



# ***Introduction to the Controlled Systems***

*Tab 3-2*

*Load Dynamics*

Presented By:  
David Sellers, Senior Engineer  
Facility Dynamics Engineering



# A Bit About Me

I intended to be an aircraft  
maintenance engineer

*How many of you are doing what  
you went to school to learn to do?*

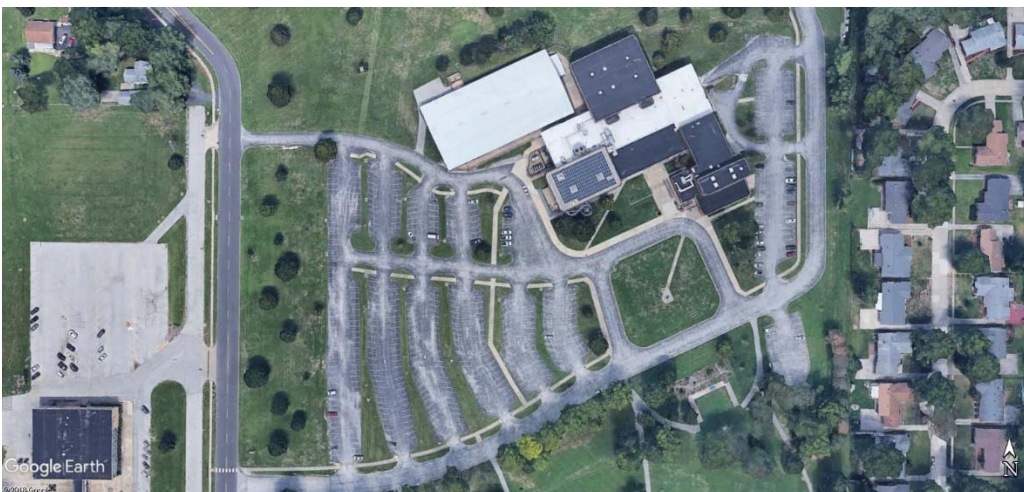
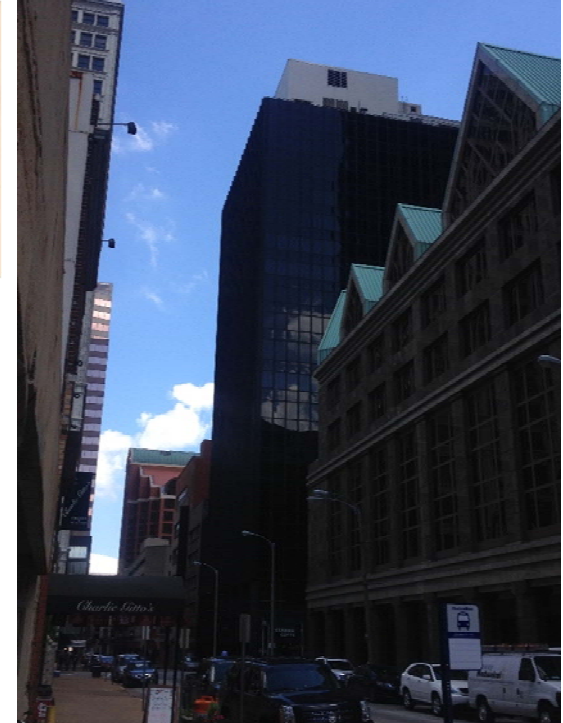


# I'm Doing Something Totally Different





# I'm Doing Something Totally Different



CX PROCESS AND SKILLS OVERVIEW, EBCX ROM BUDGETS

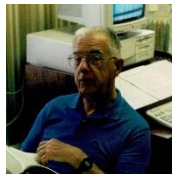
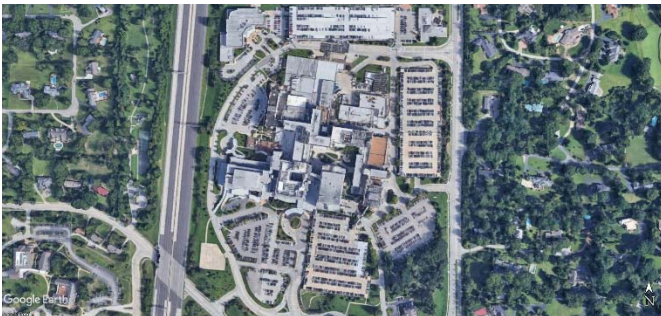


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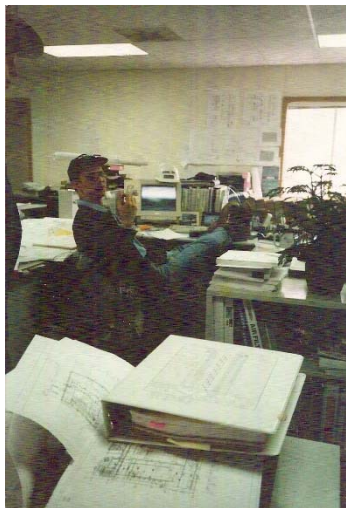


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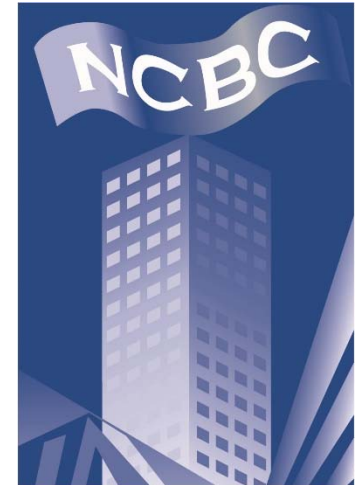


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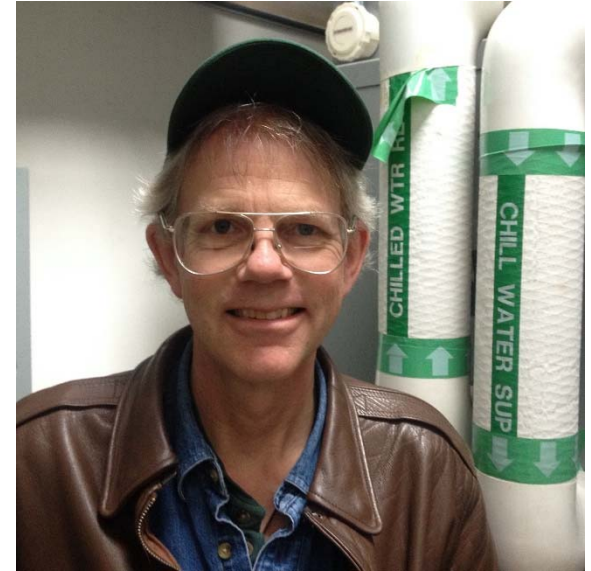


# I'm Doing Something Totally Different





# I'm Doing Something Totally Different







# I'm Doing Something Totally Different



(Go to  
<https://tinyurl.com/PVequalsmRT>  
for more pictures and videos from  
the balloon flight)



# You Can Too

NEVER NEVER LOOSE SIGHT  
OF THE FACT THAT YOU CAN BE ANYTHING  
YOU WANNA BE... YOU COULD BE SOMETHING  
AS SIMPLE AS A NOSE, MUSTACHE OR A SMILE.  
OR, FOR THAT MATTER, AS COMPLEX AS A DOG, TREE  
OR BARBED WIRE FENCE...  
HECK, YOU COULD BE  
THE PRESIDENT!



AN INSPIRATIONAL  
APPROACH TO CARTOONING

# I've Had Great Mentors Along the Way





# What We Will Cover in This Module

## Part 1

- The dynamic, interactive, nature of the loads served by HVAC systems and the challenges we face when we try to integrate them with a control system
- This is important enough that I will probably bring this up at least once ~~each day~~

## Part 2

- An overview of common components in HVAC control processes
- Understanding the relationship between the control process and the controlled equipment

## Some Resources

The location for things I hand out or use in class

<http://www.av8rdas.com/u-of-w.html>

The location of my blog

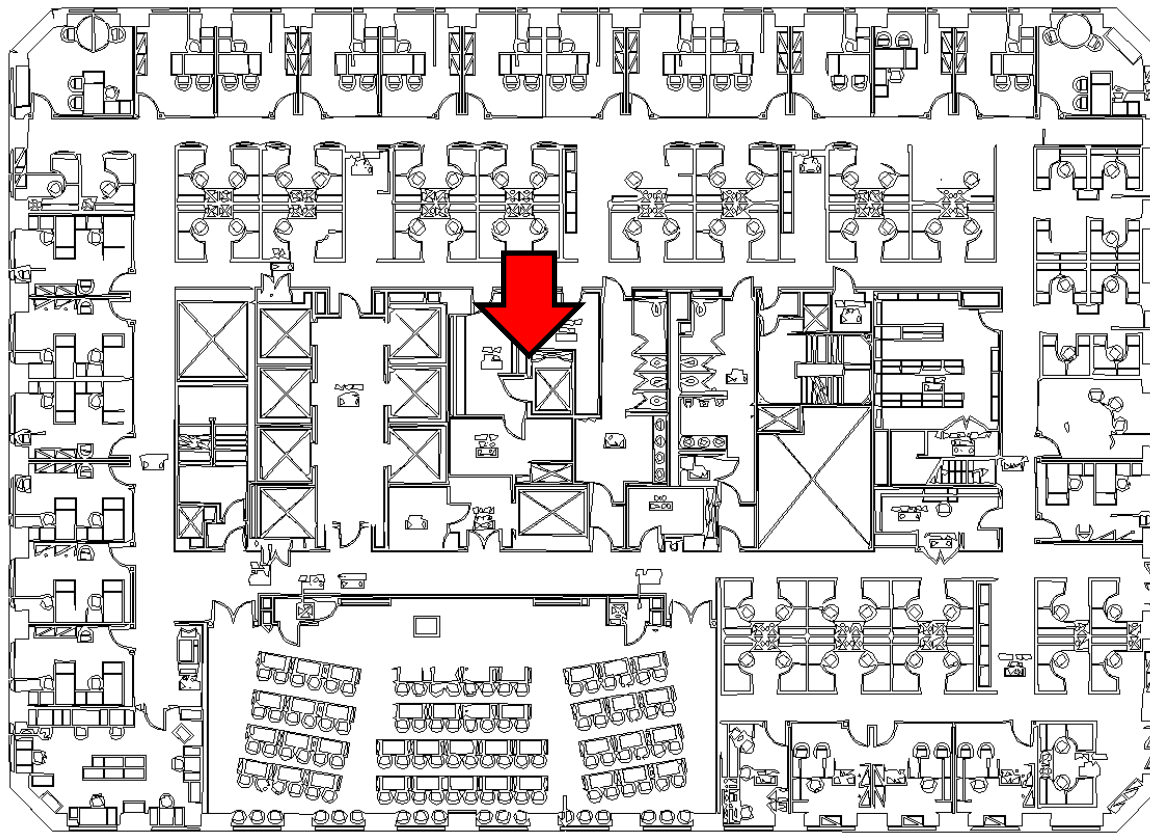
[www.Av8rDAS.Wordpress.com](http://www.Av8rDAS.Wordpress.com)

# The Built Environment

Keeping the built environment safe, productive, clean, and comfortable is a fundamental goal of HVAC systems and their controls

- Ventilation systems control contaminants by introducing filtered, conditioned outdoor air
- Heating and cooling systems track the loads to control comfort

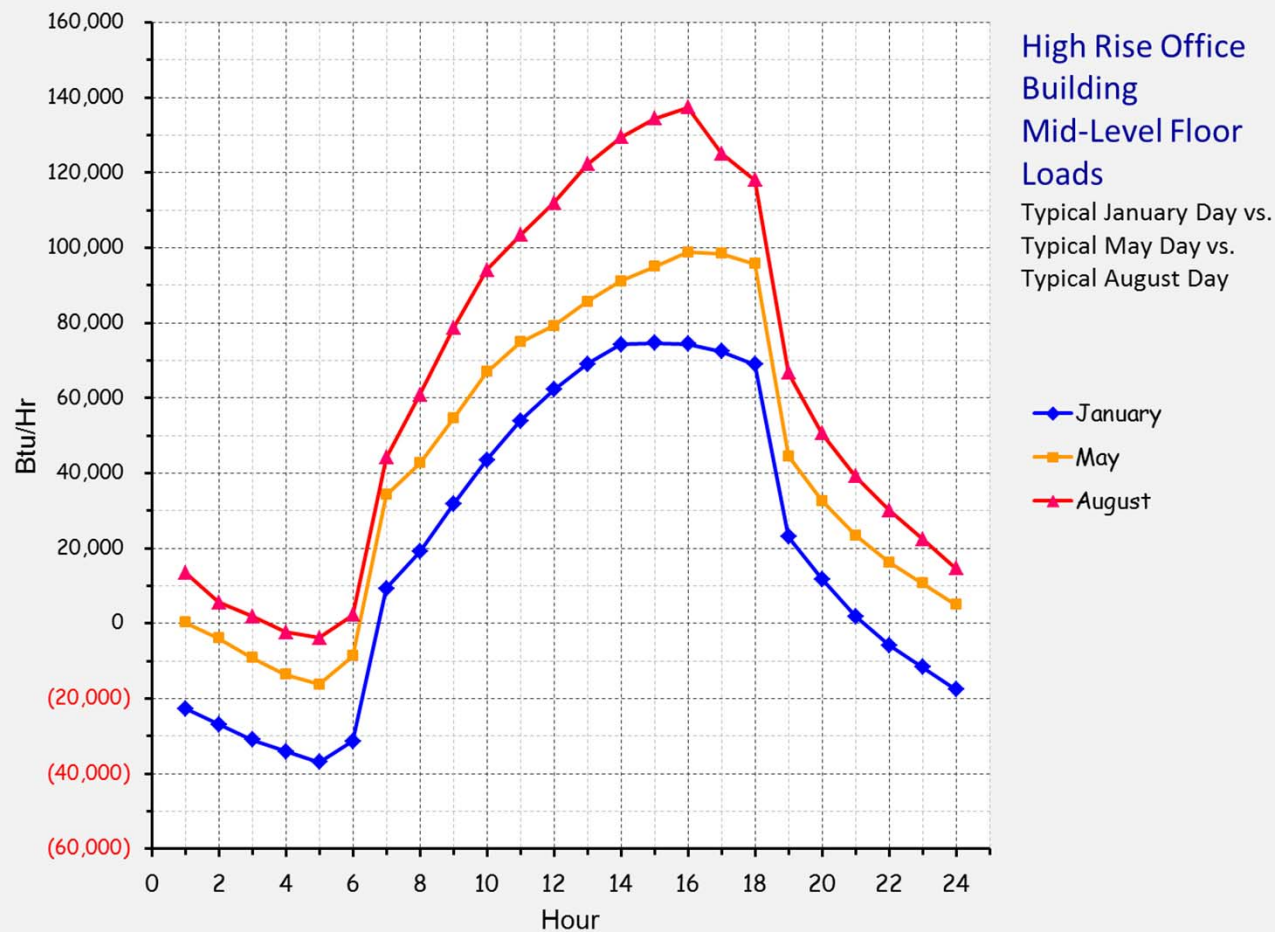




ductive, clean, and  
AC systems and

- Ventilation systems control contaminants by introducing filtered, conditioned outdoor air
- Heating and cooling systems track the loads to control comfort

# The Loads can be Very Dynamic



The Cooling Requirements Vary with Time of Day and Time of Year



# Load Dynamics

A Research Experiment by the  
FDE NW Research Lab

Dr. Riley Sellers; PhD CTK *LBNL*  
*CTPSC* \*

Hobbes Sellers; Post Doc *Applied*  
*Chaos Theory*

- \* Doctorate of Philosophy - Canine Treat  
Kinetics - Lower Buchanan National Labs,  
Canine Treat Preservation Systems Center



# Outside = Inside

## A Research Experiment by the FDE NW Research Lab

### The Experiment

- Use an environmental test chamber to assess the thermal response characteristics of different envelope configurations



Environmental Test Chamber

# Outside = Inside

## A Research Experiment by the FDE NW Research Lab

### Envelope Configuration 1

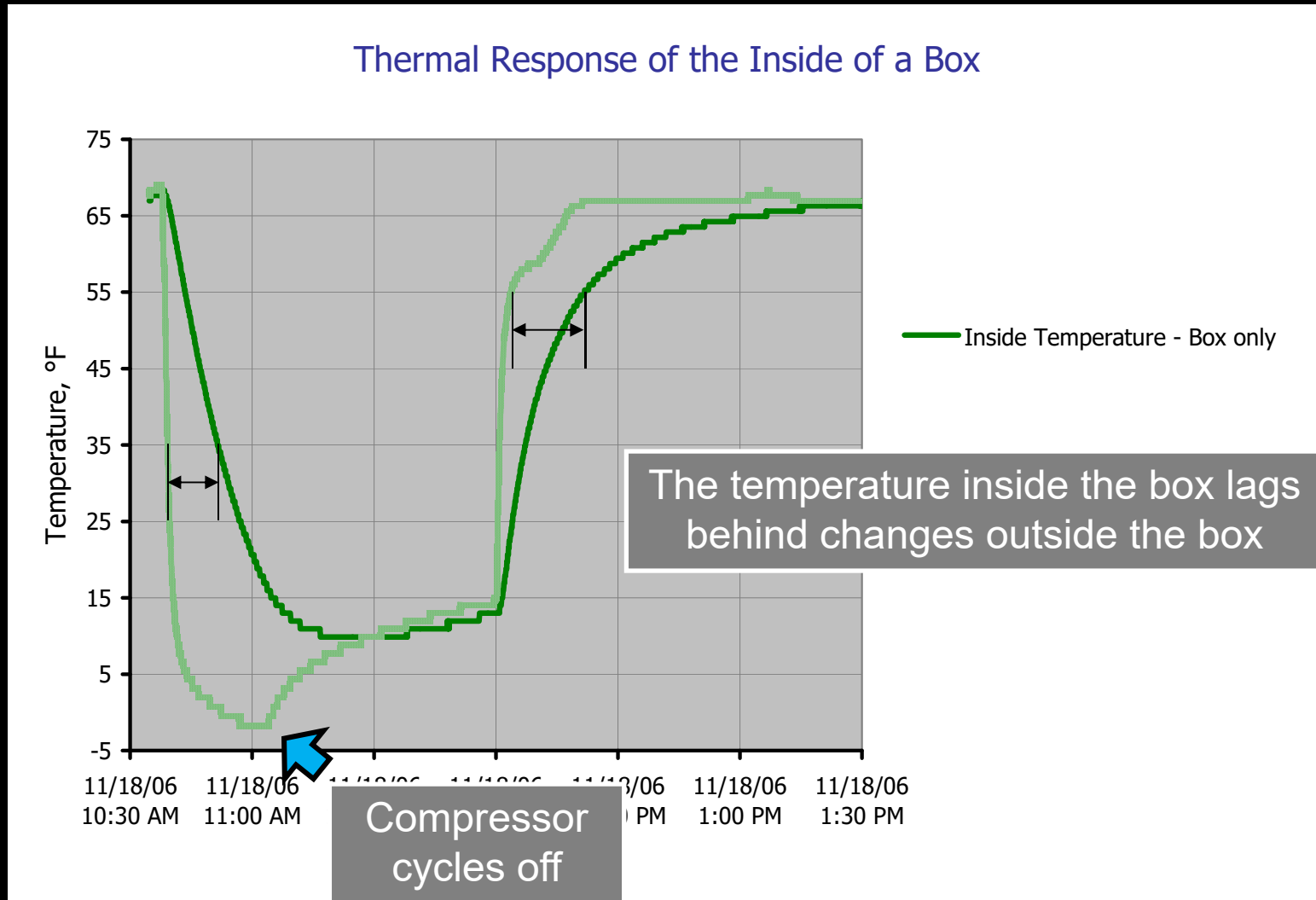
- Cardboard box, no insulation



Envelope Configuration 1



# Test Results – Envelope Configuration 1



# Outside = Inside

## A Research Experiment by the FDE NW Research Lab

### Envelope Configuration 2

- Cardboard box, insulated

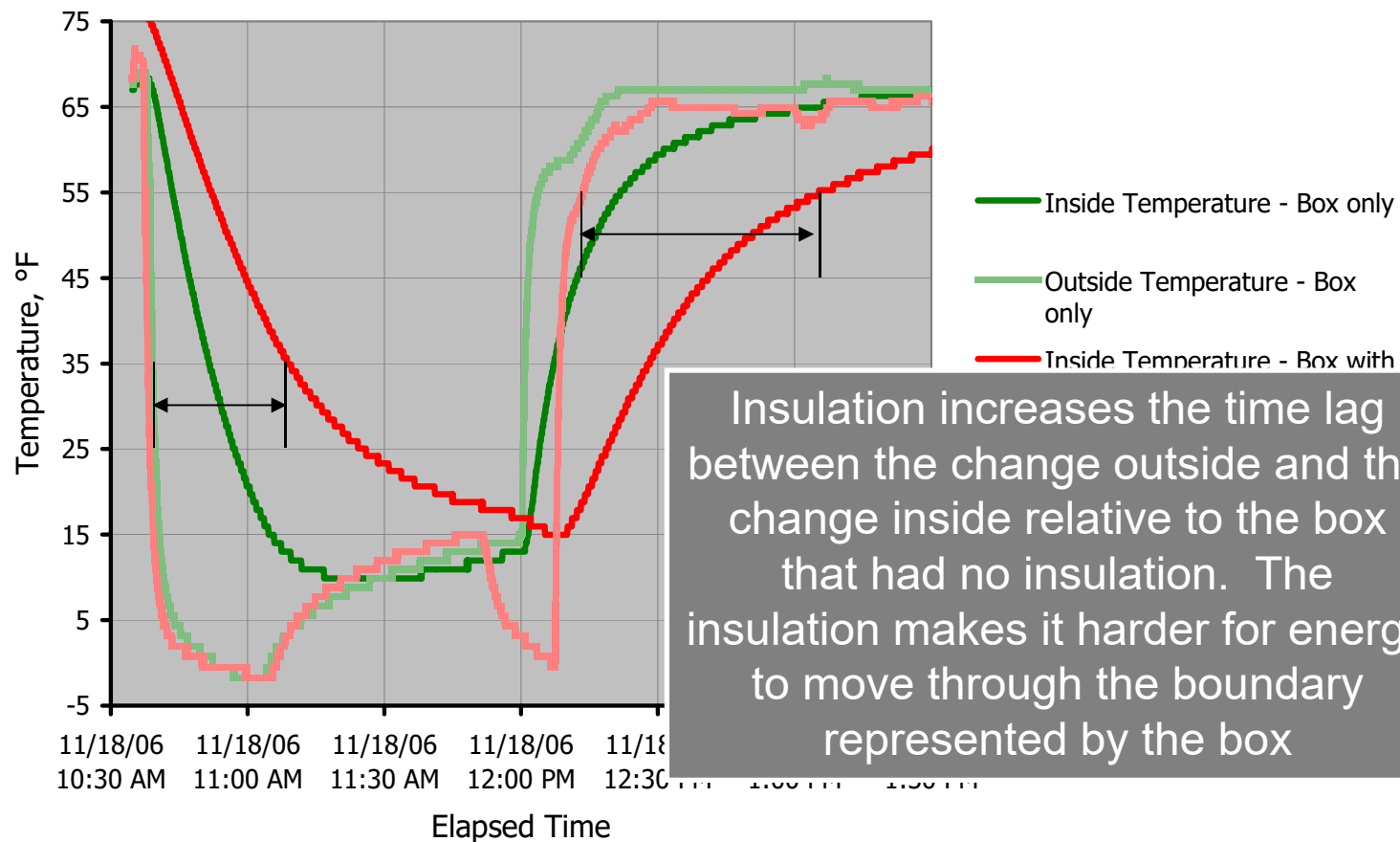


Envelope Configuration 2



# Test Results – Envelope Configuration 2

Thermal Response of the Inside of a Box



# Outside = Inside

## A Research Experiment by the FDE NW Research Lab

### Envelope Configuration 3

- Cardboard box with rocks, no insulation

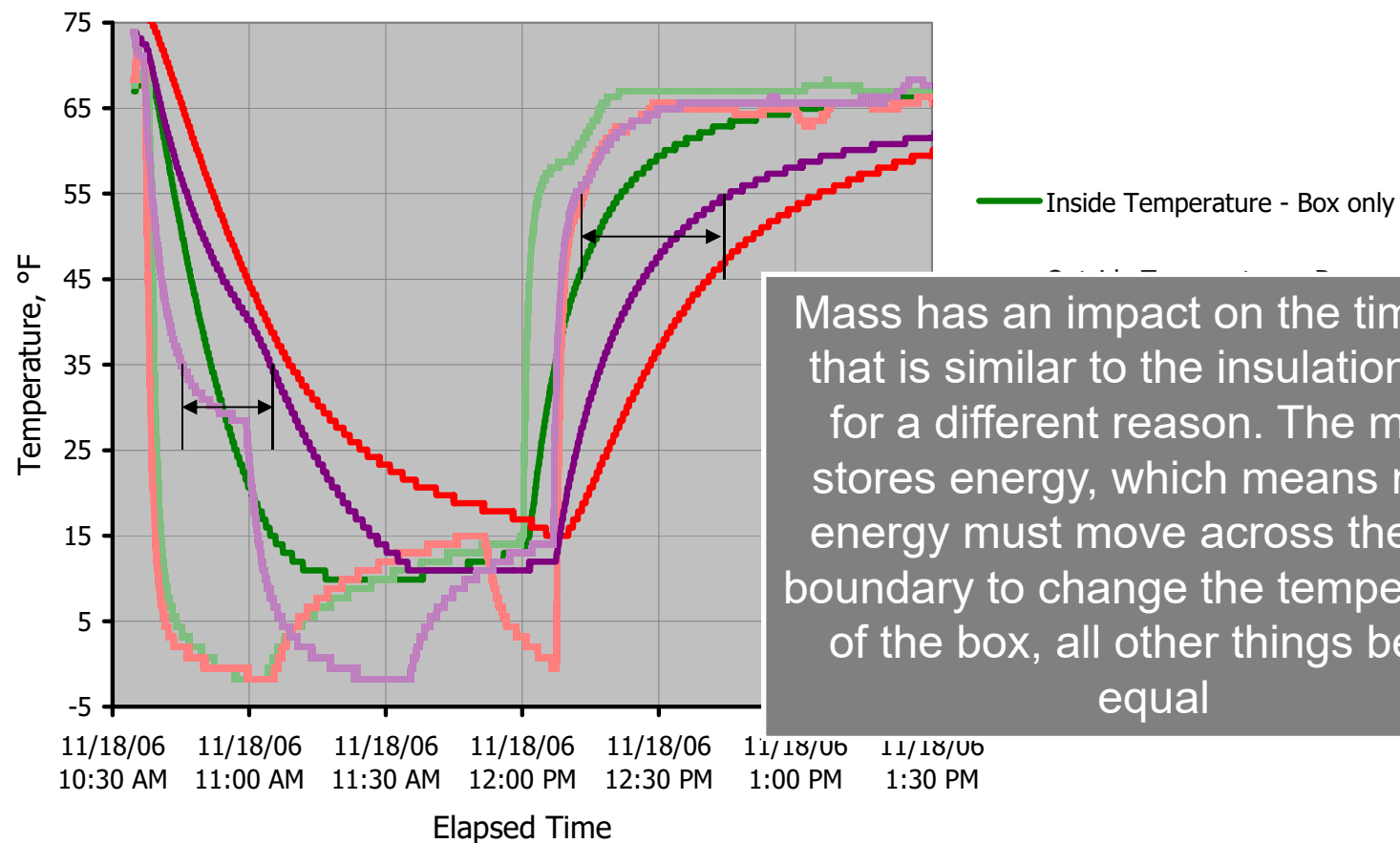


Envelope Configuration 3



# Test Results – Envelope Configuration 3

Thermal Response of the Inside of a Box



Mass has an impact on the time lag that is similar to the insulation, but for a different reason. The mass stores energy, which means more energy must move across the box boundary to change the temperature of the box, all other things being equal

# Internal Gains Have Lags Too







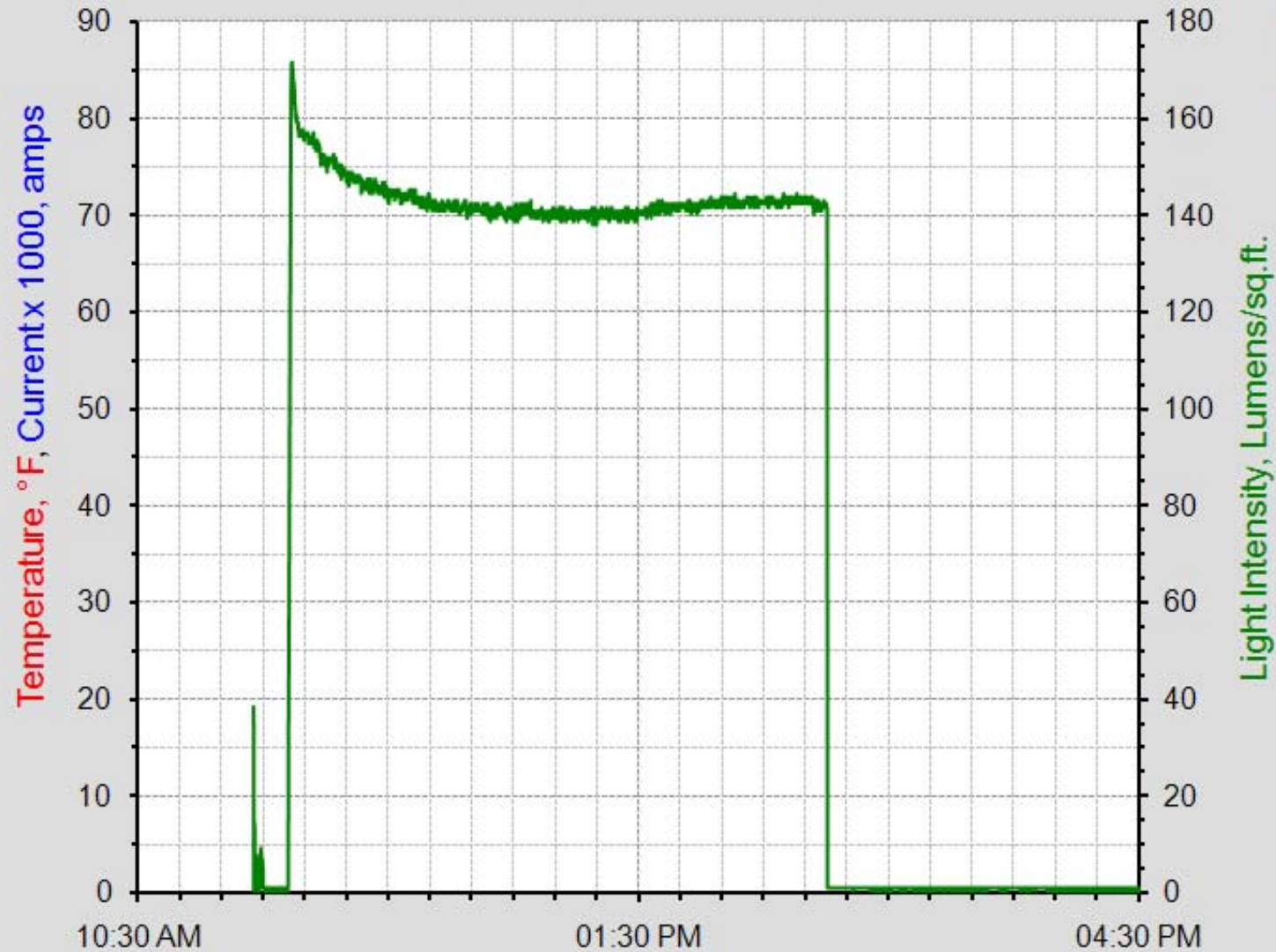
TAB 3-2 - LOAD DYNAMICS



TAB 3-2 - LOAD DYNAMICS



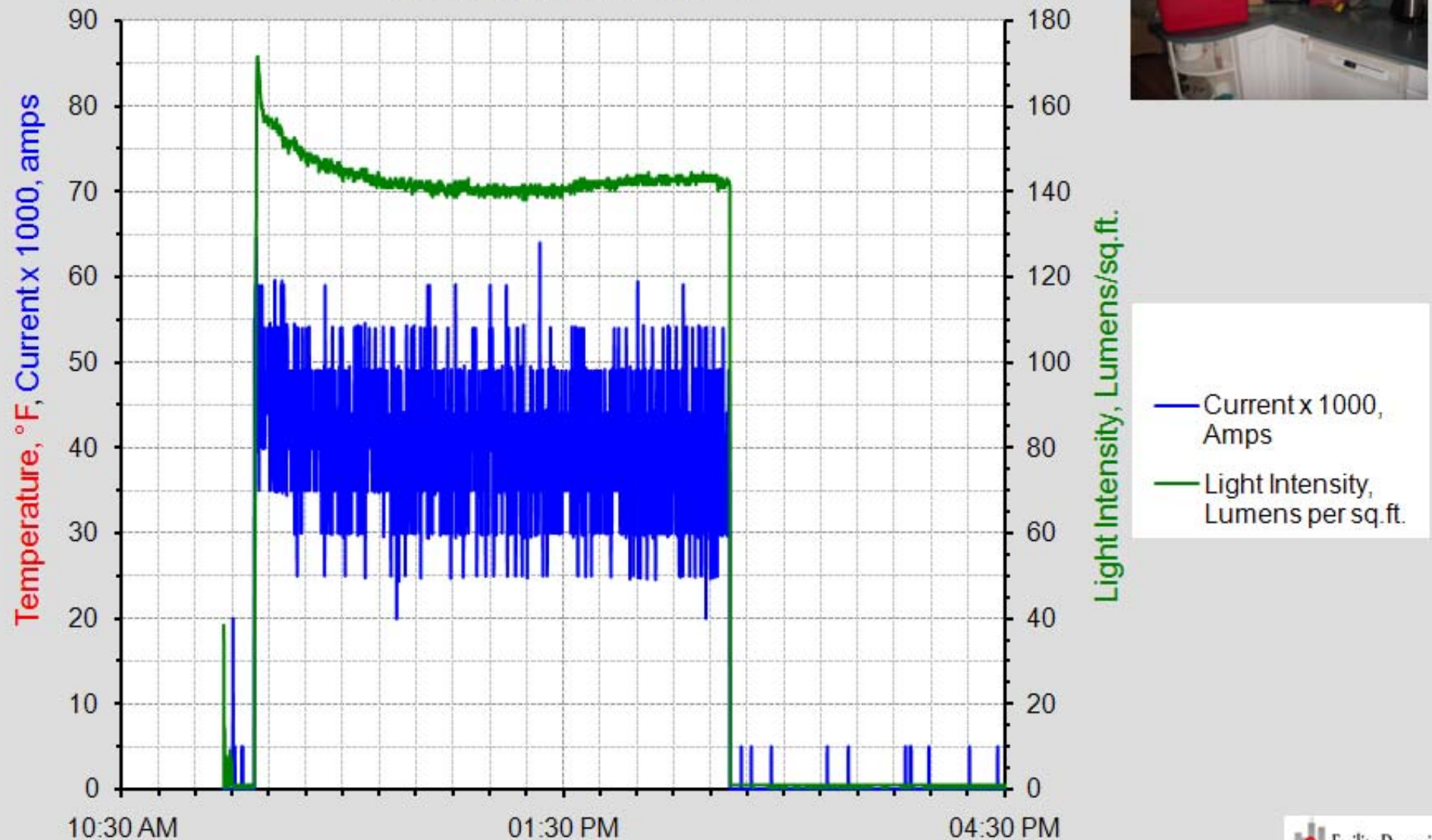
## Temperature Inside an Insulated Enclosure With and Without a Light On



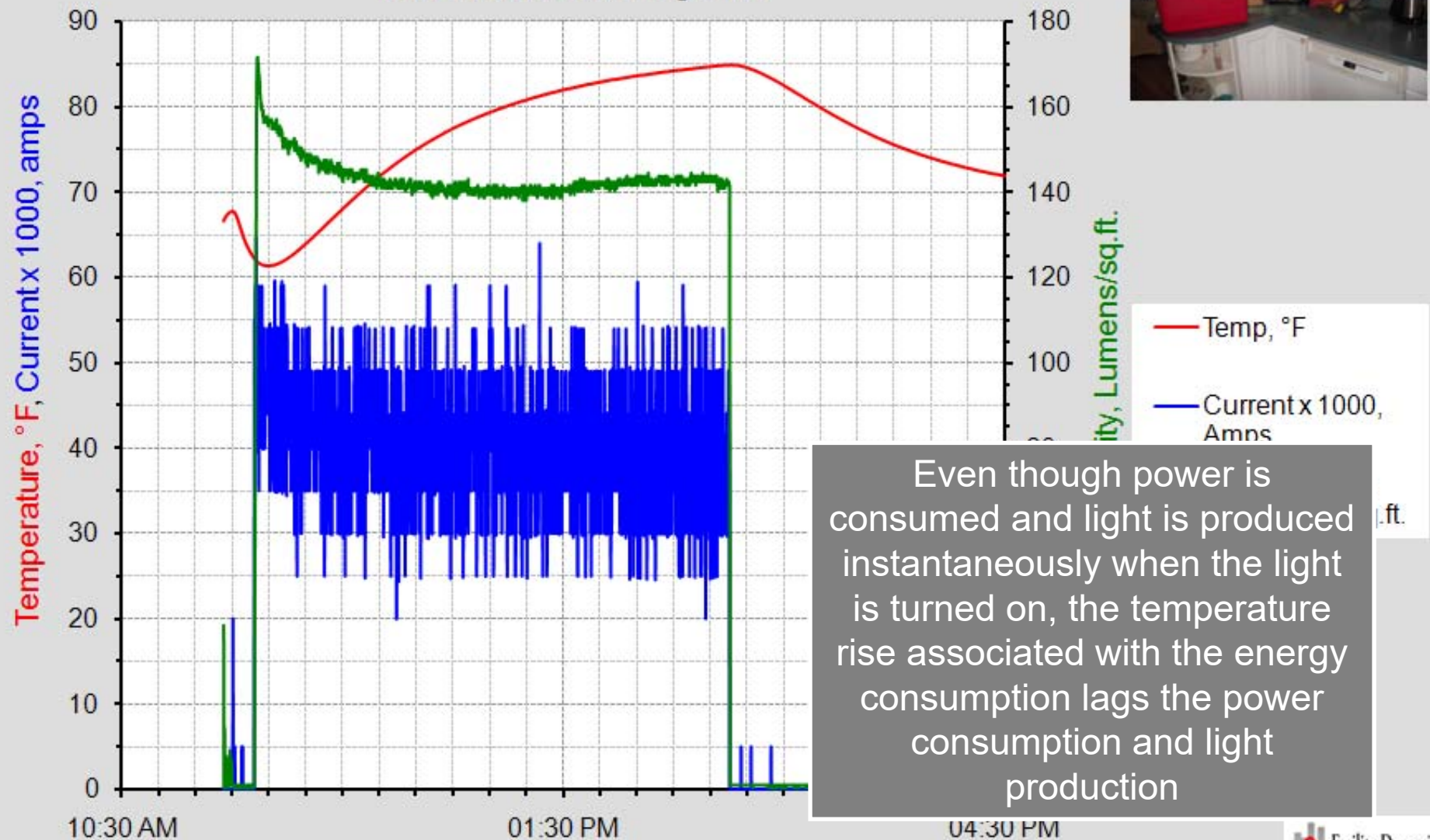
— Light Intensity,  
Lumens per sq.ft.



## Temperature Inside an Insulated Enclosure With and Without a Light On



## Temperature Inside an Insulated Enclosure With and Without a Light On





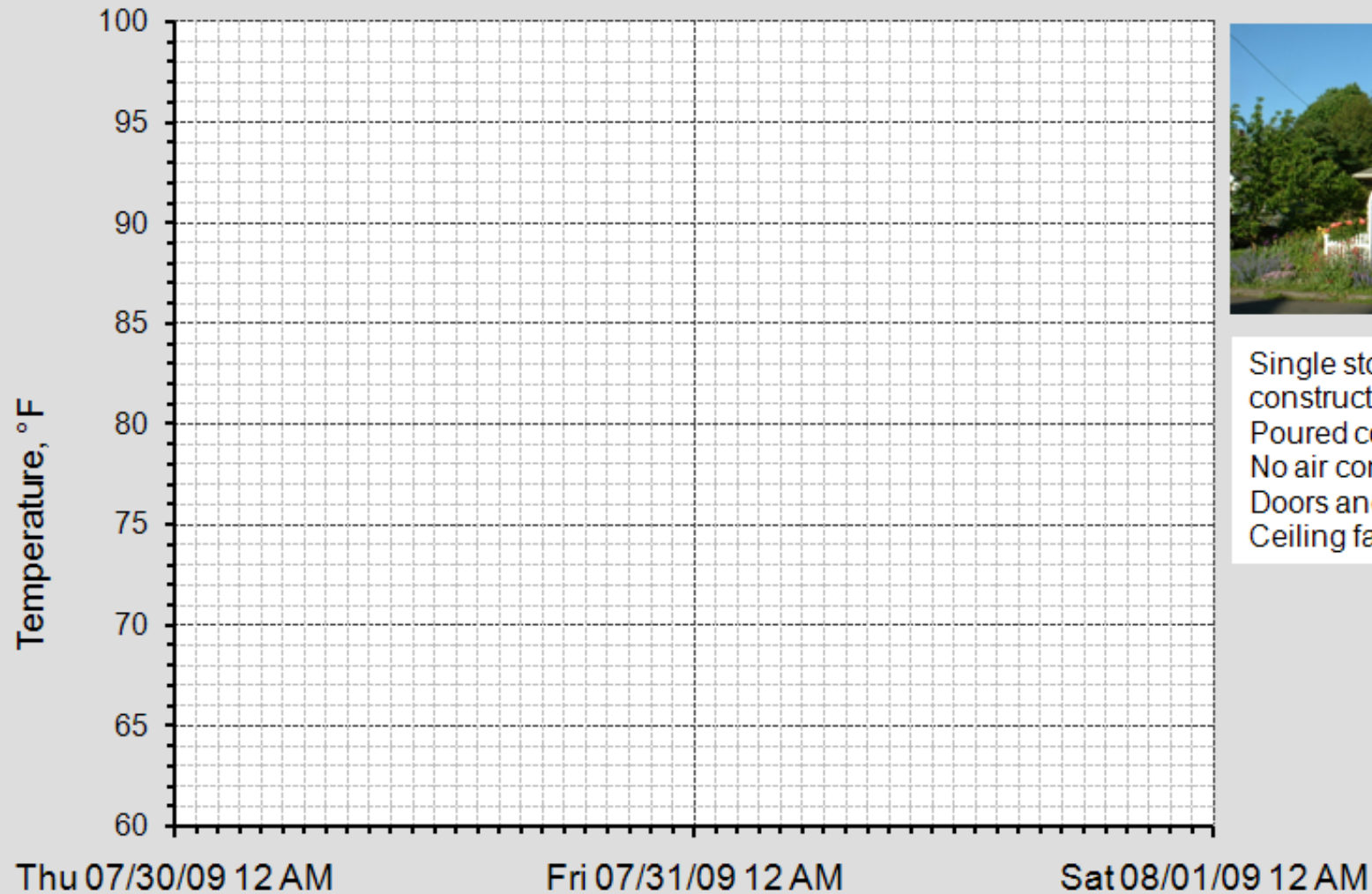
# Everything Interacts with Everything, Even in a Simple Building





## 8560 North Buchanan, Portland, OR Summer Thermal Response

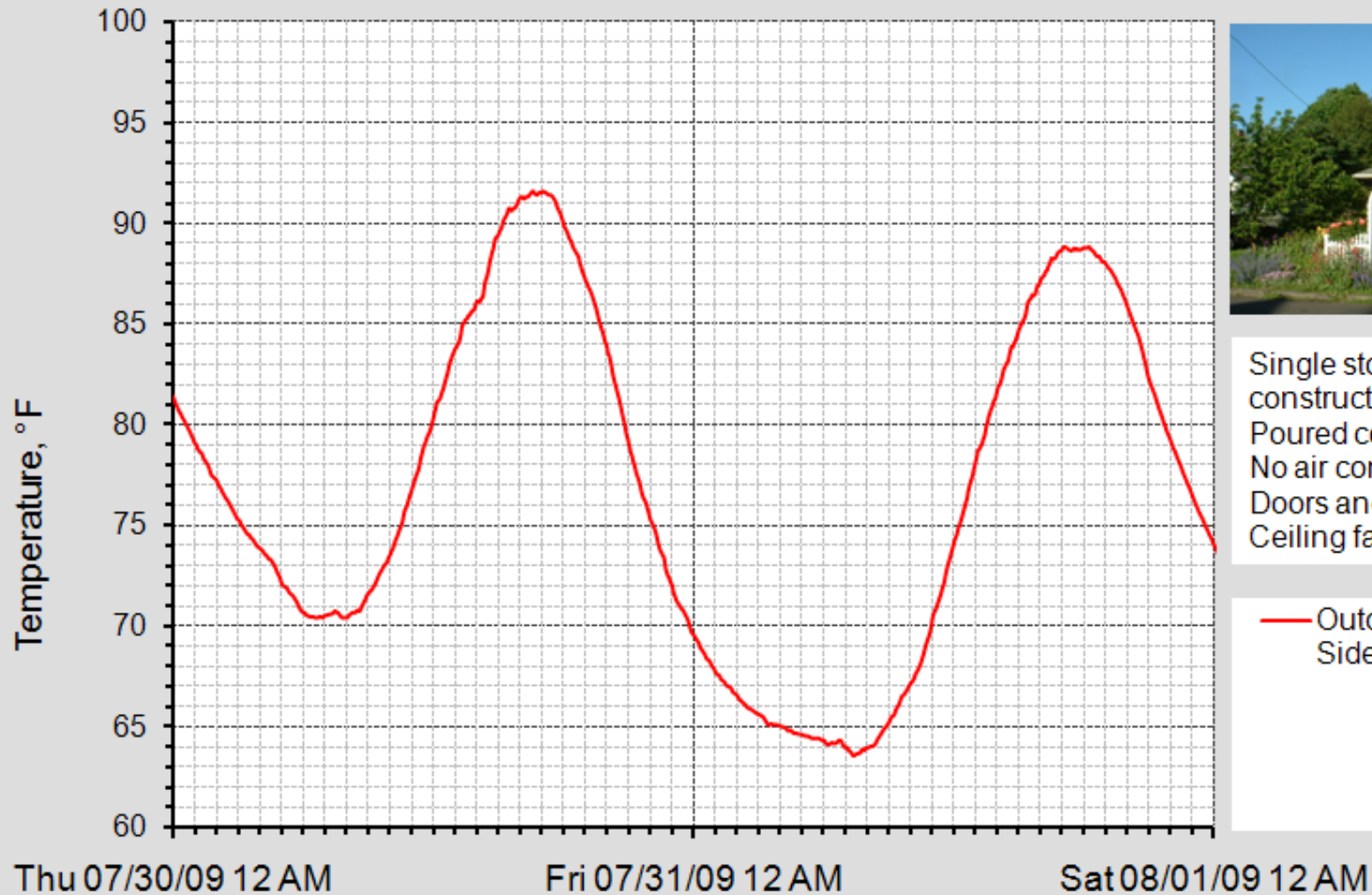
Portland 0.4% Cooling Design Condition - 90/67 °F<sub>db</sub>/t<sub>wb</sub>, 22°F Daily Range



Single story, light frame construction  
Poured concrete basement  
No air conditioning  
Doors and windows open  
Ceiling fans operating

## 8560 North Buchanan, Portland, OR Summer Thermal Response

Portland 0.4% Cooling Design Condition - 90/67 °F<sub>db</sub>/t<sub>wb</sub>, 22°F Daily Range

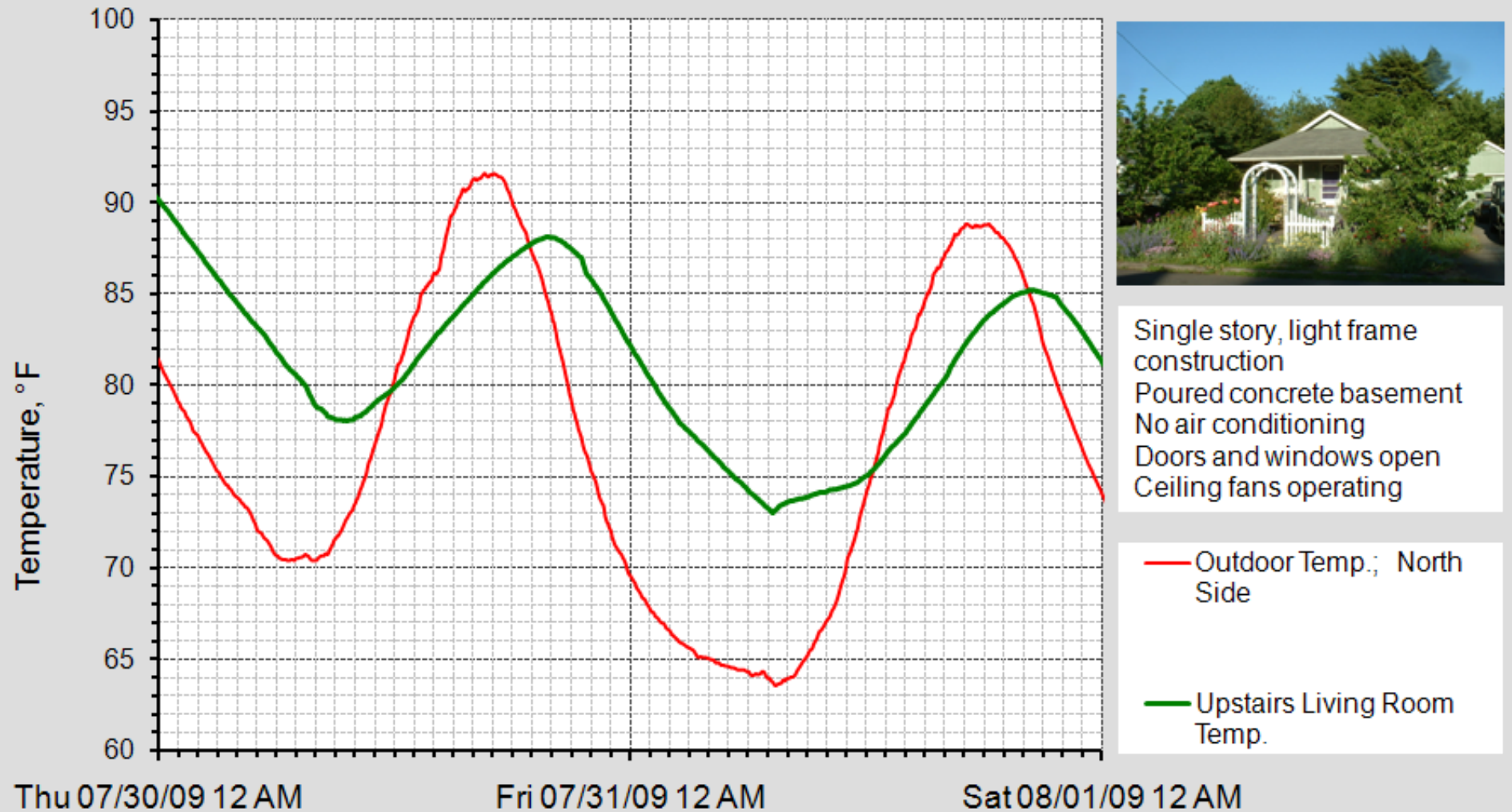


Single story, light frame construction  
Poured concrete basement  
No air conditioning  
Doors and windows open  
Ceiling fans operating

— Outdoor Temp.; North Side

## 8560 North Buchanan, Portland, OR Summer Thermal Response

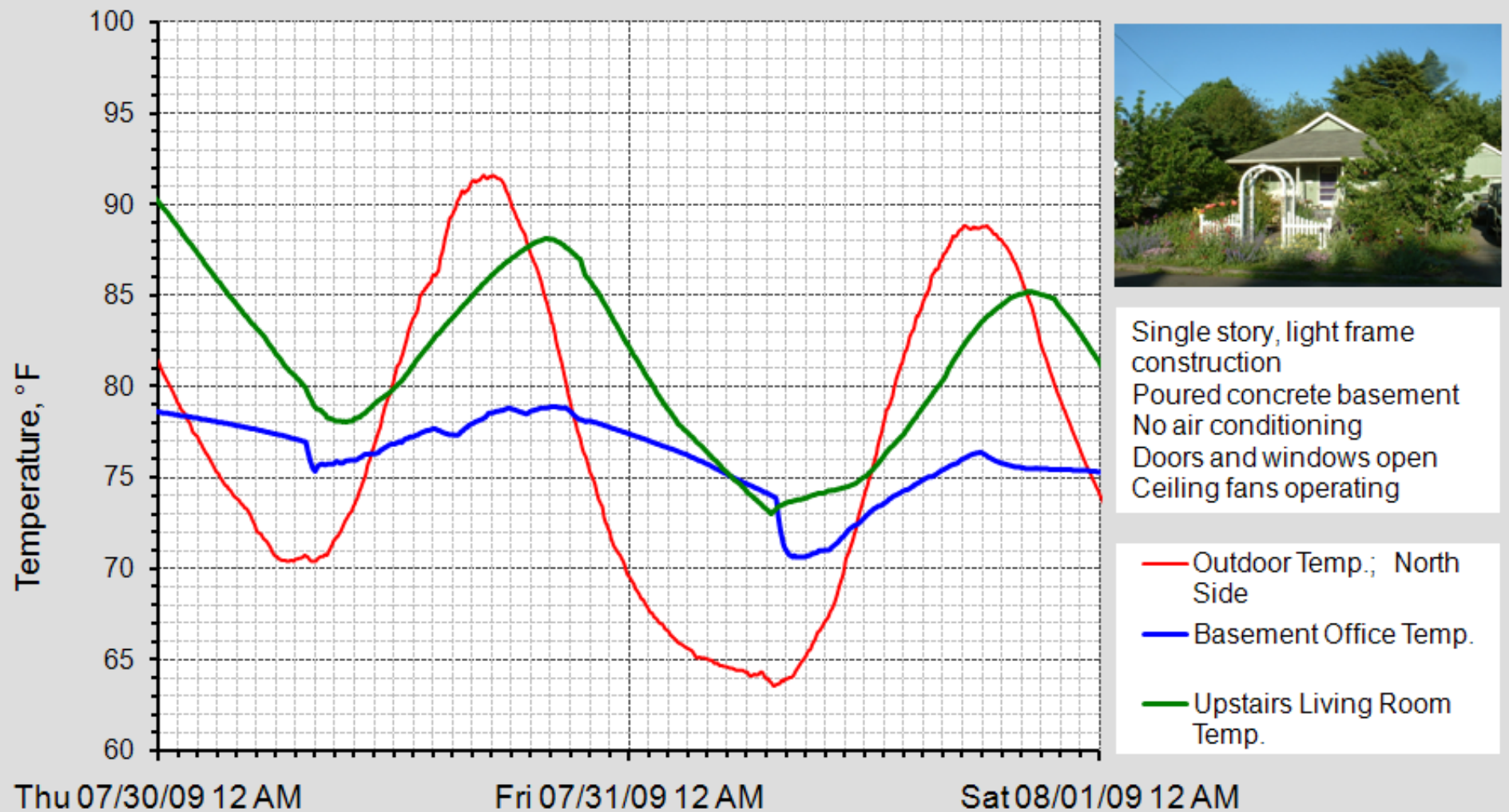
Portland 0.4% Cooling Design Condition - 90/67 °F<sub>db</sub>/t<sub>wb</sub>, 22°F Daily Range





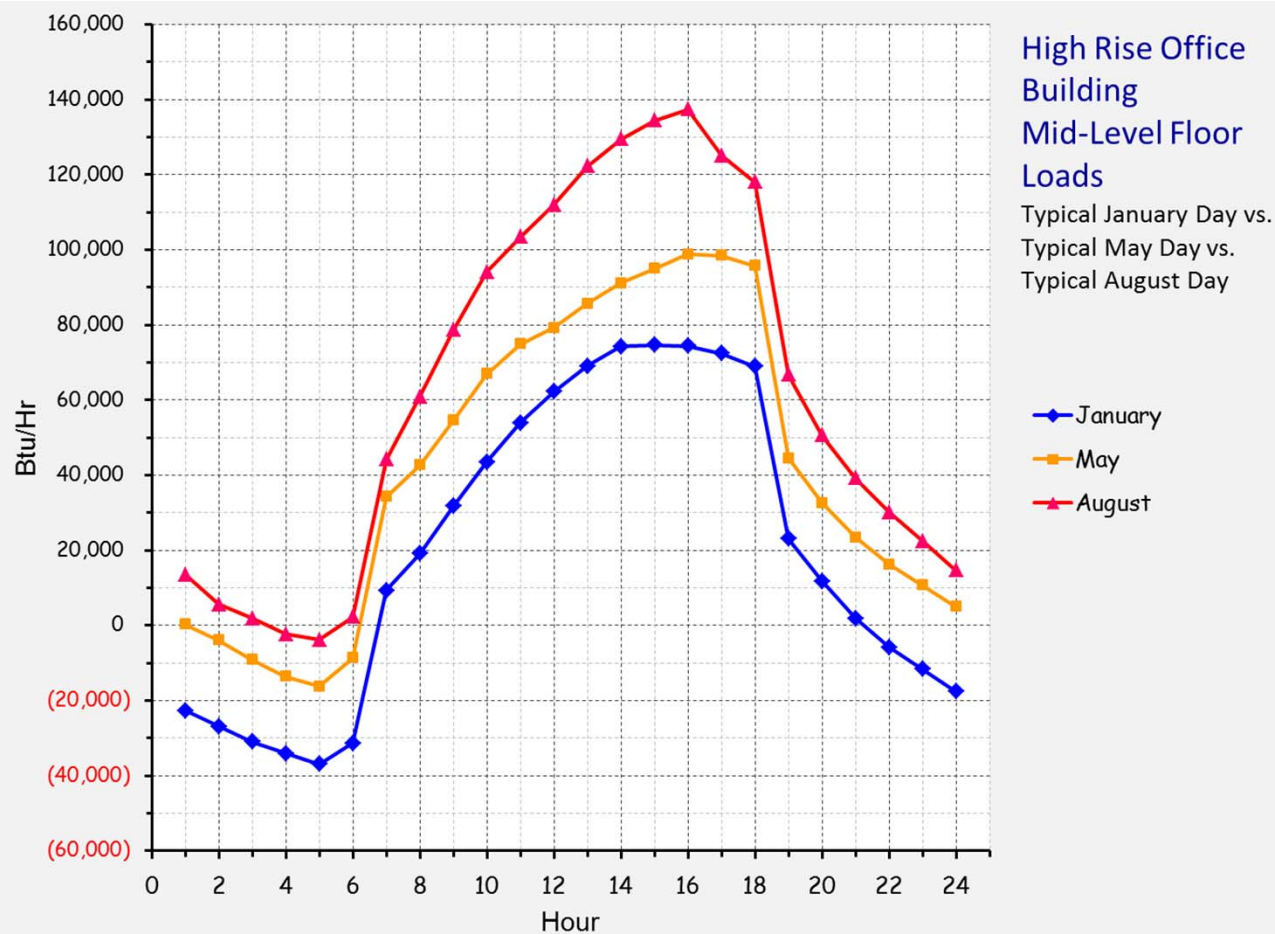
## 8560 North Buchanan, Portland, OR Summer Thermal Response

Portland 0.4% Cooling Design Condition - 90/67 °F<sub>db</sub>/t<sub>wb</sub>, 22°F Daily Range



# Cool the Building with Cool Outdoor Air

## Simple in Concept; Challenging in Reality



The Cooling Requirements Vary with Time of Day and Time of Year

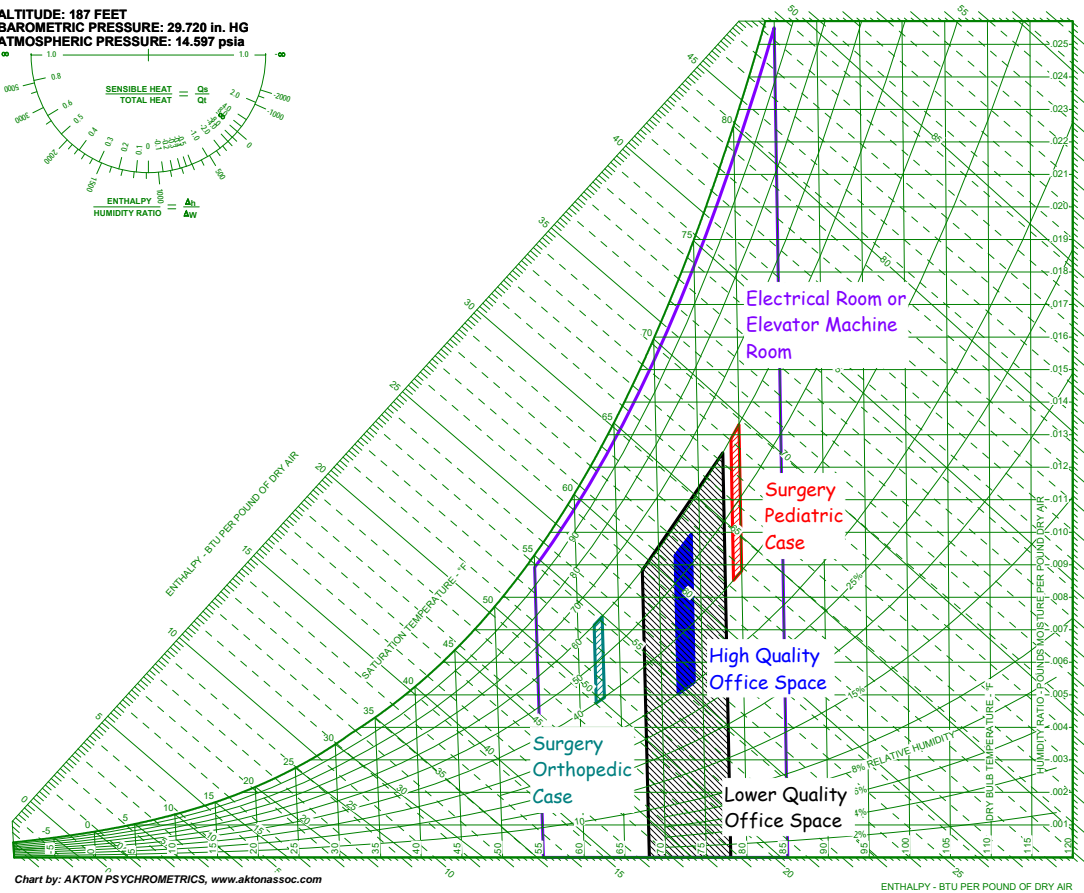
# Cool the Building with Cool Outdoor Air

## Simple in Concept; Challenging in Reality

ALTITUDE: 187 FEET  
BAROMETRIC PRESSURE: 29.720 in. HG  
ATMOSPHERIC PRESSURE: 14.597 psia

$\frac{\text{SENSIBLE HEAT}}{\text{TOTAL HEAT}} = \frac{Q_s}{Q_t}$

$\frac{\text{ENTHALPY}}{\text{HUMIDITY RATIO}} = \frac{h}{W}$

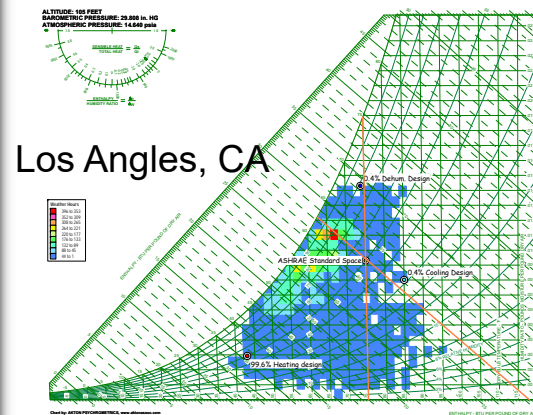
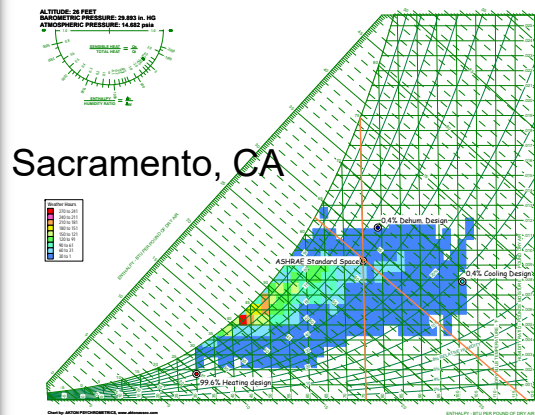
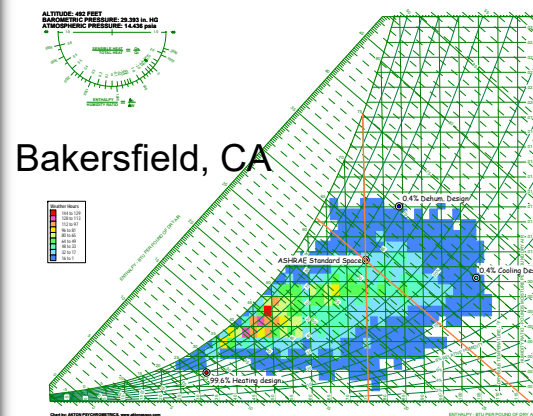
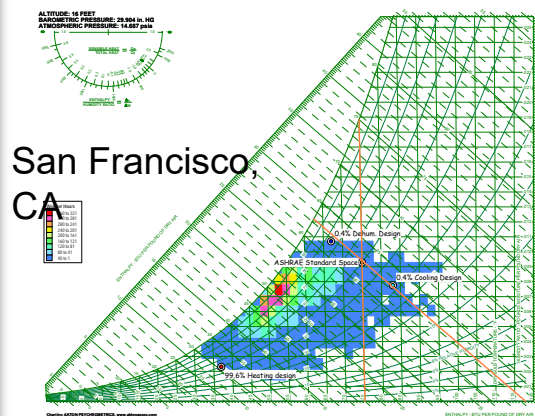


The Suitability of Outdoor Air for Cooling Varies with the Application



# Cool the Building with Cool Outdoor Air

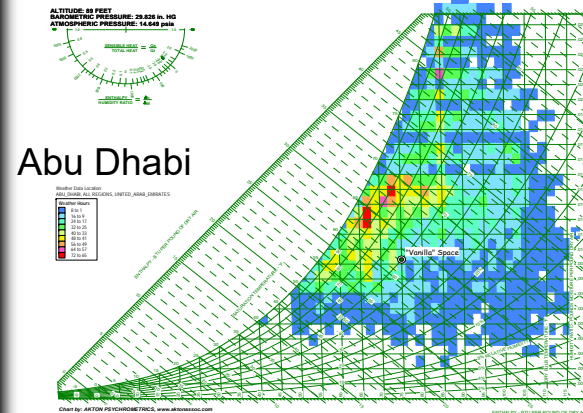
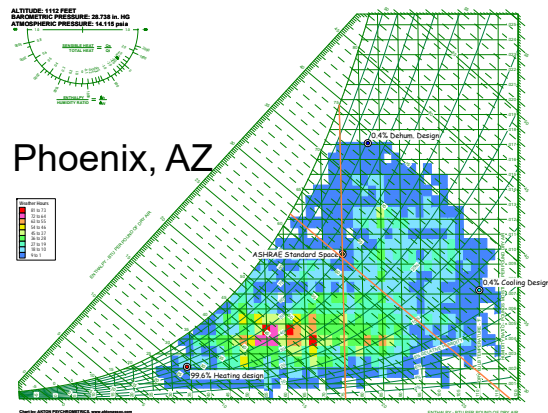
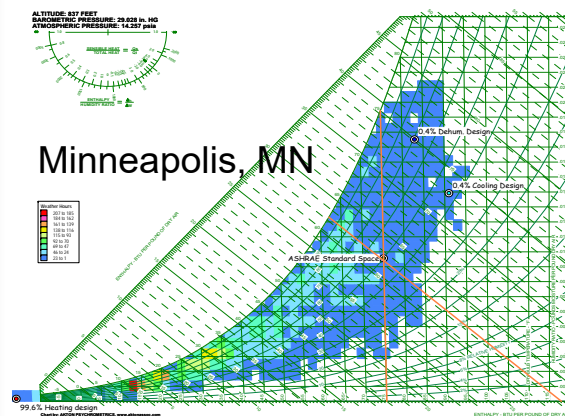
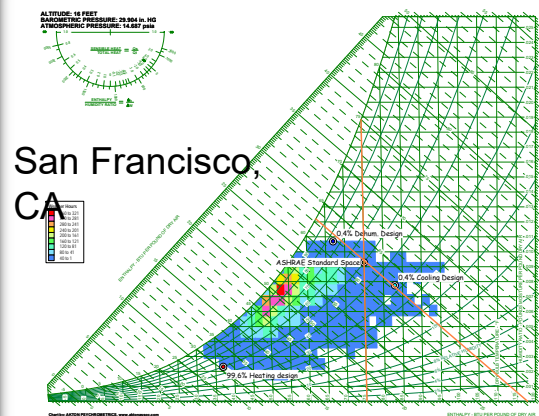
## Simple in Concept; Challenging in Reality



The Cooling Requirements Vary with Location as Does the Suitability of Outdoor Air for Cooling

# Cool the Building with Cool Outdoor Air

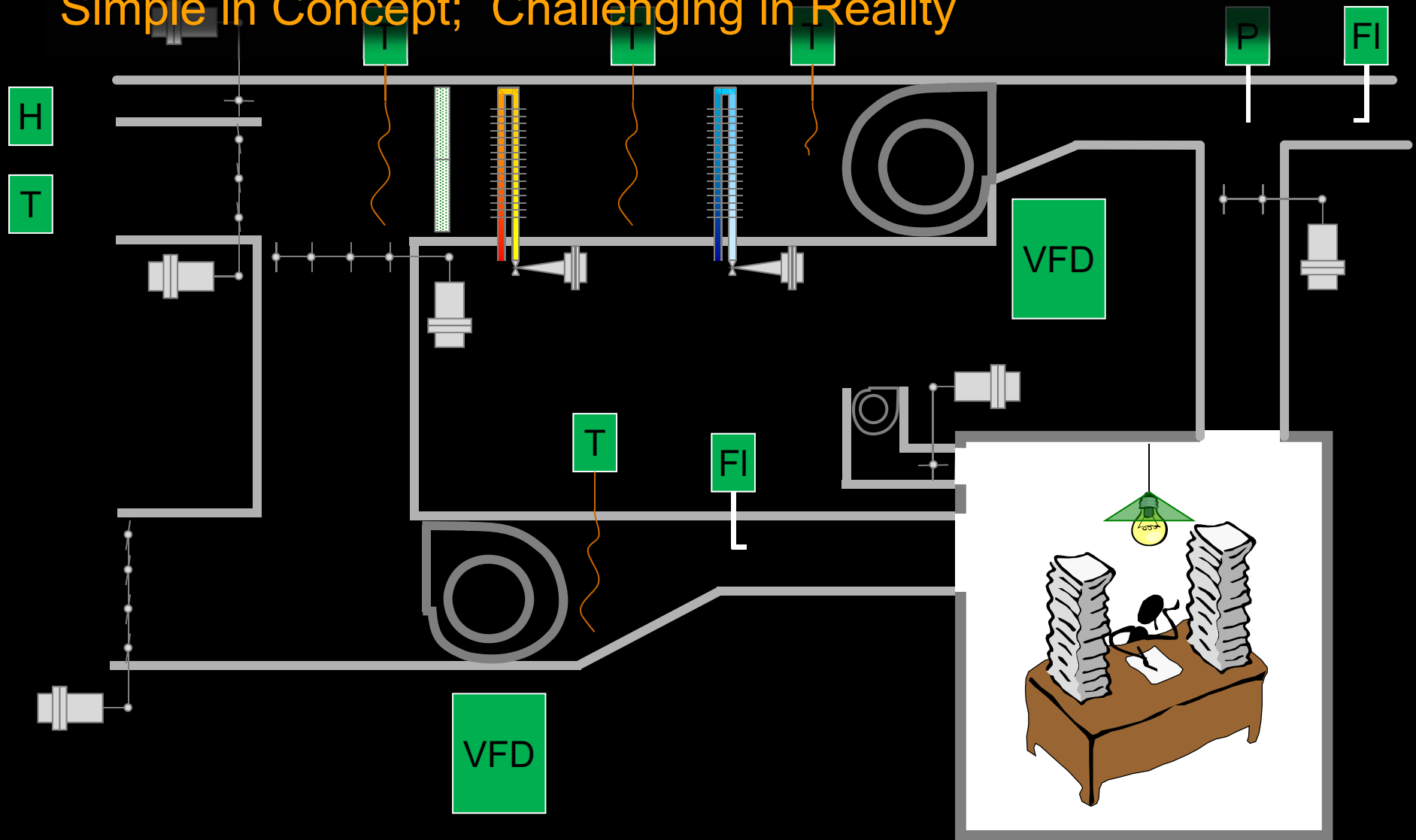
## Simple in Concept; Challenging in Reality



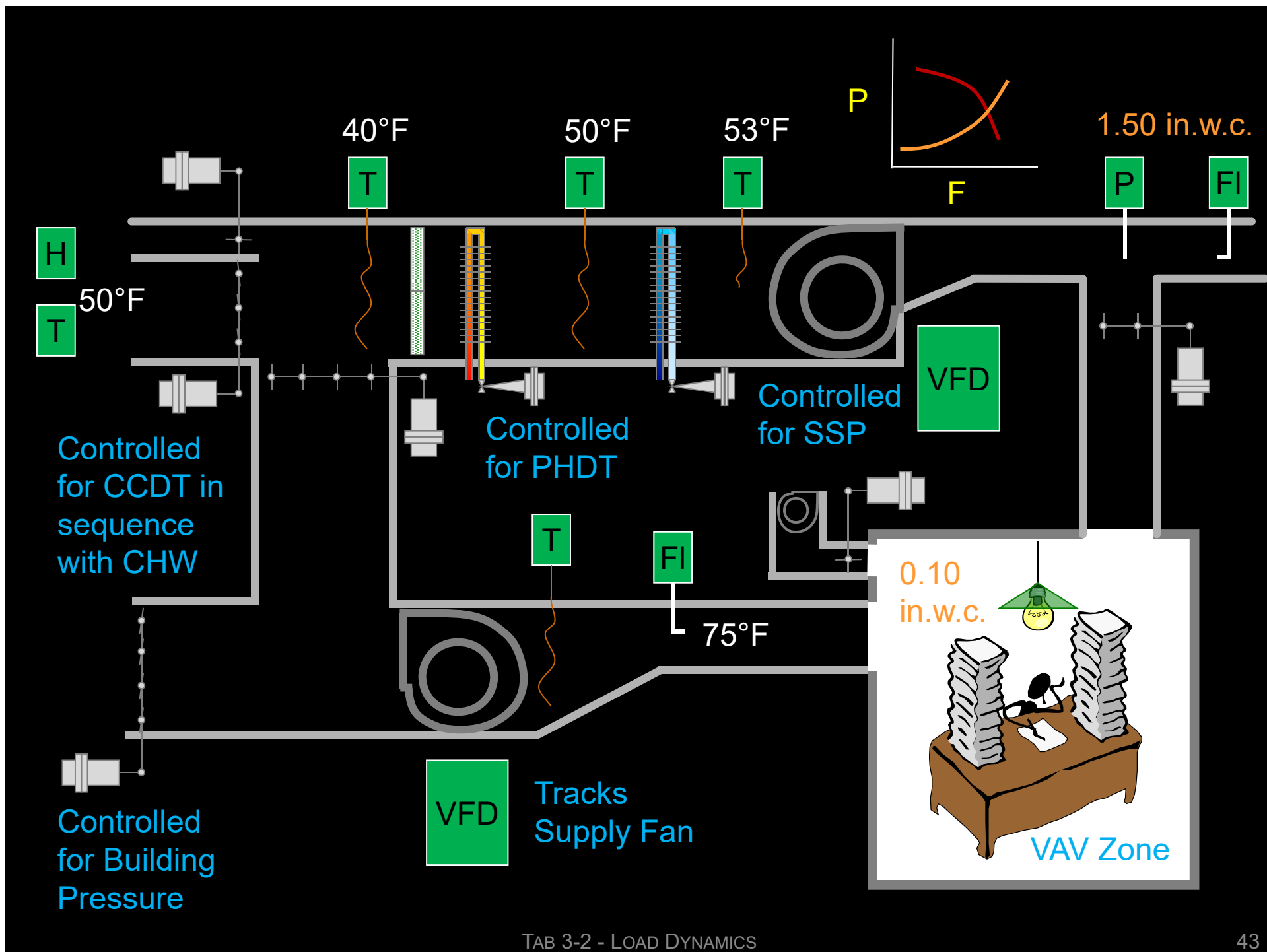
The Cooling Requirements Vary with Location as Does the Suitability of Outdoor Air for Cooling

# Cool the Building with Cool Outdoor Air

Simple in Concept; Challenging in Reality







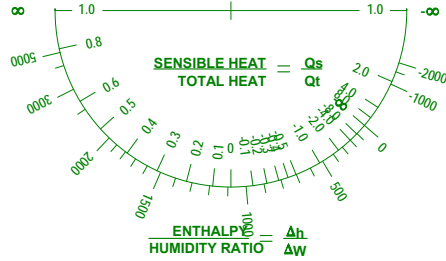
*Aside from those things, it should not be too hard to get an HVAC system to work*

# The Load Profile

The design day vs. reality



ALTITUDE: 66 FEET  
 BAROMETRIC PRESSURE: 29.851 in. HG  
 ATMOSPHERIC PRESSURE: 14.661 psia



Weather Data Location:  
 SEATTLE\_BOEING\_FIELD\_ISIS, WASHINGTON, USA

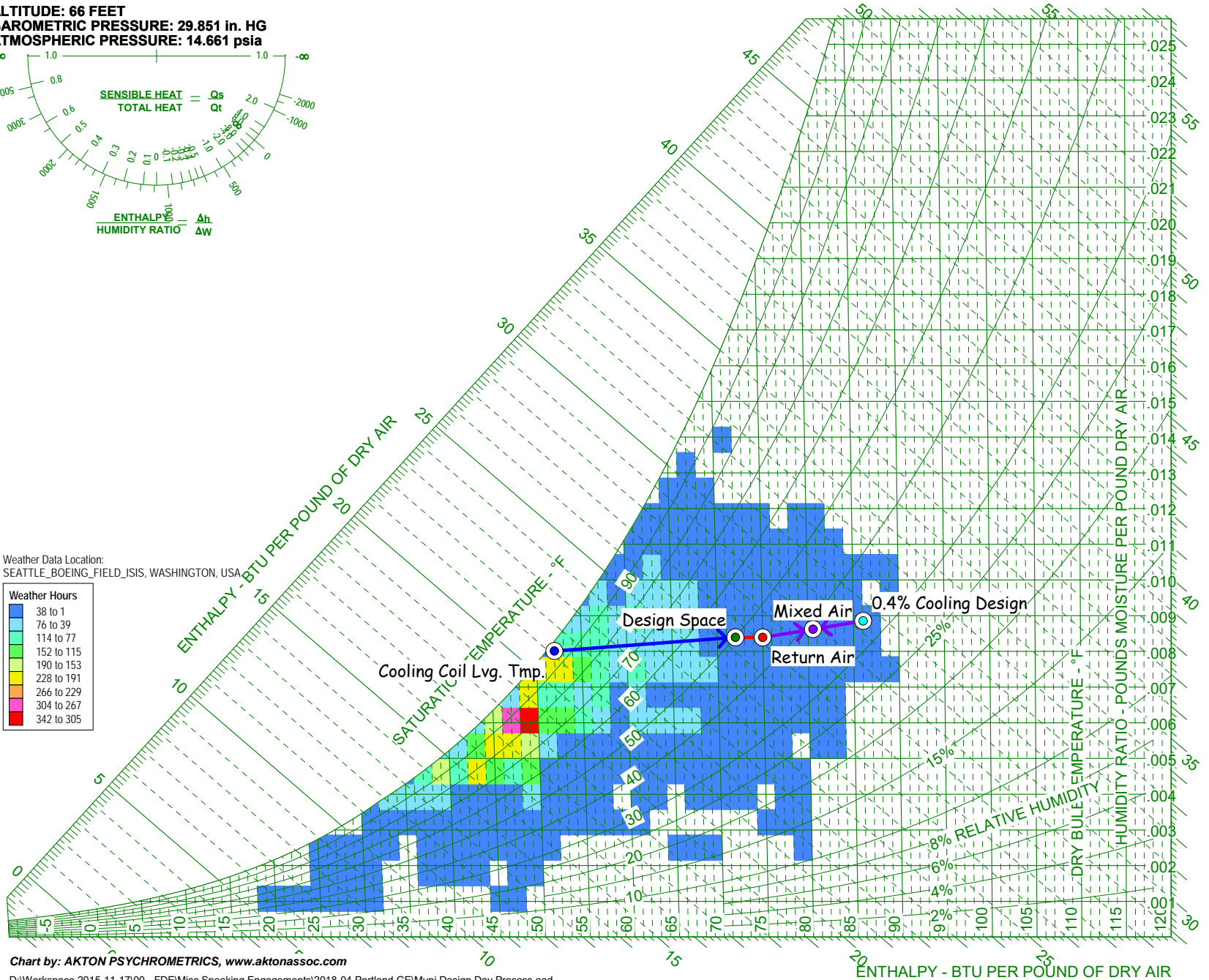
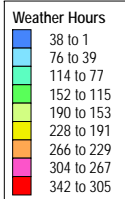


Chart by: AKTON PSYCHROMETRICS, [www.aktonassoc.com](http://www.aktonassoc.com)

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LOAD DYNAMICS.

# Load profile drivers

## 1. The state of the air

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

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

## 2. The nature of the process occurring at the load

$$\bar{Q} + \sum_1 \left[ \dot{m} \times \left( u_1 + \frac{p_1 v_1}{J} + \frac{z_1}{J} + \frac{V_1^2}{2gJ} \right) \right] = \frac{\bar{W}}{J} + \sum_2 \left[ \dot{m} \times \left( u_2 + \frac{p_2 v_2}{J} + \frac{z_2}{J} + \frac{V_2^2}{2gJ} \right) \right]$$

## 3. The process design target

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

$$w = 58.73 \text{ grains}_{\text{H}_2\text{O}}/\text{lb}_{\text{m}_{\text{DA}}}, \text{RH} = 50.000, v = 13.611 \text{ ft}^3/\text{lb}_m, \rho = .0741 \text{ lb}_m/\text{ft}^3$$

ALTITUDE: SEA LEVEL  
 BAROMETRIC PRESSURE: 29.921 in. HG  
 ATMOSPHERIC PRESSURE: 14.696 psia

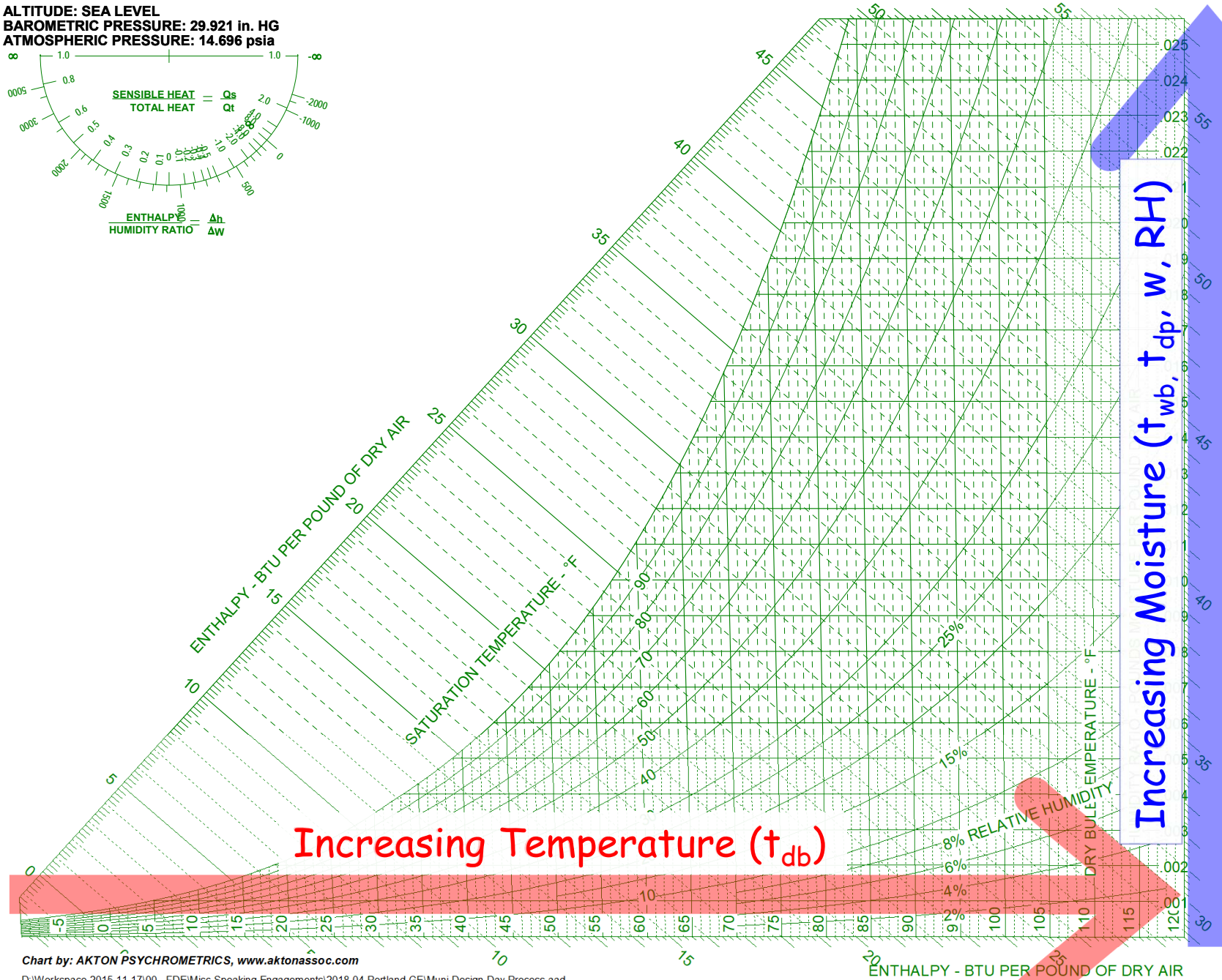
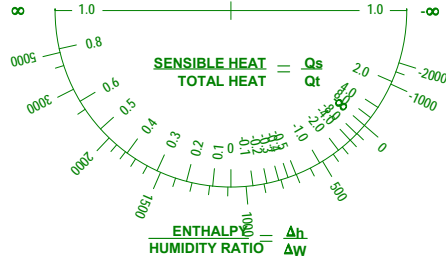


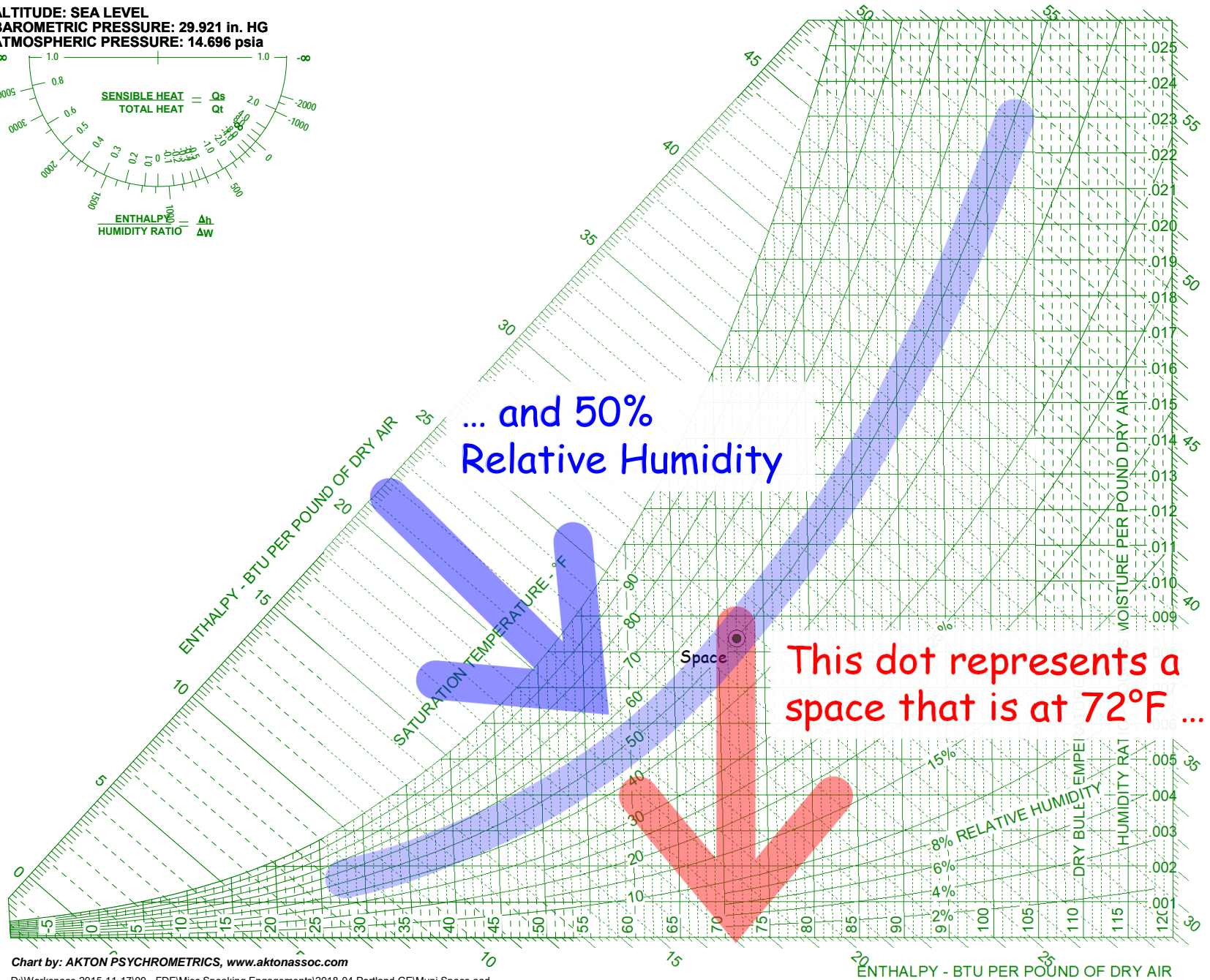
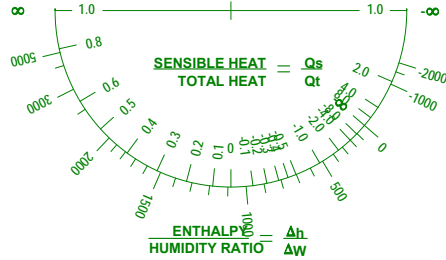
Chart by: AKTON PSYCHROMETRICS, [www.aktonassoc.com](http://www.aktonassoc.com)

D:\Workspace 2015-11-17\00 - FDE\Misc Speaking Engagements\2018-04 Portland GE\Muni Design Day Process.aad

LOAD DYNAMICS.



ALTITUDE: SEA LEVEL  
 BAROMETRIC PRESSURE: 29.921 in. HG  
 ATMOSPHERIC PRESSURE: 14.696 psia



... and 50%  
 Relative Humidity

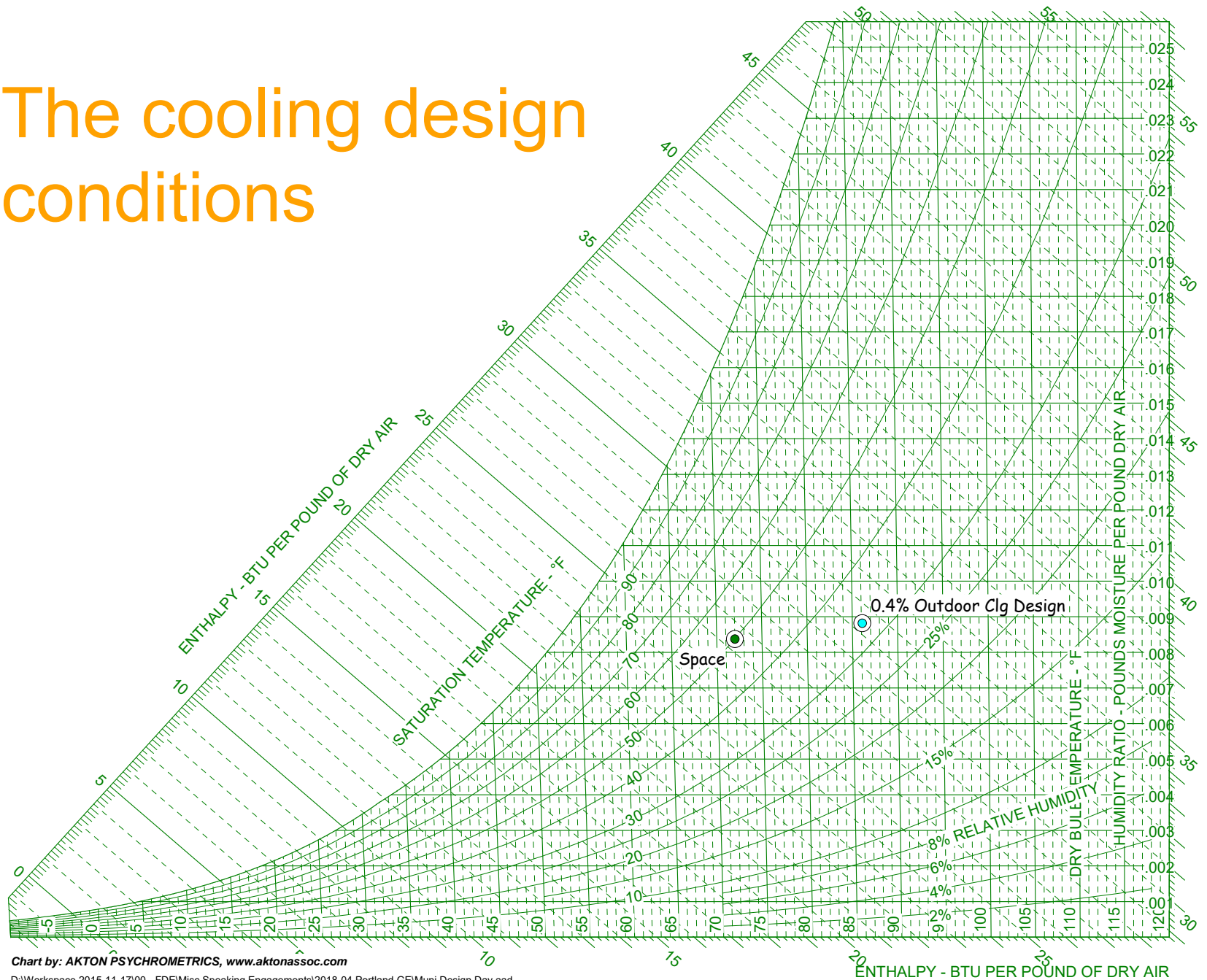
This dot represents a  
 space that is at 72°F ...

Chart by: AKTON PSYCHROMETRICS, [www.aktonassoc.com](http://www.aktonassoc.com)

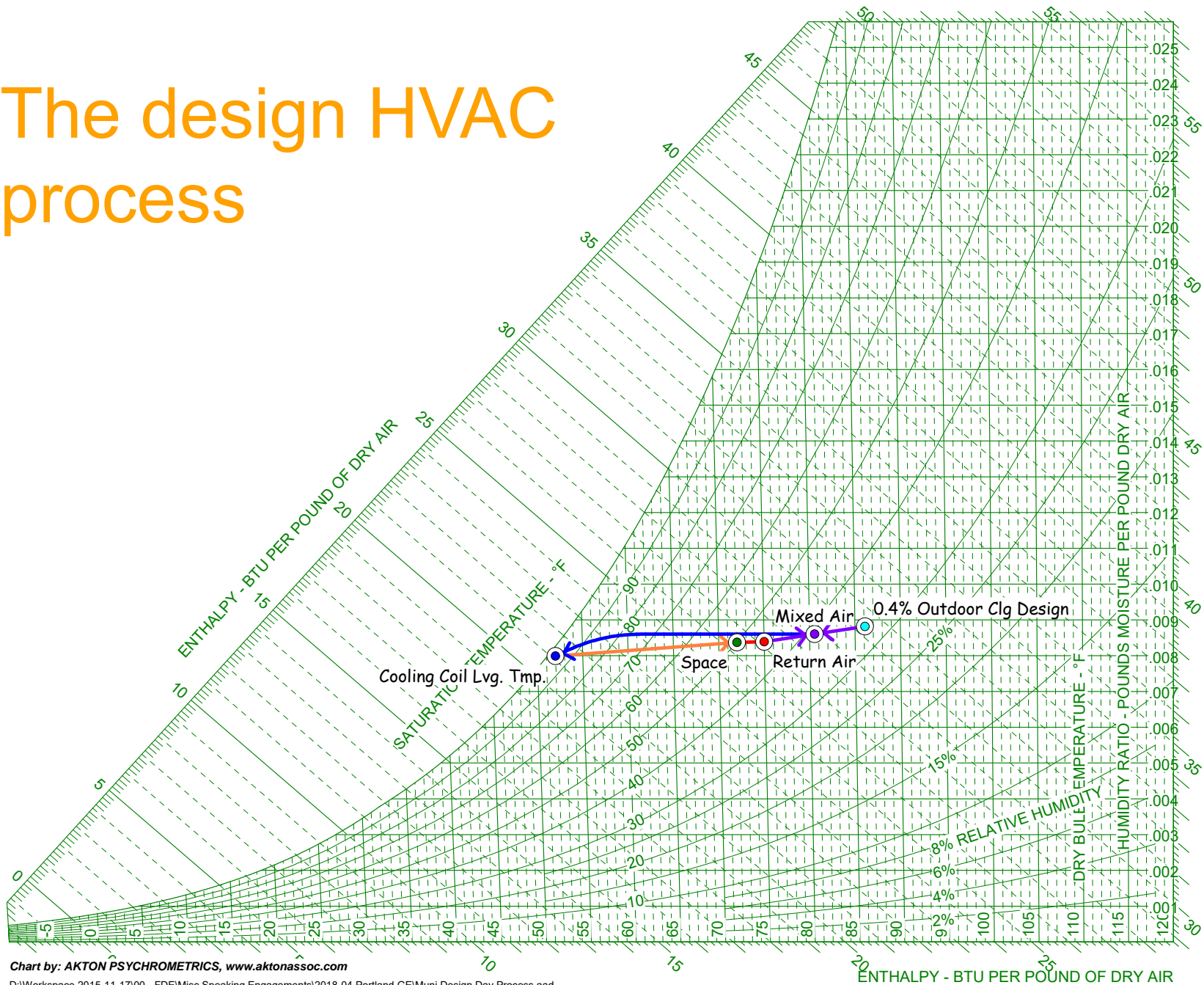
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LOAD DYNAMICS.

# The cooling design conditions



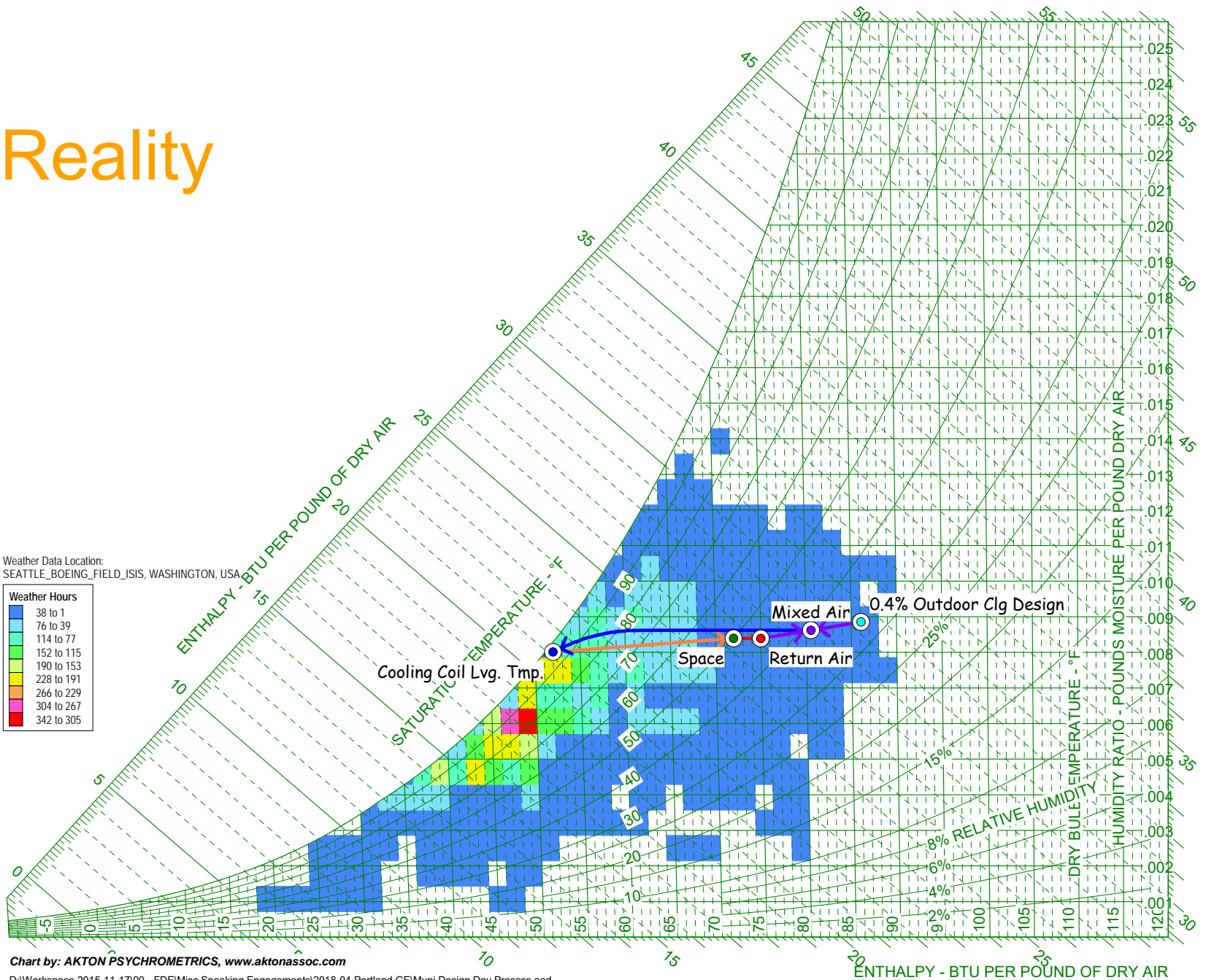
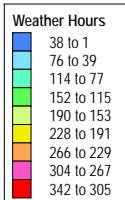
# The design HVAC process





# Reality

Weather Data Location:  
SEATTLE\_BOEING\_FIELD\_ISIS, WASHINGTON, USA



# Reality

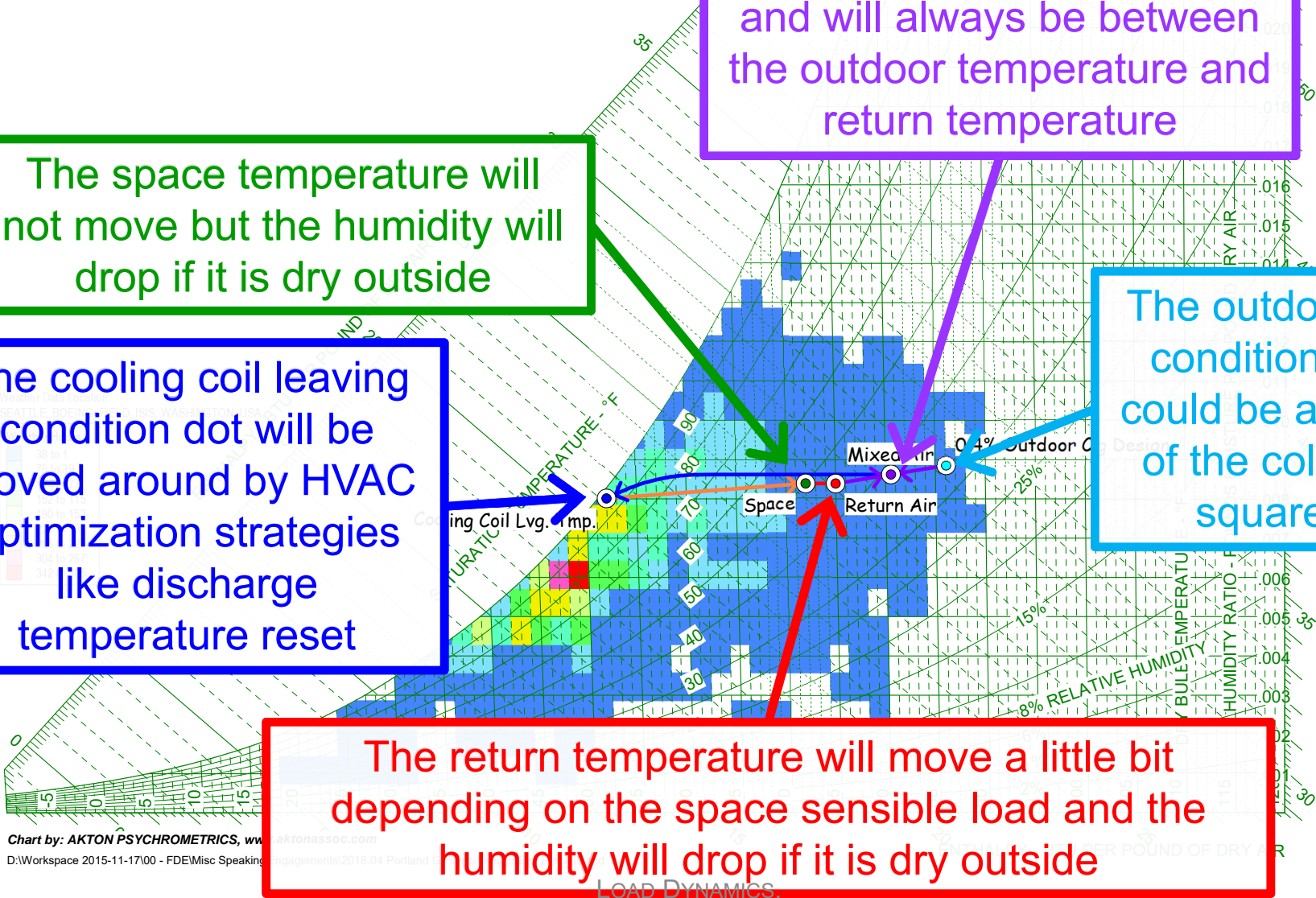
The space temperature will not move but the humidity will drop if it is dry outside

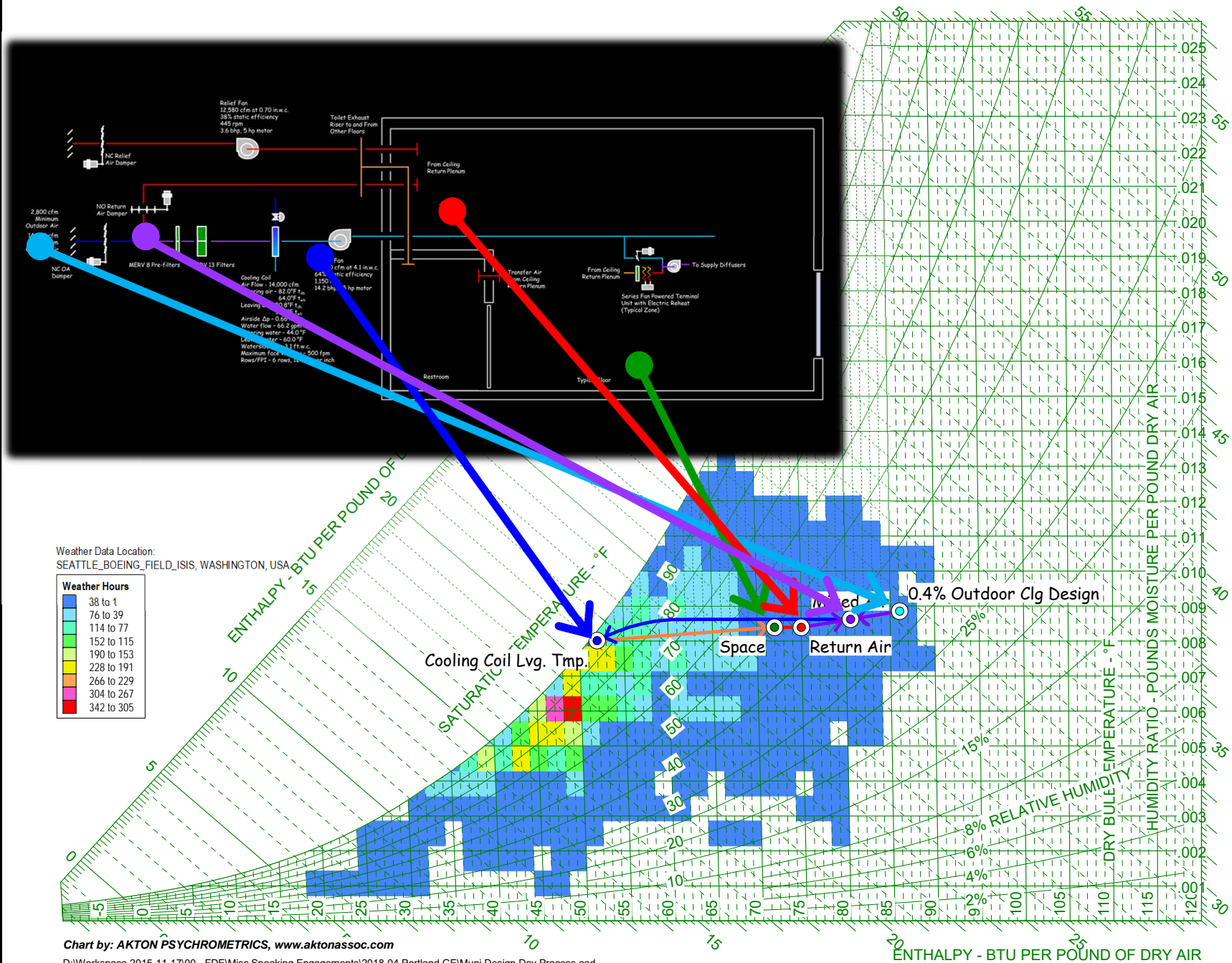
The cooling coil leaving condition dot will be moved around by HVAC optimization strategies like discharge temperature reset

The 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 outdoor air condition dot could be any of the colored squares

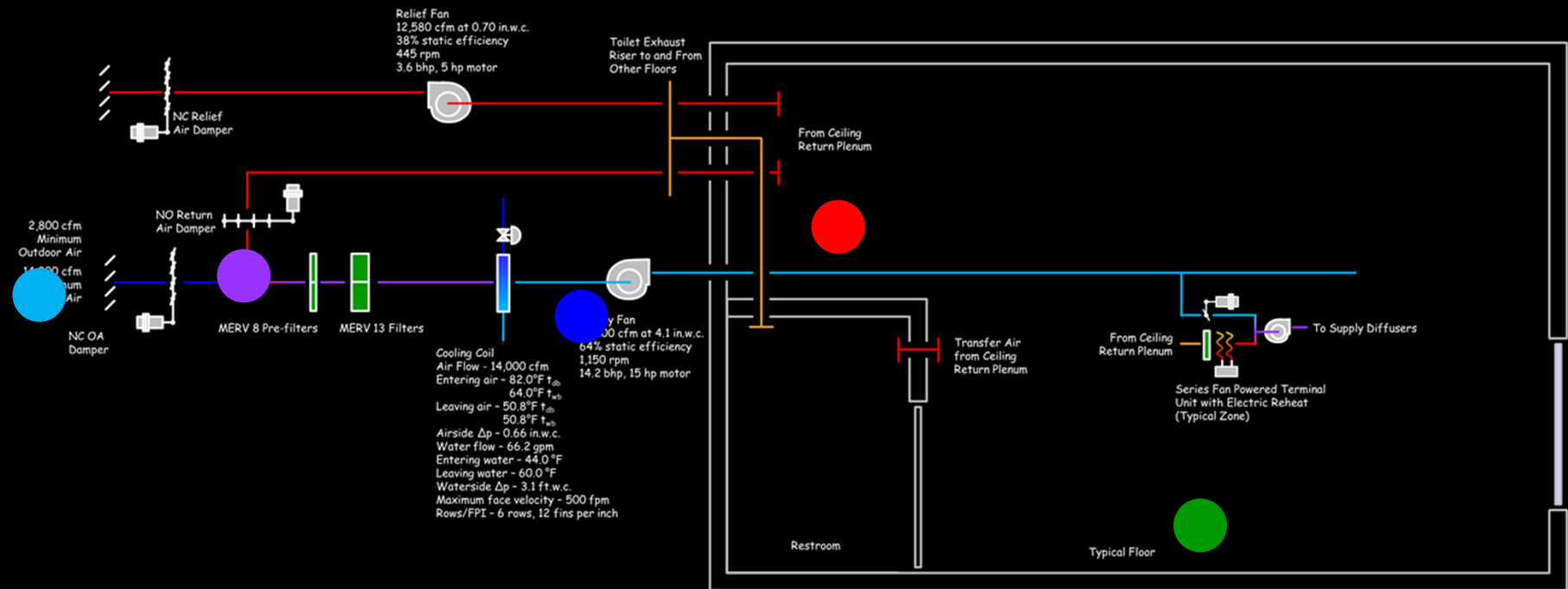
The return temperature will move a little bit depending on the space sensible load and the humidity will drop if it is dry outside



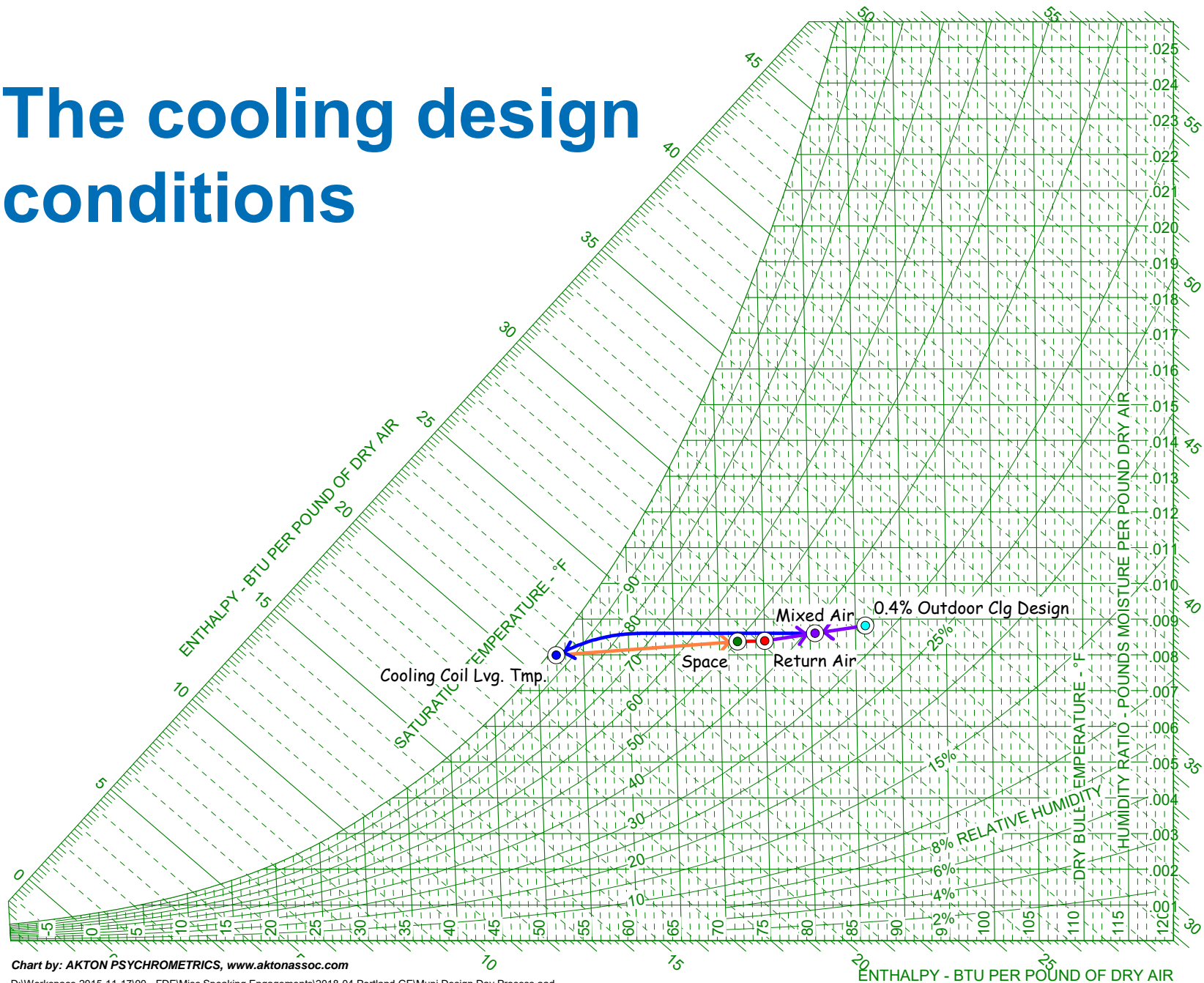


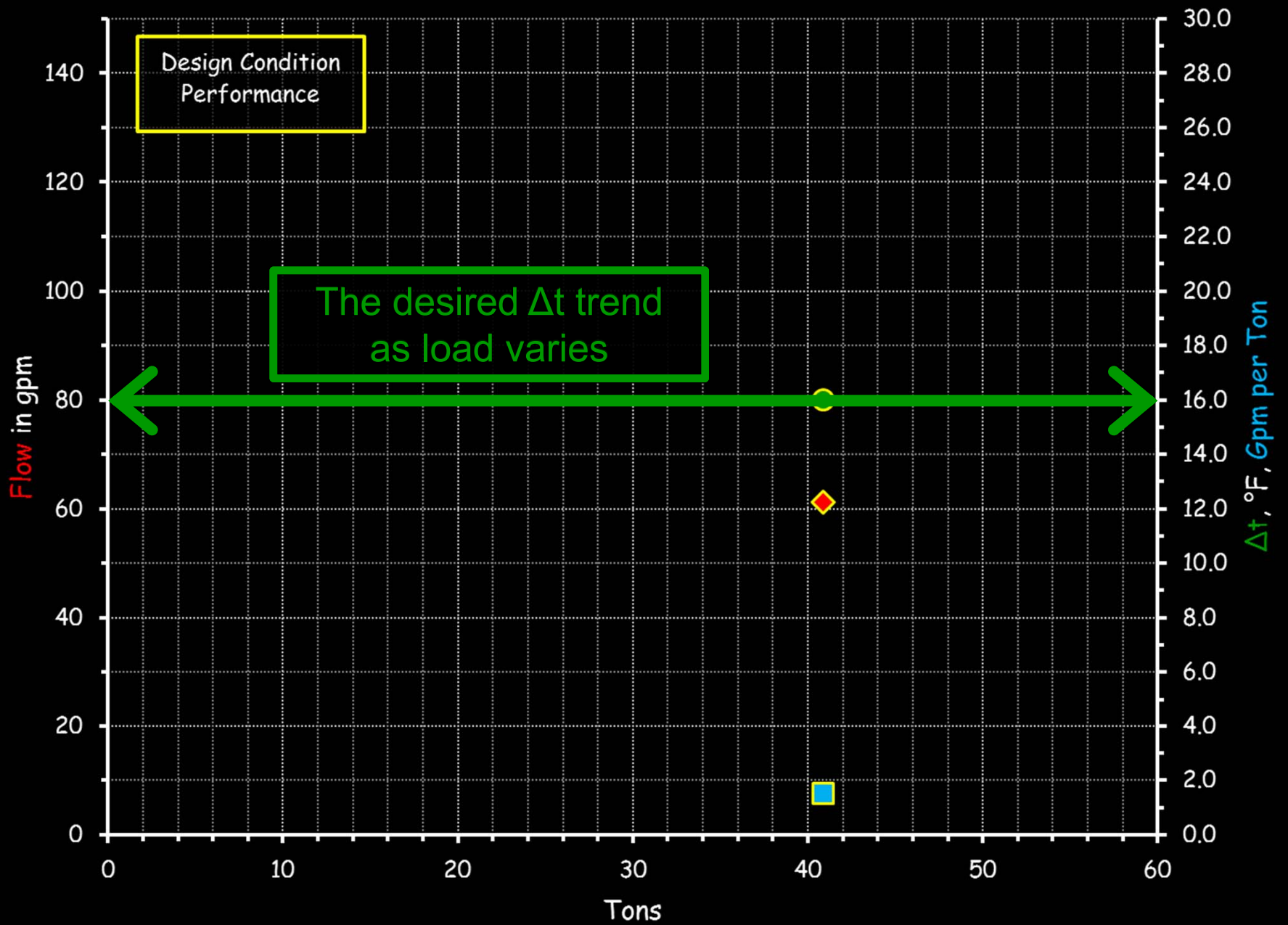


# The mixed air condition is the cooling coil entering condition

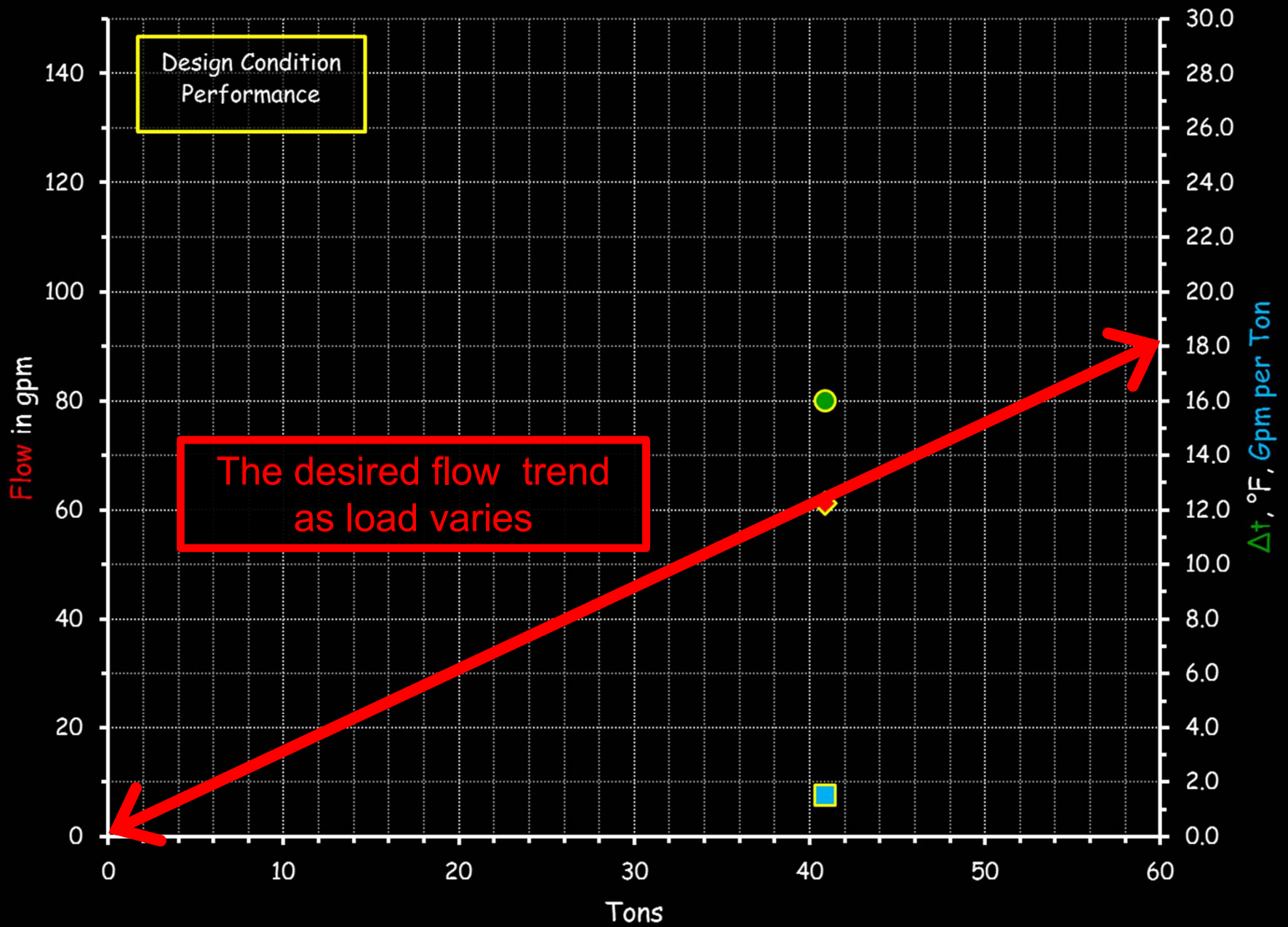


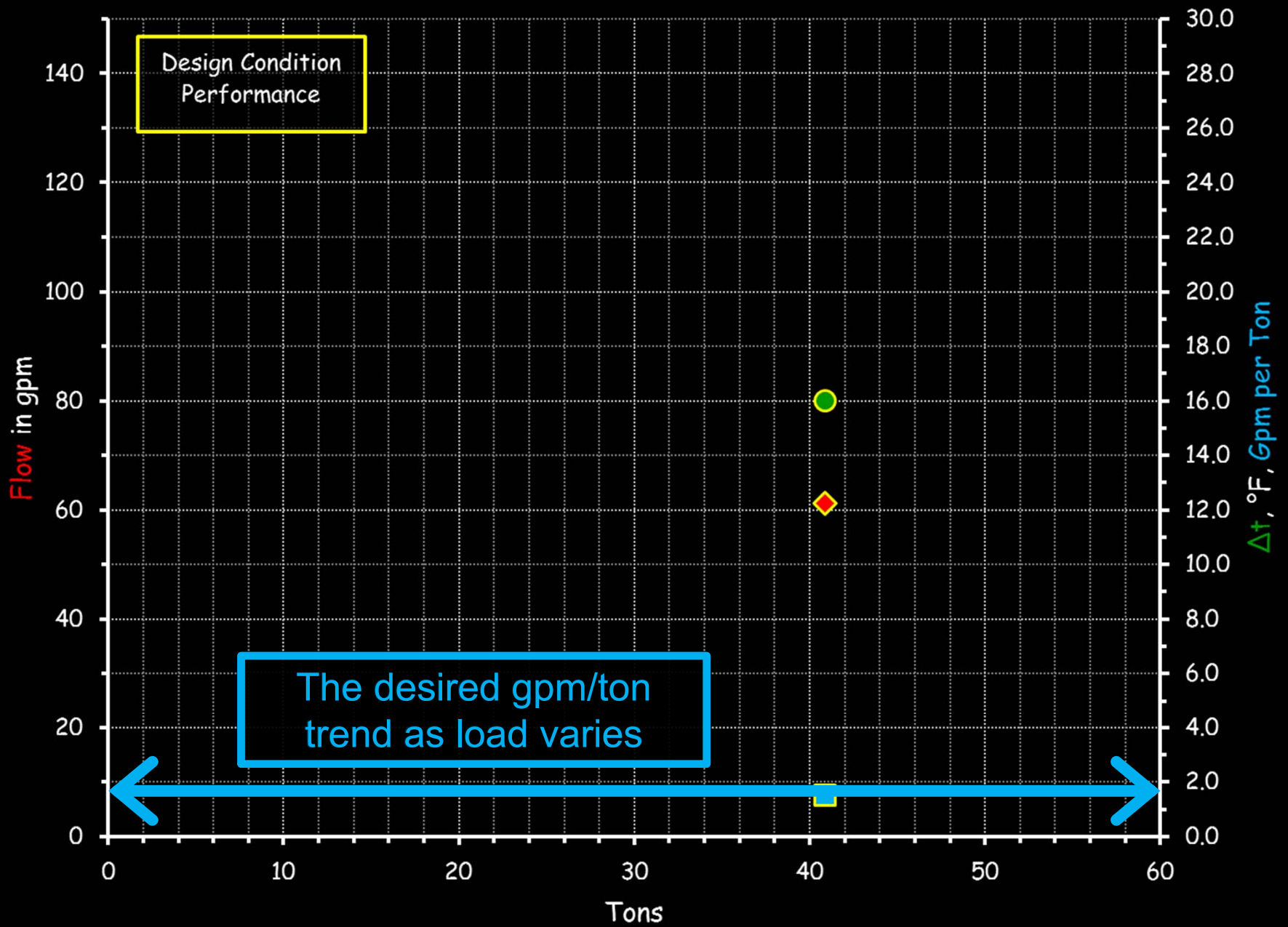
# The cooling design conditions

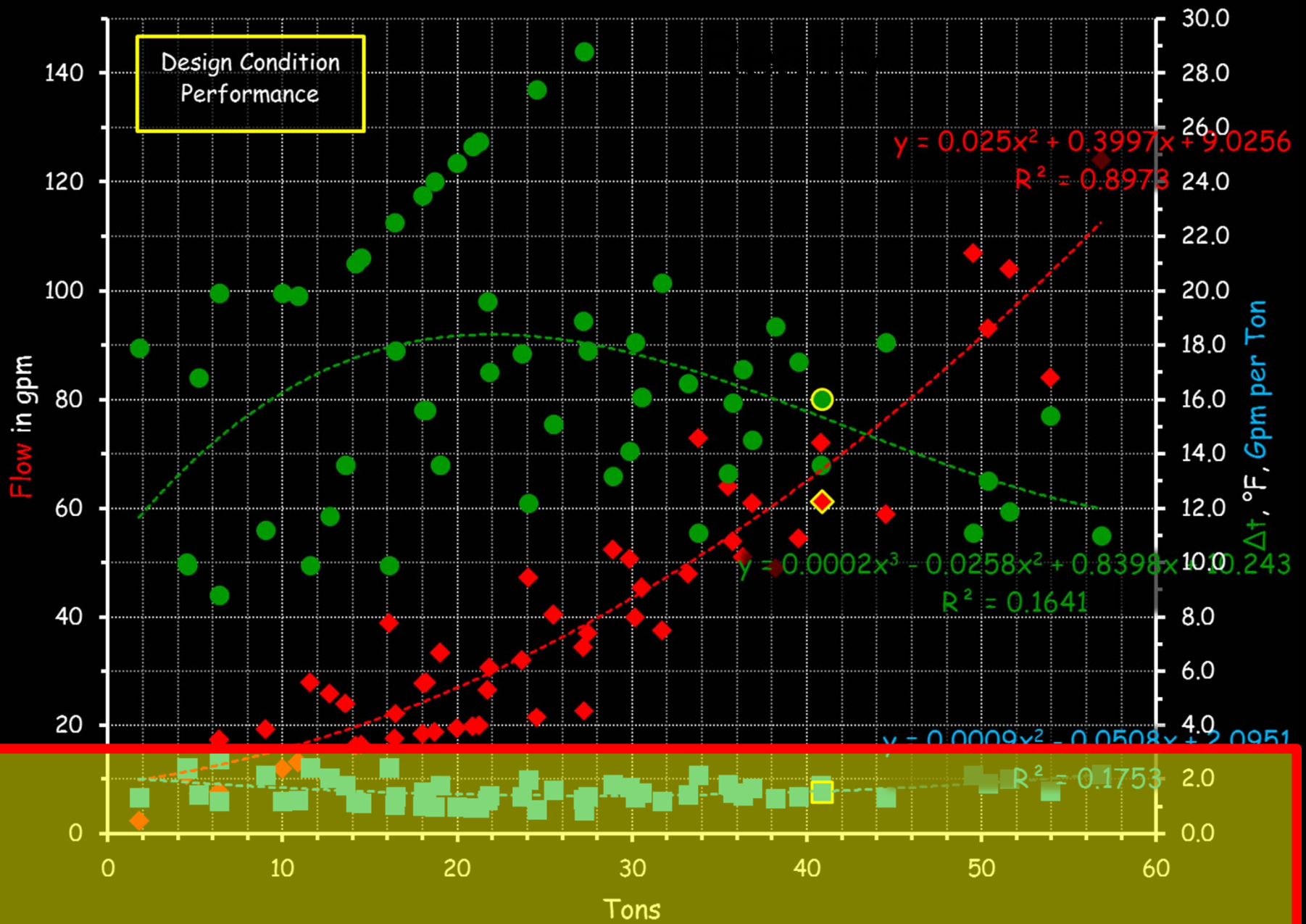






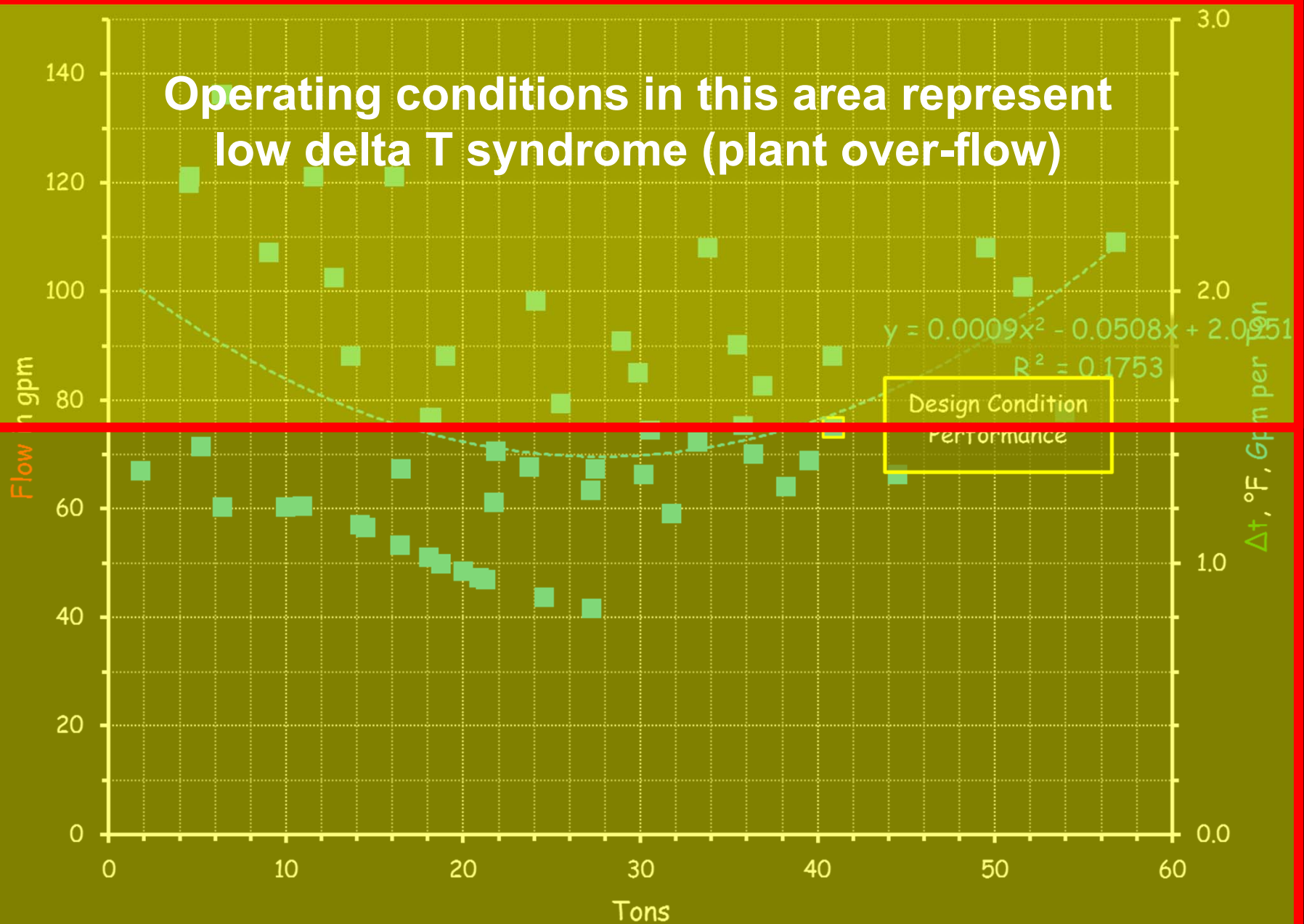






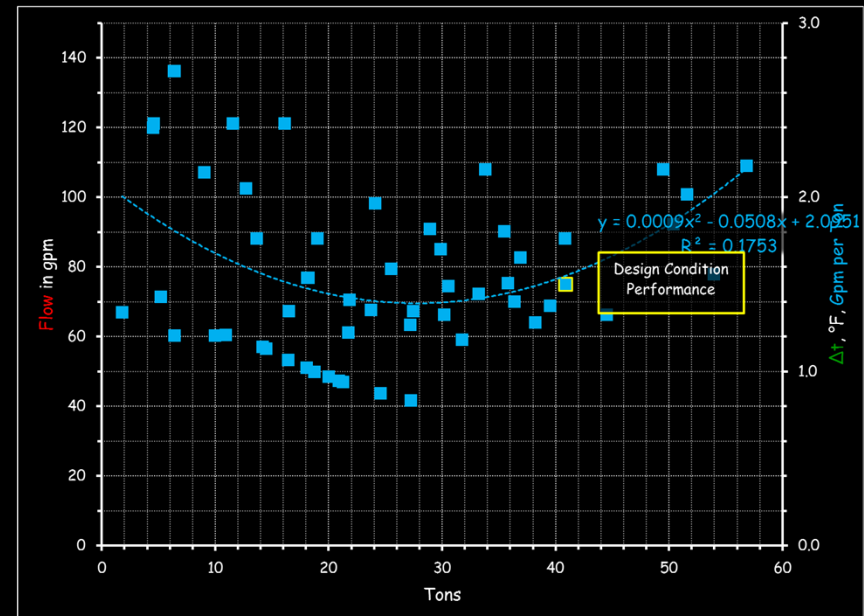
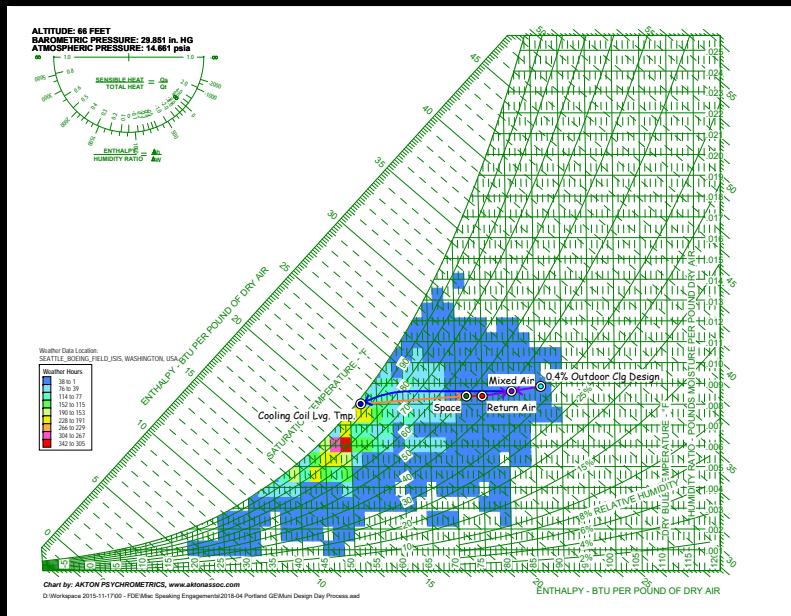


Operating conditions in this area represent  
low delta T syndrome (plant over-flow)



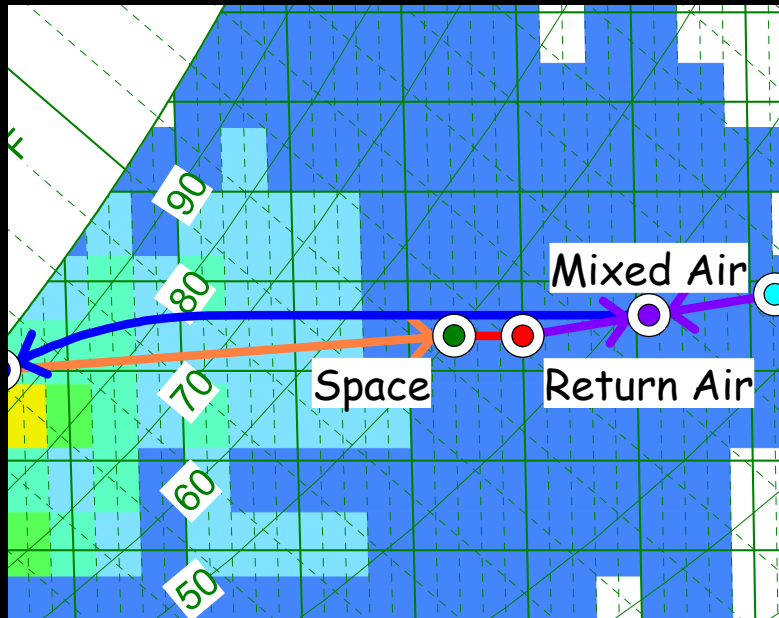
# Load profiles and performance vary with climate

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

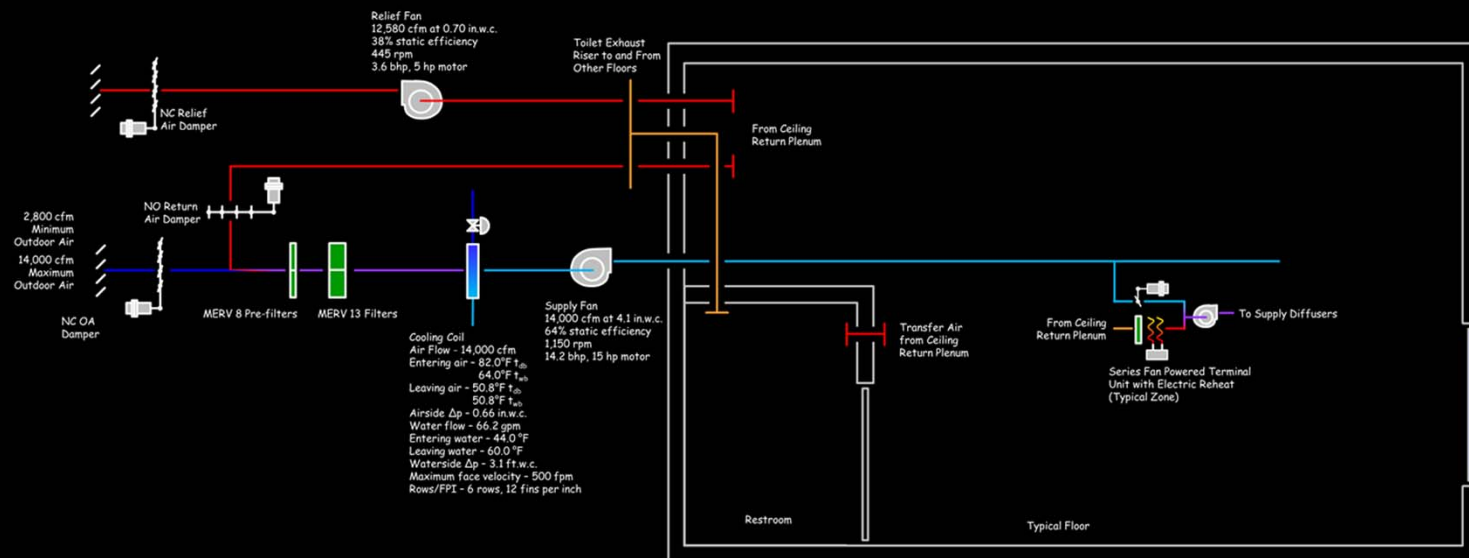
But the built environment served by our building systems needs to remain clean, safe, comfortable and productive, no matter what.





# 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

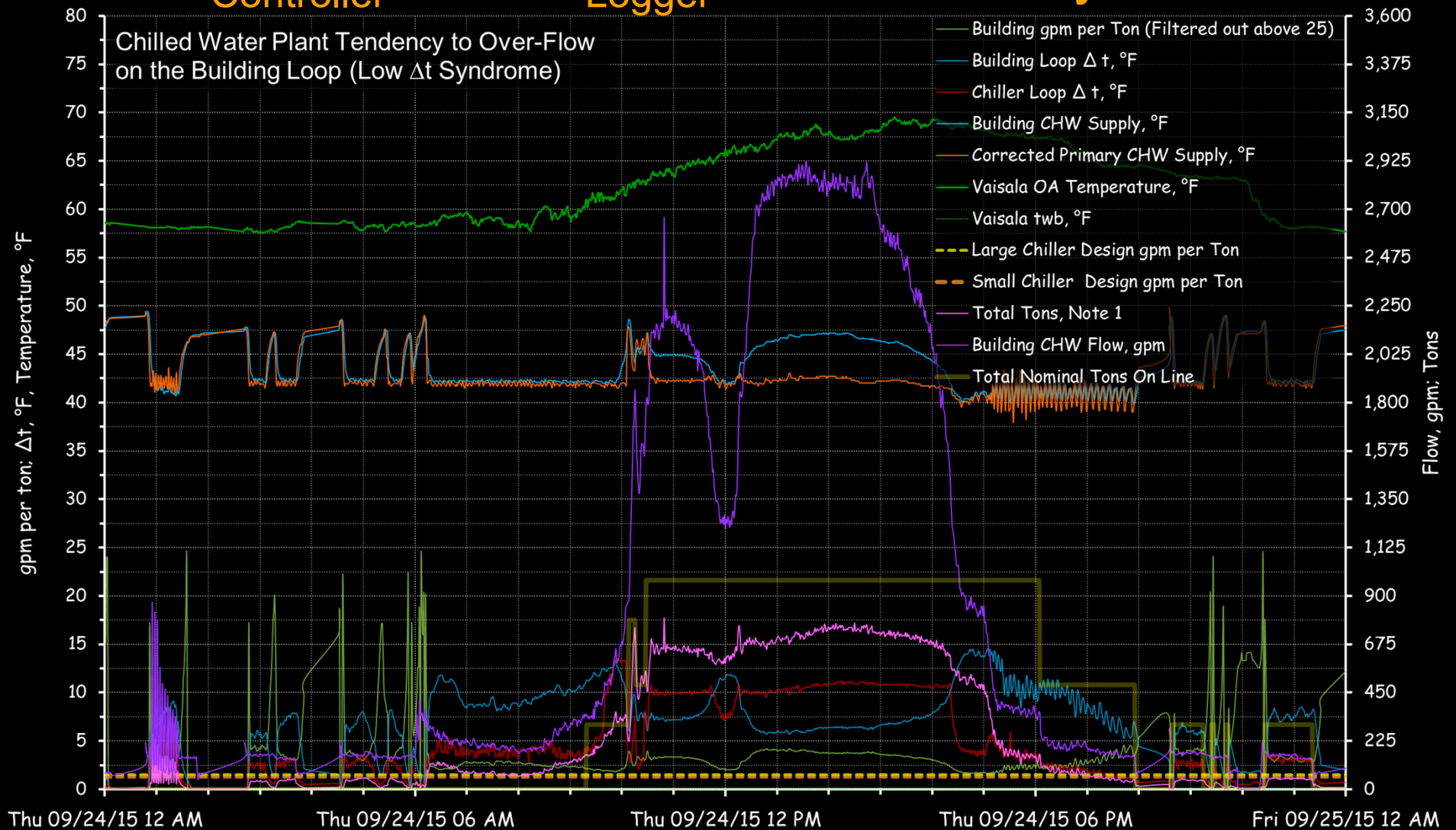
Data loggers supplement the control systems trending capabilities

- Potential for faster sampling rates
- Pick up data where points are missing in the control system

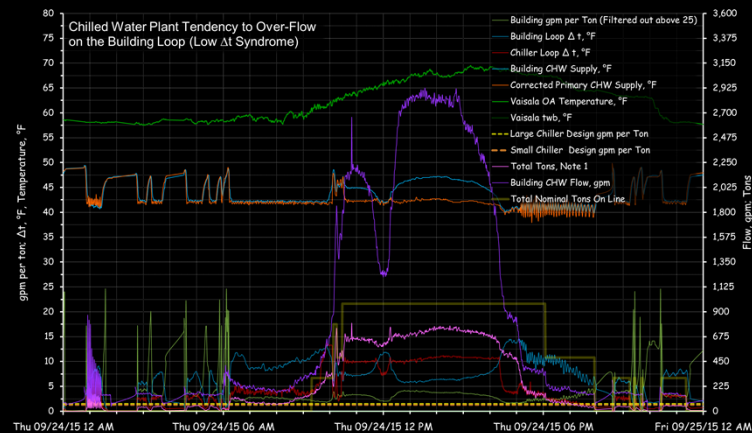
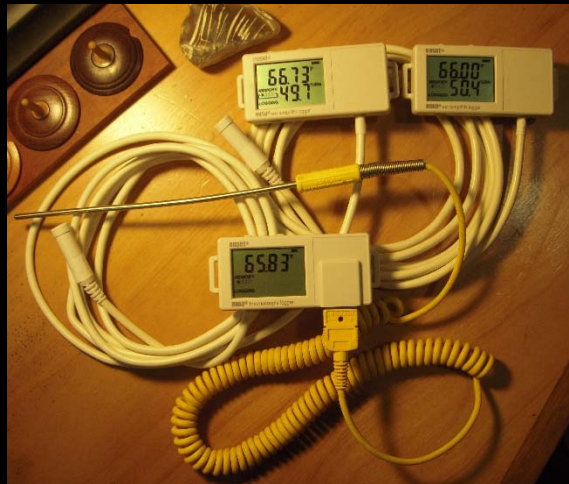




# Data<sub>Controller</sub> + Data<sub>Logger</sub> = Trend Analysis



# 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:





Pump Identification ➔			P14-3 Stand-Alone (Discharge Full Open)			P14-3 Full Open (Pumping through CH-3)		
Service Area			Primary CHW through Chiller 2			Primary CHW through Chiller 2		
Physical Location of Unit			14th Floor Mechanical Room			14th Floor Mechanical Room		
Pump Information:			Design	Submitted/TAB	Actual	Design	Submitted/TAB	Actual
Manufacturer:			Paco			Paco		
Model #:			29-60151859001			29-60151859001		
Serial #:								
Part / Catalog #:			KP 6015, 64x12			KP 6015, 64x12		
Nameplate GPM:			1,400.0			1,400.0		
Actual Flow (GPM):			1,650.0			1,650.0		
Nameplate Head (ft):			50.0			50.0		
Differential Pressure (Feet H <sub>2</sub> O)			25.0			25.0		
Nameplate HP:			24.5			24.5		
BHP:			1,150			1,150		
Nameplate RPM:			1,185			1,185		
Actual RPM:			11.9			11.9		
Listed Impeller Diameter:			12.1			12.1		
Actual Diameter (Tested):								
Manual Control Information:								
Control Type:			Manual Isolation Valve			Manual Isolation Valve		
Manufacturer:								
Model:								
Device Adjustment Position:			100%			100%		
Differential Pressure (Feet H <sub>2</sub> O)								
Control Information								
Controlled Medium:			Not Applicable			Not Applicable		
Control Type:								
Sensors (BAS / Local Controller / FDI Measured):								
Final Controlled Device Position (Hz/NoOpen, etc.):								
Motor Data: Nameplate / Operational								
Manufacturer:			GE			GE		
HP / Efficiency / kW:			25.0 / 93.6% / Not Listed			25.0 / 93.6% / Not Listed		
BHP Calc'd Motor Values / BHP VFD kW / VFD kW			21.6 / Not Applicable / Not Applicable			21.6 / Not Applicable / Not Applicable		
Nameplate RPM / Measured:			1,185 / 1,185			1,185 / 1,185		
Nameplate Volts:			460			460		
Voltage (VFD Display):			481			481		
Nameplate Amperage:			30.4			30.4		
Amperage (VFD Display):			29.8			29.8		
SFA:			Not Listed			Not Listed		
SF:			1.15			1.15		
Frame:			324T			324T		
Notes:								

## CX PROVIDER

*Then I bet the building knows how big the chillers need to be.*

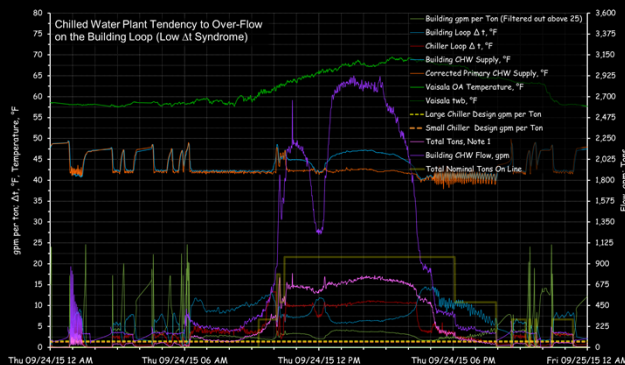
*We just need to ask it the right questions.*

## CHIEF ENGINEER

*How will we do that?*

## CX PROVIDER

*With functional testing, trending, and data logging.*



CX PROVIDER (to building)

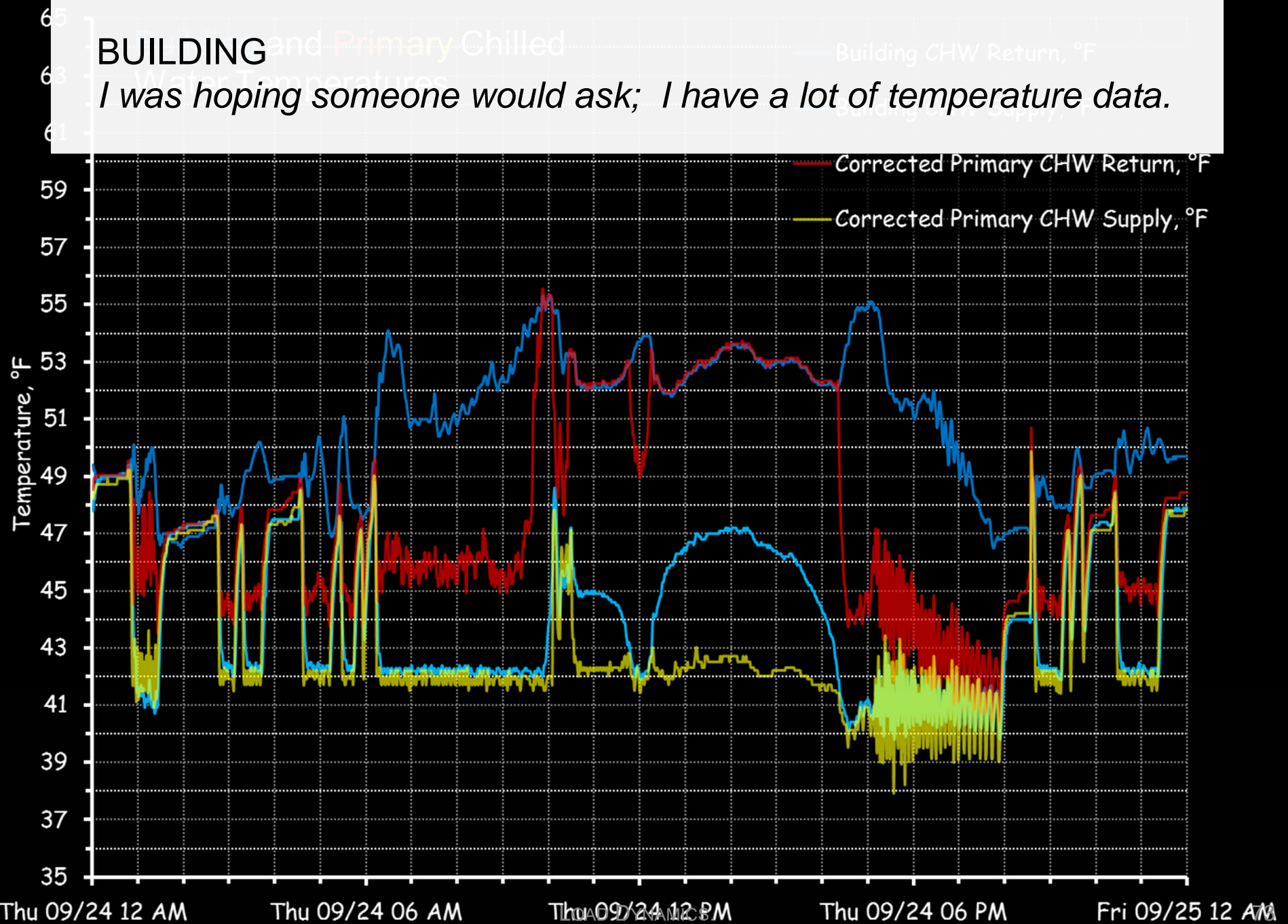
Tell me about the flow rates and temperatures in your chilled water system.





## BUILDING and Primary Chilled

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

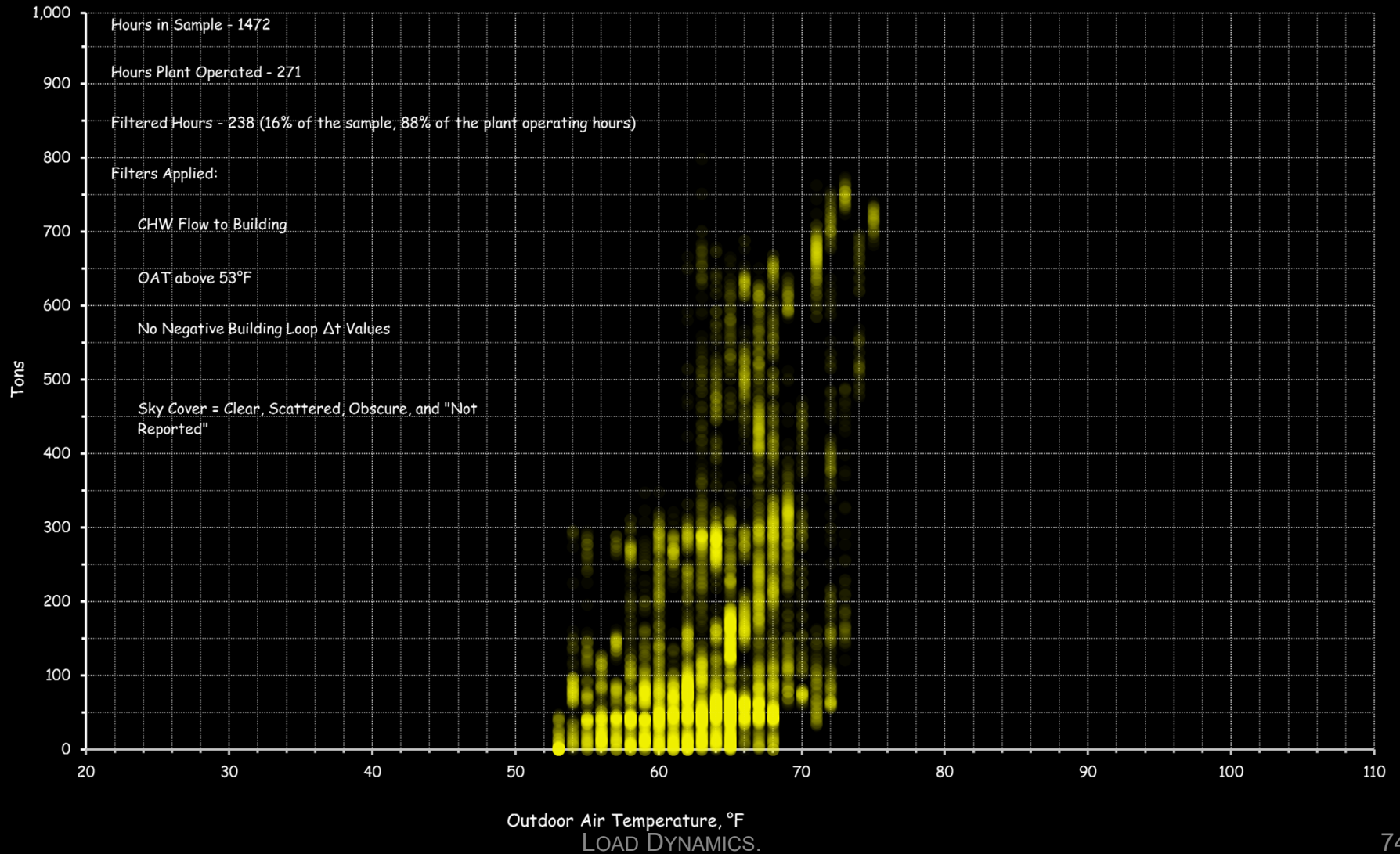


## BUILDING:

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

Central Plant Tons vs. Outdoor Temperature

Thursday 09/24/15 12:00 AM through Monday 12/07/15 11:59 PM

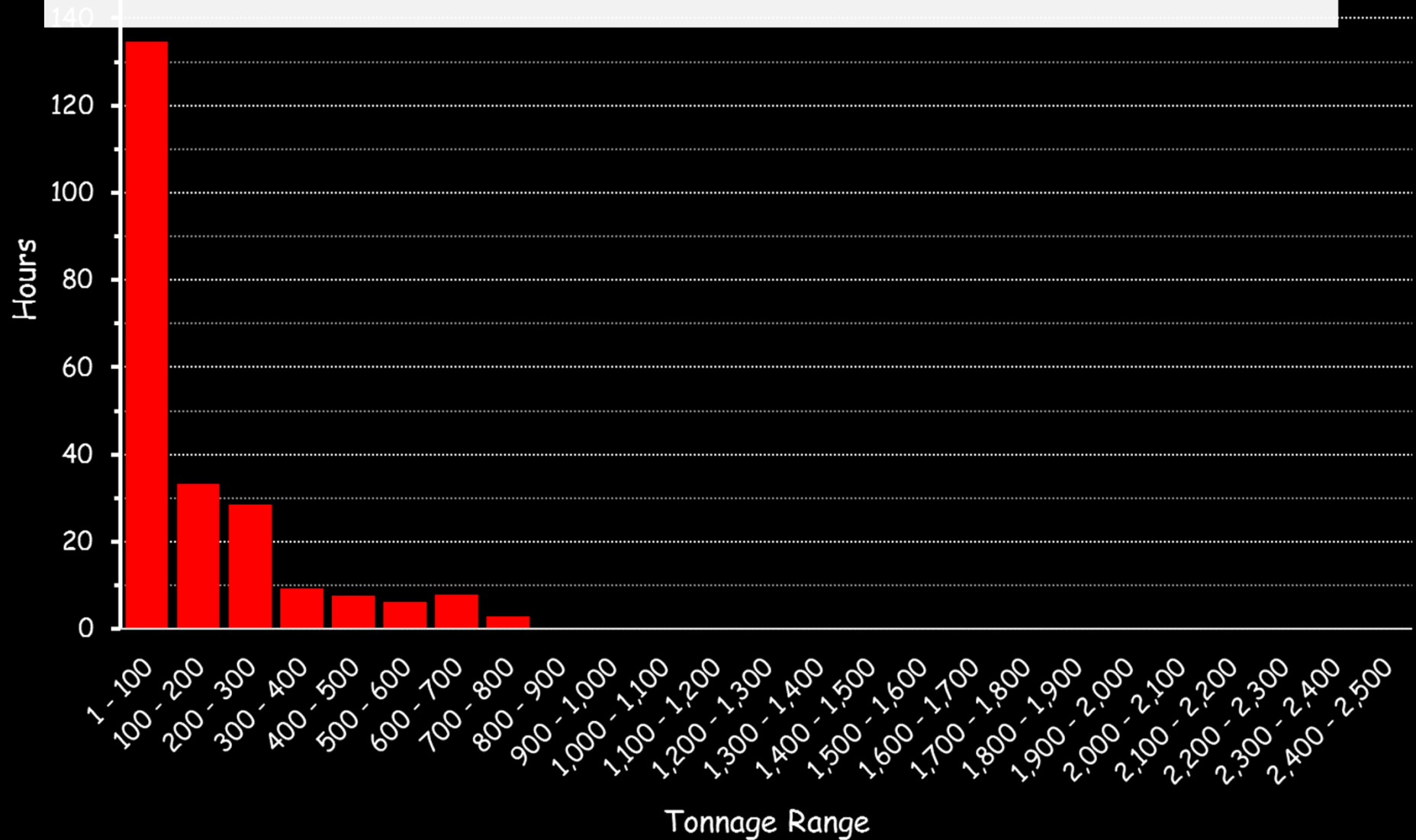


## Hours at a Given Tonnage Range

Thursday 09/24/15 12:00 AM through Monday 12/07/15 11:59 PM

CX PROVIDER:

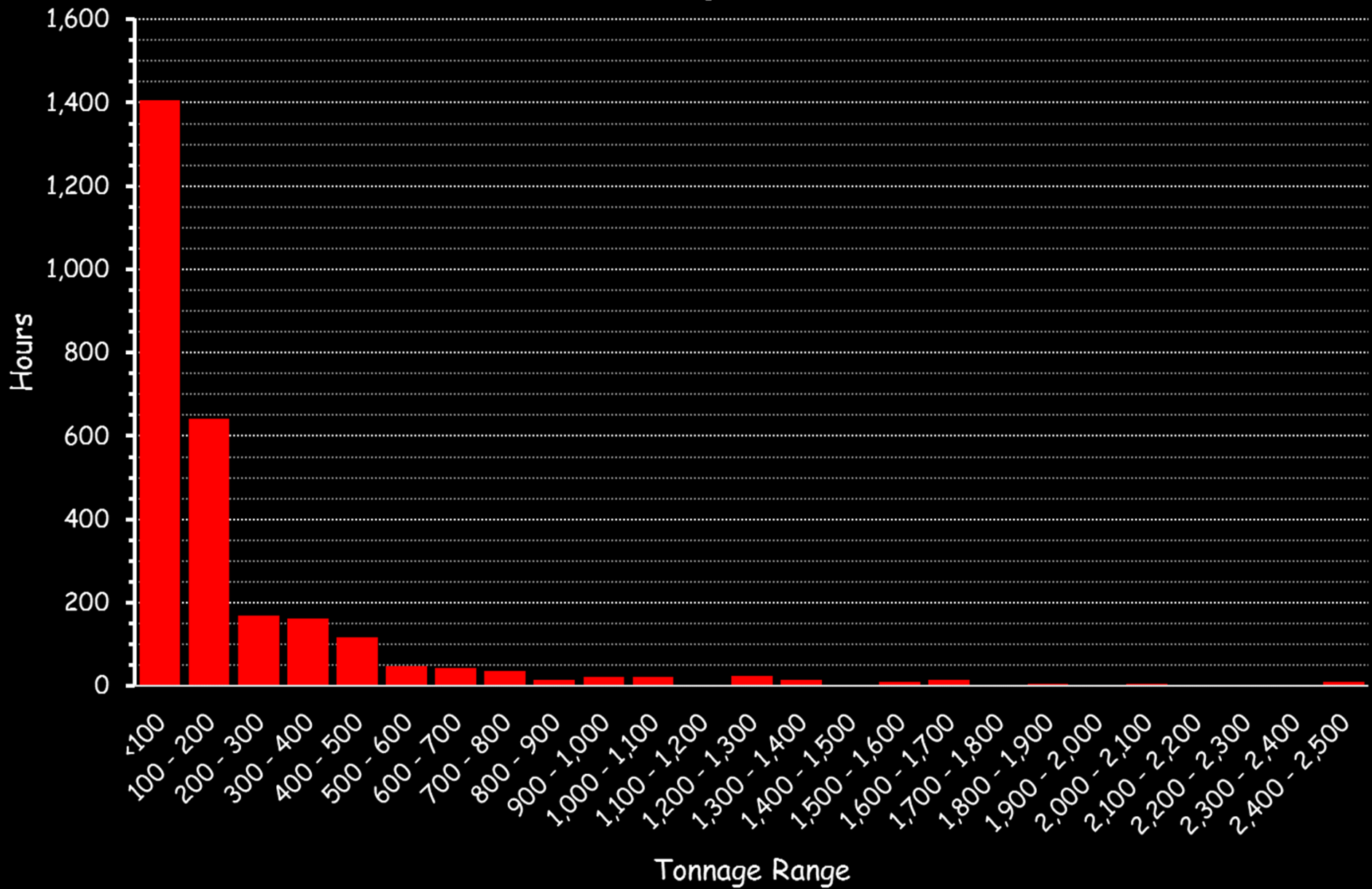
*That's O.K., you've given me enough to start with ...*



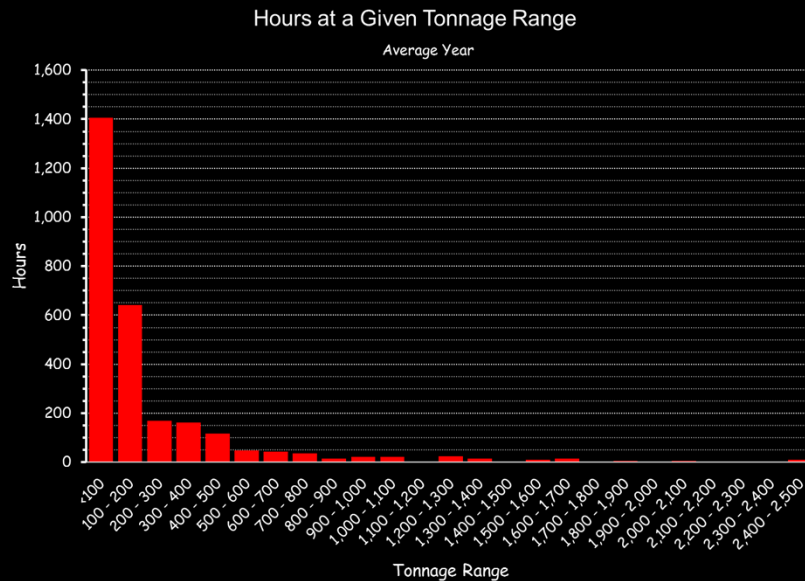


# Hours at a Given Tonnage Range

Average Year



# The design evolves and is reviewed



FADE OUT:

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



## BUILDING:

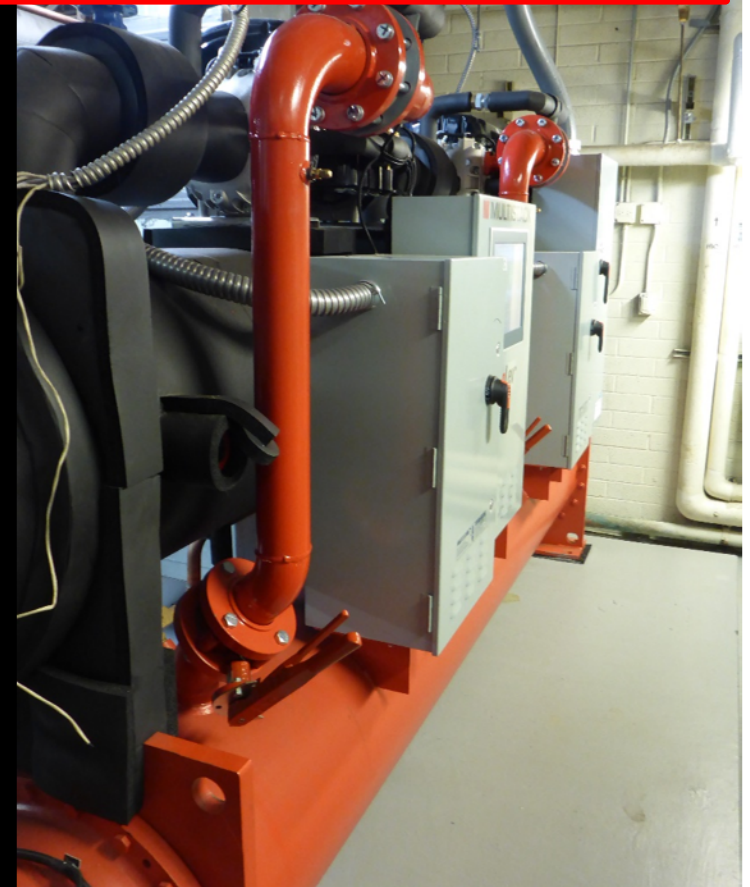
*I'm happy to see the design team paid attention to my suggestion about equipment sizes and turn down requirements.*

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
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	SMART	SMART	SMART
	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

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.

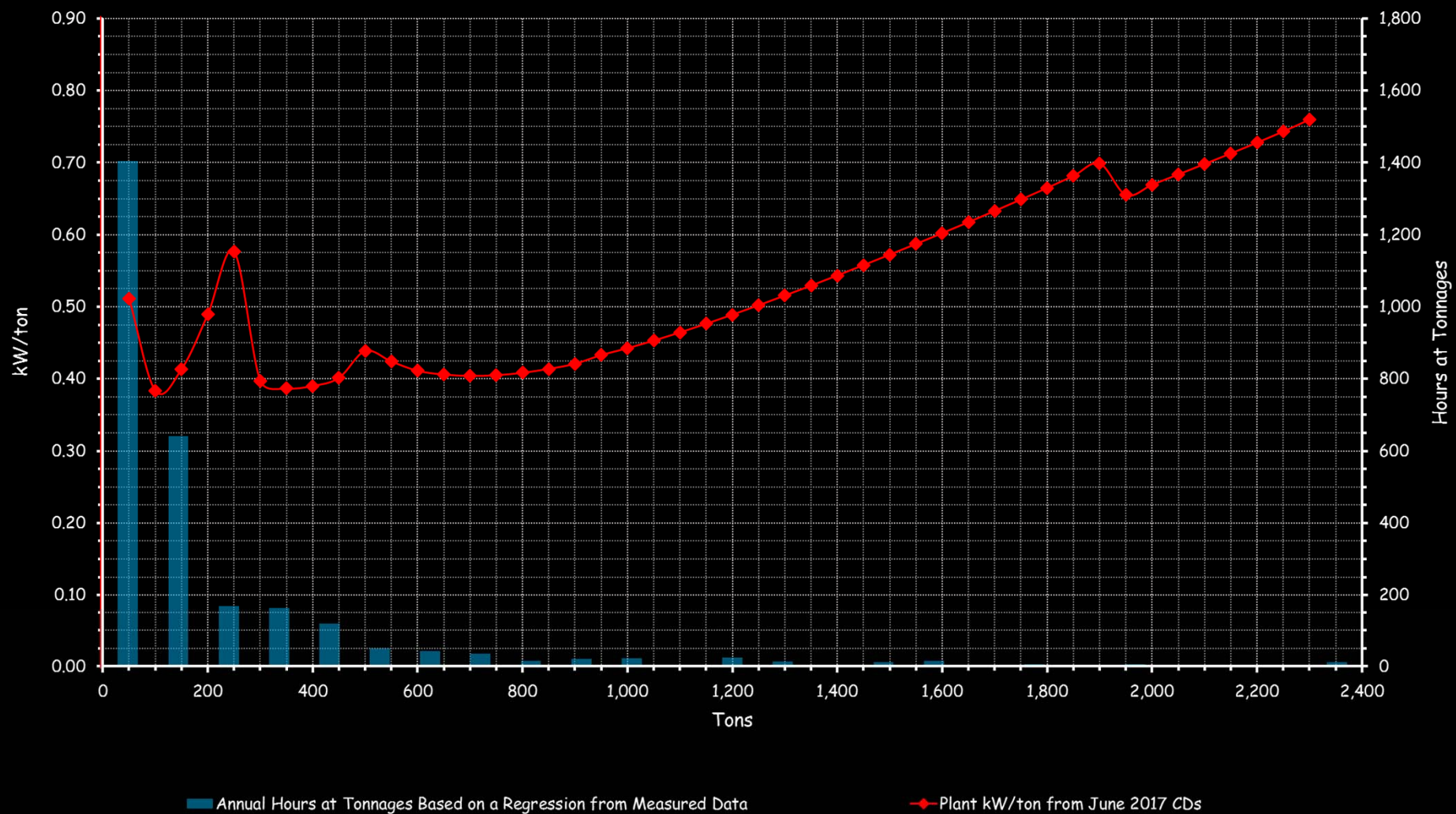
### COOLING TOWERS

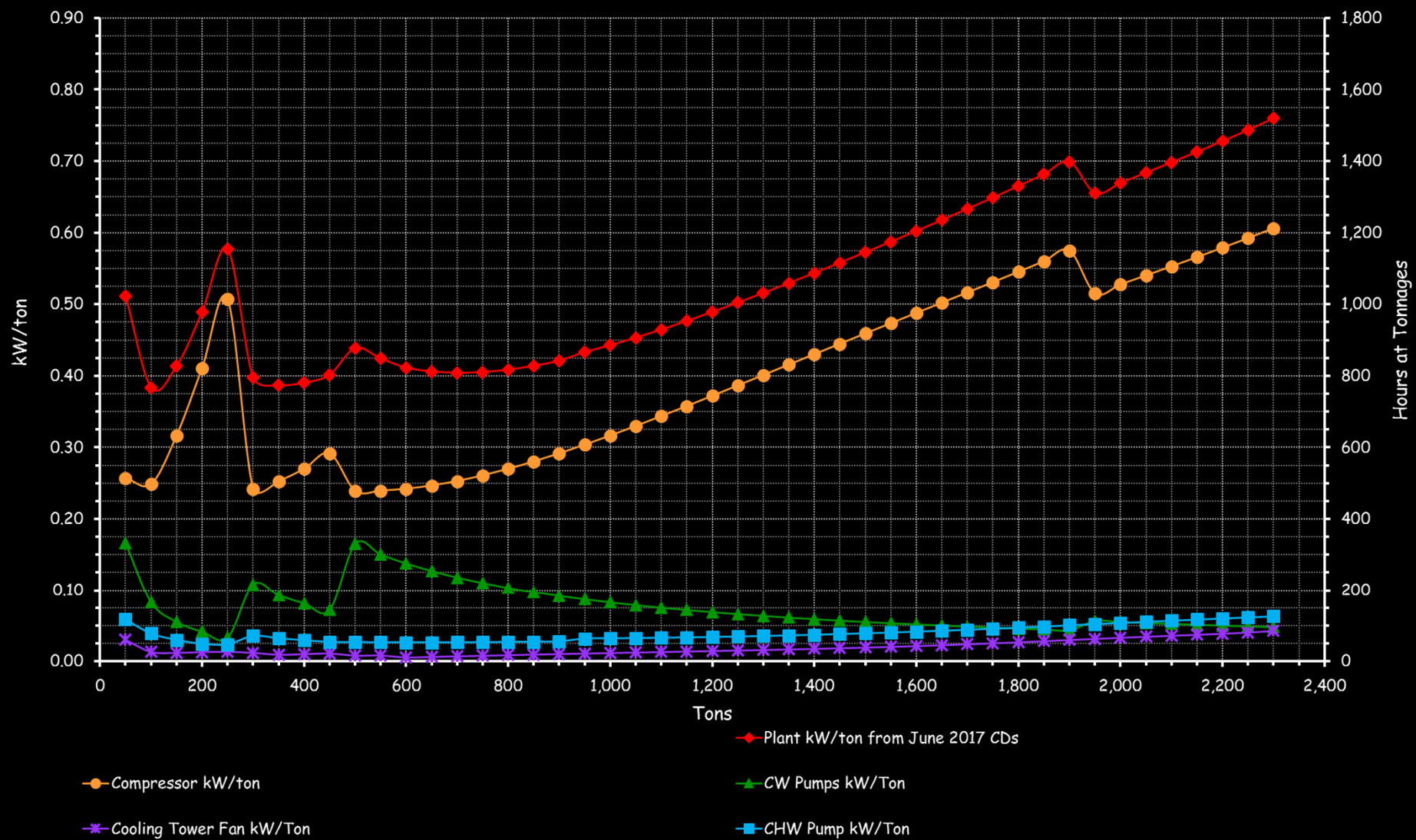
MARK		CT-1A	CT-1B
LOCATION		ROOF	ROOF
SERVES		CHILLERS	CHILLERS
TYPE	AIRFLOW CONFIG	IND DRAFT	IND DRAFT
	DISCHARGE CELLS	VERTICAL	VERTICAL
		2	2
CAPACITY [1]	HEAT REJ: TONS	1,185	1,185
	FLOW: GPM	3,450	3,450
	AMBIENT WB: F	66	66
	EWT: F	86	86
	LWT: F	76	76
	PD: FT HD	12	12
FAN	TYPE	SILENT PROP	SILENT 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.

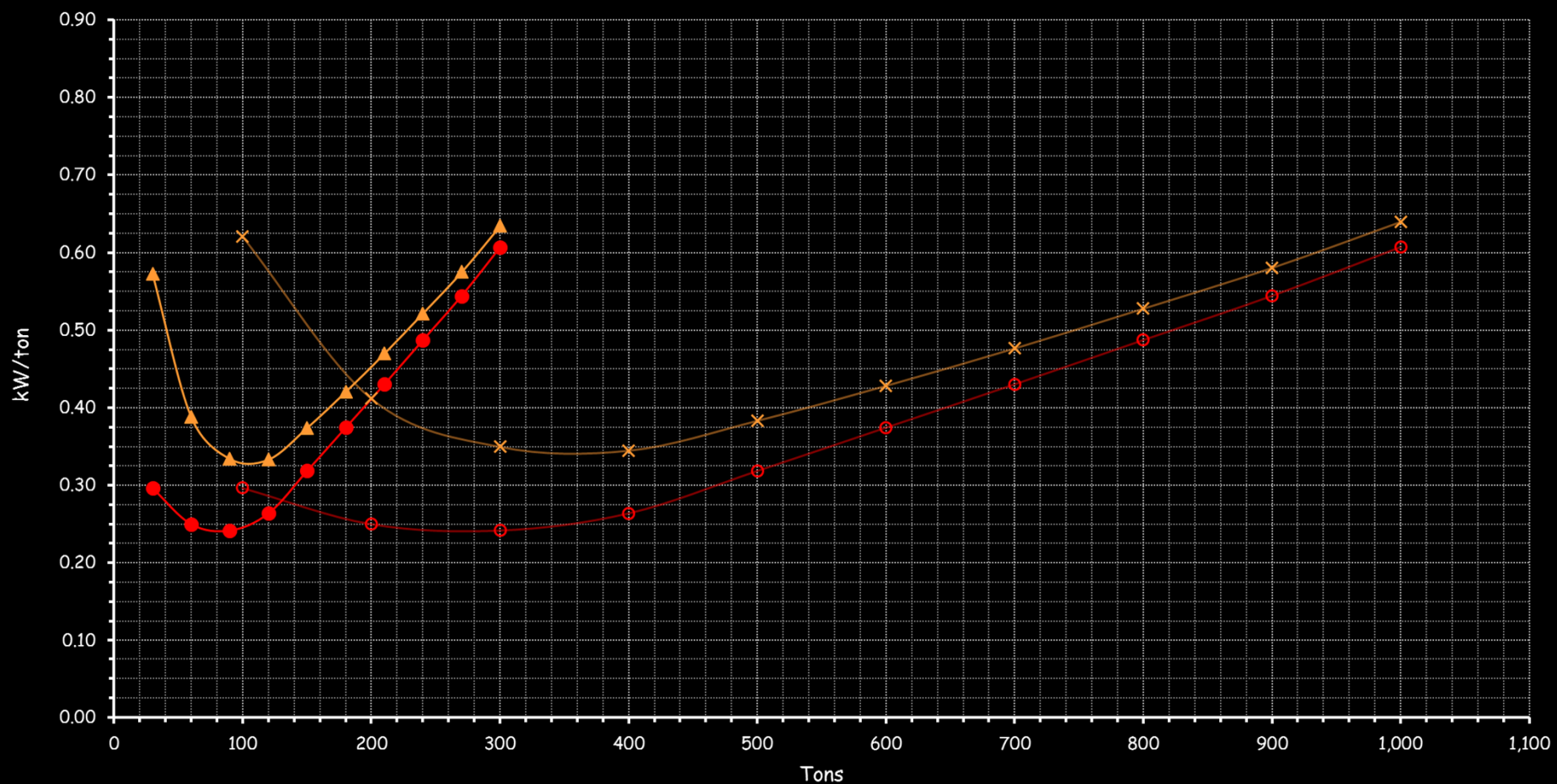
#### NOTES:

1. CAPACITIES BASED ON WATER.
2. REFER TO ELECTRICAL DRAWINGS FOR MOTOR STARTER AND DISCONNECT SWITCH.
3. PROVIDE WITH VIBRATION CUTOFF 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.









● 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

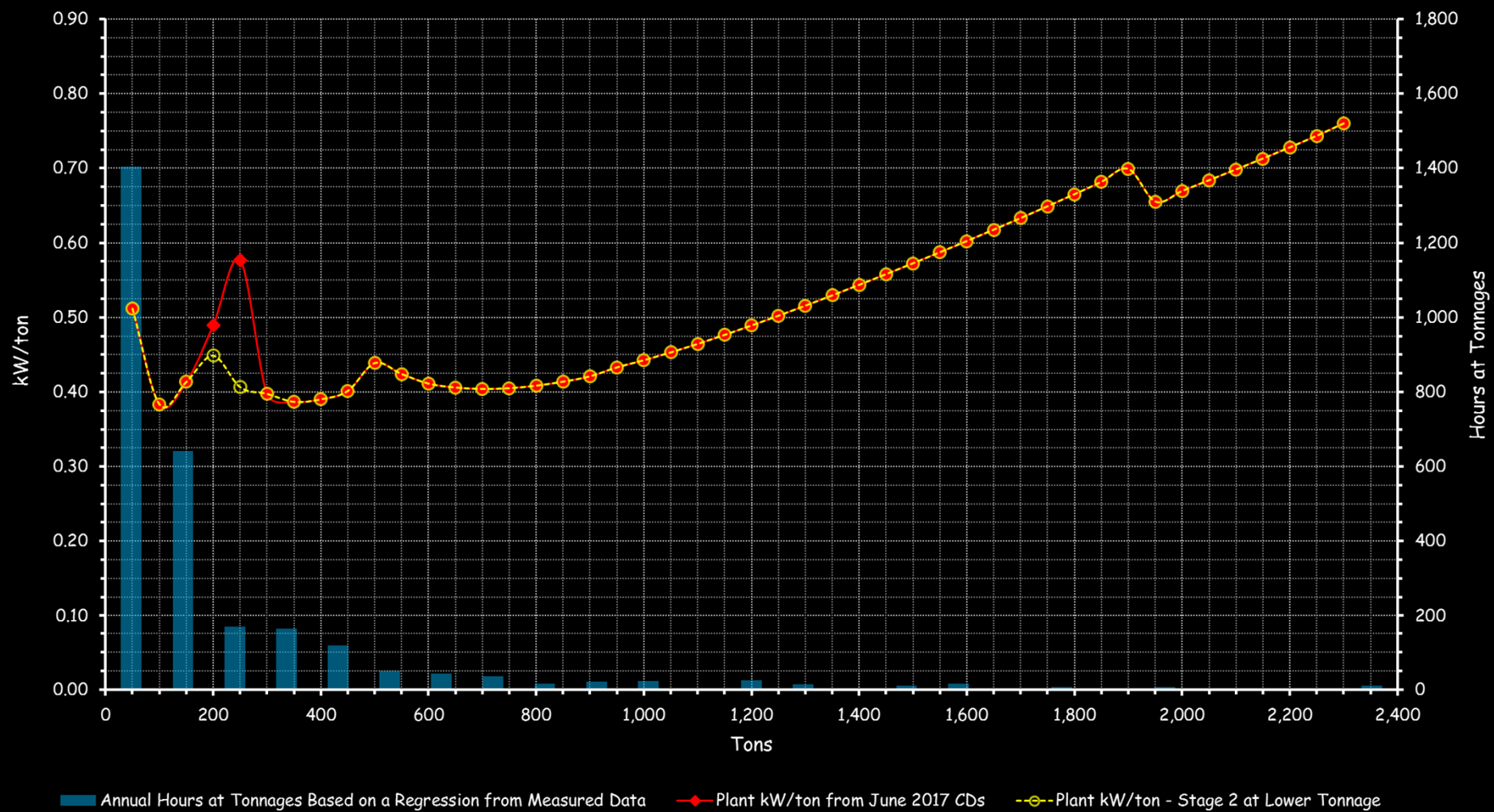
Chiller 2 Running with Chiller 3 kW/ton with CW Pumps

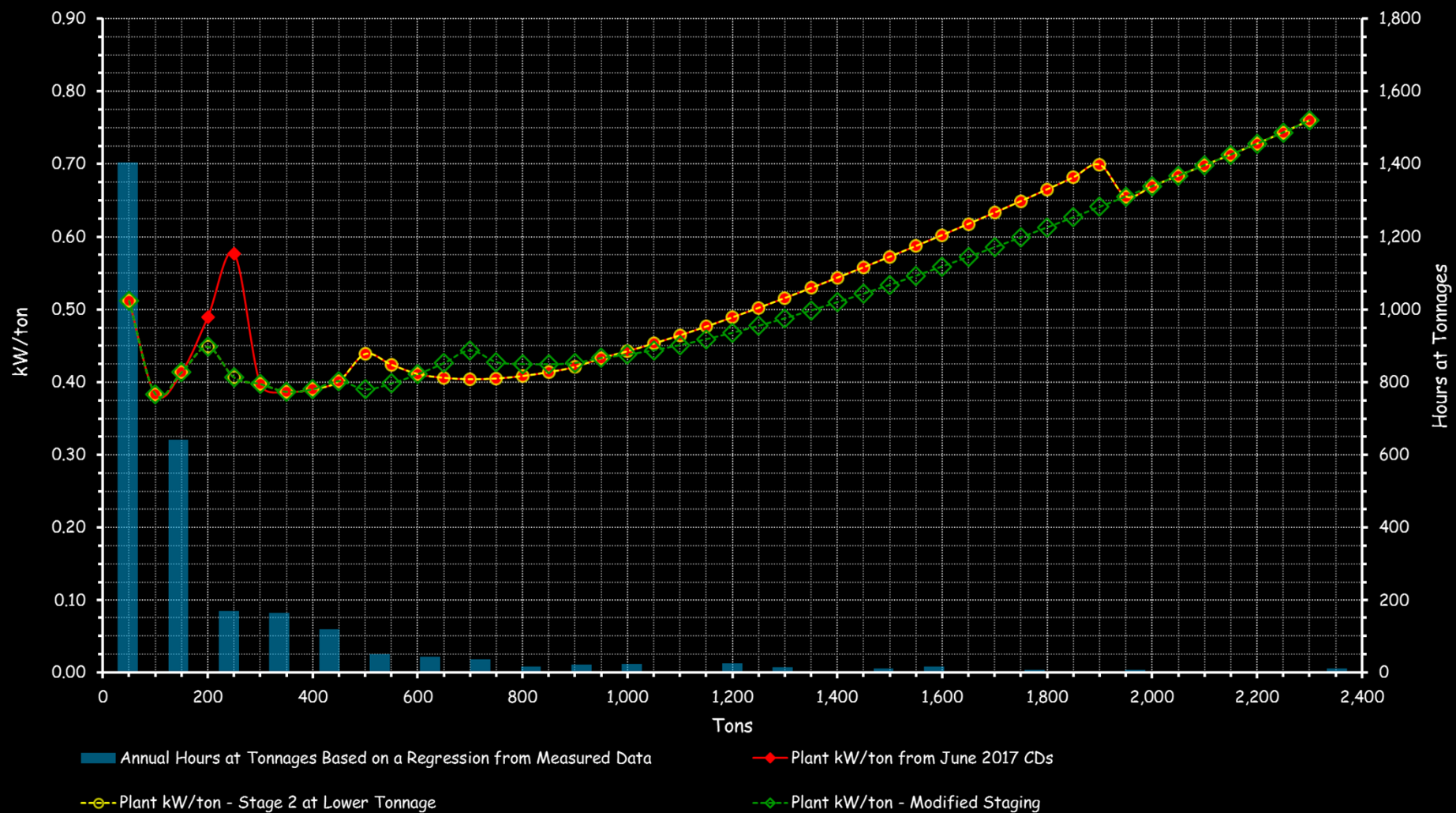
○ Chiller 2 or 3 Compressor kW/ton

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







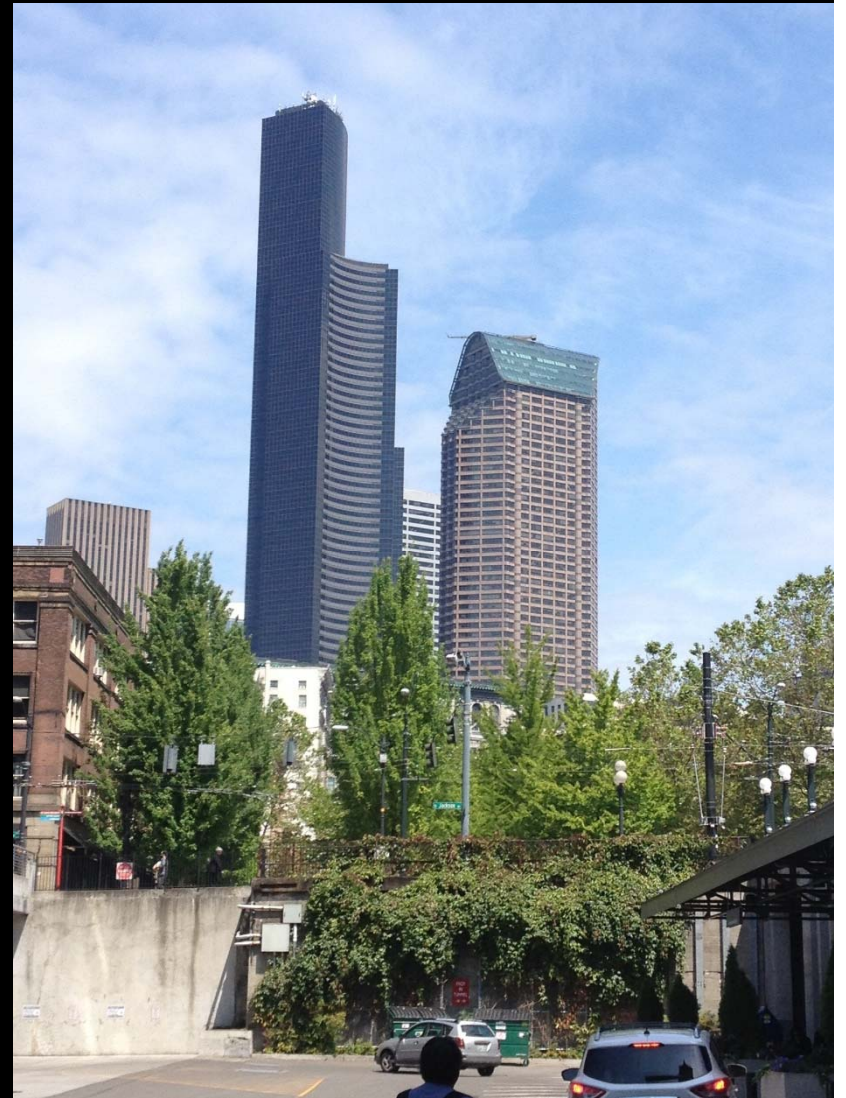
# Bottom line

Com·mis·sion

kə'miSHən/Submit

Verb; Gerund or present participle:  
Commissioning

1. A process during which buildings are mentoring us about design





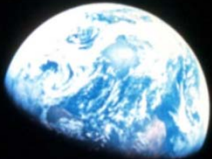
# Why This Matters

*We went to explore the Moon,  
and in fact discovered the Earth*

Gene Cernan  
Apollo 17 Commander

Image courtesy NASA Image Archives; <https://www.nasa.gov/multimedia/imagegallery/index.html>

## Why This Matters



*In a highway service station  
Over the month of June  
Was a photograph of the earth  
Taken coming back from the moon  
And you couldn't see a city  
On that marbled bowling ball  
Or a forest or a highway  
Or me here least of all*

*Joni Mitchell  
Refuge of the Roads*

Image courtesy NASA image archives  
[https://www.nasa.gov/multimedia/imagegallery/image\\_feature\\_1249.html](https://www.nasa.gov/multimedia/imagegallery/image_feature_1249.html)





## Why This Matters

### Interviewer:

*What is your strongest memory of Apollo 11?*

**Michael Collins; Command Module Pilot, Apollo 11**

*Looking back at Earth from a great distance.*

*I really believe that if the political leaders of the world could see their planet from a distance of 100,000 miles their outlook could be fundamentally changed.*

*The earth must become as it appears: blue and white, not capitalist or Communist; blue and white, not rich or poor; blue and white, not envious or envied.*

*Small, shiny, serene, blue and white, FRAGILE.*

Image courtesy NASA Image Archives; <https://www.hq.nasa.gov/office/pao/History/ap11ann/kippsphotos/6550.jpg>

# Why This Matters

**Interviewer:**

*That was 40 years ago. Would it look the same today?*

**Michael Collins; Command Module Pilot, Apollo 11**

*... It's certainly not serene, but definitely fragile, and growing more so. When we flew to the moon, our population was 3 billion; today it has more than doubled and is headed for 8 billion...*

*... The loss of habitat, the trashing of oceans, the accumulation of waste products - this is no way to treat a planet.*



Image courtesy NASA/OSIRIS-REx team and the University of Arizona

*We don't inherit the world from our ancestors,  
we borrow it from our children*

*Unknown*

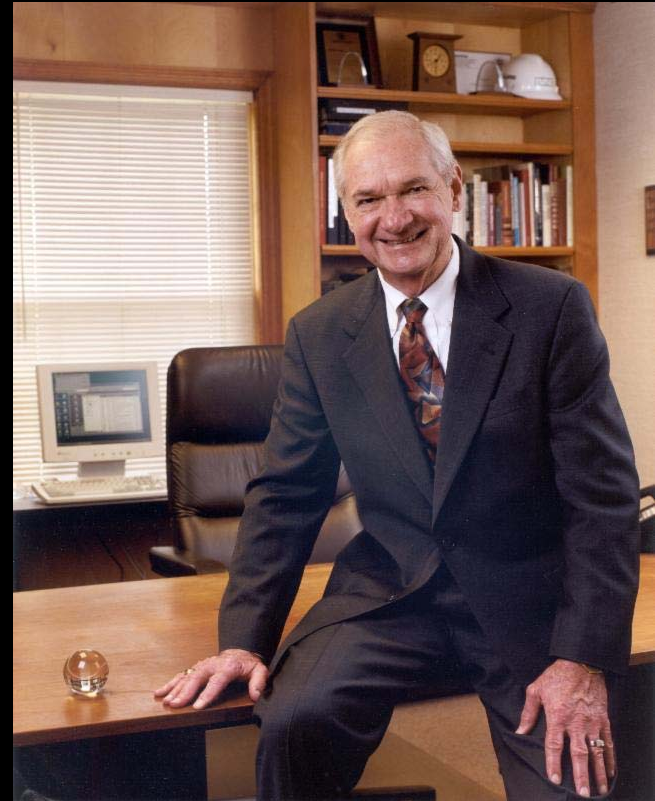




## Bill Coad's thoughts on the topic

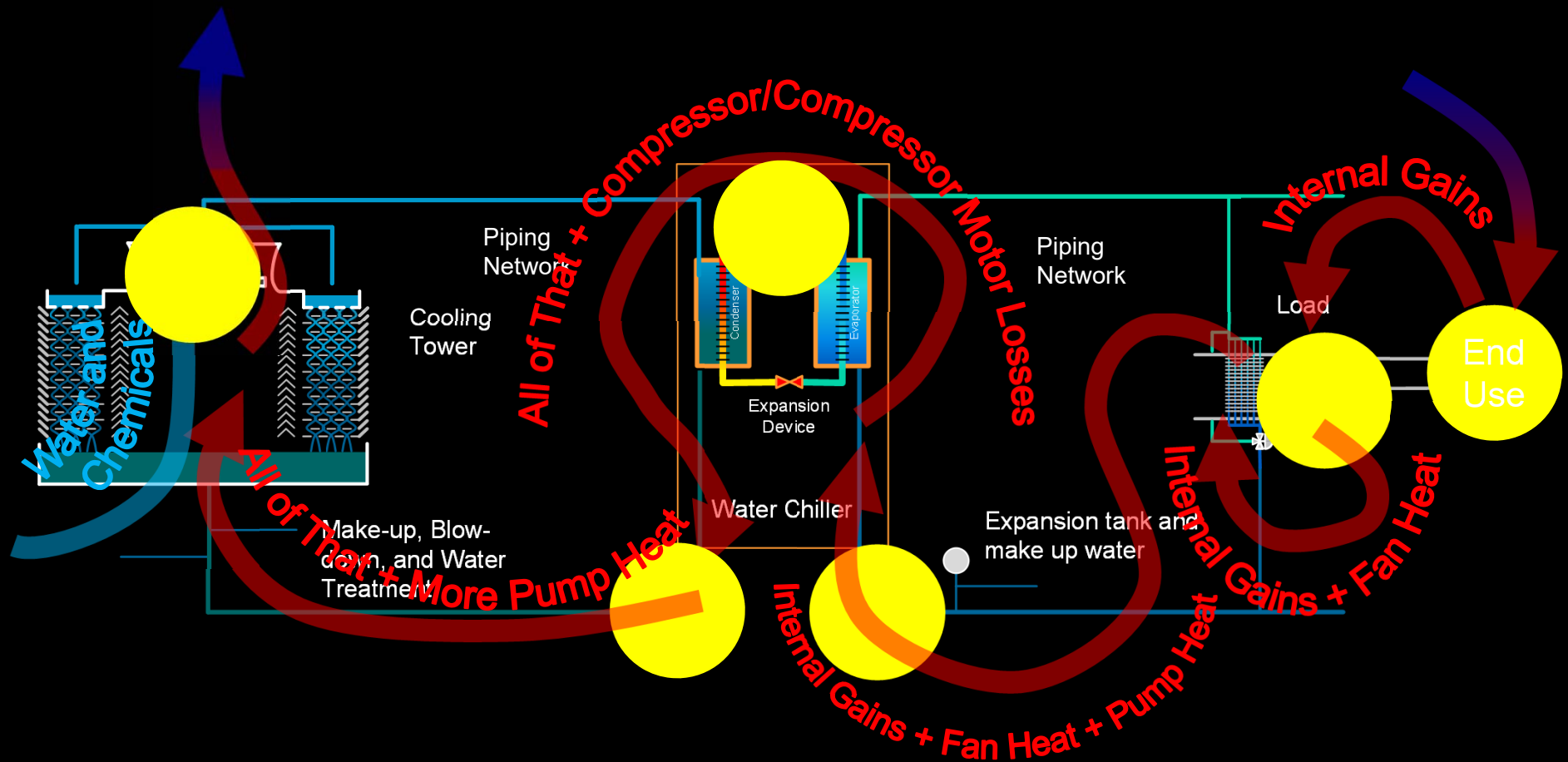
“... that is to practice our profession with an emphasis upon our responsibility to protect the long-range interests of the society we serve and, specifically, to incorporate the ethics of energy conservation and environmental preservation in everything we do.”

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

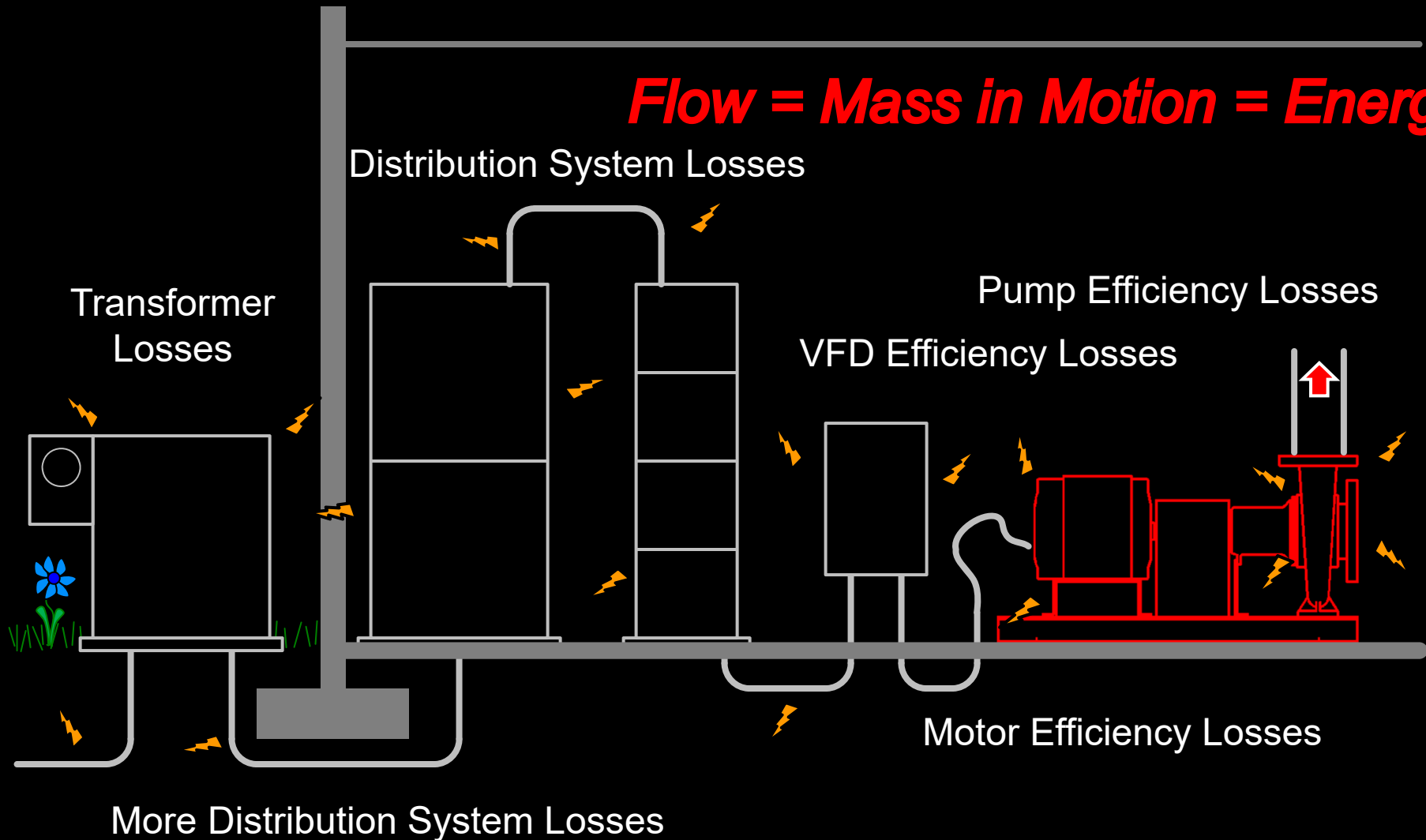


PDF available at <http://www.av8rdas.com/bill-coads-writings.html>

# Applying the commissioning tool set can have ripple effects



***Flow = Mass in Motion = Energy***





# Transmission losses are significant



There are currently 6-8% losses  
in these lines between the  
power plant and your meter

*A coal fired Midwest power plant*

Image Landsat / Copernicus

Google Earth



# Conversion losses are significant

The current average heat rate for fossil fuel fired plants is 10,000 Btus in for every 3,413 Btus out (1 kW)



Image Landsat / Copernicus

*A coal fired Midwest power plant*

Google Earth



# Physical principles will prevail

Conservation of mass and energy says that all of the mass in this pile of coal other than the fly ash will end up in the atmosphere



Image Landsat / Copernicus

Google Earth

*A coal fired Midwest power plant*



# Bottom line

Generating power consumes finite resources and impacts the environment



# Reducing atmospheric impacts

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

*Energy Strategy; [www.portlandgeneral.com](http://www.portlandgeneral.com)*



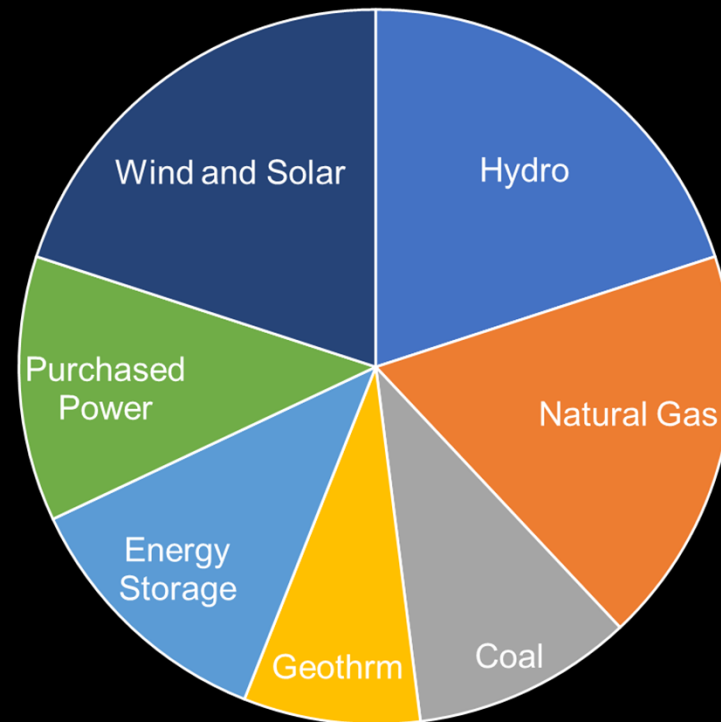
## Integrated Resource Planning

Preparing for Oregon's energy future

# Reducing atmospheric impacts

Moving away from carbon fuels is a common, long term goal for many utilities

XYZ Power Company Generating Mix



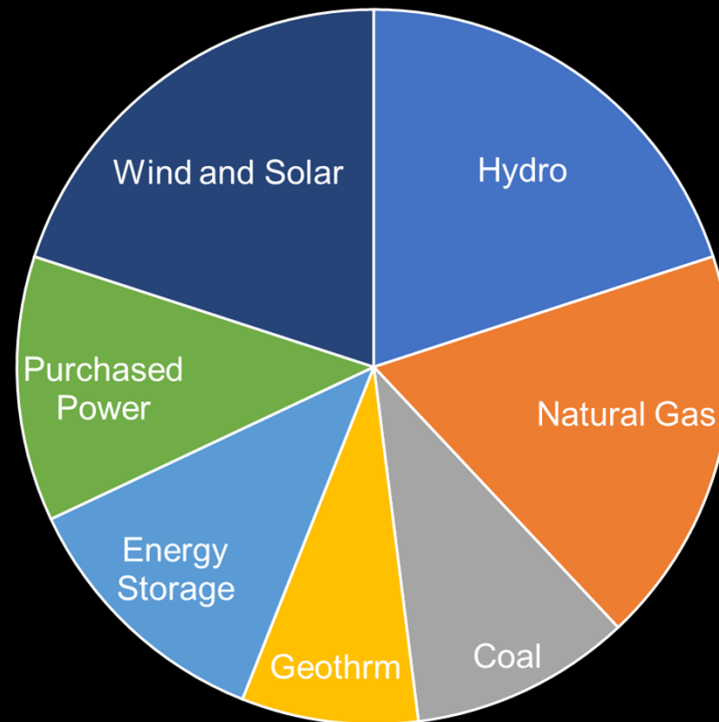


# Reducing atmospheric impacts

Functioning control systems can have an immediate impact by reducing the need for energy in the first place

*It's a win-win situation*

XYZ Power Company Generating Mix



# Start to have your own impact

Survey your building inventory for big energy users and poorly performing systems

- Read LBNLs report on the costs and benefits of commissioning at <http://cx.lbl.gov/cost-benefit.html>
- LBNL metrics indicate that the median savings from an EBCx process will be in the range of 16% of the annual energy cost

## **Building Commissioning:**

*A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions*

Evan Mills, Ph.D.  
Lawrence Berkeley National Laboratory  
Berkeley, CA 94720 USA

Report Prepared for:  
California Energy Commission  
Public Interest Energy Research (PIER)

July 21, 2009

For a downloadable version of the report and supplementary information, visit:  
<http://cx.lbl.gov/2009-assessment.html>

Sponsored by the California Energy Commission, Public Interest Energy Research Program, through the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

# Start to have your own impact

*80%-90% of the commissioning issues out there have there roots in the control system*

- Fixing the control system = having an impact
- Fixing the control system = having fun

