Economizers: Design, Performance, and Commissioning Issues

Integrating the Economizer with Other HVAC and Utility System Processes

Instructor:

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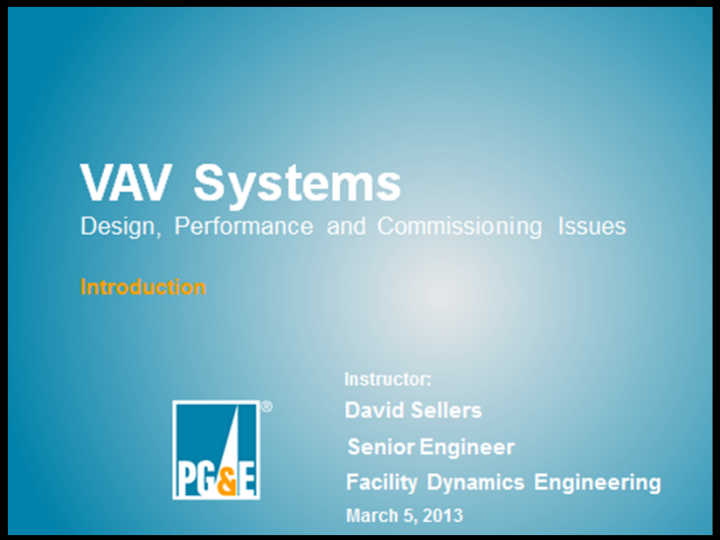
- Senior Engineer
- Facility Dynamics Engineering
- February 6, 2018

What's In This Module

- Integrating economizer operation with minimum outdoor air requirements and managing minimum outdoor air flow control
- The importance of measuring mixed air temperature accurately (and the challenges)

Detailed Discussions in Future Classes



Minimum Flow

The Zone Level Relationship with Minimum Outdoor Air

- Based on ventilation requirement in the system
  - Contaminant (IEQ) control
  - Rule of thumb – 15 cfm of outdoor air required per person
- Removed via exhaust systems
  - Hoods
  - Toilet exhaust
- Temperature of delivered air based on the design dehumidification requirement
- Optimization potential
  - Save fan energy
  - Save reheat energy

Minimum Flow

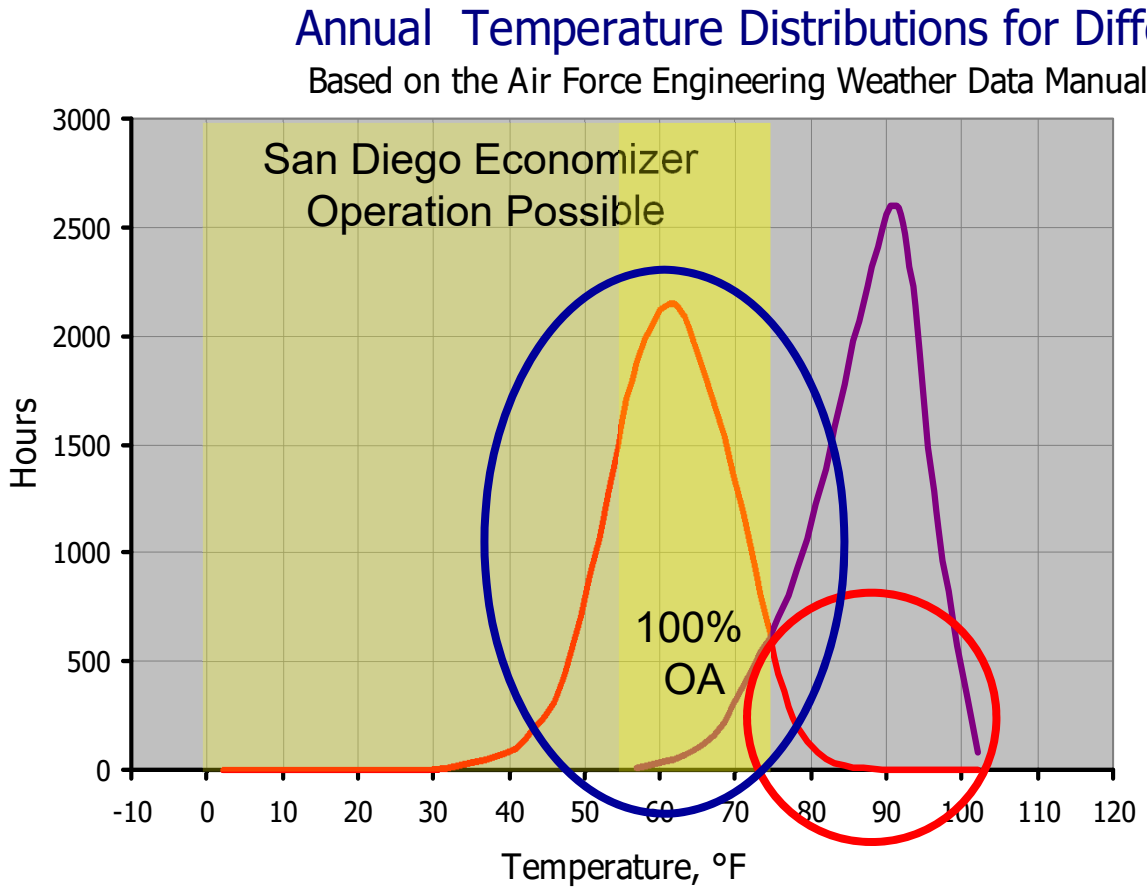
The System Level Relationship with Minimum Outdoor Air

- Based on ventilation requirement in the system
  - Contaminant (IEQ) control
  - Rule of thumb – 15 cfm of outdoor air required per person
- Removed via exhaust systems
  - Hoods
  - Toilet exhaust
- Temperature of delivered air based on the design dehumidification requirement
- Optimization potential
  - Save HVAC process energy

Under what operating conditions does the minimum outdoor air setting become critical?

Optimizing Minimum Outdoor Air Settings

The Benefits Vary with Climate



In mild climates, economizer equipped systems are at 100% outdoor much of the time anyway

Options for Setting System Level Minimum Outdoor Air Flow

Passive

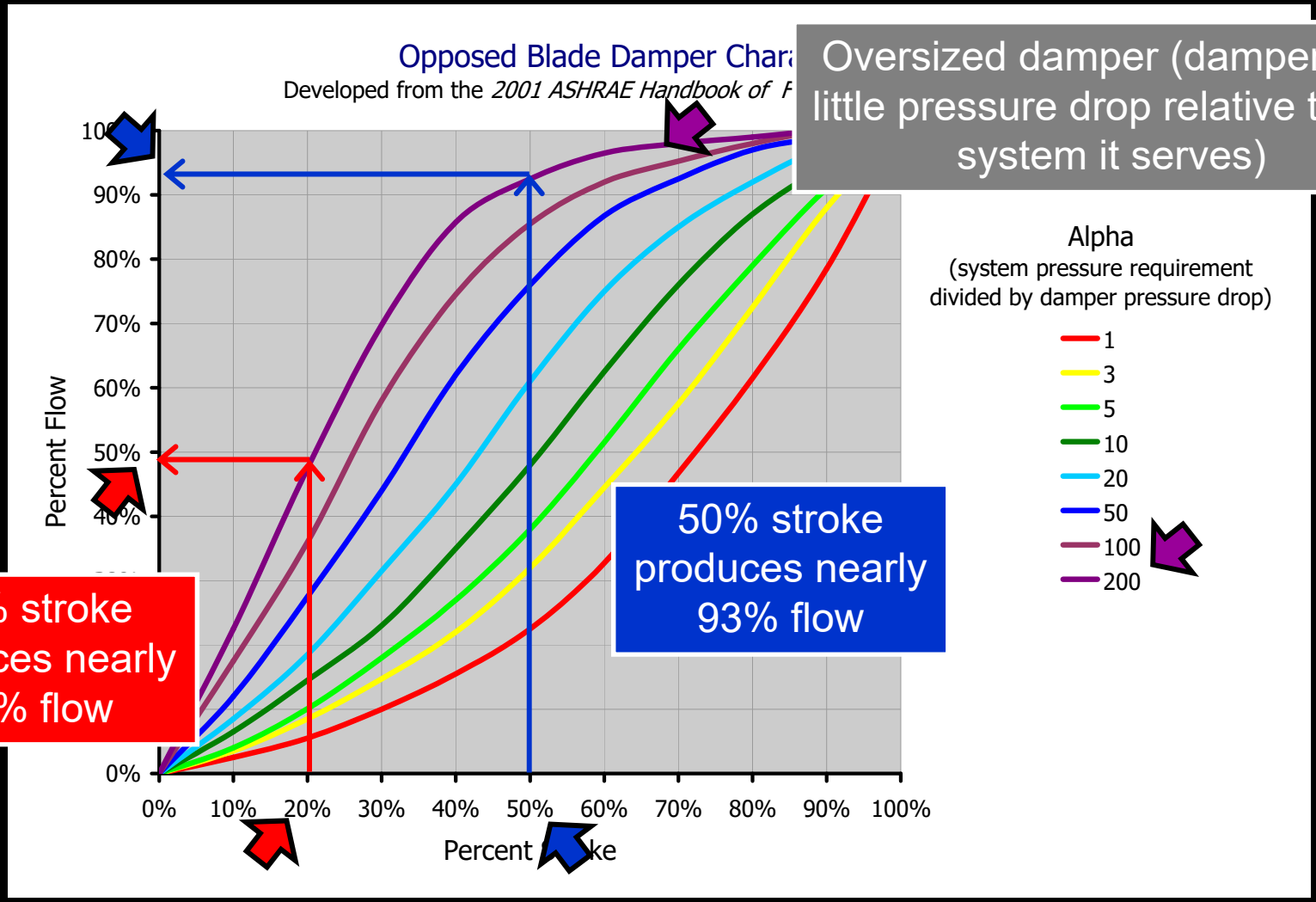
Assume you will get the required flow rate based on related settings and adjustments in the system

- Independent damper
- Minimum position setting for the maximum outdoor air damper
- Supply/return fan speed and flow control processes

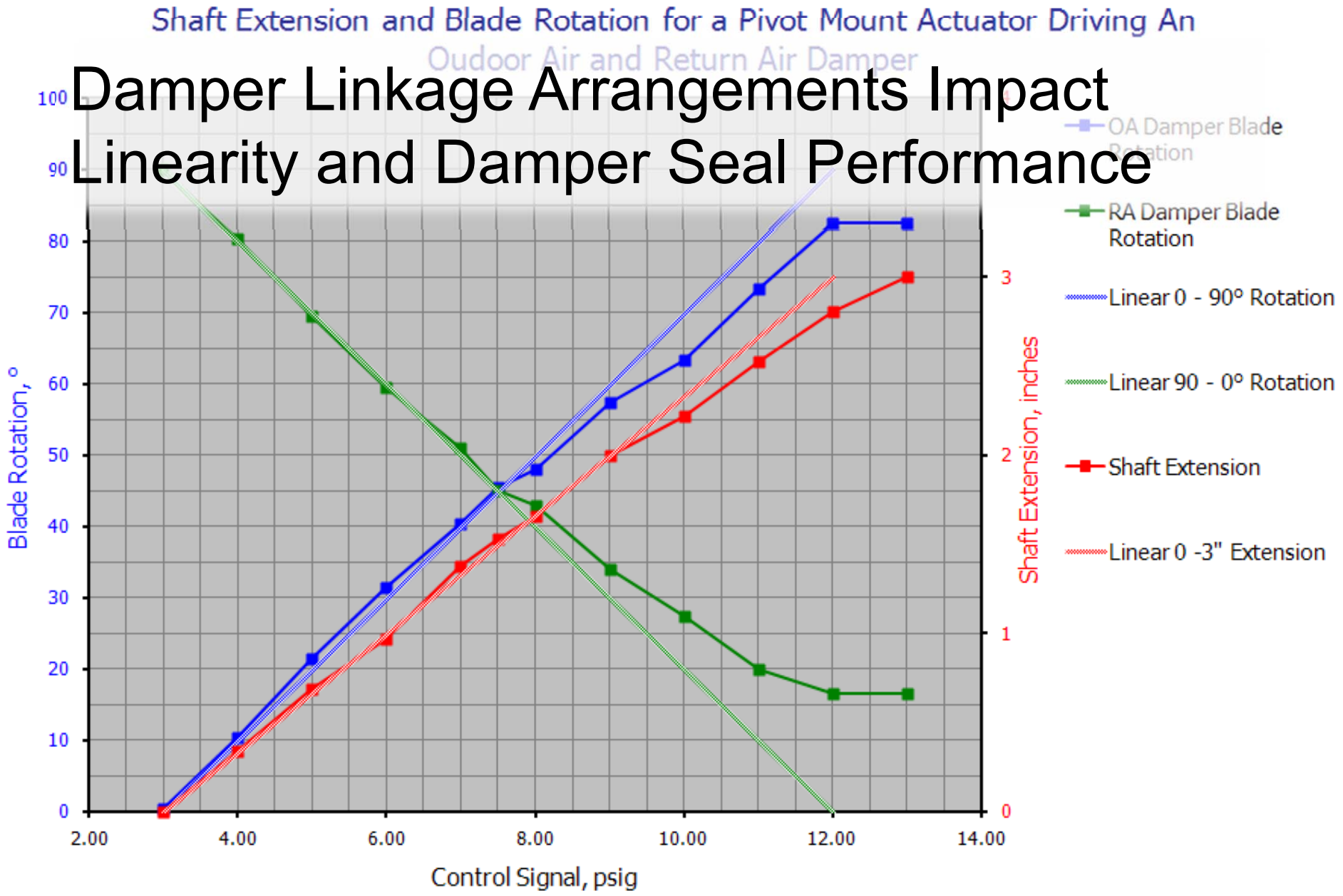
Active

Proactively measure and control the minimum outdoor air flow

Damper Sizing Impacts Linearity



Damper Linkage Arrangements Impact Linearity and Damper Seal Performance



MOA Control References

Minimum Outside Air Damper Control

- By Larry Felker, Associate Member ASHRAE
- ASHRAE Journal, April 2002

Demand Control Ventilation Using CO_2

- By Mike Schell and Dan Int-Hout, Member ASHRAE
- ASHRAE Journal, February 2001

Indoor Air Quality Primer

- By Terry M. Brennan
- Heating, Piping and Air Conditioning (HPAC) Ventilation Guide, Spring 1999

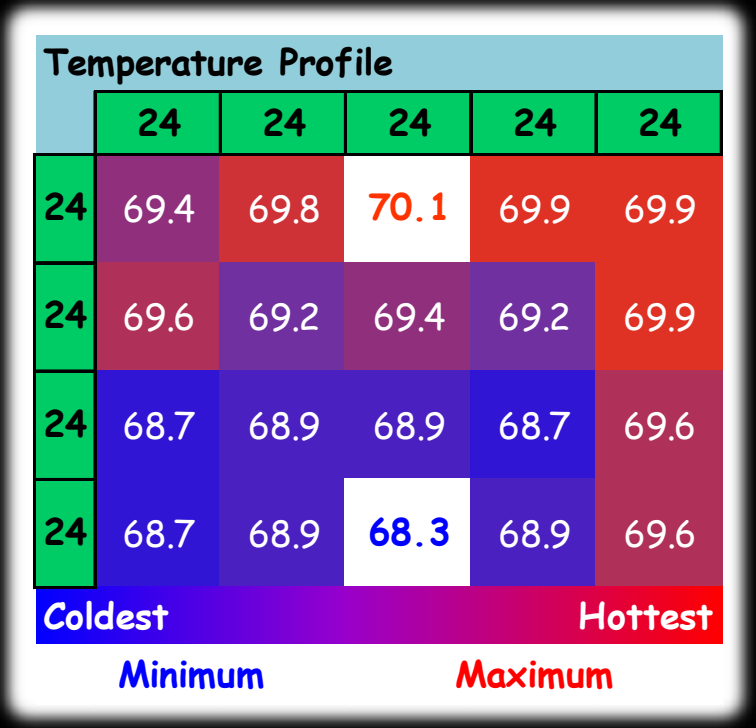
Measurements to Solve IAQ Problems

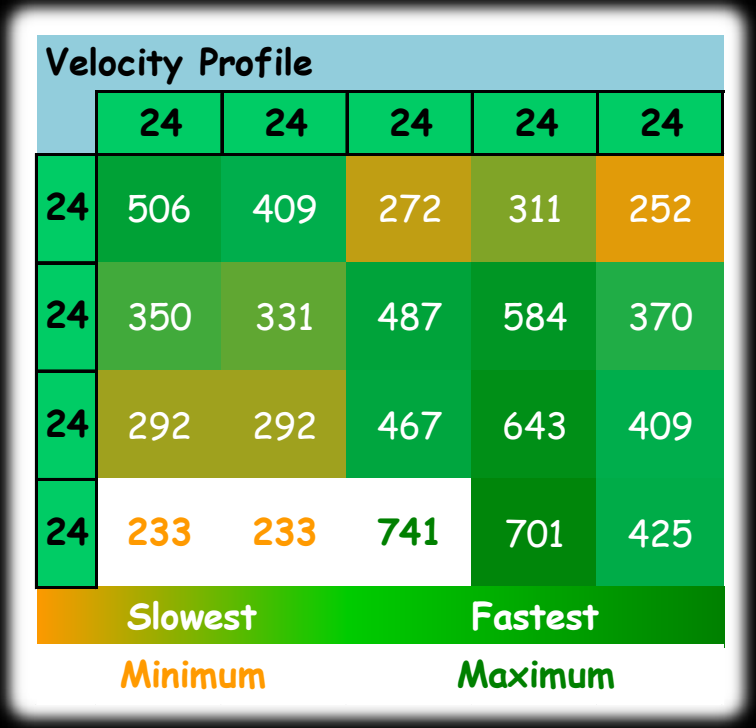
- By Terry M. Brennan
- HPAC, July 1999

Real Time Ventilation Control

- Mike Schell
- HPAC, April 2002

Non-uniform Temperature and Velocity Profiles

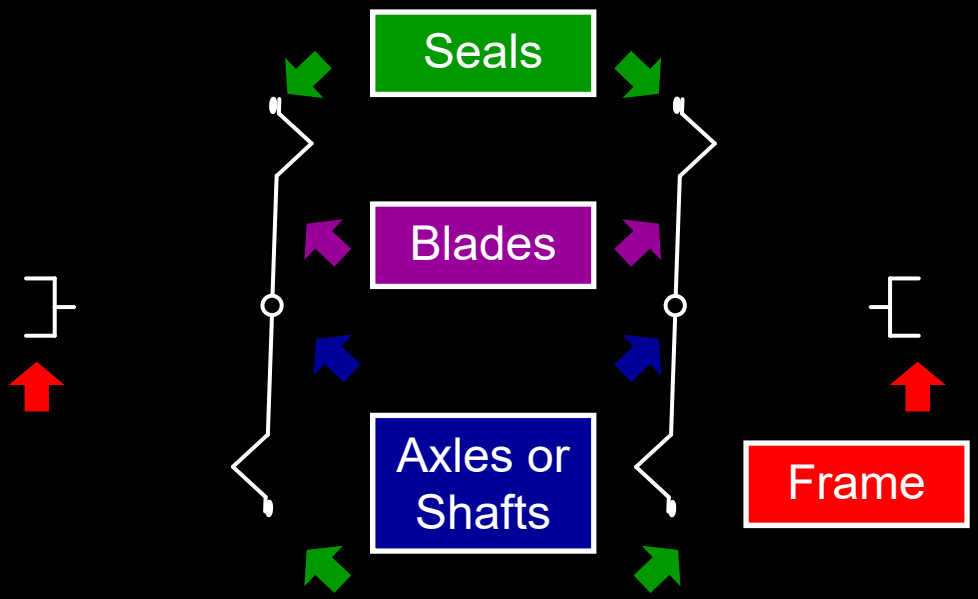


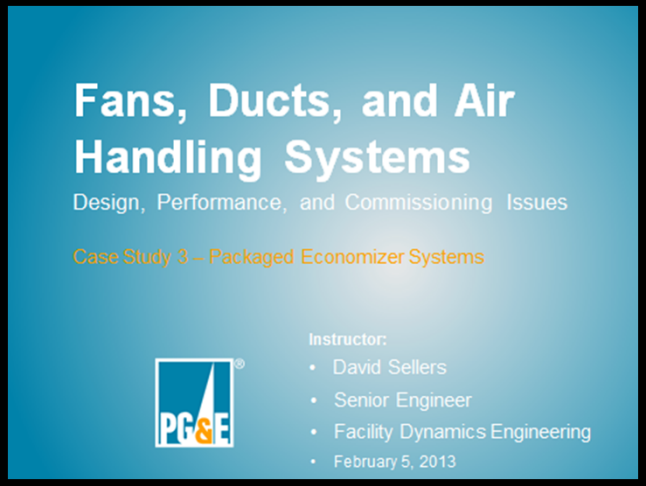


Non-uniform Temperature and Velocity Profiles

Damper Parts

- Parallel Blade Damper





A Conventional, Flat Plate Blade Cross-Section

Samples courtesy of Greenheck

A Fabricated Airfoil Blade Cross-Section

Samples courtesy of Greenheck

An Extruded Airfoil Blade Cross-Section

Samples courtesy of Greenheck

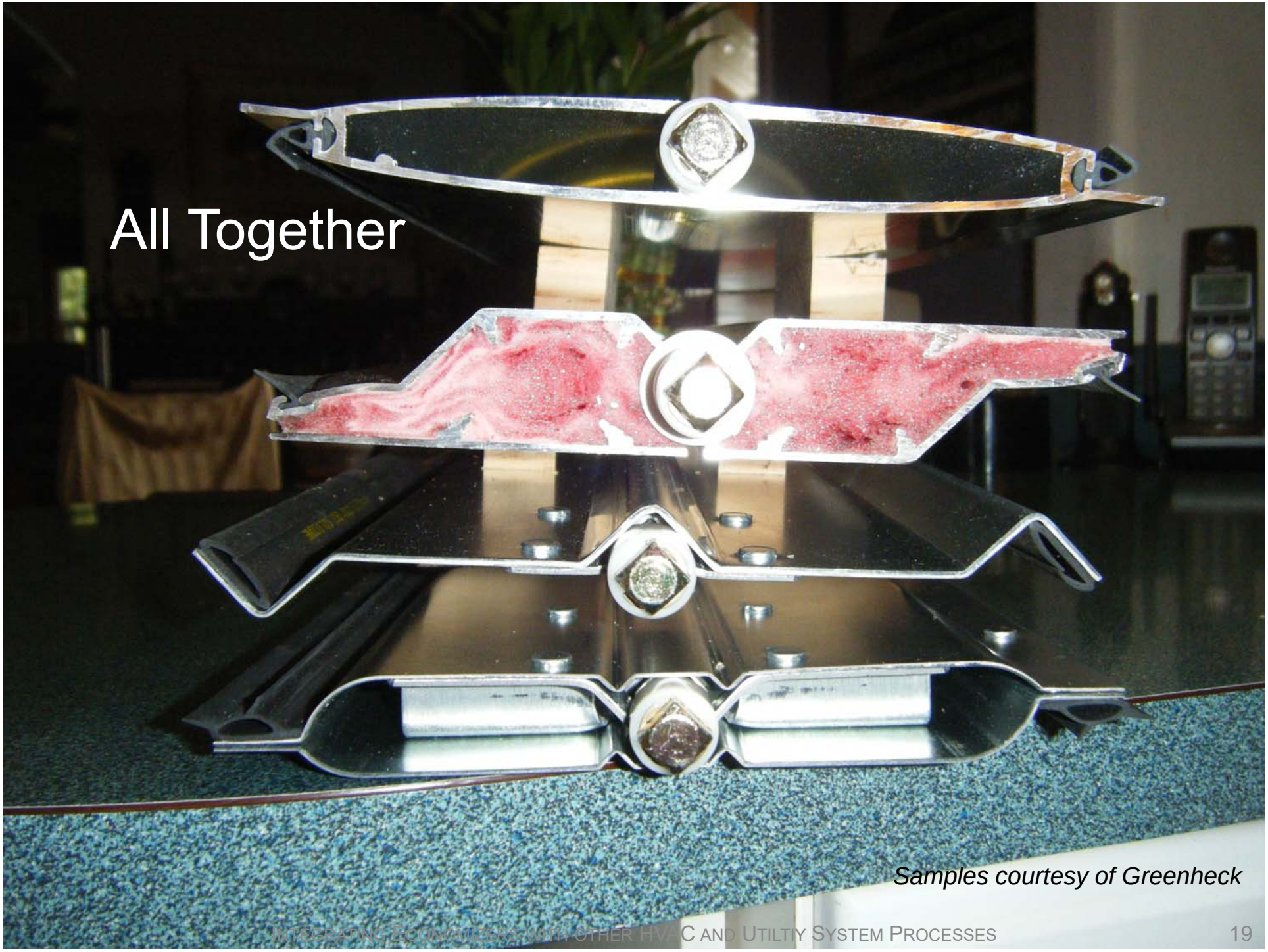
An Insulated Blade Cross-Section

Samples courtesy of Greenheck

All Together

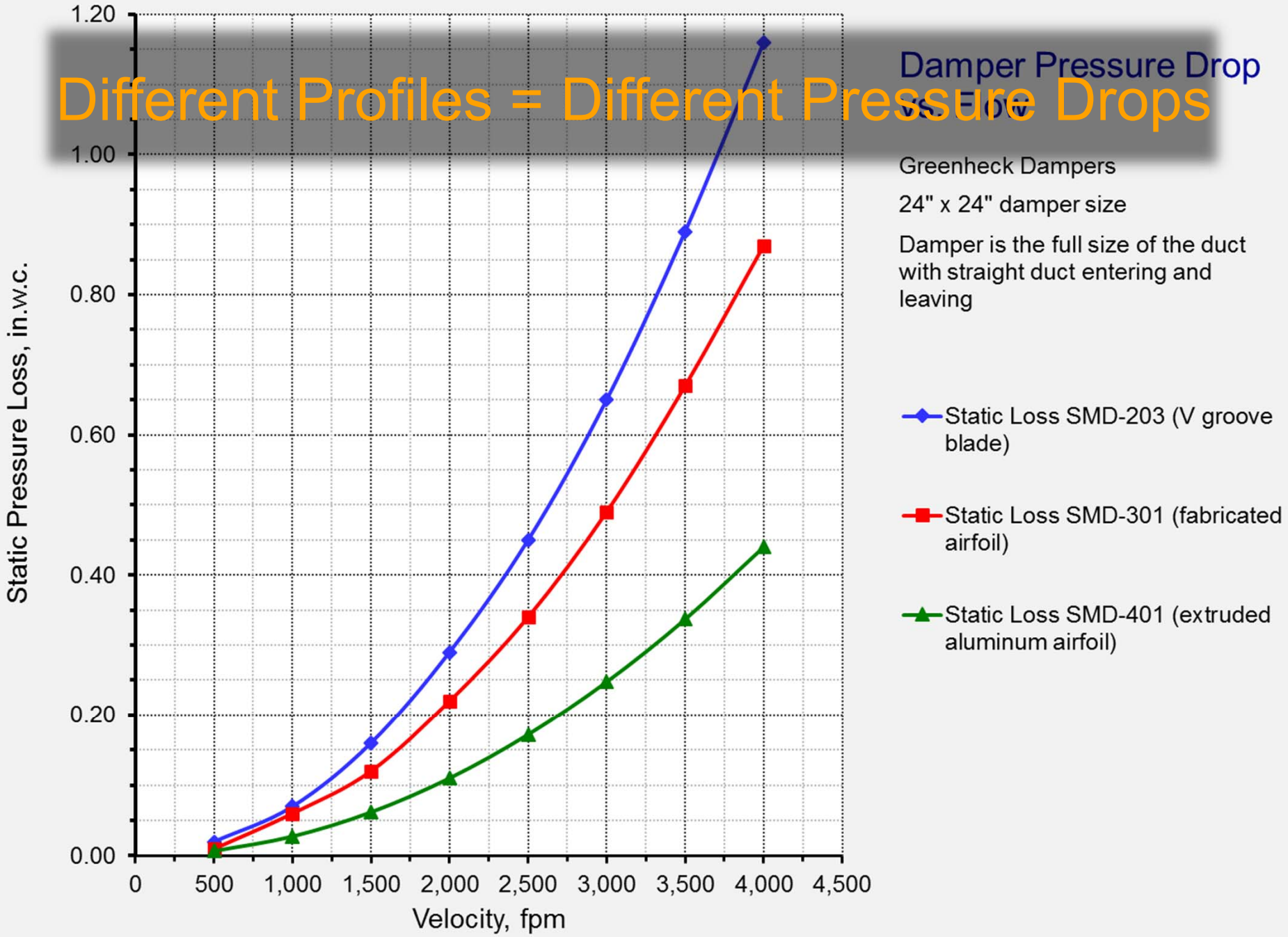
Samples courtesy of Greenheck

All Together



Samples courtesy of Greenheck

Different Profiles = Different Pressure Drops



Pressure Drop = Energy

$$bhp = \left(\frac{Flow \times Static}{6{,}356 \times Efficiency_{Fan}} \right)$$

Where:

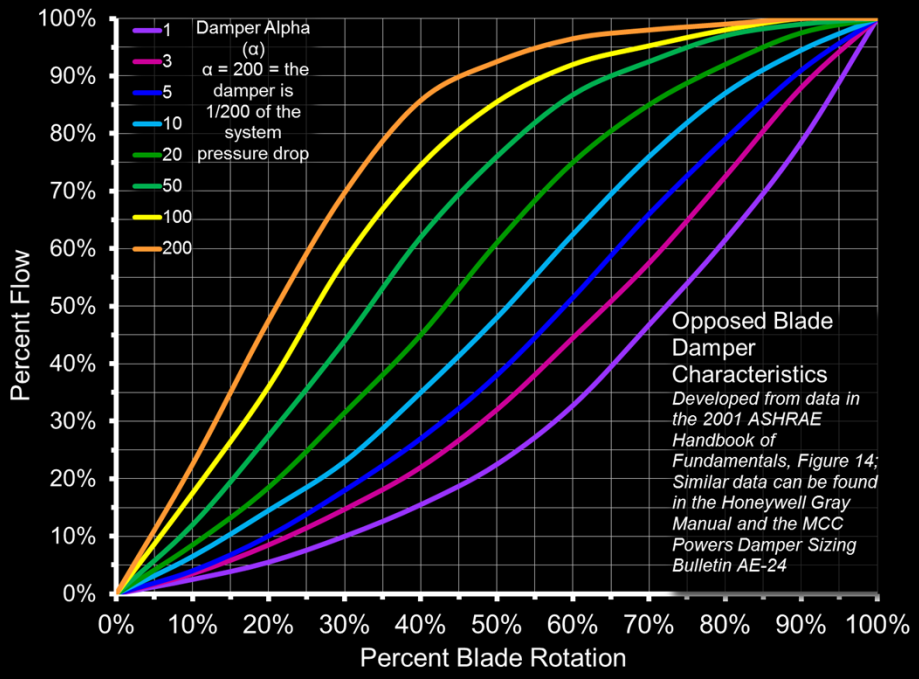
Flow = Flow produced by the fan in cfm

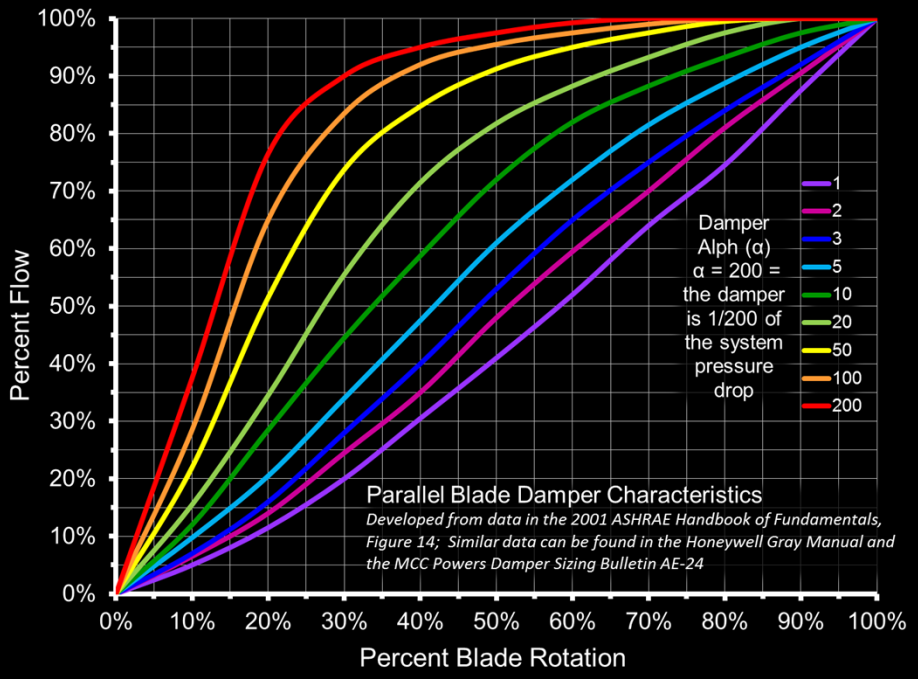
Static = Static produced by the fan in inches water column

6,356 = A units conversion constant that will work for air at the temperatures and pressures typically encountered in HVAC systems for up to about 2,000 - 3,000 feet in altitude.

$Efficiency_{Fan}$ = Fan efficiency, read from the fan curve, equipment schedule or estimated from past experience; .40 - .65 for small fans or propeller or forward curved fans, .60 - .70 for plenum fans, .70 - .80 for backward included or airfoil fans.

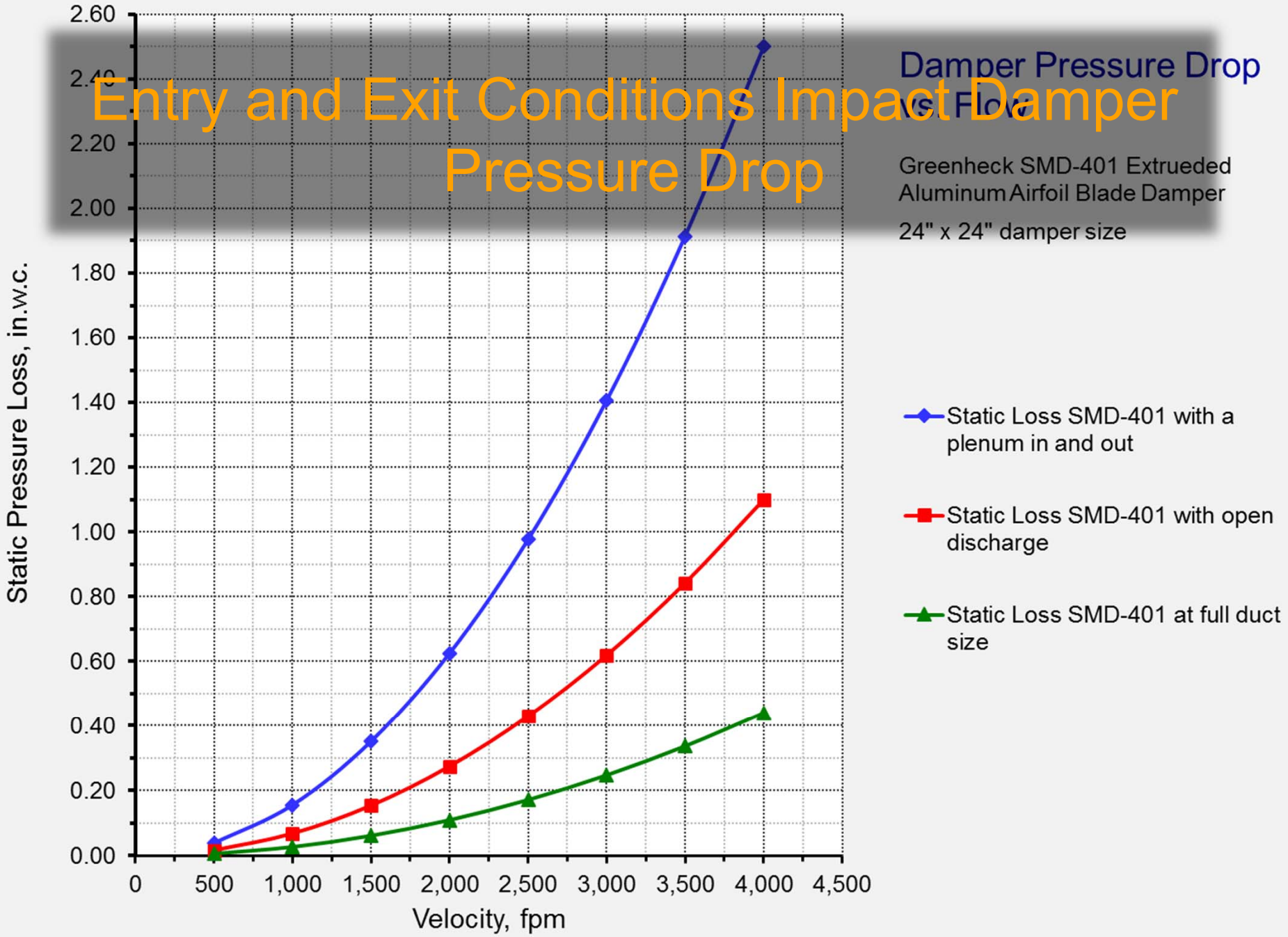
Pressure Drop Impacts Damper Performance



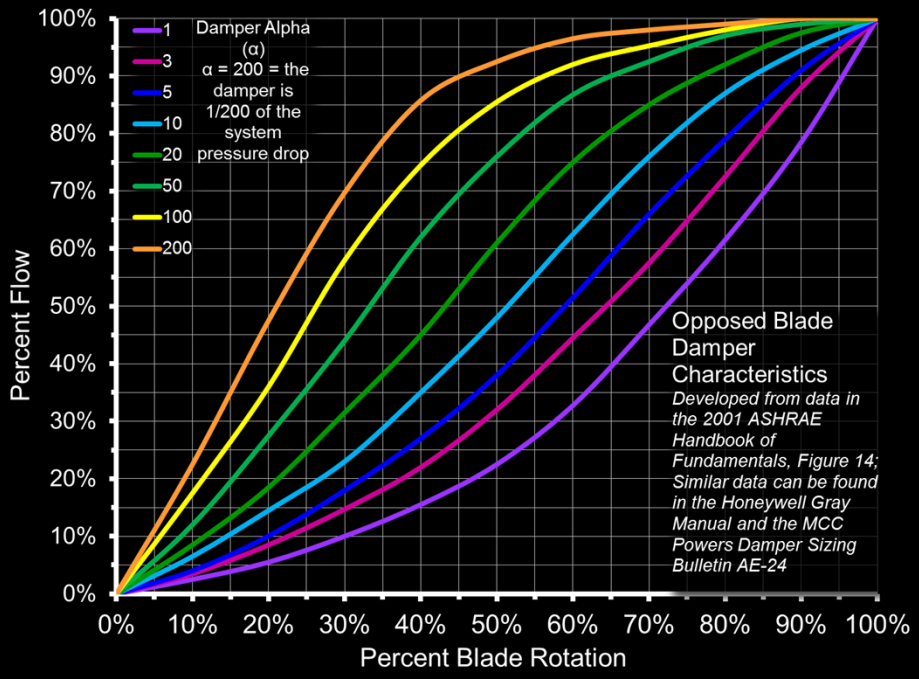


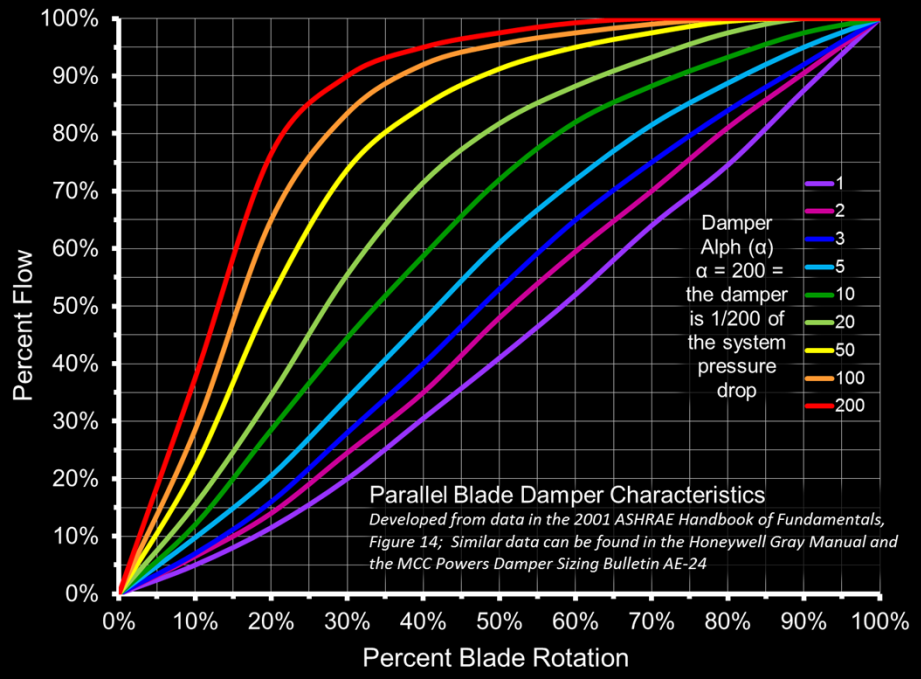
- Damper pressure drop relative to system pressure drop determines damper linearity
- Rule of thumb:1,500 – 2,500 fpm damper face velocity required for typical commercial systems

Entry and Exit Conditions Impact Damper Pressure Drop



Pressure Drop Impacts Damper Performance





- Resources
  - MCC Powers AE-24 Damper Sizing Application Bulletin
  - The Honeywell Gray Manual
  - ASHRAE Guideline 16 - Selecting Dampers for Economizers

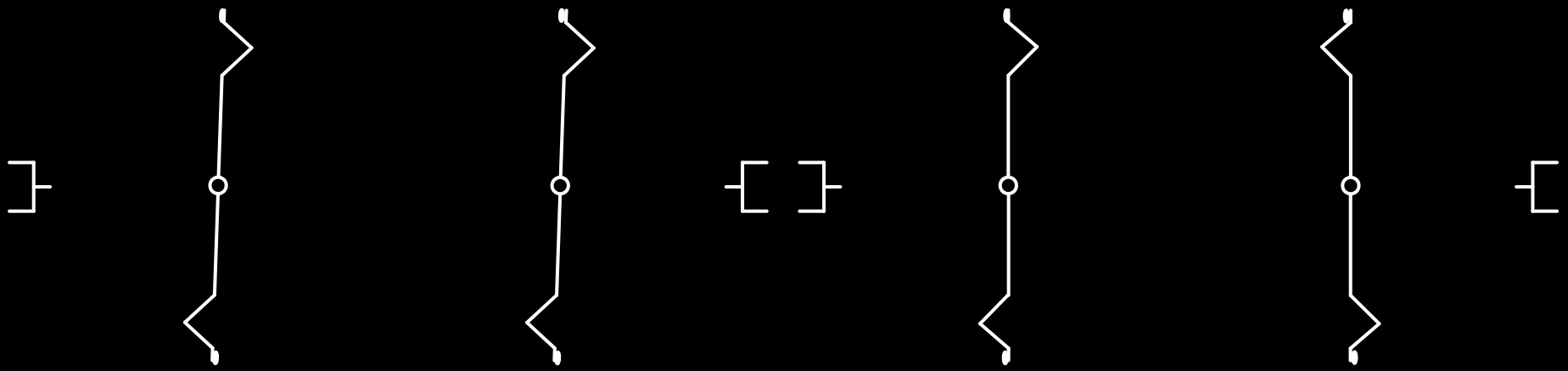
Blade Seals

Jamb Seals

Are blade and jamb seals that important in a mild environment like we have here in the San Francisco Bay area?

Parallel vs. Opposed Blade Dampers

- Parallel Blade Damper
- Opposed Blade Damper



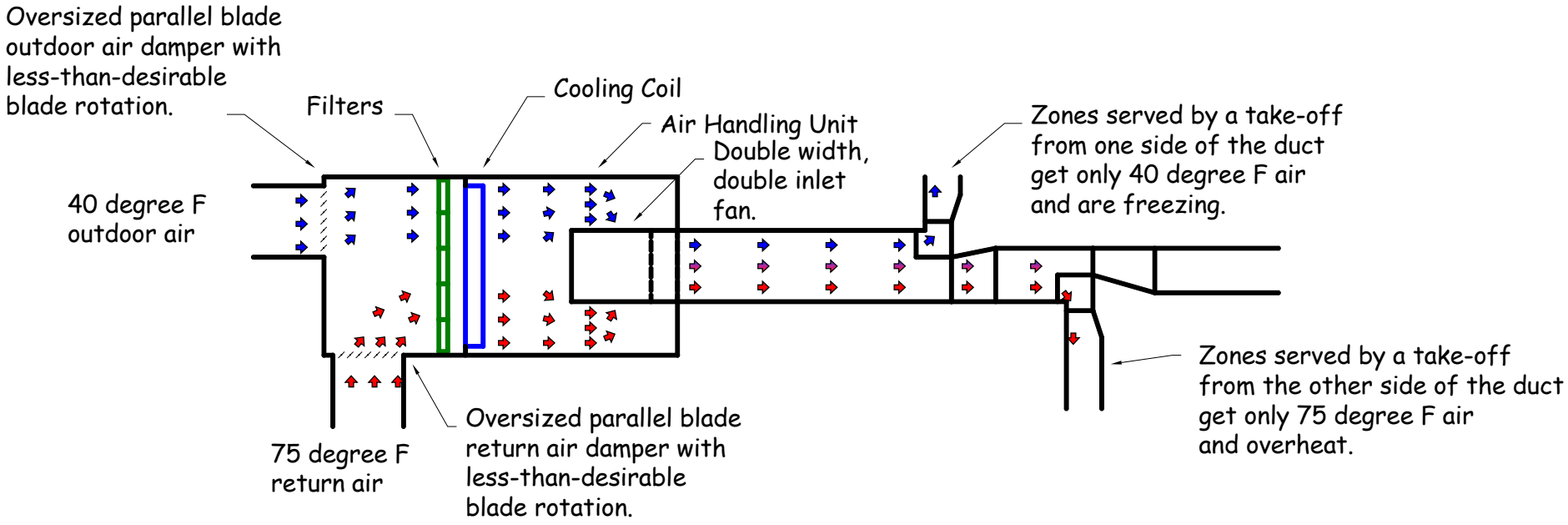
Why did I initiate the discussion about non-uniform temperature and velocity profiles by bringing up the difference between parallel and opposed blade dampers?

Mixing Performance Depends Damper Details

Damper details are critical

- Dampers are sized to promote linear characteristics
- The higher velocities associated with generating a meaningful pressure drop in the context of the system give the air momentum and promote and mixing
- Damper blade rotation can (or can not) direct air streams to promote mixing (or not)

Strange Things Can Happen

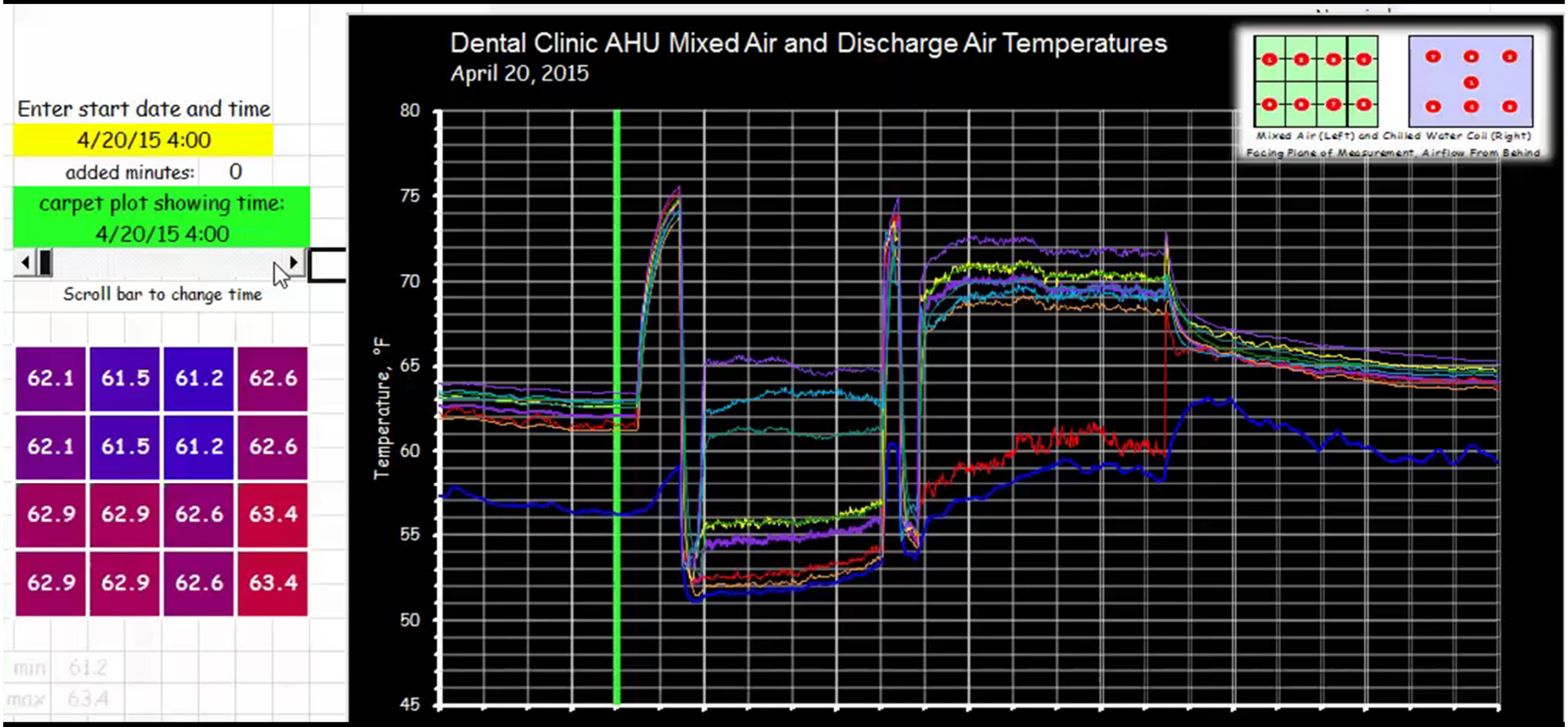


Corrections:

- Disable some damper blades to increase velocity
- Flip dampers to direct airstreams together

The AHU Behind What Follows

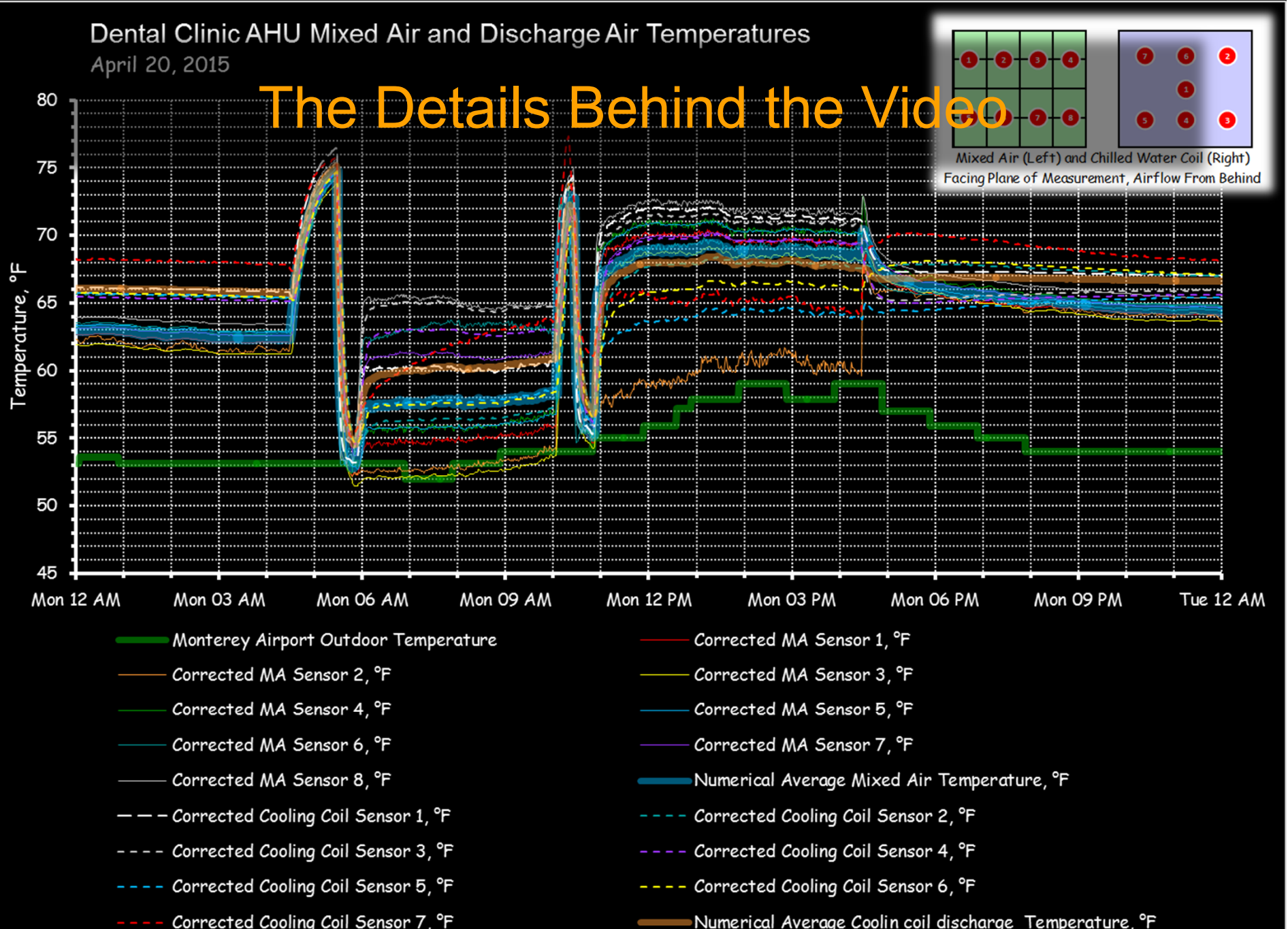
Mixing Performance Depends Having Some Distance to Mix



Animation Courtesy Jay Tulley
The Presidio at Monterey

Mixed Air Plenums are Dynamic Places

The Details Behind the Video



Coils Impact Velocity and Temperature Profiles in a Very Short Distance

Temperature (left) and Velocity (right) measurements at 20% Commanded Outdoor Air between 10:00 am and 11:00 am on 2015-05-15

71.1	74.0	74.7	74.2
73.7	74.7	75.7	75.7
73.6	74.3	75.6	75.0
72.9	73.6	75.6	75.0

Temperatures in °F at the entering face of the filters

73.1	74.5	74.5	75.4
75.6	76.4	76.1	76.8
75.8	76.3	76.6	76.5
75.3	75.2	75.9	75.9

Temperatures in °F at the leaving face of the chilled water coil

28	180	198	264
447	551	598	494
136	329	234	272
127	145	102	134

Velocities in feet per minute at the entering face of the filters

308	290	299	284
276	275	268	292
247	271	286	289
253	288	276	300

Velocities in feet per minute at the leaving face of the chilled water coil

Outdoor temperature = 58°F, Return air temperature = 77°F. Supply fan speed = 75%, Return fan speed = 65%, Chilled water valve fully closed. The temperature color gradient is relative to the minimum (blue) and maximum (red) filter face temperatures. The velocity color gradient is relative to the minimum (orange) and maximum (green) observed filter face velocities.

Theoretical OA % based on the average mixed air temperature at the coil face = 7%. Flow rate based on coil face velocities = 10,004 cfm

Difference from commanded OA% = -13%°F (positive numbers = outdoor air above the commanded %)

Filter face velocity based measurement deviation from coil face velocity based measurement = -6% (negative numbers = low flow)

71.1	71.7	72.3	72.8	73.4	74.0	74.6	75.1	75.7

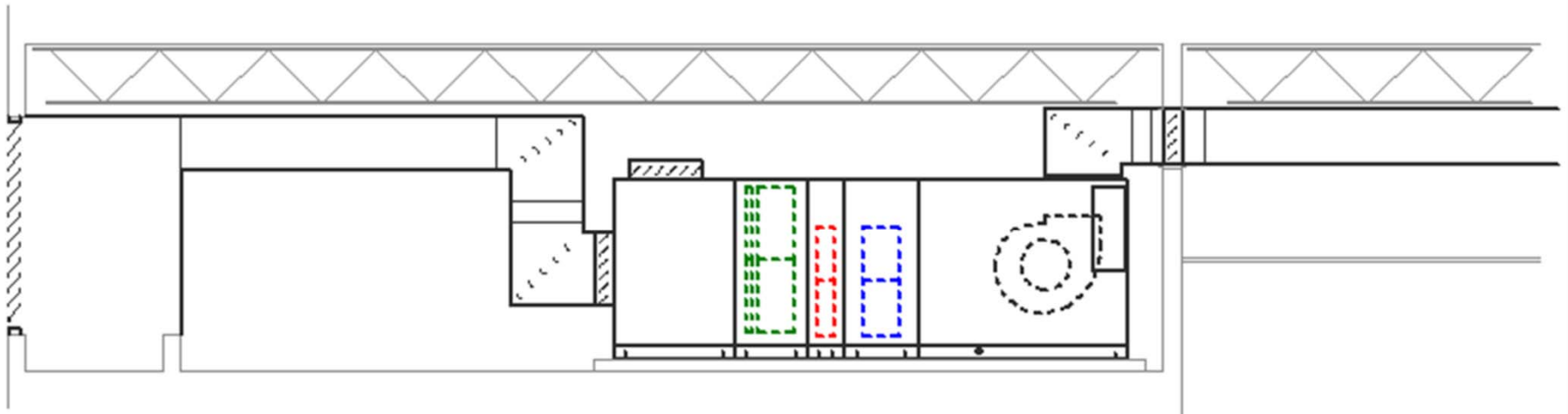
Temperature Gradient Colors

28	99	171	242	313	384	456	527	598

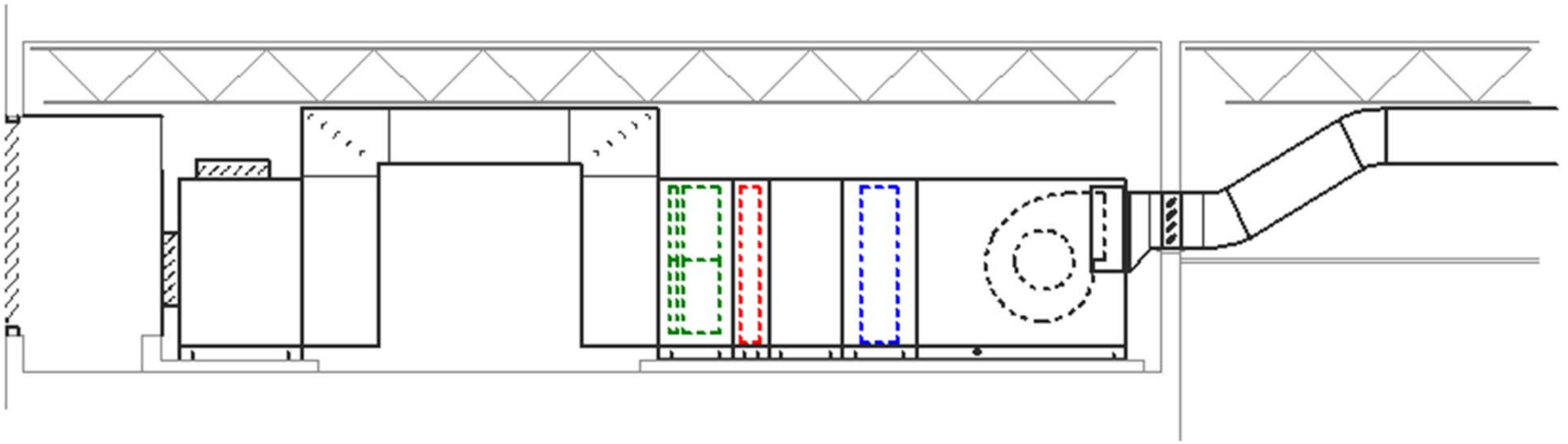
Velocity Gradient Colors

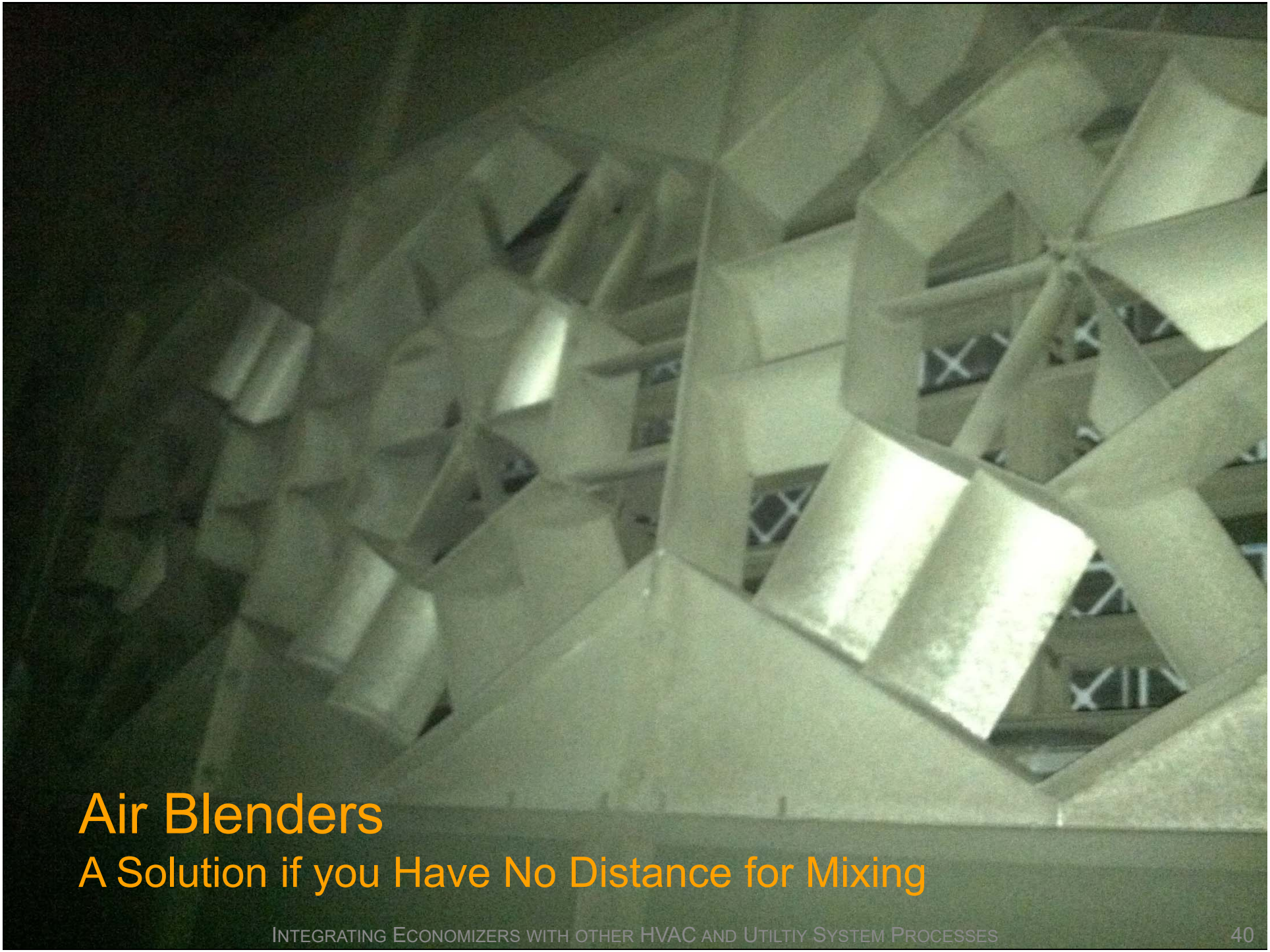
Mixing Performance Depends on Having Some Distance to Mix

Mixing Boxes Don’t Have to be Bolted to the Air Handling Unit



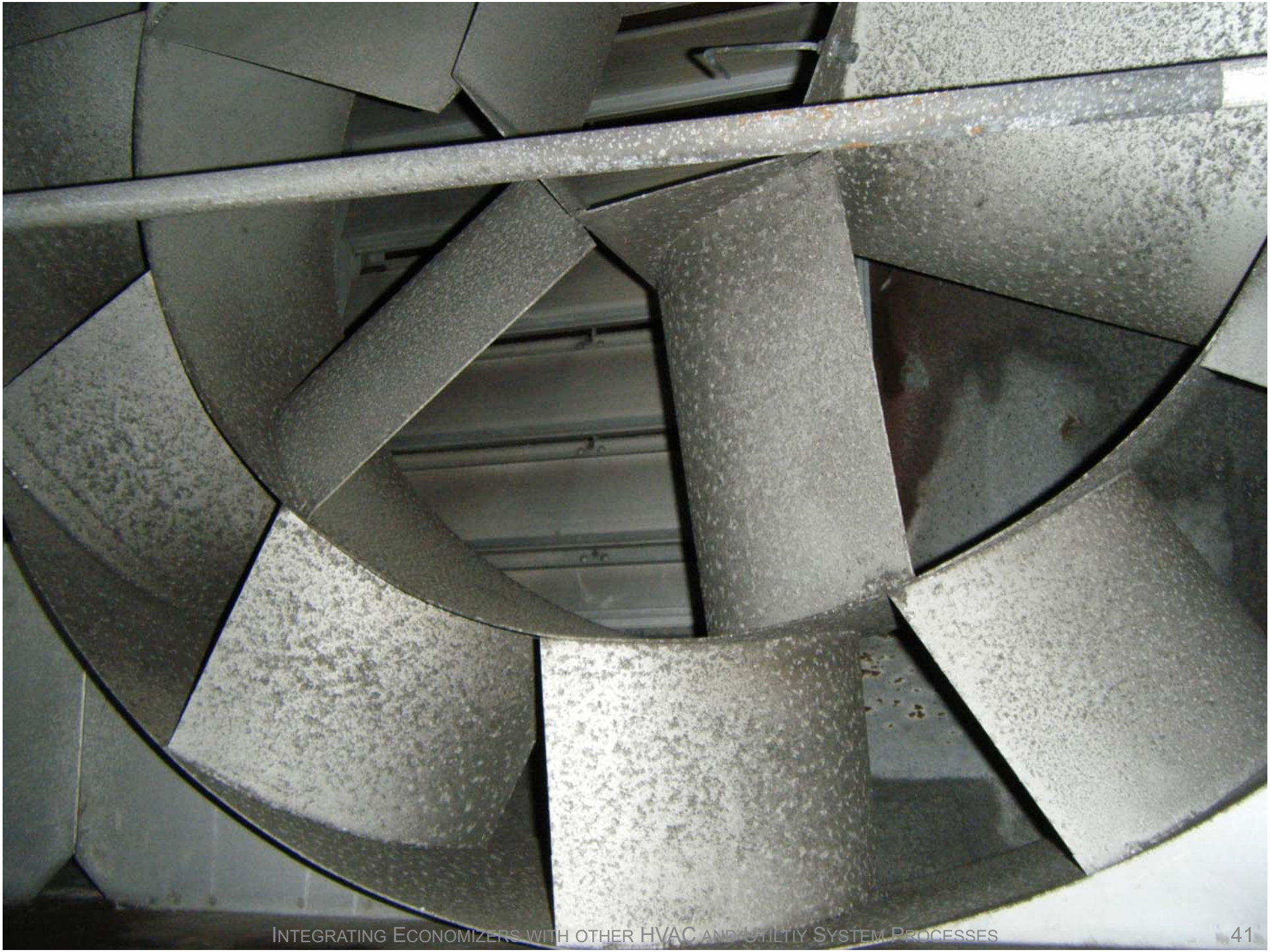
Mixing Boxes Don’t Have to be Bolted to the Air Handling Unit





Air Blenders

A Solution if you Have No Distance for Mixing



Mixing Performance Depends on Accurate Measurement of the Mixed Air Temperature

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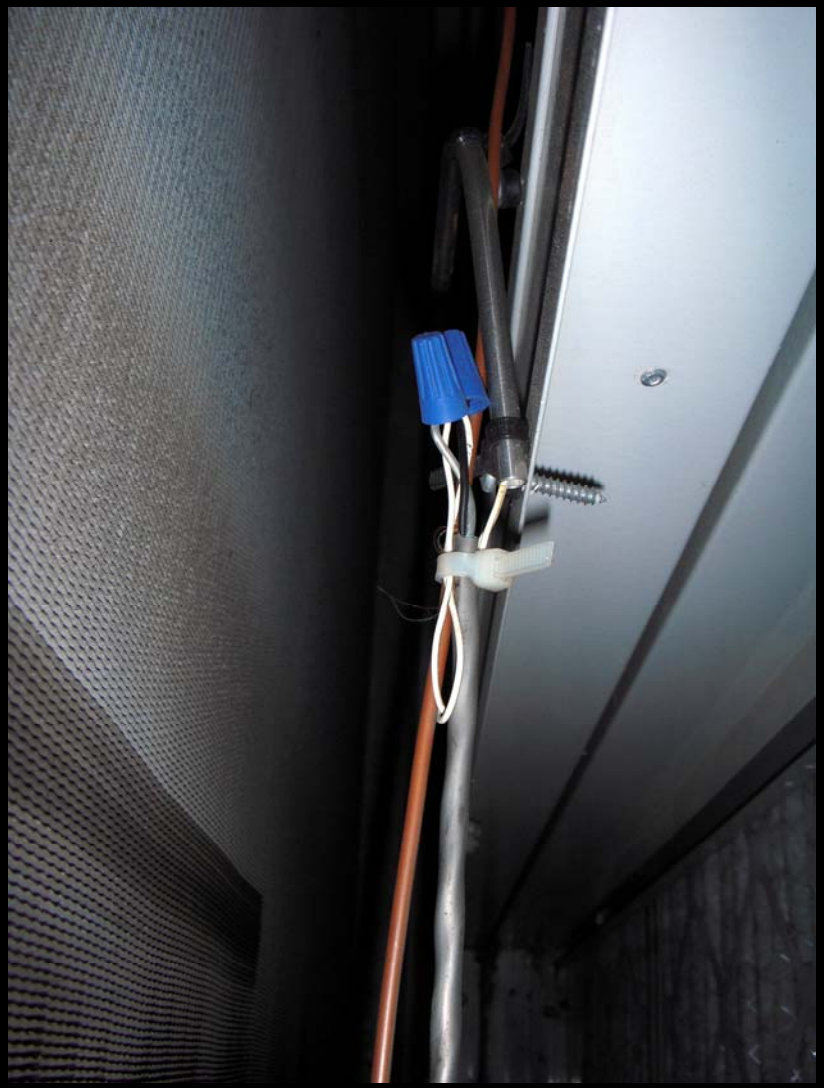

Entering Fitler Temps.

55.1	53.4	52.7	56.1
55.1	53.4	52.7	56.1
56.1	63.6	60.9	64.8
56.1	63.6	60.9	64.8

The sensor to the left is located where the green dot is in the matrix above

Sensing What is Really Going On

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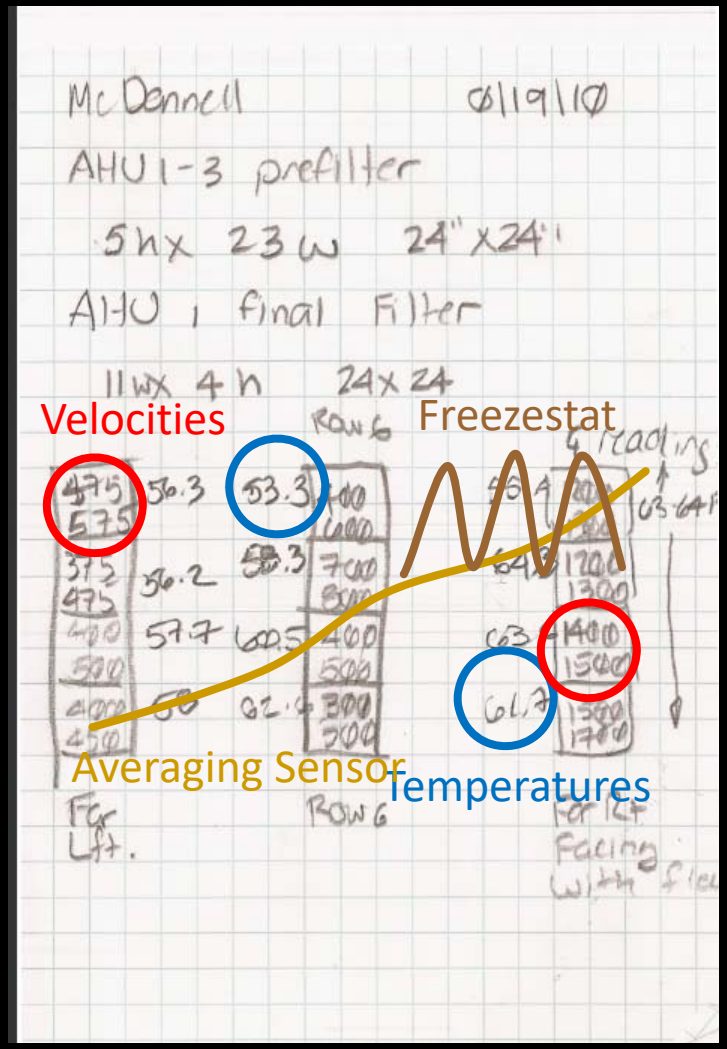
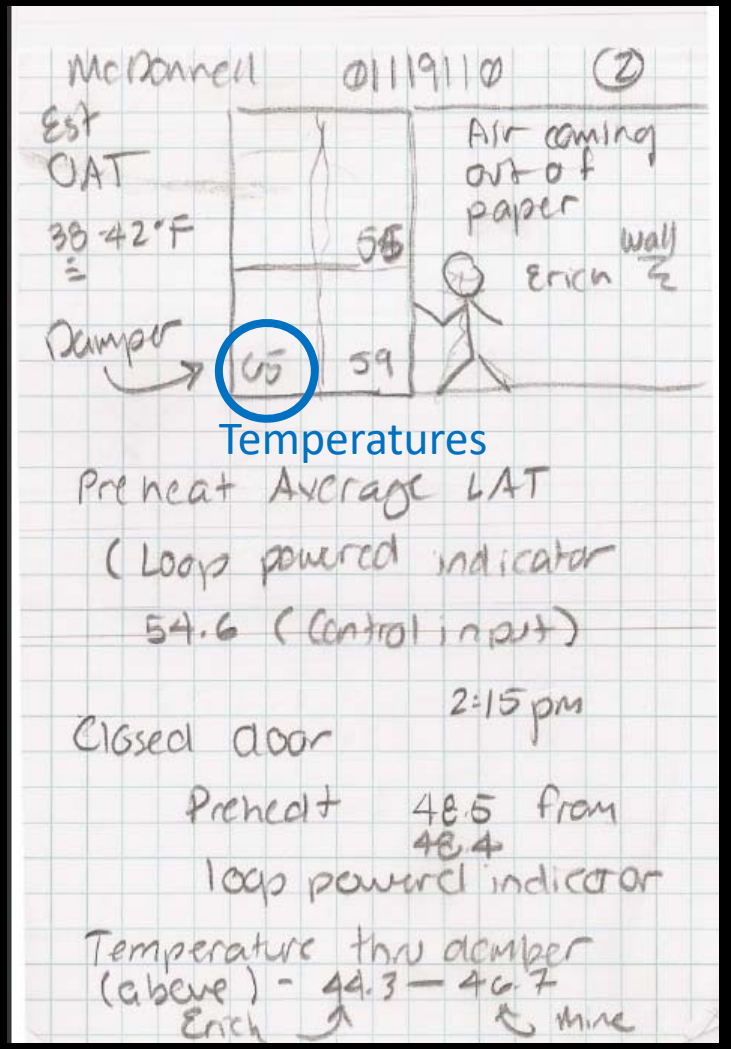
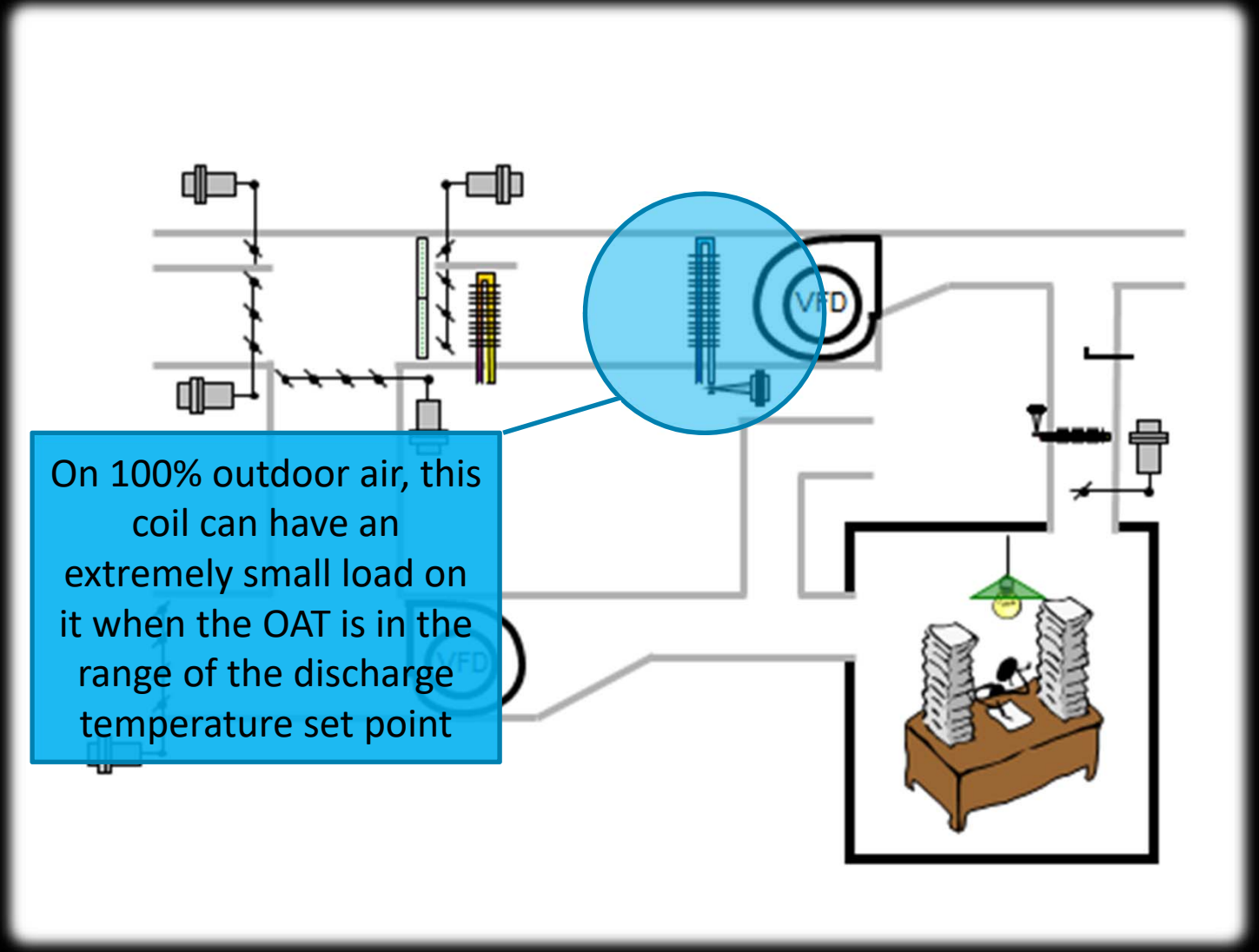
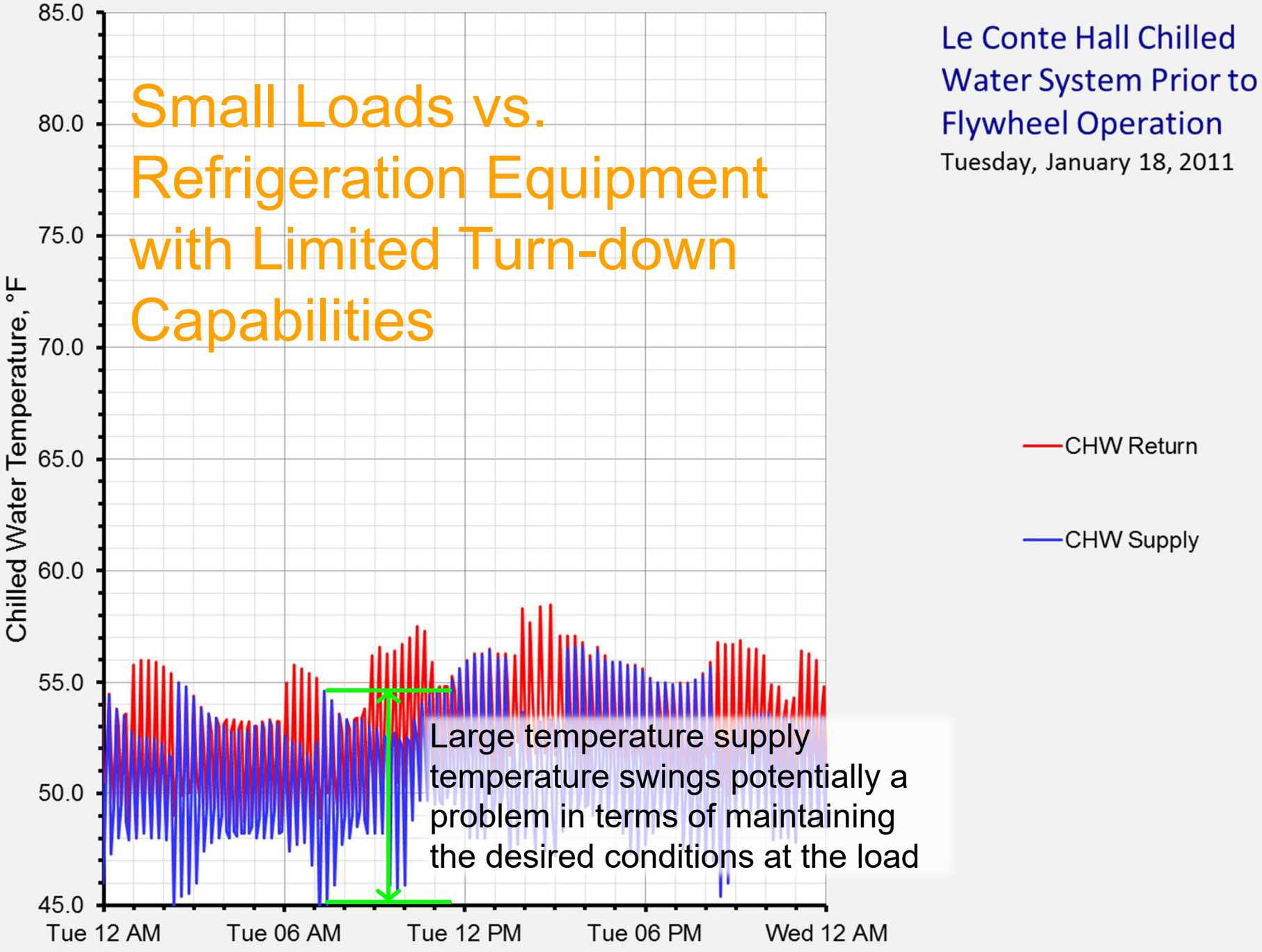


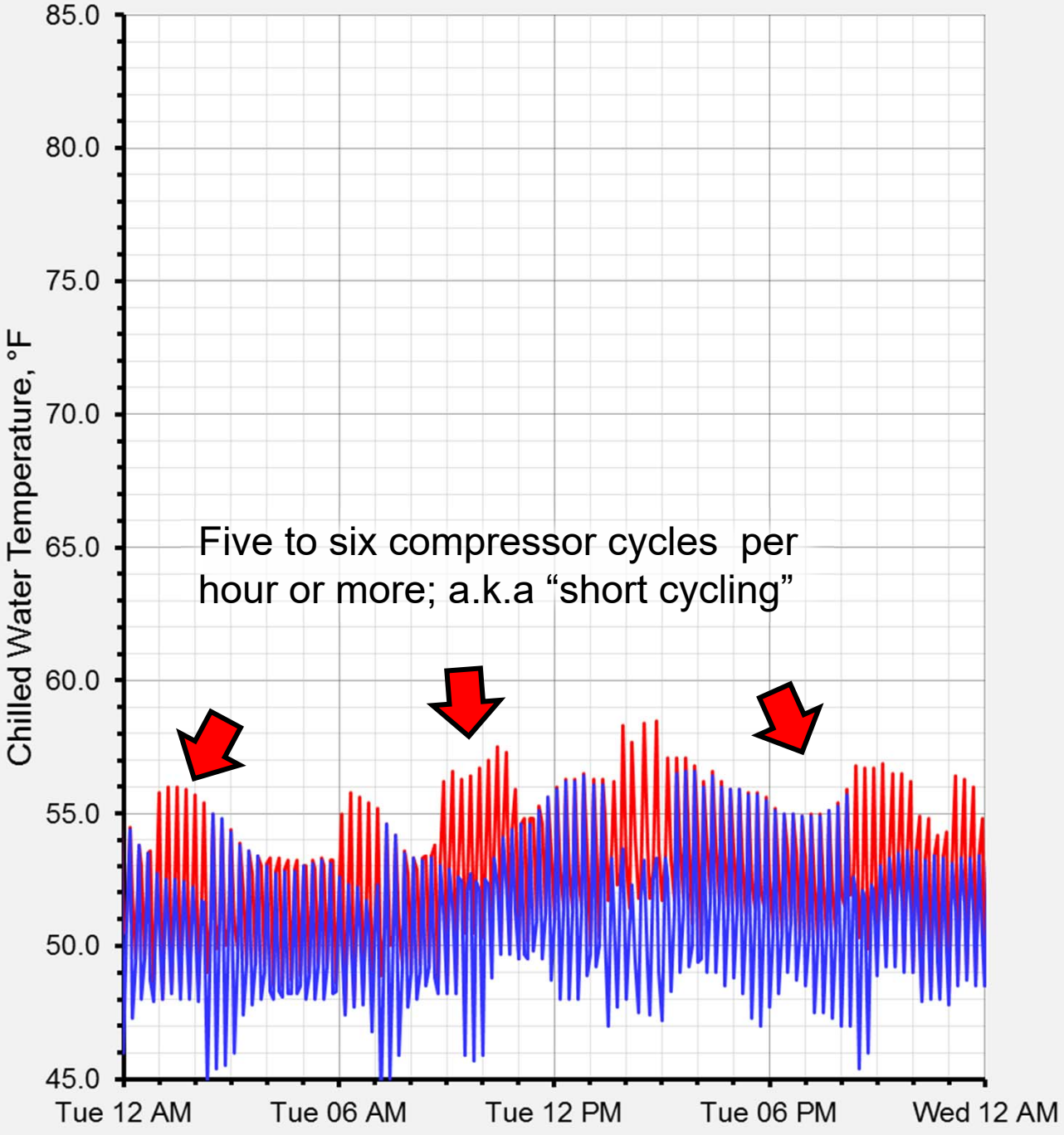


Integrating Mechanical Cooling is Harder than it Seems



Small Loads vs. Refrigeration Equipment with Limited Turn-down Capabilities




Le Conte Hall Chilled Water System Prior to Flywheel Operation
Tuesday, January 18, 2011
Chilled Water Temperature, °F
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
Tue 12 AM
Tue 06 AM
Tue 12 PM
Tue 06 PM
Wed 12 AM
Five to six compressor cycles per hour or more; a.k.a “short cycling”
CHW Return
CHW Supply

Definition

Freezing

A condition that occurs when water is cooled to the point where it changes phase from a solid to a liquid.

Definition

Water Damage

A condition that occurs after frozen water contained in a HVAC coil changes back to the liquid phase.

Definition

Expletive

A generic reference to the field terminology used to describe and discuss water damage when it occurs.

Definition

Significant Emotional Event

Any event in your life with life-changing emotions associated with it.

Freezing a coil is an example.

Protection from Freezing

Step 1

Close the outdoor air and relief dampers when the fan is off

Considerations:

- *Hardwired vs. software interlock*

Protection from Freezing

Step 2

Provide a safety interlock; typically called a "freezestat"

Protection from Freezing

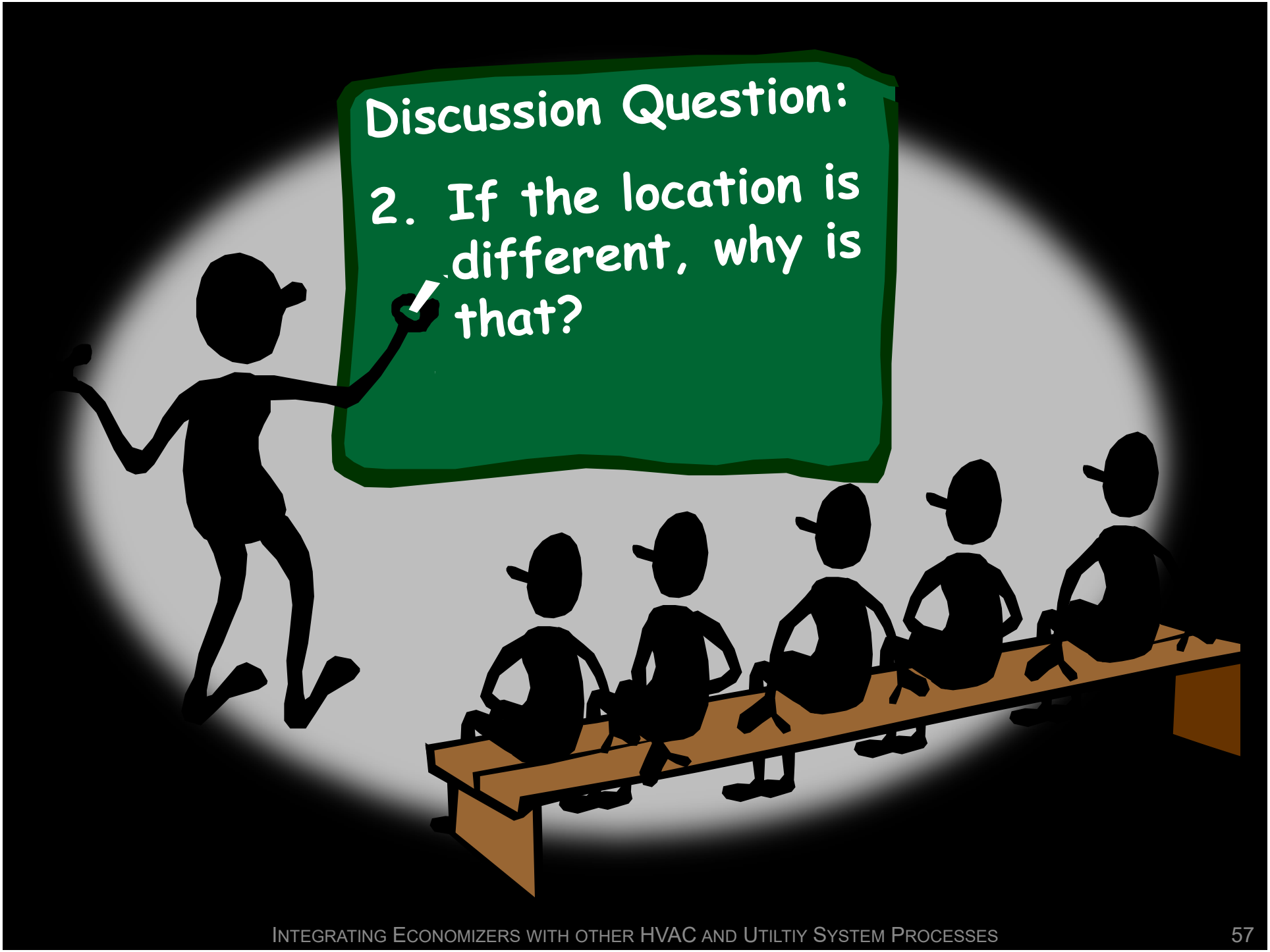
Step 2

Provide a safety interlock; typically called a "freezestat"

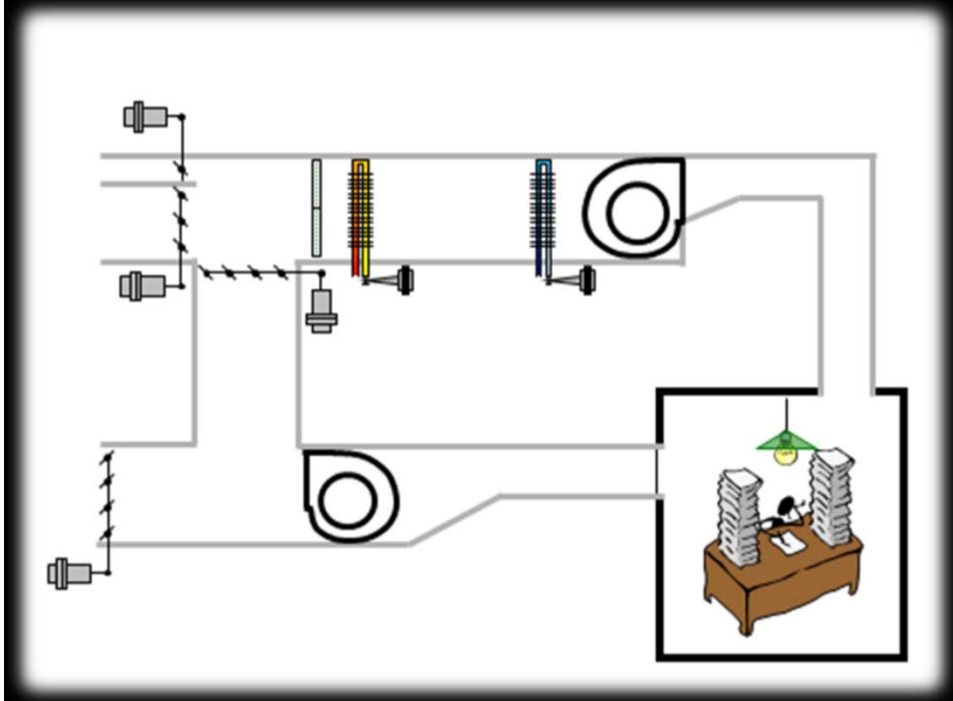
Considerations:

- *Hardwired vs. software interlock*
- *Not an averaging element*
- *Several may be required to fully cover the mixed air plenum*

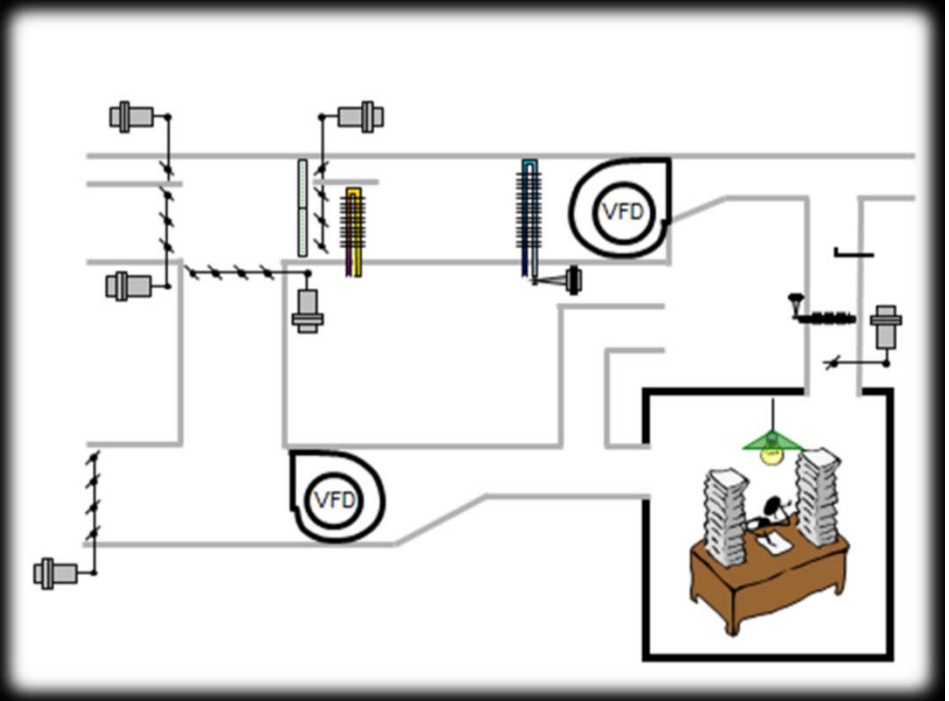

Discussion Question:
1. Where should the freezestat be located in the systems on the next slide?


Discussion Question:
2. If the location is different, why is that?

Protection from Freezing



- Hot water coil is for warm-up purposes
- Low MOA %; mixed air temperature on minimum outdoor air always above freezing

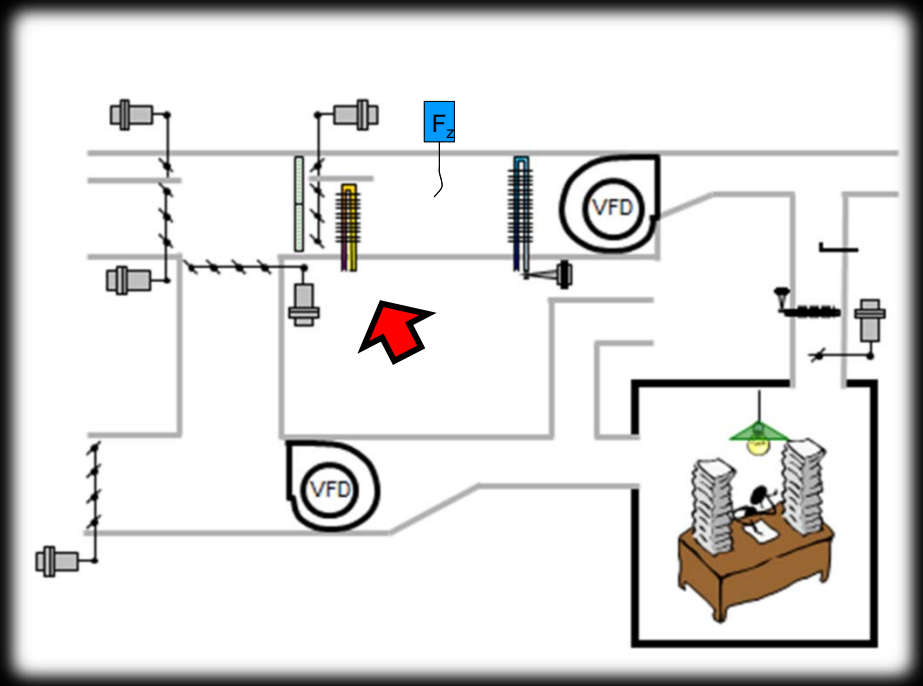


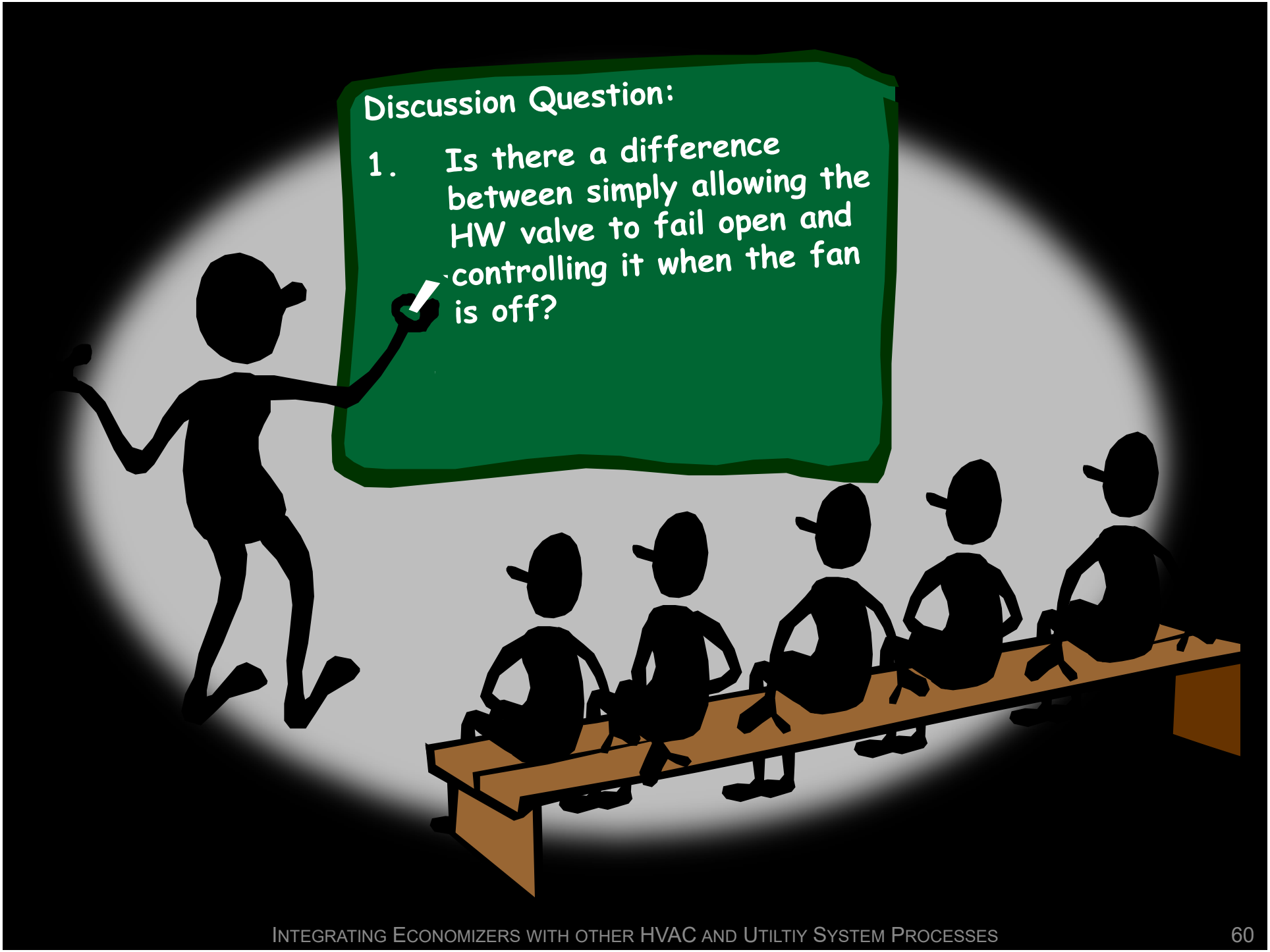
- Hot water coil is for warm-up and preheat purposes
- High MOA %; mixed air temperature on minimum outdoor air could be below freezing

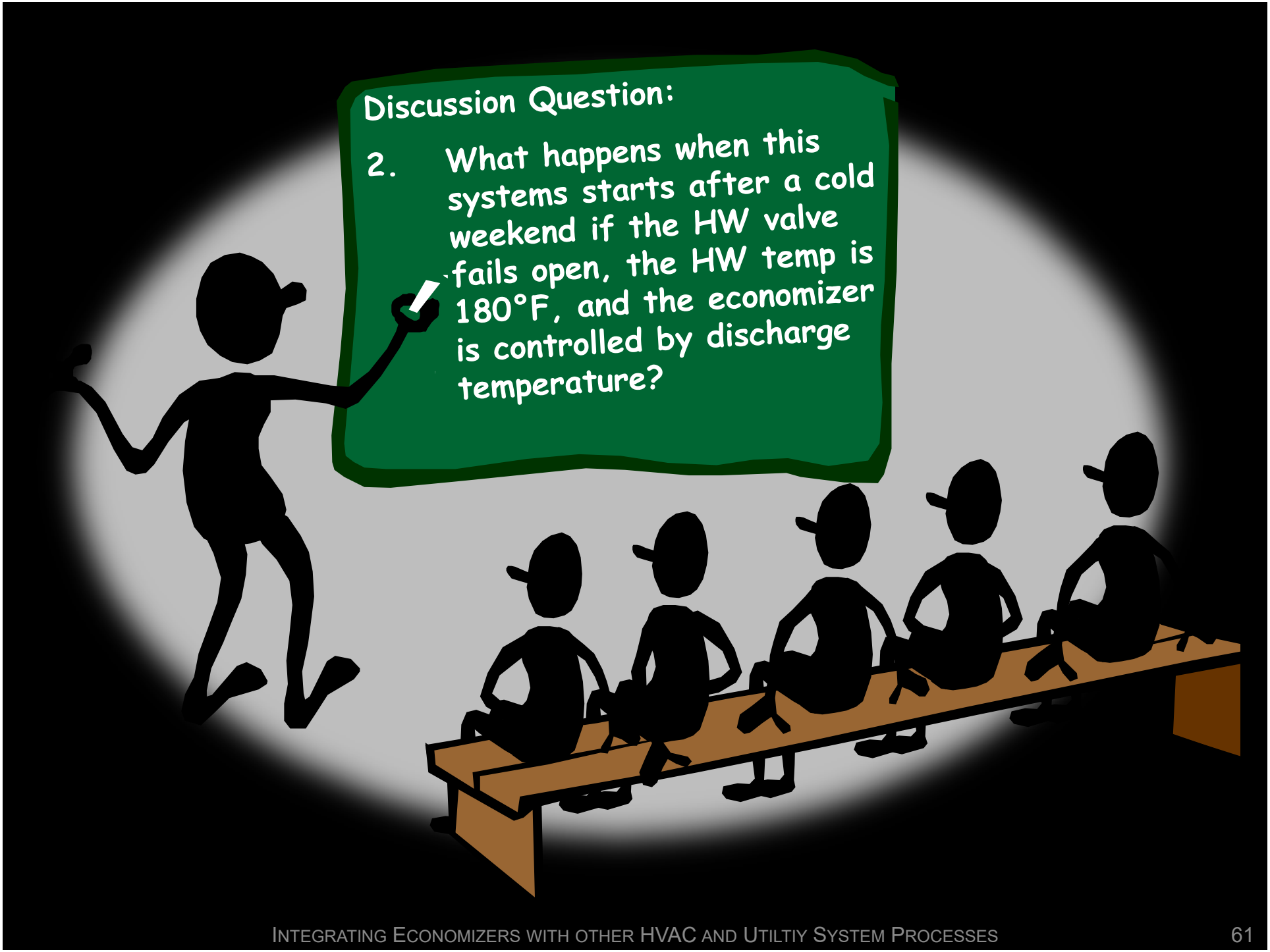
Protection from Freezing

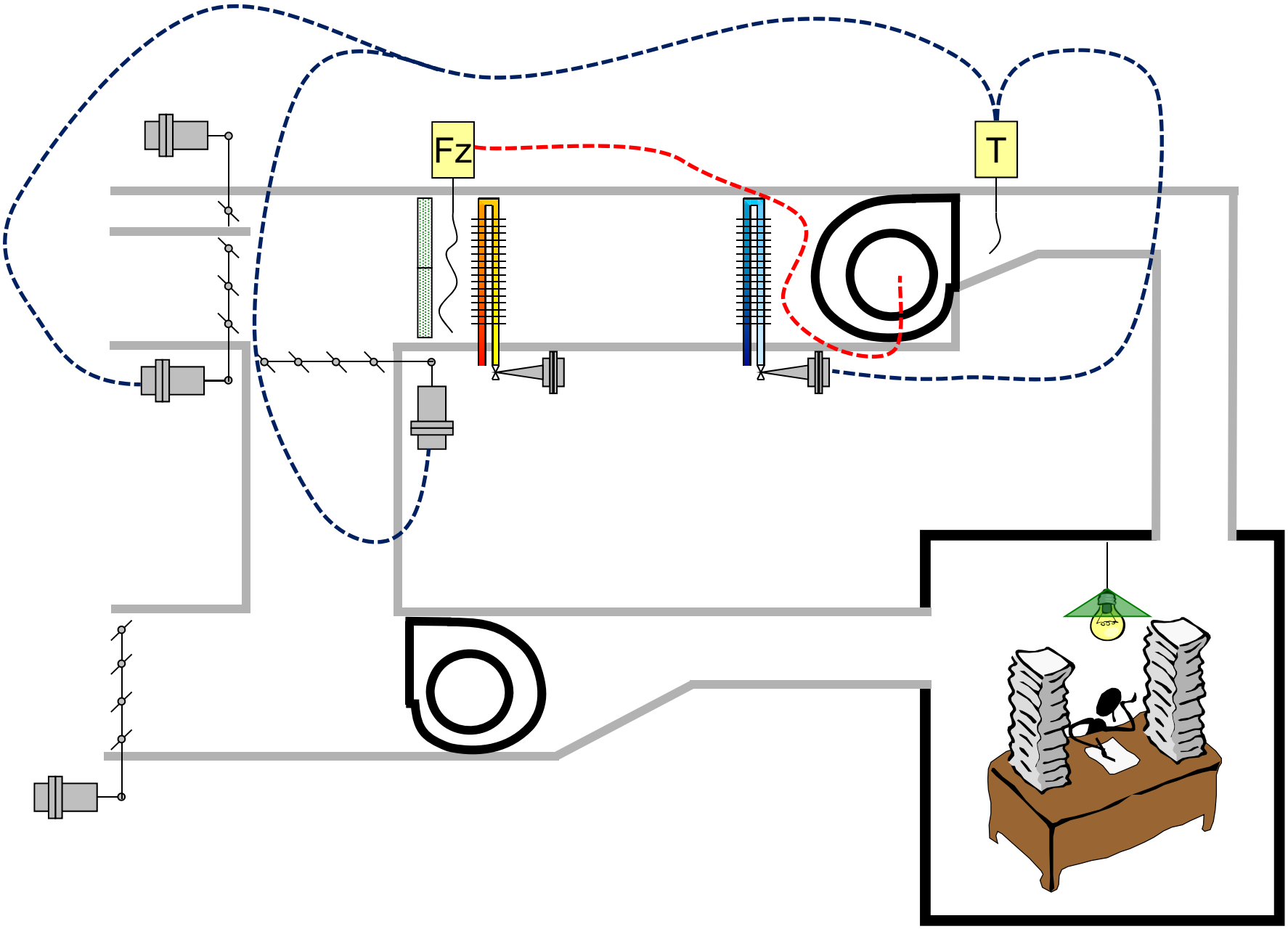
Step 3

Keep the hot water coil active when the unit is off




Discussion Question:
1. Is there a difference between simply allowing the HW valve to fail open and controlling it when the fan is off?


Discussion Question:
2. What happens when this systems starts after a cold weekend if the HW valve fails open, the HW temp is 180°F, and the economizer is controlled by discharge temperature?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Integration with Ventilation and Flow Control Processes Occurs at a Number of Locations