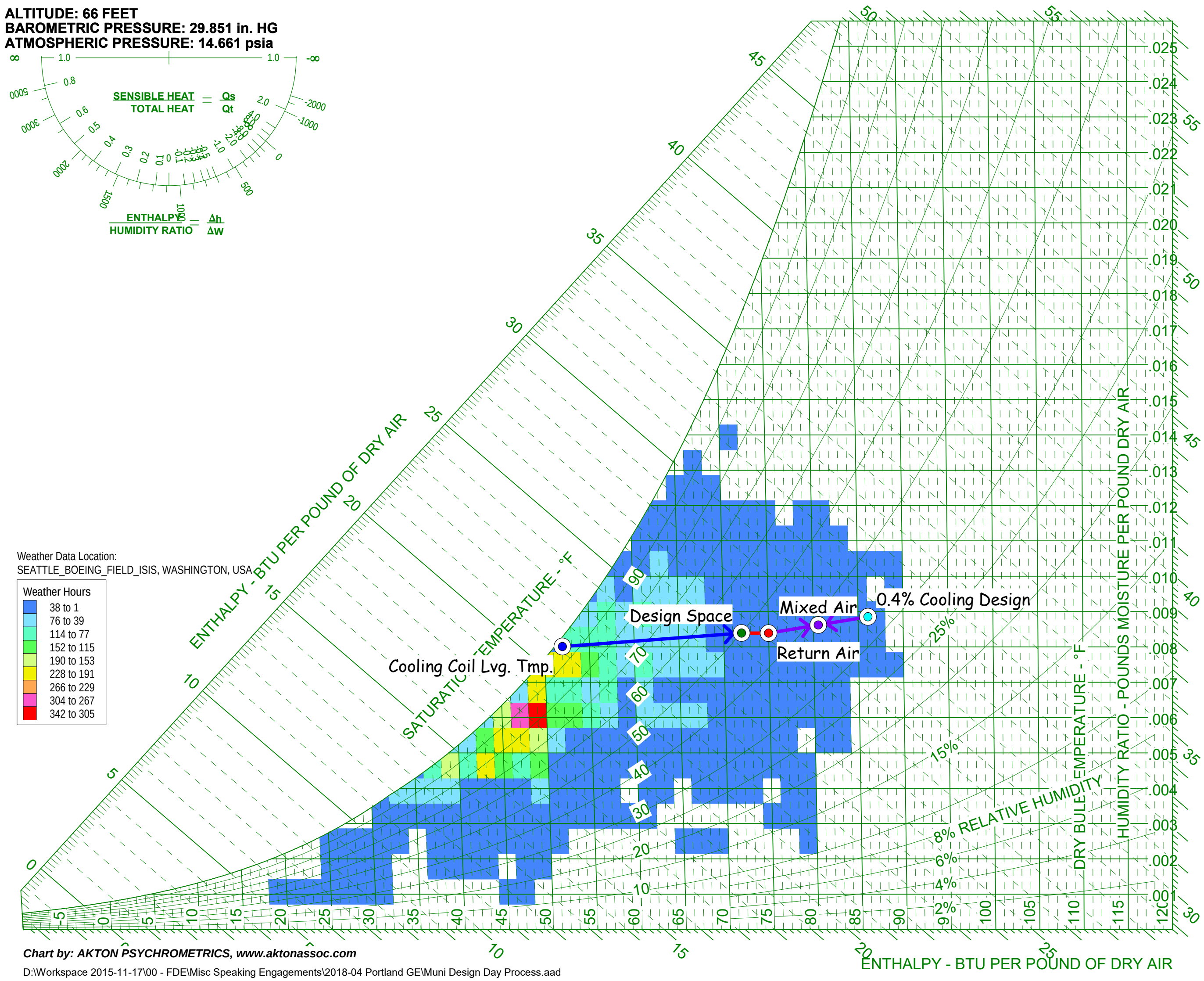
Load Profiles


ALTITUDE: 66 FEET
BAROMETRIC PRESSURE: 29.851 in. HG
ATMOSPHERIC PRESSURE: 14.661 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
Weather Data Location:
SEATTLE_BOEING_FIELD_ISIS, WASHINGTON, USA
Weather Hours
38 to 1
76 to 39
114 to 77
152 to 115
190 to 153
228 to 191
266 to 229
304 to 267
342 to 305
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
Design Space
Mixed Air
0.4% Cooling Design
Return Air
Cooling Coil Lvg. Tmp.
RELATIVE HUMIDITY
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
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Load profile drivers

1. The state of the air

$$v = \frac{1}{x_a}\left[\left|\frac{RT}{p}\right| \bullet \frac{1}{a} \bullet \left(x_a{}^2 A_{aa} + 2x_a x_w A_{aw} - X_a{}^3 A_{www} p\right)\beta\right]$$

$$h = \left[x_a h_a^{\circ} + \left(0.62198 x_w h_w^{\circ}\right)\beta - \left(x_a{}^2 B_{aa} + 2x_a x_w B_{aw} + x_w{}^2 B_{aw} + x_w{}^2 B_{ww}\right) \bullet p\alpha - \frac{1}{2} x_w{}^3 B_{www} p^2 \alpha\right]\frac{1}{x_a} + \bar{h}_a W \bar{h}_w$$

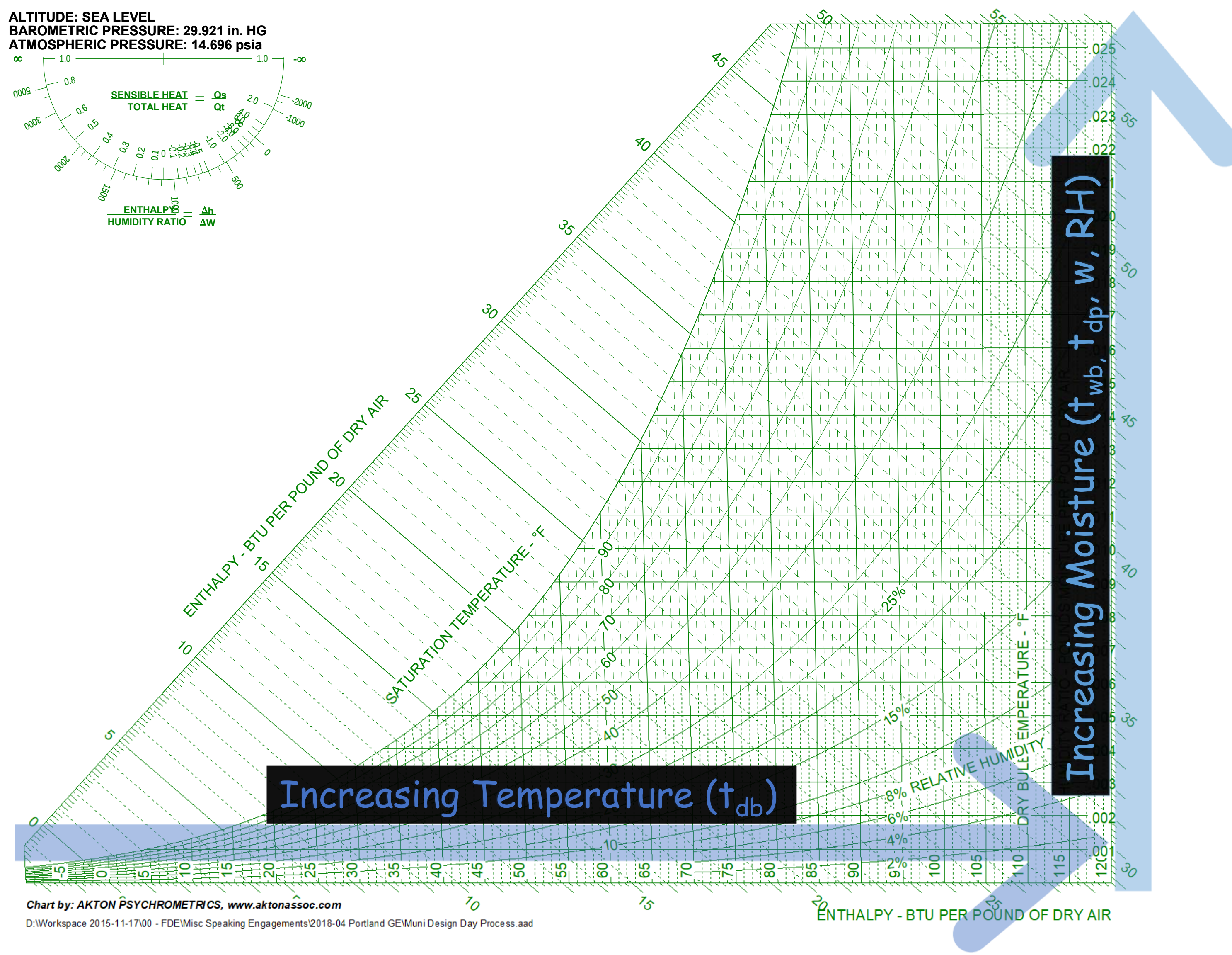
2. The nature of the process occurring at the load

$$\bar{Q} + \sum\nolimits_1 \left[\dot{m} \times \left(u_1 + \frac{p_1 v_1}{J} + \frac{z_1}{J} + \frac{V_1^2}{2gJ}\right)\right] = \frac{\bar{W}}{J} + \sum\nolimits_2 \left[\dot{m} \times \left(u_2 + \frac{p_2 v_2}{J} + \frac{z_2}{J} + \frac{V_2^2}{2gJ}\right)\right]$$

3. The process design target

$t_{db} = 72.000°\text{F}$, $t_{wb} = 60.064°\text{F}$, $t_{dp} = 52.370°\text{F}$, $h = 26.435\ \text{Btu/lb}_m$,

$w = 58.73\ \text{grains}_{H_2O}/\text{lb}_{m_{DA}}$, $\text{RH} = 50.000$, $\upsilon = 13.611\ \text{ft}^3/\text{lb}_m$, $\rho = .0741\ \text{lb}_m/\text{ft}^3$


ALTITUDE: SEA LEVEL
BAROMETRIC PRESSURE: 29.921 in. HG
ATMOSPHERIC PRESSURE: 14.696 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
RELATIVE HUMIDITY
DRY BULB TEMPERATURE - °F
Increasing Temperature (t_{db})
Increasing Moisture (t_{wb}, t_{dp}, w, RH)
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
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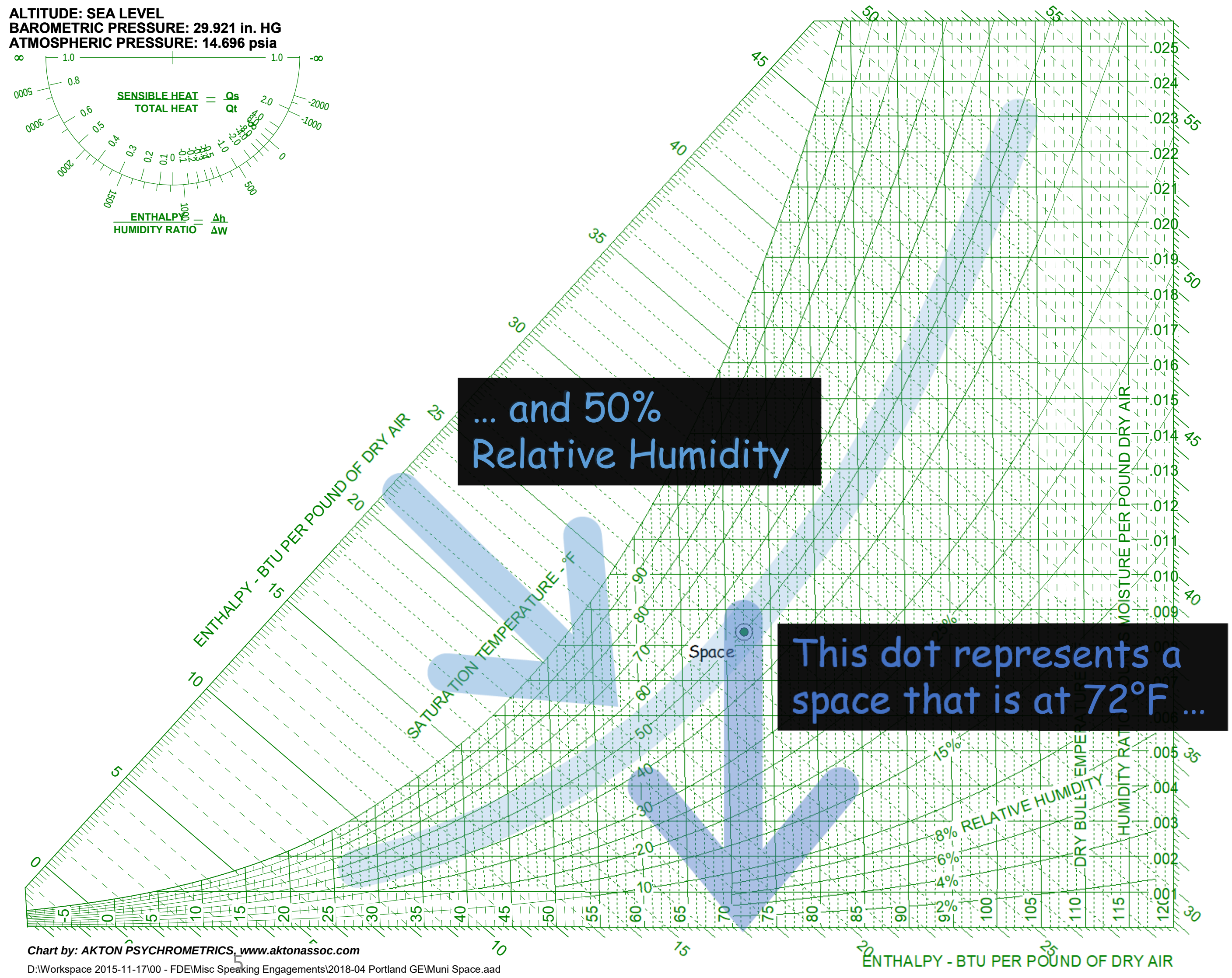

ALTITUDE: SEA LEVEL
BAROMETRIC PRESSURE: 29.921 in. HG
ATMOSPHERIC PRESSURE: 14.696 psia
SENSIBLE HEAT = Qs
TOTAL HEAT = Qt
ENTHALPY = Δh
HUMIDITY RATIO = ΔW
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
RELATIVE HUMIDITY
DRY BULB TEMPERATURE
HUMIDITY RATIO - MOISTURE PER POUND DRY AIR
Space
... and 50% Relative Humidity
This dot represents a space that is at 72°F ...
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
D:\Workspace 2015-11-17\00 - FDE\Misc Speaking Engagements\2018-04 Portland GE\Muni Space.aad

The cooling design conditions

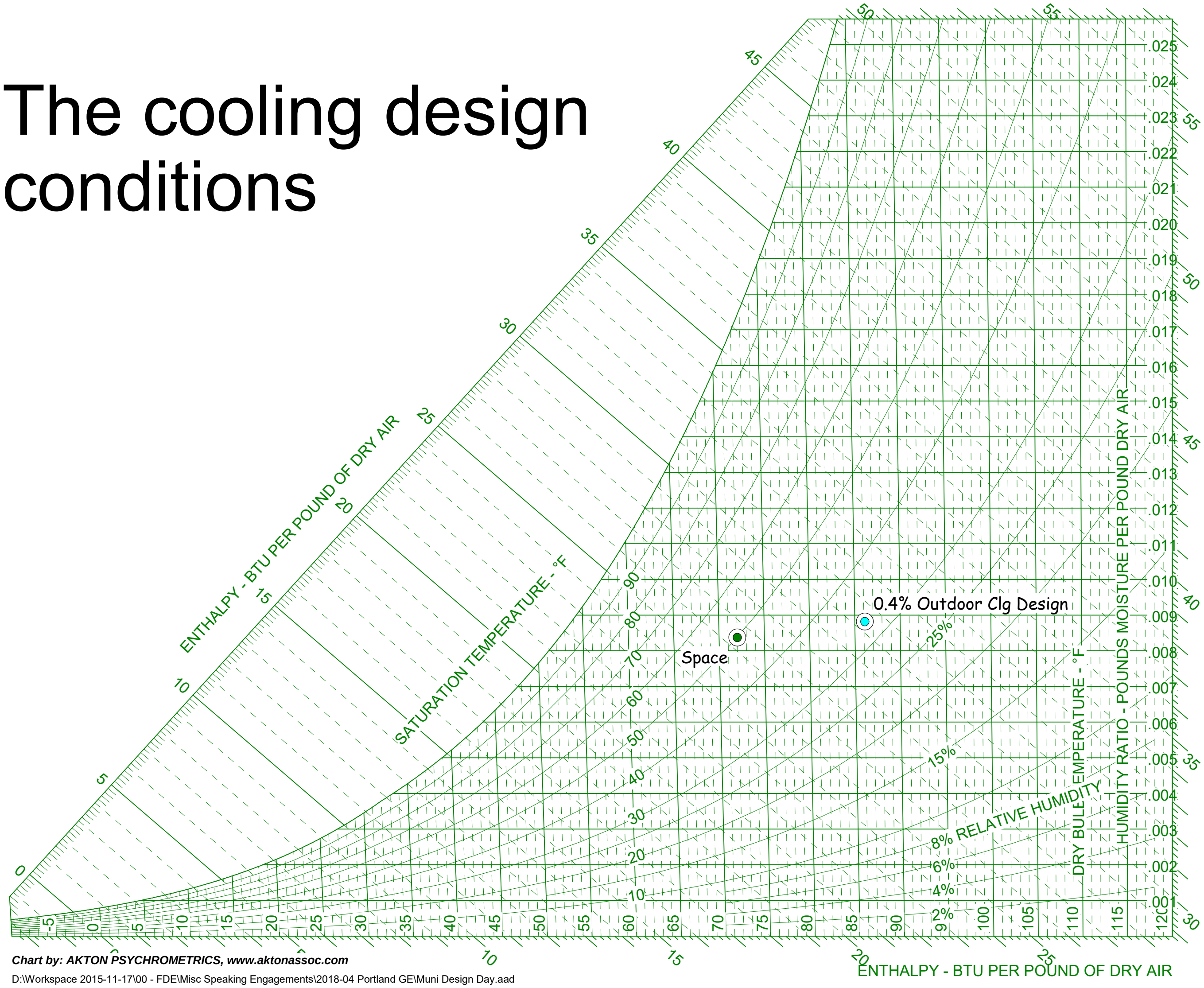

Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

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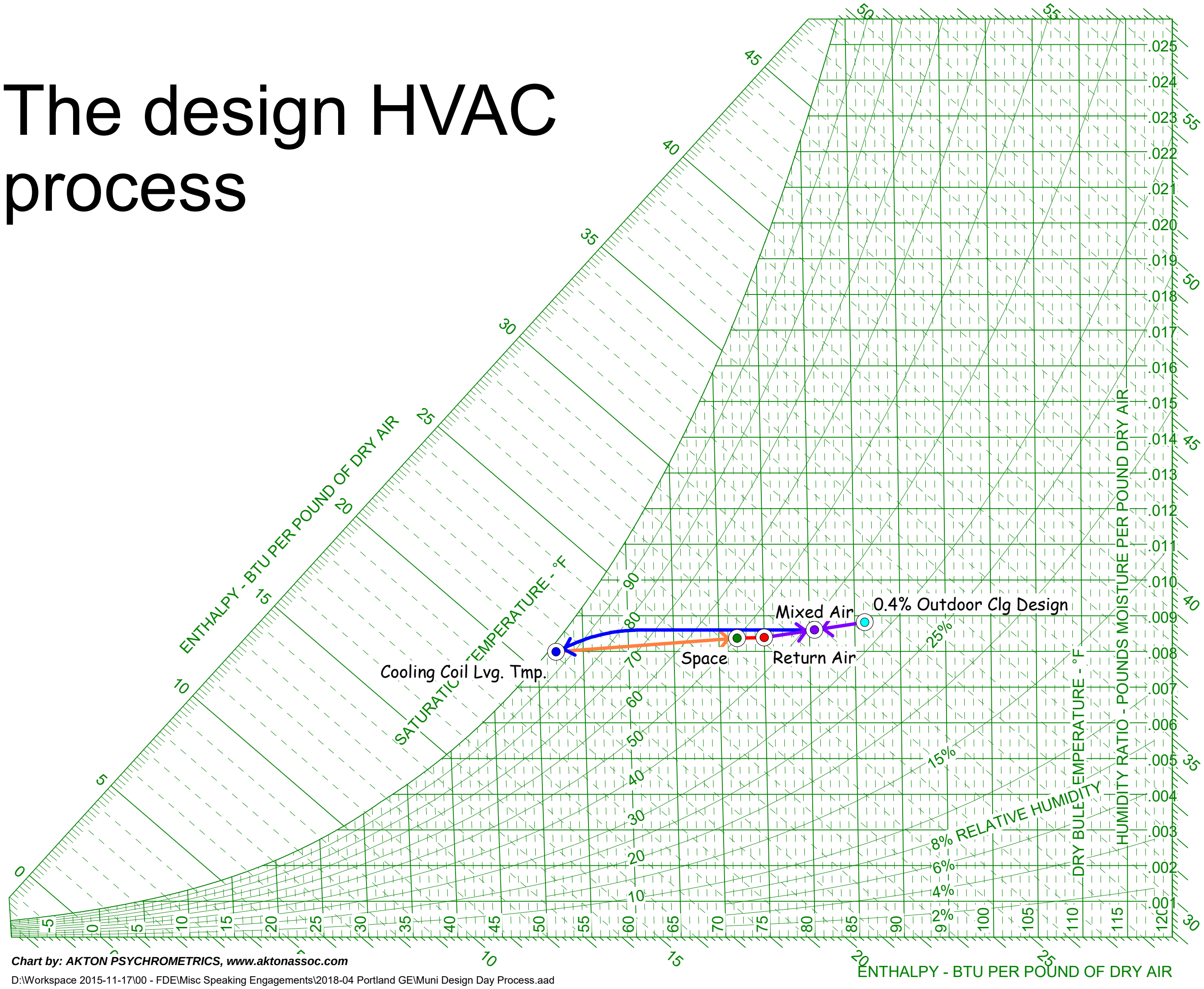
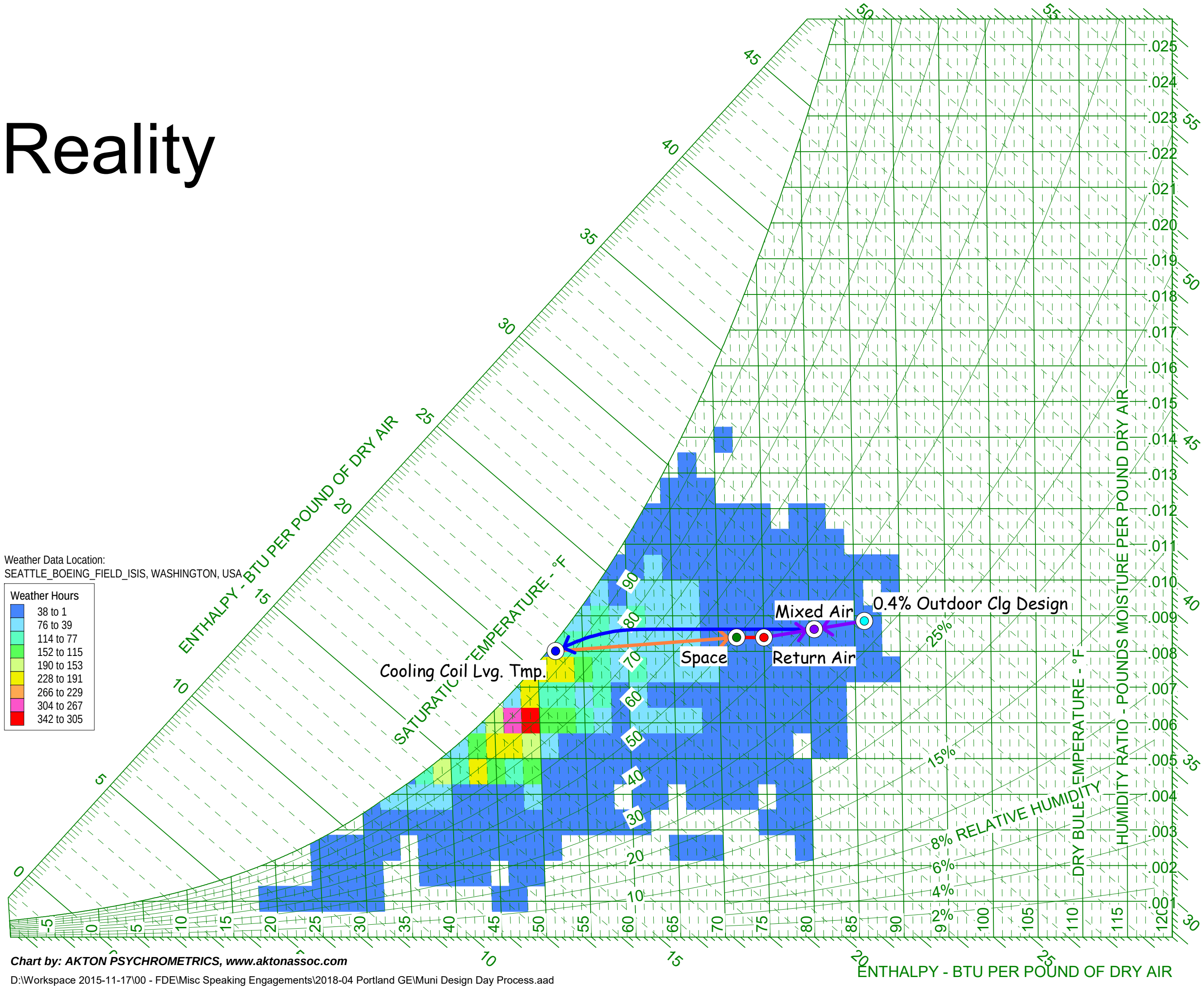
The design HVAC process



Reality



Weather Data Location:
SEATTLE_BOEING_FIELD_ISIS, WASHINGTON, USA
Weather Hours
38 to 1
76 to 39
114 to 77
152 to 115
190 to 153
228 to 191
266 to 229
304 to 267
342 to 305
Mixed Air
0.4% Outdoor Clg Design
Space
Return Air
Cooling Coil Lvg. Tmp.
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
8% RELATIVE HUMIDITY
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
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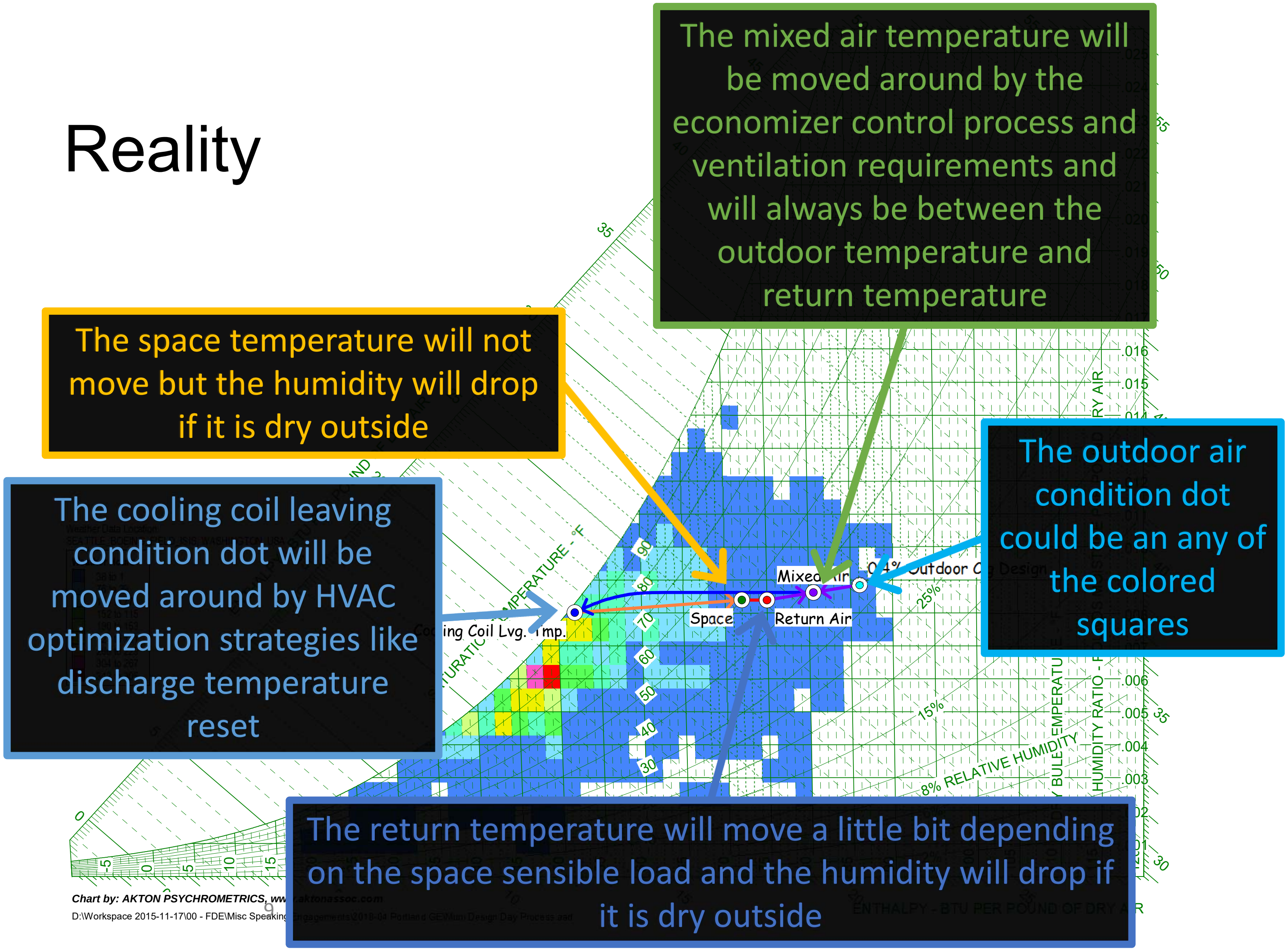
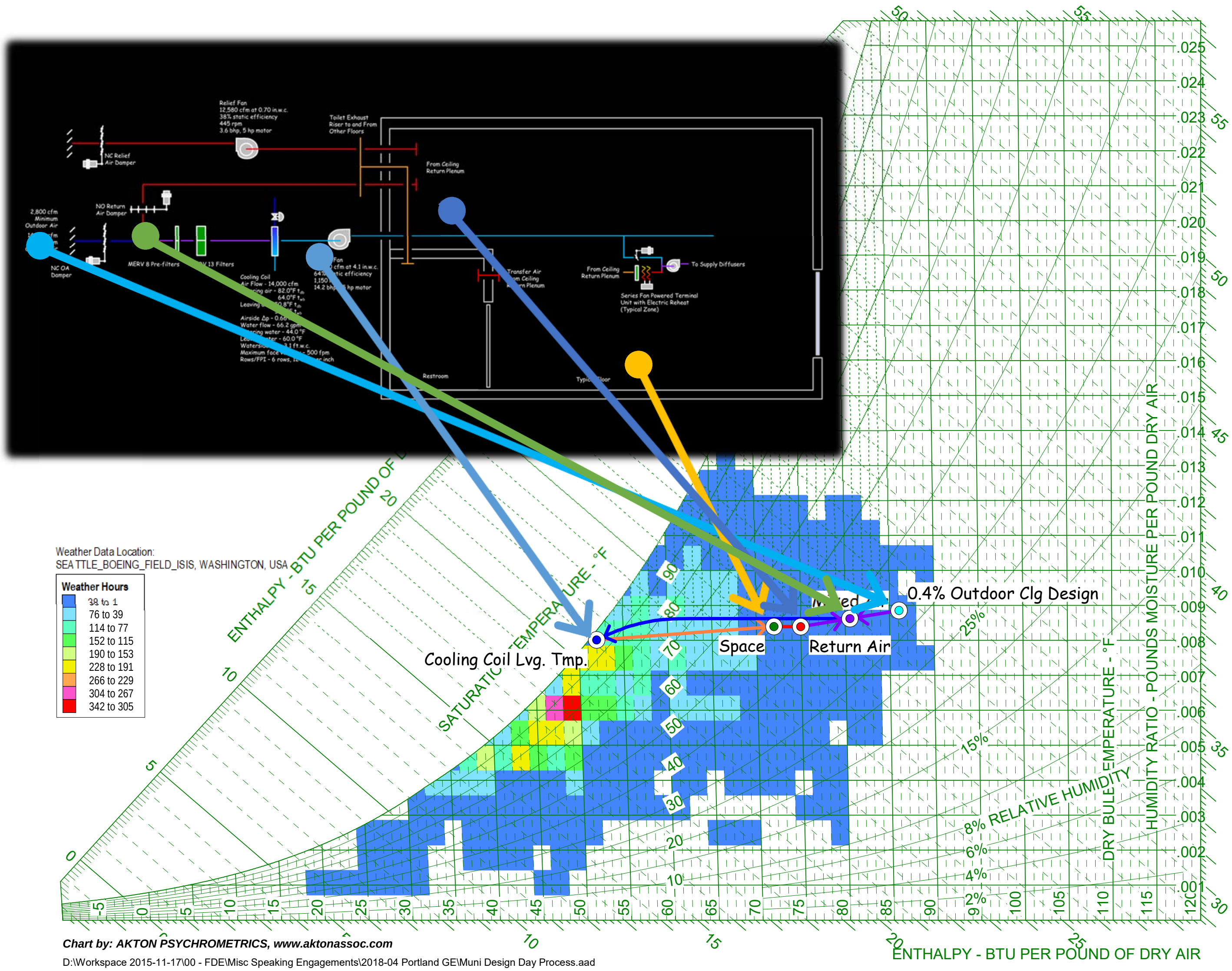
Reality



The mixed air temperature will be moved around by the economizer control process and ventilation requirements and will always be between the outdoor temperature and return temperature
The space temperature will not move but the humidity will drop if it is dry outside
The cooling coil leaving condition dot will be moved around by HVAC optimization strategies like discharge temperature reset
The outdoor air condition dot could be an any of the colored squares
The return temperature will move a little bit depending on the space sensible load and the humidity will drop if it is dry outside
Mixed Air
Space
Return Air
Outdoor
Cooling Coil Lvg. Tmp.
25%
15%
8% RELATIVE HUMIDITY
Chart by: AKTON PSYCHROMETRICS



Weather Data Location:
SEATTLE_BOEING_FIELD_ISIS, WASHINGTON, USA
Weather Hours
38 to 1
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0.4% Outdoor Clg Design
Space
Return Air
Cooling Coil Lvg. Tmp.
ENTHALPY - BTU PER POUND OF DRY AIR
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
RELATIVE HUMIDITY
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
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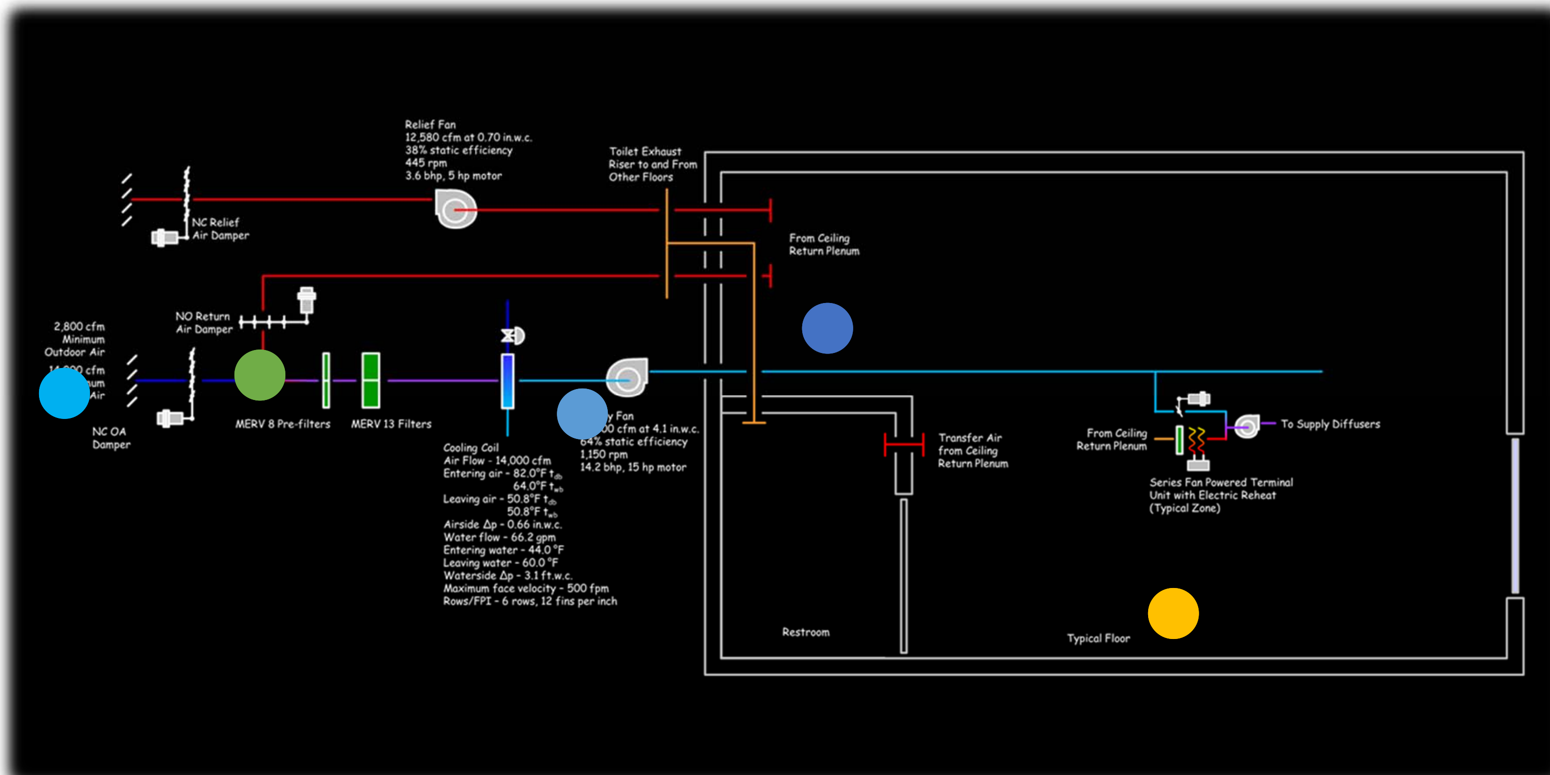
The mixed air condition is the cooling coil entering condition



The cooling design conditions

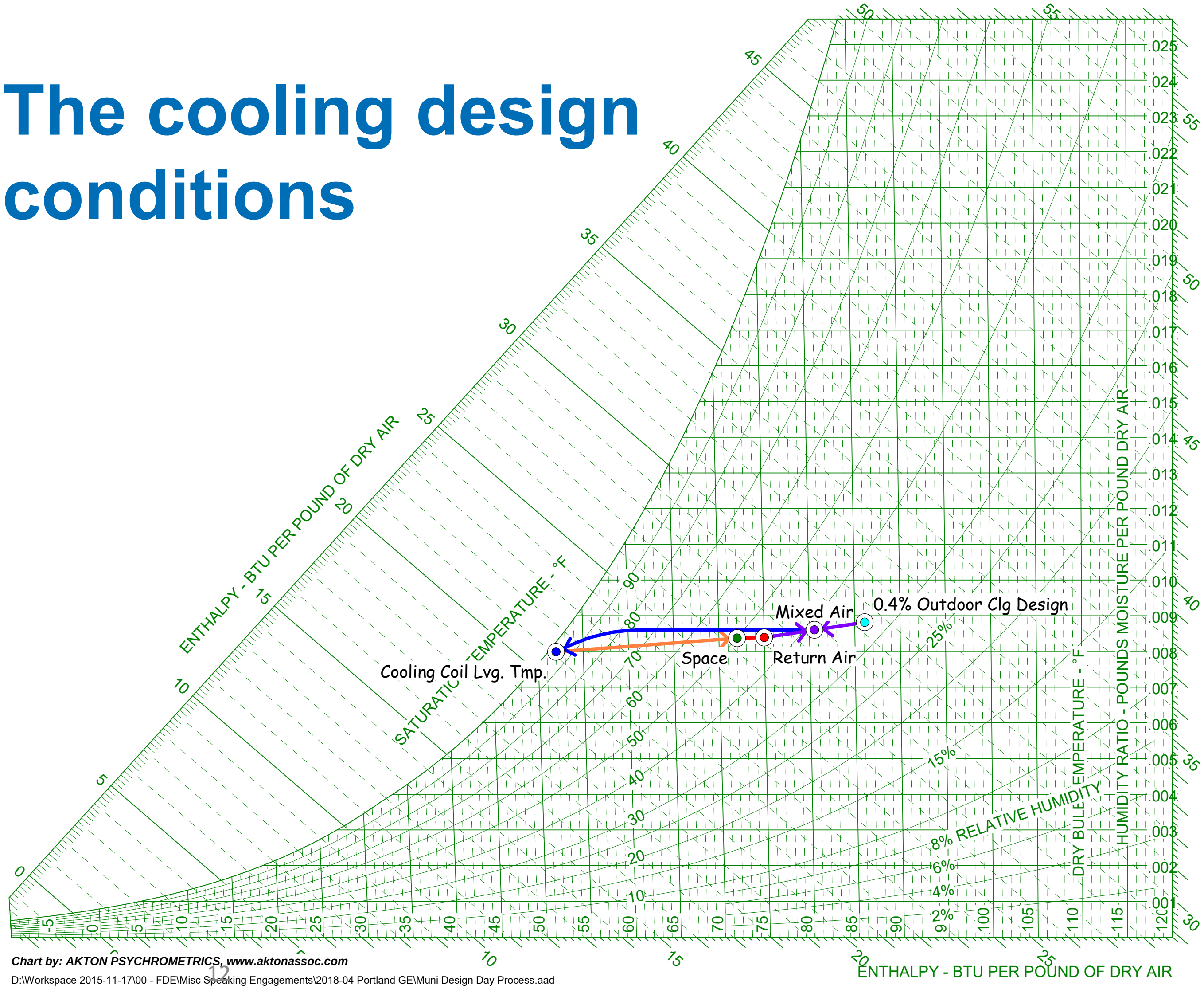


Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

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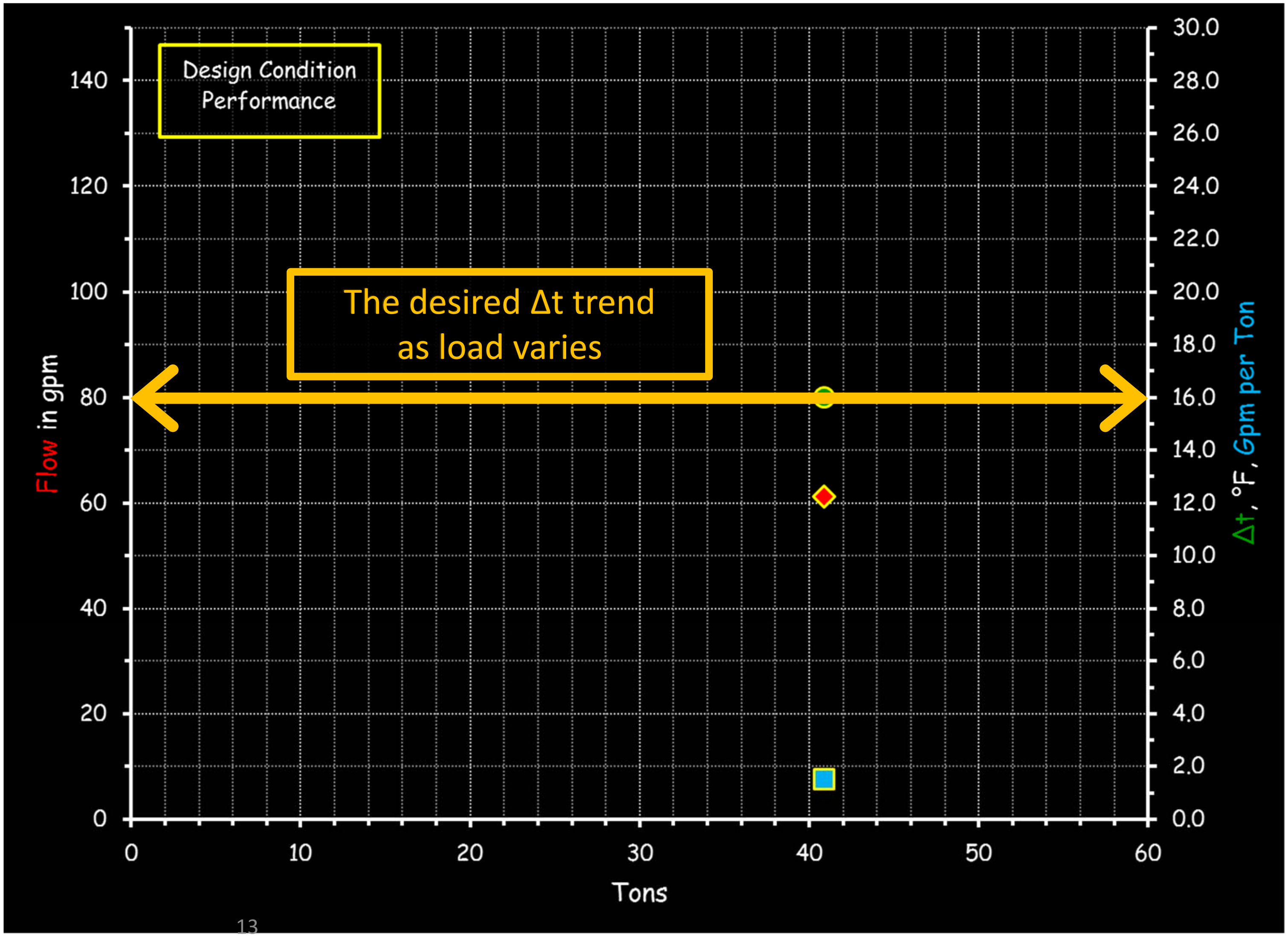
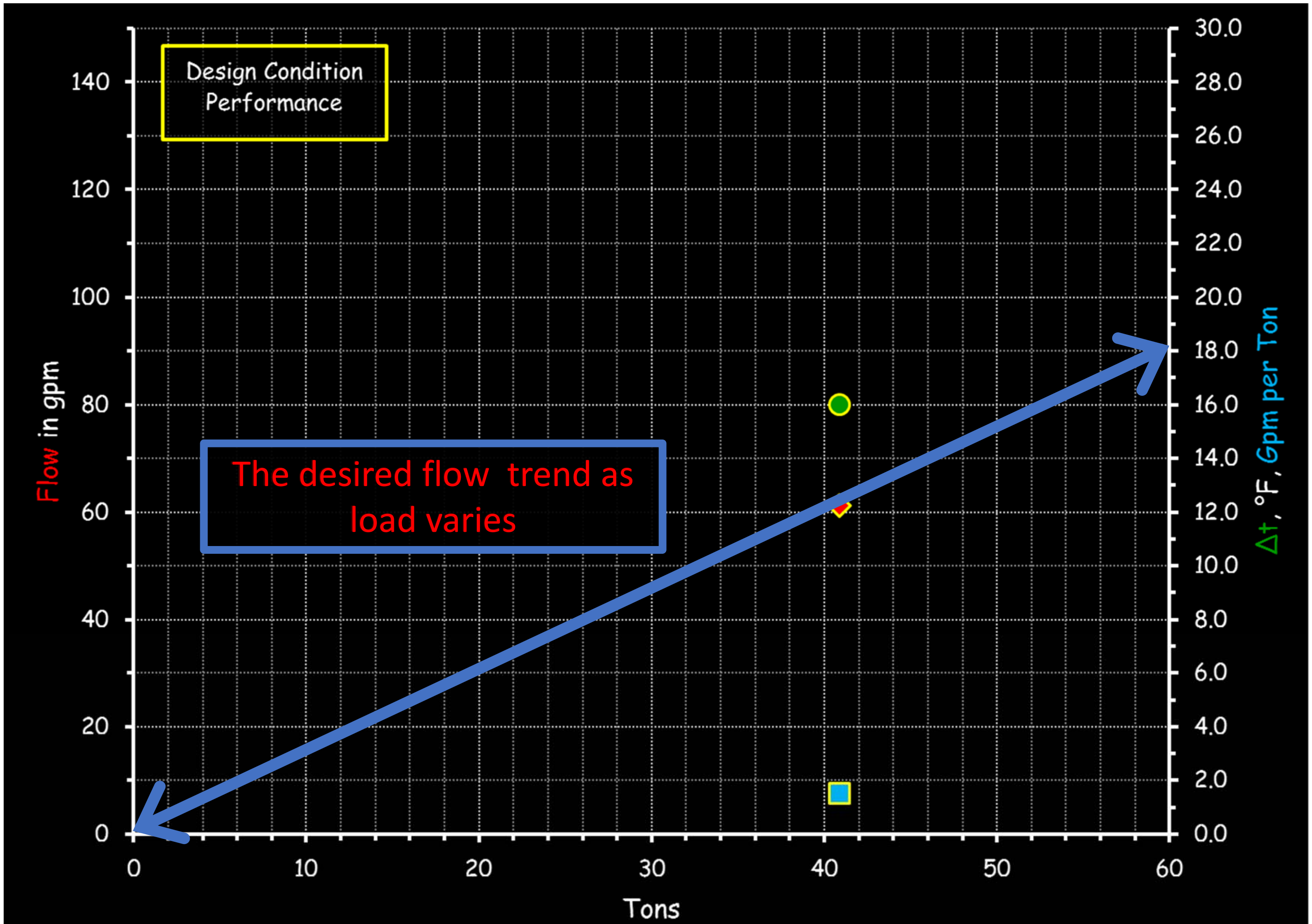
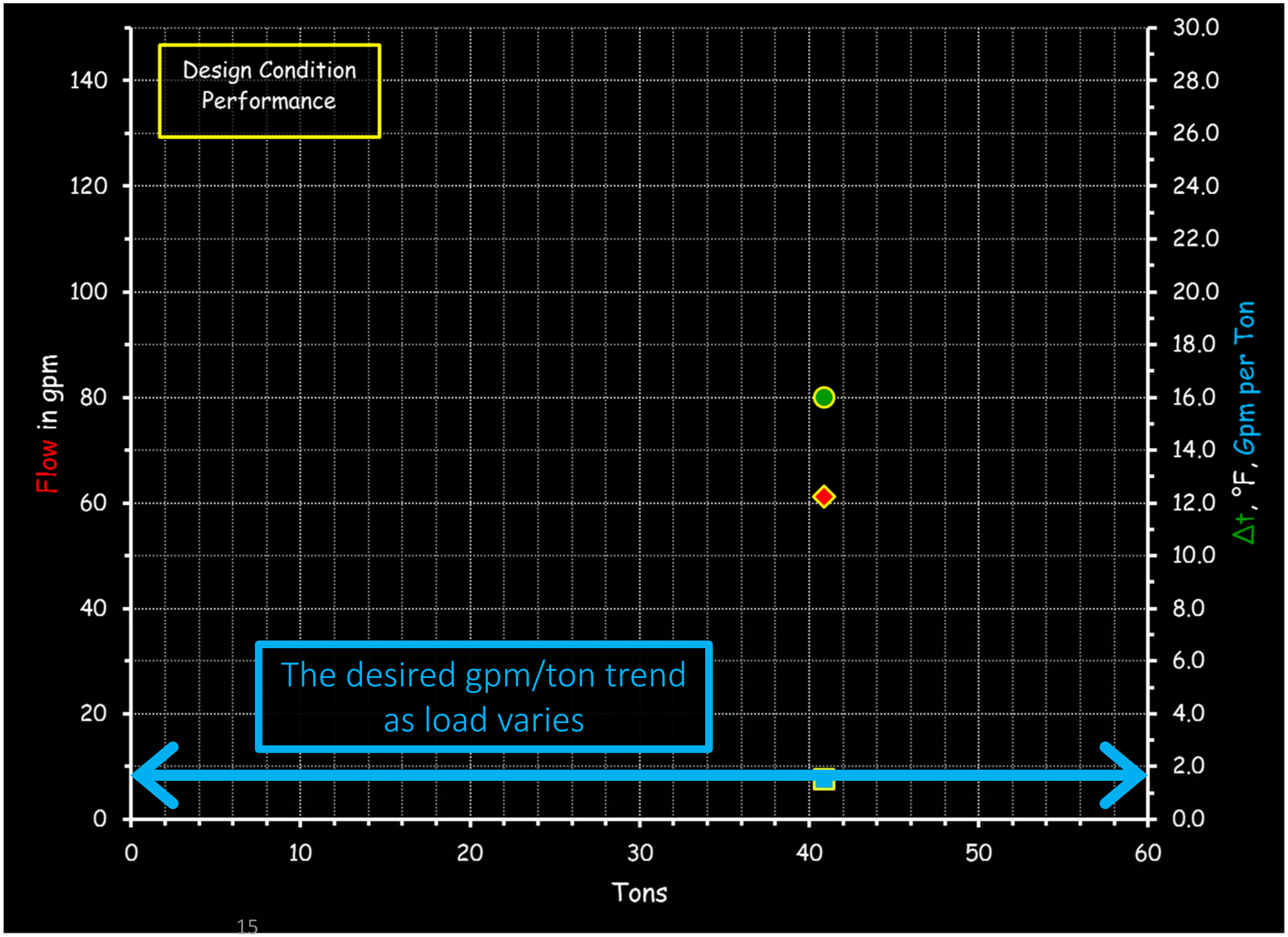
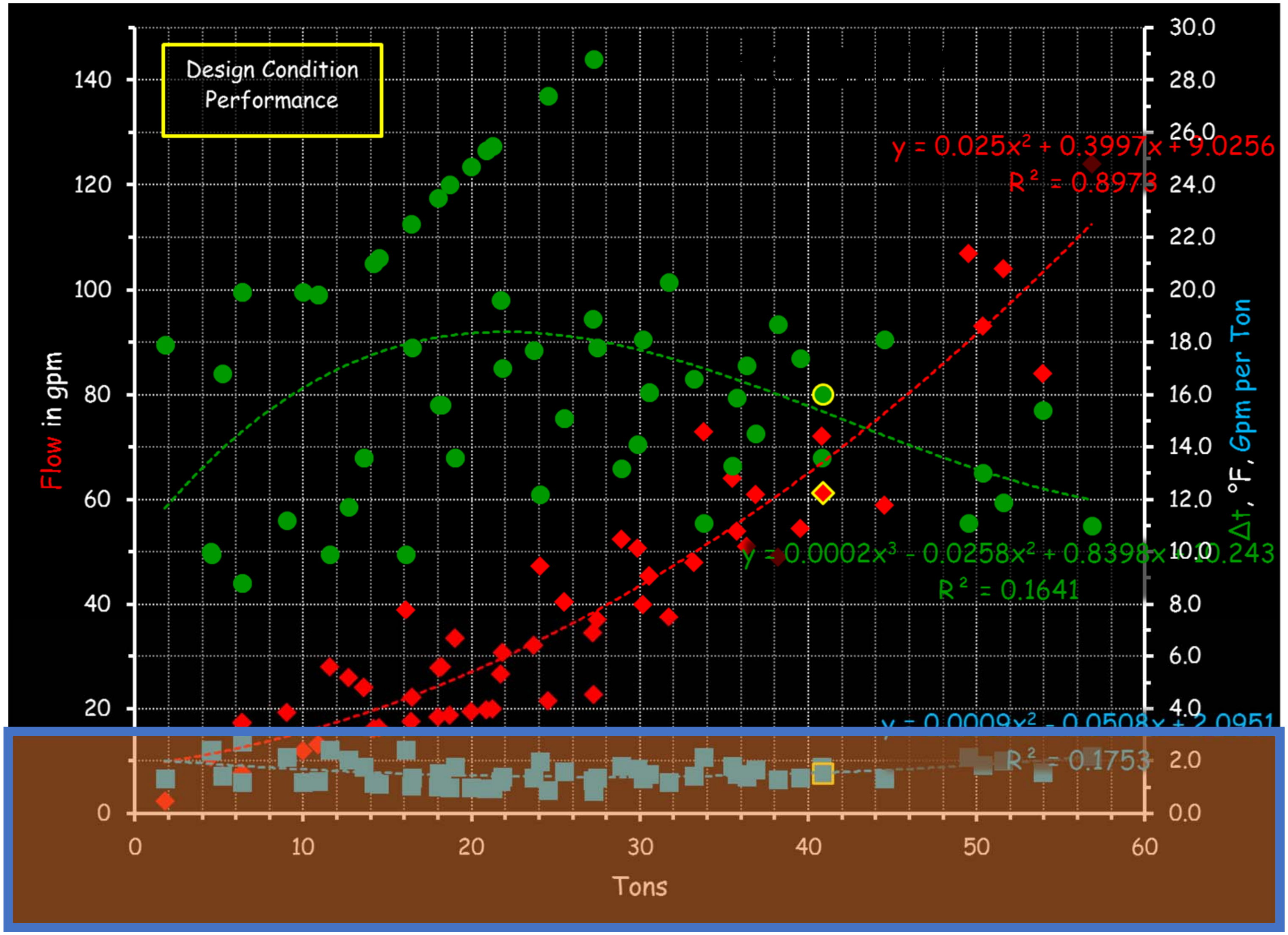


Design Condition
Performance
The desired Δt trend
as load varies
140
120
100
80
60
40
20
0
Flow in gpm
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Δt, °F, Gpm per Ton
0
10
20
30
40
50
60
Tons

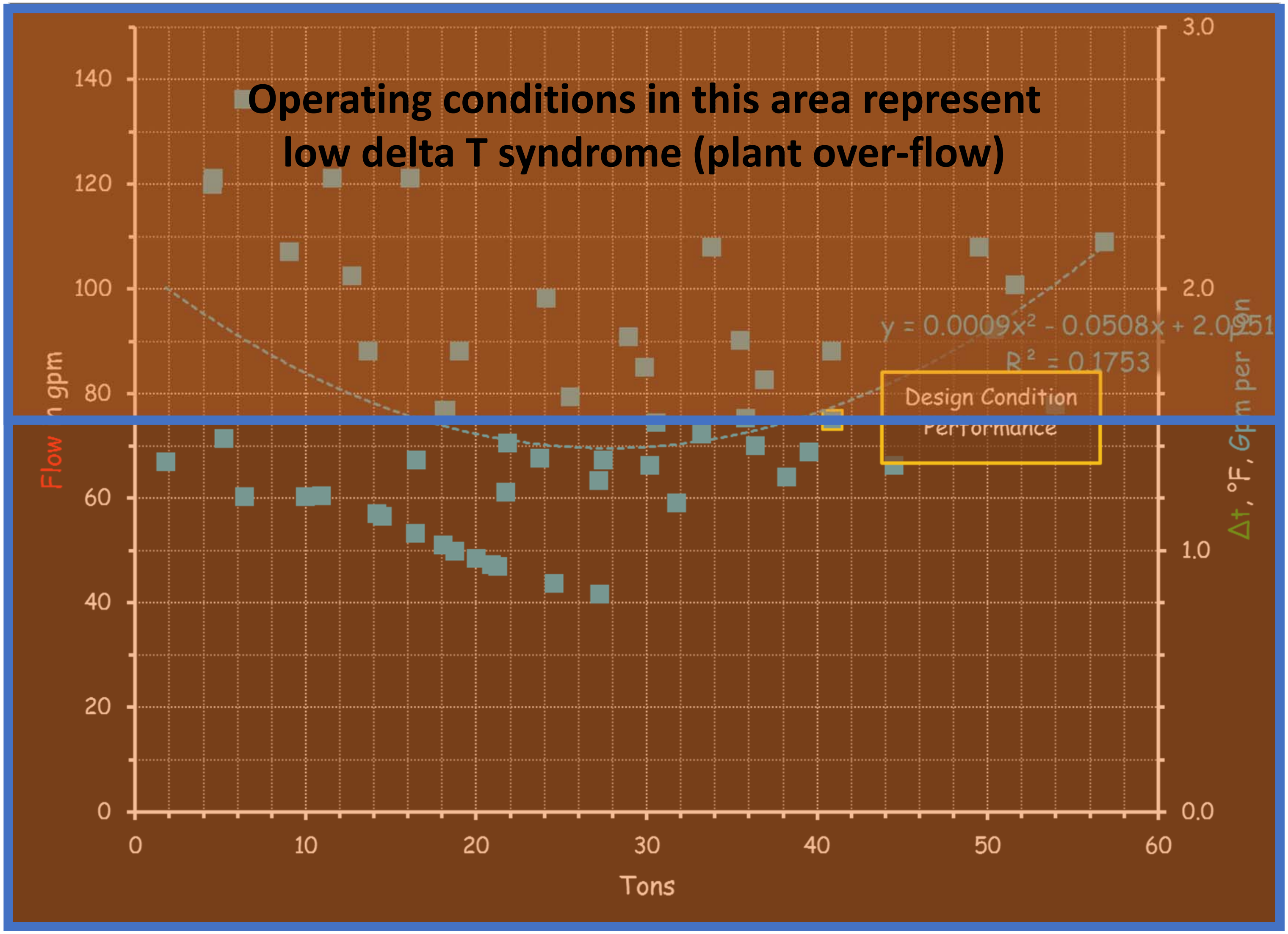


Design Condition
Performance
The desired flow trend as
load varies
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
10
20
30
40
50
60
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0


Design Condition
Performance
The desired gpm/ton trend
as load varies
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
0
10
20
30
40
50
60



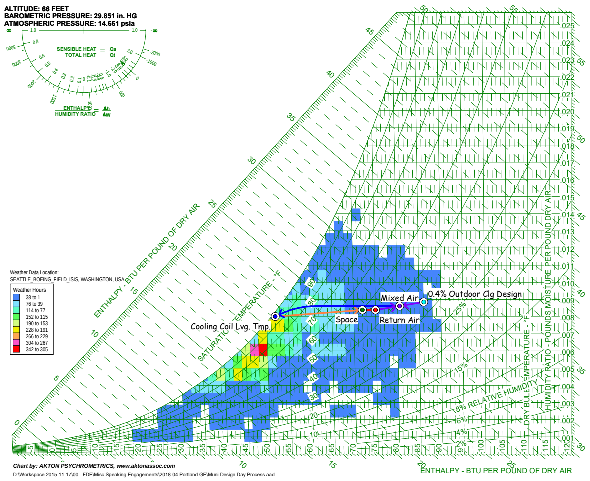
Design Condition
Performance
y = 0.025x² + 0.3997x + 9.0256
R² = 0.8973
y = 0.0002x³ - 0.0258x² + 0.8398x + 10.243
R² = 0.1641
y = 0.0009x² - 0.0508x + 2.0951
R² = 0.1753
Flow in gpm
Δt, °F, Gpm per Ton
Tons

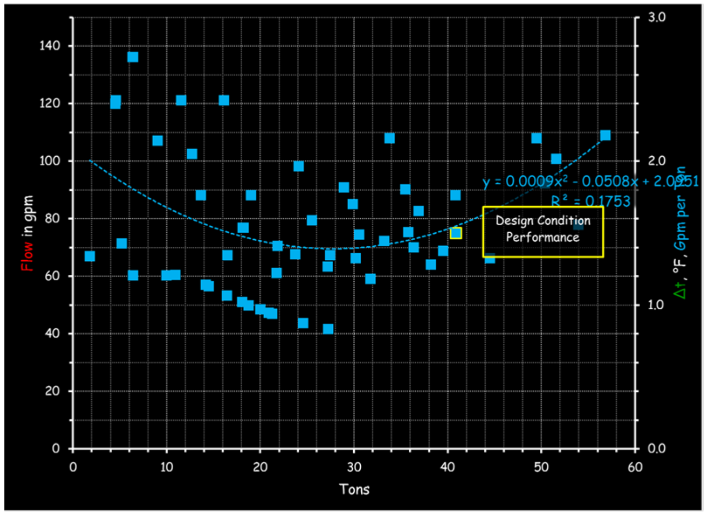


Operating conditions in this area represent
low delta T syndrome (plant over-flow)
y = 0.0009x² - 0.0508x + 2.0951
R² = 0.1753
Design Condition
Performance
Flow
Δt, °F, Gpm per Ton
Tons

Load profiles and performance vary with climate

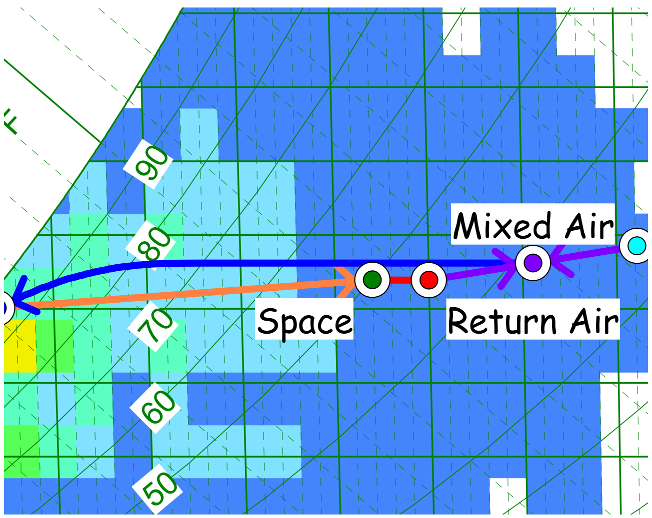
- The seasonal and daily load profile seen by our building systems will vary a lot due to the nature of the climate and the performance characteristics of the equipment dealing with the climate





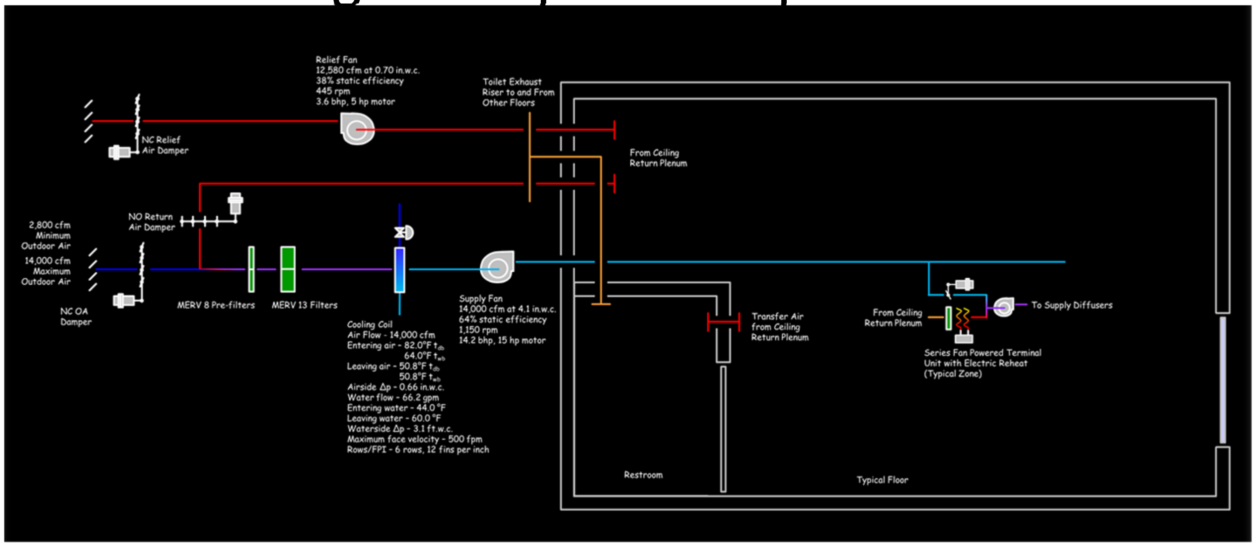
Load profiles and performance vary with climate

- But the built environment served by our building systems needs to remain clean, safe, comfortable and productive, no matter what.



Equipment performance must follow load profile

- Selecting, controlling and tuning the systems to follow the seasonal and daily load profile is a very important part of the over-all design, commissioning and operation process



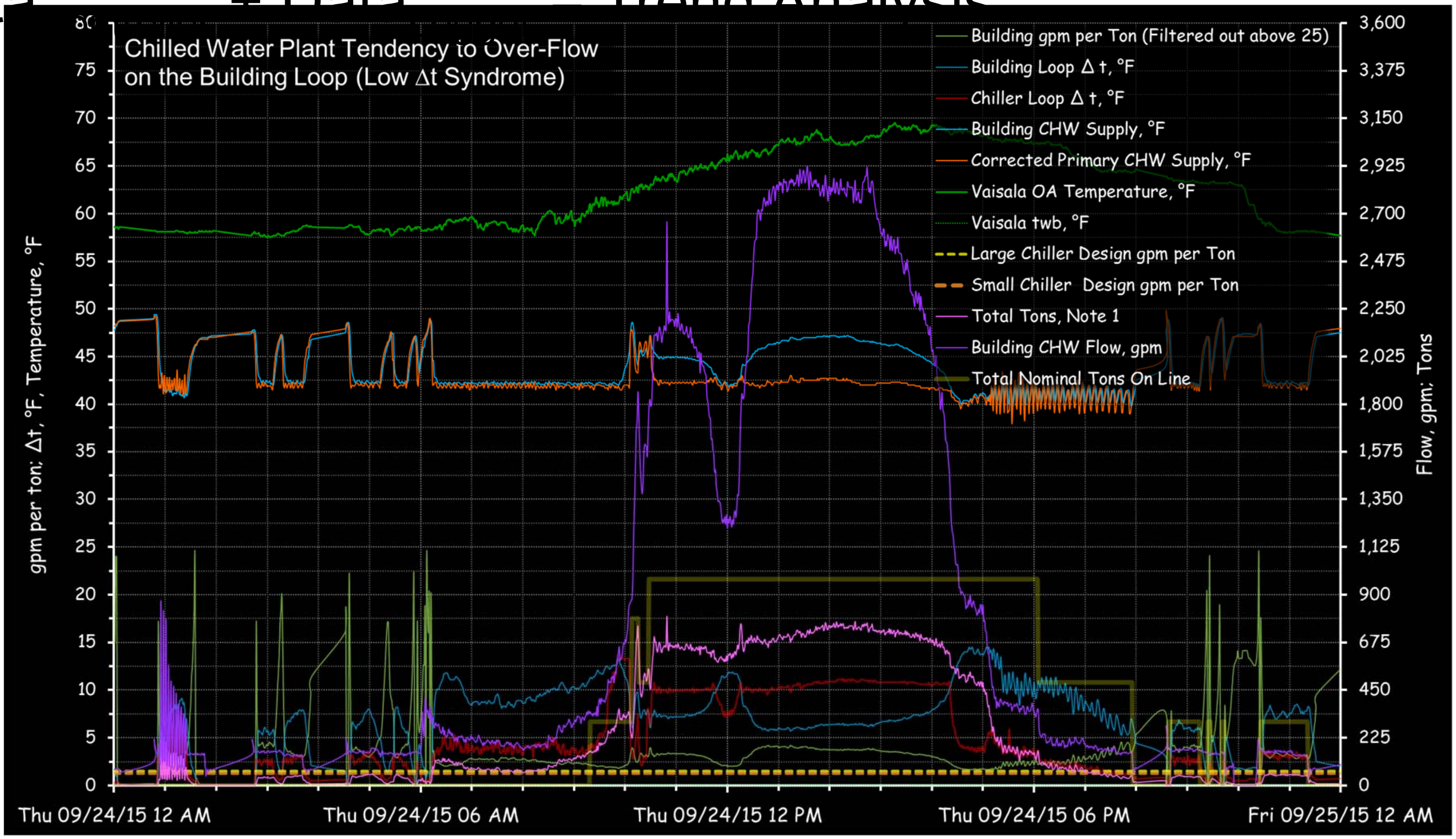
The control system's crucial role

- Ensures systems perform as intended
- Manages system dynamics associated with load profile variations
- Supports functional testing
- Supports data logging and trending
- Supports persistence
- Informs future decisions

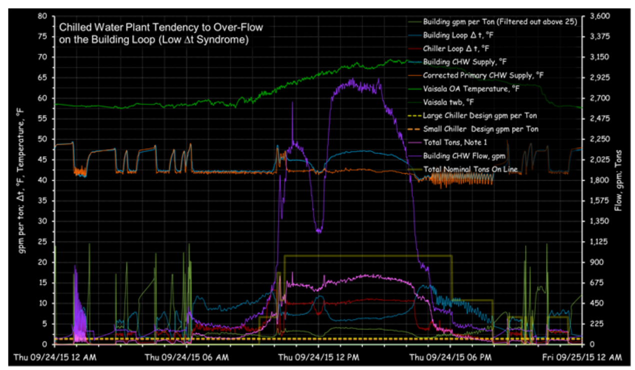
Data loggers

- Data loggers supplement the control systems trending capabilities
- Potential for faster sampling rates
- Pick up data where points are missing in the control system

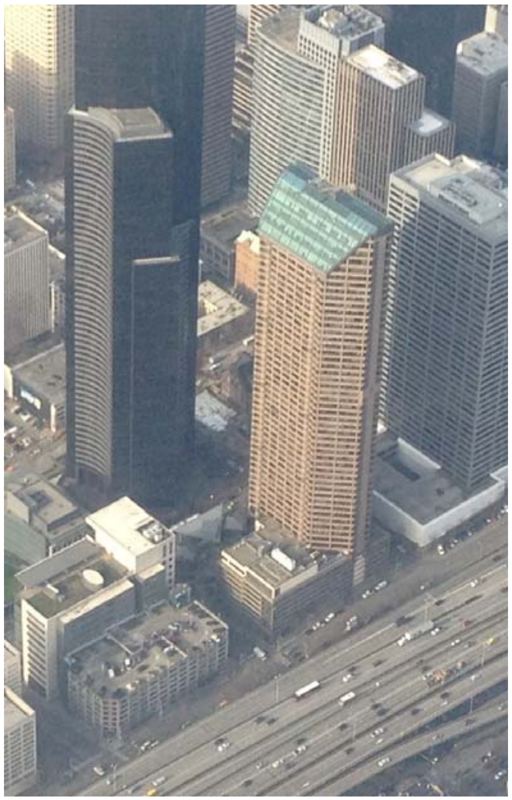
Data + Data = Trend Analysis



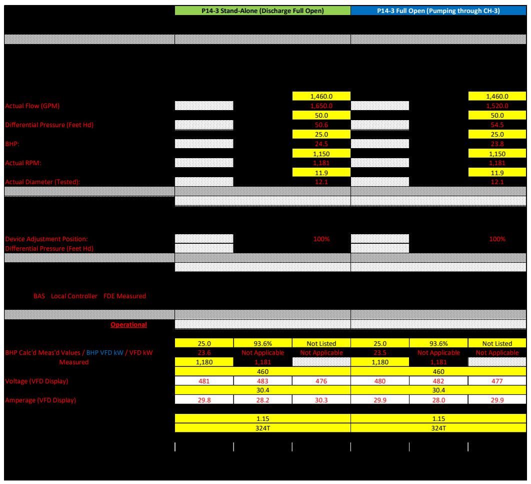
Trend analysis + Testing = A building dialog



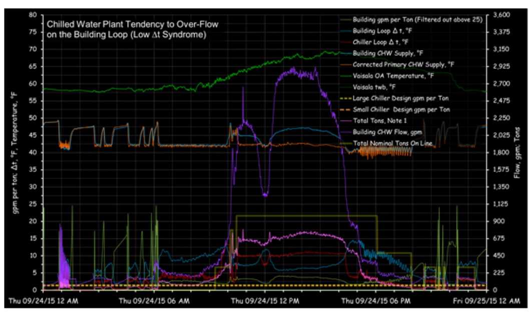
Example of a load profile dialog



- FADE IN:
- EXT. EARLY – MORNING
  - Cx provider with tool kit enters building and is greeted by the operating staff and a project manager
- PROJECT ENGINEER (To Operating Team)
- *Our Cx provider has an idea about how to size the chillers for our new plant and would like to see what we have currently*
- CHIEF ENGINEER
- Sure, let’s head up and take a look around
- FADE TO CHILLER PLANT:



	P14-3 Stand-Alone (Discharge Full Open)			P14-3 Full Open (Pumping through CH-3)		
			1,460.0			1,460.0
Actual Flow (GPM)			1,650.0			1,520.0
			50.0			50.0
Differential Pressure (Feet Hd)			50.6			54.5
			25.0			25.0
BHP:			24.5			23.8
			1,150			1,150
Actual RPM:			1,181			1,181
			11.9			11.9
Actual Diameter (Tested):			12.1			12.1
Device Adjustment Position:			100%			100%
Differential Pressure (Feet Hd)						
BAS Local Controller FDE Measured						
Operational						
	25.0	93.6%	Not Listed	25.0	93.6%	Not Listed
BHP Calc'd Meas'd Values / BHP VFD kW / VFD kW	23.6	Not Applicable	Not Applicable	23.5	Not Applicable	Not Applicable
Measured	1,180	1,181		1,180	1,181	
	460			460		
Voltage (VFD Display)	481	483	476	480	482	477
	30.4			30.4		
Amperage (VFD Display)	29.8	28.2	30.3	29.9	28.0	29.9
	1.15			1.15		
	324T			324T		

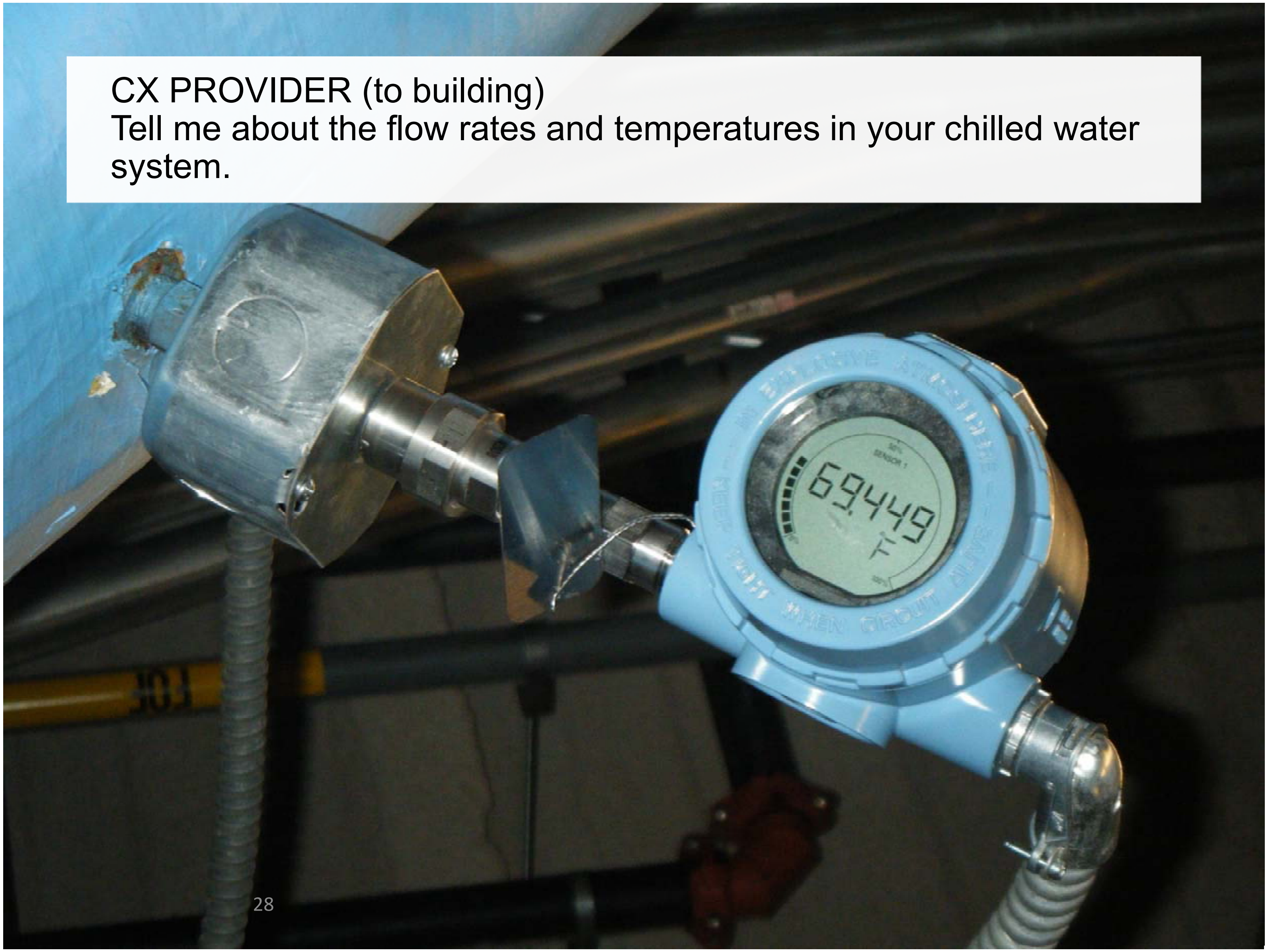


- CX PROVIDER
- *Then I bet the building knows how big the chillers need to be.*
- *We just need to ask it the right questions.*

- CHIEF ENGINEER
- *How will we do that?*

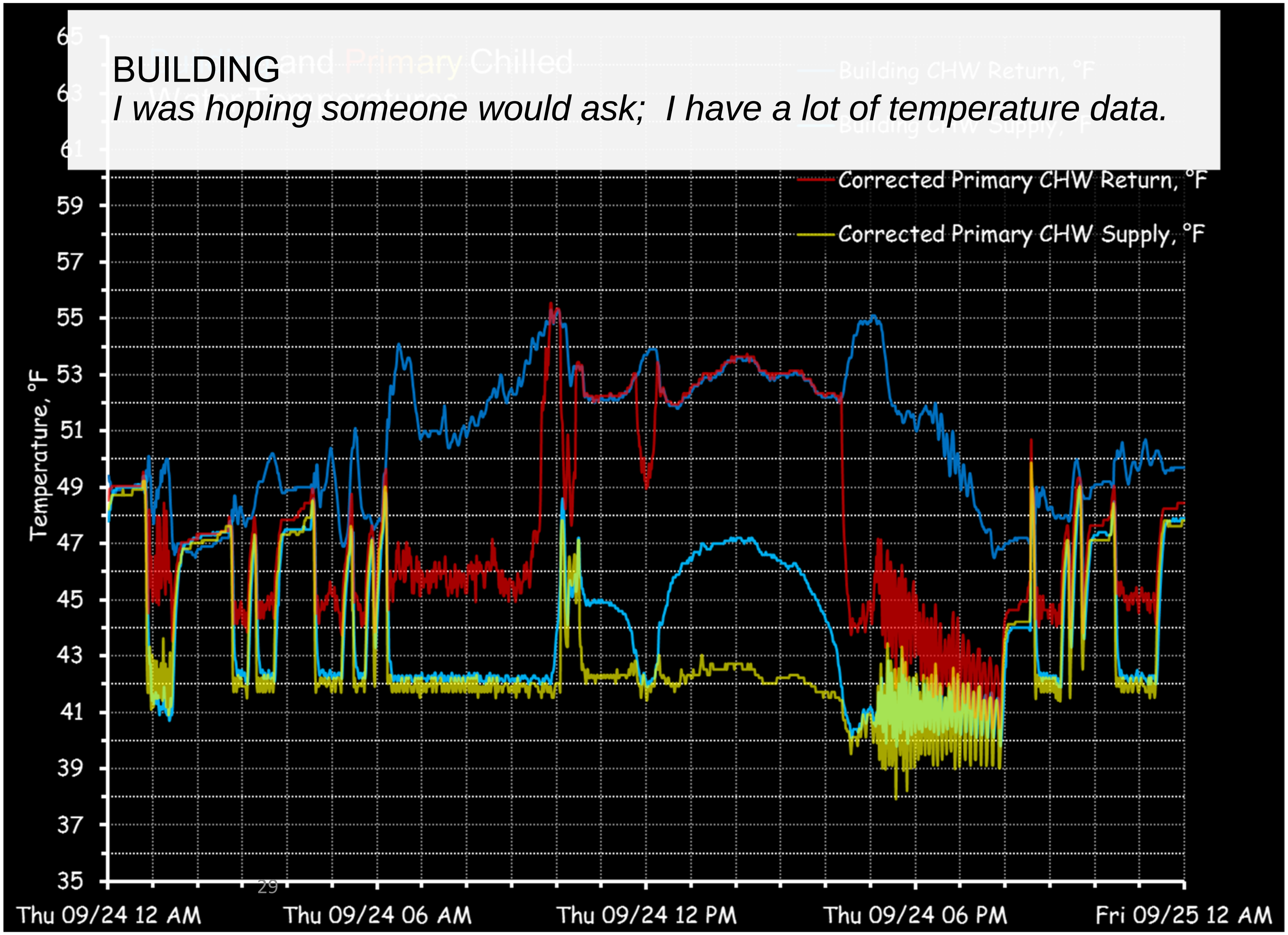
- CX PROVIDER
- *With functional testing, trending, and data logging.*

CX PROVIDER (to building)
Tell me about the flow rates and temperatures in your chilled water system.



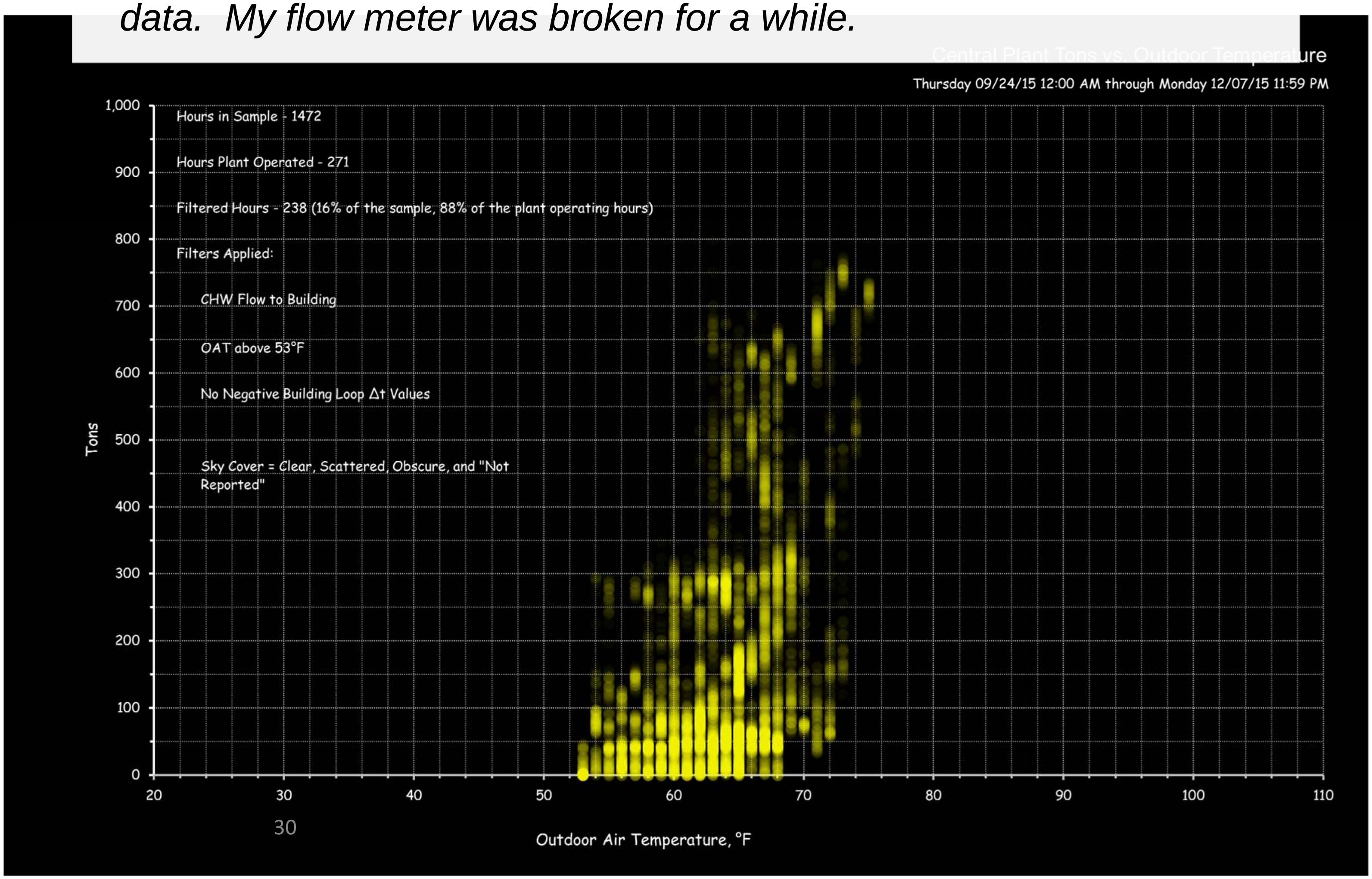
BUILDING

I was hoping someone would ask; I have a lot of temperature data.

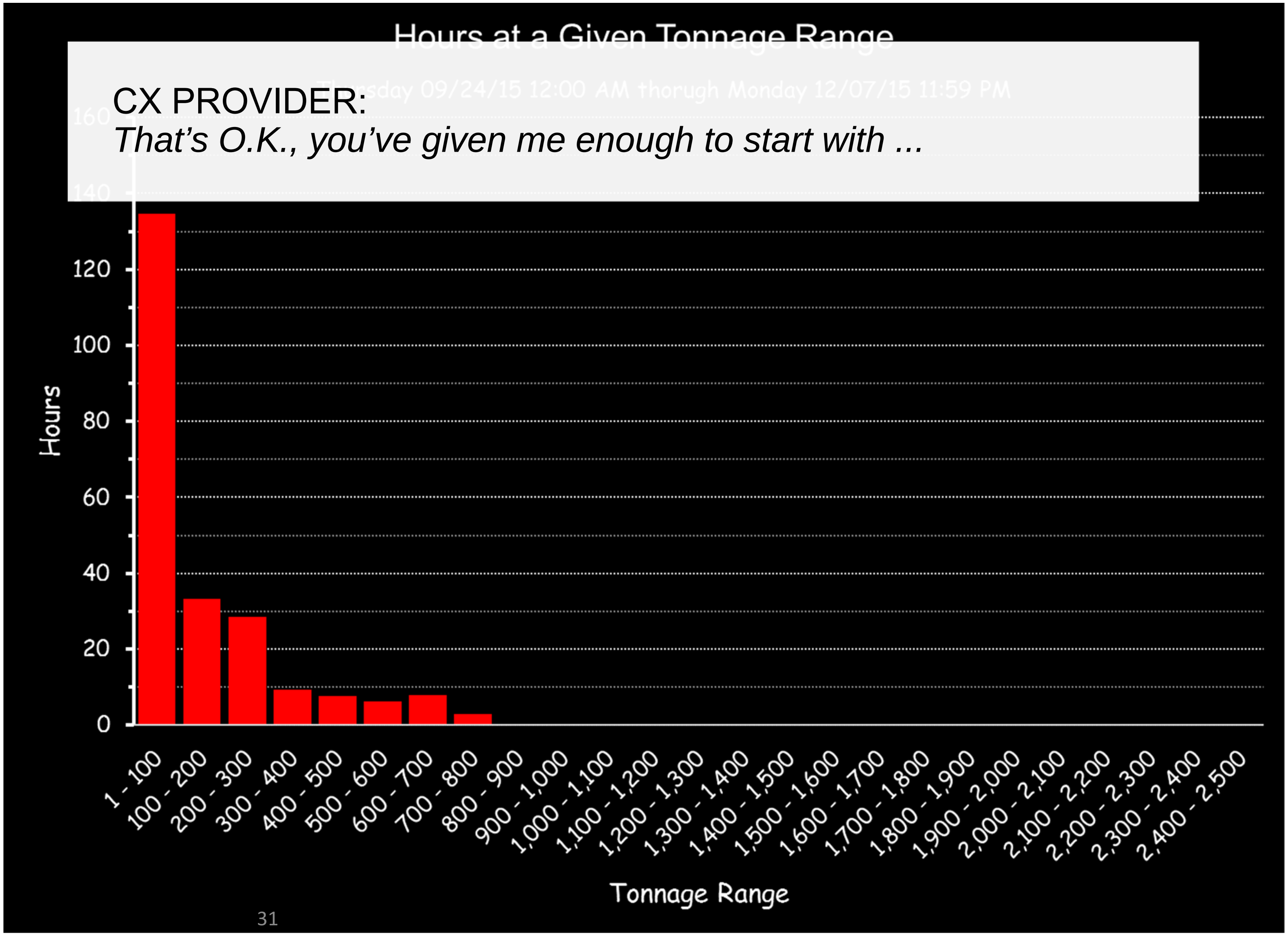


BUILDING:

But I am afraid I only have a couple of months of flow and tonnage data. My flow meter was broken for a while.

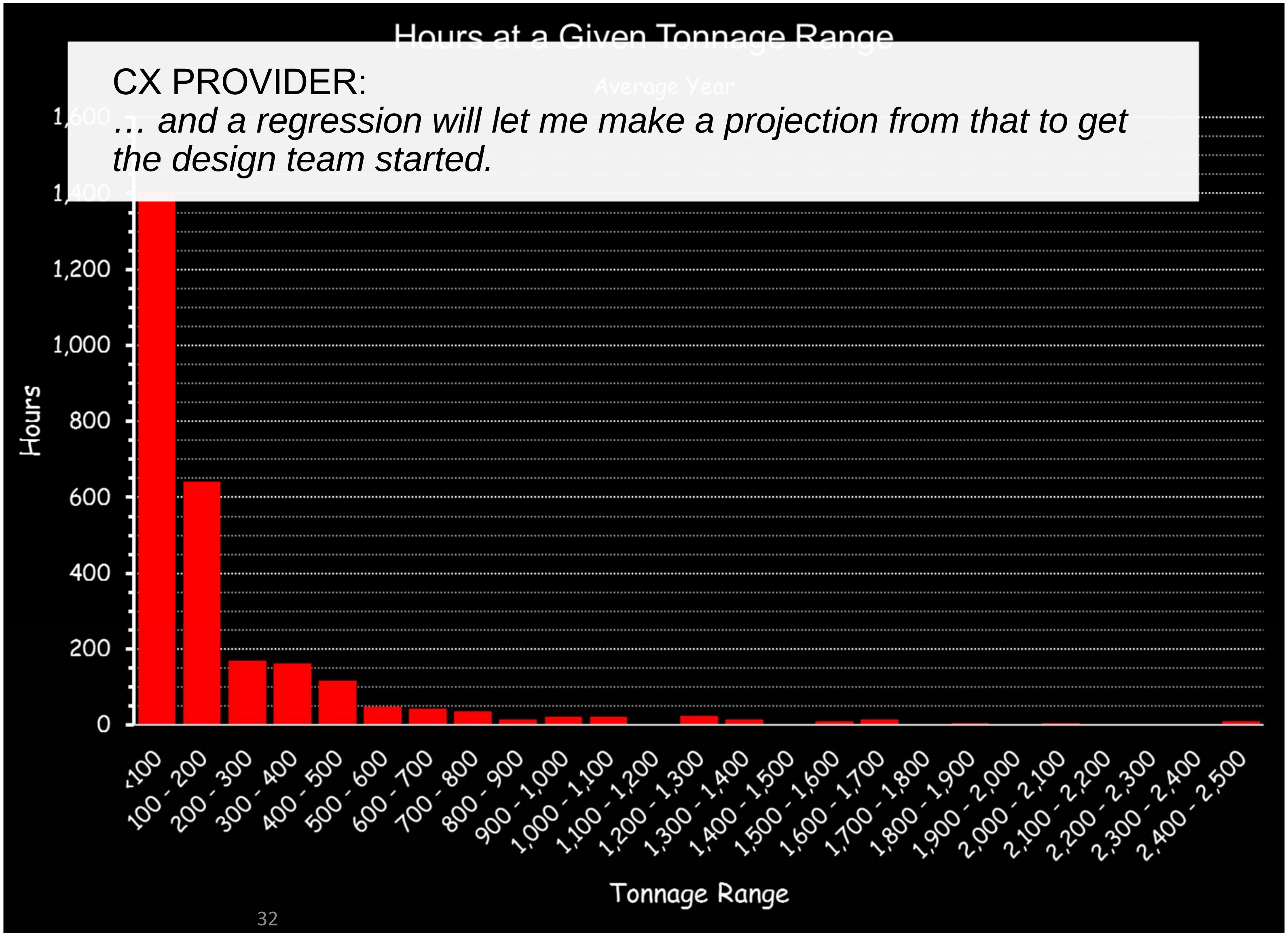


CX PROVIDER:
That’s O.K., you’ve given me enough to start with ...

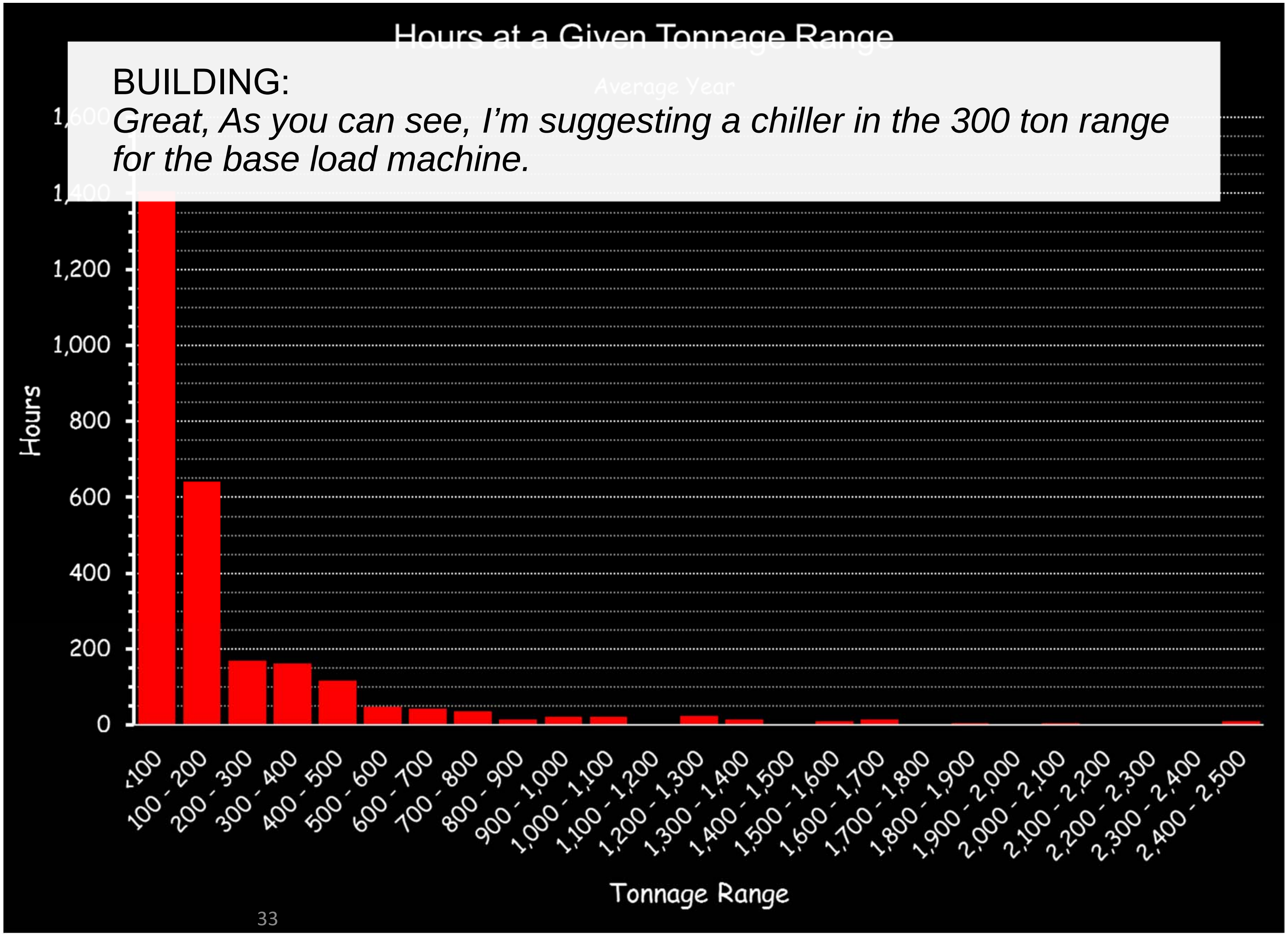


CX PROVIDER:

… and a regression will let me make a projection from that to get the design team started.

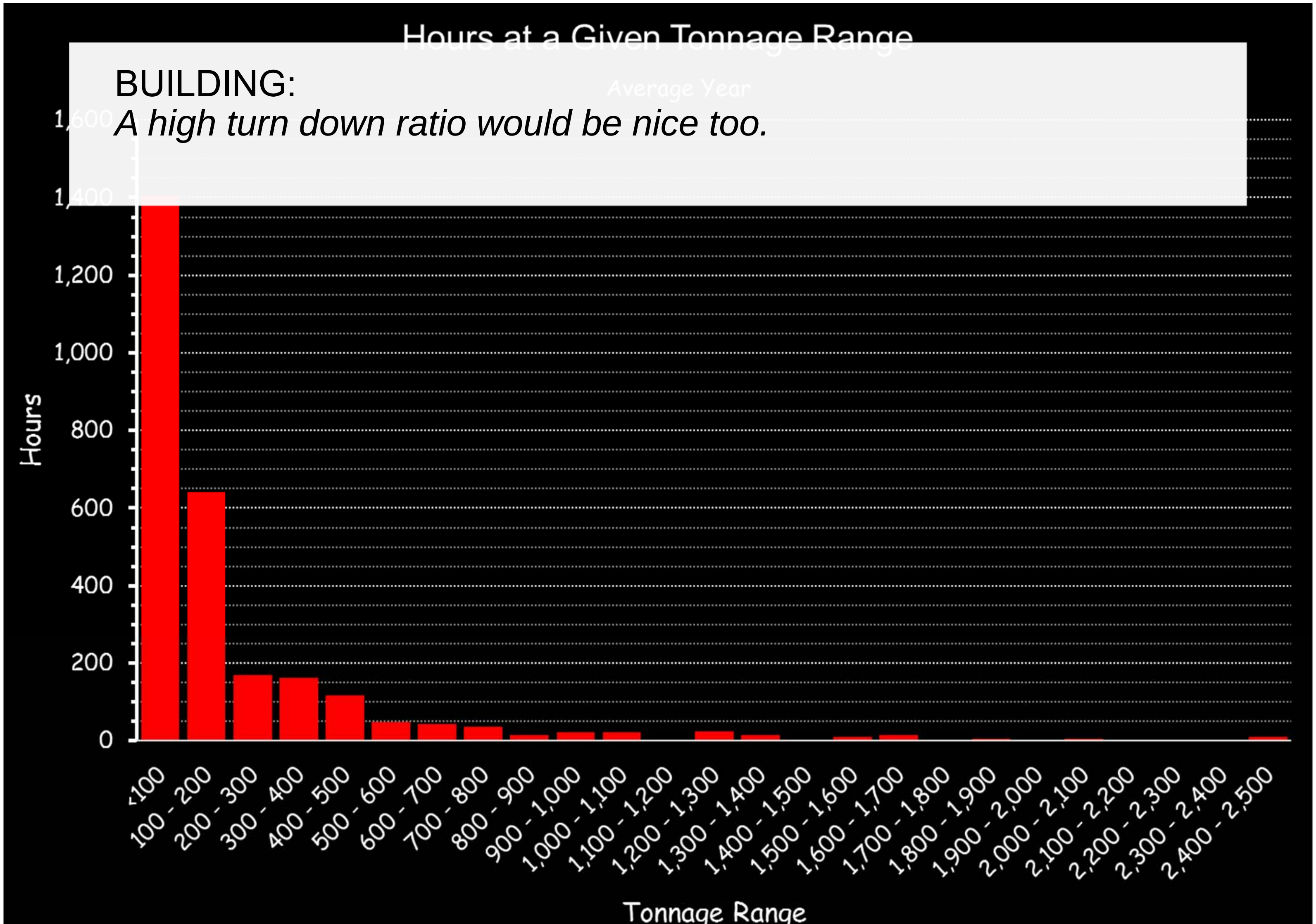


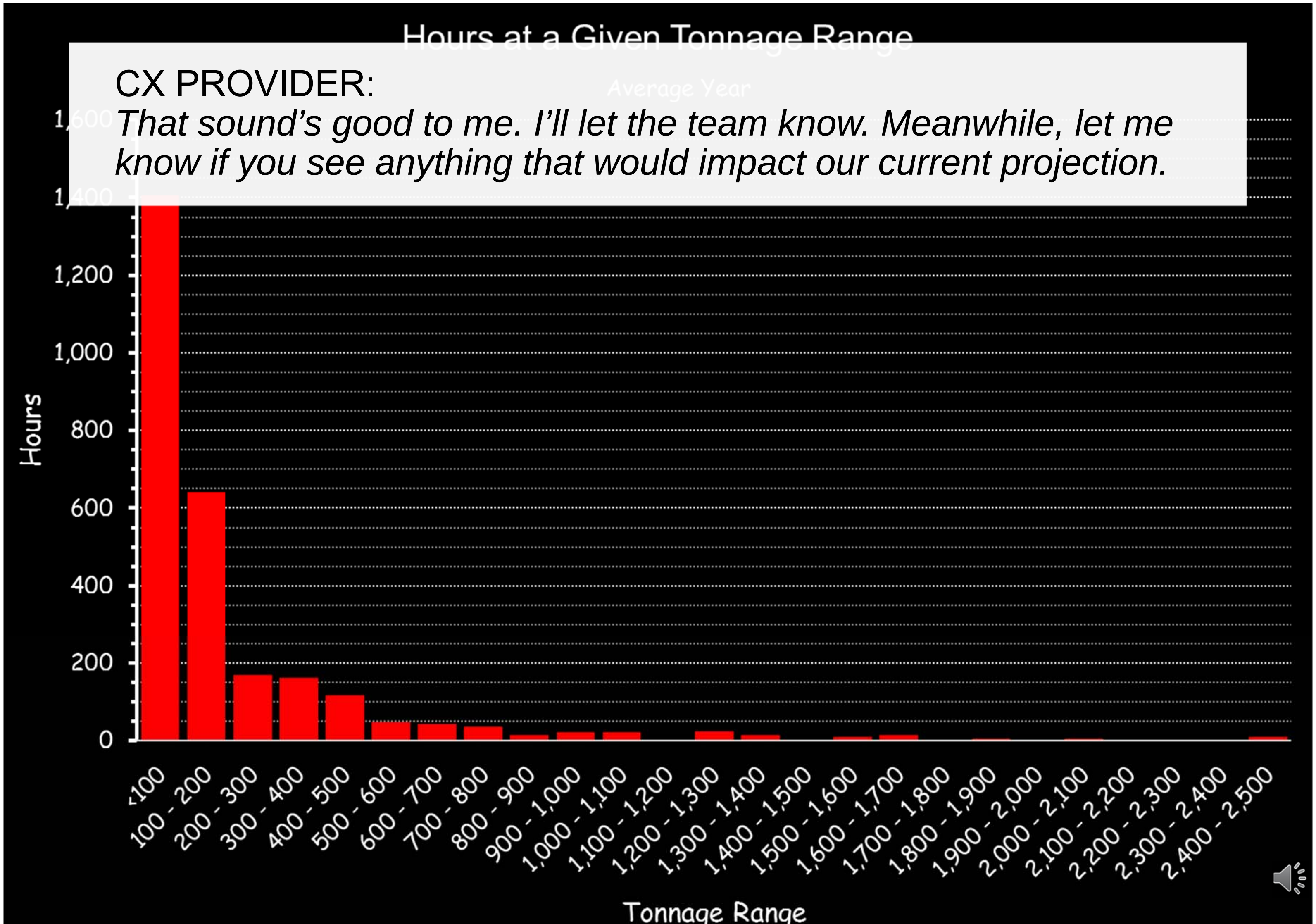
BUILDING:
Great, As you can see, I’m suggesting a chiller in the 300 ton range for the base load machine.



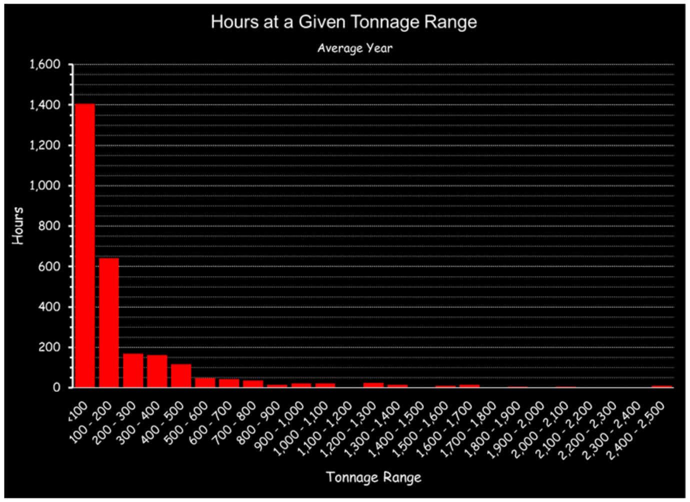
BUILDING:

A high turn down ratio would be nice too.




Hours at a Given Tonnage Range
CX PROVIDER:
That sound's good to me. I'll let the team know. Meanwhile, let me know if you see anything that would impact our current projection.
Average Year
Hours
Tonnage Range
0
200
400
600
800
1,000
1,200
1,400
1,600
<100
100 - 200
200 - 300
300 - 400
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1,000
1,000 - 1,100
1,100 - 1,200
1,200 - 1,300
1,300 - 1,400
1,400 - 1,500
1,500 - 1,600
1,600 - 1,700
1,700 - 1,800
1,800 - 1,900
1,900 - 2,000
2,000 - 2,100
2,100 - 2,200
2,200 - 2,300
2,300 - 2,400
2,400 - 2,500

The design evolves and is reviewd



- FADE OUT:
- FADE IN TIME PASSING MUSIC
- FADE IN CX PROVIDER DOING DESIGN REVIEW ON THE NEW CENTRAL PLANT DESIGN

BUILDING:

I'm happy to see the design team paid attention to my suggestion about equipment sizes and turn down requirements.

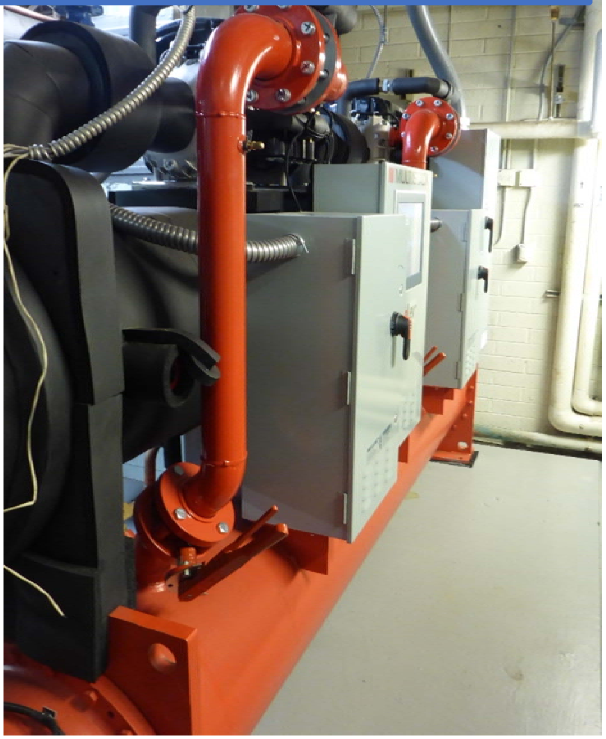
KW/TON	0.554	0.470	0.470

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.



BUILDING:

I think I will need to run some pumps and cooling towers when I run those new chillers. Will that impact how you would sequence them?

PUMPS - HYDRONIC

		P14-1	P14-2	P14-3	P14-4	P14-5	P14-6
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.

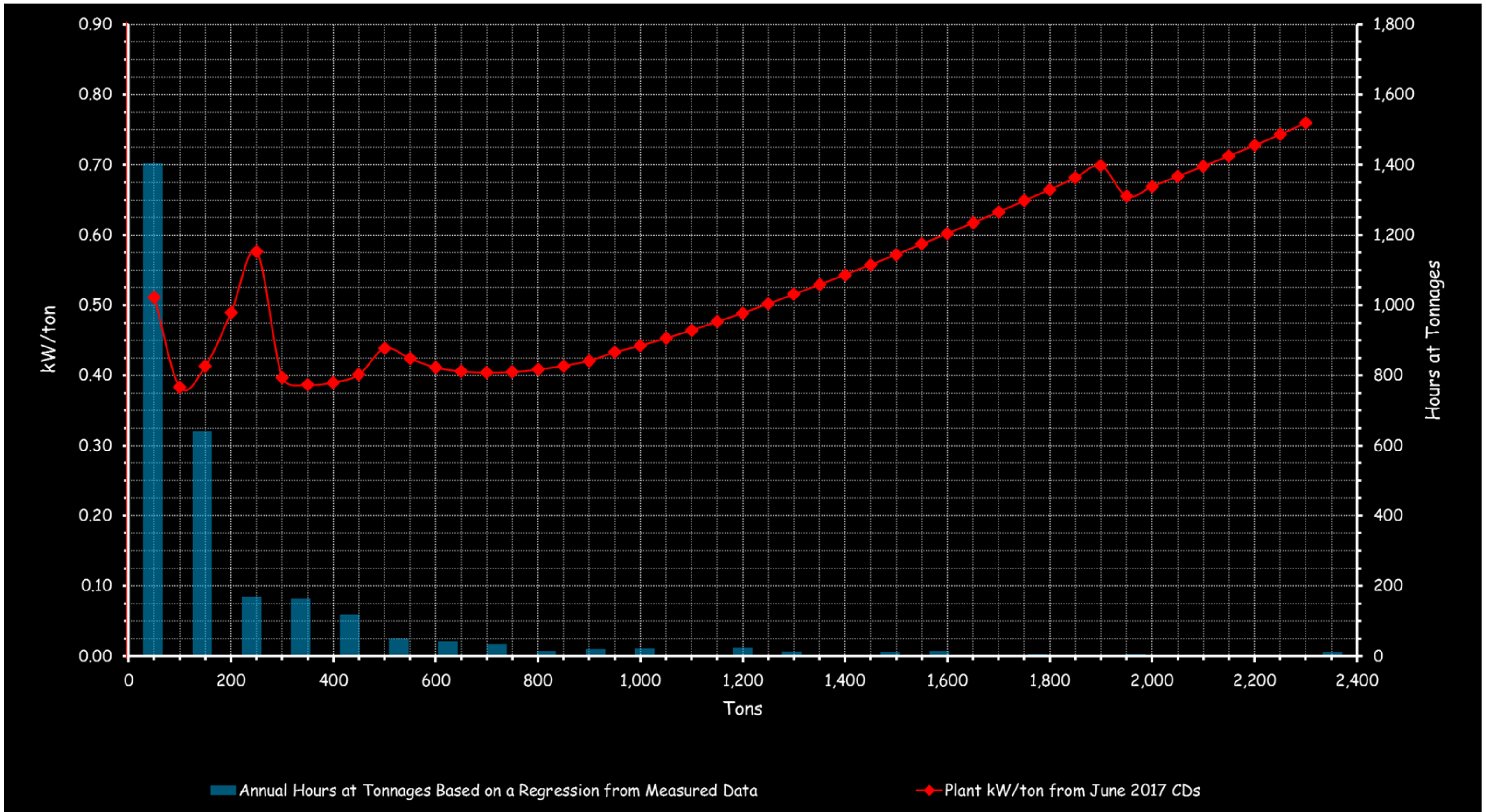
COOLING TOWERS

		CT-1A	CT-1B
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]

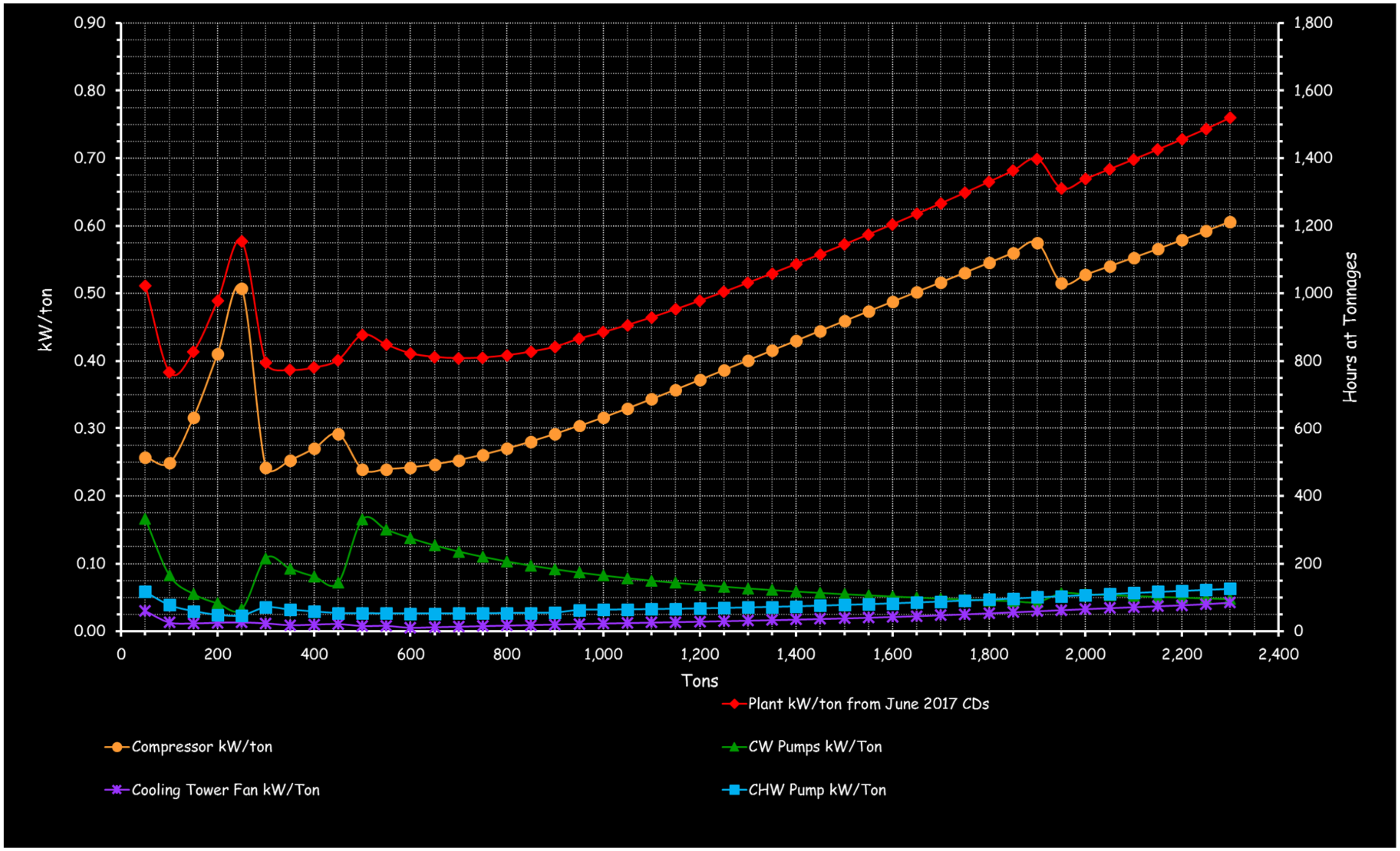
PROVIDE ALL COOLING TOWERS FROM ONE MANUFACTURER.

NOTES:

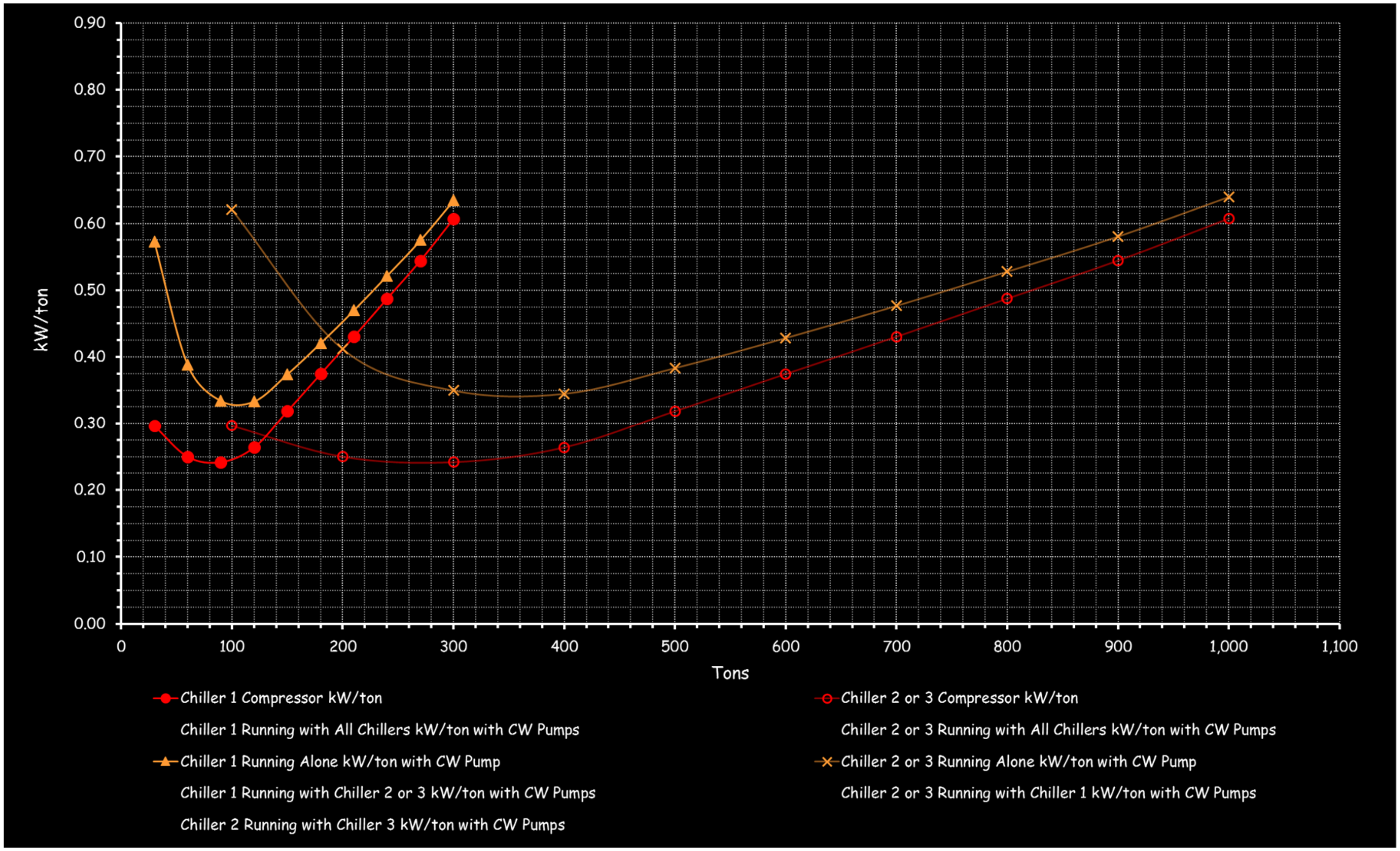
1. CAPACITIES BASED ON WATER.
2. REFER TO ELECTRICAL DRAWINGS FOR MOTOR STARTER AND DISCONNECT SWITCH.
3. PROVIDE WITH VIBRATION CUTOUT SWITCH.
4. PROVIDE WITH VARIABLE SPEED DRIVE AND FAN MOTORS.
5. PROVIDE WITH VORTEX ELIMINATOR AND BOTTOM PIPING CONNECTIONS.
6. PROVIDE STAINLESS STEEL PAN AND SUMP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

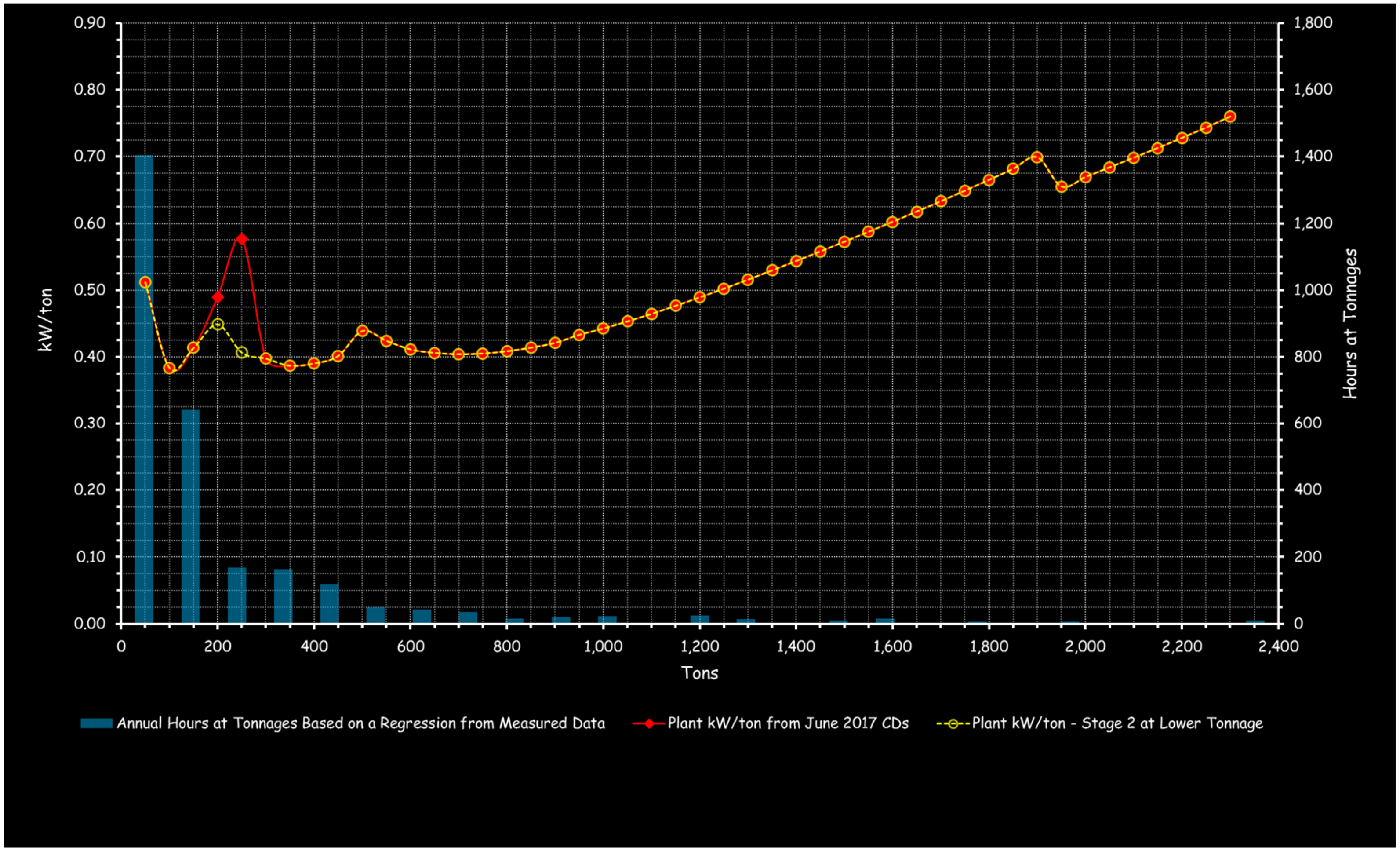


kW/ton
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
Tons
Hours at Tonnages
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Annual Hours at Tonnages Based on a Regression from Measured Data
Plant kW/ton from June 2017 CDs

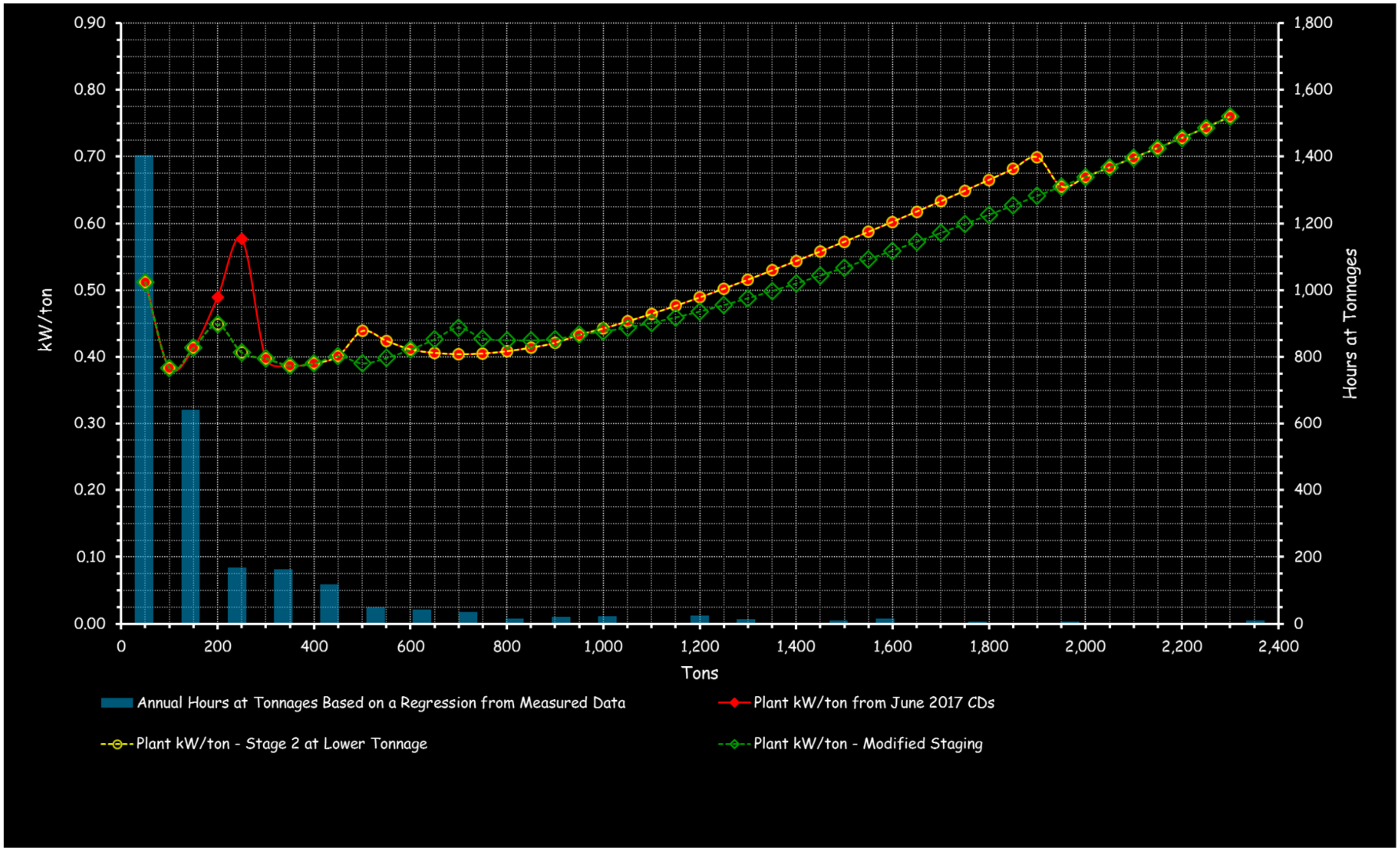


kW/ton
Hours at Tonnages
Tons
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
Plant kW/ton from June 2017 CDs
Compressor kW/ton
CW Pumps kW/Ton
Cooling Tower Fan kW/Ton
CHW Pump kW/Ton


0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
kW/ton
0
100
200
300
400
500
600
700
800
900
1,000
1,100
Tons
Chiller 1 Compressor kW/ton
Chiller 1 Running with All Chillers kW/ton with CW Pumps
Chiller 1 Running Alone kW/ton with CW Pump
Chiller 1 Running with Chiller 2 or 3 kW/ton with CW Pumps
Chiller 2 Running with Chiller 3 kW/ton with CW Pumps
Chiller 2 or 3 Compressor kW/ton
Chiller 2 or 3 Running with All Chillers kW/ton with CW Pumps
Chiller 2 or 3 Running Alone kW/ton with CW Pump
Chiller 2 or 3 Running with Chiller 1 kW/ton with CW Pumps



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



kW/ton
Hours at Tonnages
Tons
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
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
Plant kW/ton - Stage 2 at Lower Tonnage
Plant kW/ton - Modified Staging

Bottom line

- Com·mis·sion
- kəˈmiSHən/Submit
- Verb; Gerund or present participle: Commissioning
- 1. A process during which buildings are mentoring us about design