Functional Performance: Tools, Rigor and Collaboration

David Sellers, Senior Engineer
Facility Dynamics Engineering

NCBC 2013

21st National Conference on Building Commissioning

AIA Quality Assurance

The Building Commissioning Association is a Registered Provider with ***The American Institute of Architects Continuing Education Systems (AIA/CES)***. Credit(s) earned on completion of this program will be reported to ***AIA/CES*** for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This program is registered with ***AIA/CES*** for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Presentation Description

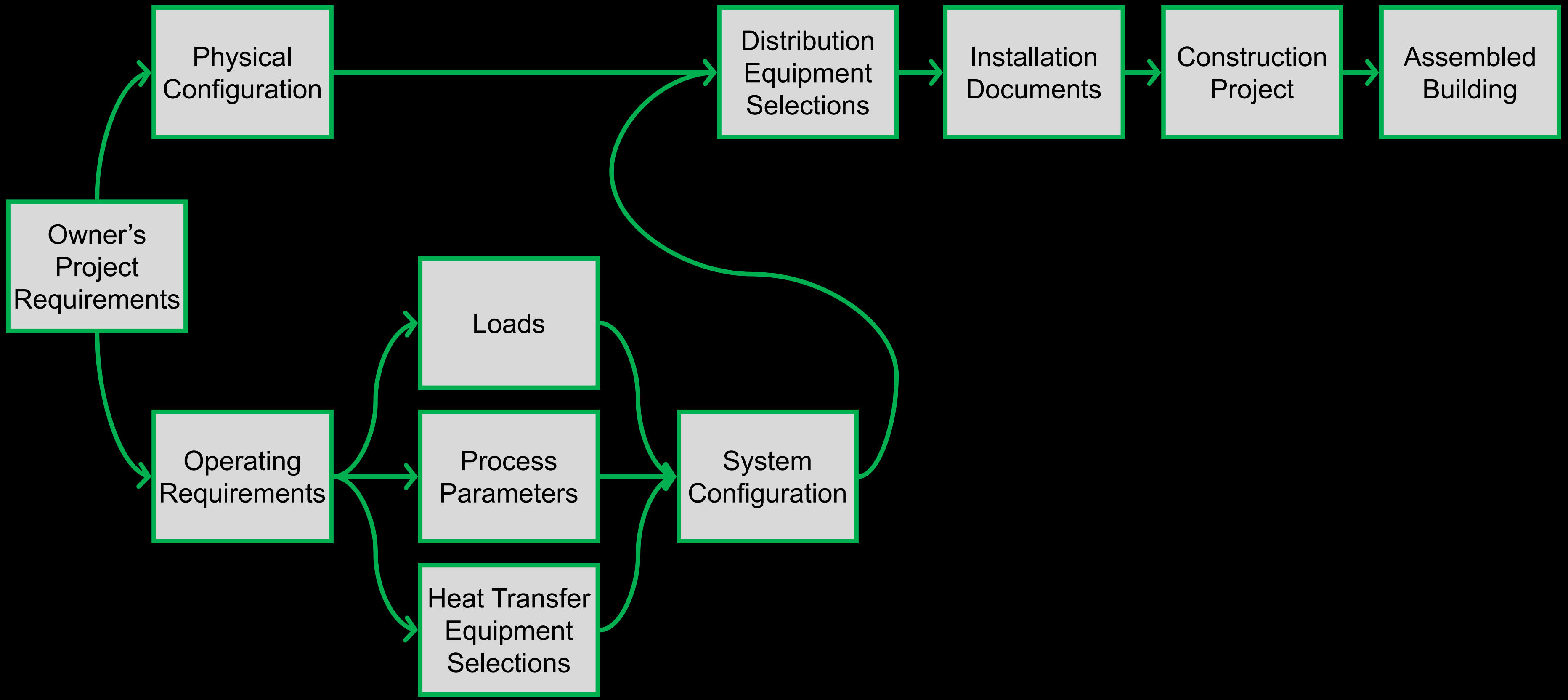
This presentation uses a case study format to explore functional testing in an existing building commissioning process. Specifically, a functional test is developed to assess the thermal flywheel potential of a small chilled water system. The results are then used to develop control system program modifications that allow a short cycling problem to be resolved while still providing the required environmental conditions inside the facility.

Learning Objectives

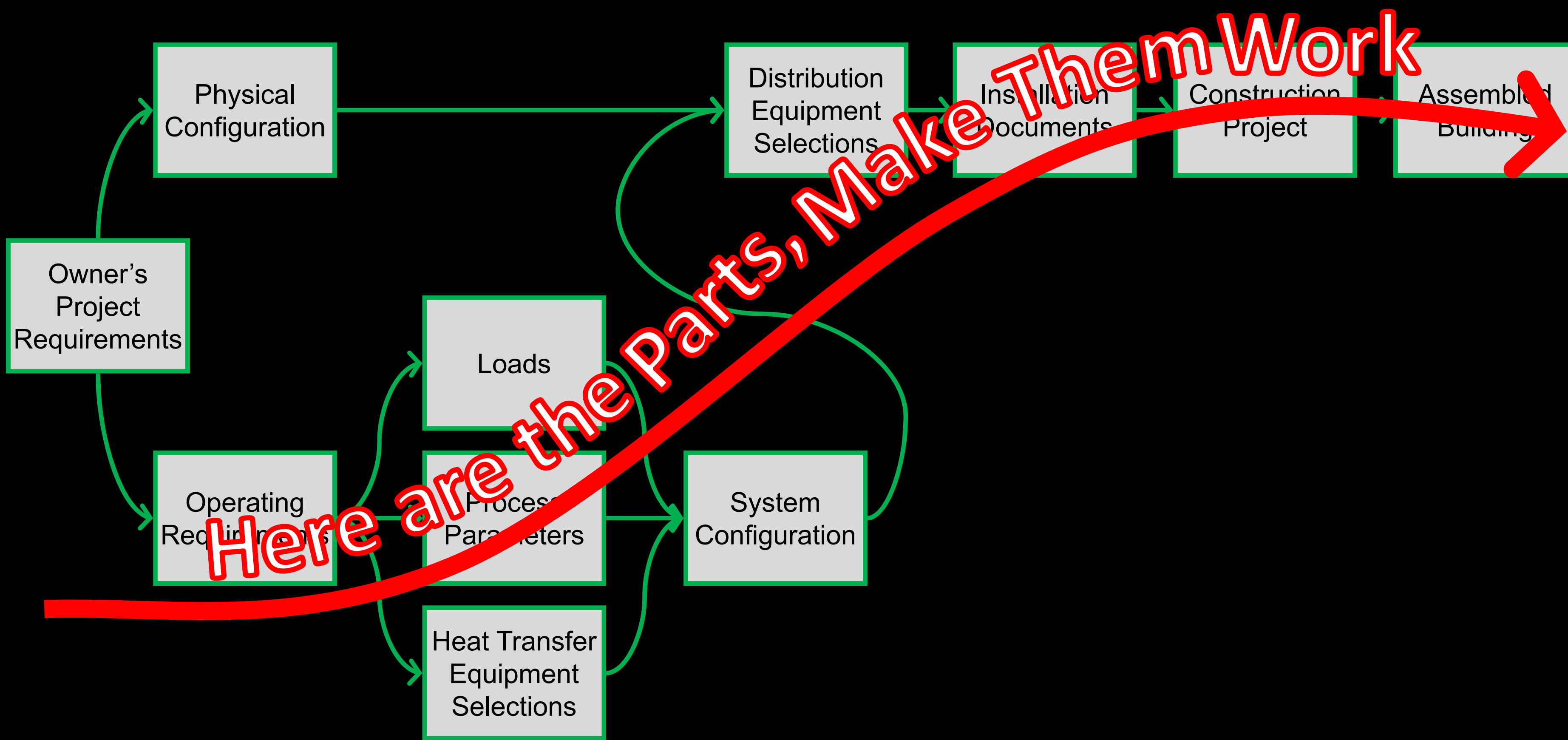
At the end of this session, participants will be able to:

1. Understand the difference between a functional testing process in an existing building commissioning environment vs. a new construction environment
2. Understand that there can be a hierarchy to a functional testing process
3. Understand the key elements associated with developing a functional test
4. Understand how functional testing can be used as a diagnostic tool in an existing building commissioning process
5. Understand how a functional test can be used to gather useful data in an existing building commissioning process

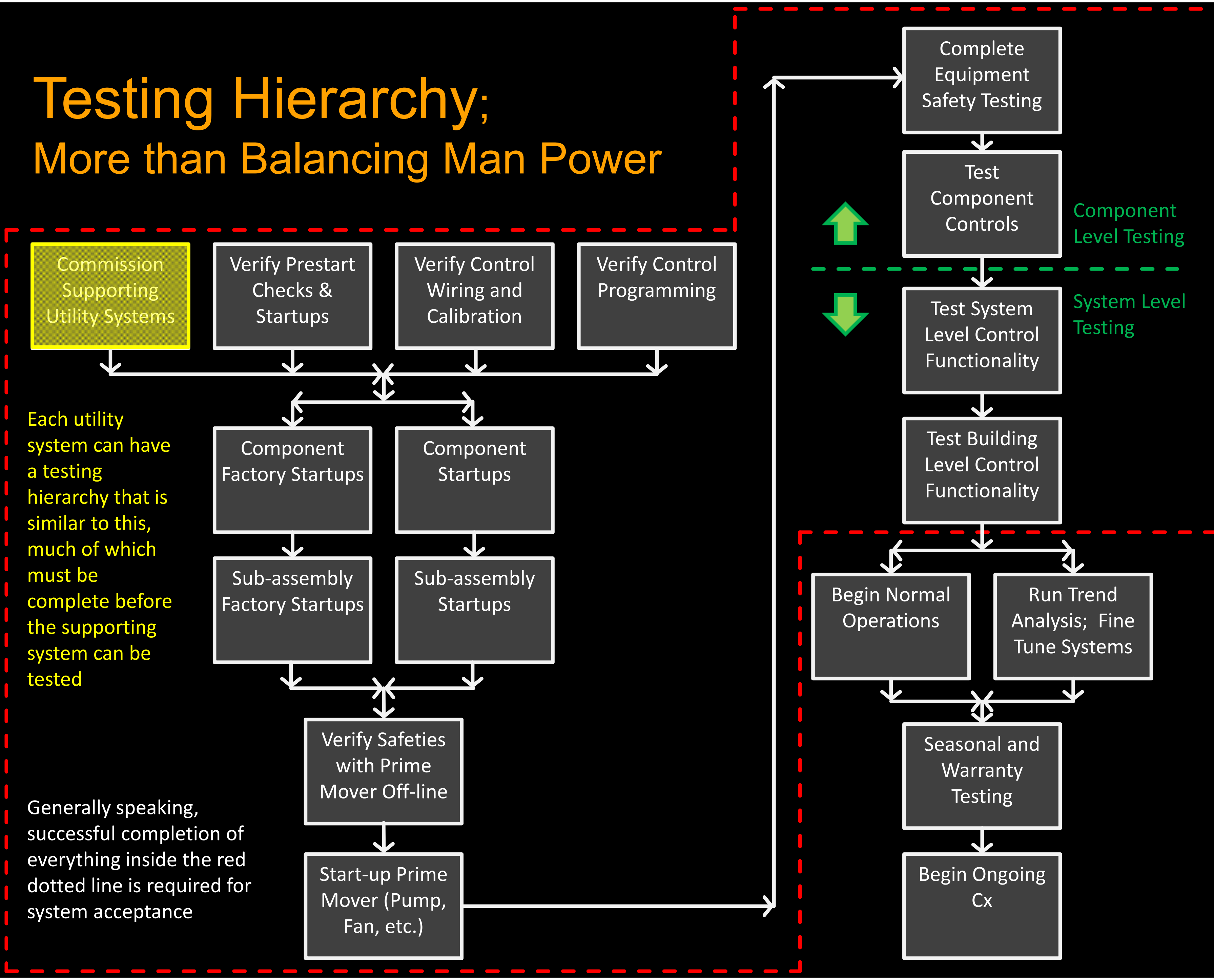
The Path to Selecting Equipment and Systems



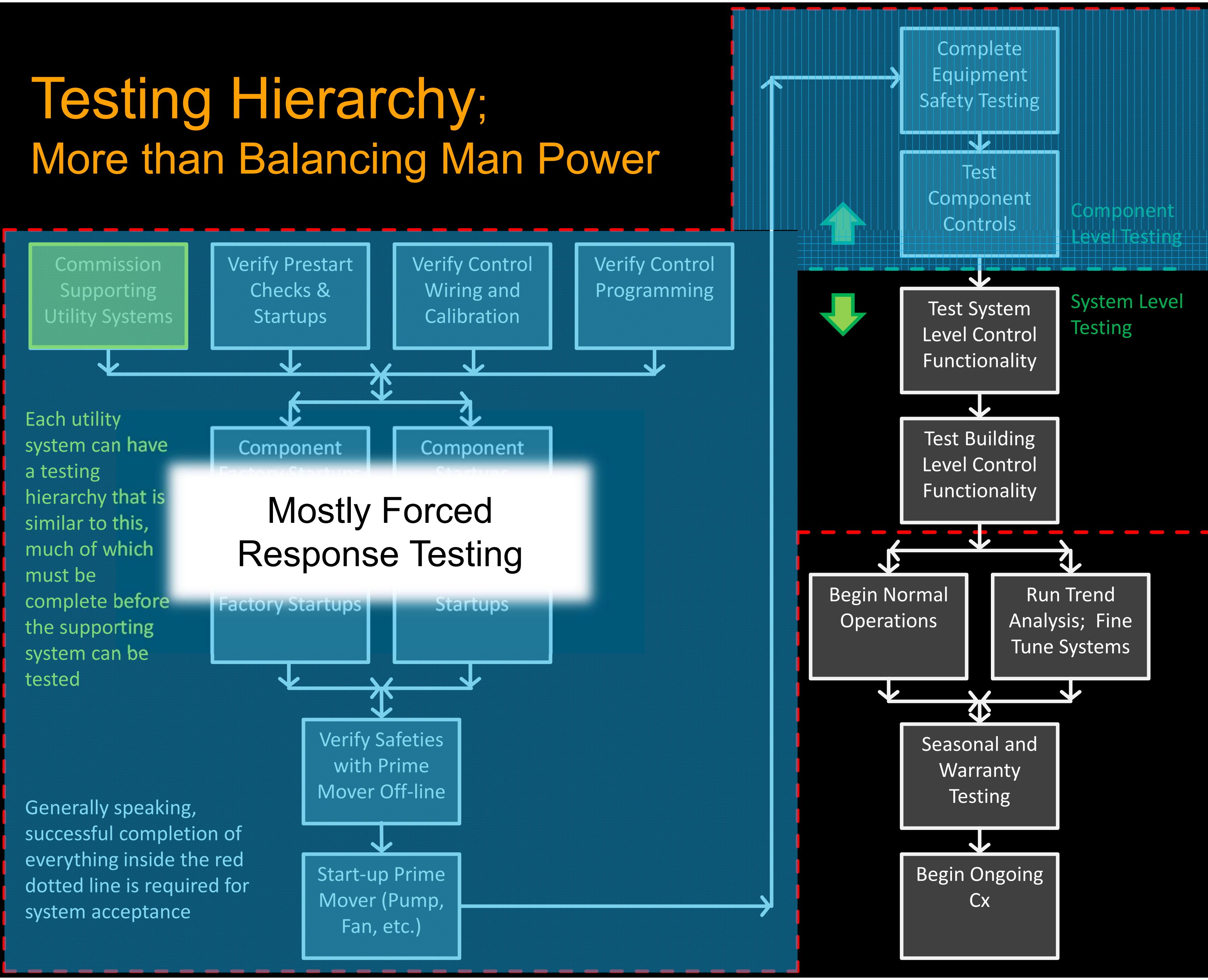
The New Construction Perspective on Functional Testing



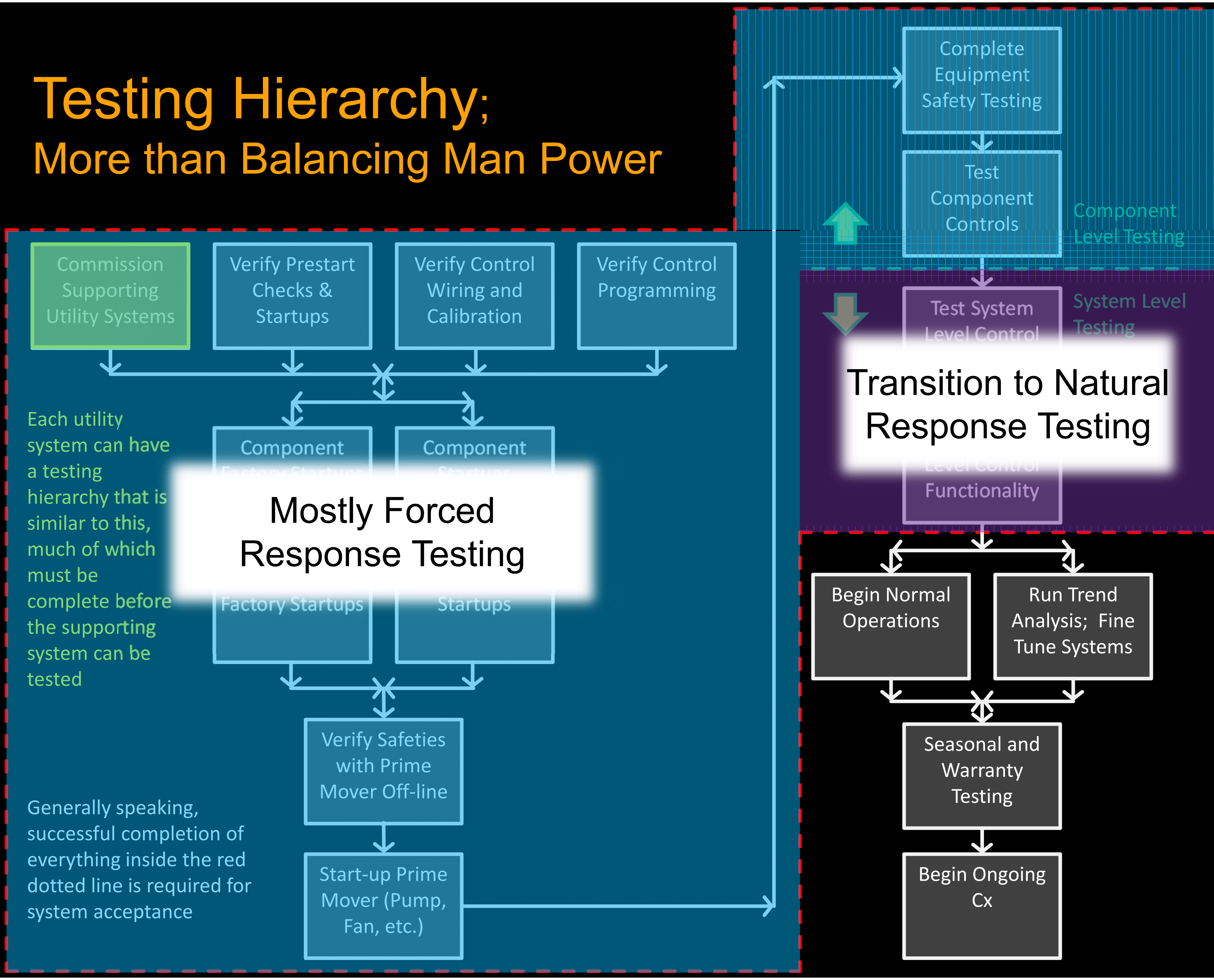
Testing Hierarchy;
More than Balancing Man Power



Testing Hierarchy;
More than Balancing Man Power

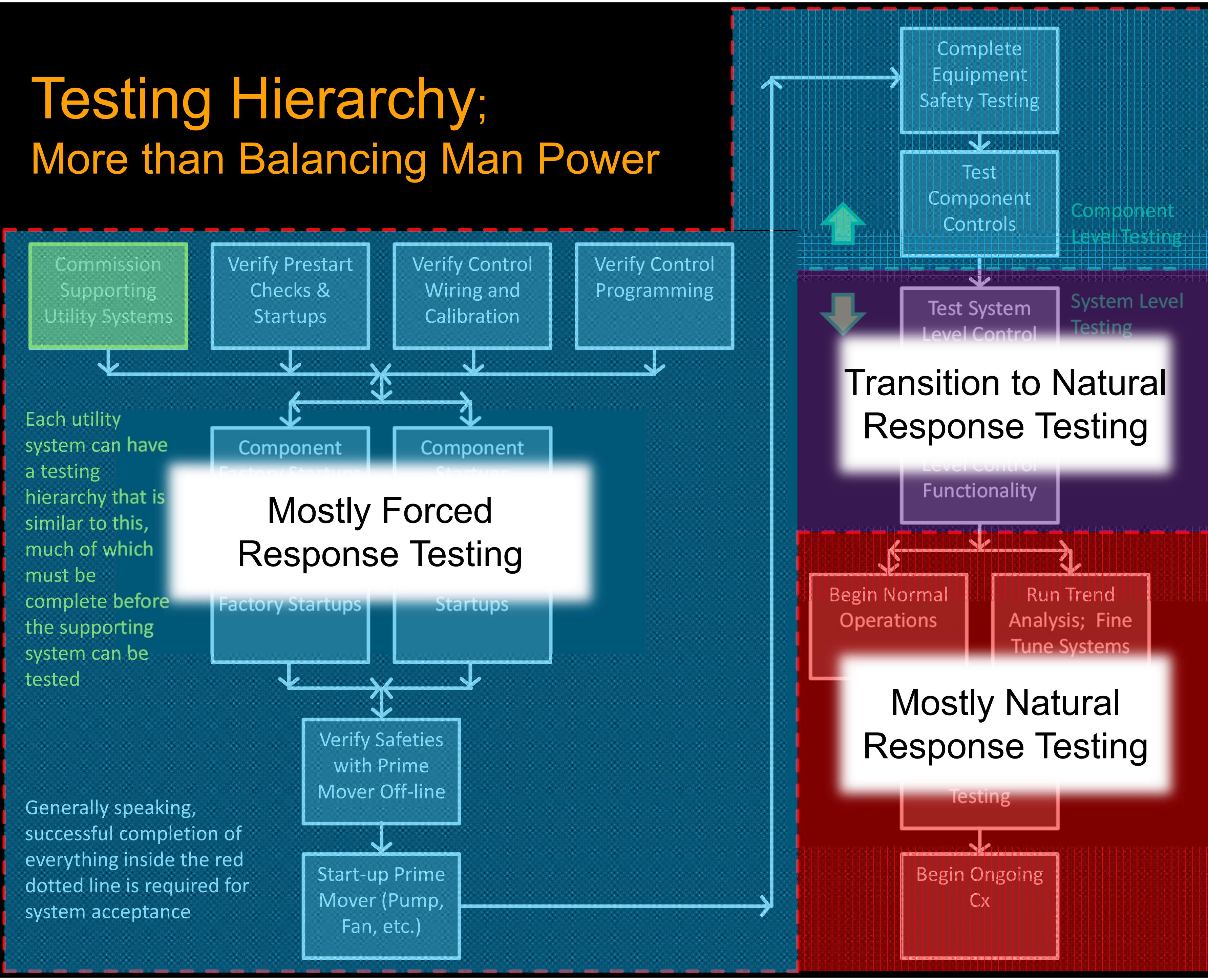


Testing Hierarchy;
More than Balancing Man Power

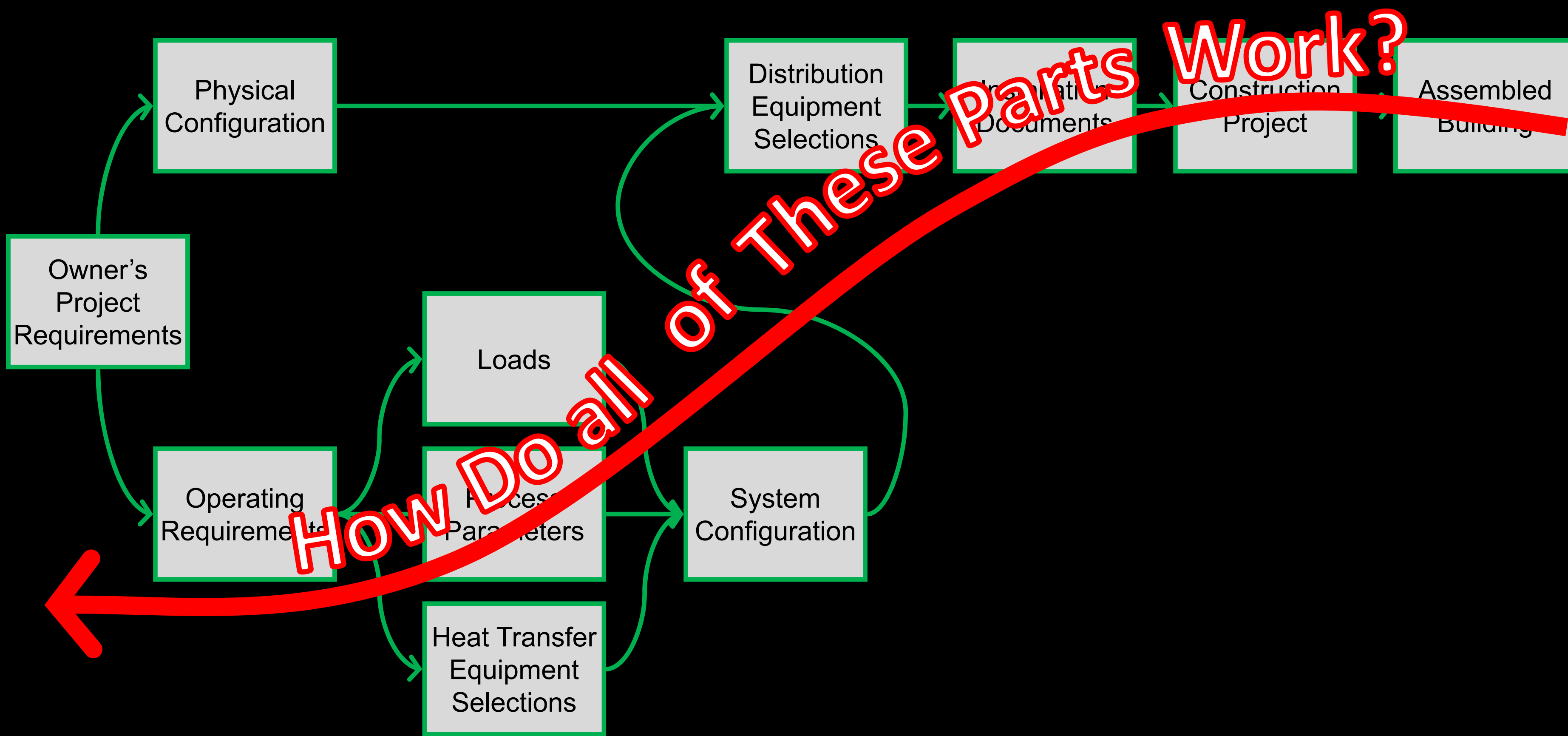


Testing Hierarchy;

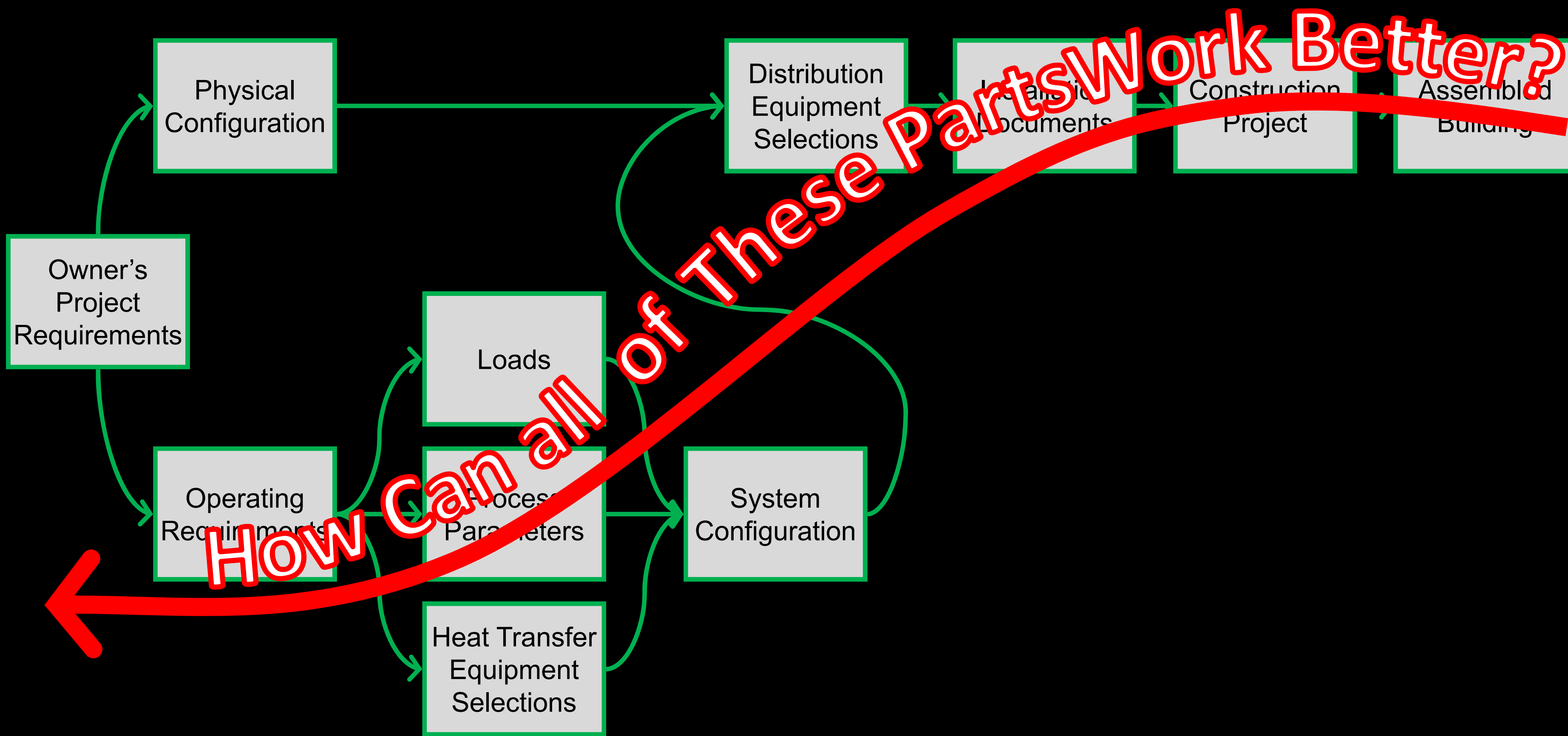
More than Balancing Man Power



The Existing Building Perspective on Functional Testing



The Existing Building Perspective on Functional Testing



New Construction versus EBCx Testing

New Construction

- Trying to prove design intent
- Demonstrate all elements of the system meet requirements
- Verification and quality assurance process

EBCx

- Trying to understand design intent
- Focused on certain elements of the system
- Diagnostic and troubleshooting process

Le Conte Hall

- UC Berkeley Physics Department Home
- 148,000 square feet
- Four floors plus basement
  - Floors 1 and 2 - Classrooms and research
  - Floors 3 and 4 - Offices, class rooms, informal meeting space
- Interconnected with other physics department buildings
- MBCx program participant since 2009
- MBCx Best Practices Award winner for the 2009 program cycle

Le Conte Hall

- UC Berkeley Physics Department Home
- 148,000 square feet
- Four floors plus basement
  - Floors 1 and 2 - Classrooms and research
  - Floors 3 and 4 - Offices, class rooms, informal meeting space
- Interconnected with other physics department buildings
- MBCx program participant since 2009
- MBCx Best Practices Award winner for the 2009 program cycle

It Takes a Team to Succeed

Left to Right

Anthony Vitan, Eleanor Crump, Julia Gee, Chuck Frost

Le Conte Hall

- UC Berkeley Physics Department Home
- 148,000 square feet
- Four floors plus basement
  - Floors 1 and 2 - Classrooms and research
  - Floors 3 and 4 - Offices, class rooms, informal meeting space
- Interconnected with other physics department buildings
- MBCx program participant since 2009
- MBCx Best Practices Award winner for the 2009 program cycle

It Takes a Team to Succeed

Left to Right

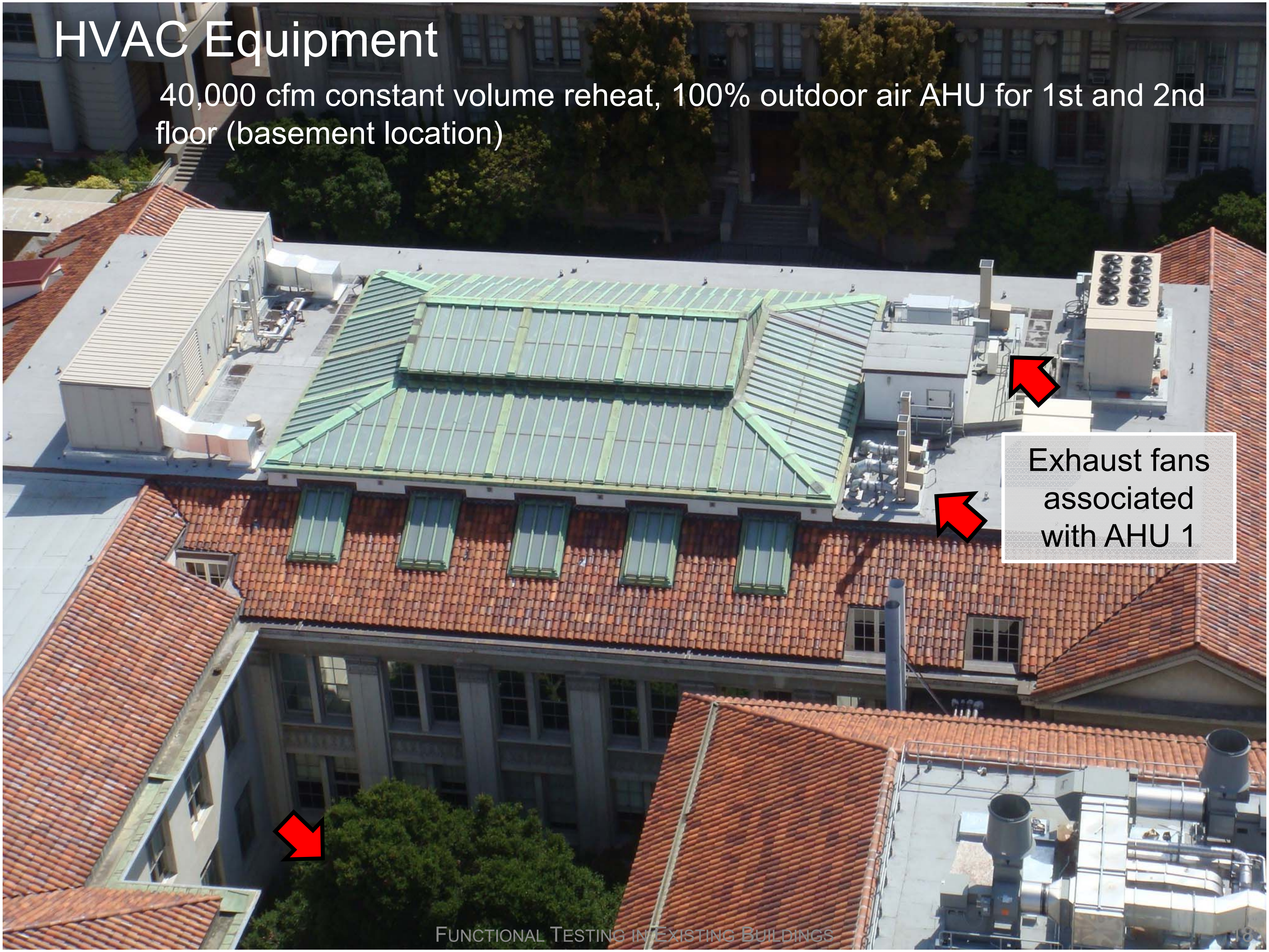
Ancestors of David Sellers, Mark Porter, Ron Simens, Gary Kawabuchi and Mark Arney test a new idea

2004 – 2007 Renovation

- Seismic issues
- Deferred maintenance
- Reconfiguration
- Restoration
- MEP Update

HVAC Equipment

40,000 cfm constant volume reheat, 100% outdoor air AHU for 1st and 2nd floor (basement location)



HVAC Equipment

32,000 cfm constant volume reheat, economizer equipped AHU for 3rd and 4th floor

HVAC Equipment

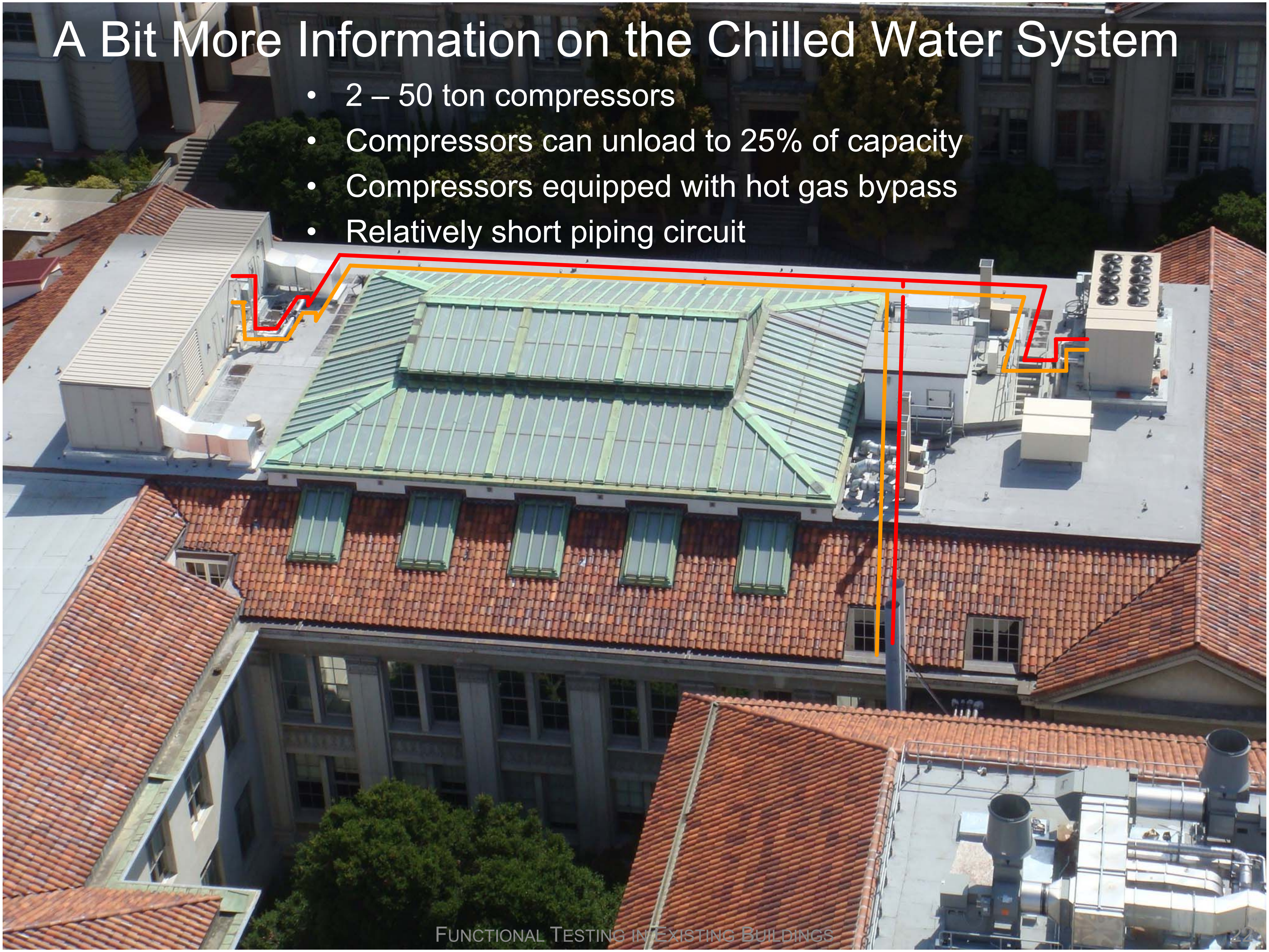
Steam fired variable flow heating hot water system (basement location)

HVAC Equipment

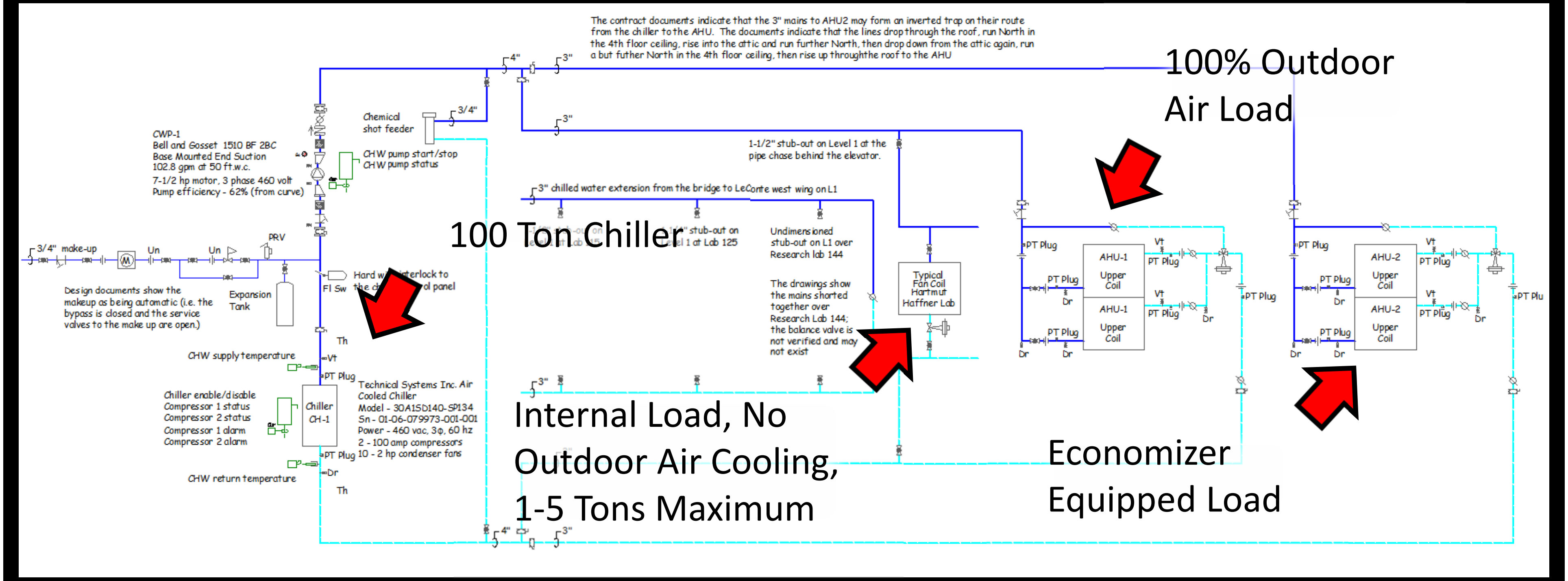
Air cooled constant volume chilled water system

A Bit More Information on the Chilled Water System

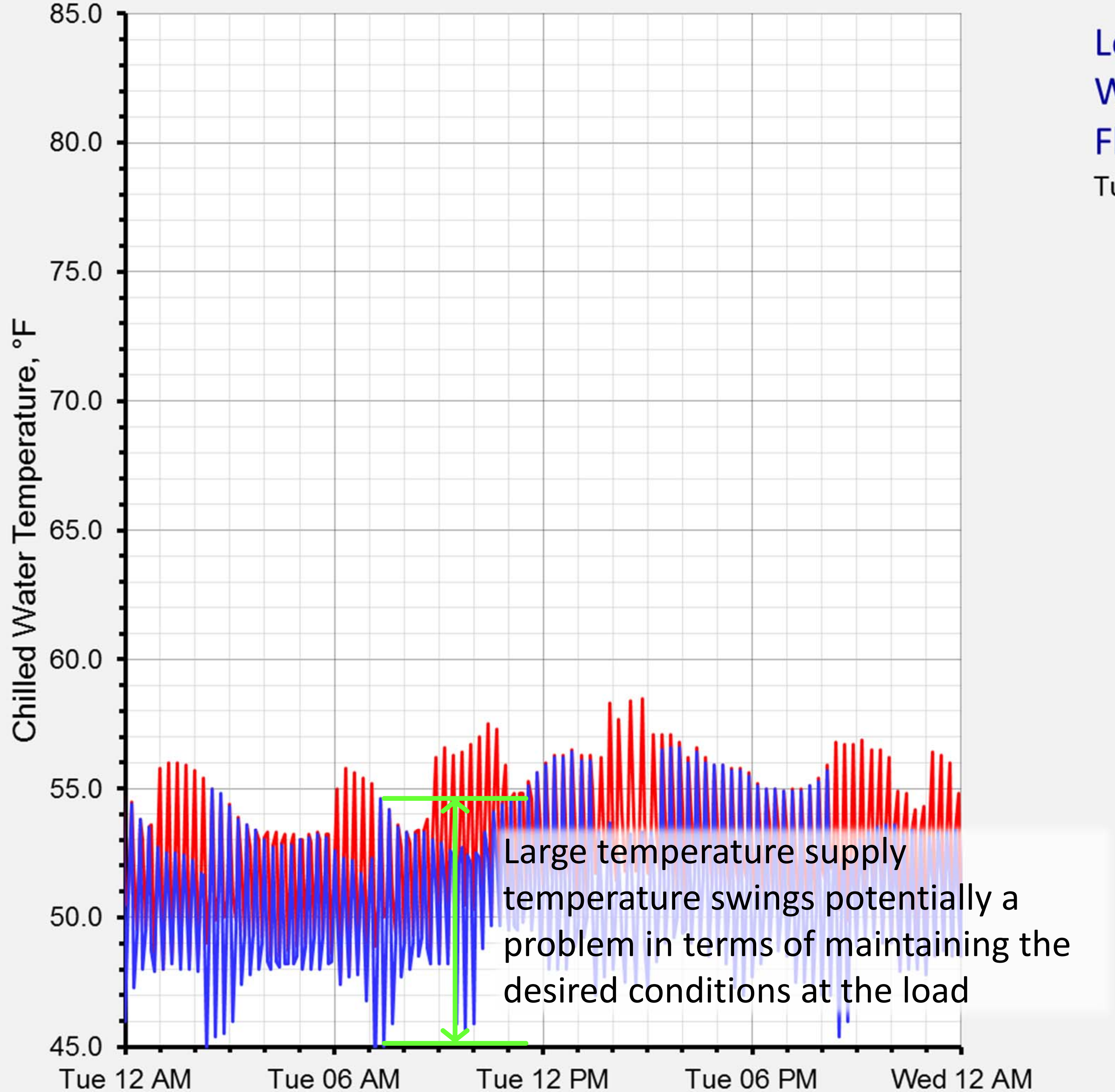
- 2 – 50 ton compressors
- Compressors can unload to 25% of capacity
- Compressors equipped with hot gas bypass
- Relatively short piping circuit



Small Load + Large (Relatively) Chiller = Potential Problem

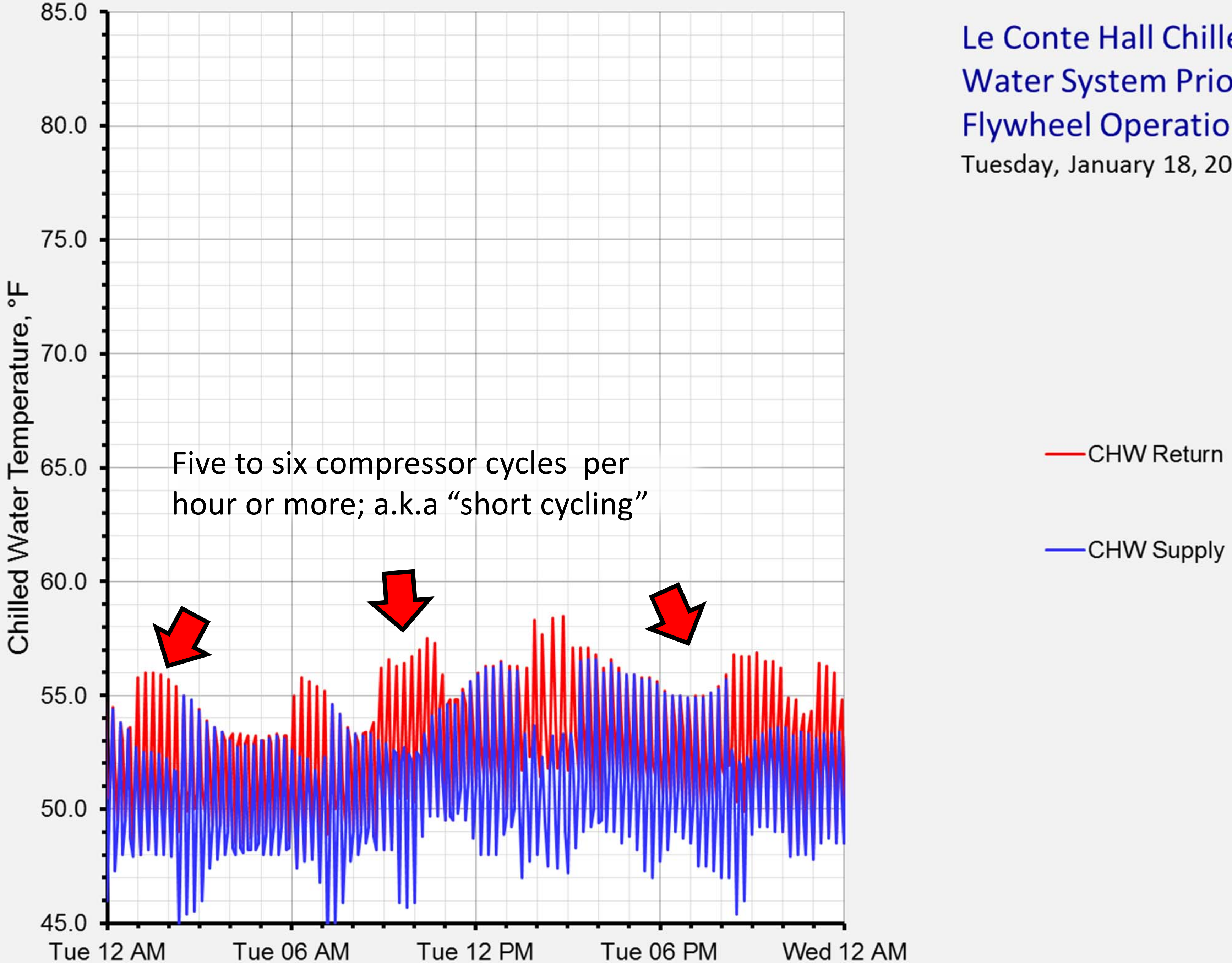


Visit www.Av8rdas.wordpress.com for a larger copy of the system diagram; Link located on the right side of the home page under 03 – Materials from Classes and Presentations



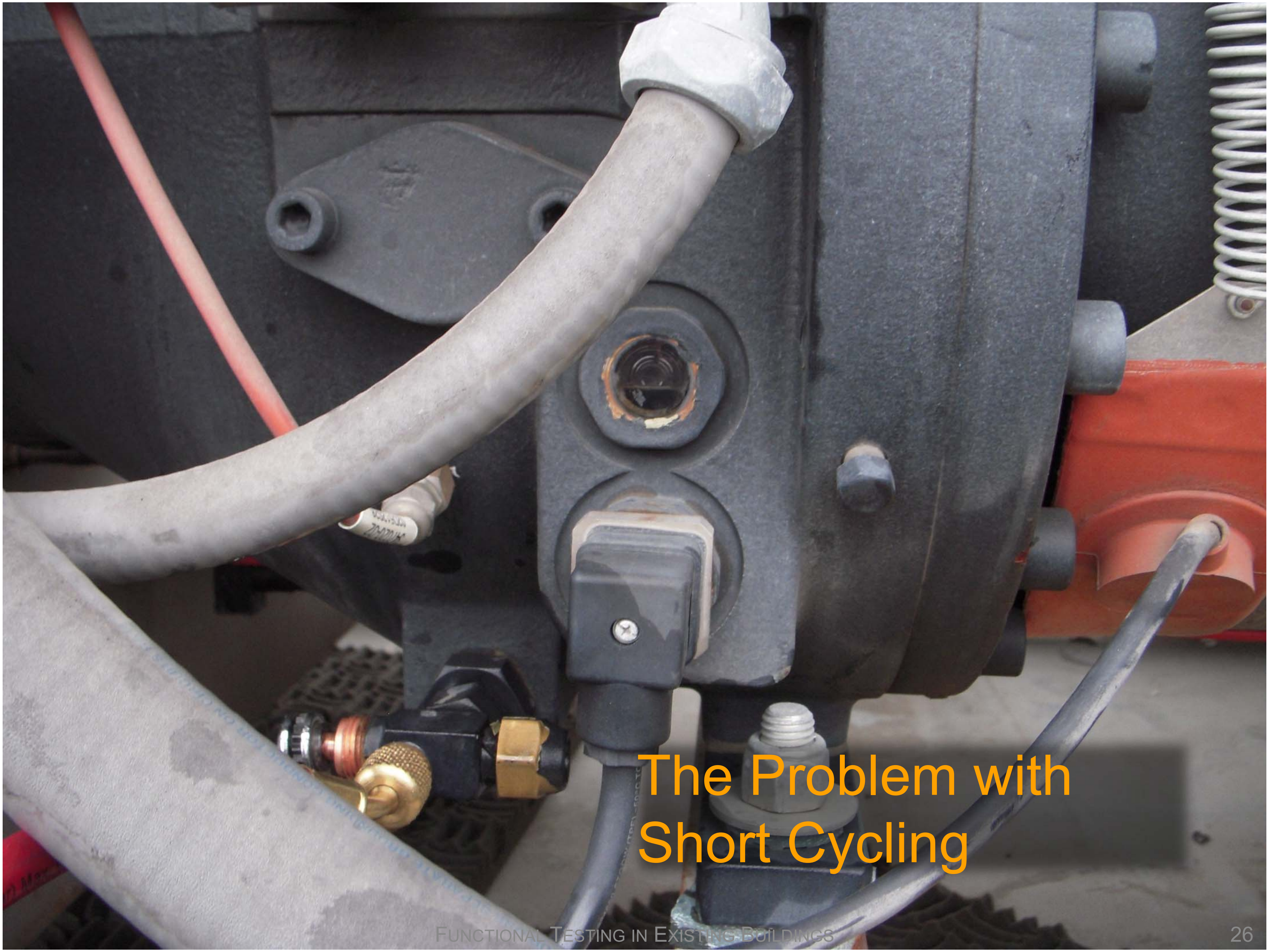
Le Conte Hall Chilled Water System Prior to Flywheel Operation

Tuesday, January 18, 2011



Le Conte Hall Chilled Water System Prior to Flywheel Operation

Tuesday, January 18, 2011



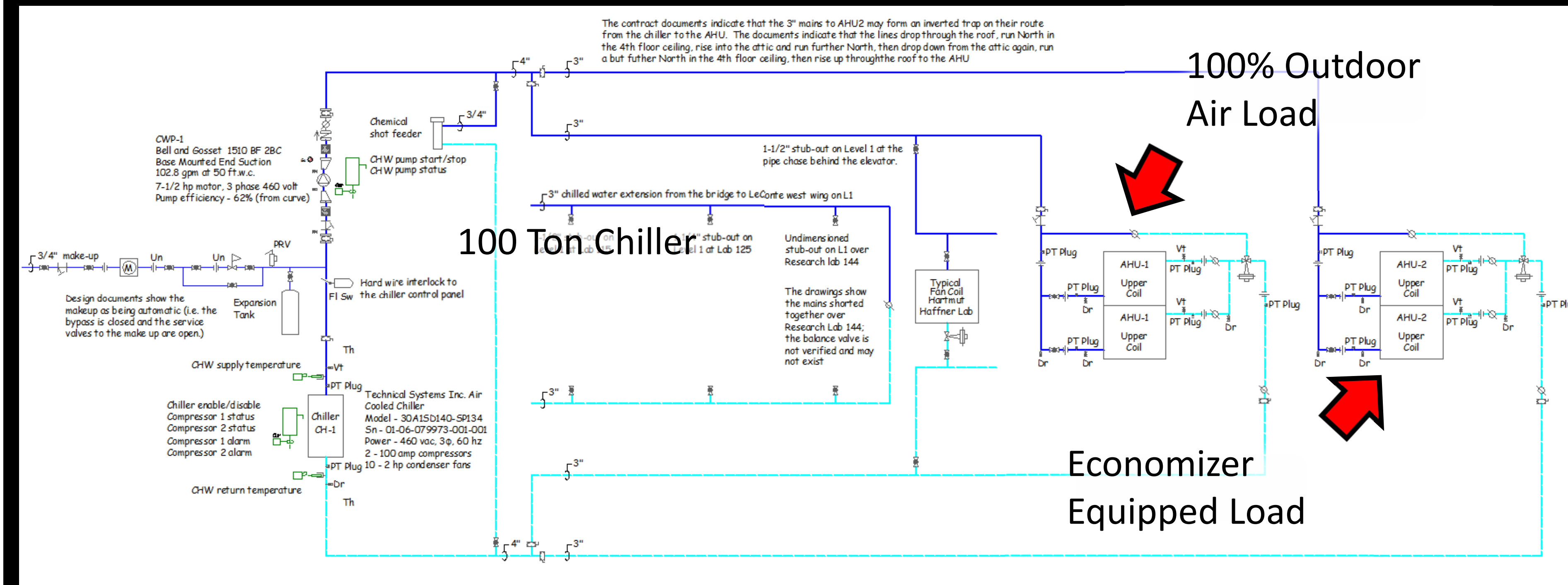
The Problem with Short Cycling

Unresolved short cycling cost impacts

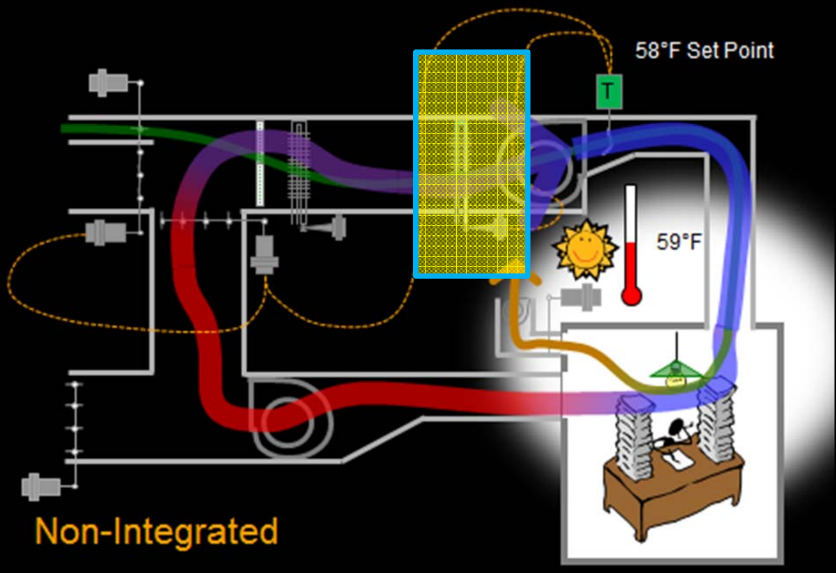
- Less than optimal temperature control
  - IEQ issues in hot and humid climates
  - Product quality issues
  - Ripple effects (other control processes become unstable
- Premature compressor or motor failure
  - Unscheduled outage
  - Unscheduled cost - $20,000 - $40,000 each for the 50 ton compressors on this project

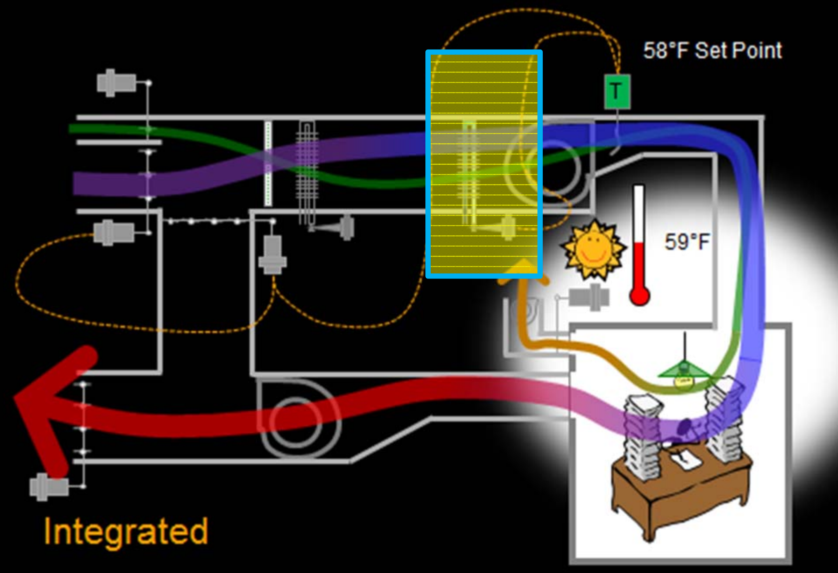
The Problem with Short Cycling

The Research Load is Not the Only Small Load



Non-integrated vs. Integrated

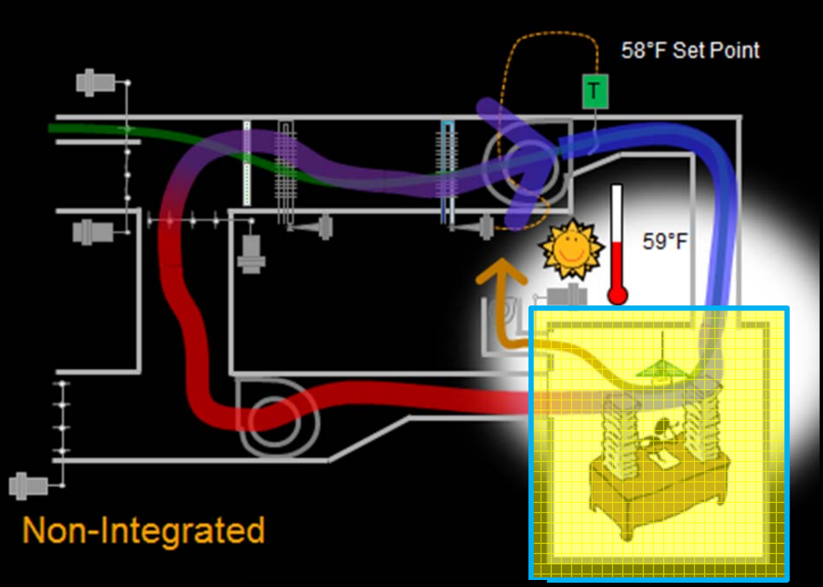


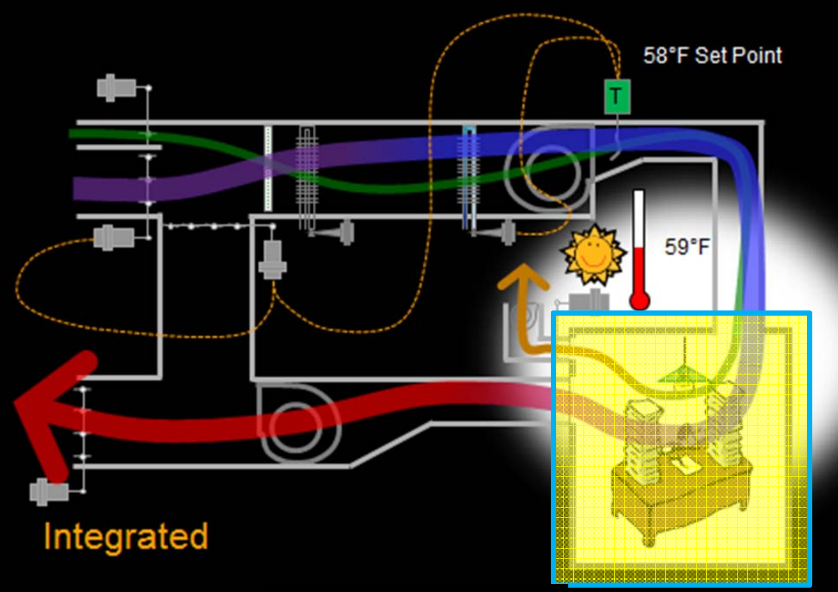


- Cooling coil load
- Q = 4.5 x cfm x Δh
- Q = 4.5 x 30,000 x (25.4 – 22.8)
- Q = 351,0000 Btu/hr
- Q = 29.3 tons

- Cooling coil load
- Q = 4.5 x cfm x Δh
- Q = 4.5 x 30,000 x (22.8 – 22.6)
- Q = 27,0000 Btu/hr
- Q = 2.3 tons

Non-integrated vs. Integrated

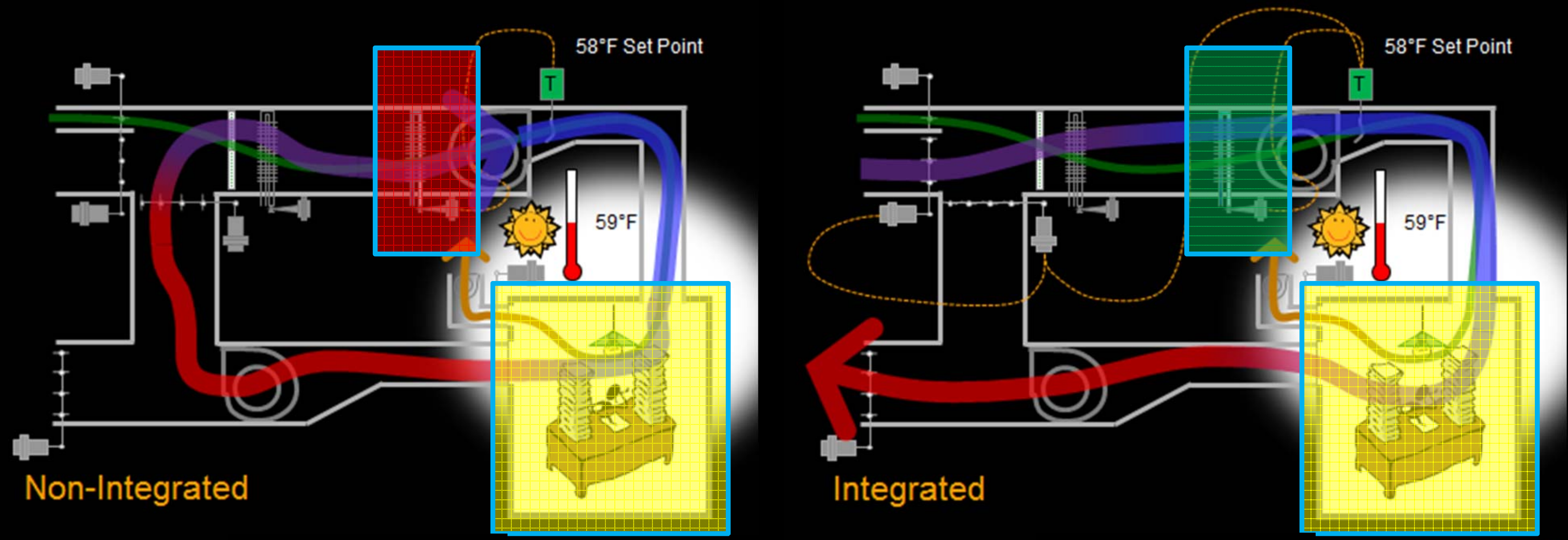




- Space Conditions
- Space temperature = 72°F
- Space RH = 50%
- Space enthalpy = 26.4 Btu/lb

- Space Load (average cooling coil leaving conditions)
- Q = 4.5 x cfm x Δh
- Q = 4.5 x 30,000 x (26.4–22.7)
- Q = 499,500 Btu/hr
- Q = 41.6 tons

Non-integrated vs. Integrated



LOADS

Space	Coil – Non-Integrated Economizer	Coil – Integrated Economizer
41.6 tons	29.3 tons	2.3 tons

Dealing with Short Cycling

- Infinite Capacity Modulation
  - No refrigeration compressor can modulate over an infinite range on its own
    - Technology dependent (reciprocating vs. centrifugal vs. scroll vs. screw vs. absorption)
    - System dependent
      - Size of the piping network
      - Relative sizes of the prime movers
- False load
  - Serve a recirculating constant volume reheat load
  - Hot gas bypass

Dealing with Short Cycling

- Infinite Capacity Modulation
  - No refrigeration compressor can modulate over an infinite range on its own
    - Technology dependent (reciprocating vs. centrifugal vs. scroll vs. screw vs. absorption)
    - System dependent
      - Size of the piping network
      - Relative sizes of the prime movers

- False load
  - Serve a recirculating constant volume reheat load
  - Hot gas bypass

Dealing with Short Cycling

- Infinite Capacity Modulation
  - No refrigeration compressor can modulate over an infinite range on its own
    - Technology dependent (reciprocating vs. centrifugal vs. scroll vs. screw vs. absorption)
    - System dependent
      - Size of the piping network
      - Relative sizes of the prime movers
- False load
  - Serve a recirculating constant volume reheat load
  - Hot gas bypass
- Lengthen the compressor run cycles and off cycles
  - Anti-recycle timer
  - Thermal flywheels

Dealing with Short Cycling

- Infinite Capacity Modulation

Not Possible for the Le Conte Hall System

- False load

Energy Intensive

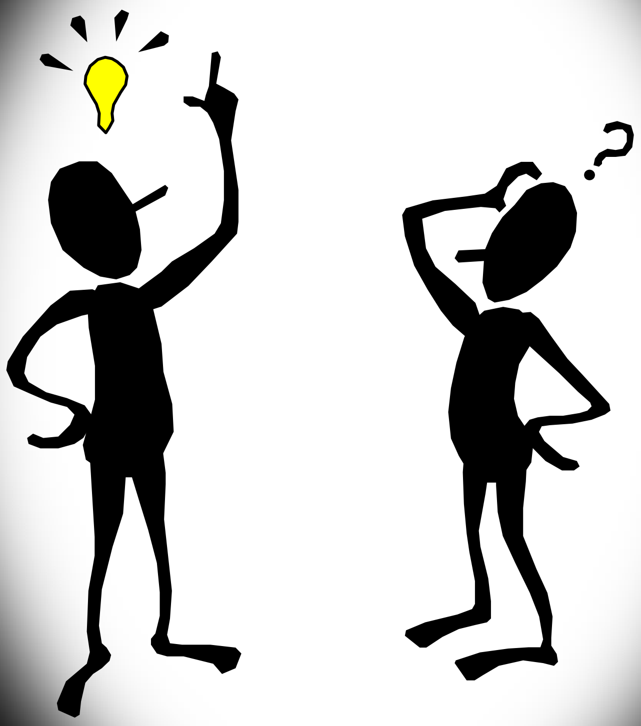
Hot gas bypass

- Lengthen the compressor run

Saves $3,830 per Year

Here's a Question

How much of a thermal flywheel does the existing piping system represent?



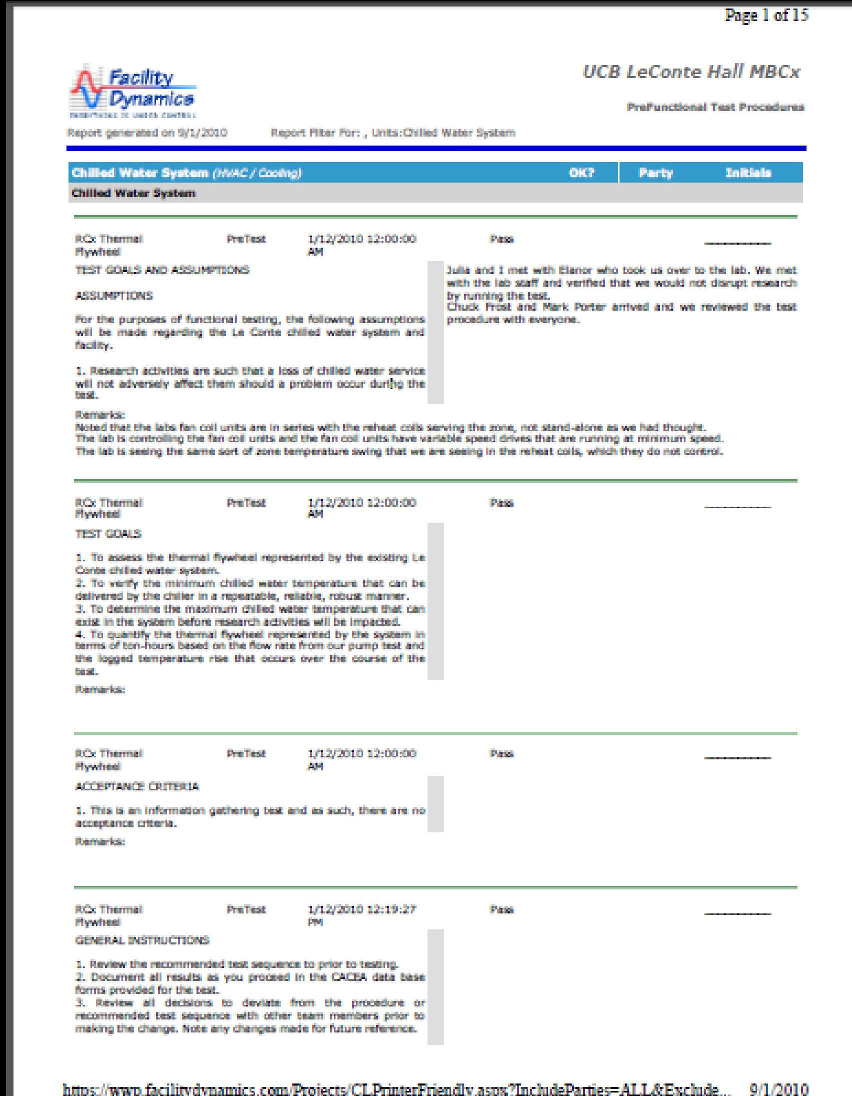
Who Knows the Answer?

… the Building Knows

How Do We Ask The Building About It?

- We perform a functional test
- Functional test components
  - Statement of purpose
  - Instructions for using the test form
  - Equipment requirements
  - Acceptance criteria
  - Precautions
  - Documentation
  - Procedure
  - Return to Normal and Follow-up

Visit www.Av8rdas.wordpress.com for a copy of the test; Link located on the right side of the home page under 03 – Materials from Classes and Presentations


Page 1 of 15

Facility Dynamics

UCB LeConte Hall MBCx

PreFunctional Test Procedures

Report generated on 9/1/2010   Report Filter For: , Units:Chilled Water System

Chilled Water System *(HVAC / Cooling)*	OK?	Party	Initials
Chilled Water System			

RCx Thermal Flywheel | PreTest | 1/12/2010 12:00:00 AM | Pass | ________

TEST GOALS AND ASSUMPTIONS

ASSUMPTIONS

For the purposes of functional testing, the following assumptions will be made regarding the Le Conte chilled water system and facility.

1. Research activities are such that a loss of chilled water service will not adversely affect them should a problem occur during the test.

Julia and I met with Elanor who took us over to the lab. We met with the lab staff and verified that we would not disrupt research by running the test.
Chuck Frost and Mark Porter arrived and we reviewed the test procedure with everyone.

Remarks:
Noted that the labs fan coil units are in series with the reheat coils serving the zone, not stand-alone as we had thought.
The lab is controlling the fan coil units and the fan coil units have variable speed drives that are running at minimum speed.
The lab is seeing the same sort of zone temperature swing that we are seeing in the reheat coils, which they do not control.

RCx Thermal Flywheel | PreTest | 1/12/2010 12:00:00 AM | Pass | ________

TEST GOALS

1. To assess the thermal flywheel represented by the existing Le Conte chilled water system.
2. To verify the minimum chilled water temperature that can be delivered by the chiller in a repeatable, reliable, robust manner.
3. To determine the maximum chilled water temperature that can exist in the system before research activities will be impacted.
4. To quantify the thermal flywheel represented by the system in terms of ton-hours based on the flow rate from our pump test and the logged temperature rise that occurs over the course of the test.

Remarks:

RCx Thermal Flywheel | PreTest | 1/12/2010 12:00:00 AM | Pass | ________

ACCEPTANCE CRITERIA

1. This is an information gathering test and as such, there are no acceptance criteria.

Remarks:

RCx Thermal Flywheel | PreTest | 1/12/2010 12:19:27 PM | Pass | ________

GENERAL INSTRUCTIONS

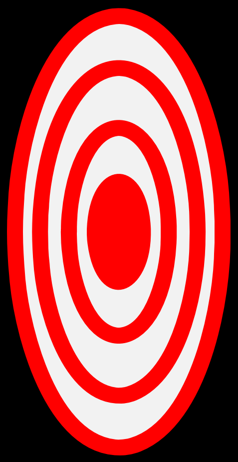
1. Review the recommended test sequence to prior to testing.
2. Document all results as you proceed in the CACEA data base forms provided for the test.
3. Review all decisions to deviate from the procedure or recommended test sequence with other team members prior to making the change. Note any changes made for future reference.

https://wwp.facilitydynamics.com/Projects/CLPrinterFriendly.aspx?IncludeParties=ALL&Exclude... 9/1/2010

Start With A Statement of Purpose

General Guidelines

- Target the effort
- Goal of the test
- Underlying assumptions
- Desired outcome
  - Tie to acceptance criteria



Our Statement of Purpose

- Assess the thermal flywheel represented by the existing piping system
  - Determine the minimum and maximum chilled water temperatures that can be tolerated
  - Quantify the thermal flywheel in terms of ton-hours

Test Form Instructions

General Guidelines

- How should results be documented?
  - Pass
  - Fail
  - Intermediate information
  - Comments
- Date and time stamps
- Initials

Be clear; words have different meanings to different people

Test Form Instructions

General Guidelines

- How should results be documented?
  - Pass
  - Fail
  - Intermediate information
  - Comments
- Date and time stamps
- Initials

Our Instructions

- Review the procedure prior to testing
- Document the results in the CACEA commissioning tool
- Review decisions to deviate from the plan with the team and note changes
- If the test is suspended prior to completion, run through the return to normal procedure

Required Equipment

General Guidelines

- Standard tool set
- Special tools
  - Unusual measurement requirement
  - Critical accuracy requirement
  - Expediency

"I have an appointment to demonstrate our new line of ear protectors."

Required Equipment

General Guidelines

- Standard tool set
- Special tools
  - Unusual measurement requirement
  - Critical accuracy requirement
  - Expediency

Our Equipment

- Standard tool set

Acceptance Criteria

General Guidelines

- Tied directly to the test's stated goals
  - Measured parameters
  - Documented conditions
- Clear and unambiguous terms
- Special documentation requirements
  - Picture
  - Witness signature
  - Control system report
  - Trend data

Acceptance Criteria

General Guidelines

- Tied directly to the test's stated goals
  - Measured parameters
  - Documented conditions
- Clear and unambiguous terms
- Special documentation requirements
  - Picture
  - Witness signature
  - Control system report
  - Trend data

Our Acceptance Criteria

- Information only test; There are no acceptance criteria
  - Acceptance criteria are less common for EBCx testing
  - A similar test in a new construction process may have acceptance criteria

Precautions

General Guidelines

- Safety concerns
  - Protection
  - Comfort level
- Risk management
  - Operational risks
    - Cost vs. benefit
    - Likelihood of the problem
  - Equipment damage
  - Temporary over-rides

Precautions

General Guidelines

- Safety concerns
  - Protection
  - Comfort level
- Risk management
  - Operational risks
    - Cost vs. benefit
    - Likelihood of the problem
  - Equipment damage
  - Temporary over-rides

Our Precautions

- Be careful working around rotating machinery
- Remember that there are other things connected to the system, directly and indirectly when manipulating system parameters
- Exercise caution when driving chilled water temperatures to lower than normal ranges

Documentation

General Guidelines

- What do you need to support the test?
  - Submittals
  - Performance data
  - System diagrams
  - Calibration data
  - Factory start-up data
- What do you need to capture before starting?
  - Nameplate data
  - As found conditions

Our Documentation

- Supporting information
  - Located on the project web portal
  - System diagram
  - Mechanical drawings
  - Control sequences
  - Control shop drawings
  - O&M information and equipment submittal data
- Capture before starting
  - Current set points
  - Lab operating criteria

Prerequisites

General Guidelines

- Conditions necessary to test
  - Weather
  - Operating mode
- System readiness
- People required for testing
  - Owner
  - Contractor/Technicians
  - Code official
  - Factory representative
- Some items may tie back to precautions

Our Prerequisites

- Low load condition required
- Research and other building functions can tolerate loss of chilled water
- Verify staff buy-in/available:
  - Lab
  - Building/campus management
  - Physical plant

Preparation

General Guidelines

- Team members in position
  - Rehearsal
- Monitoring equipment
  - In position
  - Activated
  - Calibrated
- Coordinated with building functions
- As found conditions documented

Preparation

General Guidelines

- Team members in position
  - Rehearsal
- Monitoring equipment
  - In position
  - Activated
  - Calibrated
- Coordinated with building functions
- As found conditions documented

Our Preparation

- Verify system flow rate has been documented via pump test
- Verify logging is working for critical parameters

The Procedure

General Guidelines

- Thinking it through ahead of time is important
- Be clear

Requirement	Data	Completed
20. Perform a shut off test to verify the pump size		

Requirement	Data Include units	Completed Initials, Date and Time
20. Perform a shut off test to verify the pump size by briefly closing the discharge valve and and documenting the pump differential pressures. Proceed as follows:		
Document discharge valve position		
Start the second pump to prevent a chiller safety shut down due to loss of flow.		
Briefly close the discharge valve and		
document:		
Pump suction pressure		
Pump discharge pressure		
Return discharge valve to original position.		

The Procedure

General Guidelines

- Thinking it through ahead of time is important
- Be clear
- Include cross-references
  - Multiple indications of results
  - Take more data than you need

Our Procedure

- Run the supply water temperature as far down as possible with out nuisance safety trips
- Monitor the zone temperatures
  - When researchers indicate they are concerned:
    - Document the cycle time
    - Document the chilled water temperature
- Run the chilled water temperature back down and document the run cycle time

Visit www.Av8rdas.wordpress.com for a copy of the test; Link located on the right side of the home page under 03 – Materials from Classes and Presentations

Return To Normal and Follow up

General Guidelines

- Don't take off for home as soon as you've finished the test!
  - Release manual over-rides
  - Return set points to normal
  - Wait to make sure things are working properly!

Return To Normal and Follow up

General Guidelines

- Don’t take off for home as soon as you’ve finished the test!
  - Release manual over-rides
  - Return set points to normal
  - Wait to make sure things are working properly!
- Did all go as planned?
  - Does the data make sense?
  - Is it telling you something that requires immediate action?
  - Are your documentation needs covered?
- Issue preliminary reports

Return To Normal and Follow up

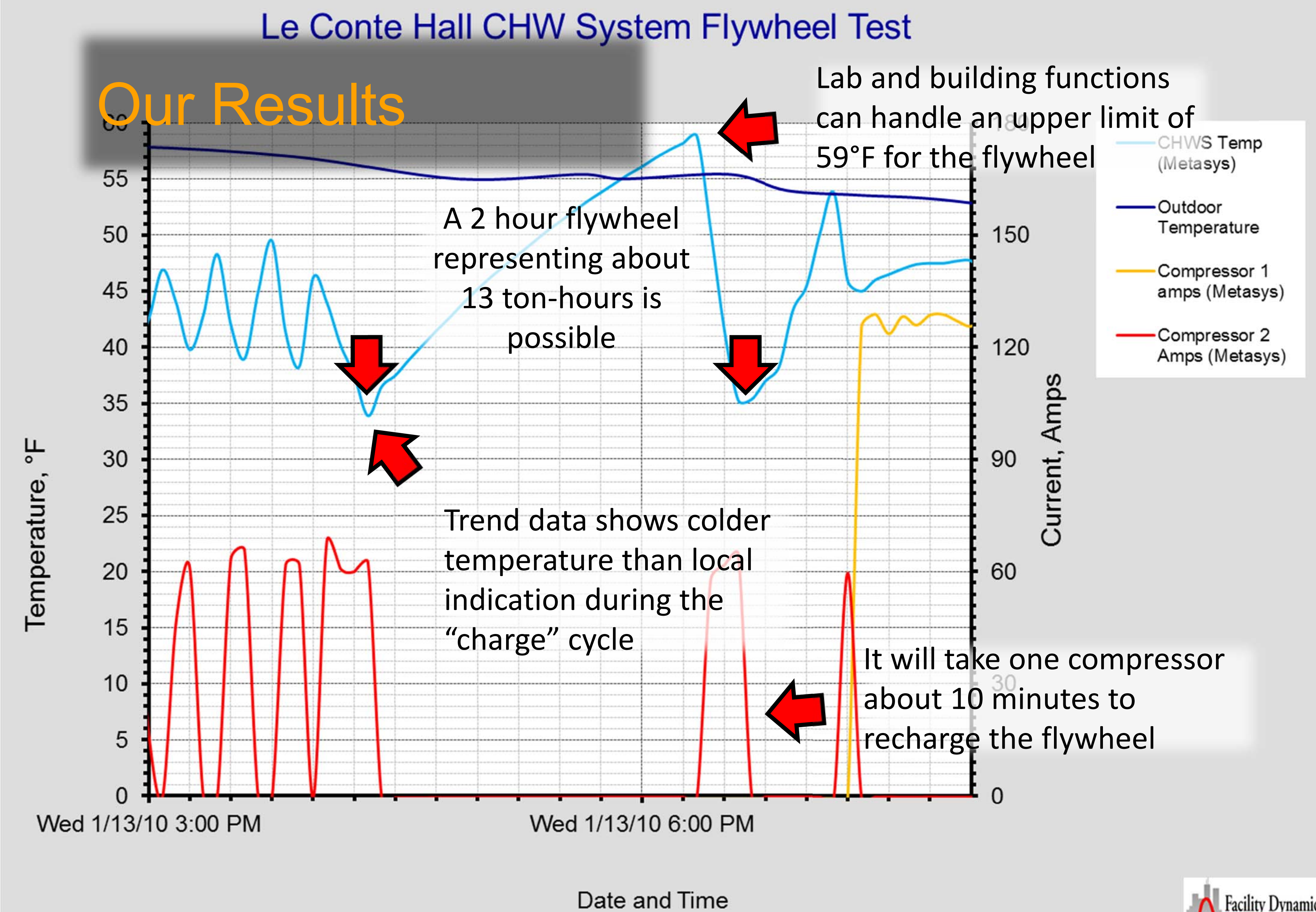
General Guidelines

- Don't take off for home as soon as you've finished the test!
  - Release manual over-rides
  - Return set points to normal
  - Wait to make sure things are working properly!
- Did all go as planned?
  - Does the data make sense?
  - Is it telling you something that requires immediate action?
  - Are your documentation needs covered?
- Issue preliminary reports

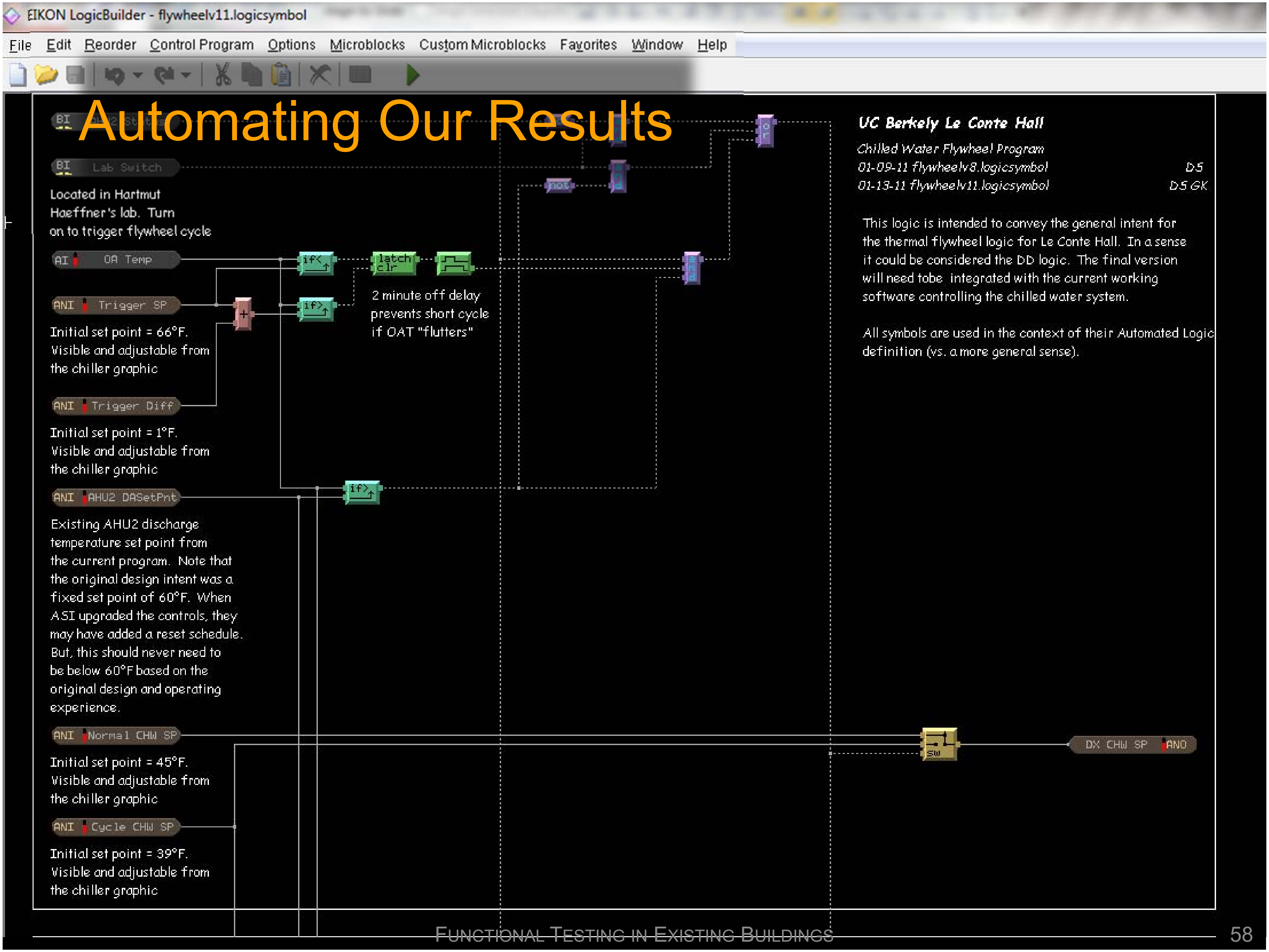
Our Return to Normal

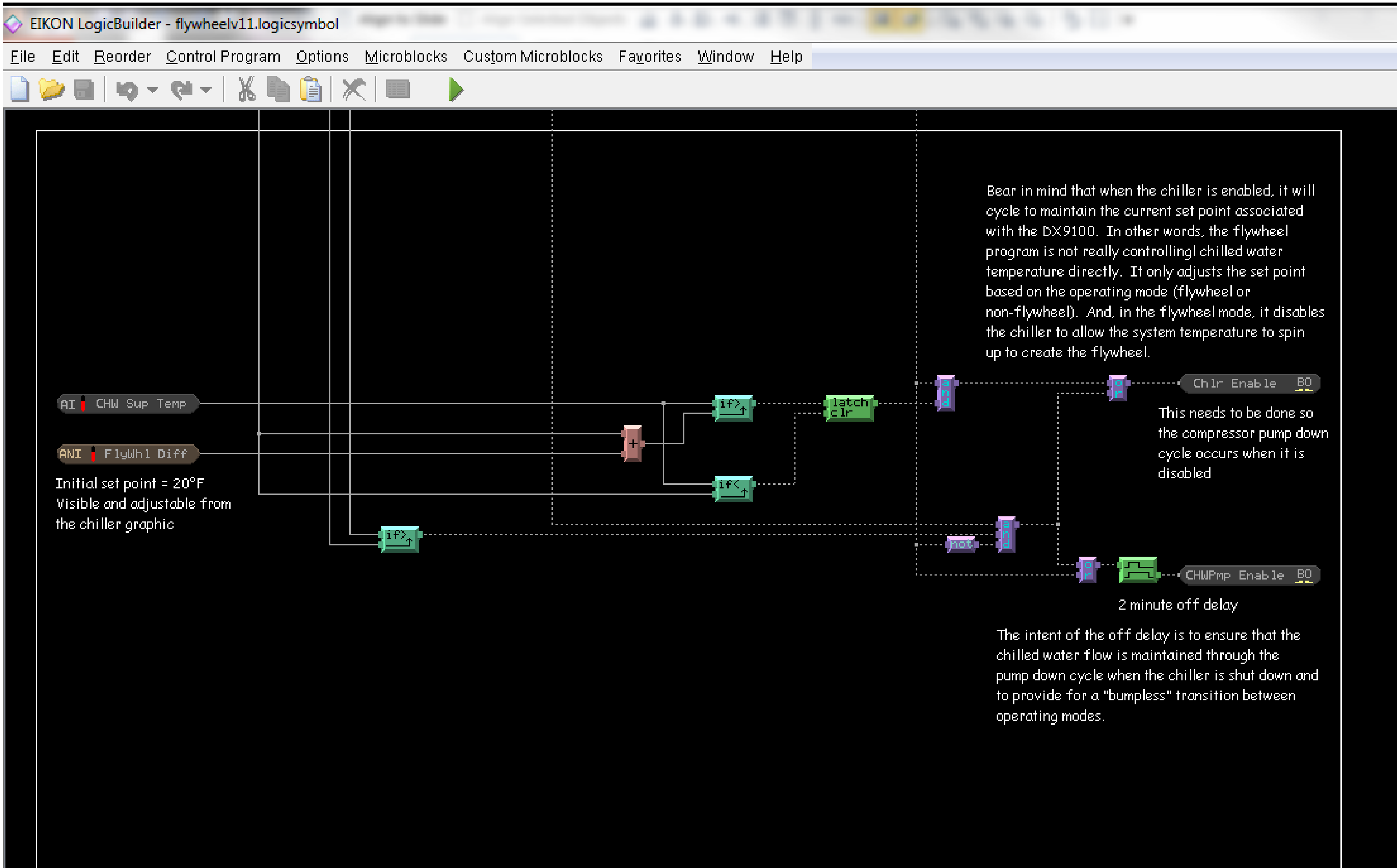
- Release any manual over rides and return set points to normal settings
- Retrieve and save trend data
- Document the results on the web portal
- Notify contractors and UCB of any issues that were discovered

Our Results

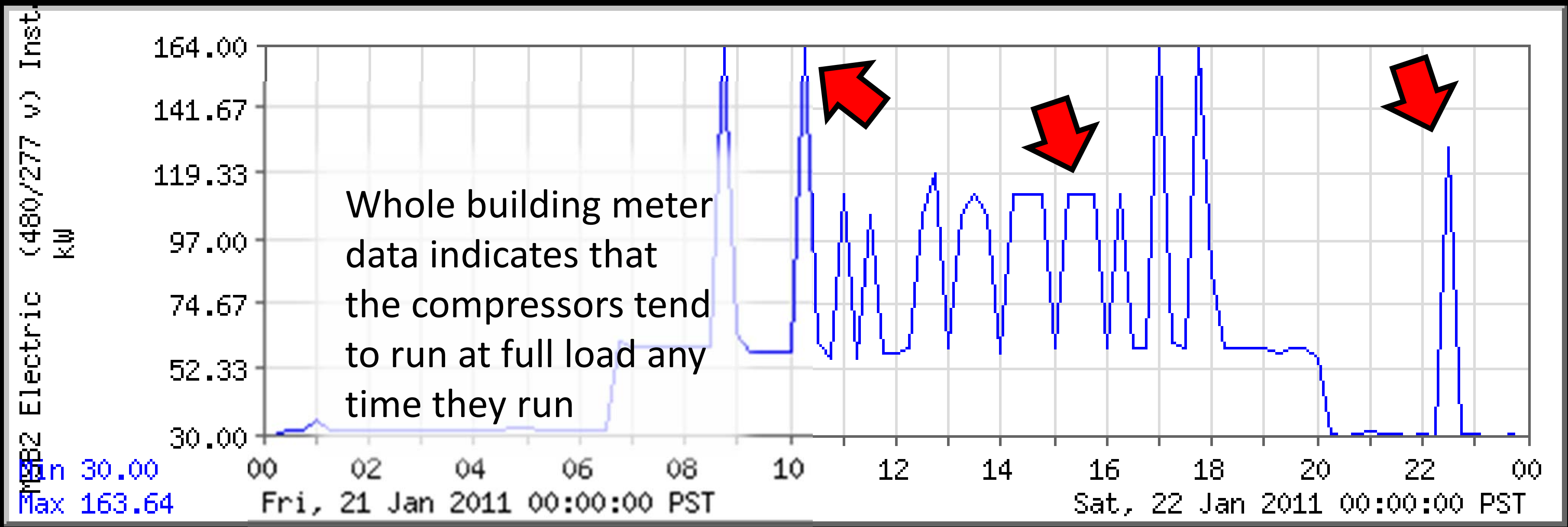

Le Conte Hall CHW System Flywheel Test
Lab and building functions can handle an upper limit of 59°F for the flywheel
A 2 hour flywheel representing about 13 ton-hours is possible
Trend data shows colder temperature than local indication during the "charge" cycle
It will take one compressor about 10 minutes to recharge the flywheel
CHWS Temp (Metasys)
Outdoor Temperature
Compressor 1 amps (Metasys)
Compressor 2 Amps (Metasys)
Temperature, °F
Current, Amps
55
50
45
40
35
30
25
20
15
10
5
0
150
120
90
60
30
0
Wed 1/13/10 3:00 PM
Wed 1/13/10 6:00 PM
Date and Time

Automating Our Results



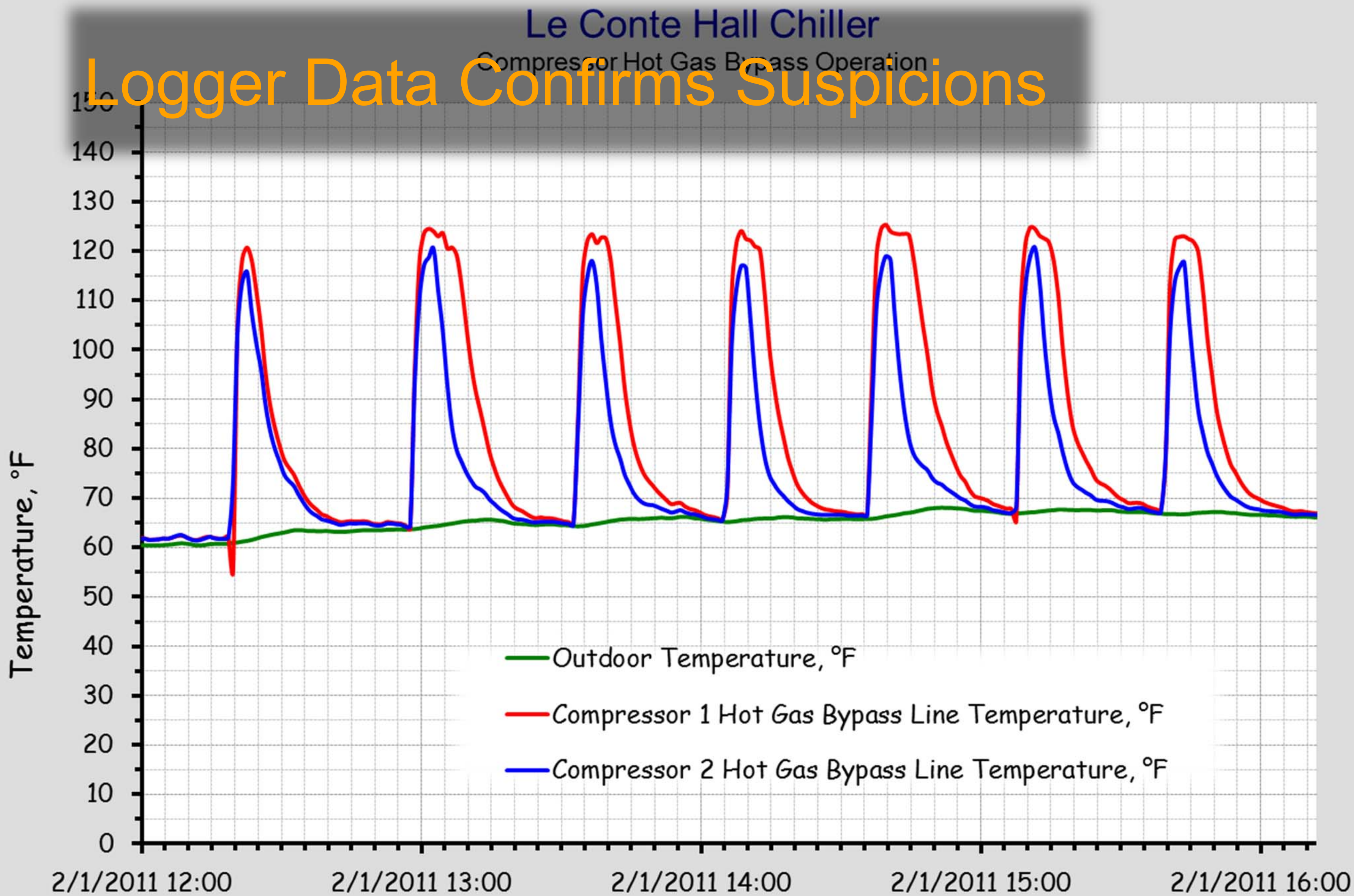


Opportunity 1 - Captured



Opportunity 2 - Identified

Logger Data Confirms Suspicions



Unnecessary Hot Gas = Unrealized Savings

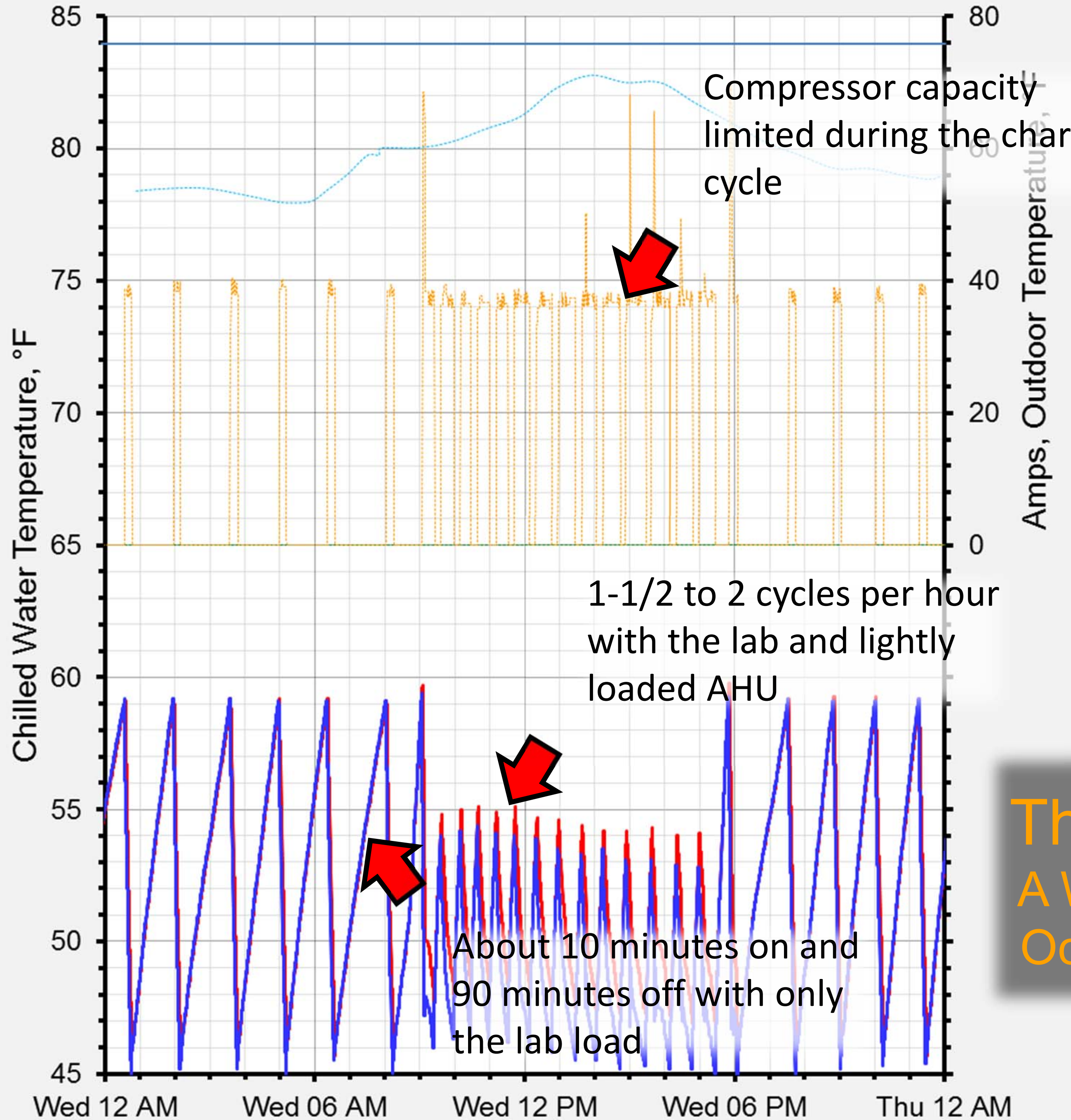
Good News

- Flywheel cycle captures 26,900 kWh/$2,690 of savings via the MBCx project
  - Testing performed as part of the general MBCx effort
  - Programming modified “on the fly”
- Additional savings potential justifies a factory service call
  - Perform routine checks and maintenance
  - Optimize set points
  - Optimize controls

Bad News

- 11,404 kWh/$1,140 of savings “left on the table

Visit www.Av8rdas.wordpress.com for the complete story

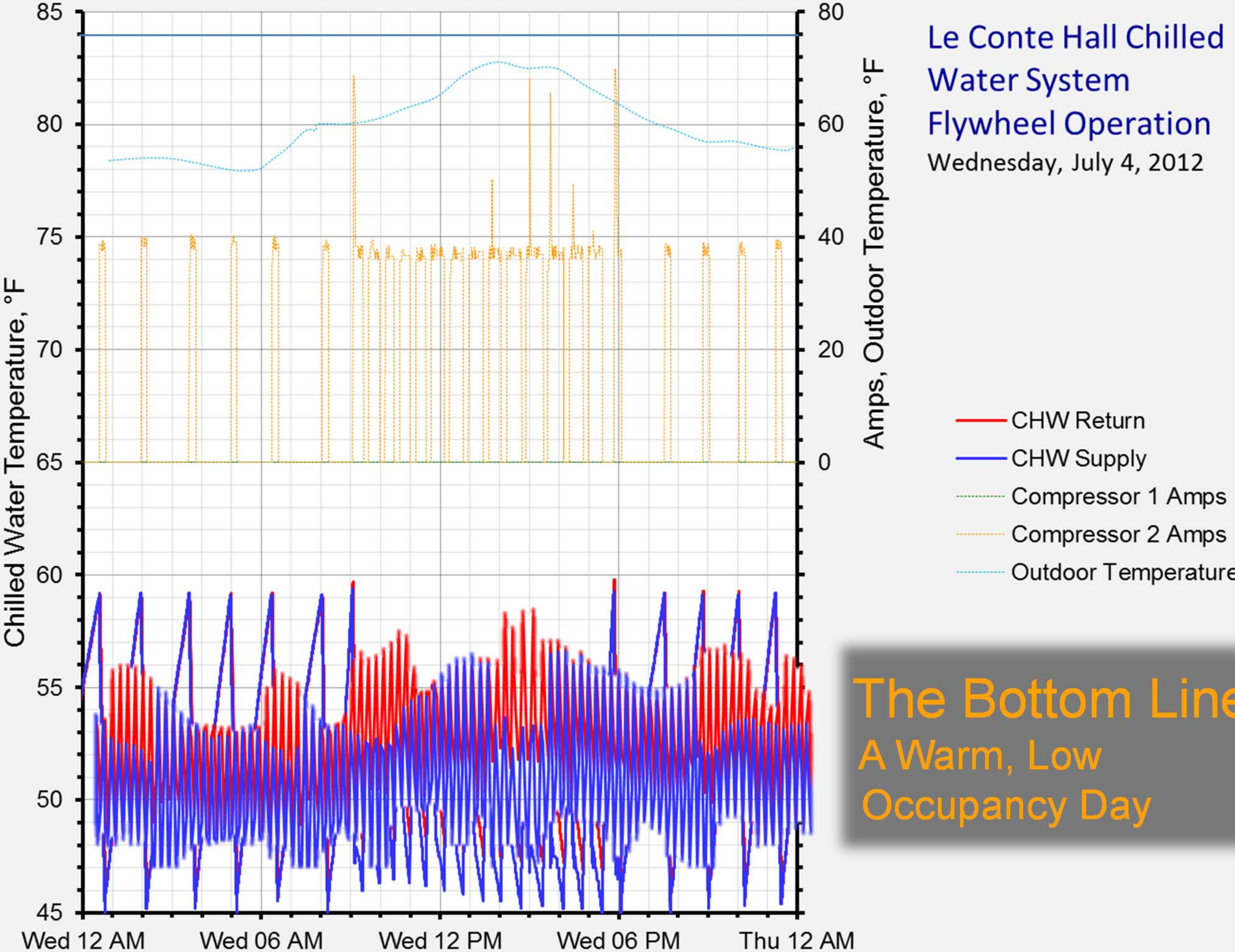


Le Conte Hall Chilled Water System Flywheel Operation

Wednesday, July 4, 2012

The Bottom Line

A Warm, Low Occupancy Day



Le Conte Hall Chilled Water System Flywheel Operation

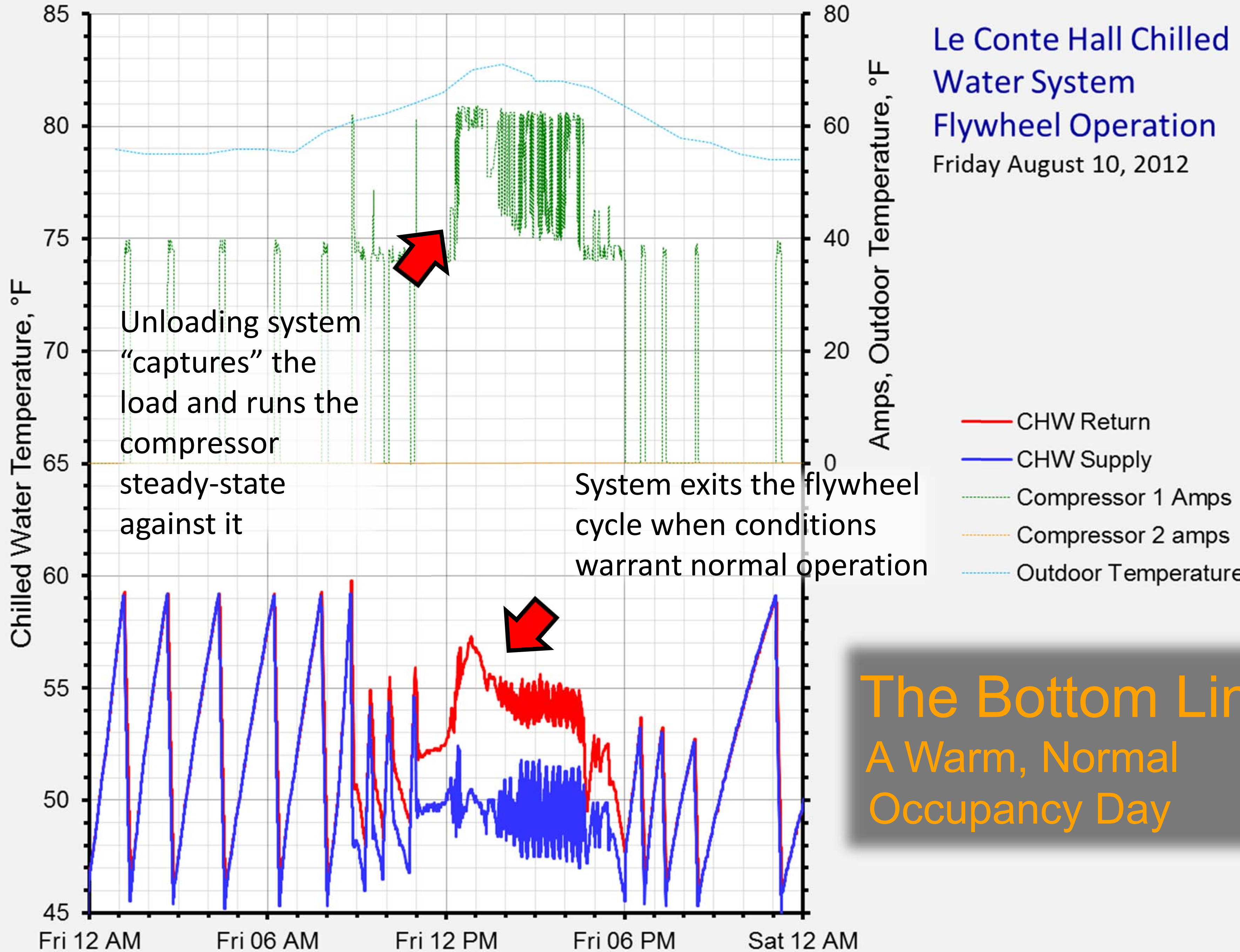
Wednesday, July 4, 2012

The Bottom Line

A Warm, Low Occupancy Day

Le Conte Hall Chilled Water System Flywheel Operation

Friday August 10, 2012

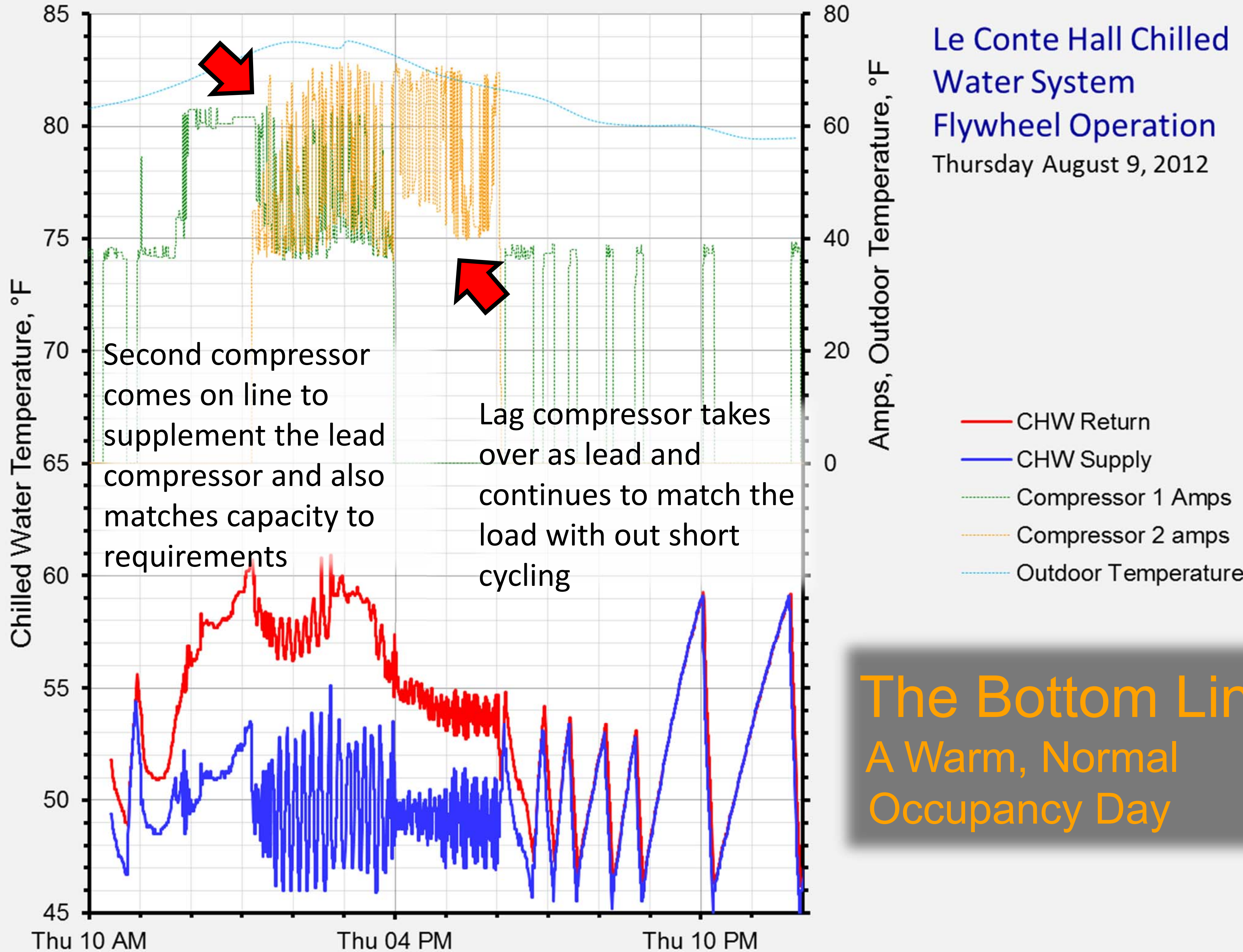


The Bottom Line

A Warm, Normal Occupancy Day

Le Conte Hall Chilled Water System Flywheel Operation

Thursday August 9, 2012

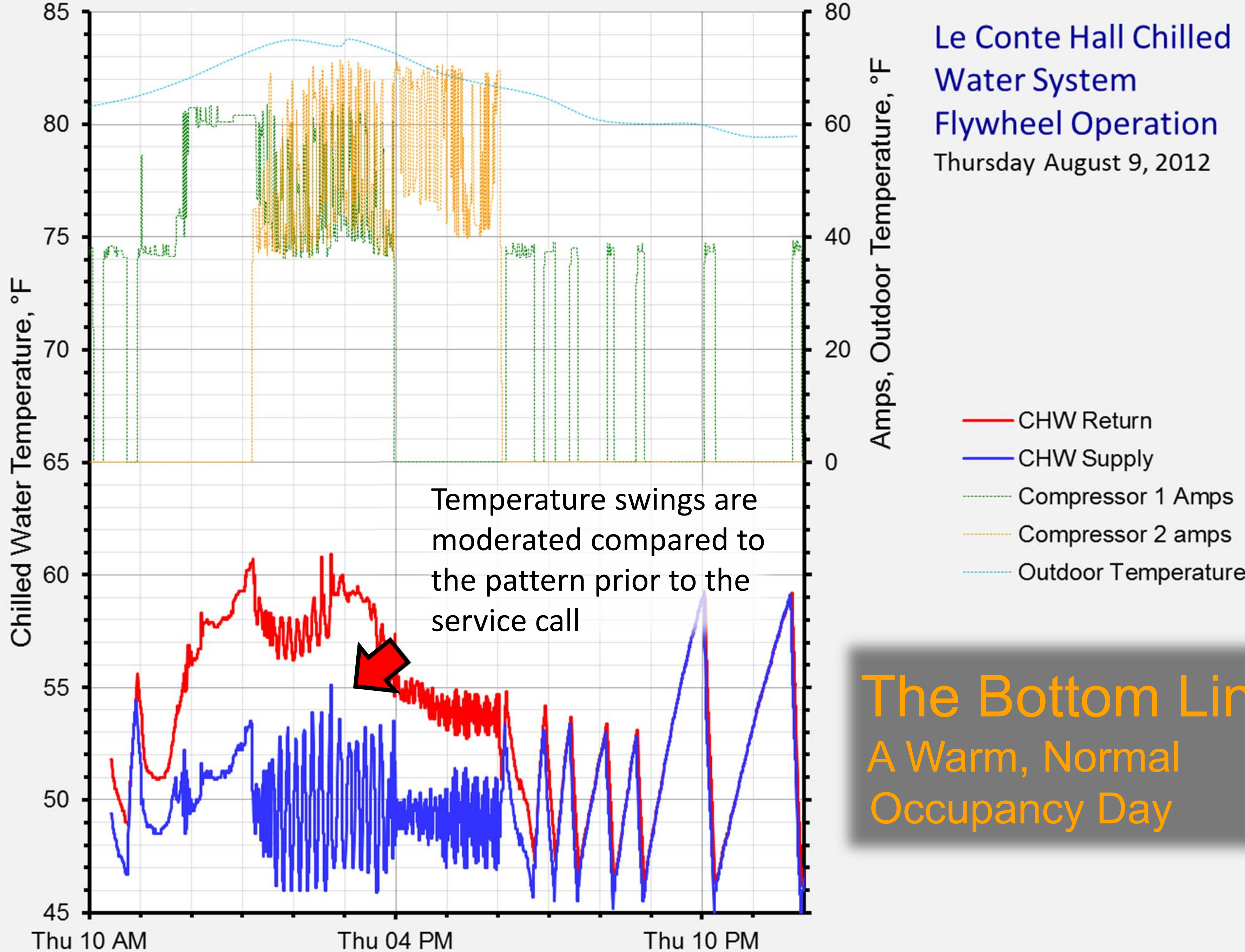


The Bottom Line

A Warm, Normal Occupancy Day

Le Conte Hall Chilled Water System Flywheel Operation

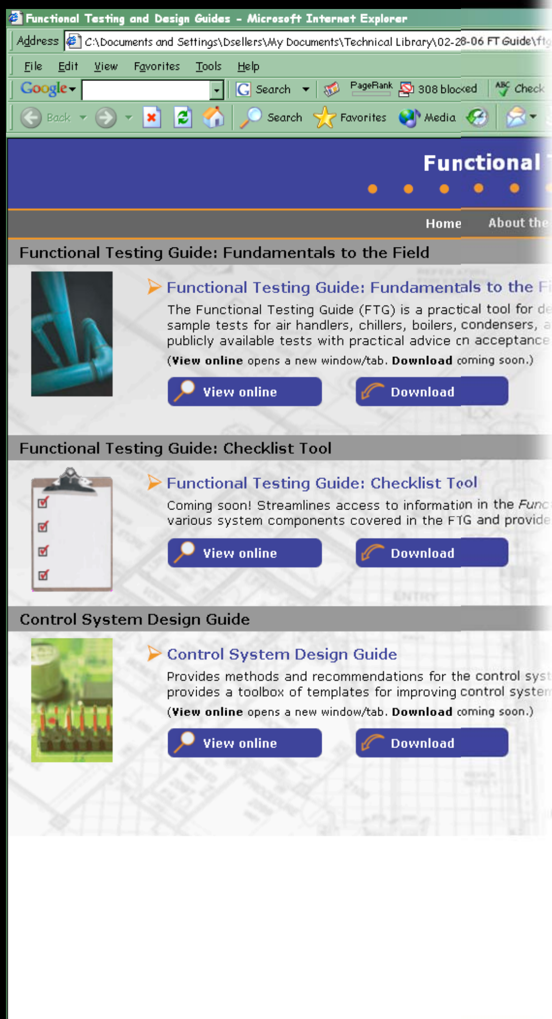
Thursday August 9, 2012

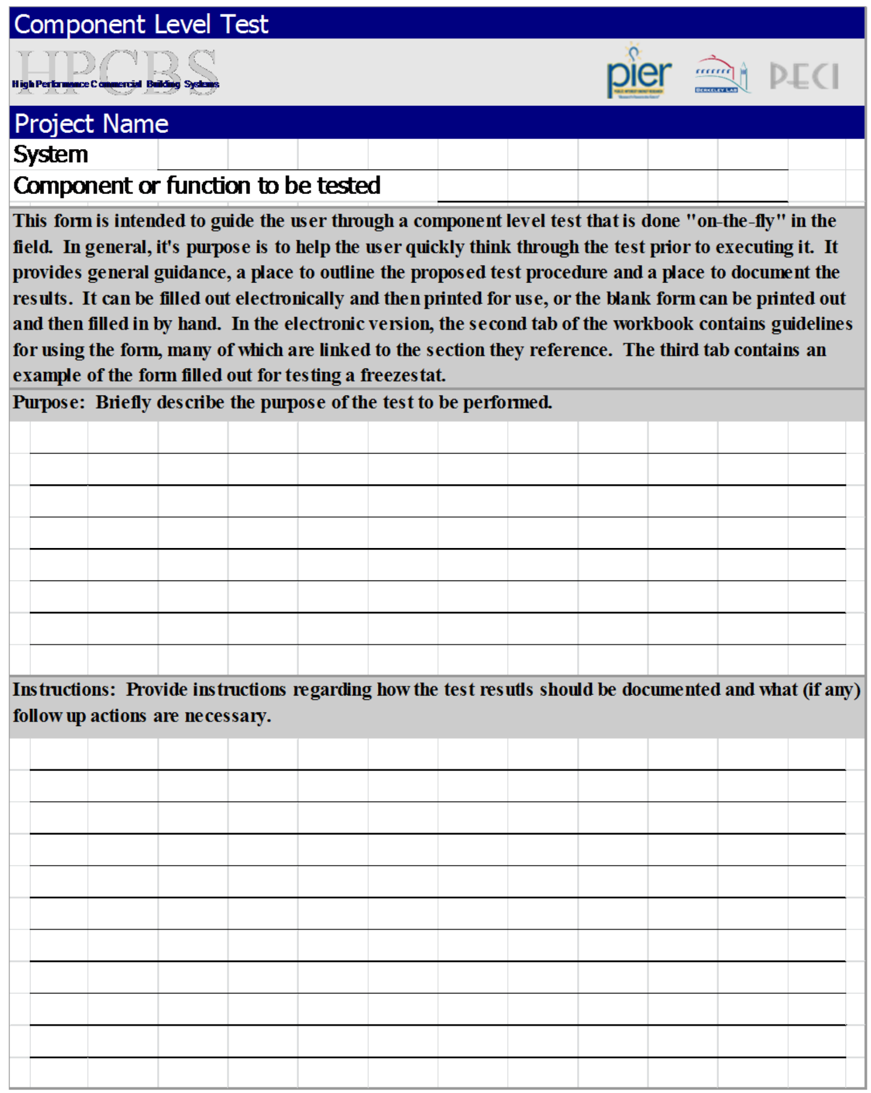


The Bottom Line

A Warm, Normal Occupancy Day

How Can the Functional Testing Guide Help?





Component Level Test

HPCBS High Performance Commercial Building Systems

pier PECI

Project Name

System

Component or function to be tested

This form is intended to guide the user through a component level test that is done "on-the-fly" in the field. In general, it's purpose is to help the user quickly think through the test prior to executing it. It provides general guidance, a place to outline the proposed test procedure and a place to document the results. It can be filled out electronically and then printed for use, or the blank form can be printed out and then filled in by hand. In the electronic version, the second tab of the workbook contains guidelines for using the form, many of which are linked to the section they reference. The third tab contains an example of the form filled out for testing a freezestat.

Purpose: Briefly describe the purpose of the test to be performed.

Instructions: Provide instructions regarding how the test resutls should be documented and what (if any) follow up actions are necessary.

THANK YOU

David Sellers, Senior Engineer

Facility Dynamics Engineering

NW Satellite Office

DSellers@Facility Dynamics.com

Office: (503) 286-1494

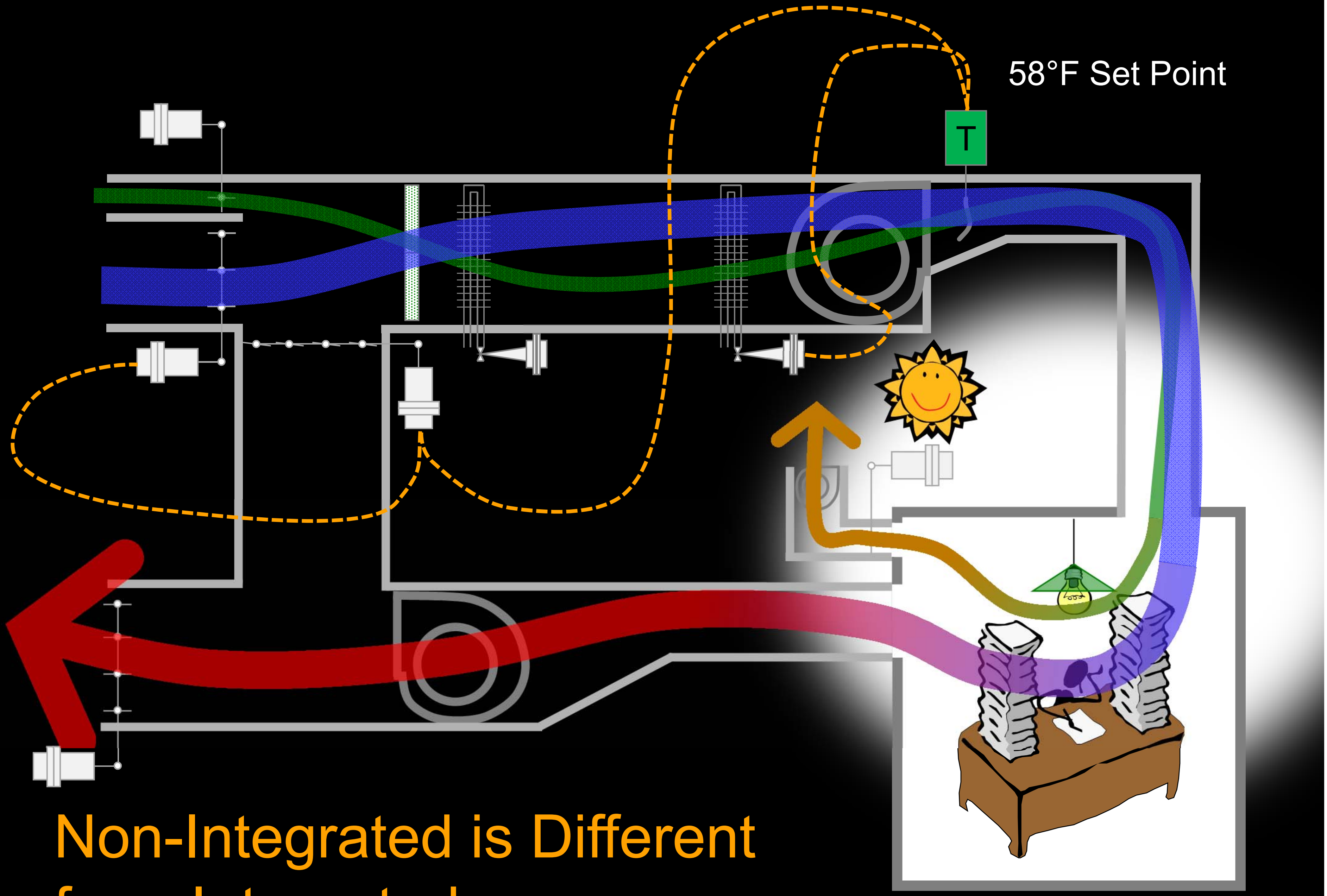
Cell: (503) 320-2630

www.FacilityDynamics.com

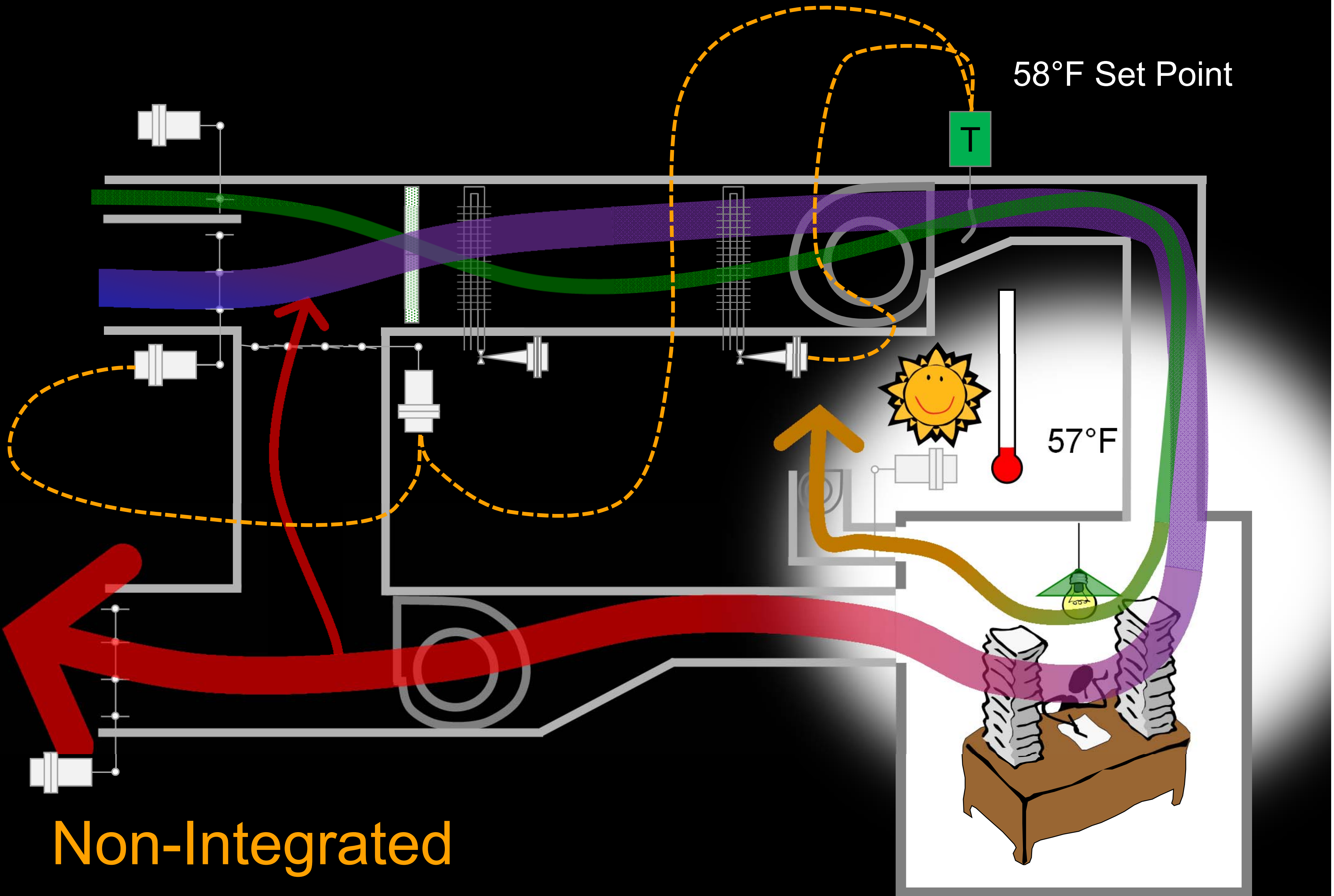
Technical blog on WordPress at Av8rdas.Wordpress.com

SUPPLEMENTAL INFORMATION

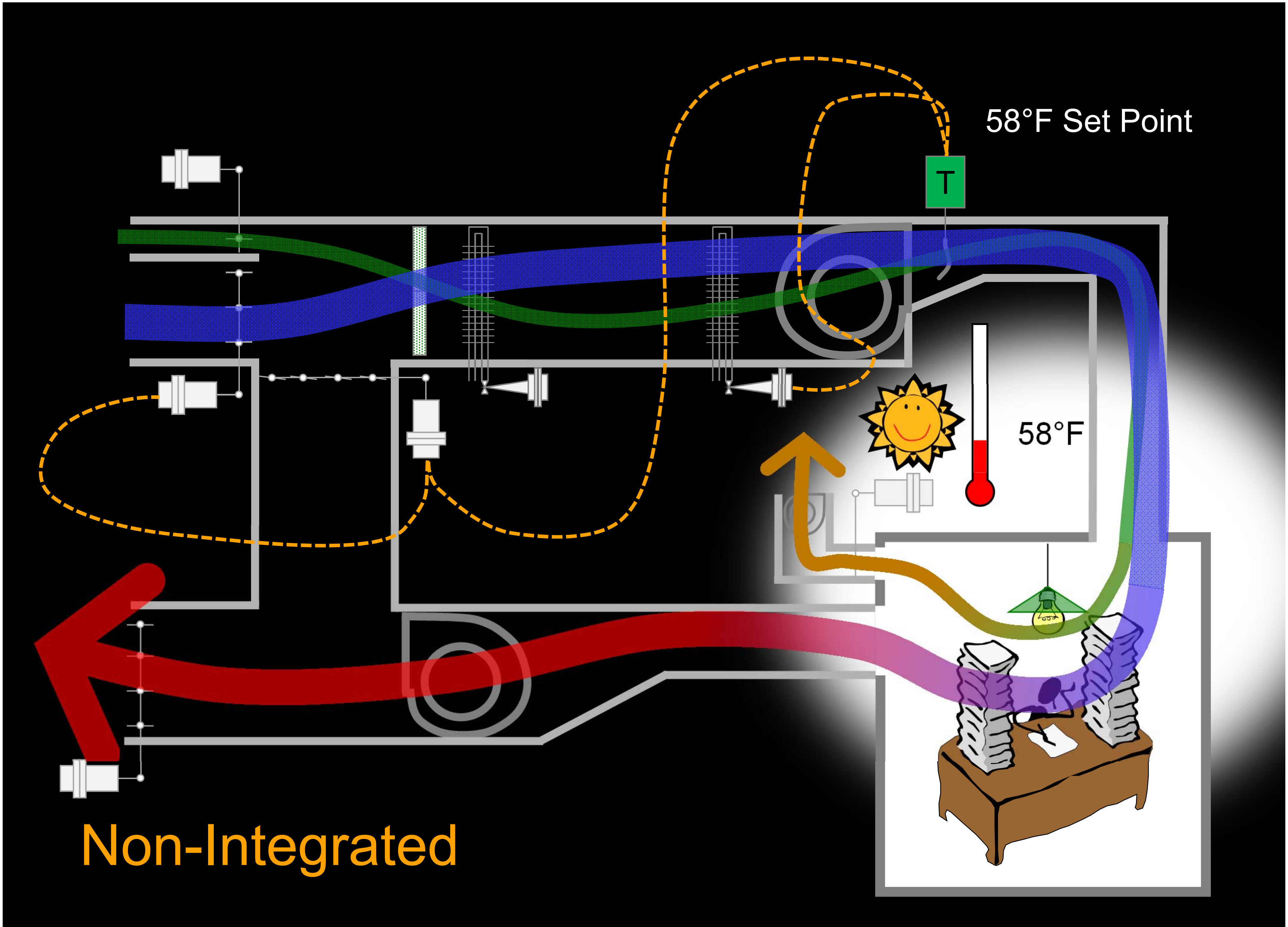
Integrated vs. Non-Integrated Economizer Operation

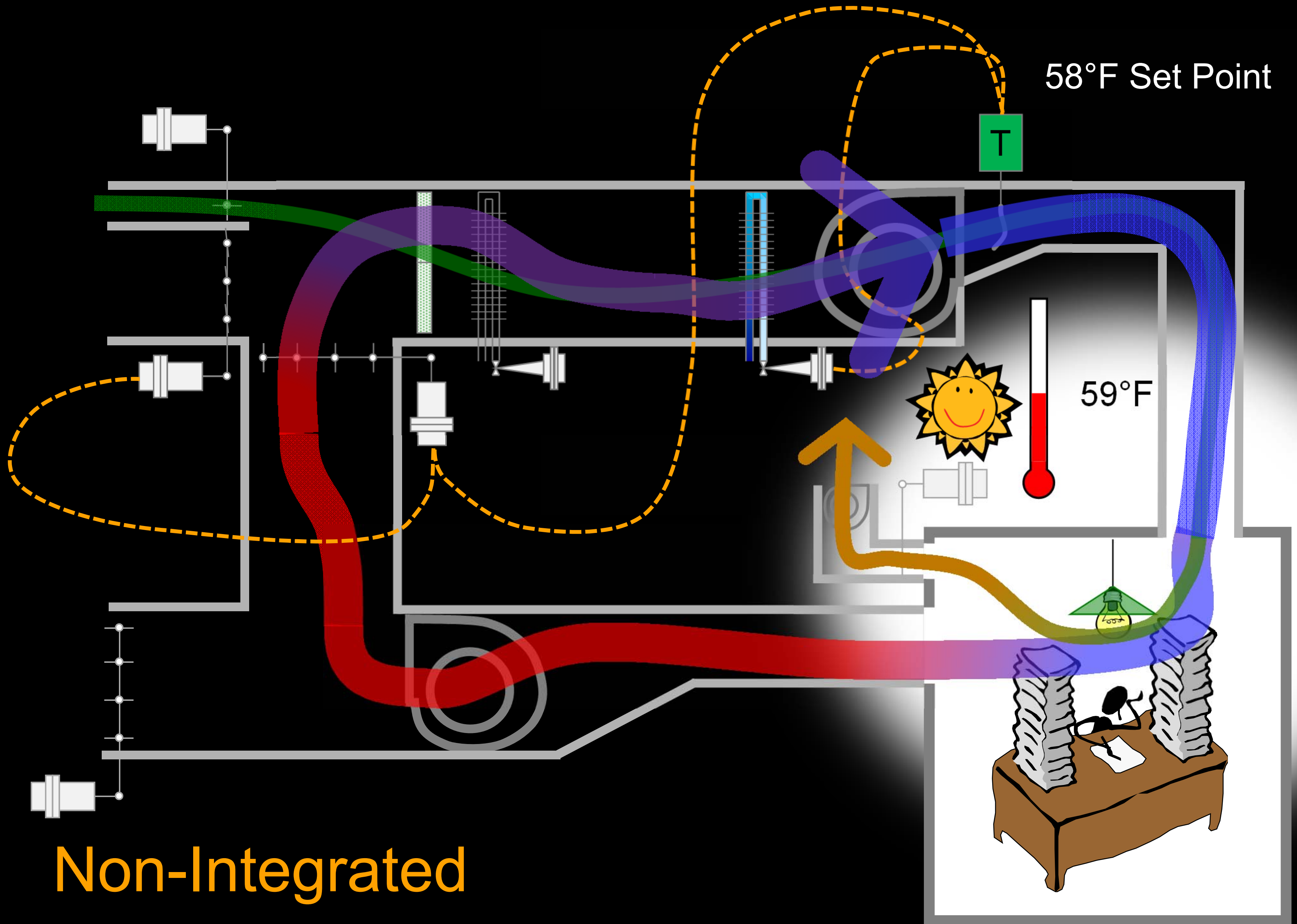


Non-Integrated is Different from Integrated



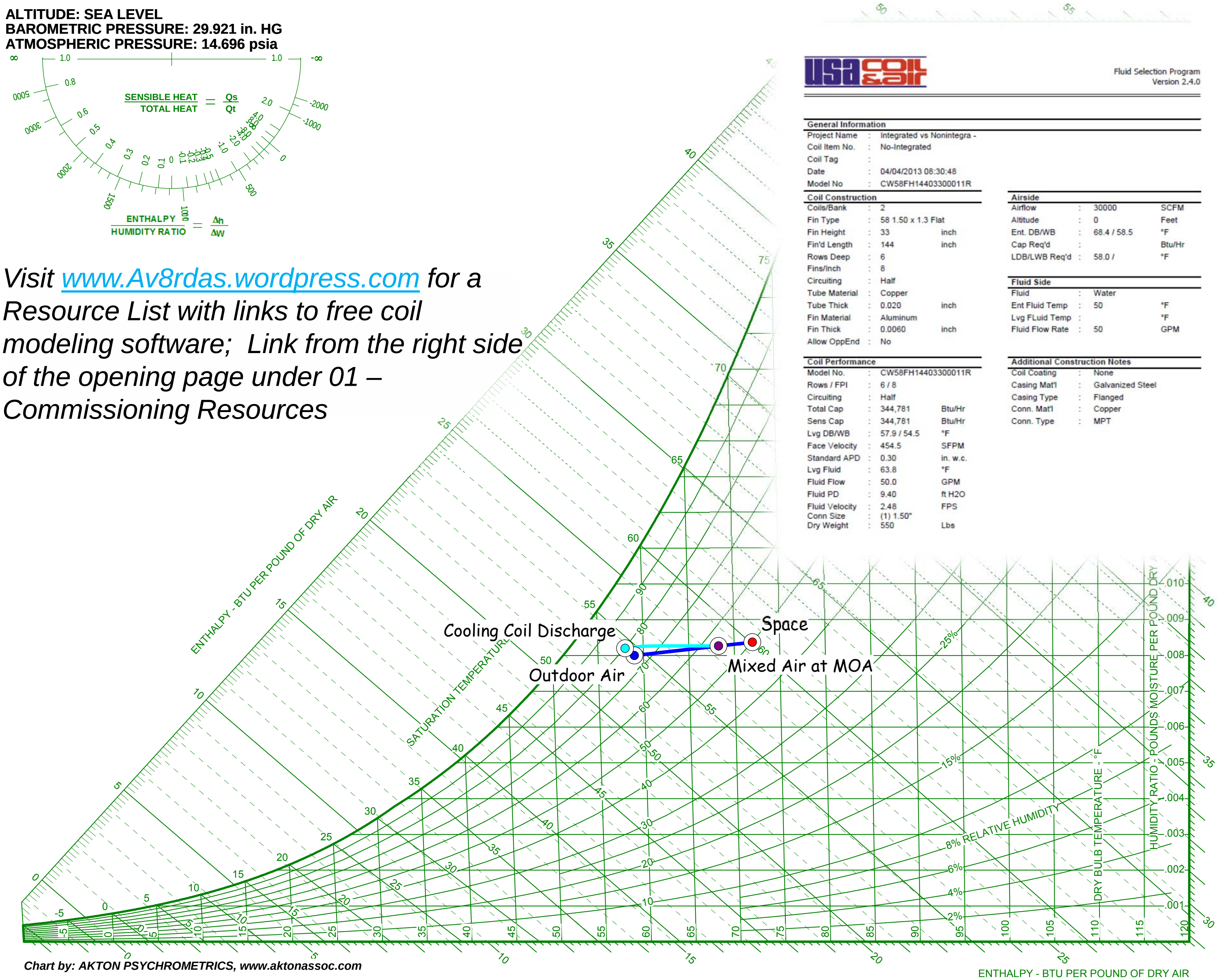
Non-Integrated


58°F Set Point
T
58°F
Non-Integrated



Non-Integrated

Visit www.Av8rdas.wordpress.com for a Resource List with links to free coil modeling software; Link from the right side of the opening page under 01 – Commissioning Resources



Fluid Selection Program
Version 2.4.0

General Information

Project Name	:	Integrated vs Nonintegra -
Coil Item No.	:	No-Integrated
Coil Tag	:	
Date	:	04/04/2013 08:30:48
Model No	:	CW58FH14403300011R

Coil Construction

Coils/Bank	:	2	
Fin Type	:	58 1.50 x 1.3 Flat	
Fin Height	:	33	inch
Fin'd Length	:	144	inch
Rows Deep	:	6	
Fins/Inch	:	8	
Circuiting	:	Half	
Tube Material	:	Copper	
Tube Thick	:	0.020	inch
Fin Material	:	Aluminum	
Fin Thick	:	0.0060	inch
Allow OppEnd	:	No	

Airside

Airflow	:	30000	SCFM
Altitude	:	0	Feet
Ent. DB/WB	:	68.4 / 58.5	°F
Cap Req'd	:		Btu/Hr
LDB/LWB Req'd	:	58.0 /	°F

Fluid Side

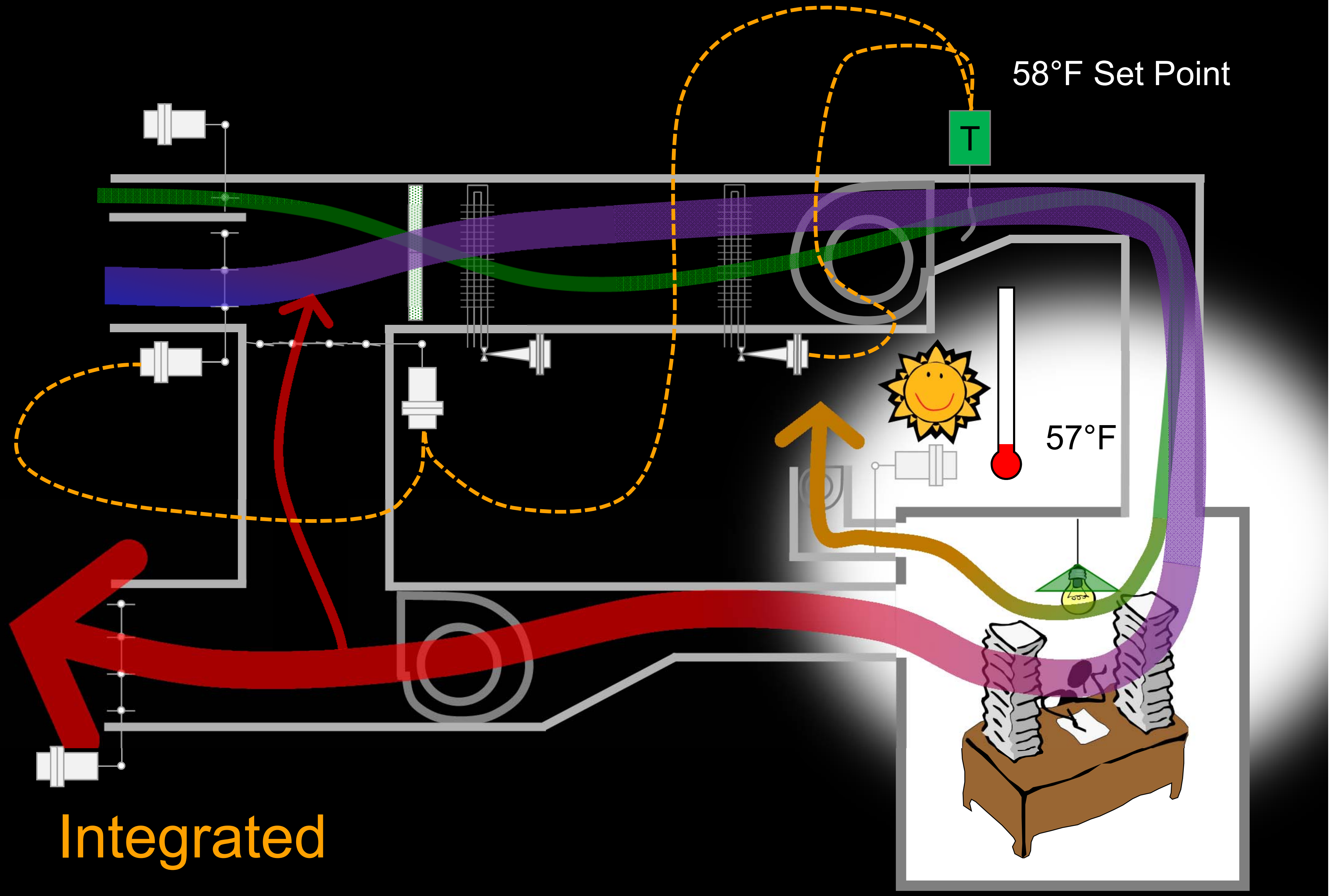
Fluid	:	Water	
Ent Fluid Temp	:	50	°F
Lvg FLuid Temp	:		°F
Fluid Flow Rate	:	50	GPM

Coil Performance

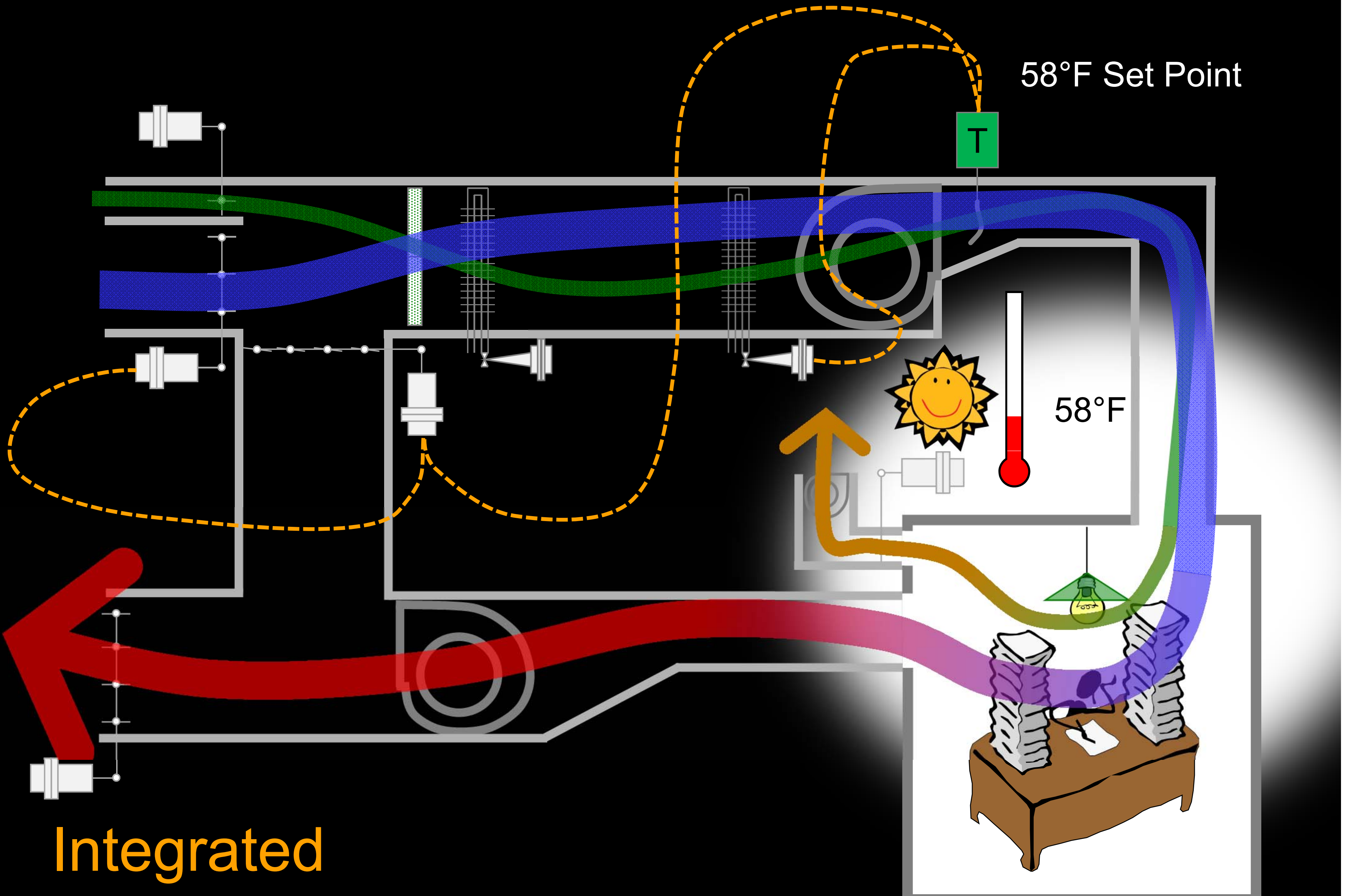
Model No.	:	CW58FH14403300011R	
Rows / FPI	:	6 / 8	
Circuiting	:	Half	
Total Cap	:	344,781	Btu/Hr
Sens Cap	:	344,781	Btu/Hr
Lvg DB/WB	:	57.9 / 54.5	°F
Face Velocity	:	454.5	SFPM
Standard APD	:	0.30	in. w.c.
Lvg Fluid	:	63.8	°F
Fluid Flow	:	50.0	GPM
Fluid PD	:	9.40	ft H2O
Fluid Velocity	:	2.48	FPS
Conn Size	:	(1) 1.50"	
Dry Weight	:	550	Lbs

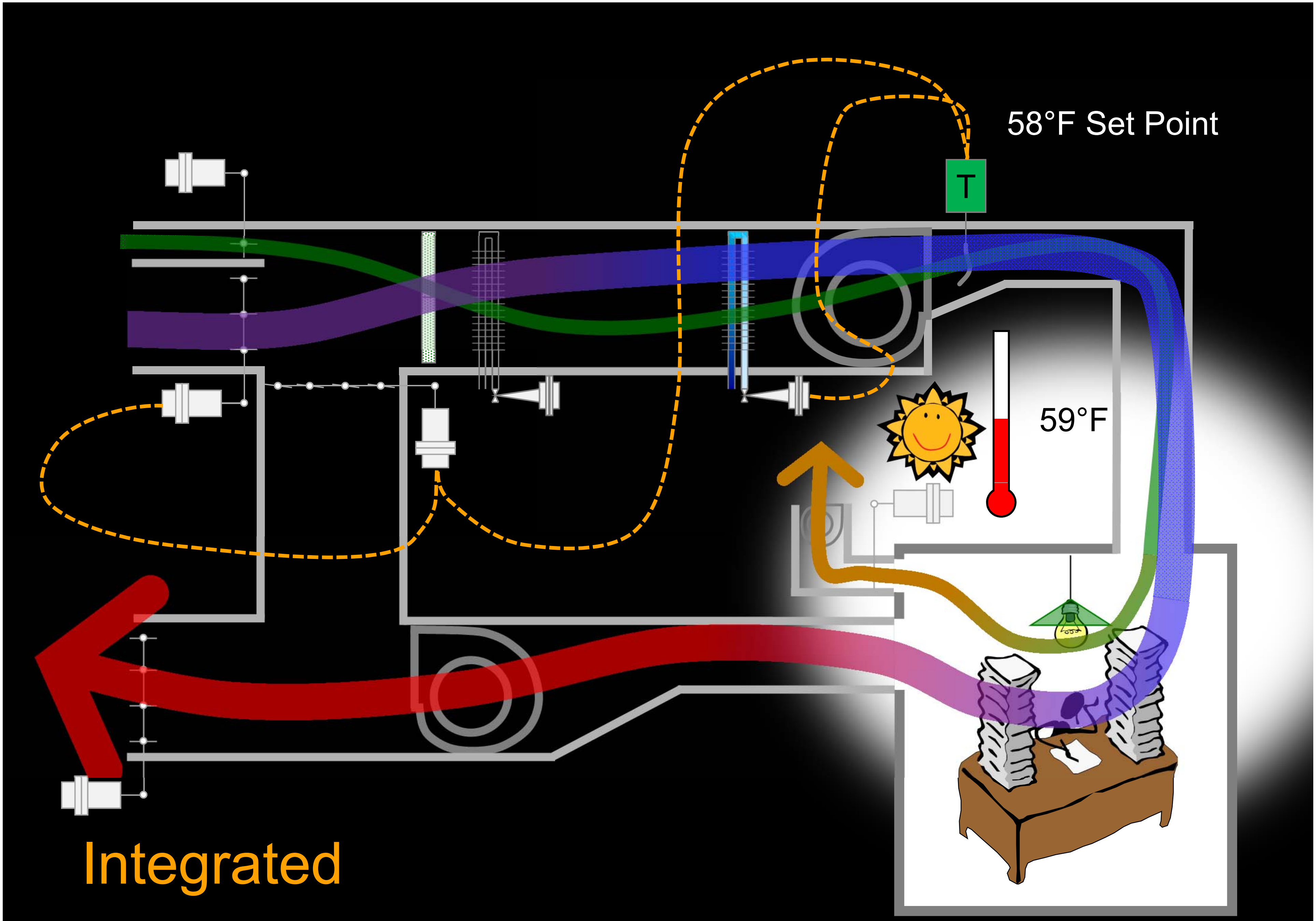
Additional Construction Notes

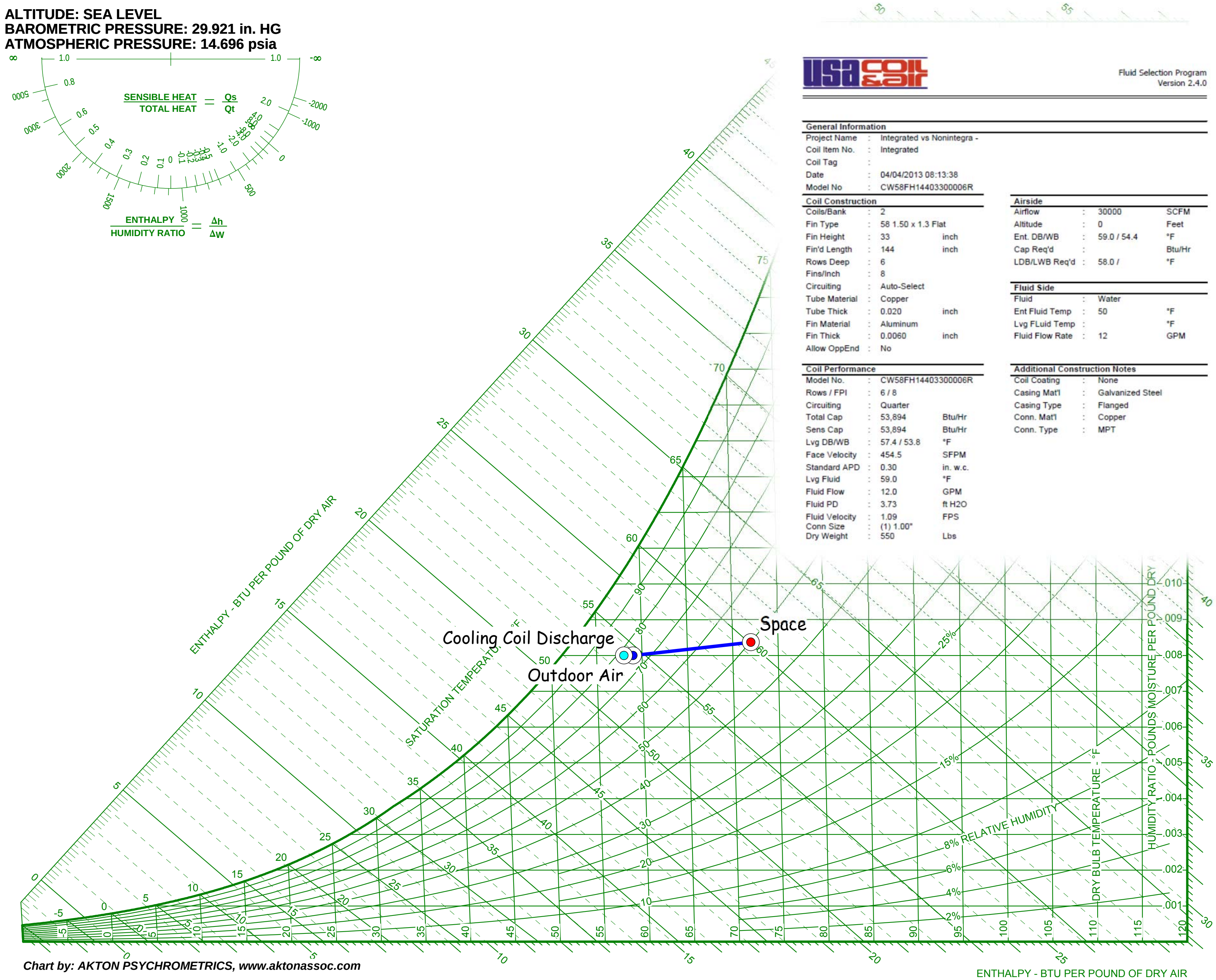
Coil Coating	:	None
Casing Mat'l	:	Galvanized Steel
Casing Type	:	Flanged
Conn. Mat'l	:	Copper
Conn. Type	:	MPT



Integrated


58°F Set Point
T
58°F
Integrated


58°F Set Point
T
59°F
Integrated



USA Coil & Air

Fluid Selection Program
Version 2.4.0

General Information

Project Name	:	Integrated vs Nonintegra -
Coil Item No.	:	Integrated
Coil Tag	:	
Date	:	04/04/2013 08:13:38
Model No	:	CW58FH14403300006R

Coil Construction

Coils/Bank	:	2	
Fin Type	:	58 1.50 x 1.3 Flat	
Fin Height	:	33	inch
Fin'd Length	:	144	inch
Rows Deep	:	6	
Fins/Inch	:	8	
Circuiting	:	Auto-Select	
Tube Material	:	Copper	
Tube Thick	:	0.020	inch
Fin Material	:	Aluminum	
Fin Thick	:	0.0060	inch
Allow OppEnd	:	No	

Airside

Airflow	:	30000	SCFM
Altitude	:	0	Feet
Ent. DB/WB	:	59.0 / 54.4	°F
Cap Req'd	:		Btu/Hr
LDB/LWB Req'd	:	58.0 /	°F

Fluid Side

Fluid	:	Water	
Ent Fluid Temp	:	50	°F
Lvg FLuid Temp	:		°F
Fluid Flow Rate	:	12	GPM

Coil Performance

Model No.	:	CW58FH14403300006R	
Rows / FPI	:	6 / 8	
Circuiting	:	Quarter	
Total Cap	:	53,894	Btu/Hr
Sens Cap	:	53,894	Btu/Hr
Lvg DB/WB	:	57.4 / 53.8	°F
Face Velocity	:	454.5	SFPM
Standard APD	:	0.30	in. w.c.
Lvg Fluid	:	59.0	°F
Fluid Flow	:	12.0	GPM
Fluid PD	:	3.73	ft H2O
Fluid Velocity	:	1.09	FPS
Conn Size	:	(1) 1.00"	
Dry Weight	:	550	Lbs

Additional Construction Notes

Coil Coating	:	None
Casing Mat'l	:	Galvanized Steel
Casing Type	:	Flanged
Conn. Mat'l	:	Copper
Conn. Type	:	MPT