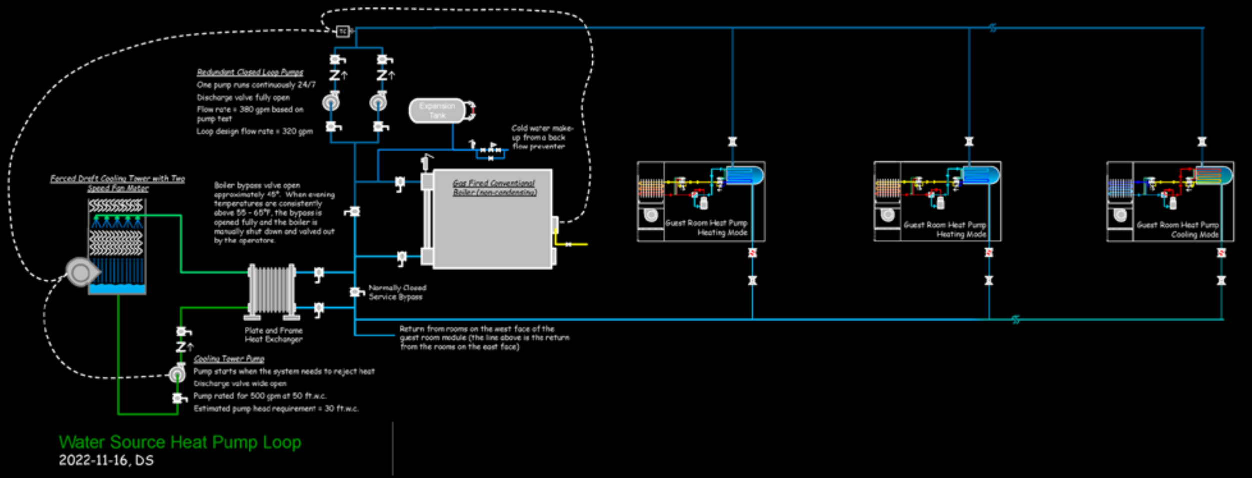
Point Name	System and Service
Analog Inputs	
System Supply Temperature	Guest Room Heat Pump Loop Supply Temperature
Digital Outputs	
Hot Water Boiler Enable	Auxilliary Heat Boiler Enable
Cooling Tower Fan Start/Stop	Cooling Tower Fan Control
Cooling Tower Pump Start/Stop	Cooling Tower Pump Control

Water Source Heat Pump Loop Points

Point Name	Point Number	System and Service	Sensor Type
Analog Inputs			
System Supply Temperature		Guest Room Heat Pump Loop Supply Temperature	
Analog Outputs			
Digital Inputs			

Assignment

- Add the points needed to be able to do diagnostics and ongoing commissioning for the system
- Start to consider how you would fill out some of the other fields in the point list such as:
    - Sensor accuracy
    - Alarms
    - Trend sampling rate



Water Source Heat Pump Loop Points	
Point Name	System and Service
Analog Inputs	
System Supply Temperature	Guest Room Heat Pump Loop Supply Temperature
Digital Outputs	
Hot Water Boiler Enable	Auxilliary Heat Enable
Cooling Tower Fan Start/Stop	Cooling Tower Fan Control
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Water Source Heat Pump Loop Points			
Point Name	Number	System and Service	Sensor Type
Analog Inputs			
System Supply Temperature		Guest Room Heat Pump Loop Supply Temperature	
Analog Outputs			
Digital Inputs			

Water Source Heat Pump Loop Points

Point		System and Service	Sensor		Features											Notes
Name	Number		Type	Accuracy	Alarms				Trending							
					Limit		Warning		Samples[1]	Commissioning[5]			Operating[5]			
					Hi	Lo	Hi	Lo		Time[2]	Local[3]	Archive[4]	Time[2]	Local[3]	Archive[4]	
Analog Inputs																
System Supply Temperature		Guest Room Heat Pump Loop Supply Temperature														
Analog Outputs																
Digital Inputs																
Digital Outputs																
Hot Water Boiler Enable		Auxilliary Heat Enable														
Cooling Tower Fan Start/Stop		Cooling Tower Fan Control														
Cooling Tower Pump Start/Stop		Cooling Tower Pump Control														
Hard Wired Points and 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)																
Guest Room Thermostat		Guest Room Heat Pump	Manfacturer's Standard Product						N/A							
Network Points																
Virtual Points																

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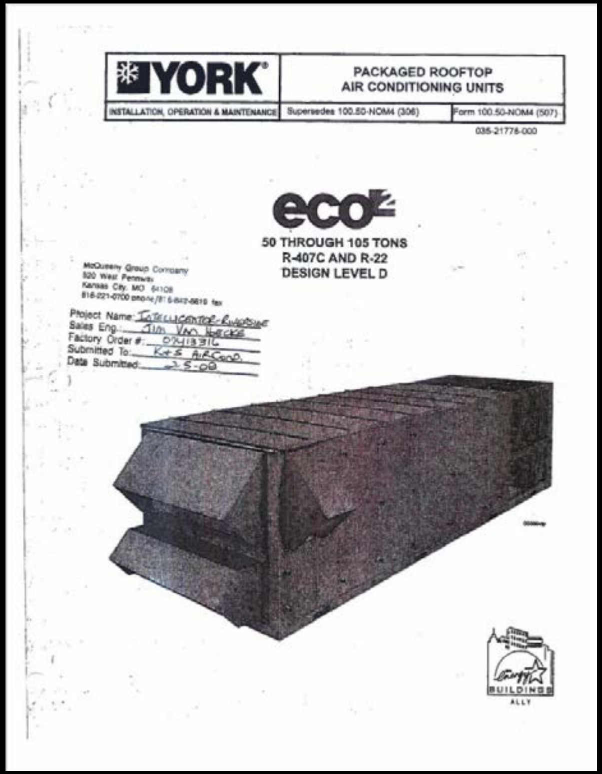
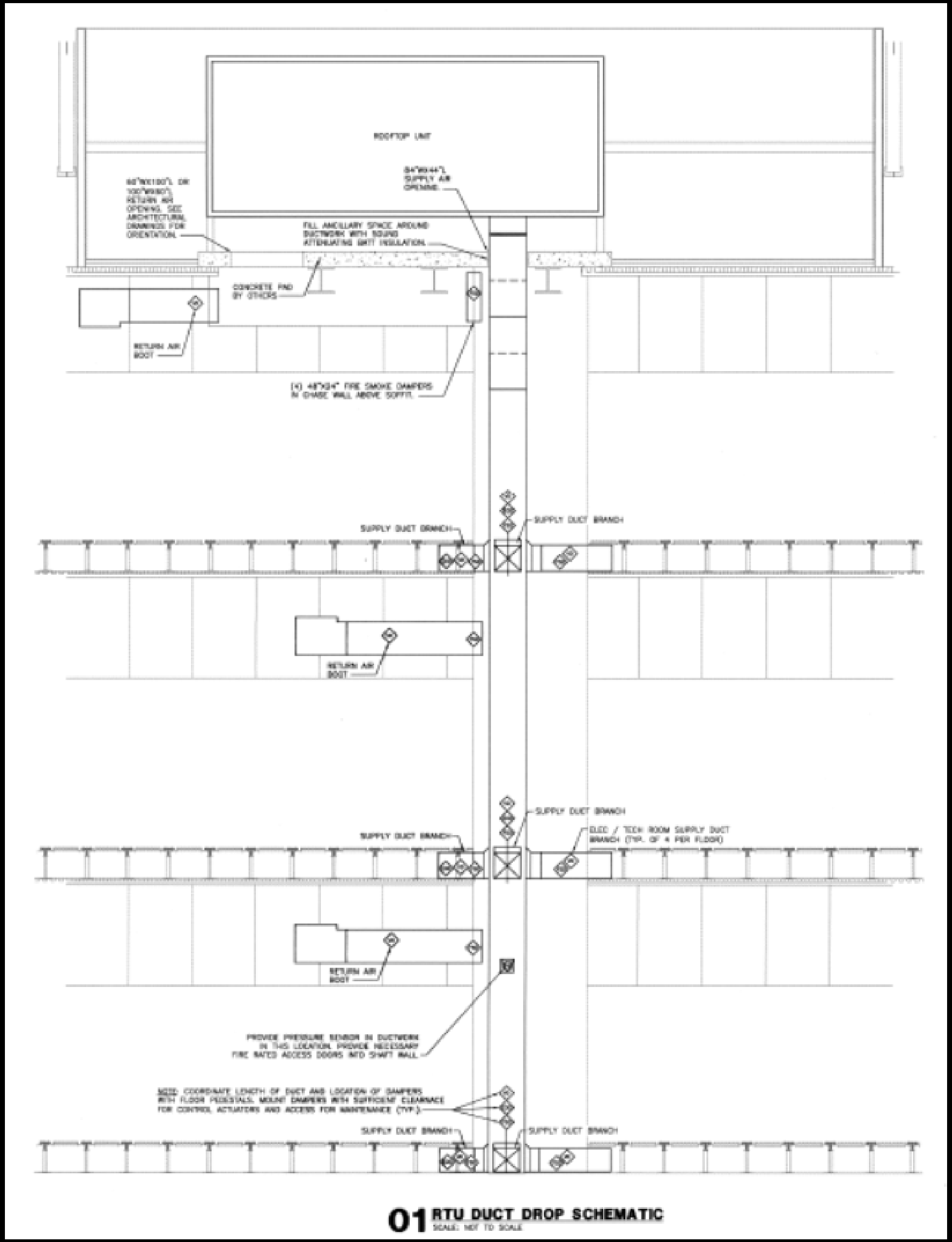
Avoiding Legacy Issues

Given

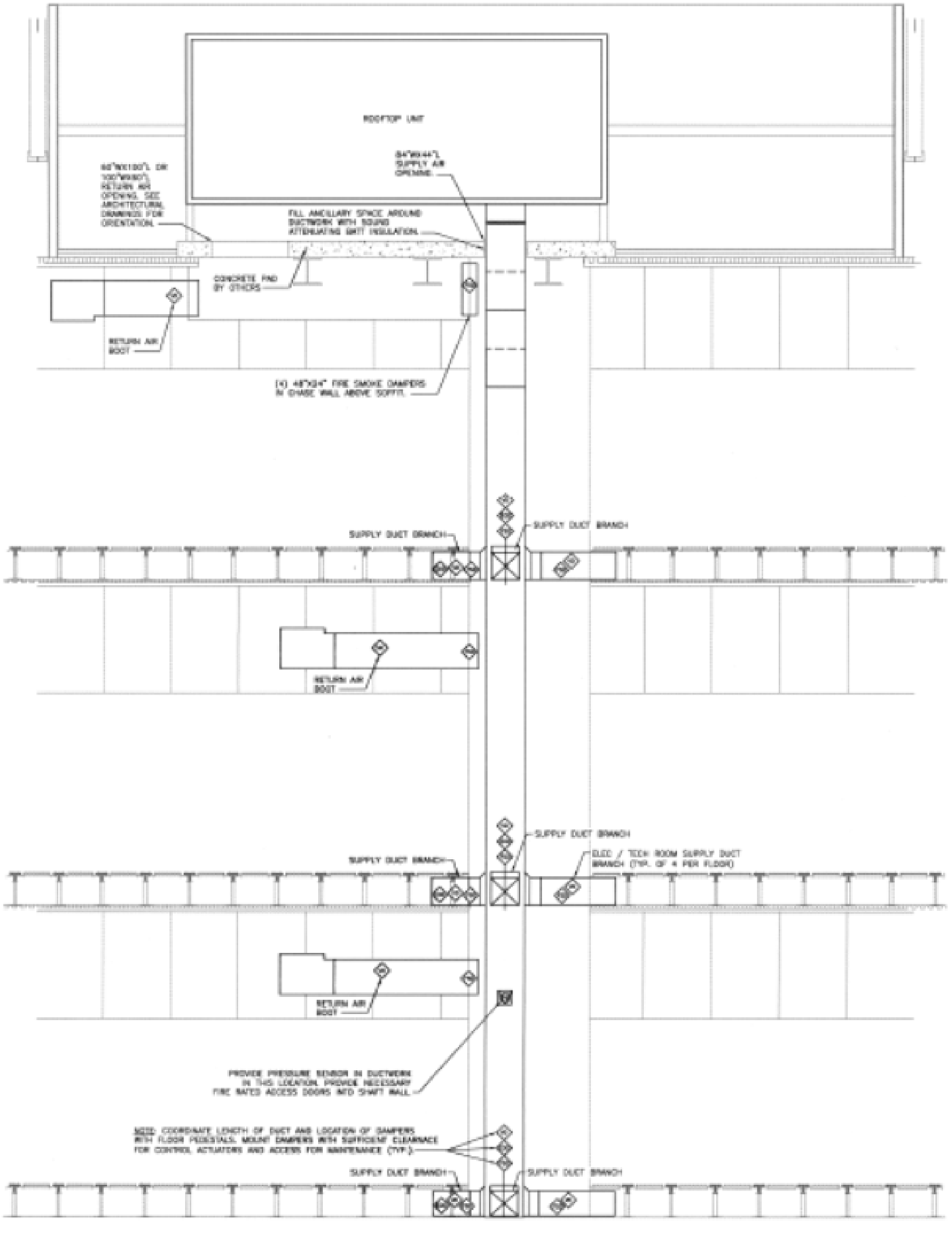
- Class Example Drawings
- RTU Manual





Assignment

- Identify the very significant problem that is apparent in the RTU Duct Drop Schematic
- Do you see other things that would merit comment during design review



01 RTU DUCT DROP SCHEMATIC
SCALE: NOT TO SCALE

Questions?

Thank you for participating!

Visit our website at www.FacilityDynamics.com

Visit our blog at https://av8rdas.wordpress.com/

Visit our commissioning resources website at https://www.av8rdas.com/

Contact me at Dsellers@FacilityDynamics.com

- David Sellers; Facility Dynamics Engineering
- Senior Engineer
- March 12, 2017

AEP ADVANCED ENGINEERING PROGRAM

AEP 2023