ASHRAE Guideline 36 – Advanced HVAC Control Sequences

Cx associates LLC

***Rick Stehmeyer* - Senior Engineer**

***Matt Napolitan, P.E., CCP, CPMP, LEED AP BD+C* - Principal**

Note: If you're reading this in PDF Format, please keep in mind it was sourced from a presentation and there are cues to click listed in the notes that would trigger animations in the presentation. Please ignore these cues in the following notes.

About us:
Rick Stehmeyer
Matt Napolitan

Presentation Overview

- Guideline 36 is 176 pages. We will not cover EVERYTHING!
- GL 36 advocates for:
  - Using technology, experience and science, even if it results in complexity, to reduce energy use.
  - Using Closed Loop Controls
  - Using the variable you are trying to control to inform your control system.
  - Identifying potential problems before they become alarms.

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Guideline 36 is long and comprehensive. We won't cover it all.

To give you an idea of some key points in the GL…

GL 36 advocates for…

<click>

Concepts in this Presentation

- Purpose and Scope of Guideline 36
- Document Arrangement
- Zone Grouping and Control
- VAV with Reheat Control
- Multizone AHU Mixing Box Control
- Closed Loop SAT Reset
- Using an Importance Multiplier and Heating and Cooling Requests
- SAT Trim and Respond
- Controls Network Architecture
- Smart Alarming
- FDD

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The concepts we'll cover are…

I told you we'd have to move quickly.

I'll turn it over to Rick to get us started.

<click>

Current State of Affairs

4

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Energy Efficiency can be achieved many different ways.

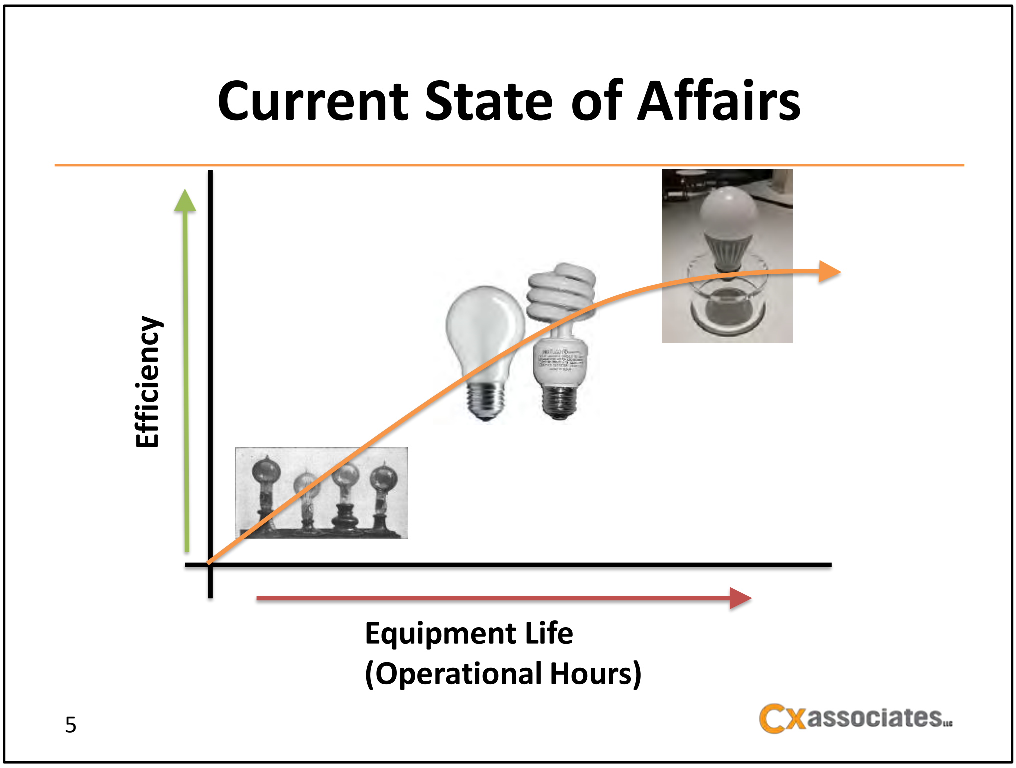
Historically efficiency is achieved by swapping out hardware.

This works in a lot of cases and makes technical and financial sense.

Cars for instance wear out both internally and externally.

They need to be entirely replaced.

Usually, the newer model is as affordable as the last one you bought, but comes with greater efficiency.



Since new equipment can live longer a barrier for greater efficiency is created as time goes on.

Nobody ran out and replaced all their perfectly good lightbulbs with CFLs when they came out. Same with LEDs.

You wait for your light bulb to die,

and all the ones on the shelf to die,

before you buy the next best tech.

Also, people have to accept the change,

remember when Obama pushed CFLs?

Efficiency has to be worked into our culture as well as in to our technology.

So we have to consider energy efficiency via the process of hardware-swap-out to be a limited resource.

Hardware in this setting for us means these guys <click>

Ye Old Bulbs:
https://upload.wikimedia.org/wikipedia/commons/8/80/Edison_incandescent_lights.jpg

CFL & Incan:
https://upload.wikimedia.org/wikipedia/commons/c/c8/Incandescent_and_fluorescent_light_bulbs.png

LED :
https://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Hitachi,_LED_light_bulb,_LDA15D-G,_E26_cap,.jpg/180px-Hitachi,_LED_light_bulb,_LDA15D-G,_E26_cap,.jpg

Rick

Get outside the box. No really.

6

We have to use our innovation, imagination and knowledge to find efficiency here.

With Roof top units, with AHUs, with HVAC equipment you have in your building right now.

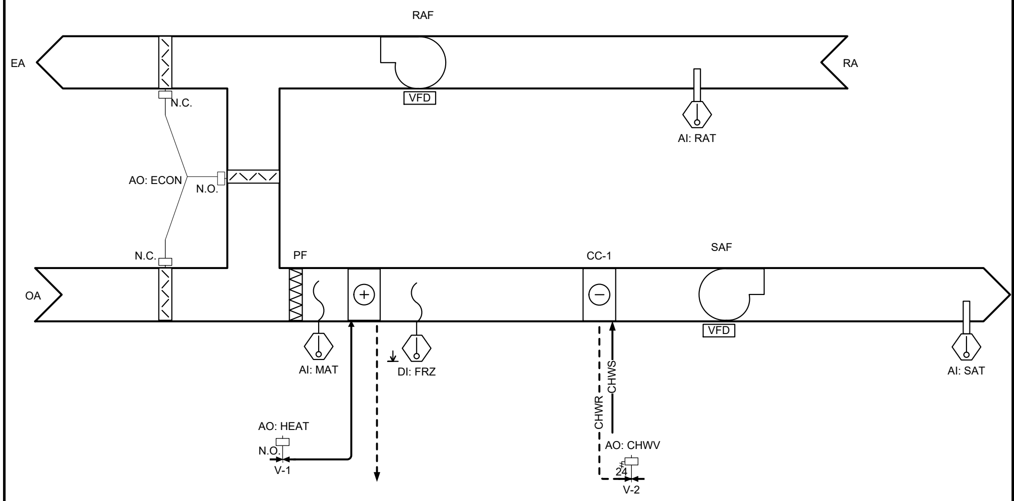
We have to think outside the box of “more efficient hardware”.

We have to challenge status quo and get outside our “comfort zones” with approach (excuse the pun)

<click>

RTU :
https://upload.wikimedia.org/wikipedia/commons/9/90/Rooftop_Packaged_Units.JPG
Rick

Current state of HVAC Design



7

There are a lot of barriers to efficiency that we need to consider.

First off is the status quo as shown here, in particular the mixing box.

Status quo sequences and configurations of HVAC equipment currently dominate the industry.

Source: Cx Associates

Rick

We’ve always done it this way

8

All this makes a culture where changing building automation systems is difficult.

Its confusing to most folks, and there tends to be a lot of educated guess work and repeating “what works”

Image Source: https://pixabay.com/en/road-sign-arrow-advance-change-1076229/

Rick

The most dangerous phrase

9

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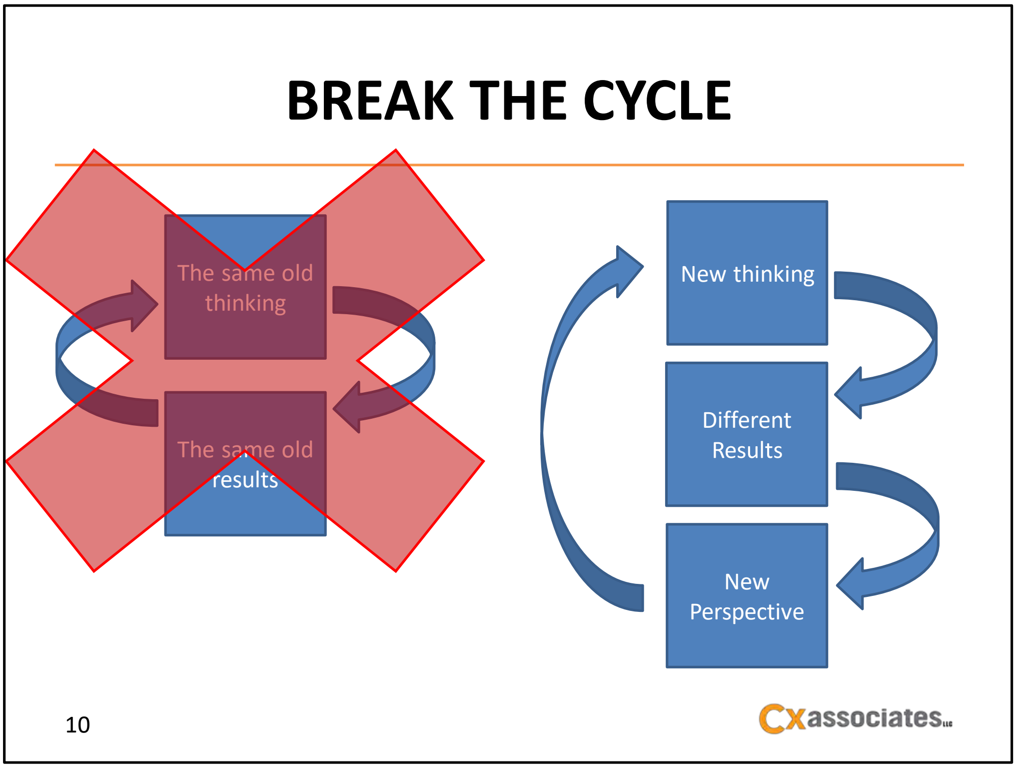
But this causes stagnation and may result in excessive energy use.

Image Source: https://pbs.twimg.com/media/CoDZrP8XEAEydEK.jpg
Rick



We need to break the cycle of this type of “do what works” thinking.

<matt> 4:12

Rick

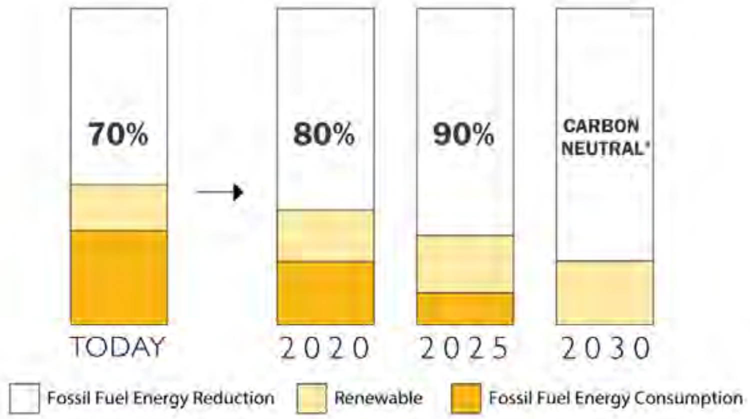
The 2030 Challenge

"We're a non-profit think tank transforming climate change problems into solutions through the design of the built environment"

CXassociates

Founded by Edward Mazria in 2002 within his own practice first.
Matt

The 2030 Challenge

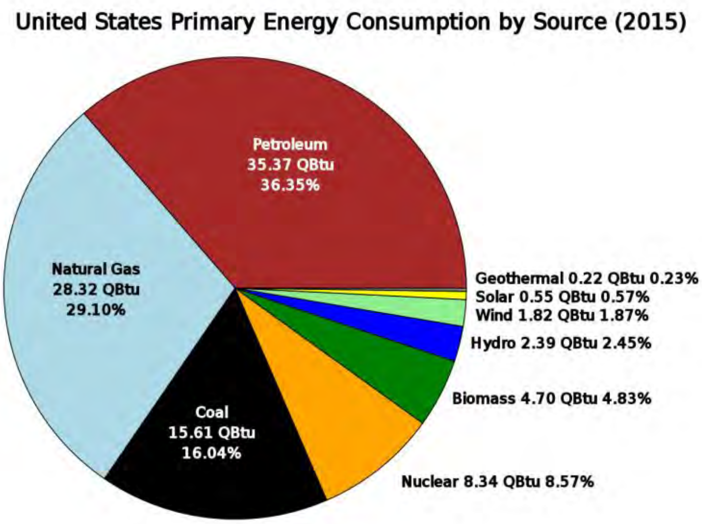


The 2030 Challenge

*Using no fossil fuel GHG emitting energy to operate

Matt

Energy Production in USA

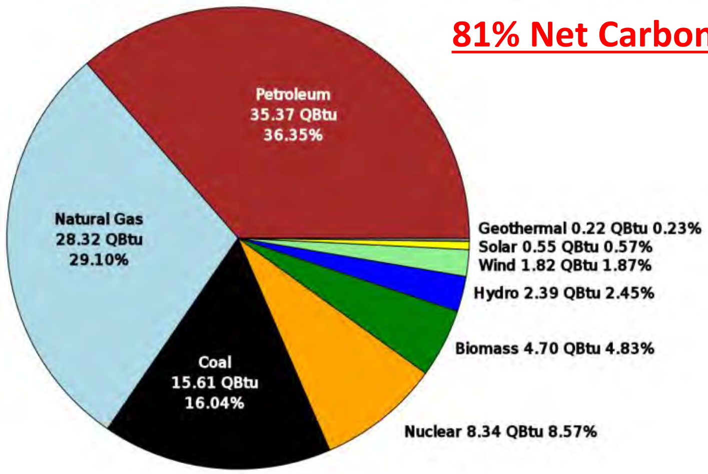


Matt

Energy Production in USA

United States Primary Energy Consumption by Source (2015)

81% Net Carbon Emitters



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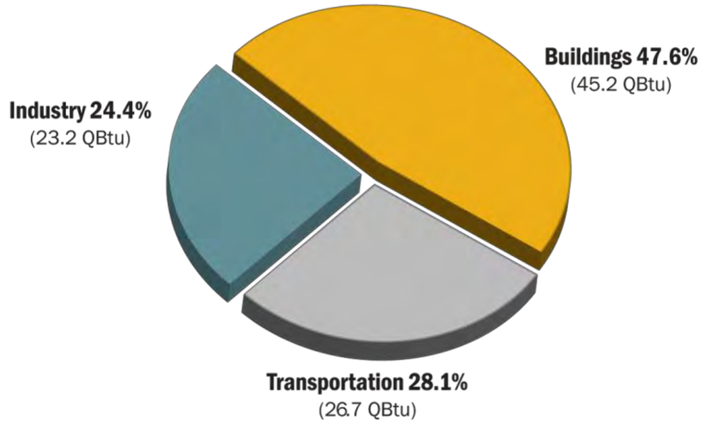
Matt

Energy Consumption in USA



U.S. Energy Consumption by Sector

Data Source: U.S. Energy Information Administration (2012).

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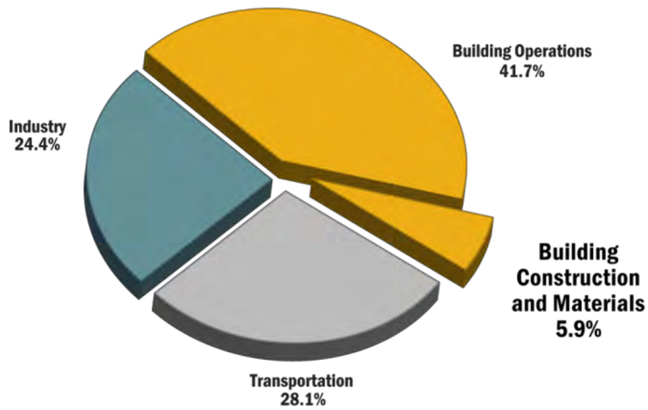
Matt

Energy Consumption in USA



U.S. Energy Consumption by Sector

Source: ©2013 2030, Inc. / Architecture 2030. All Rights Reserved.
Data Source: U.S. Energy Information Administration (2012).

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Matt

The AIA Is On Board

AIA 2030™

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AIA 2030 Commitment provides A/E firms with a roadmap to measure and improve towards achieveing the goal.

Matt

ASHRAE Is On Board

CXassociates

ASHRAE is working to provide engineers with the tools to realize the 2030 commitment.

Matt

Guideline 36

BSR/ASHRAE Guideline 36P

__________Advisory Public Review Draft

High Performance Sequences of Operation for HVAC Systems

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One of those tools is GL 36.

Matt

The Guideline currently only covers Air Side systems only

Note: From Avatar the last air bender – Check this out if you've not seen it.

Image Source:
http://i1222.photobucket.com/albums/dd484/EuTerak/Korra%20gifs/i3zriRdN4nzIc.gif
http://3.bp.blogspot.com/-qMHmBAJx1vY/VlutNRukyUI/AAAAAAAAAZQ/R7ArYaQk_fs/s1600/tumblr_mgxz6ceMyH1rgq6iro1_500.gif
http://i1222.photobucket.com/albums/dd484/EuTerak/Korra%20gifs/i3zriRdN4nzIc.gif
http://www.playbuzz.com/geekgirl10/how-well-do-you-know-avatar-the-last-airbender-and-avatar-the-legend-of-kora

Matt

Guideline 36 – Field Verified

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Energy savings have been proven in field testing

These are not pie-in-the sky “bright ideas”. They’ve been proven.

Matt

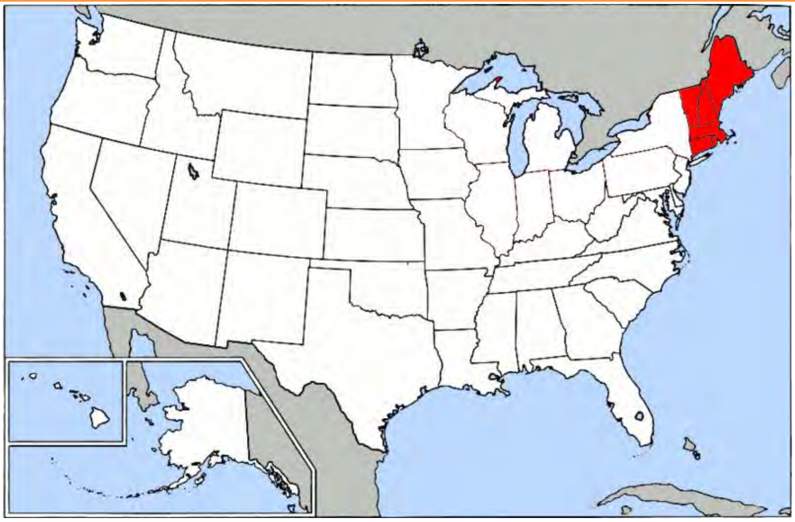
Guideline 36 – Verified on the West Coast

On the west coast.

<click>

Matt

Guideline 36 – In New England



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When you translate those sequences of operation to northern New England, you can't take everything for granted.

<click> for thinking cap

Matt

Guideline 36 – In New England

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That means you have to put on your thinking cap and sharpen your pencils.

Especially when it comes to building pressure control and OA damper sequencing.

<click>

Matt

The GL DOES NOT require a bunch of new hardware

In a typical AHU set up, you are adding MAYBE two damper actuators and two air flow stations.

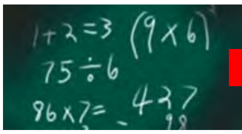
That’s it! All the gains that GL 36 gives us are done with more thoughtful applications of sequences of operation including better use (or the use at all) of available information.

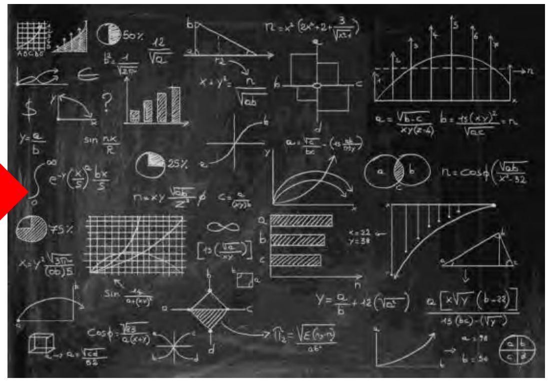
<click>

Matt

Guideline 36

- Sequences are more complex and more involved than the status quo.





"Wringing more efficiency out of VAV systems requires more complex sequences of operation."

Sequences are more complex, necessarily. Nothing is rocket science, but it needs careful attention.

The GL is not yet publicly released. It does not cover ALL HVAC systems yet.

Rick is going to go over the systems and equipment currently covered by the GL.

<click> 8:30
Matt

Document Arrangement

- Guideline 36 is a collection of sequences:
  - Standardization is the goal
  - Contains
    - Definitions
    - Point Layouts
    - Sequences
    - FDD

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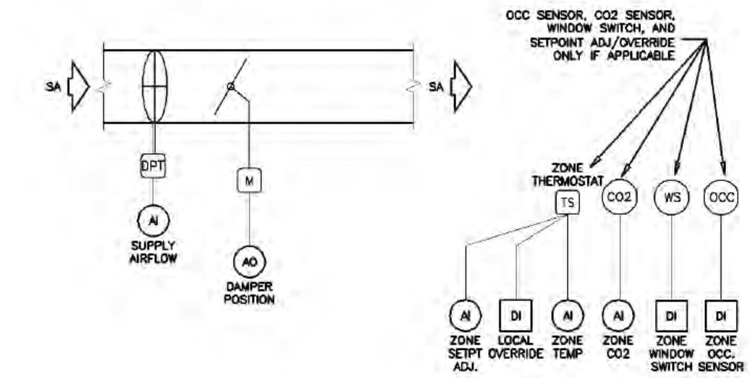
RIck

Guideline Overview and Systems

A. VAV Terminal Unit, - Cooling Only



28

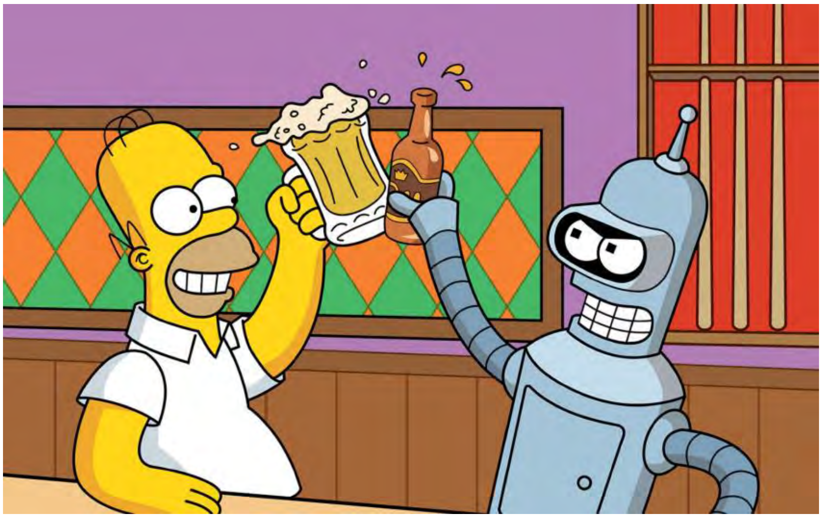
The guideline covers air side systems and provides point layouts for each system covered.

This is really nice because this allows both designers and implementers to standardize their layouts on each job.

You will always know what is expected for hardware for your application.

Image Source: GPC36 PPR1 05-16-2016
Rick

Designers and Implementers Working Together



29

They wanted to reduce time for both design engineers and control contractors by uniting them under common practice, and while advancing the state of the art.

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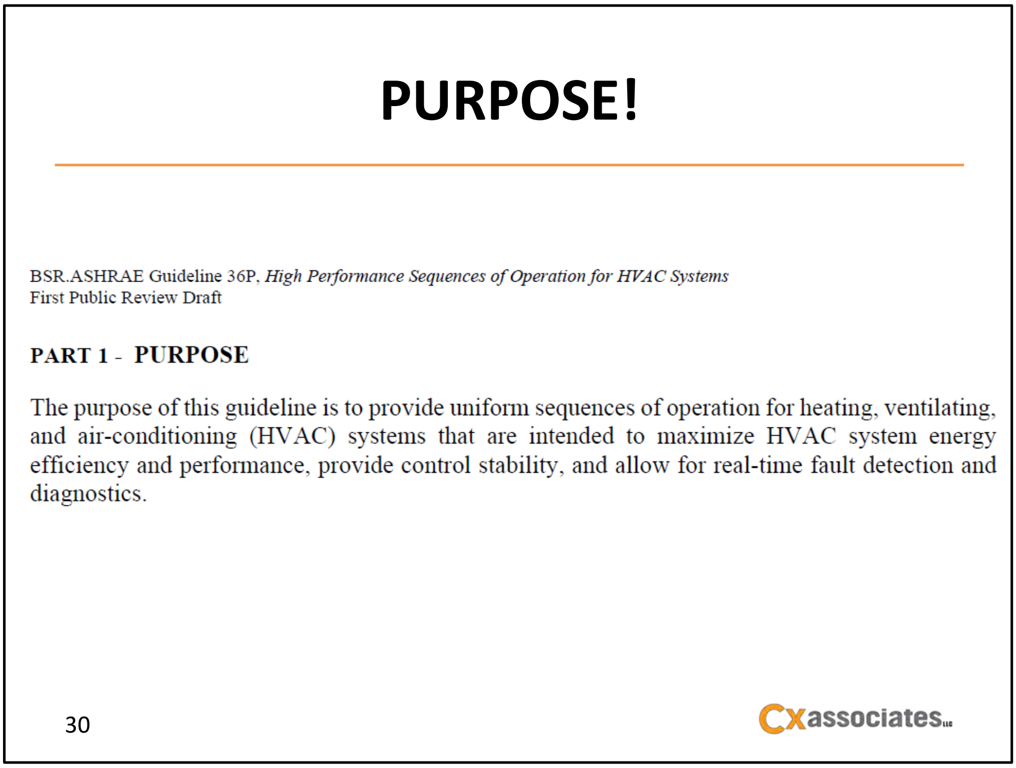
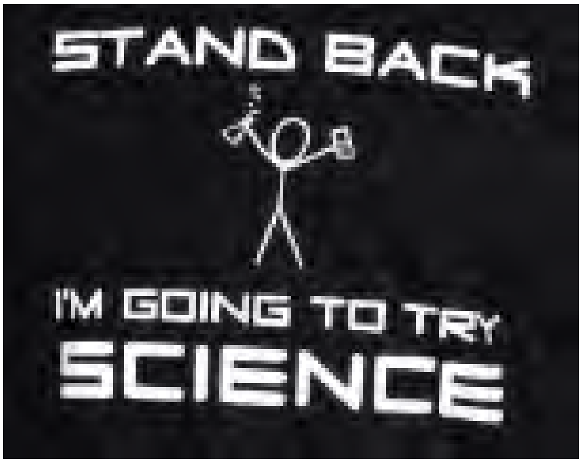
Image Source: https://i.stack.imgur.com/zcq8S.jpg
Rick



Purpose: Provide uniform sequences of operation for heating, ventilating, and air-conditioning (HVAC) systems that are intended to maximize HVAC system energy efficiency and performance, provide control stability, and allow real-time fault detection and diagnostics

Image Source: https://i.stack.imgur.com/zcq8S.jpg
Rick

Born out of research



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They incorporated ASHRAE Standards

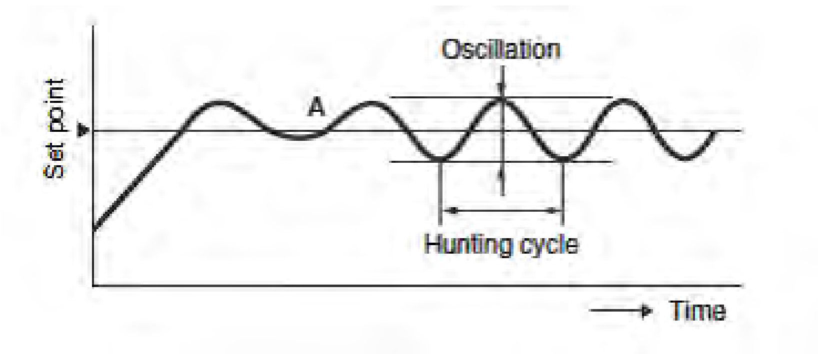
90.1 (Energy)
55 (Comfort)
62.1 (Ventilation)

Tech committee 1.4’s other current research projects are informing the guideline as they progress.

Image Source: https://store.xkcd.com/products/try-science

Rick

Born out of research



32

Tech committee 1.4's other current research projects are informing the guideline as they progress.

One exciting examples is

RP-1587, Control Loop Performance Assessment

and

RP-1746, Validation of RP-1455 Advanced Control Sequences for HVAC Systems – Air Distribution and Terminal Systems.

This is a research project to create testing for GL36 compliance

THE POINT IS THAT ASHRAE IS TAKING THIS VERY SEROIUSLY AND IS DEDICATING SIGNIFICANT RESOURCES TO GETTING THIS RIGHT.

Image Source: https://www.ia.omron.com/support/faq/answer/include/faq00667/img/FAQ00667-1.jpg

Application

33

It applies to mainly commercial office buildings currently, but can be adapted to most commercial buildings with multizone VAVs.

Any use of the guideline has to be done in a conscientious manner. That is,

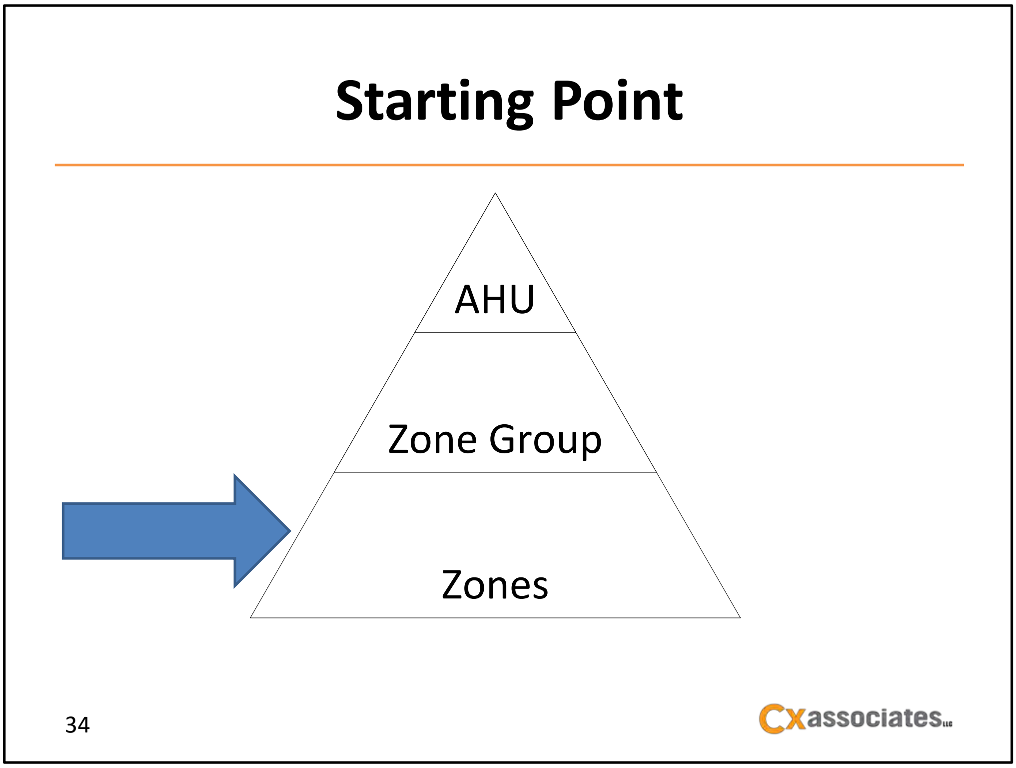
It is not something you can take off the shelf verbatim and just stick into a spec document.

So lets dive in to the first set of equipment the document covers:

<Click>

Image Source: https://planetlandon.files.wordpress.com/2009/01/office-space-06_full1.jpg

Rick



The guideline starts at the bottom level of any building: the zones

Image Source:

Rick

Spaces? Zones?

35

It begins by defining the characteristics of zone control instead of leaving it up to imagination.

Image Source: http://theredlist.com/media/database/films/tv-series/fantasy-and-sci-fi/1950/the-twilight-zone/001-the-twilight-zone-theredlist.jpg

Rick

Zone Control Characteristics

Zone Type	Occupied		Unoccupied	
	Heating	Cooling	Heating	Cooling
VAV	21°C (70°F)	24°C (75°F)	16°C (60°F)	32°C (90°F)
Mech./Elec Rooms	18°C (65°F)	29°C (85°F)	18°C (65°F)	29°C (85°F)
Networking/Computer	18°C (65°F)	24°C (75°F)	18°C (65°F)	24°C (75°F)

This means starting set points

Image Source:

Rick

Zone Control Characteristics

Occupancy Category	CO_2 Setpoint (ppm)	Occupancy Category	CO_2 Setpoint (ppm)
Day Care Sickroom	716	Computer (Not Printing)	738
Classrooms (Age 5 – 8)	864	Pharmacy (Preparation Area)	820
Classrooms (Age 9+)	942	Photo Studios	983
Lecture Classroom	1,305	Transportation Waiting	1,305
Lecture Hall (Fixed Seats)	1,305	Public Assembly Spaces	
Art Classroom	837	Auditorium Seating Area	1,872
Science Laboratories	894	Place of Religious Worship	1,872
University/College Lab	894	Courtrooms	1,872
Wood/Metal Shop	1,156	Legislative Chambers	1,872
Computer Lab	965	Libraries	805
Media Center	965	Lobbies	2,628
Music/Theater/Dance	1,620	Museums (Children's)	1,391
Multiuse Assembly	1,778	Museum/Galleries	1,620
Food and Beverage Service		Retail	
Restaurant Dining Rooms	1,418	Sales (Except Below)	1,069
Cafeteria/Fast-Food Dining	1,536	Mall Common Areas	1,620
Bars, Cocktail Lounges	1,536	Barbershop	1,267
General		Beauty and Nail Salons	723
Break Rooms	1,267	Pet Shops (Animal Areas)	709
Coffee Stations	1,185	Supermarket	1,116
Conference/Meeting	1,620	Coin-operated Laundries	1,322
Hotels, Motels, Resorts, Dormitories		Sports and Entertainment	
Bedroom/Living Area	910	Spectator Areas	1,778

37

Including CO2 if you want demand control ventilation.

But it starts to get interesting right after these sections <click>

Image Source:

Rick

Deviation from Status Quo

5. Control Loops

a. Two separate control loops shall operate to maintain space temperature at setpoint, the Cooling Loop and the Heating Loop.

1) The Heating Loop shall be enabled whenever the space temperature is below the current zone heating setpoint temperature, and disabled when space temperature is above the current zone heating setpoint temperature and the Loop output is zero for 30 seconds. The Loop may remain active at all times if provisions are made to minimize integral windup.

2) The Cooling Loop shall be enabled whenever the space temperature is above the current zone cooling setpoint temperature, and disabled space temperature is below the current zone cooling setpoint tempe and the Loop output is zero for 30 seconds. The Loop may remain act all times if provisions are made to minimize integral windup.

b. The Cooling Loop shall maintain the space temperature at the active co setpoint. The output of the loop shall be a software point ranging from 0 cooling) to 100% (full cooling).

c. The Heating Loop shall maintain the space temperature at the active he setpoint. The output of the loop shall be a software point ranging from 0 heating) to 100% (full heating).

38

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Each zone is required to have two separate PIDs controlling the space temperature!!

This tends to be a shocker for some in the controls world who are very comfortable with the "keep it simple approach"

This is the typical reaction I get from those folks <click for animation>

Image Source: GPC36 PPR1 05-16-2016
https://media.giphy.com/media/5yTY0Gmntws4E/giphy.gif

Rick

Simultaneous Heating and Cooling

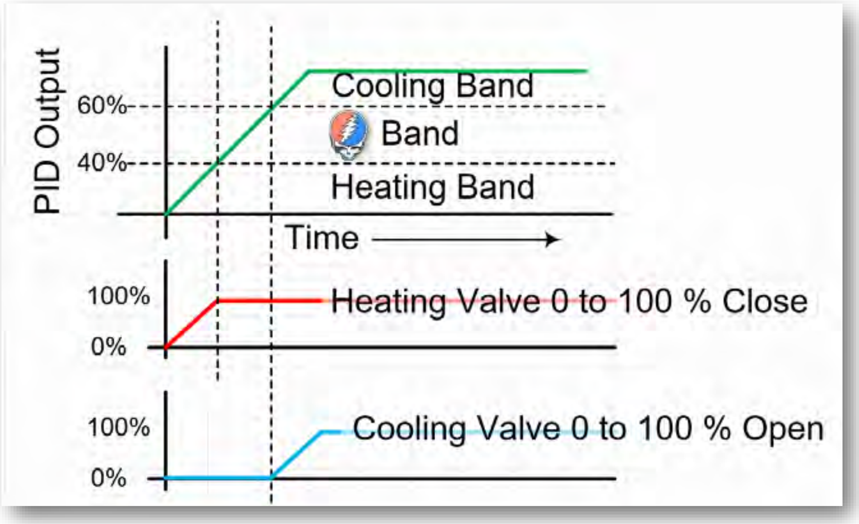
39

You'll have simultaneous heating a cooling!

Image Source: https://s-media-cache-ak0.pinimg.com/originals/06/c1/1c/06c11c35eb9d5d7be2ff305313266c15.jpg

Rick

"This is what we always do, it works!"



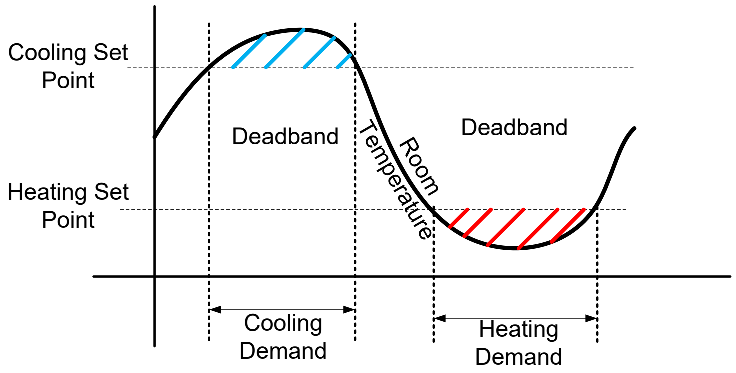
40

This was left over from pneumatics and carried over into DDC.

Image Source: https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcT0WNB1eHw67ryX4rLZomYLGPBCNt83fWuhYz5MFZCSoBjcD0ObQA

Rick

Deviation from Status Quo



41

Its ok, they can relax.

The Guideline specifies when you enable / disable the loops to prevent a tug of war.

They're only enabled when there is heating / cooling demand as shown here.

This too is important because your control product has to allow for a programmer to stop a loop from calculating or winding up.

Image Source:
Rick

Another Deviation from Status Quo

10. All setpoints, timers, deadbands, PID gains, etc., listed in sequences shall be adjustable by the user with appropriate access level whether indicated as adjustable in sequences or not. Software points shall be used for these variables. Fixed scalar numbers shall not be embedded in programs except for physical constants and conversion factors.

All hardware points, not just inputs, should be capable of being overridden for purposes of testing and commissioning. For example, the commissioning agent should be able to command damper positions, valve positions, fan speeds, etc., directly through Building Automation System (BAS) overrides.
The following requirement to equate hardware points to software points is necessary for systems that do not allow overriding real input points.

42

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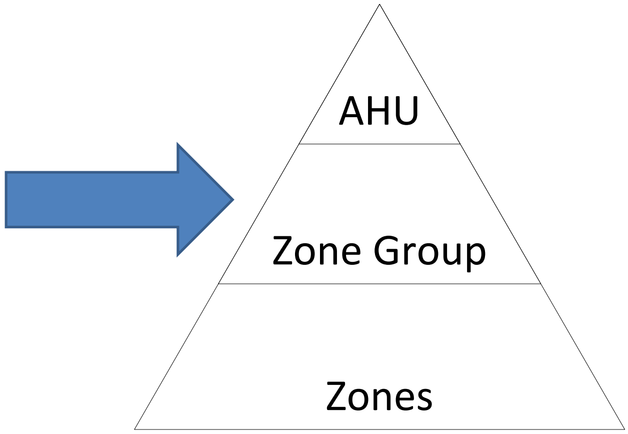
Also it calls for everything to be adjustable and overridable!

Image Source: GPC36 PPR1 05-16-2016
http://i.imgur.com/Waq9PDp.png
Rick

Grouping



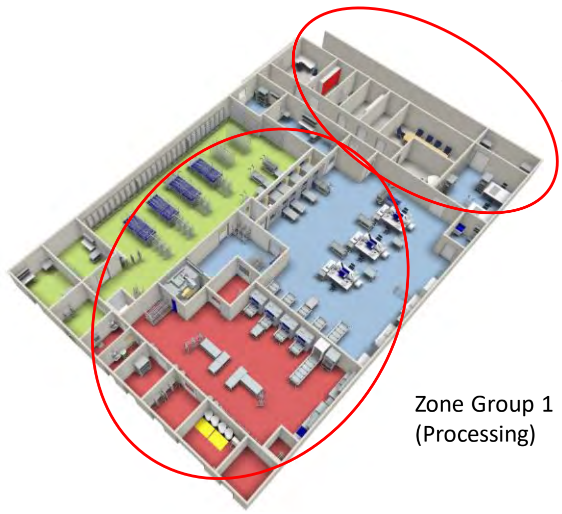
43

Then the describe zone groups.

Control might want to be grouped by area and process in that area.

Image Source:
Rick

Grouping



Zone Group 2
(Offices)

Zone Group 1
(Processing)

44

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Like Grouping Central Sterile processing in a smaller facility.

You might have some offices served by the same AHU as the area doing the work,

but they might not have the same schedule.

They might not even have the same setpoints or loads

However, they all represent a common load as far as the AHU is concerned.

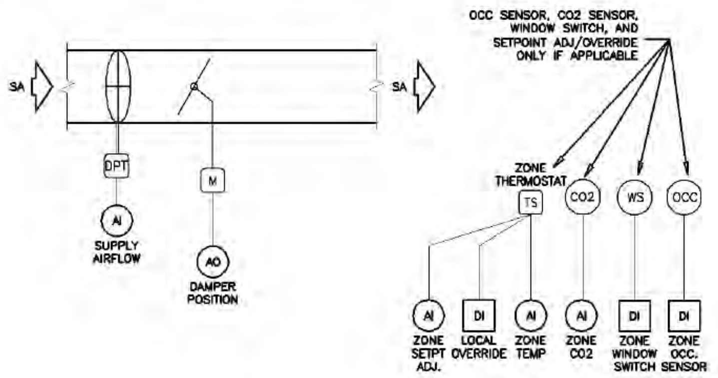
Image Source: http://www.getinge.com/files/architectural-portal/Picture%20Planning%20and%20Type%20Examples%20page.jpg
Rick

VAV with Reheat

- We are covering this because it is the most common piece of equipment
- The Guideline:
  - Links the VAV sequence to the Zone definition and zone Group definition
  - Provides point layout

VAVs!

A. VAV Terminal Unit, - Cooling Only



46

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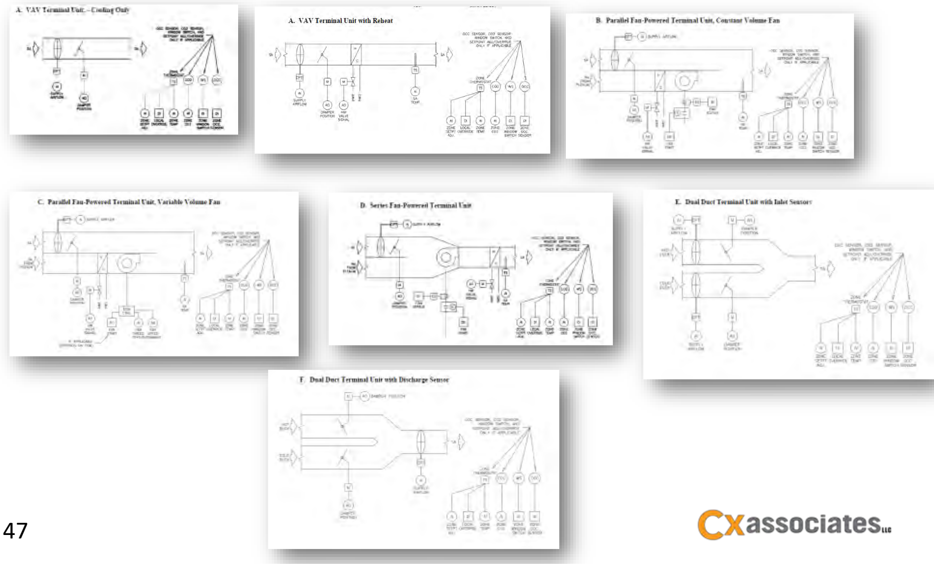
Lets dive into the VAV sequence shall we!

Image Source: GPC36 PPR1 05-16-2016
Rick

VAVs Covered



47

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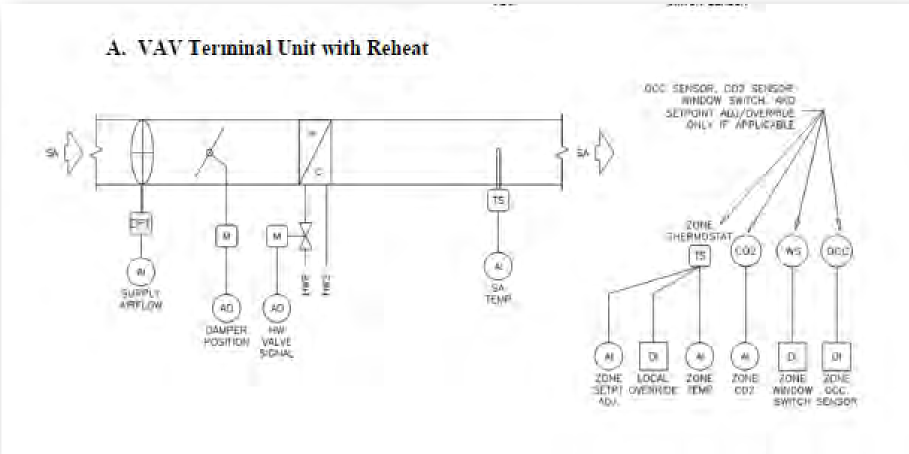
The Guideline Covers

A) VAV – Cooling only
B) VAV with reheat
C) Parallel Fan-Powered Terminal unit, Constant volume fan
D) Parallel fan-powered Terminal unit, variable volume fan
E) Series Fan-Powered Terminal Unit
F) Dual Duct Terminal unit with inlet sensors
G) Dual Duct Terminal unit with discharge sensors

What's not covered is variable volume terminal units (VVT!)

Image Source: GPC36 PPR1 05-16-2016
Rick

VAV with Reheat



48

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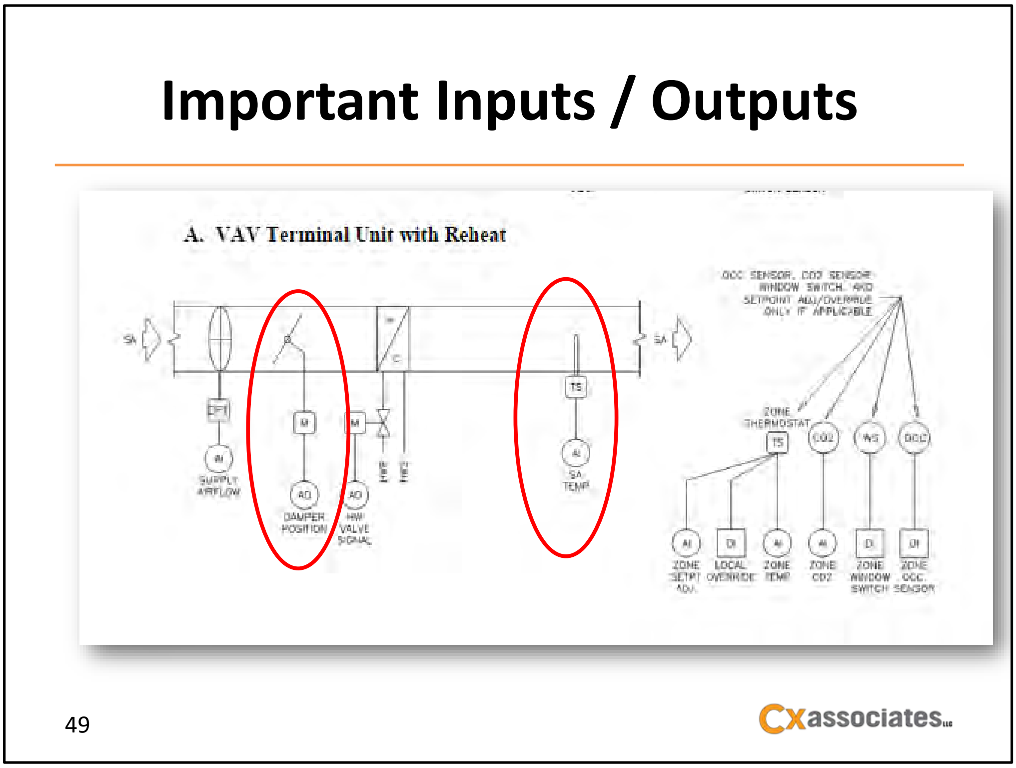
Here is the standard layout for VAV with reheat

Everything here is fairly typical for a more elaborate VAV than status quo normally provides, but not out of most people's comfort zones (no pun intended).

Image Source: GPC36 PPR1 05-16-2016
Rick



You really want to make sure your product allows for

1) Actual damper position Feedback
2) Supply air temperate leaving the VAV

In a new construction situation this is cost neutral

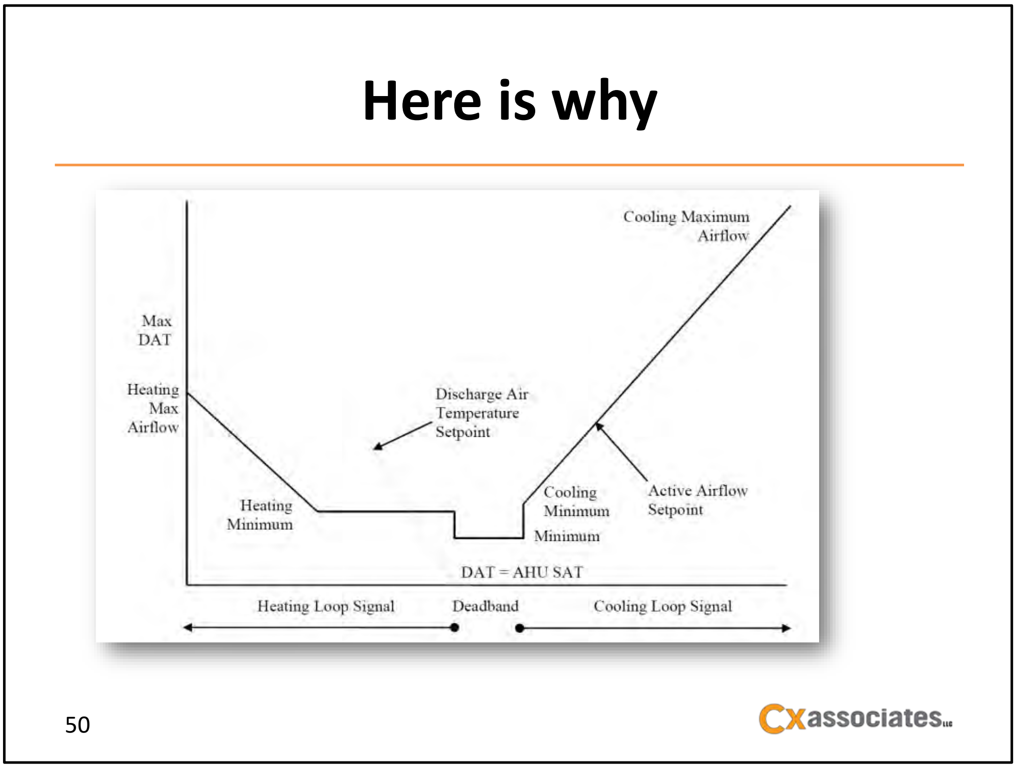
In retrofit situations, there may VAV controllers that do not have position feedback.

There are ways to deal with this, we are happy to talk about those at the end of the presentation.

That being said, here is why these points are important:

<Click>

Image Source: GPC36 PPR1 05-16-2016
Rick



Remember how I was talking about the two PIDs.

Here is where they come into play

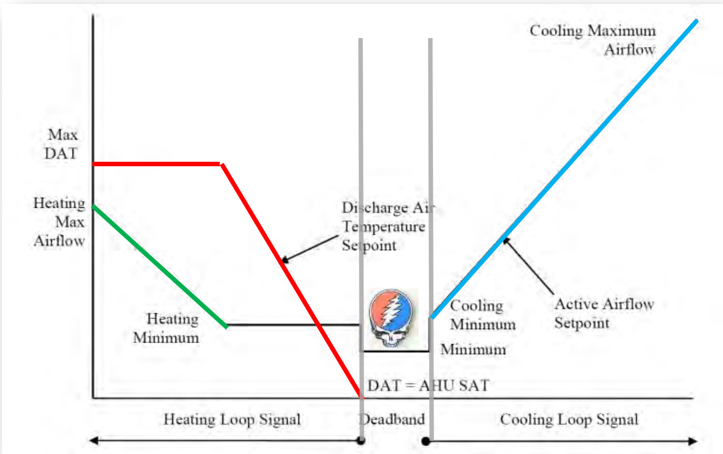
When they are enabled, there is demand for them.

They in turn generate a 0 -100% signal (called a… demand signal)

The demand signals are mapped to the valve and damper as shown <click for color>

Image Source: GPC36 PPR1 05-16-2016
Rick

Now in Color!



51

This is a cascaded style control.

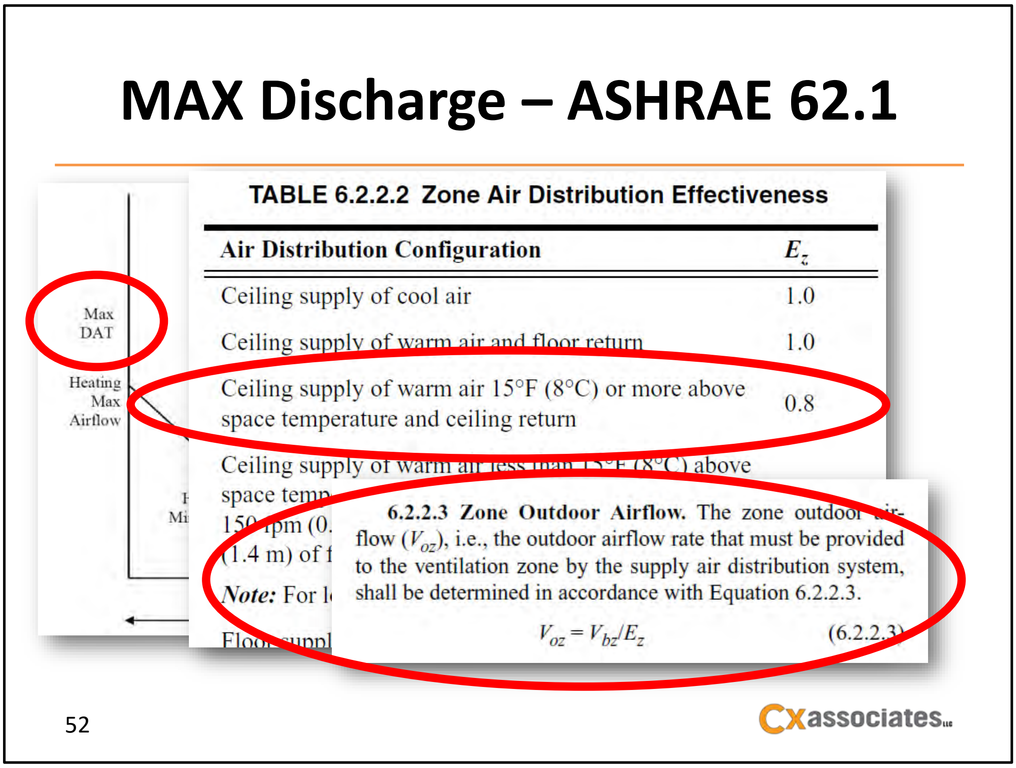
Here is your heating demand signal
Affects first Valve position for reheat
Then affects damper control

Cooling demand affects only damper control, but on a different scale

And the sequence imposes a discharge air temperate limit.

<Let me get the professor to give you the run down of this limit>

Image Source: GPC36 PPR1 05-16-2016
Rick



Matt to jump in and talk about Vent. Effectiveness at: DAT > (RMT+15)

Standard 62.1 (2013) Table 6.2.2.2 – Zone Air Distribution Effectiveness

Ceiling Supply and Ceiling Return systems

Results in a distribution Effectiveness of 0.8 that is used in multizone equation for vent. In the breathing zone (Vbz)

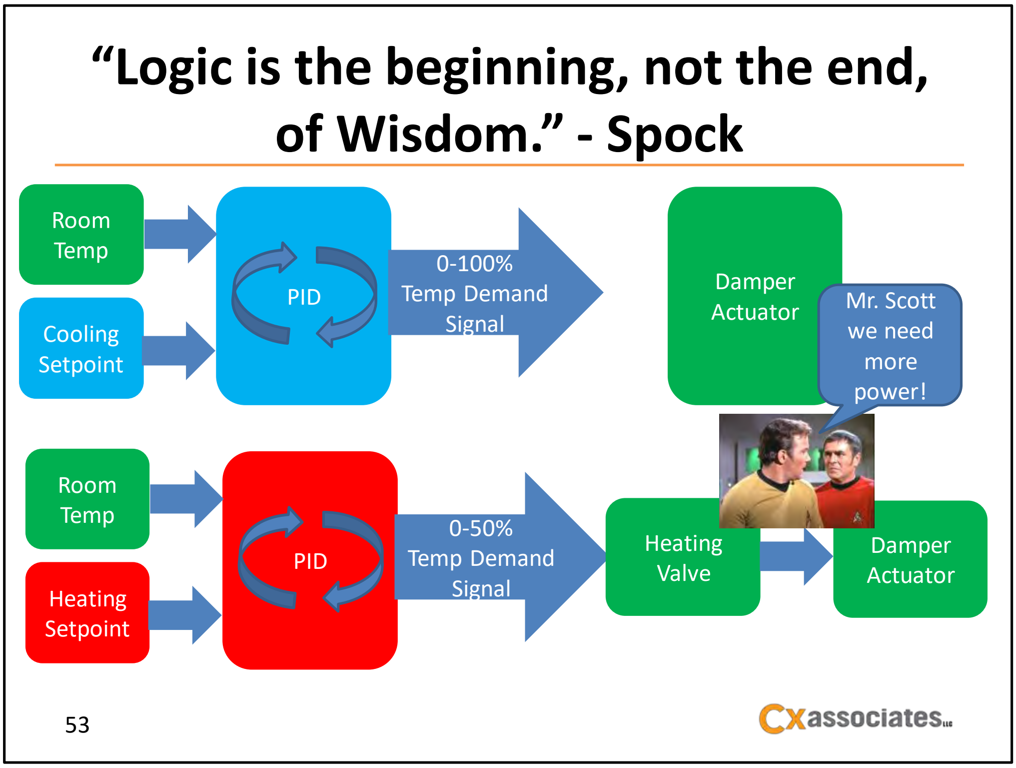
Zone outdoor airflow – the actual amount of Outdoor air that the standard allows you to consider when verifying compliance

Is increased by an effectiveness less than one.

You need to provide 20% more outdoor air than your calculated uncorrected breathing zone requirement

So its easier to keep the DAT limited for better mixing of your OA into your Vbz than to modify your minimum OA damper control to accommodate a warmer DAT from any VAV.

Image Source: ASHRAE Standard 62.1



The cooling PID, on a call for cooling is activated and drives the VAV from min cooling flow (or min flow) to max flow.

The heating PID on a call for heating

First drives the heating valve open without changing flow

Then on a call for more heating (as the PID winds up more) <click>

The VAV modulates the damper open to heating max air flow (which is different from Cooling Max Flow).

There is one more thing I'd like to point out:

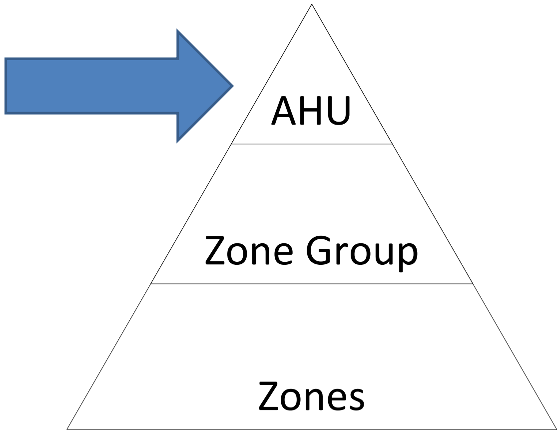
The PIDs allow you to have different tuning parameters for each piece of the sequence.

This allows for different reactions to your heating coil vs your damper actuator. There can be seasonal tuning adjustments made to further refine control.

Moving on, we are going to now talk about Multizone AHUs <click> 20:00

Image Source:
https://jameskillough.files.wordpress.com/2012/04/scotty.jpg

Grouping



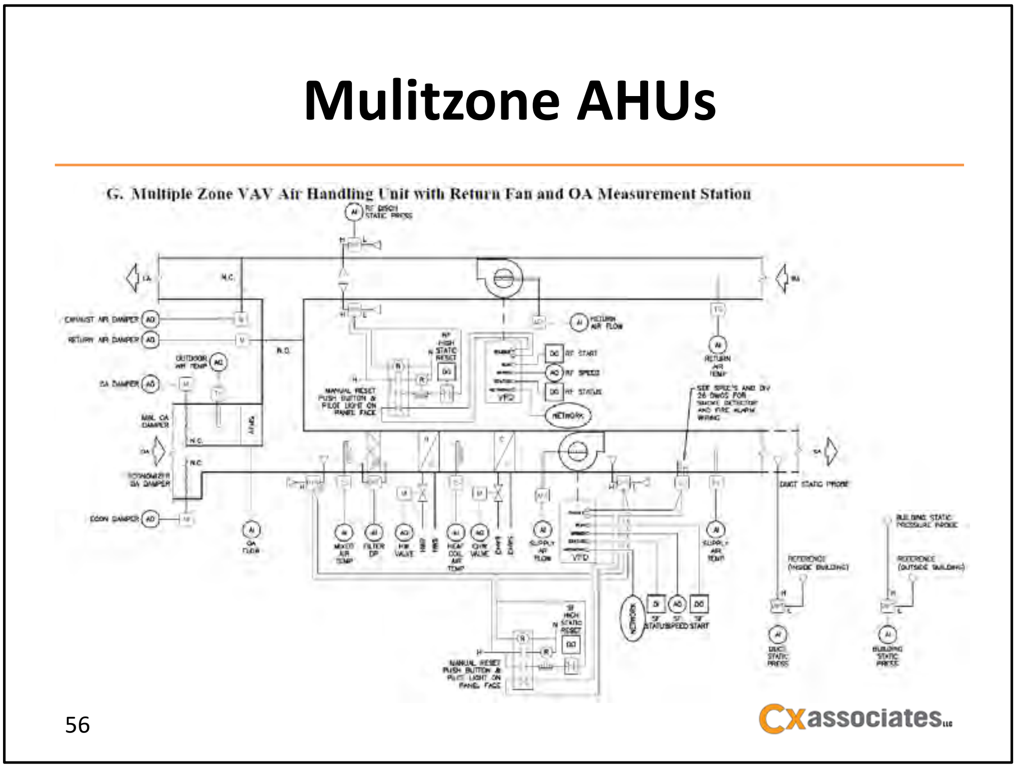
54

Now onto AHUs

Image Source:
Rick

Multizone AHU Mixing Box Control

- The guideline provides some key differences that are important to know about.
- We will be covering mixing box control and supply air control
- There are other new control strategies that the guideline implements for multizone AHU’s that we will not be covering today.



This is one of the AHU layouts they provide.

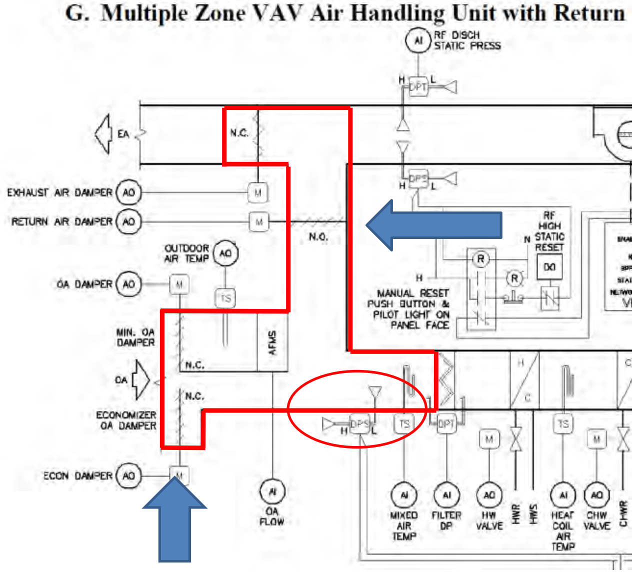
There are some key things I'd like to point out here

First off everybody knows what a mixing box is correct? <Click>

Image Source: GPC36 PPR1 05-16-2016
Rick

Mulitzone AHUs

G. Multiple Zone VAV Air Handling Unit with Return



57

CXassociates

A Mixing box is this section right here where the Return Air damper and the Outside air dampers work to mix the air before it

Is drawn through the heating and cooling coils by the supply fan.

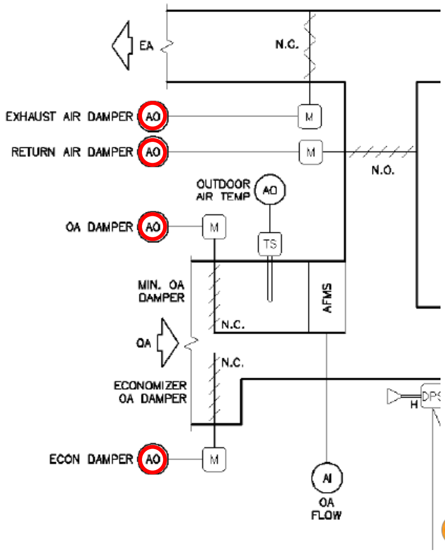
Sometimes people just call this the economizer.

The idea being using free cold air (freecooling) when its cold out helps your economic situation in the winter

Image Source: GPC36 PPR1 05-16-2016
Rick

Deviation from Status Quo

Individual Analog Outputs for each actuator on the economizer dampers!



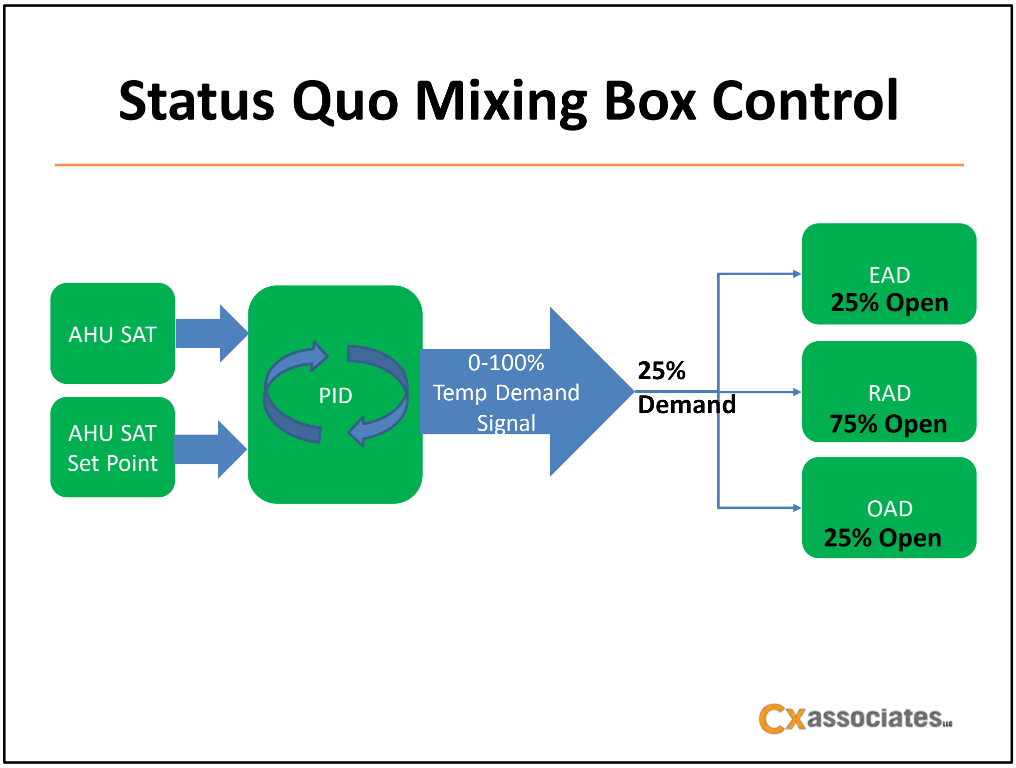
58

CXassociates

There are some key things I'd like to point out here

This is because Mixing box control has evolved form status quo <click>

Image Source: GPC36 PPR1 05-16-2016
Rick



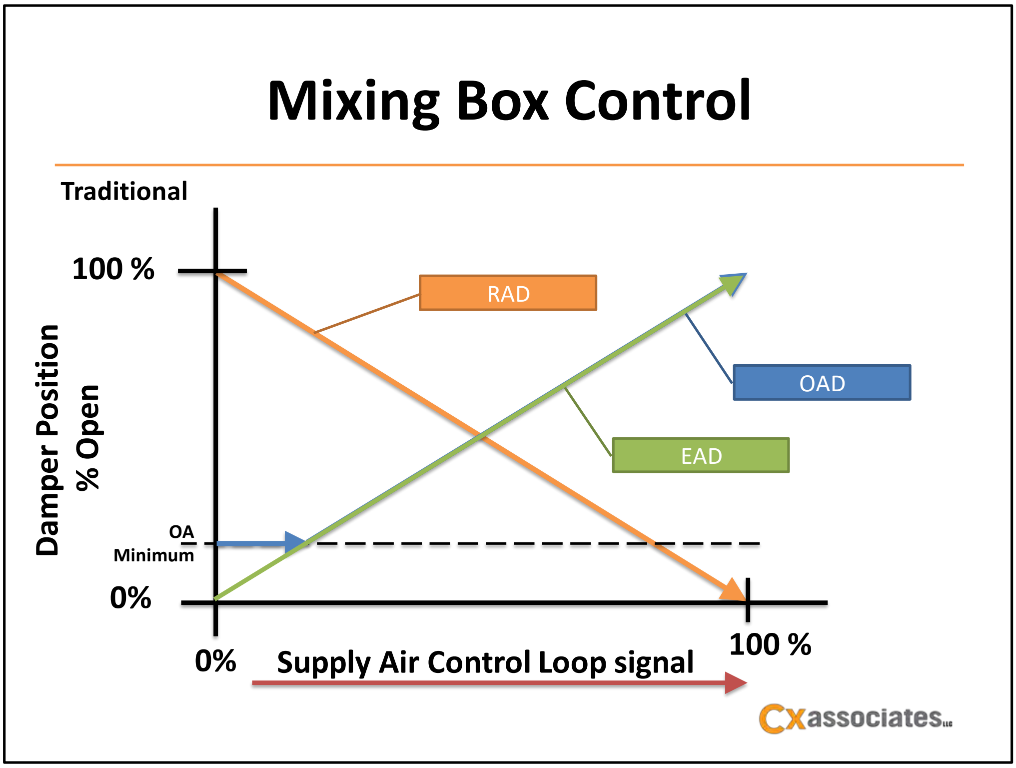
Here is a typical Mixing Box control

Here a PID looks at the difference between AHU SAT and setpoint and calculates a demand signal.

This is entirely the demand based on deviation of temperature from setpoint.

All three dampers react in unison to this deviation in temperature.

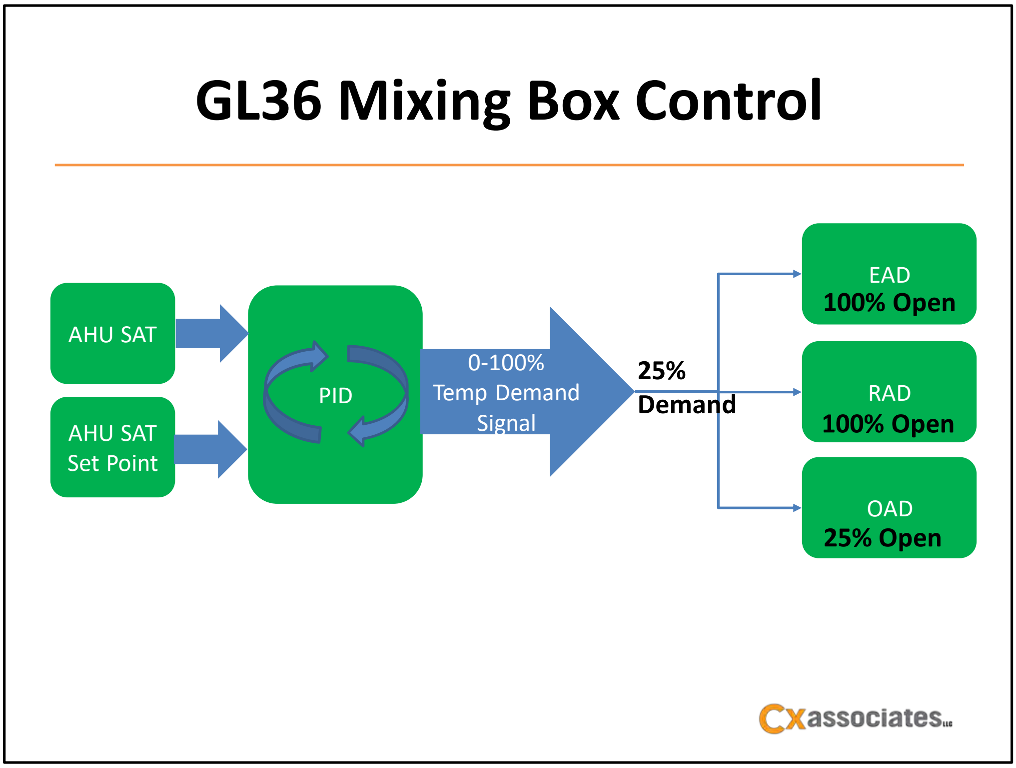
It looks like this when graphed: <click>
Rick



The dotted line is the minimum OA setting determined by the engineer to meet ASHRAE 62.1 requirements for ventilation.

Here you can see all three dampers react proportionally and simultaneously to that PID loop output.

Here is GL36's sequence:
Rick



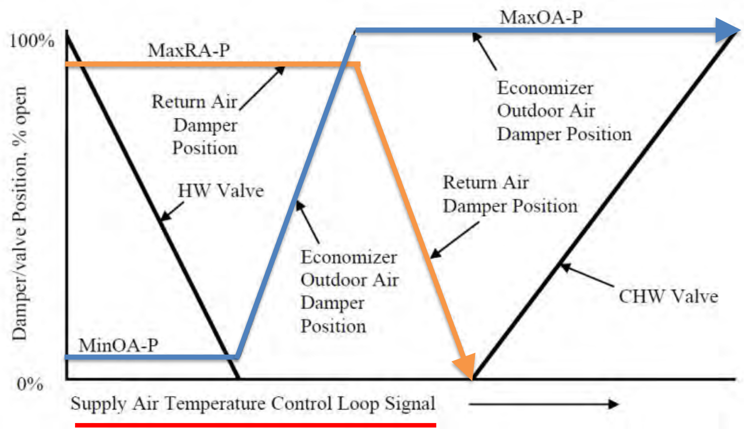
Here is a GL36 Mixing Box control

For the same situation as previously shown.

Again, we have 25% demand signal, but what's different here is that 2 of 3 dampers are full open.

It looks like this when graphed: <click>
Rick

New Mixing Box Control



62

CXassociates

This mixing box control is very different from what you may have seen in the past.

Notice how they control based on supply air temperature demand

Staggered and sequenced.

Also notice that the variable names are different. That's because the GL gives recommendations on the maximum limits of these individual damper control strategies

Image Source: GPC36 PPR1 05-16-2016
Rick

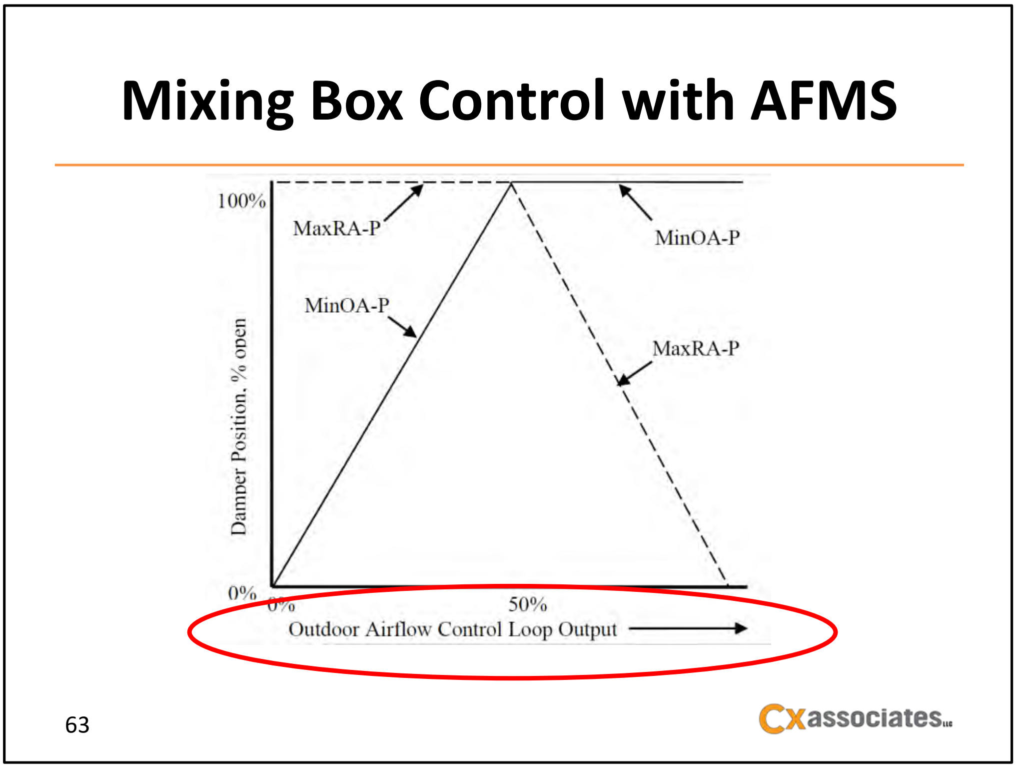


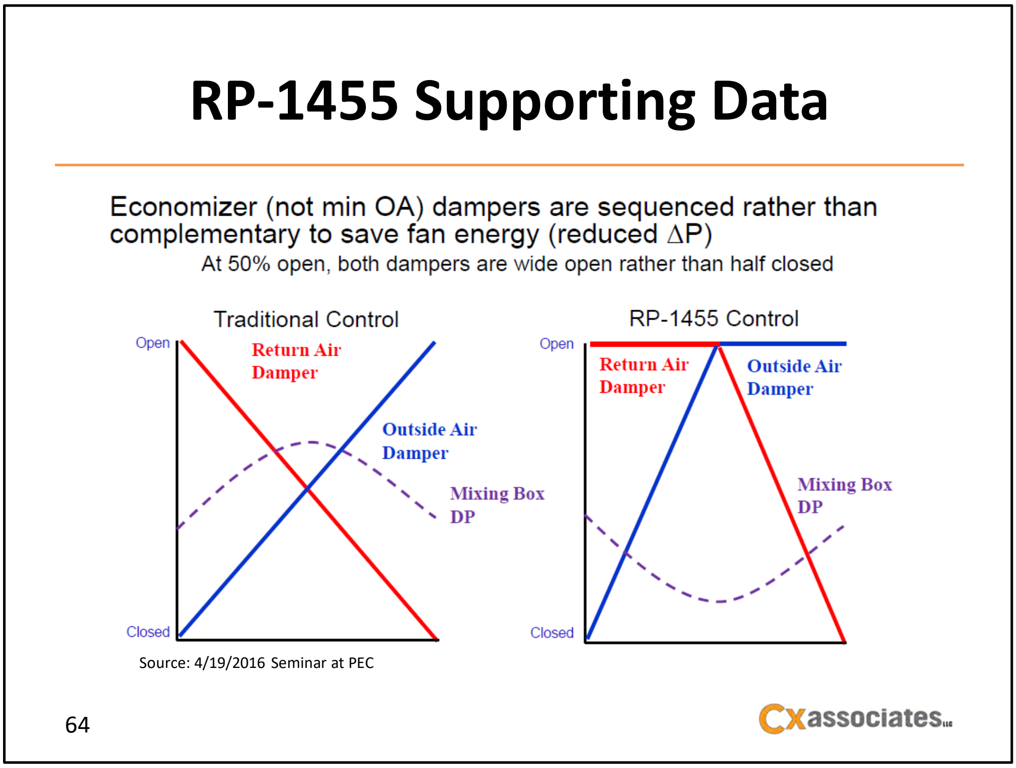
Image directly from GL36

Notice here that this is in response to Outdoor Airflow control (from the AFMS that we talked about earlier).

So there are two controlling process variables acting on the same set of dampers here, and its important to review both sets

of sequence verbiage and tweak the variable as described in the guideline.

Image Source: GPC36 PPR1 05-16-2016
Rick



They did this because they wanted to reduce the mixing box pressure thus saving fan energy on the supply fan

These charts are from the research project they conducted to inform this new sequence.

You'll notice that at 50% demand (they indicated open here), both dampers again are wide open.

Notice the difference in pressure as graphed by the dotted line.

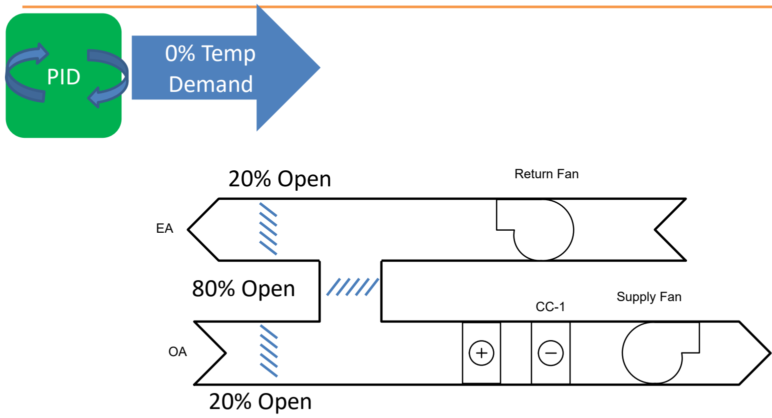
This change again only requires two more damper actuators and two analog outputs on the sequence to bring to life.

Matt will walk through an example of this.

<pass to matt>

Image Source: GPC36 PPR1 05-16-2016
Rick

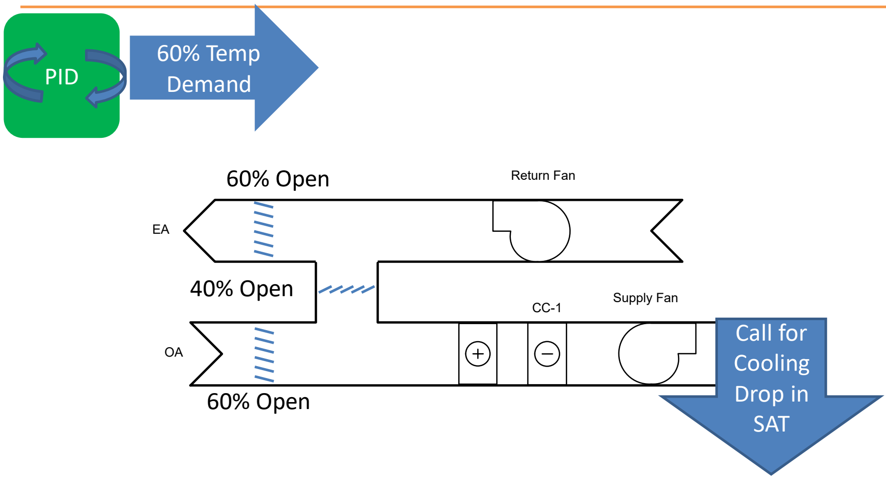
Example S.Q. Mixing box



65

Image Source: GPC36 PPR1 05-16-2016
Matt

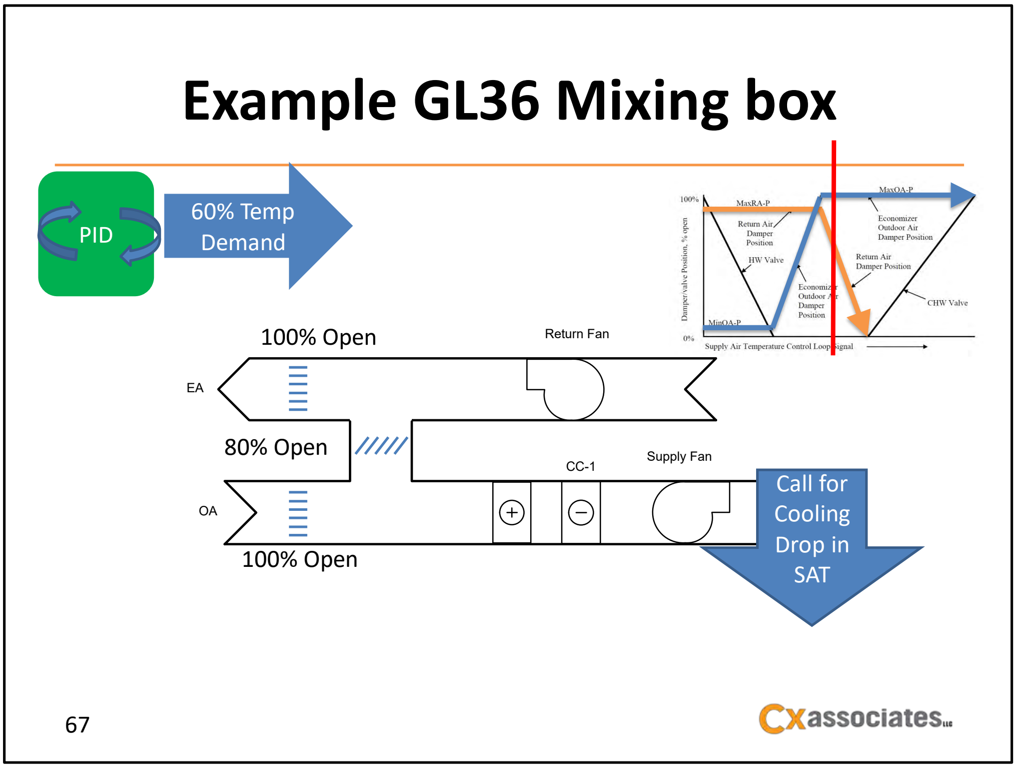
Example S.Q. Mixing box



66

Call for cooling

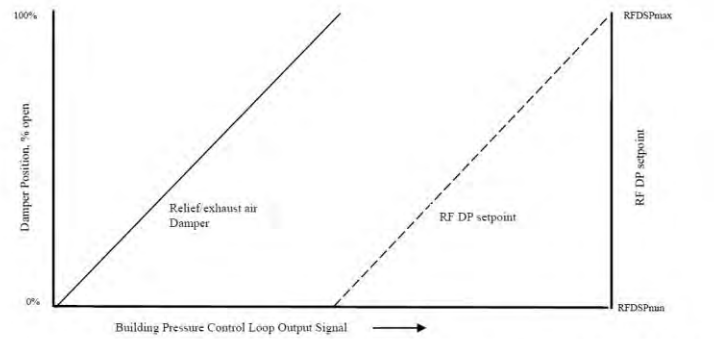
Image Source: GPC36 PPR1 05-16-2016
Matt



<hand off to matt?>

Image Source: GPC36 PPR1 05-16-2016
Matt

GL36 Building Pressure Control



1) From 0% - 50%, the building pressure control loop shall modulate the exhaust dampers from 0% to 100% open.
2) From 51% - 100%, the building pressure control loop shall reset the return fan discharge static pressure setpoint from RFDSPmin at 50% loop output to RFDSPmax at 100% of loop output. See 3.2A.3.b for RFDSPmin and RFDSPmax

68

Building pressure Control.

The sequences are engineered with this in mind. So be mindful of it.

Image Source: GPC36 PPR1 05-16-2016
Matt

No Building pressure Control?

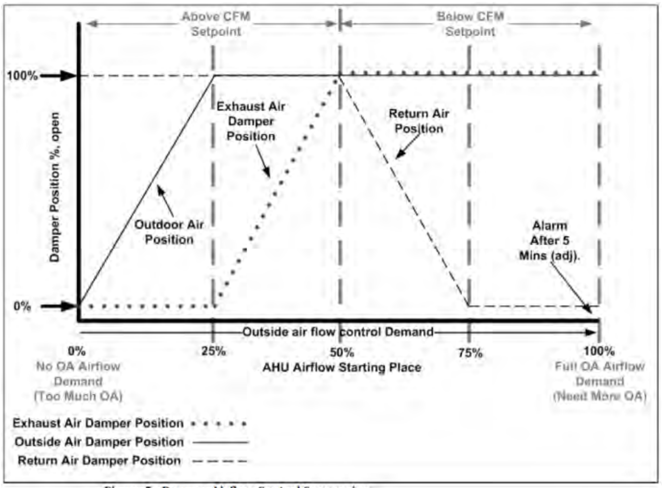


Figure 5 - Damper Airflow Control Sequencing

69

No building pressure Control?

No problem!

By directly measuring the values you are trying to control (OA and RA CFM)

You can achieve the desired control.

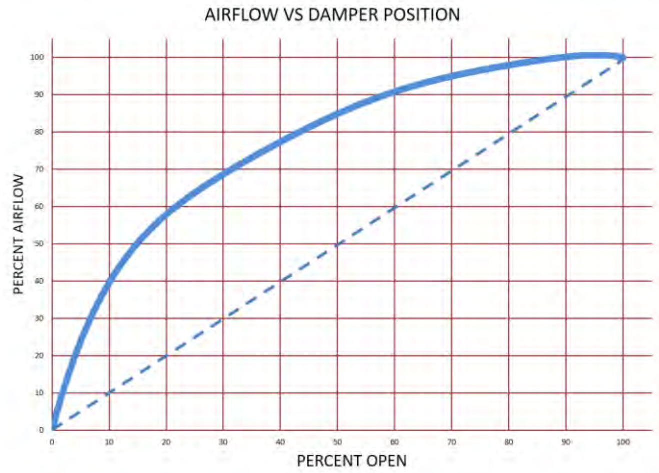
<step through the graph>

<click>

Image Source: GPC36 PPR1 05-16-2016
Matt

Guideline 36 vs Status Quo

Mixing Box Control – Status Quo – Dependent Damper Control



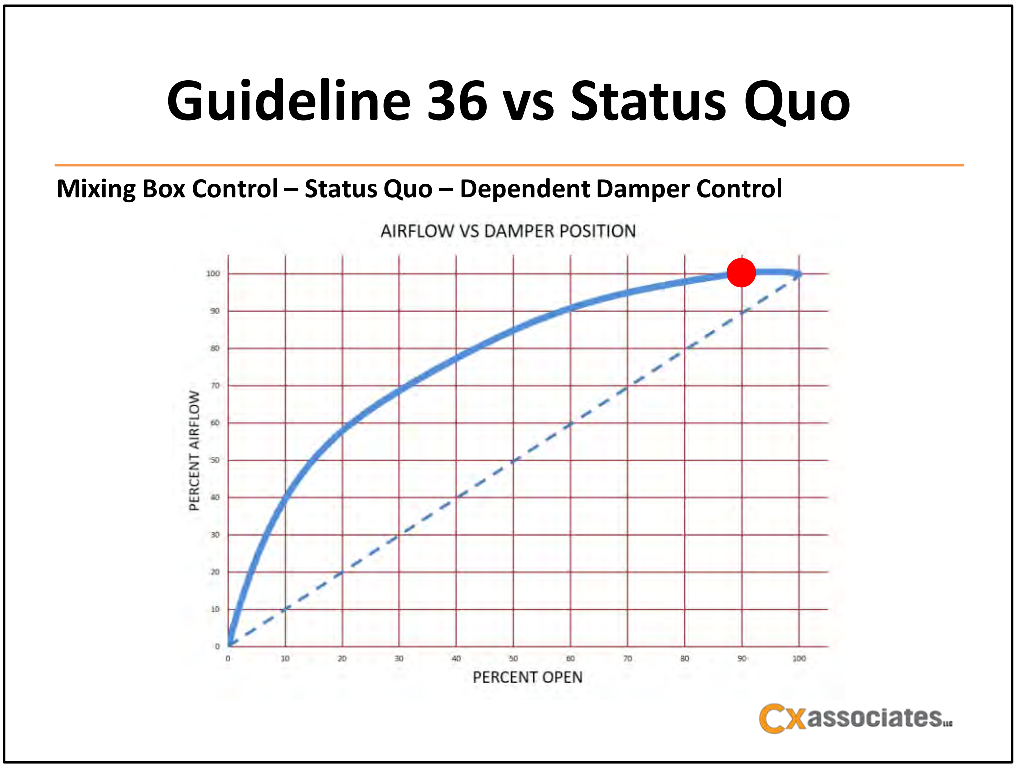
CXassociates

Airflow through a damper is NOT linearly proportional to its position.

This is a damper with about 10% authority.

<click>

Matt



Airflow through a damper is NOT linearly proportional to its position.

This is a damper with about 10% authority.

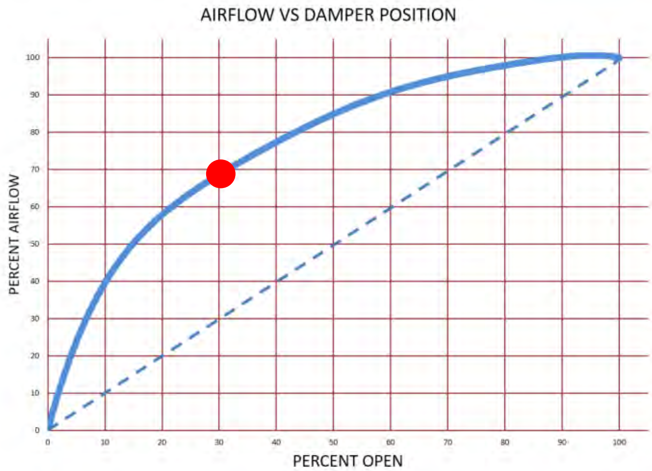
You get 100% airflow at 90% open.

<click>

Matt

Guideline 36 vs Status Quo

Mixing Box Control – Status Quo – Dependent Damper Control

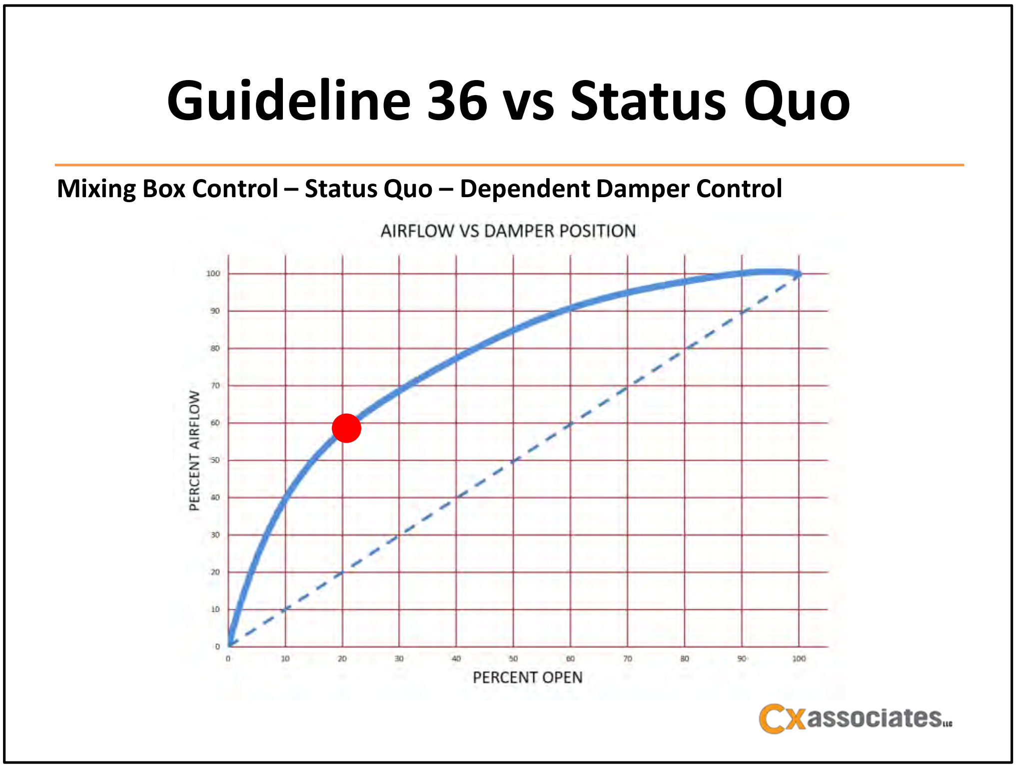


CXassociates LLC

At 30% open gets you70% airflow.

<click>

Matt



Then…Set it to 20%...you get 60% OA CFM!

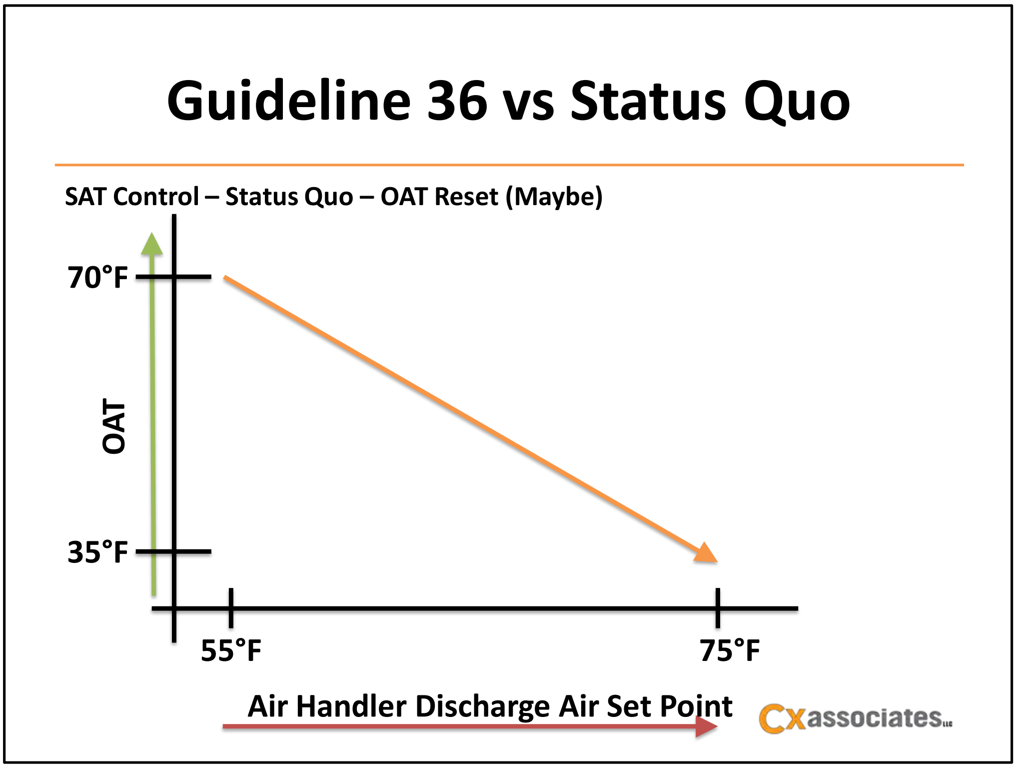
Check your CO2 levels. I bet they're in the 600 – 700 range if you have this control.

<click>

Matt

Multizone AHU Supply Air Control

- How is GL 36 Different?
  - We just saw changes in mixing box control
  - The GL uses space demand to inform the AHU supply air temp. Not OAT.
    - Space demand is weighted to better reflect the demand's potential impact on the system.



OAT Reset vs Trim and Respond

IF your AHUs reset their SAT's at all, the traditional method is to reset SAT is reset on OAT.

As the OAT goes down, the need for warmer air goes up right?

OAT is the proxy variable for building load. This is "the way we've always done it".

Is that a valid reason for doing something? Yes, because chances are it worked. It achieved the result. Is it the BEST way? Is it the most efficient?

Matt

Guideline 36 vs Status Quo

SAT Control – Status Quo – OAT Reset (Maybe)

CXassociates LLC

OAT Reset vs Trim and Respond

WHY did OAT reset work? –

Because old buildings or buildings with relatively low internal loads roughly follow OA conditions in terms of H/C needs.

Modern buildings or building with high internal gains – not so much.

Matt

Guideline 36 vs Status Quo

Initially, reset was done via purely mechanical devices.

Here we see a pneumatic reset controller and a pneumatic control panel for a large AHU.

Mechanical or pneumatic inputs and outputs means simplicity was a must.

One input (OAT) is used to determine one output.

Matt

Guideline 36 vs Status Quo

SAT Control – Status Quo

CXassociates

When computers started to supplant pneumatics

they were relatively slow
had very little real computational power,
and so we kept doing "what we have always done"

As you can imagine, the first DDC systems simply recreated pneumatic controls eclectically.

They therefore inherited all the same terminology and strategies.

So the computer based system was no more energy efficient than the pneumatics.

Matt

Guideline 36 vs Status Quo

SAT Control – GL 36

CXassociates

Very different today.

We have TONS of computing power in tiny packages.

Modern computers can reliably gather, parse and utilize large amounts of data, gigabytes of data, in milliseconds…WAY faster than any HVAC system needs to respond…and they can even look really cool!!!

With all this computing power available, we are able to step outside the norm and this power with more sophisticated control sequence that wrings out energy efficiency.

Matt

Open vs Closed Loop Control

- This is a key concept to bringing modern day control to life
- Being able to identify open / closed loop control is essential to understanding why they implemented some of these sequences
- Lets talk about it in terms of Supply air temperature reset

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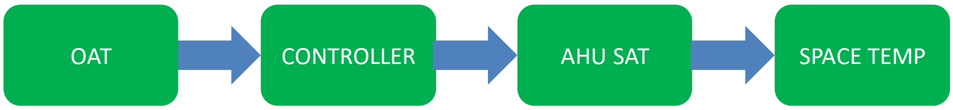
Status Quo – Open Loop SAT Reset

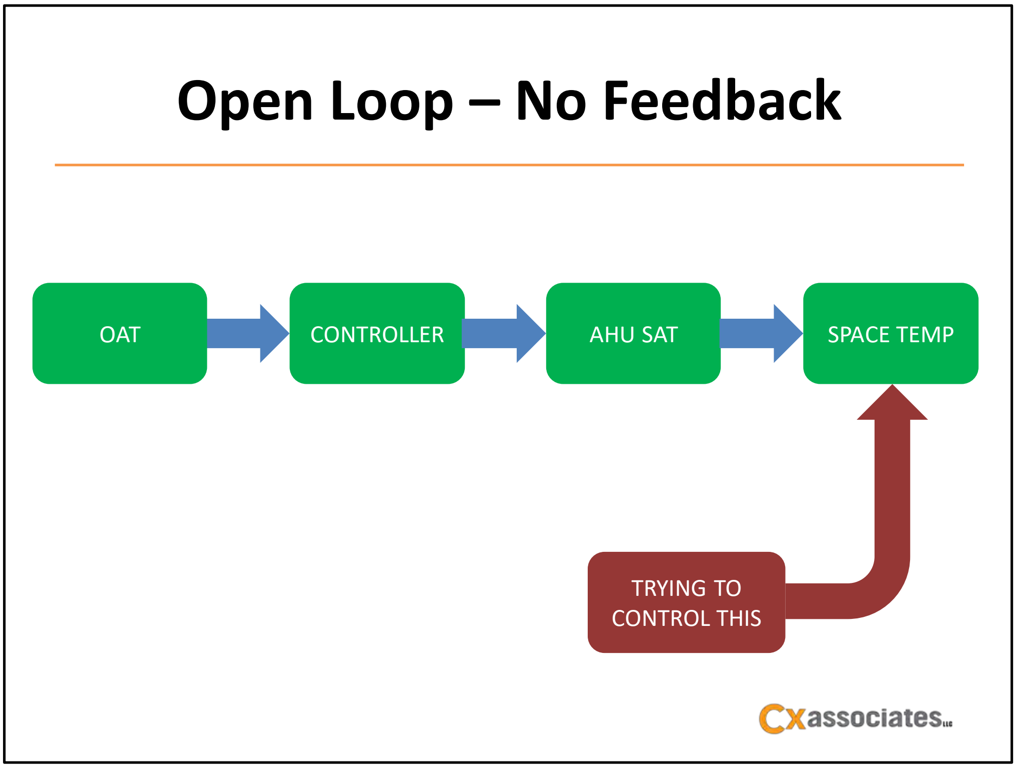


Cxassociates

OAT reset is what is known as open-loop controls.

Open loop controls do not use a feedback loop from the outcome of the process to inform what they are doing.

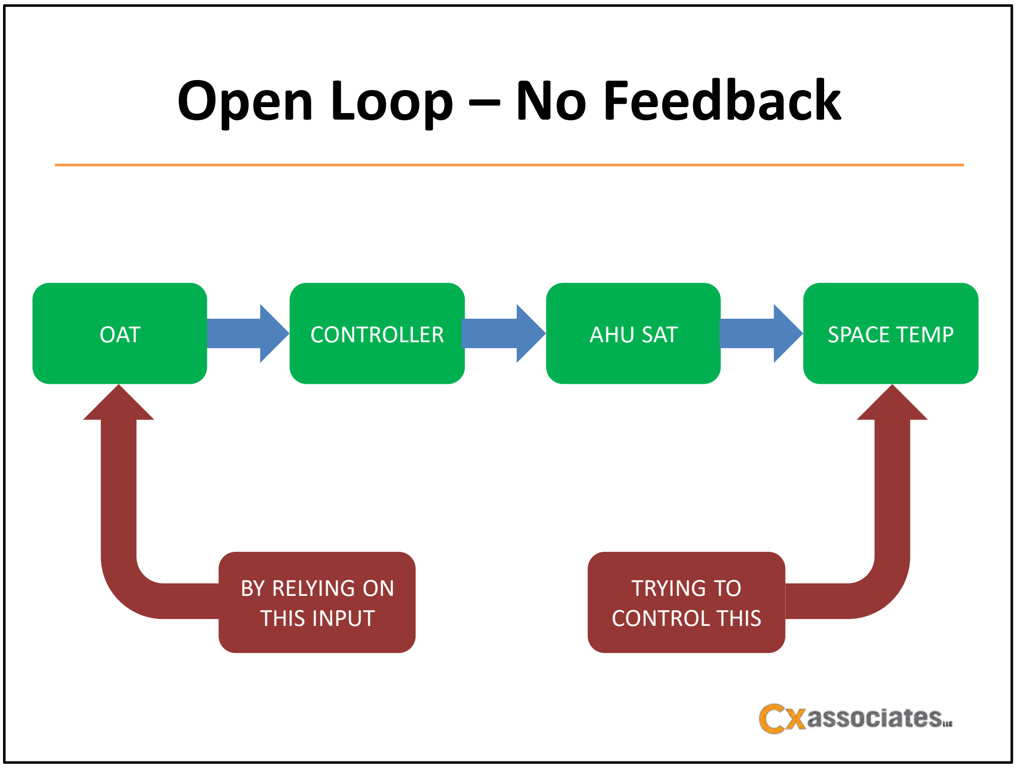
Matt



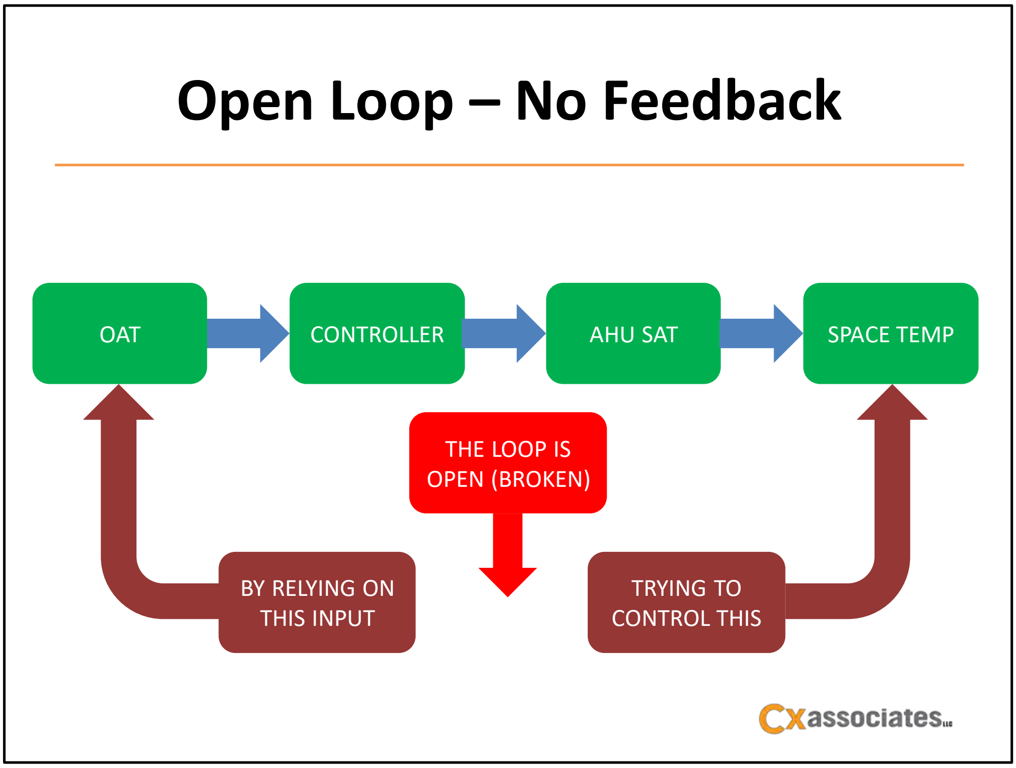
OAT reset is what is known as open-loop controls.

Open loop controls do not use a feedback loop from the process to inform what they are doing.

Matt



OAT Reset vs Trim and Respond
OAT reset is what is known as open-loop controls. Open loop controls do not use a feedback loop from the process to inform what they are doing.
Matt



OAT reset is what is known as open-loop controls.

Open loop controls do not use a feedback loop from the process to inform what they are doing.

Matt

Open Loop at Home

Clothes Dryer is Open Loop – Heat Setting plus Timer = Hopefully Dry

CXassociates

An older household dryer that runs for a preset amount of time is an open loop system.

A dryer with a "dryness setting" is closed loop.

Matt

Closed Loop at Home

Refrigerator is Closed Loop – Too Warm Inside, Turn on the Compressor

CXassociates LLC

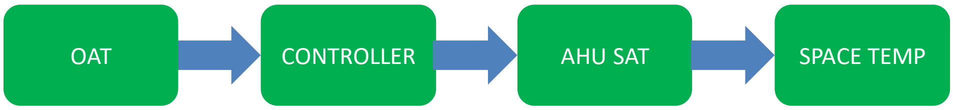
A refrigerator that runs to maintain a temperature is a closed loop system.

The thermostat provides feedback into the controlling loop.

Matt

Status Quo – Open Loop SAT Reset

OAT Determines SAT



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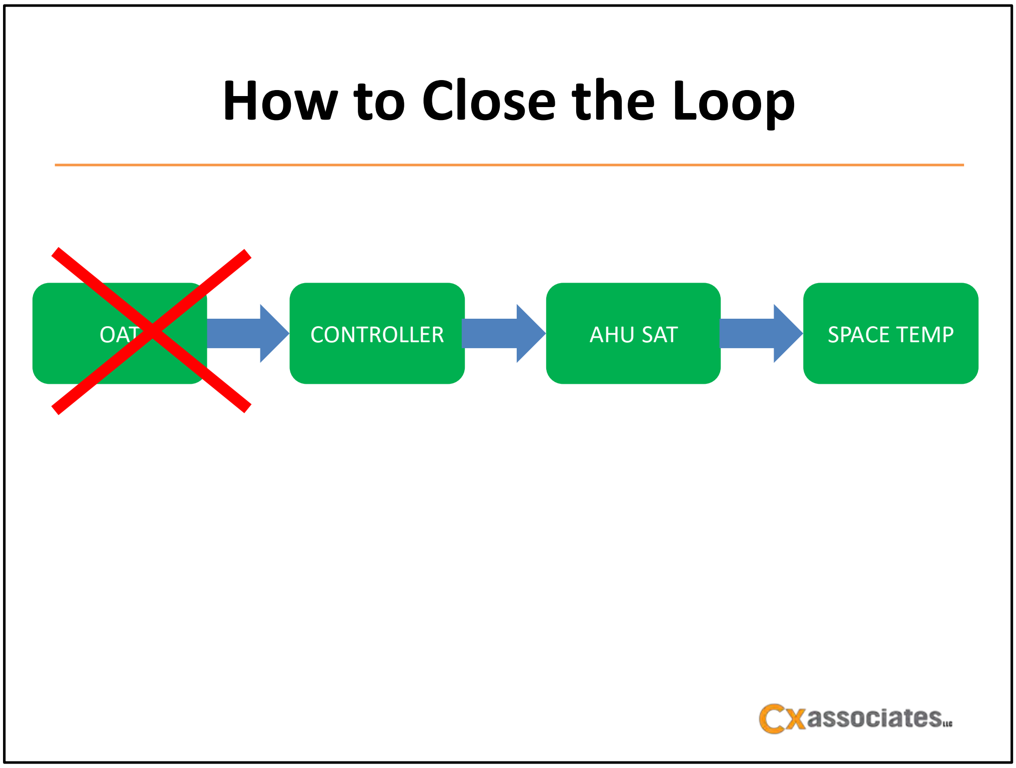
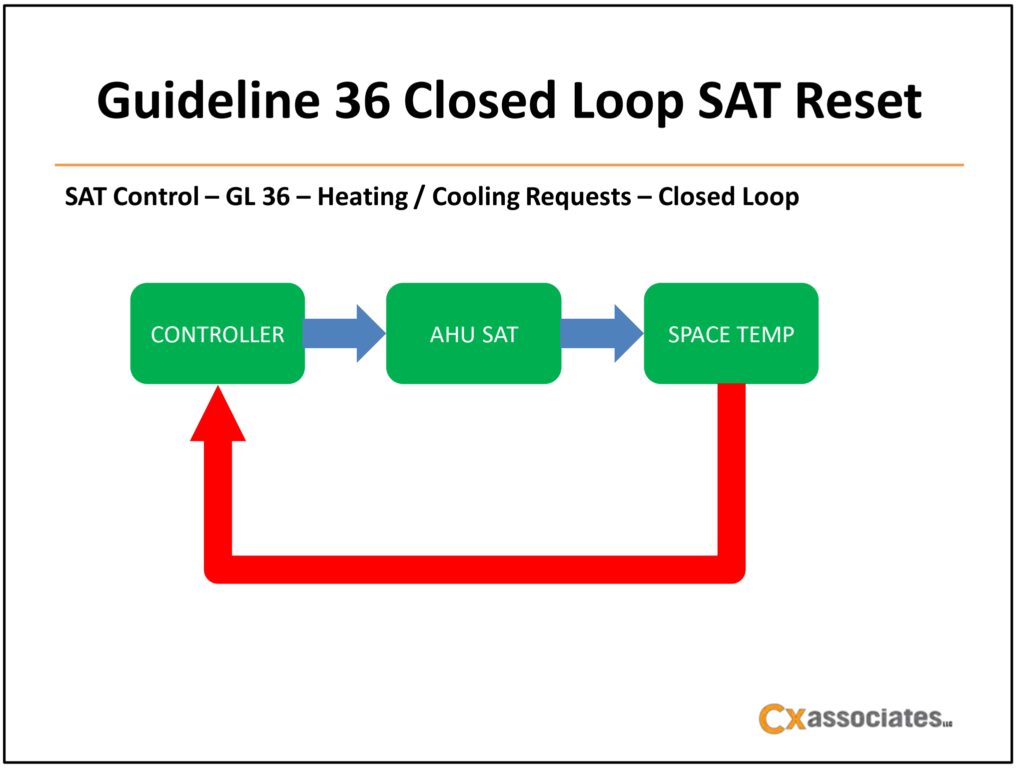
This was the old way. How do we make it better?

Matt



Remove the input that doesn’t know anything about the final output of the control loop. We need to provide the controller with a new input that is affected by the controller output.

Matt



Allow the output we want controlled, the space we want to satisfy, to tell the controller what to do.

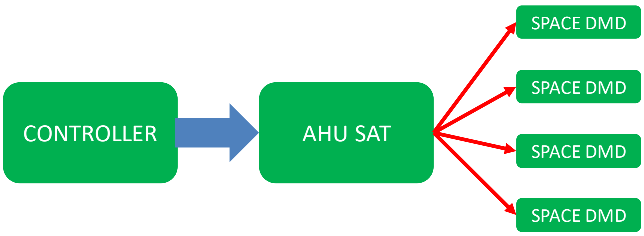
OA is still INFLUENCING the load, it's just not controlling the H/C delivered to the space. Matt

This is the point where BAS Controls network architecture becomes important because a failure in network communications has a bigger impact using these sequence than what it traditionally would have had.

ASHRAE has a guideline (GL 13) that discusses controls network Architecture which Rick will go over in detail later on.

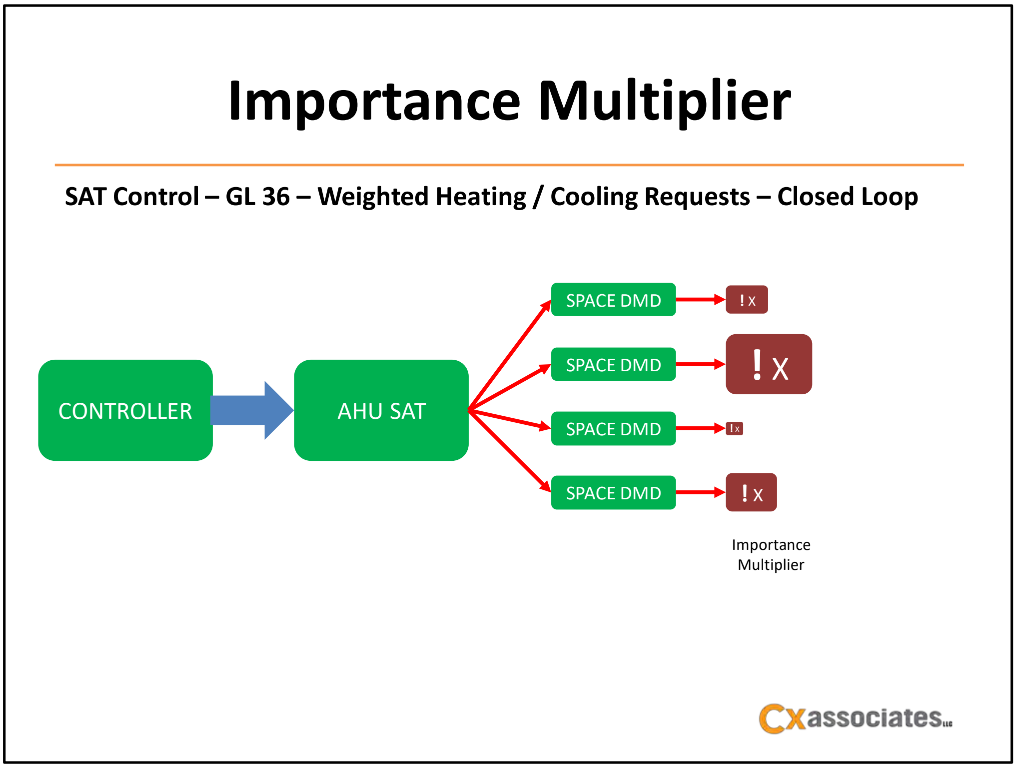
Importance Multiplier

SAT Control – GL 36 – Heating / Cooling Requests – Closed Loop



CXassociates

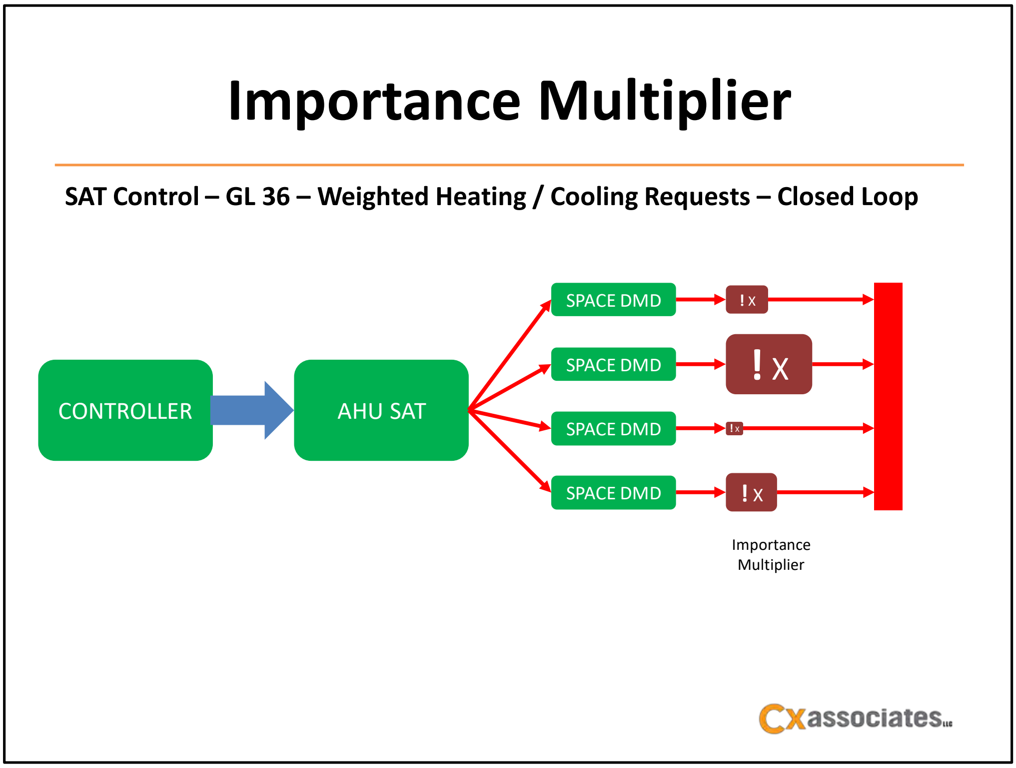
Now we go a step further. Every AHU serves multiple spaces. Some of those spaces are more important than others. Some are larger, some are more critical, etc.
Matt



We assign each space an “importance multiplier”. In the GL, these are numbers between 0 and 1. I prefer 0 to 10 for simplicity.

Weighted Heating / Cooling Requests

Matt

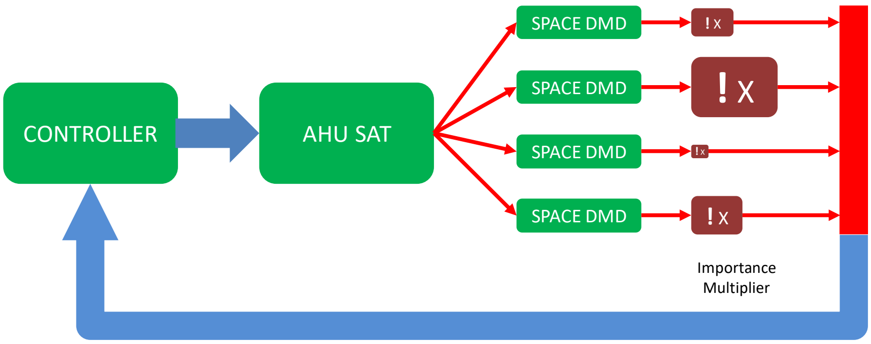


All the space temperature demands are multiplied by their importance multiplier. Those values are summed and…

Matt

Guideline 36 vs Status Quo

SAT Control – GL 36 – Weighted Heating / Cooling Requests – Closed Loop



CXassociates

Sent back to the controller where the SPACE DEMAND, not OAT, determines the supply air temperature.

Matt

Guideline 36 vs Status Quo

SAT Control – Status Quo

1) Supply air temperature will be reset proportionally based on the outside air temperature per the following schedule:

OAT	SAT
35	75
70	55

This is the sequence for a status quo OAT reset. Notice the page is mostly blank? Yes, its simple, but it does not reflect the needs of your building.

<click>

Matt

Guideline 36 vs Status Quo

SAT Control – GL 36 –Importance Multiplier Example

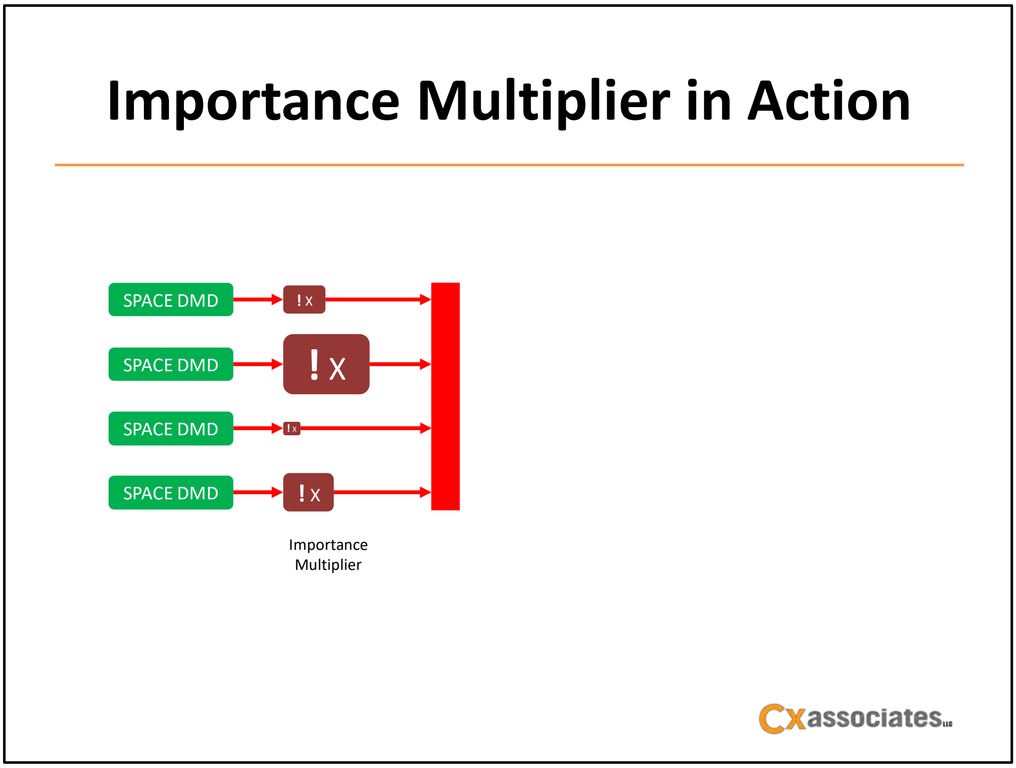
1) Supply air temperature will be reset using a weighted heating and cooling request and response. A PID will handle the response portion to the summed heating and cooling requests where:
    1) Heating and cooling requests cancel each other out.
    2) The heating/cooling request value is calculated as the difference between room and overage of the current heating or cooling set point as seen in Figure 3 - Heating Cooling Request Graph (Zone level Logic). A pseudo logical block diagram of this can be found in ATC 1.11.
    3) The request value is multiplied by the design CFM of the VAV box. This multiplication is called an “importance multiplier” and will be referenced in other sequences.
    4) The result of the multiplied value is then summed with all the other requests from all the other VAVs.
    5) The result of that summation is then divided by the discharge total CFM provided by the AHU.
6) The result of the division is then used as the input of a PID with a fixed set point of zero. This result may be multiplied by 10 or 100 if required by the specific PID being used. The PID shall be configured in such a way that the loop will output 50% when its input is equal to set point (or PID Bias will equal 50%).
7) The result of the PID is then used as the input of a linear reset. This reset shall use the PIDs output range (0-100) to reset the supply air temperature set point between SAT-min and SAT-max.
8) The calculated supply air temperature set point shall be able to be overridden at the user interface.

CXassociates LLC

Sequence text from a recent project, largely based on GL 36.

A user adjustable multiplier was not included in these sequences.

Matt



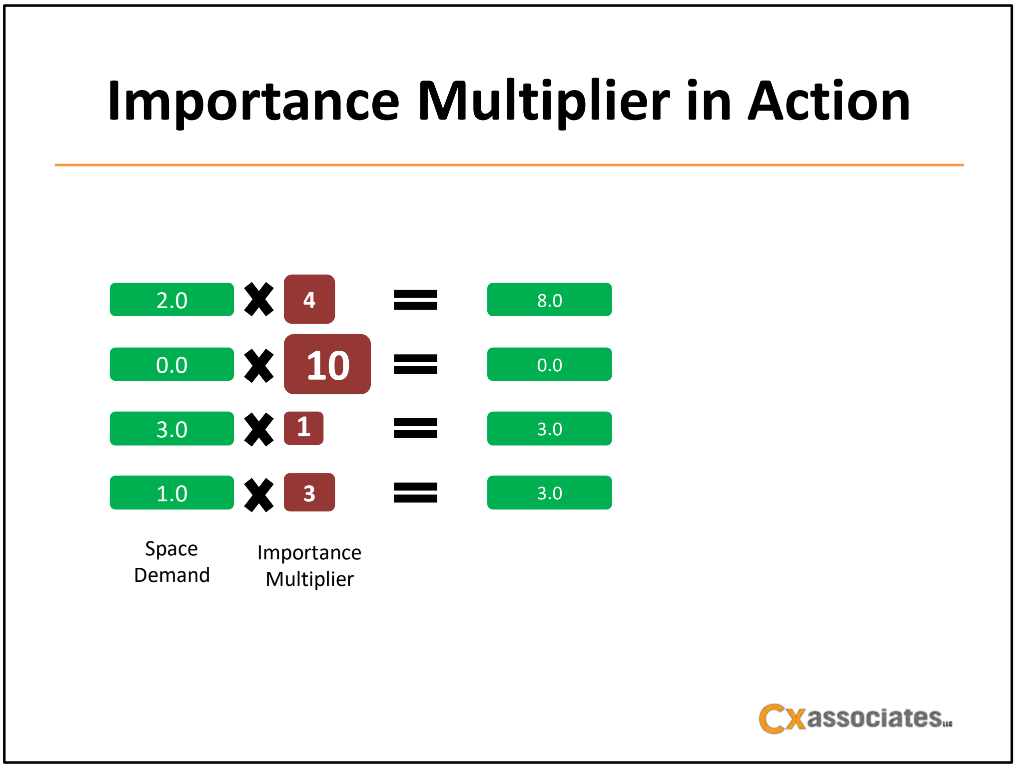
Importance multiplier in action.

Remember this part of the earlier slides?

Now we'll assign values.

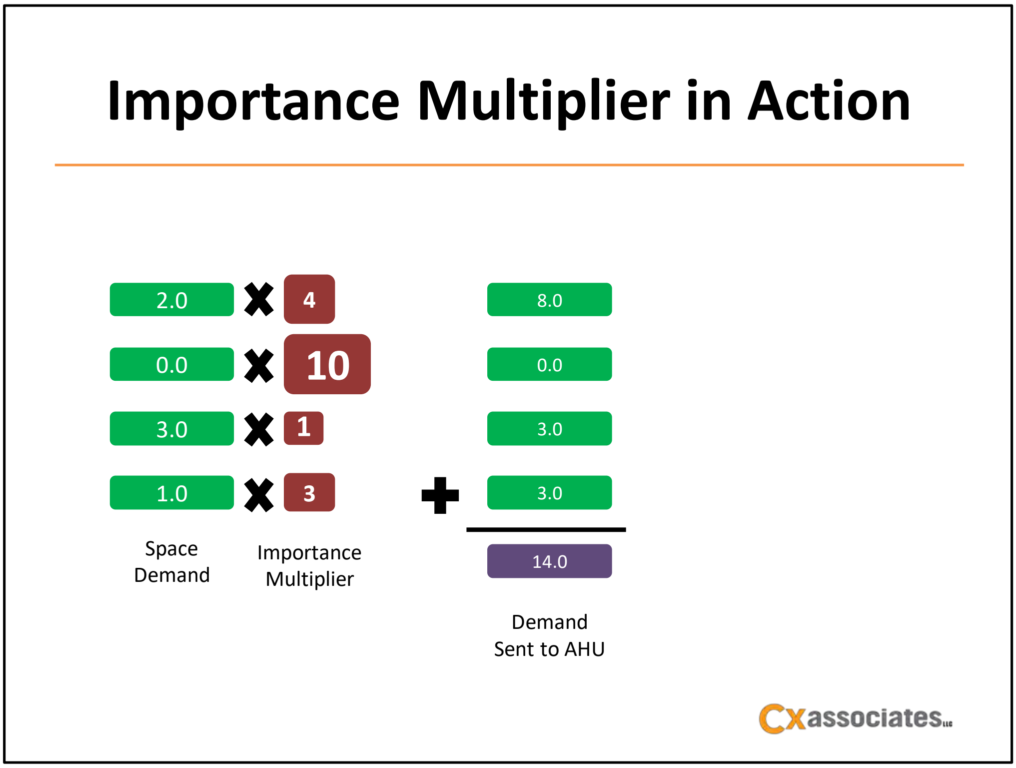
<click>

Matt



All the space temperature demands are multiplied by their importance multiplier. Those values are summed and…

Matt

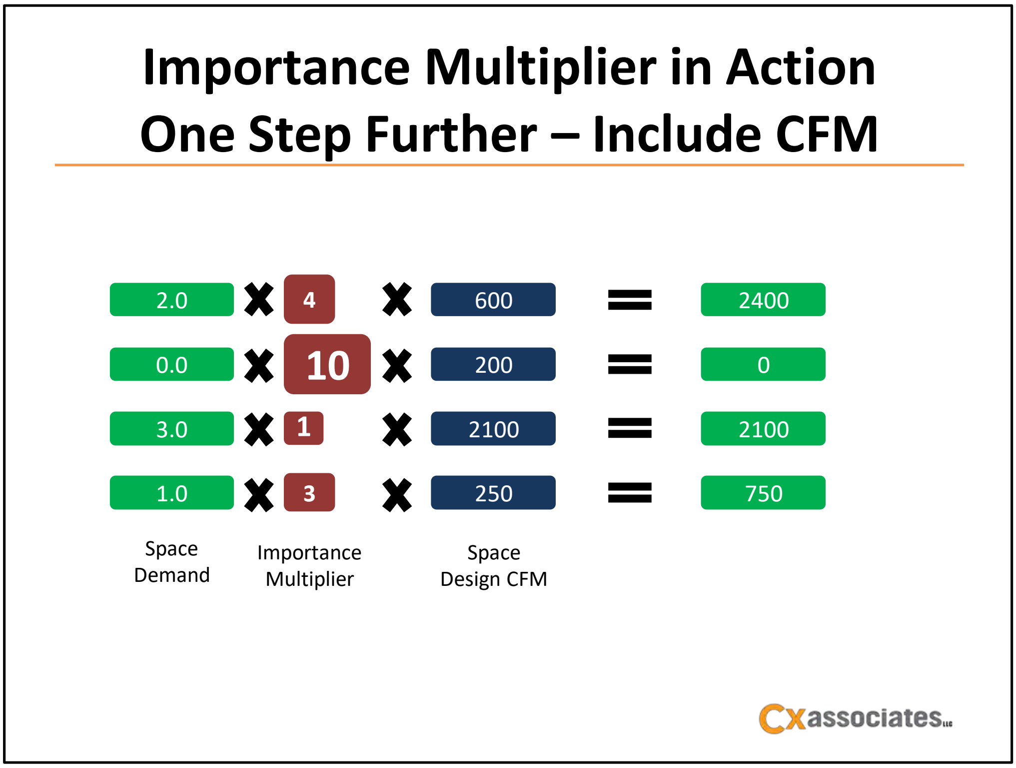


The total demand sent the AHU is determined to be 14.

We suggest going a step further…

<click>

Matt



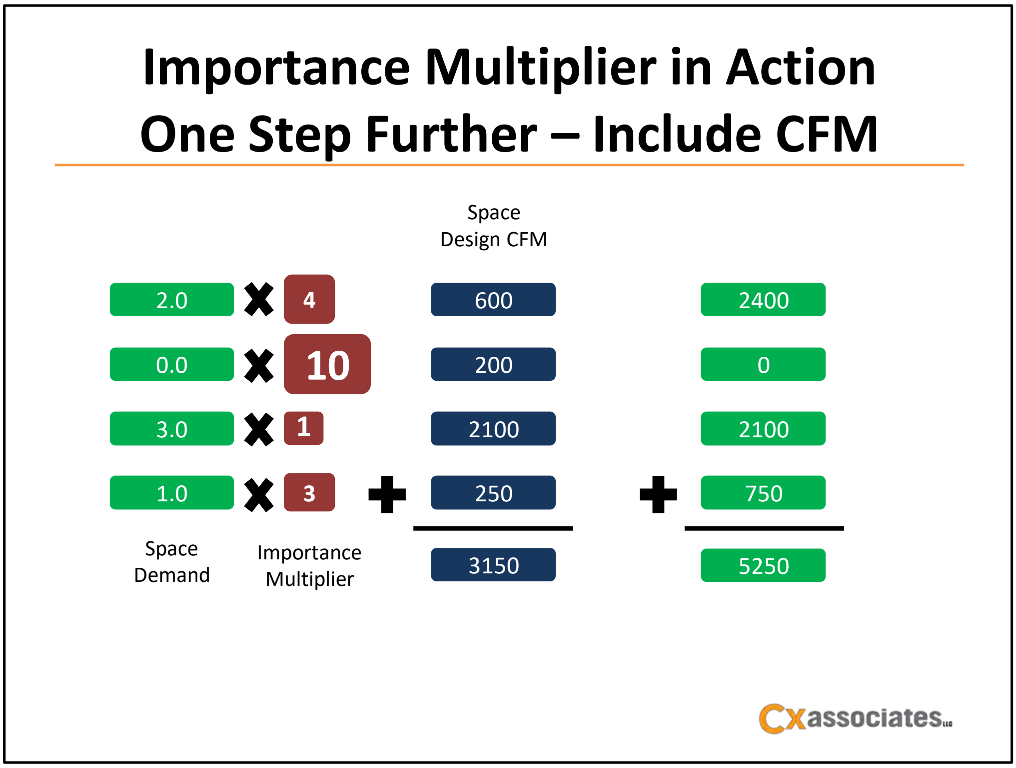
Now we include the zone design CFM.

The CFM is a direct reflection of the zone's potential demand on the AHU.

It's in the spirit of the GL but volumetrically weights the demand.

<click>

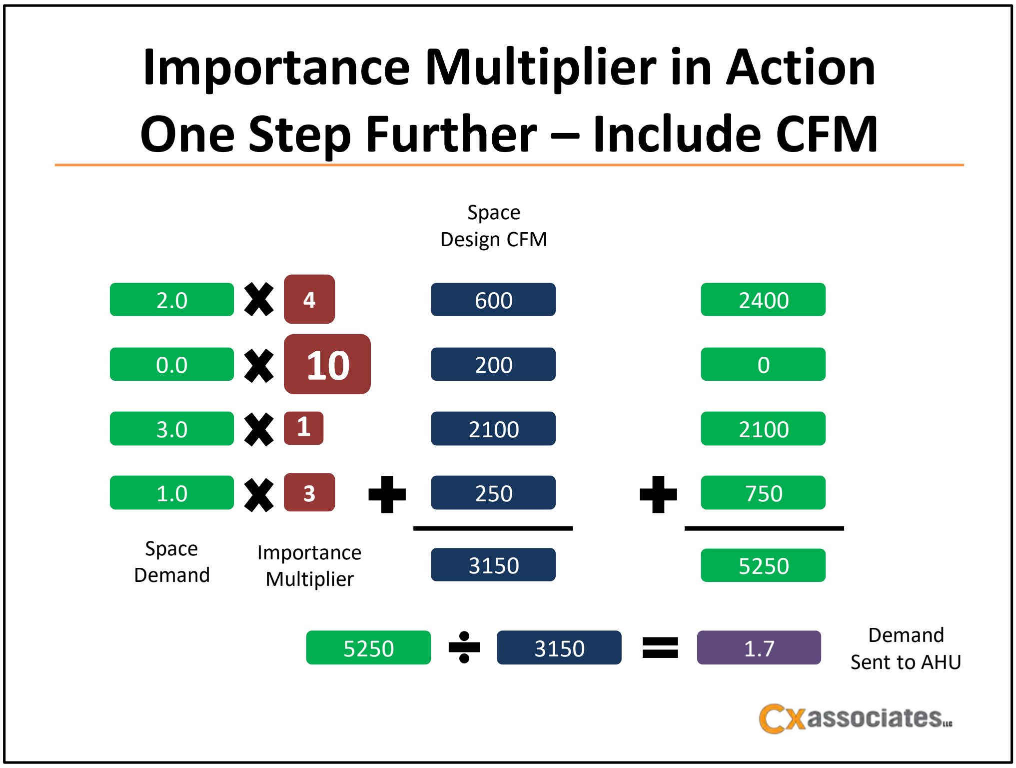
Matt



Now we sum the design CFM and the resultant zone demands.

<click>

Matt



The demand divided by the total CFM gives us a weighted demand that is now sent to the AHU.

Matt

Importance Multiplier
Quick Review

- <u>**GL 36 uses an integer importance multiplier.**</u>
  - Requires user / designer input
  - Allows for future modification
  - Can default to 1 for all zones at turnover

- <u>**We suggest including the zone design CFM.**</u>
  - Implementer has this information readily available
  - Direct reflection of zone's potential demand on AHU

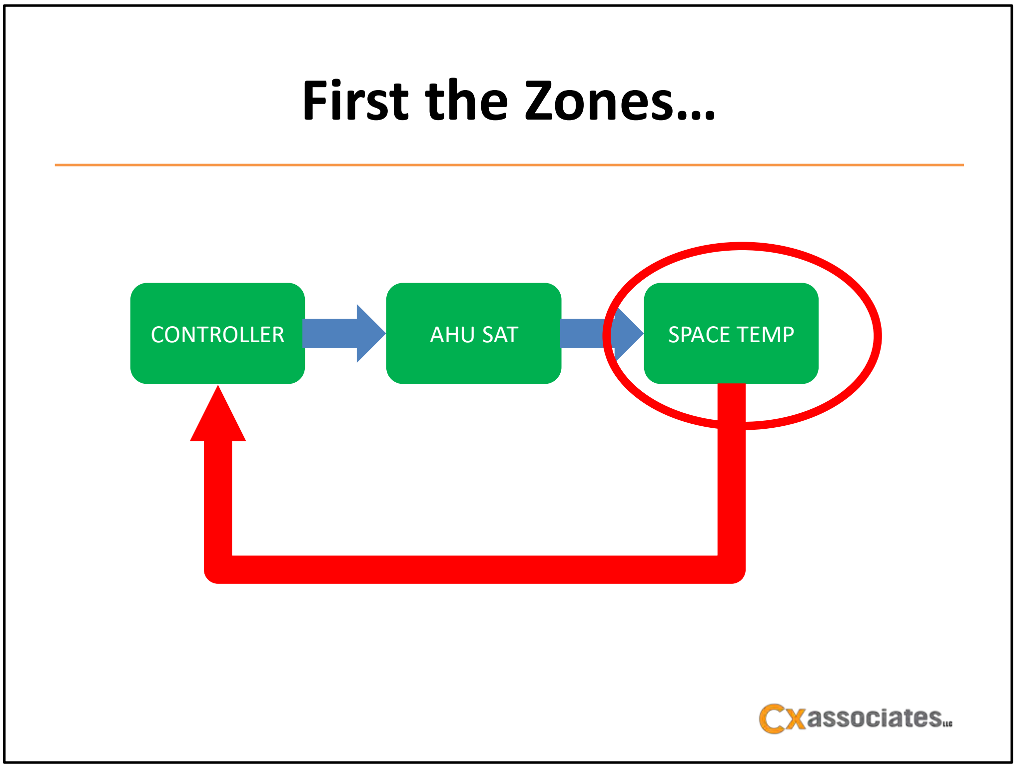
Here's a quick review of the importance multiplier.

There is a lot of information that flows back and forth. Remember this.

Later, Rick will talk about network architecture as it applies to GL 36 sequences.

<pass to Rick>

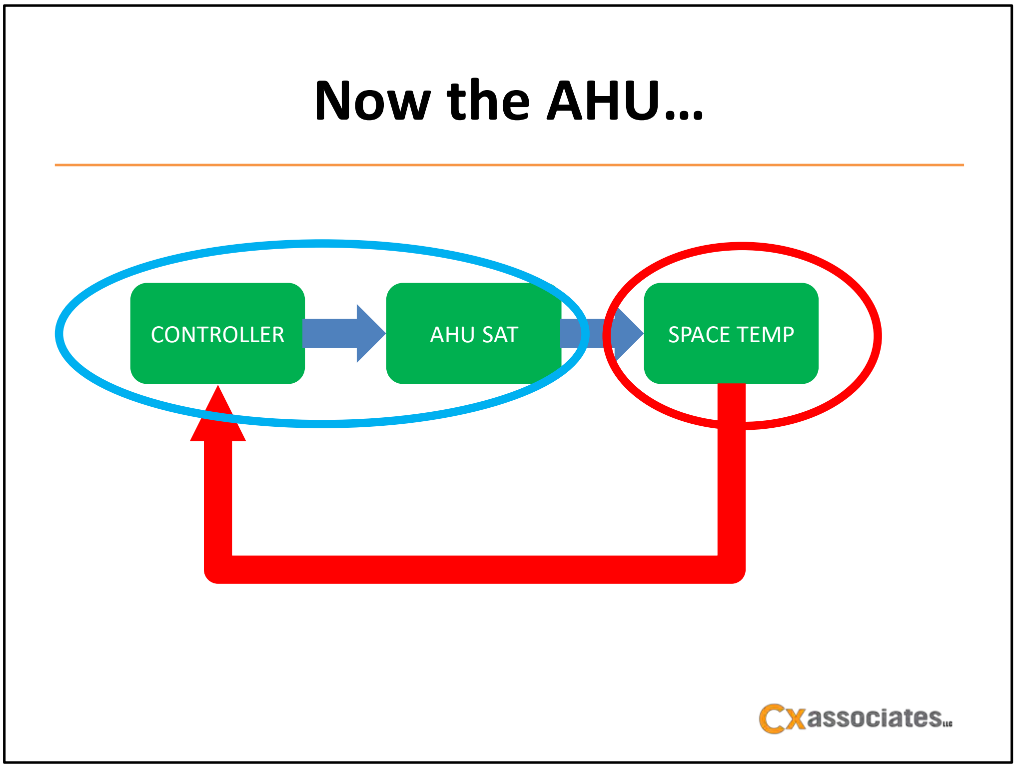
Matt



So we've just covered the space level control which feeds into the AHU SAT Reset Control.

<click>

<Rick>

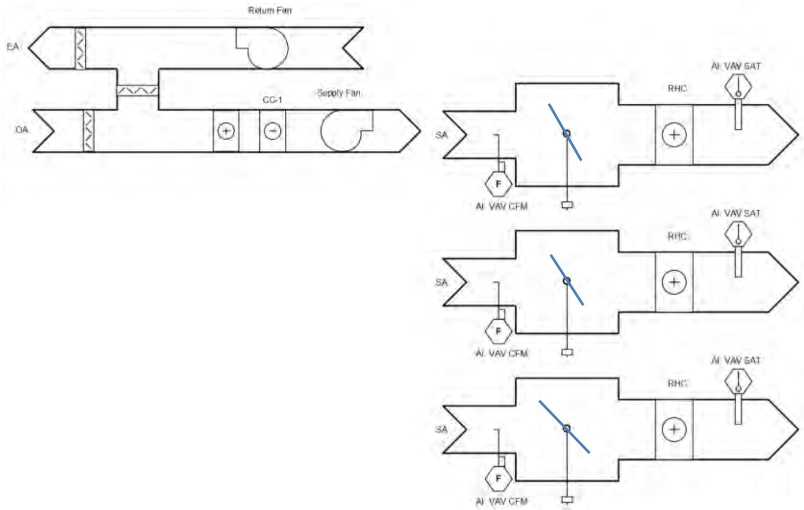


Next I'll talk about the AHU response to the space temperature feedback.

This response is called "Trim and respond".

<RICK>

Trim and Respond



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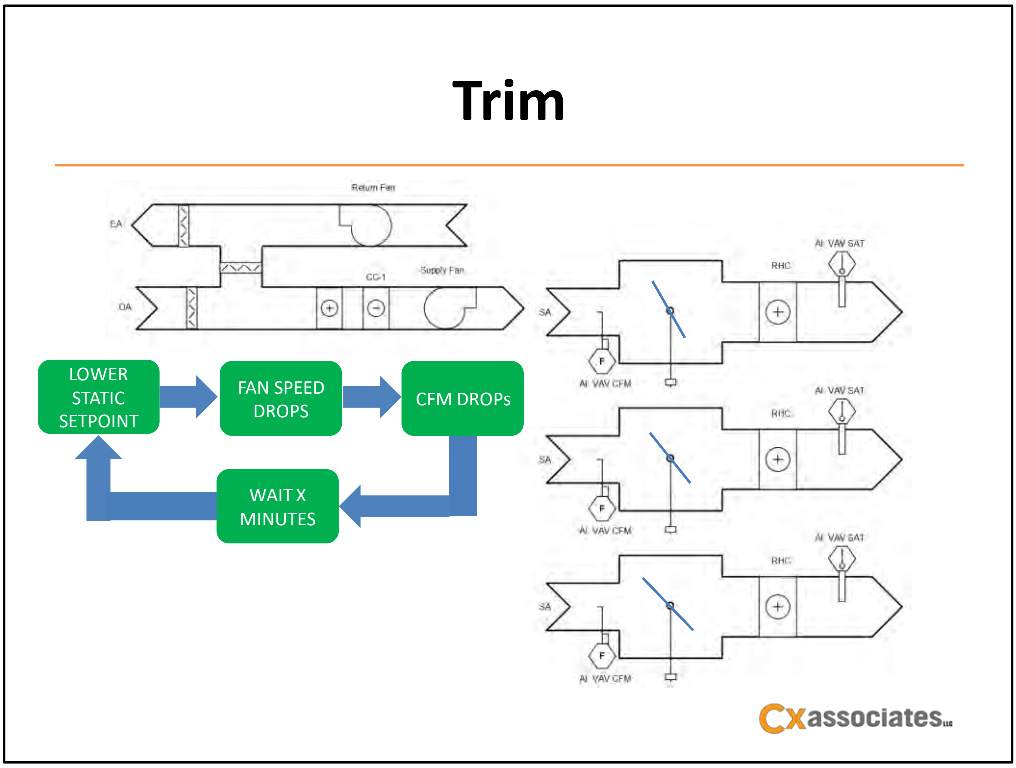
So the idea is to constantly reduce the setpoint at a fixed rate until a downstream zone is no longer satisfied and generates a call

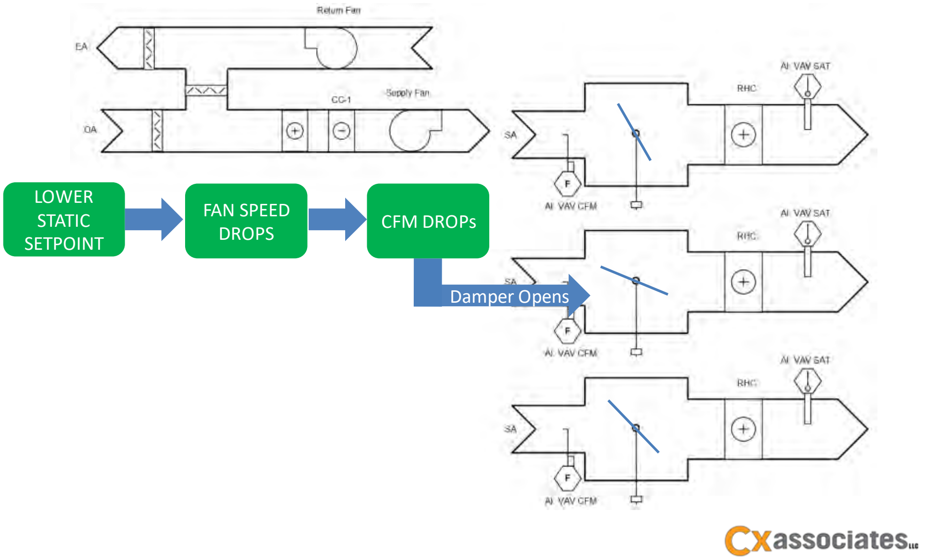
Rick



This is the Trim portion of Trim and respond. It's the time based component that seeks to constantly lower the static pressure in the system. This creates fan energy savings.

The system can only trim to a point however, eventually there will be a down stream reaction.
Rick

Trim

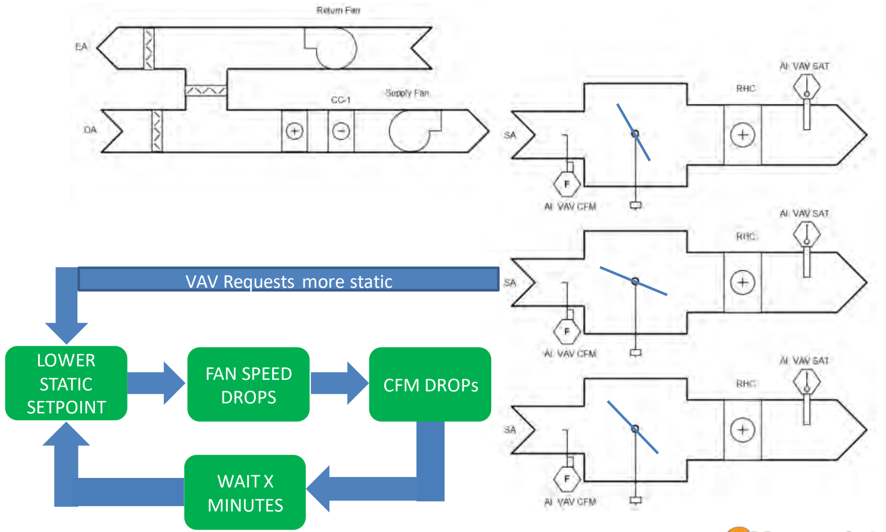


The damper crosses a positional threshold that the AHU looks for.

It generates a Request

Rick

Trim

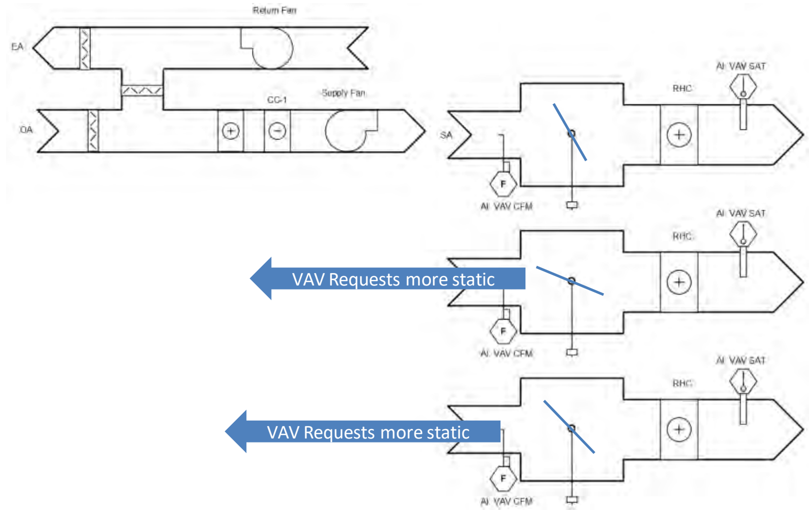


This request goes back to the AHU from the VAV

Or rather the AHU controller polls the damper positions of all the VAVs and compares it to a value indicative of a "request" for more static.

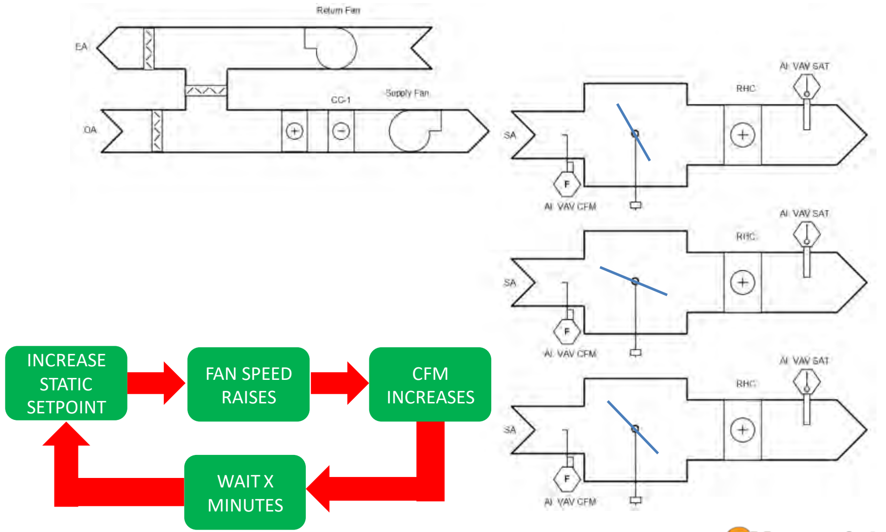
(This is why we talked about network architecture – there is a network dependency here to be considered)
Rick

…and Respond



When enough dampers make this request (which is an adjustable value so you can cancel out the effect of rogue zones)
Rick

Respond



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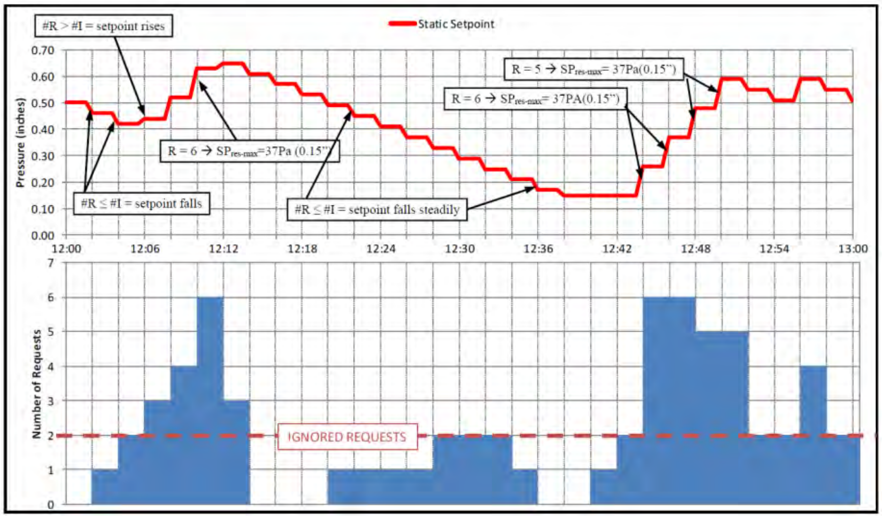
The system starts increasing static setpoint until the box requests are satisfied. Rick

Trim and Respond



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The net result is a low frequency oscillation that we can accept because it proves to reduce fan energy when properly tuned without affecting thermal comfort.

You'll notice it spends most of the time decreasing the setpoint and responds rather quickly by design.
Rick

From the Horse's Mouth

Trim & Respond logic resets a setpoint for pressure, temperature, or other variables at an air handler or plant. It reduces the setpoint at a fixed rate, until a downstream zone is no longer satisfied and generates a request. When a sufficient number of requests are present, the setpoint is increased in response. The importance of each zone's requests can be adjusted to ensure that critical zones are always satisfied. When a sufficient number of requests no longer exist, the setpoint resumes decreasing at its fixed rate. A running total of the requests generated by each zone is kept to identify zones that are driving the reset logic.

Trim and Respond logic is optimal for controlling a single variable that is subject to the requirements of multiple downstream zones (such as the static pressure setpoint for a VAV air handler). In this application, it is easier to tune than a conventional control loop and provides for fast response without high frequency chatter or loss of control of the downstream devices. It typically does generate low frequency cyclic hunting, but this behavior is slow enough to be non-disruptive.

See the end of this section for an example of T&R implementation.

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You can use this same approach for supply air temperature control

Valve position and differential pressure reset in hydronic systems

Any system with one fluid mover or heat exchanger serving many downstream connected loads can be considered for trim and respond logic by an experienced engineer.
Rick

Guideline 36 vs Status Quo

Trim and Respond – Lot's O' Variables

Variable	Definition
SP_0	Initial setpoint
SP_{min}	Minimum setpoint
SP_{max}	Maximum setpoint
T_d	Delay timer
T	Time step
I	Number of ignored Requests
R	Number of Requests from zones/systems
SP_{trim}	Trim amount
SP_{res}	Respond amount (must be opposite in sign to SP_{trim})
$SP_{res\text{-}max}$	Maximum response per time interval (must be same sign as SP_{res})

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OAT Reset vs Trim and Respond

HVAC systems are dynamic, but they are slow (lab hoods not withstanding).

We don't want our AHU responding too quickly to requests just like we don't want our VAV box responding too quickly.

Both result in cycling or hunting and increase wear on components and result in poor space comfort or deficient air change rates.

Table is from GL 36 and lists all the variables that go into trim and respond. There is no calculus here, but there is more to it than just a 1 to 1 correspondence.

Further more, I'd like to give a quick overview of controls network architecture due to the added network traffic and dependencies that heating/cooling requests, and trim and respond generate.

<Rick>

Network Traffic

- Guideline 36 is a collection of sequences, and doesn't give much guidance in terms of the controls network
- All these new sequences create more dependency on a fully networked control system
- Therefore, it's important to discuss the network architecture when talking about implementing the guideline.

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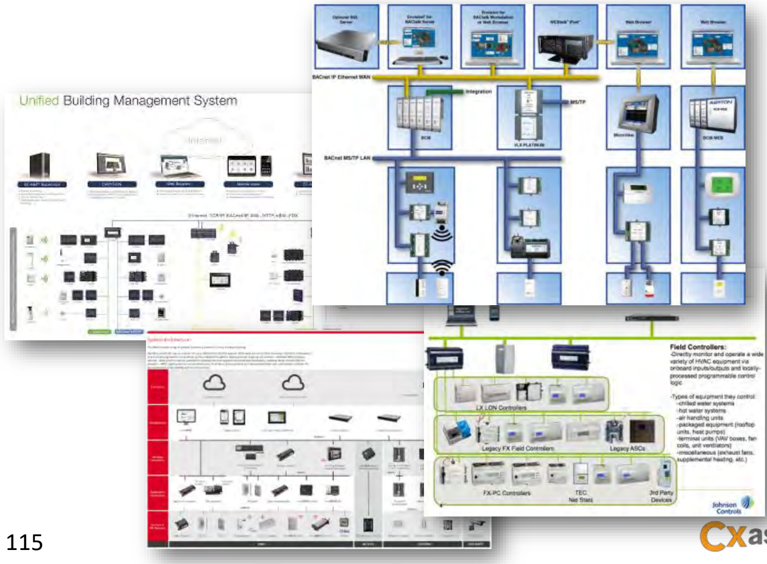
Controls Network Architecture



115

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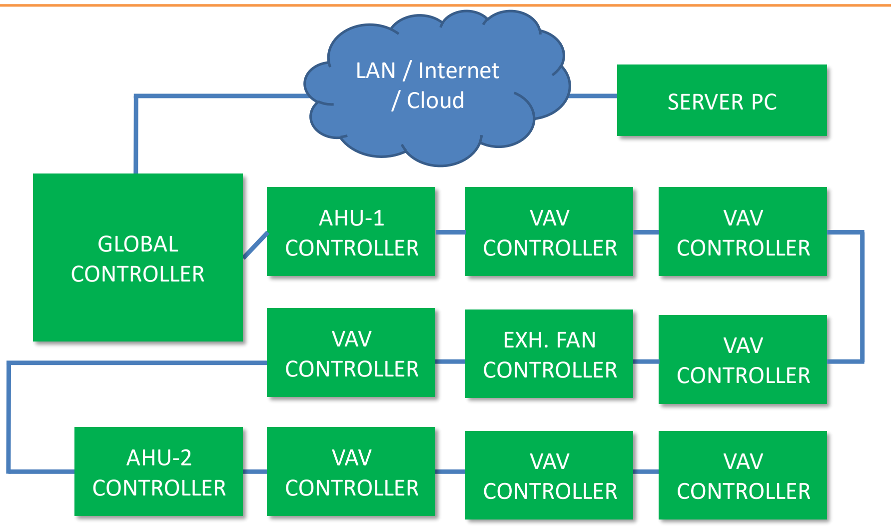
Here are some examples of what we would consider status quo controls architecture diagrams.

Image Source: http://www.distech-controls.com/~/media/images/products/general/architecture-small-products.ashx
http://hensen.com.hk/images/Logo/DeltaContols_SystemArchitecture-2013.png
http://www.eccoregon.com/images/imagebank/Architecture.jpg
http://www.broudyprecision.com/portals/17/jci_architecture_broudy.jpg

Controls Network Architecture



116

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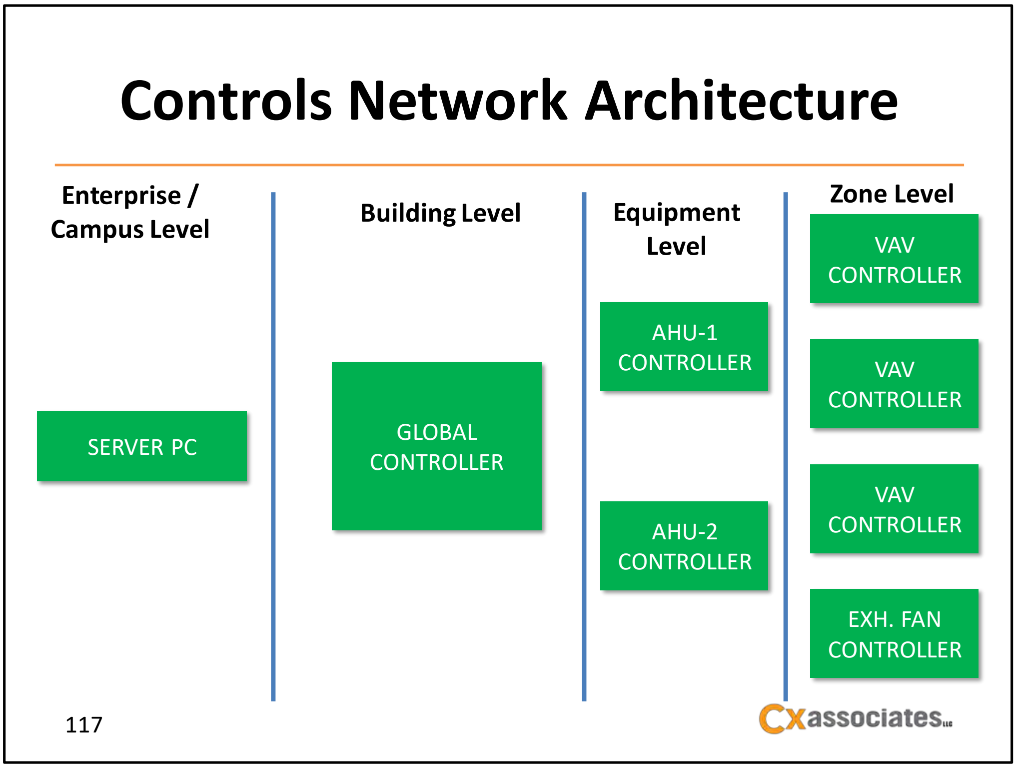
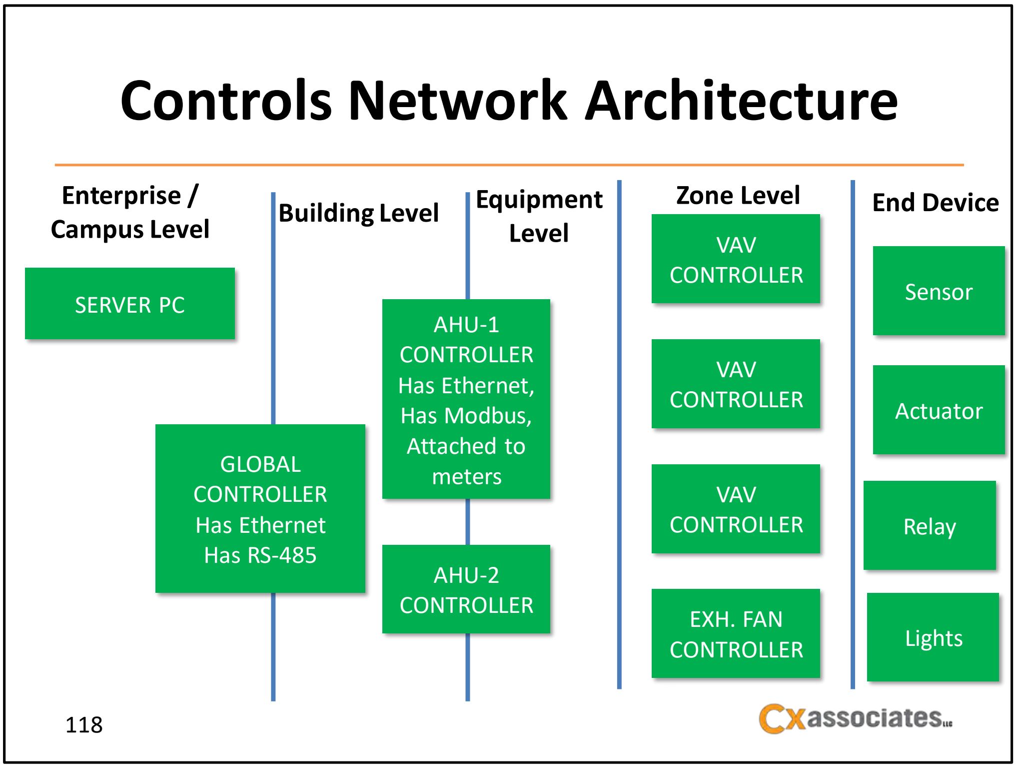
Most of the time, controls have a very flat architecture that's global controller centric.

This is cheap, and easy when done right.



You can categorize these controllers based on what they cover.

They can be grouped by the areas they serve!

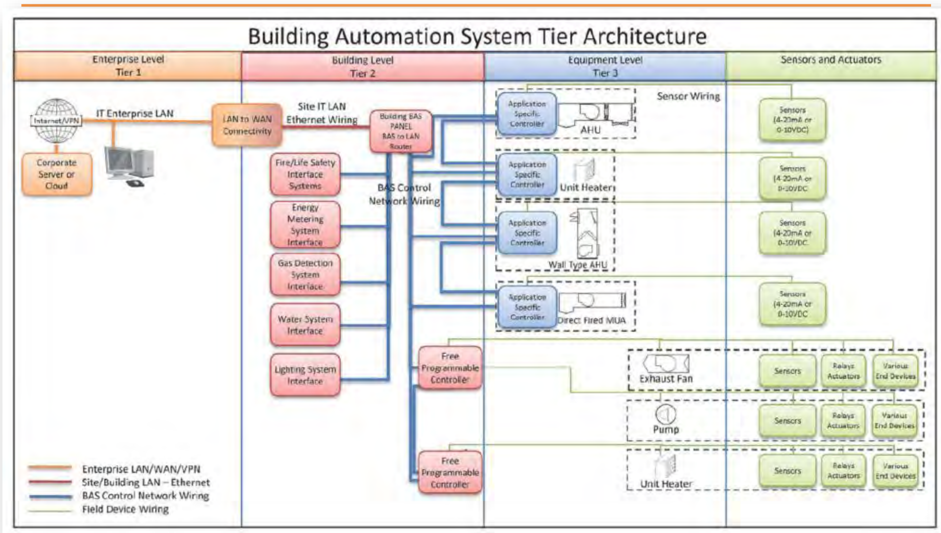


Sometimes controllers can ride these lines due to their feature sets.

So its not always super clear

But you can generally get an idea of how your product works by starting to separate equipment out on these tiers

Controls Network Architecture



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Because of this, architecture is important to pay attention to

We used ASHRAE Guideline 13 to inform a very smart architecture:

Source ASHRAE Guideline 13-2015 Page 7 Figure 4.3.1.3

Controls Network Architecture

8.7.9.3.1 For Information Exchange at the Management or Supervisory Level. A network of controllers that serve a common function (an entire building, a new wing, or a lab BAS) could be connected to a higher-level open network using a gateway. This serves to isolate islands of systems that use other protocols. This also provides a way to segment responsibility. The protocol and architecture from the gateway to the lower-level controllers would be determined, and the vendor would then supply the products (including the gateway).

The BAS designer will need to ensure these protocols are appropriate for this level of communication. In addition, the system architecture may be affected by this decision. See Informative Annex F for a reference to open-protocol guideline specification language.

7. The building controller shall communicate with networked BAS devices on the network using the protocol-specific communication requirements. Controller-to-controller communication shall be peer-to-peer and not require a master or host server for communication.

120

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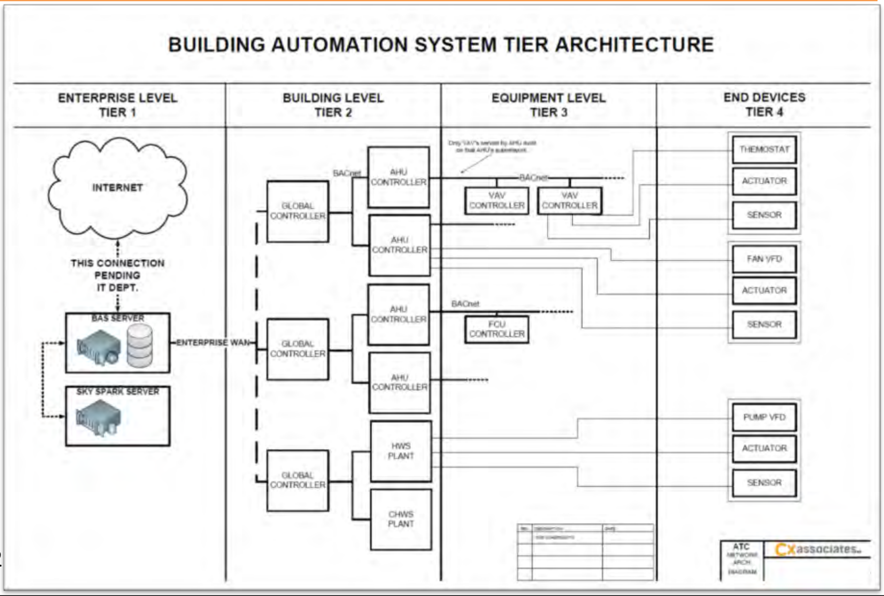
One key thing that's buried in Guideline 13 is

- **Design to isolate island of systems**
- **Provide segmentation of responsibility**
- **Utilize peer to peer!**

Source ASHRAE Guideline 13-2015 Page 60

Controls Network Architecture



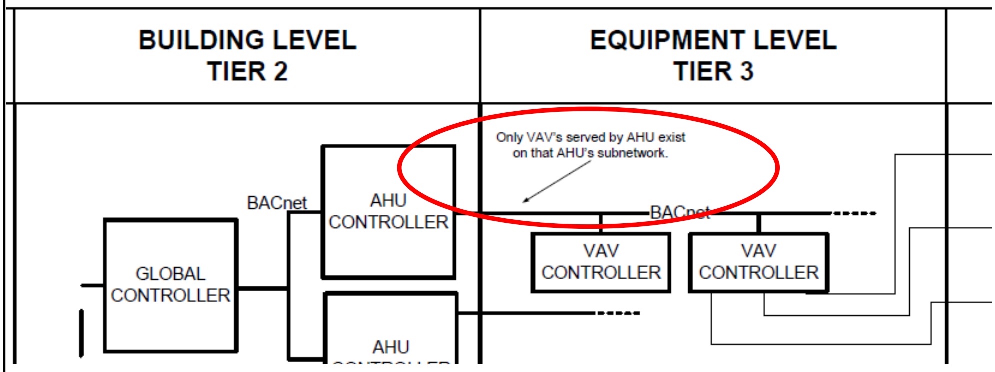
12

So we took that into consideration. We laid out our architecture

We tried to:

- Provide segmentation of responsibility
- Utilize peer to peer!

Controls Network Architecture



122

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isolate island of systems

segmentation of responsibility

Controls Network Architecture

1.5 DESCRIPTION

A. General: The control system shall consist of a high-speed, peer-to-peer network of DDC controllers, a control system server, and/or an operator workstation.

2.3 COMMUNICATION

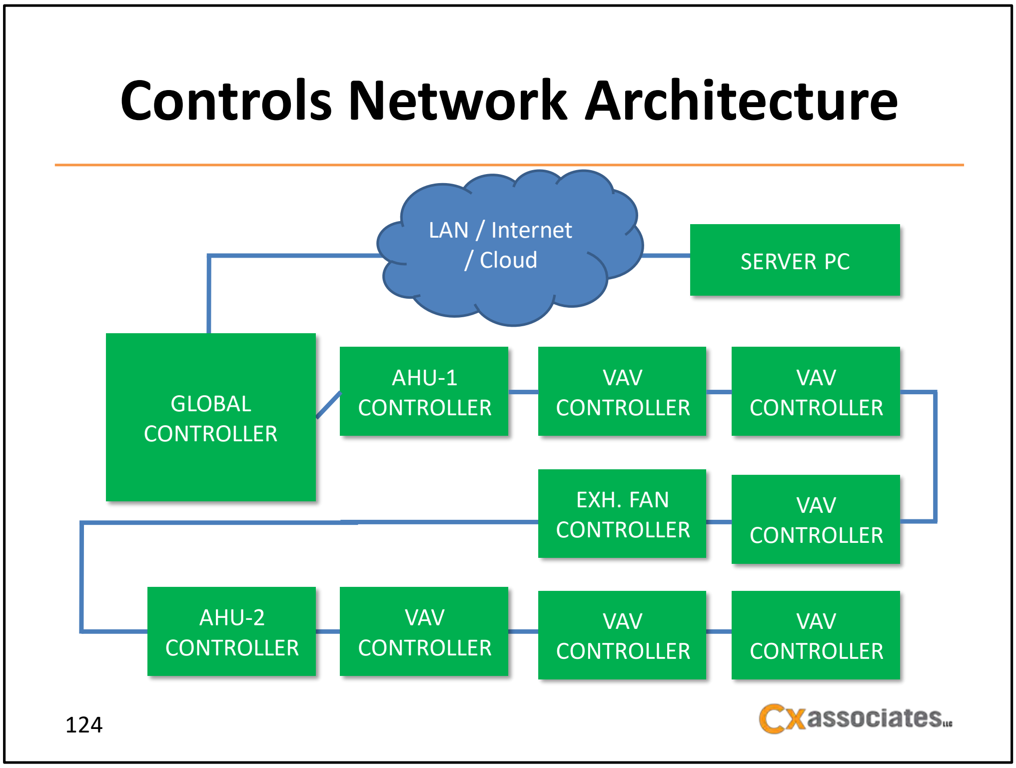
A. All IP based BAS communications shall exist on their own separate controls network provided by the IT department. They shall not have access to any other network resources other than those required for inter-controller communication and communication to the BAS server.

B. Data shall be shareable between any two controllers (peer to peer). The global controller may be used as a path between two physically disconnected subnetworks if the architecture requires it.

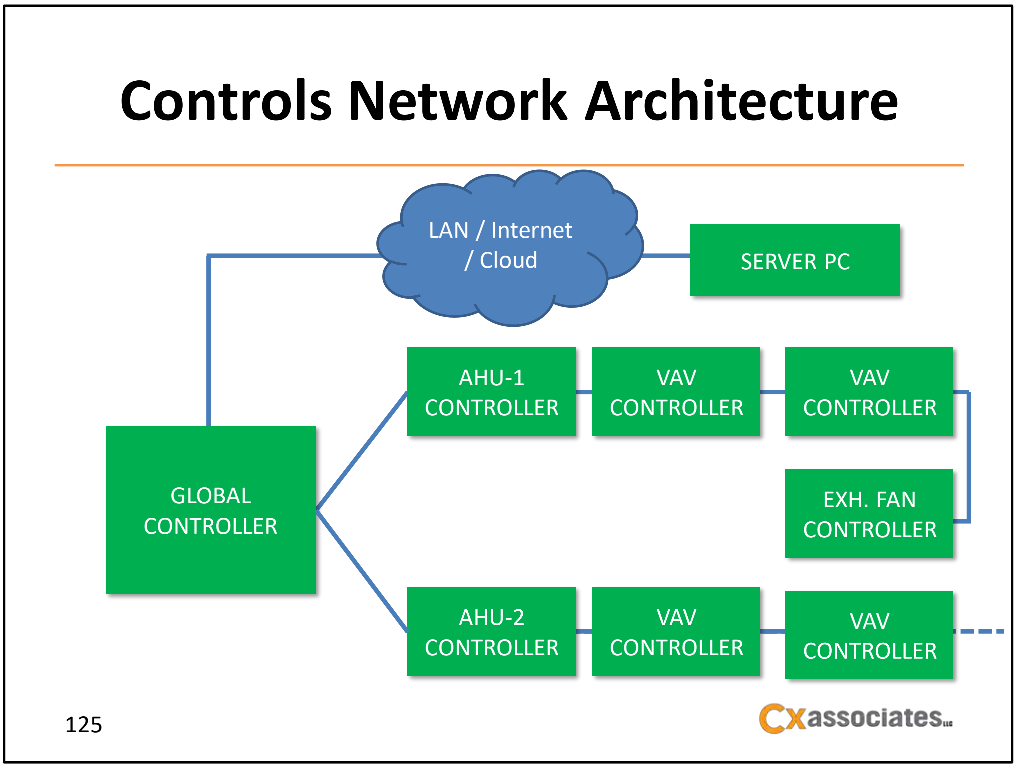
i. As much as possible the network architecture should be designed such that network variable dependencies are localized to subnetworks to minimize dependence of global controllers as network gateways. Global passing of data should be avoided as much as possible even though it is understood that some will be required (Such as OAT).

And in our spec, we mandated peer to peer

Then you have to check your submittals because you might end up with this:<click>



When you wanted this <click>



And if you reject the submittal, be prepared for this: <click>

If it ain't broke…

126

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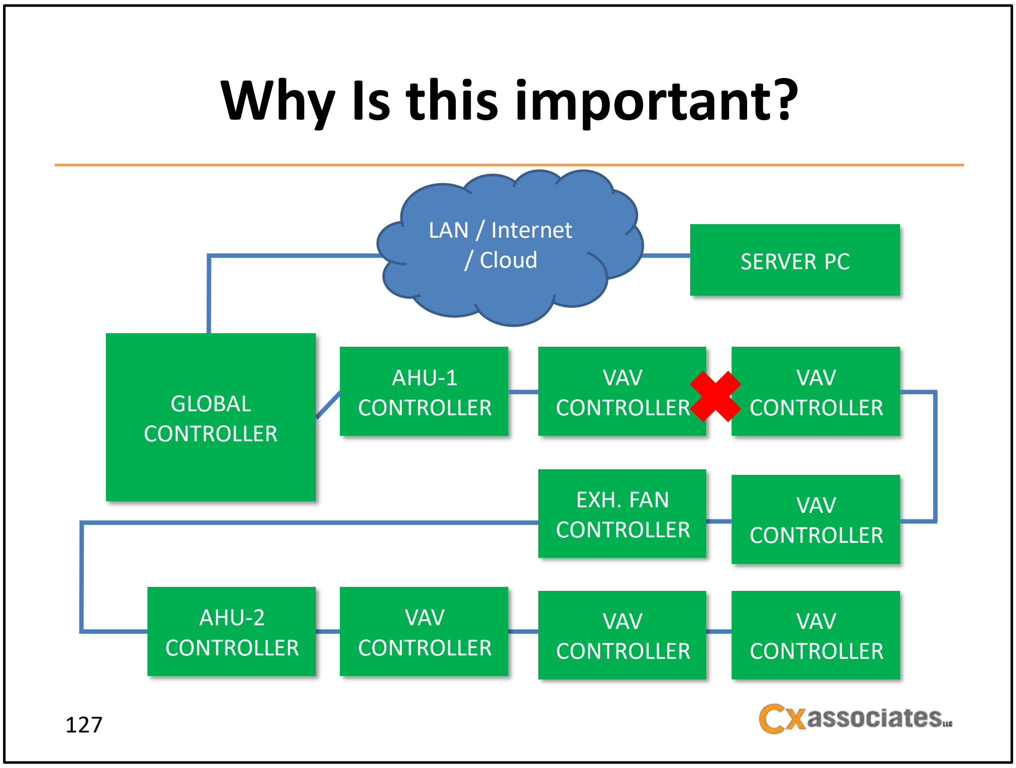
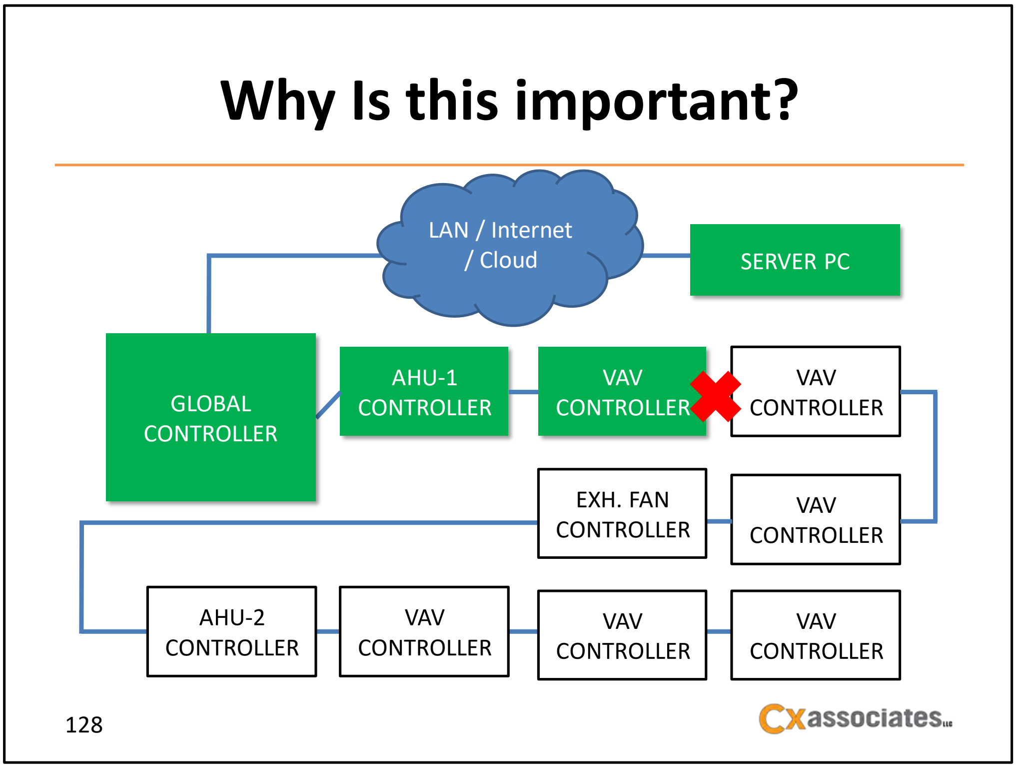


Why go to all this trouble.

But lets keep going on reliability and islands of control

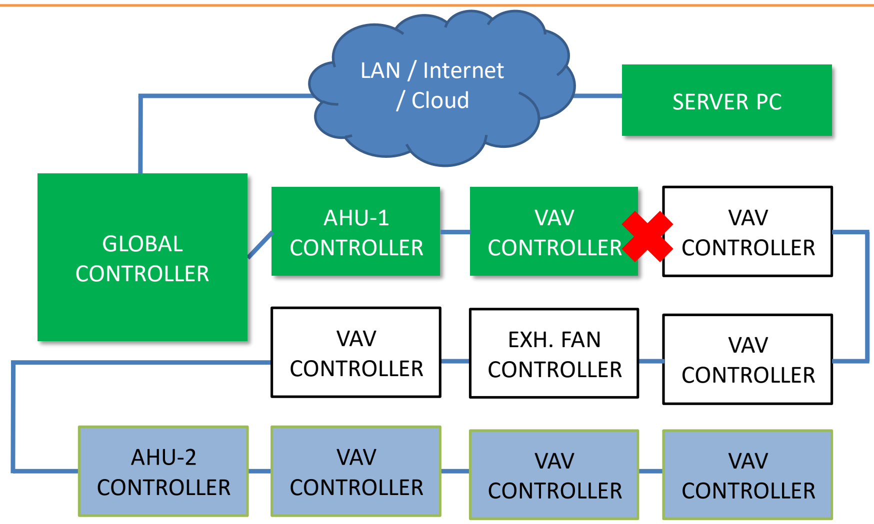
A break in the Bus here and… <click>



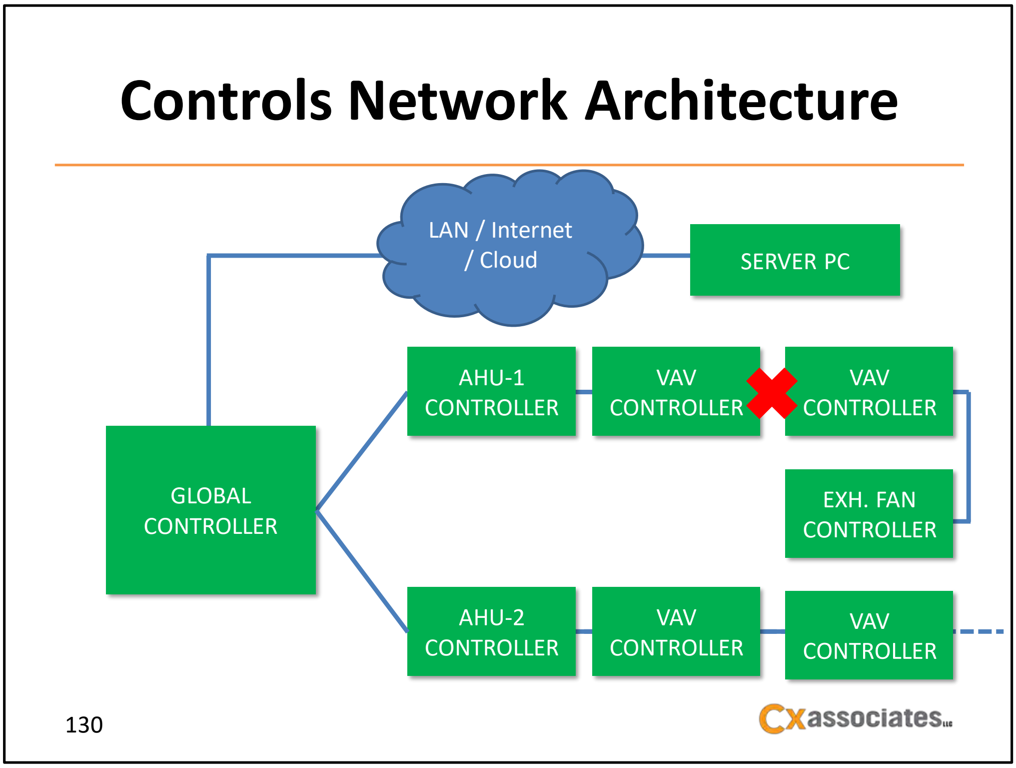
You lose communications to all these guys

Hopefully they're peer to peer

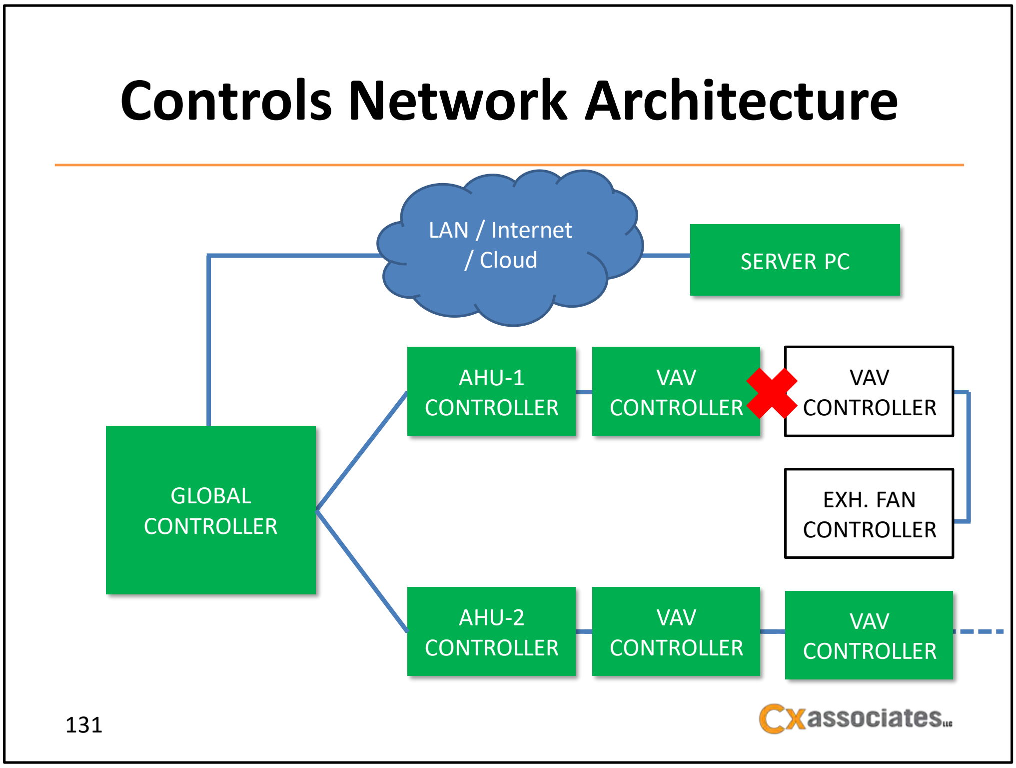
Why Is this important?



Assuming none of AHU-1's VAVs are after AHU 2 on the physical wire.



If we recreate that same break here under that GL13 Network architecture paradigm:



You only impact that small network segment and you only create problem for the single AHU and the zones after the break.

Not to mention, you reduce traffic by segmentation like this, and decrease troubleshooting time and increasing reliability

You can no longer not know that

132

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And now you know, you'll never look at a flat architecture the same.

While we are on architecture, lets look at Alarming which is very built architecturally up in the new GL36 approach.

<Rick>

Source: http://stream1.gifsoup.com/view6/1933241/happy-dance-it-crowd-o.gif

Network Architecture
Quick Review

- <u>**GL 36 sequences require more network traffic that usual**</u>
  - ASHRAE GL 13 architecture limits failure impact
  - Easy to implement, requires planning
  - Collaborate with your implementer (this may be new to them).
  - Yes Traffic is increased, however, not beyond the capacity of a modern day control system using a industry standard open communications protocol.

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Here's a quick review of the importance of Network Architecture.

While we are on architecture, lets look at Alarming which is very built architecturally up in the new GL36 approach.

<Rick>

PASS TO MATT

Matt

Efficient Alarming

Hierarchical alarm suppression is described in a paper by Jeffrey Schein and Steven Bushby, published in HVAC&R Research January, 2006.
It is a technique for suppressing extraneous or nuisance alarms, based on the principle that if a fault occurs both at a source (e.g., AHU) and a load (e.g., VAV box), then the fault at the load is likely caused by the fault at the source and is at any rate of a lower priority than the source fault; as such, the alarm for the load fault is suppressed in favor of the alarm for the source fault, so that the operator's attention is focused on the problem at the source.

Efficient Alarming – GL 36 employs hierarchical alarming.

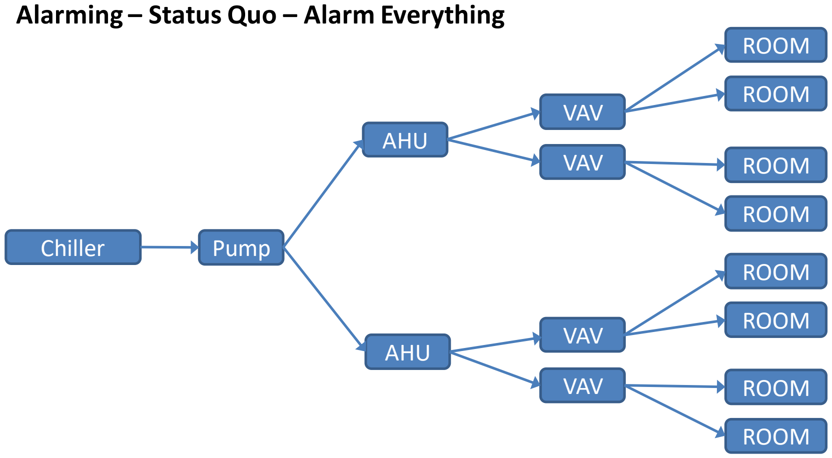
Basically – alarm only what needs to be alarmed.

Minimizing alarms allows operators to focus on operations, not tracking down false or spurious alarms.

<click>
Matt

Traditional Alarming

Alarming – Status Quo – Alarm Everything



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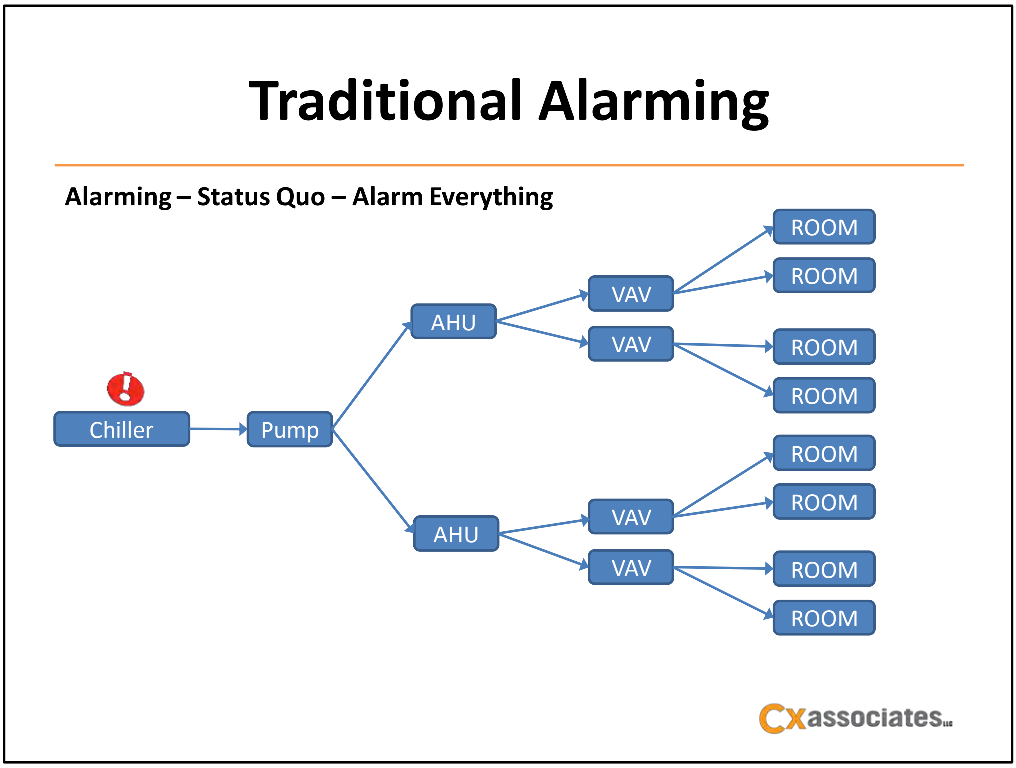
Example of a chiller serving AHUs that, in turn, serve VAV boxes that condition rooms.



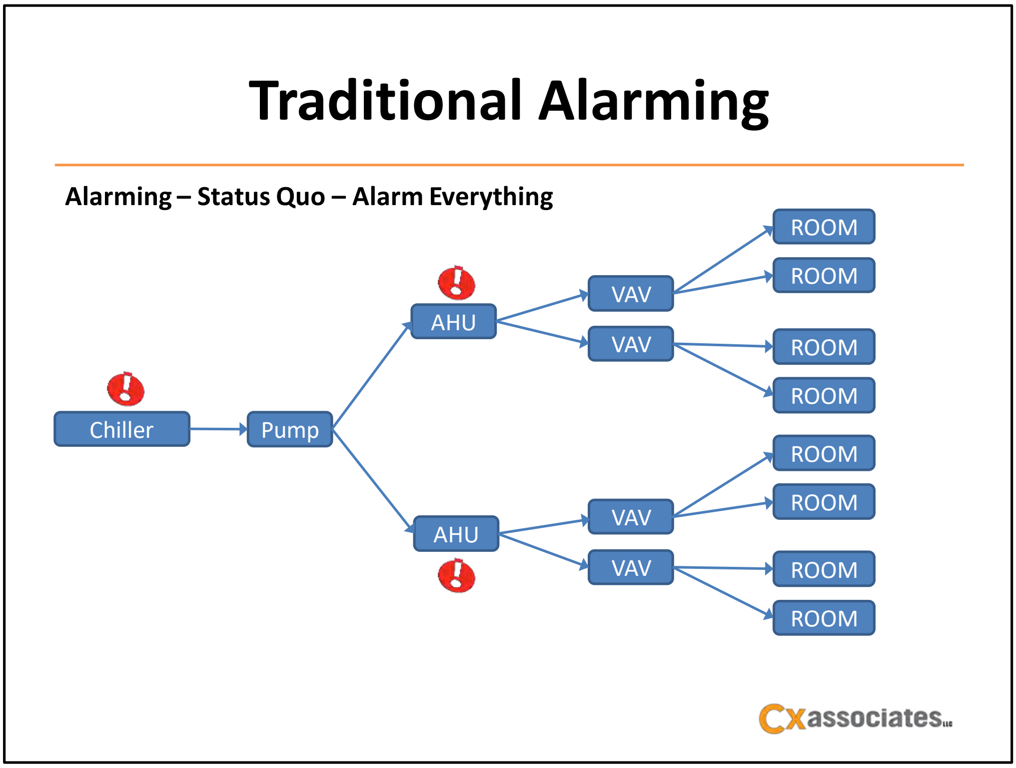
There's a chiller failure that can't be resolved immediately.

Some mechanical failure.

You get the chiller alarm as you'd expect.

You want that alarm because the equipment needs attention.

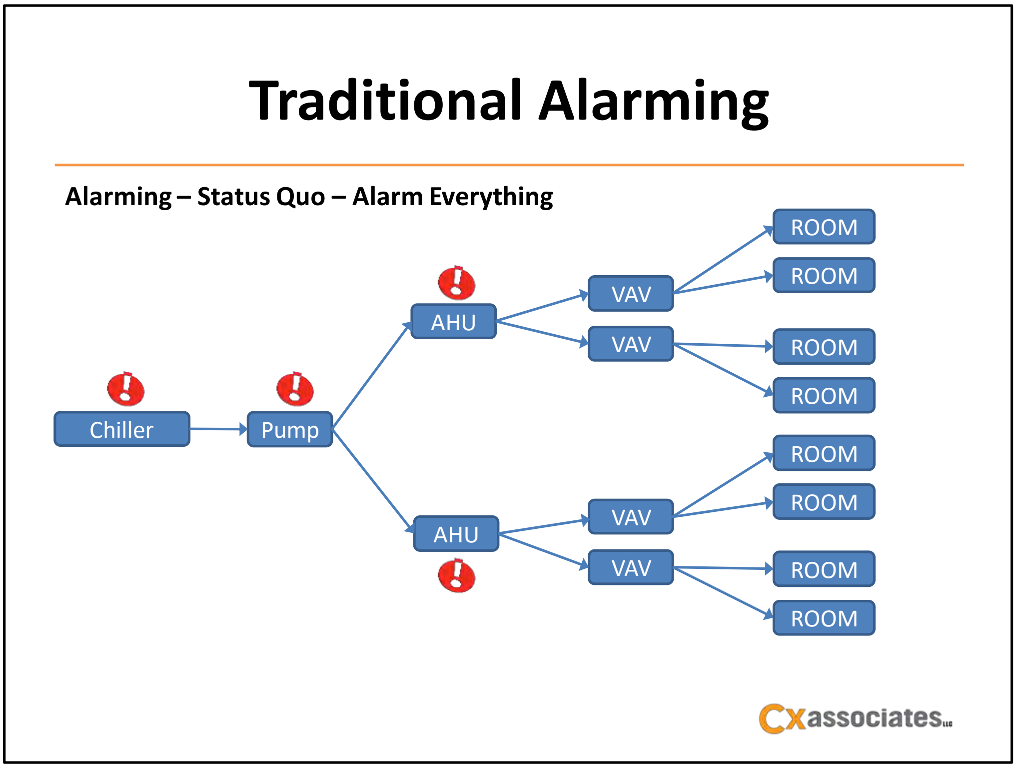
<click>



Pretty soon the AHU's cant met their SAT setpoints and you get an AHU alarm.

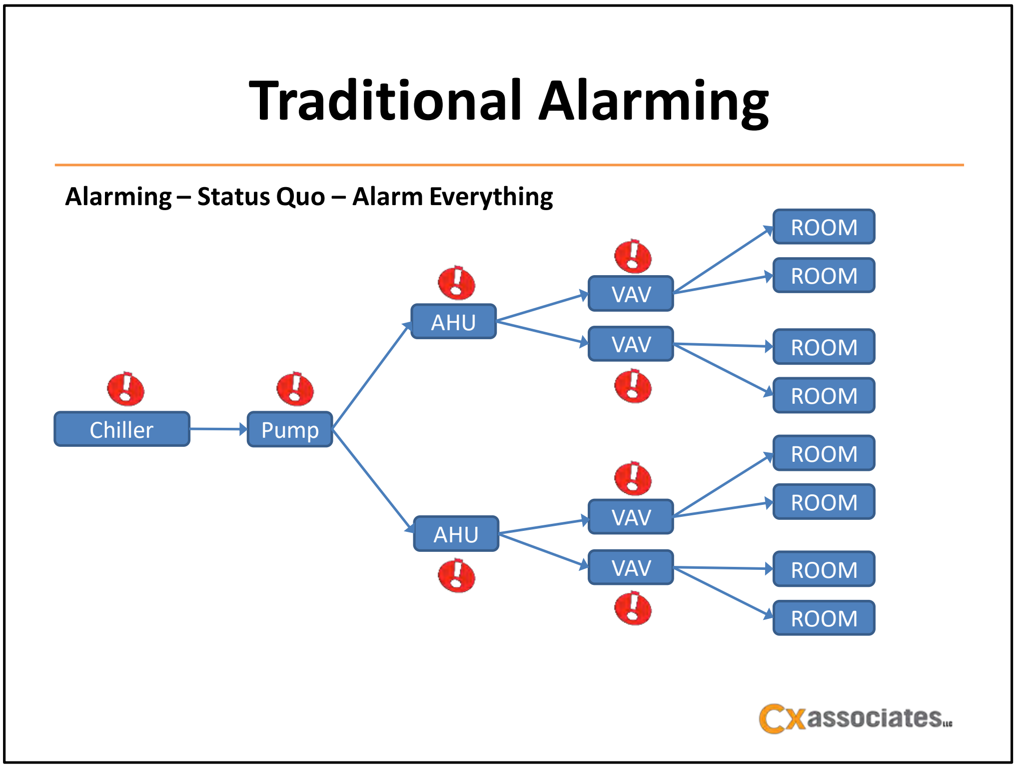
You'll likely get an alarm on each AHU served by the chiller plant.

<click>



Because all the AHU's CHW valves are wide open and now your pumps can't meet DP, the pumps alarm.

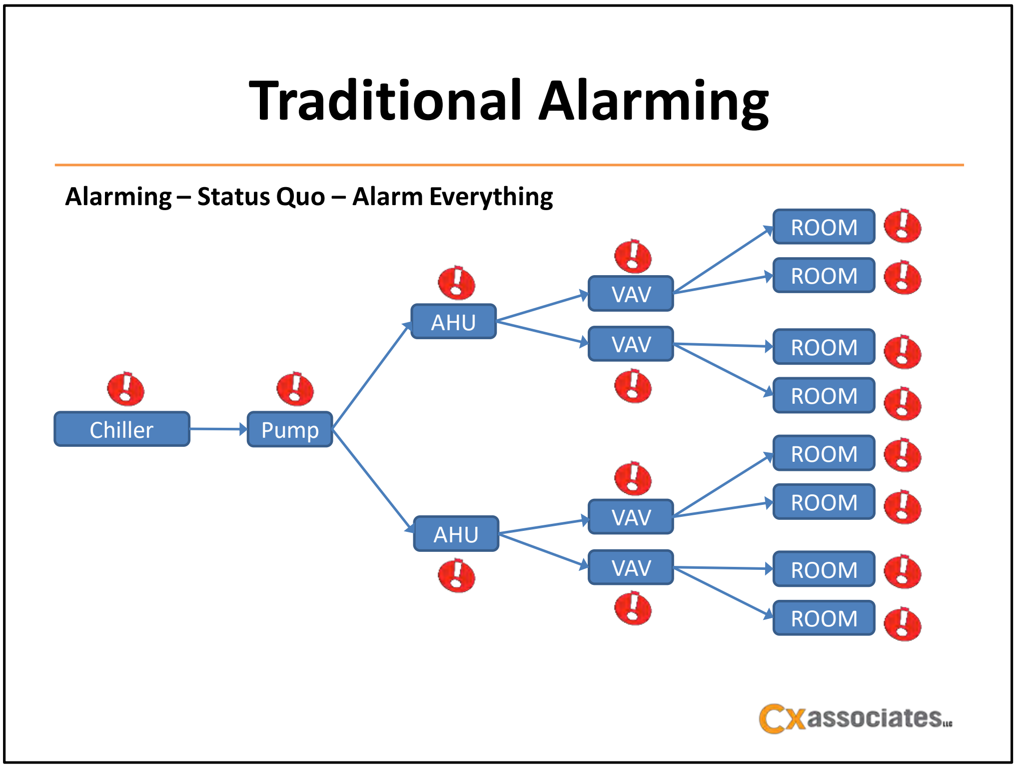
<click>



As the rooms warm up, the VAV's respond and eventually the AHUs can't provide design CFM to ALL the VAVs.

Now the VAVs go into alarm.

<click>



Once the VAV's can't meet airflow and the air is no longer conditioned, the rooms get warm and after a bit, they alarm too.

This is a very limited example. 8 rooms. 8 rooms result in 16 or more alarms. How many rooms are in your facility?

How do we Prevent the Unnecessary Alarms?

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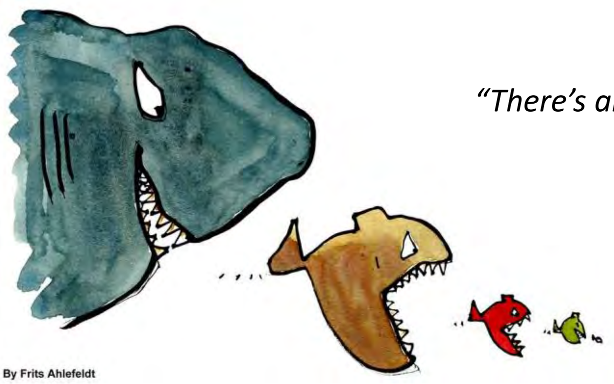
What's the solution?

Use a Hierarchy

Alarming – GL 36 – Hierarchical Alarming



By Frits Ahlefeldt

"There's always a bigger fish"

CXassociates

What's the solution?

Use a hierarchy.

Another way to think about a hierarchy is in terms of dependencies.

Extra points if you know the quote.

<click>

Use a Hierarchy

Alarming – GL 36 – Hierarchical Alarming

Source

Load

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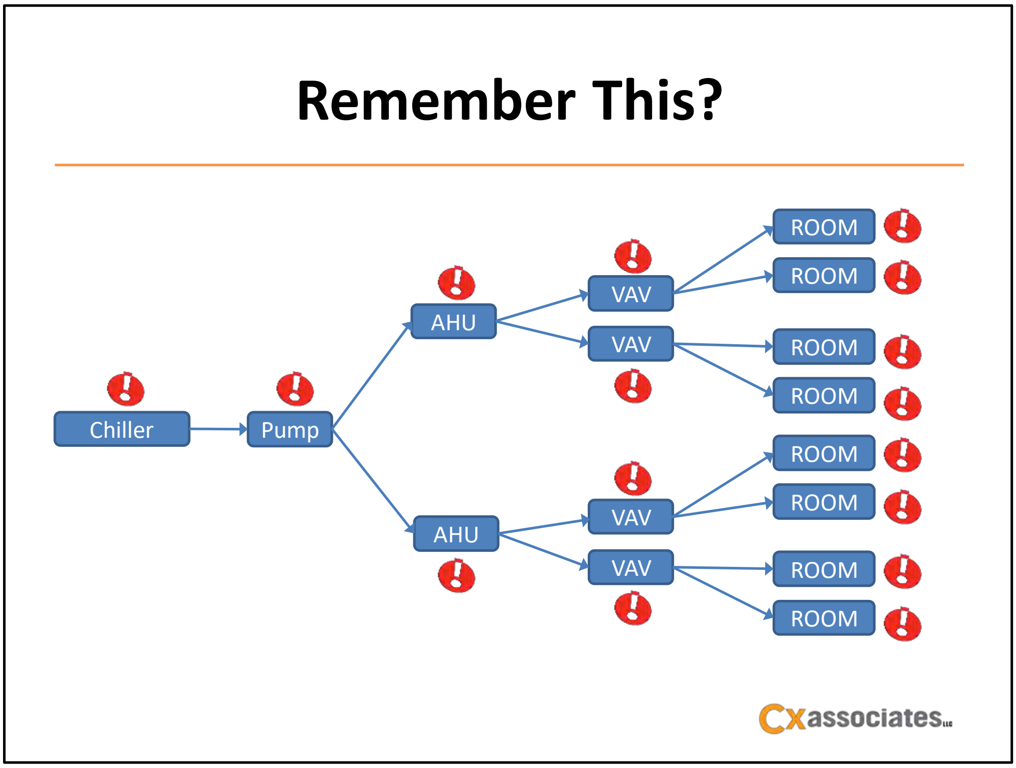
Here we introduce the concept of a source and a load.

In this example, the chiller is the source of cooling.

The AHU is the load that needs cooling.

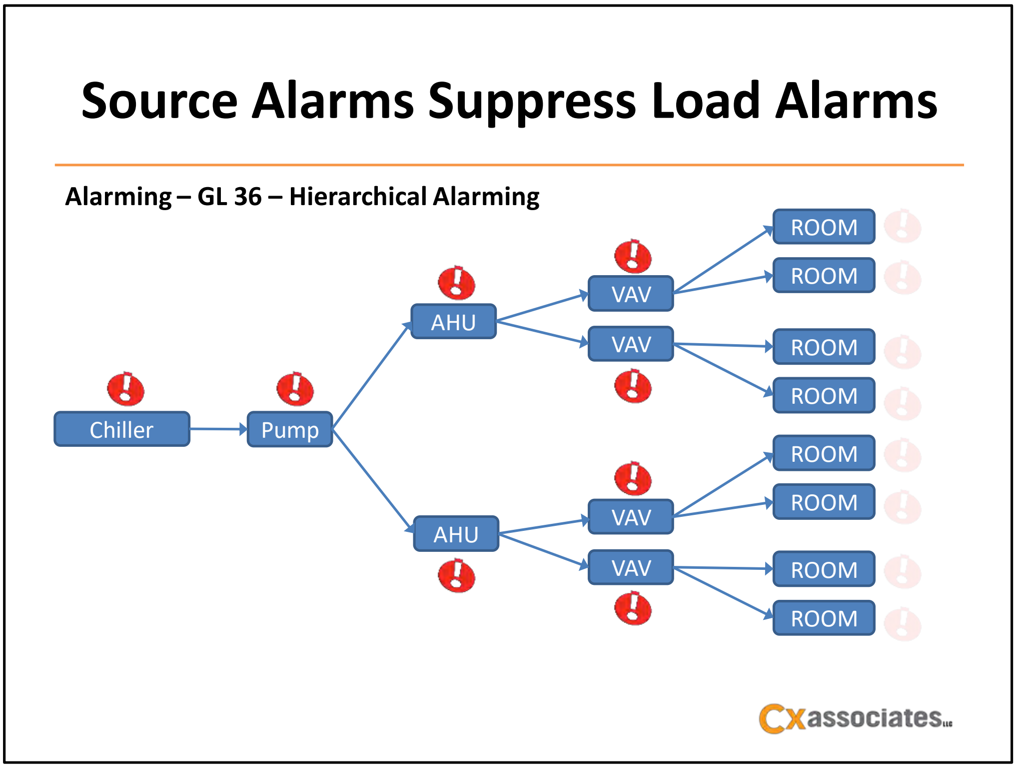
The AHU could be the source and the room a load.

<click>



Let's review this again.

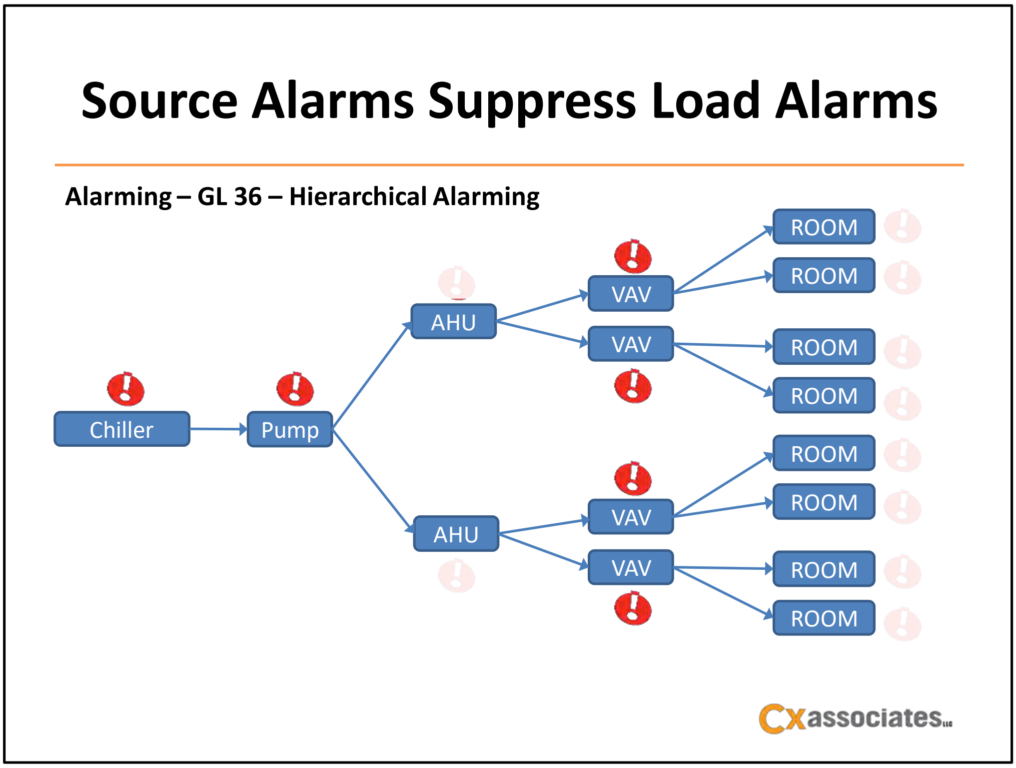
As soon as we loose the chiller, (the source), we know the rooms (loads) will all get hot.



Because of the chiller alarm, we can suppress all the room alarms.

They might be generated, but they won't be reported.

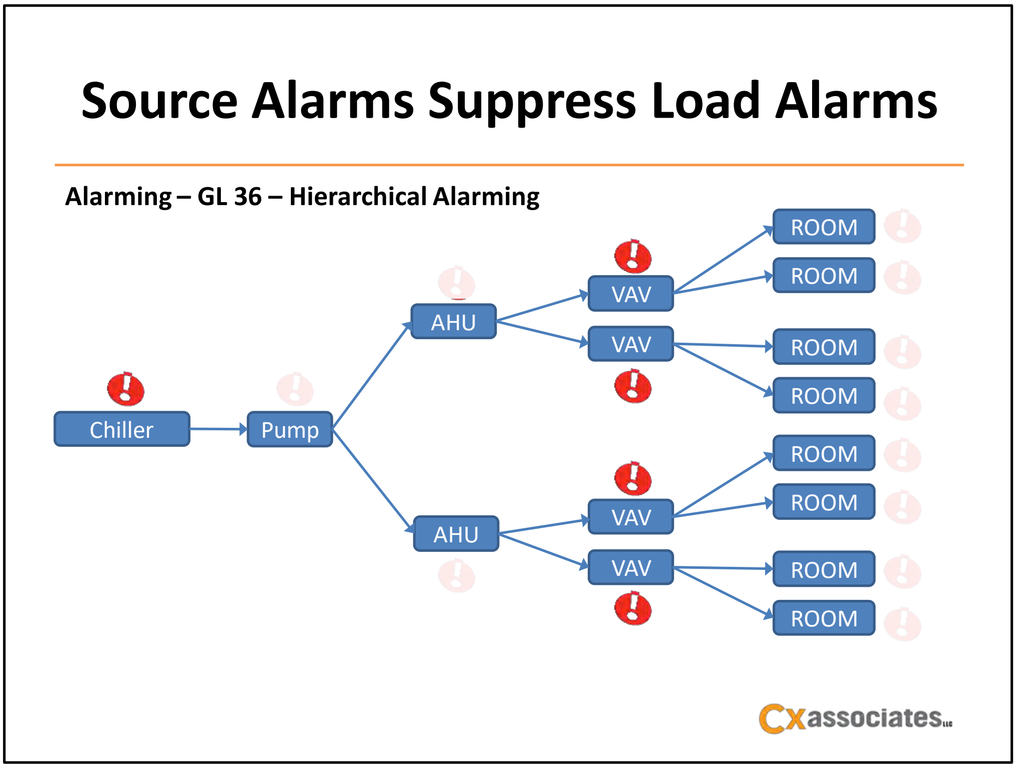
<click>



We also know the AHUs (another load) won't be able to meet set point.

Let's keep them quiet as well.

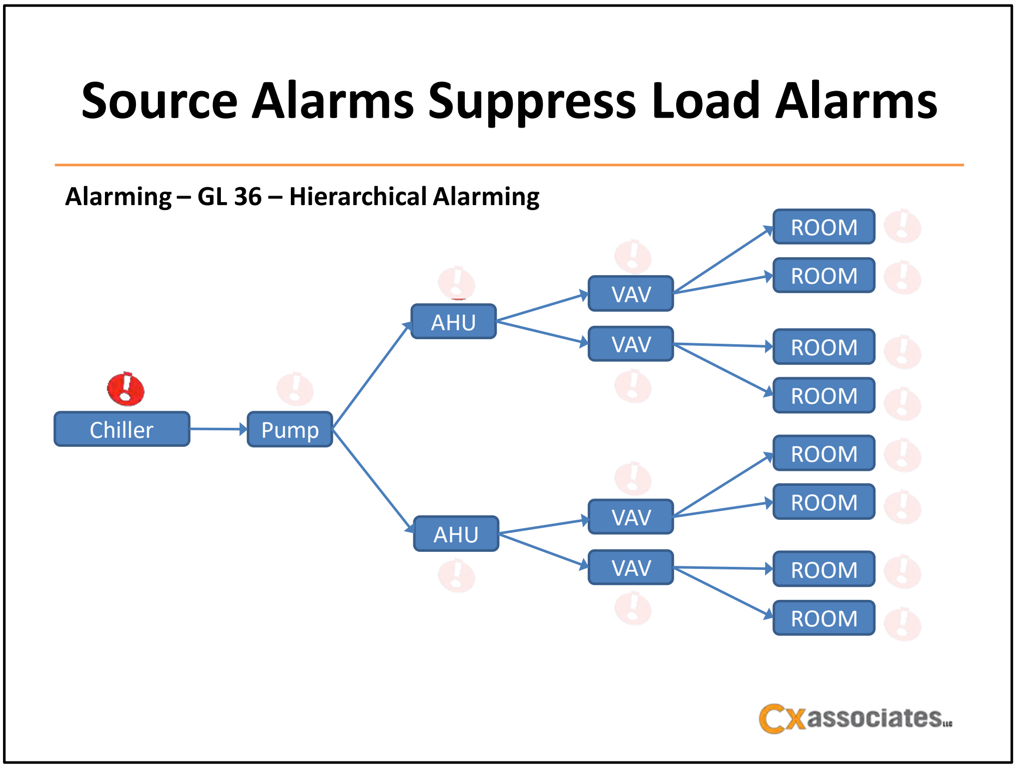
<click>



It's safe to assume that if your chiller is in alarm, it's not making chilled water.

If it's not making chilled water, we can expect the AHU's to all go to full call which means we can probably suppress the pump DP alarm as well.

With the VAVs, I would argue that once the chiller is in alarm, we know we can't make chilled water and we just agreed on all the other alarm suppression so if the chiller is in alarm…



So we can suppress the airflow alarms as well.

From no fewer than 16 alarms to 1 with some careful thought, up front planning, and a skilled programmer.

Now, the last section we'll be talking about addresses how we can get ahead of alarming in the first place

<click>

Smart Alarming Quick Review

- **Guideline 36 provides a source / load alarm relationship**
  - Creates significantly fewer alarms in the system
  - Makes the system more time efficient from a troubleshooting perspective
  - Aims at using a bit more logic to inhibit alarms intelligently
  - No more “boy cried wolf” alarm logs

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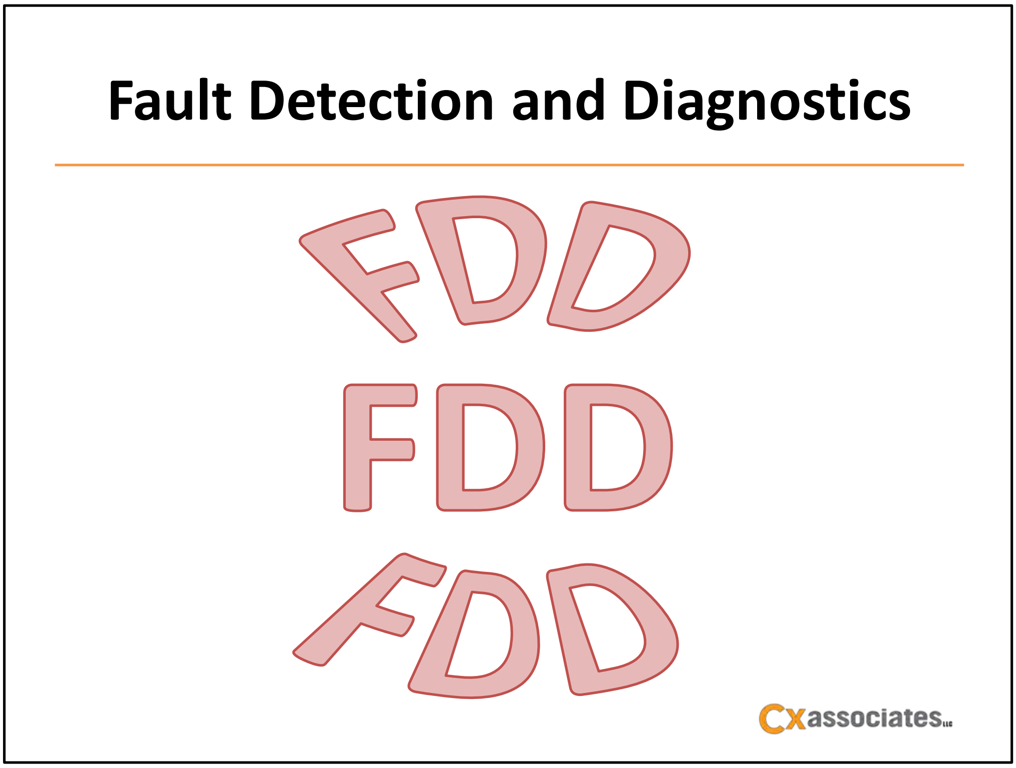
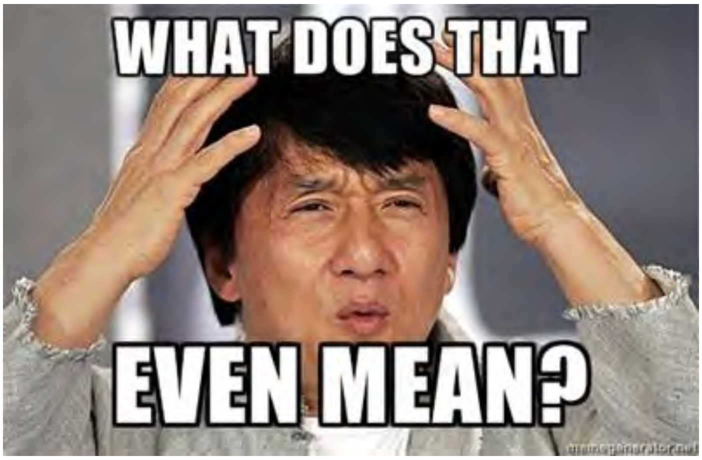


GL 36 calls it AFDD, A for automatic

Fault Detection and Diagnostics



Important to define to ensure expectations are understood.

Fault Detection and Diagnostics

Fault Detection and Diagnostics – Defined in GL 36 as:

Assessing equipment performance

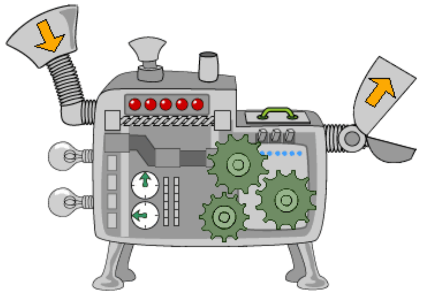
GL talks about assessing AHU performance because the GL only pertains to air side systems so far.

Fault Detection and Diagnostics

Fault Detection and Diagnostics – Defined in GL 36 as:

Assessing equipment performance

By comparing BAS inputs and outputs



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Fault Detection and Diagnostics

Fault Detection and Diagnostics – Defined in GL 36 as:

Assessing equipment performance
By comparing BAS inputs and outputs
To potential fault conditions

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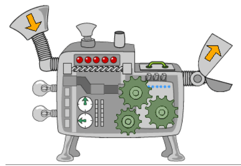
Fault Detection and Diagnostics

Fault Detection and Diagnostics – Defined in GL 36 as:

Assessing equipment performance
By comparing BAS inputs and outputs
To potential fault conditions



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Some may refer to FDD as Continuous Commissioning, Building Analytics, A "Dashboard"

While those names mean different things, what is important is the methodology.

What it boils down to…

<click>

Fault Detection and Diagnostics

Fault Detection and Diagnostics

A Binary Comparison – PASS / FAIL

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Is that if "FDD" does not result in a pass / fail outcome, it is not FDD.

Even complex calculations such as predicted energy use,

given past performance and current weather conditions,
can result in a pass / fail (with some thinking).

It is up to the system designer and building operator to define the pass / fail criteria.

FDD Implementation

Equipment Operating State (OS)

Operating State	Heating Valve Position	Cooling Valve Position	Outdoor Air Damper Position
#1: Heating	>0	=0	=MIN
#2: Economizer Cooling, Modulating OA	=0	=0	Min < X <100%
#3: Mechanical + Economizer Cooling	=0	>0	=100%
#4: Mechanical Cooling + Min OA	=0	>0	=MIN
#5: Unknown or Dehumidification	No other OS applies		

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Operating states are important because faults that occur, say, in heating mode are not applicable in cooling mode. The OS is a filter on the determination of P/F.

Alarms happen after the issue happened. FDD tries to get ahead of the issue.

Very important – most of us inherently know that in heating mode, the heating valve is likely a bit open. But, by defining the OS as illustrated, the designer takes full ownership and removes interpretation. In our commissioning work we are continually in the position of translating or interpreting. Be specific and use criteria that are binary.

FDD Implementation

Variable Definition

Variable Name	Description	Default Value
ΔT_{SF}	Temperature rise across supply fan	2 °F
ΔT_{MIN}	Minimum difference between OAT and RAT to evaluate economizer error conditions	5°F
θ SAT	Temperature error threshold for SAT sensor	2°F
θ RAT	Temperature error threshold for RAT sensor	2°F
θ MAT	Temperature error threshold for MAT sensor	2°F
θ OAT	Temperature error threshold for OAT sensor	2°F
θ F	Airflow Error threshold	3%
θ VFD_{SPD}	VFD Speed Error threshold	5%
θ DSP	Duct static pressure error threshold	0.2"
ΔOS_{Max}	Maximum number of changes in Operating State	7
Mode Delay	Time in minutes to suspend fault condition evaluation after a change in operating state.	90
Alarm Delay	Time in minutes that a fault condition must persist before triggering an alarm	60

Define the variables to be used.

Again - very important – The designer takes full ownership and removes interpretation.

However, many of these values depend on the chosen equipment. Implementers need to provide input.

Airflow example – highly dependent on not only the hardware but the installation as well. Can be as low as 3% or as high as 10% when correctly installed.

Airflow threshold is 30% in the GL.

FDD Implementation - AHU Example

Supply Air Temperature Fault

OS

(operating state)

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First step is to evaluate in which OS the system resides. Those are OS icons. Operating Systems. It's a joke.

FDD Implementation - AHU Example

Mixed Air Temperature Fault

FC #3	Equation	$MAT_{AVG} - \theta_{MAT} > MAX\ [(RAT_{AVG} - \theta_{RAT}), (OAT_{AVG} - \theta_{OAT})]$	Applies to: OS #1- #5
	Description	MAT too high; should be between OAT and RAT	
	Possible Diagnosis	RAT sensor error MAT sensor error OAT sensor error	

FC = Fault Condition. This is FC #3 out of the Guideline. We could call it FC #3 or FC-A. Again, looking to keep things consistent.

The information in the box is all contained in the GL and should be carried over to the project specifications.

The Description and Possible Diagnosis should be shown on the graphics when the fault occurs.

They are the human readable elements of these equations

Theta is temp error threshold (sensor error).

FDD Implementation - AHU Example

Mixed Air Temperature Fault

$$MAT_{AVG} - \theta_{MAT} > MAX\ [(RAT_{AVG} - \theta_{RAT}), (OAT_{AVG} - \theta_{OAT})]$$

Variable Name	Example Value
RAT_{AVG}	68 °F
MAT_{AVG}	52 °F
OAT_{AVG}	28 °F
θ RAT	2°F
θ MAT	1°F
θ OAT	2°F

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FC #3 gives us an equation to evaluate. We've included some example values for the variables in question. We'll talk about the AVG temperature values in a minute.

Theta is temp error threshold (sensor error).

FDD Implementation - AHU Example

Mixed Air Temperature Fault

$$MAT_{AVG} - \theta_{MAT} > MAX\ [(RAT_{AVG} - \theta_{RAT}), (OAT_{AVG} - \theta_{OAT})]$$

Variable Name	Example Value
RAT_{AVG}	68 °F
MAT_{AVG}	52 °F
OAT_{AVG}	28 °F
θ RAT	2°F
θ MAT	1°F
θ OAT	2°F

$$(52 - 1) > MAX\ [(68 – 2), (28 - 2)]$$

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Theta is temp error threshold (sensor error).

FDD Implementation - AHU Example

Mixed Air Temperature Fault

$$MAT_{AVG} - \theta_{MAT} > MAX\,[(RAT_{AVG} - \theta_{RAT}), (OAT_{AVG} - \theta_{OAT})]$$

Variable Name	Example Value
RAT_{AVG}	68 °F
MAT_{AVG}	52 °F
OAT_{AVG}	28 °F
θ RAT	2°F
θ MAT	1°F
θ OAT	2°F

$$(52 - 1) > MAX[(68 – 2), (28 - 2)]$$

Is (51) > (66)?

No, ∴ No Fault

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Now lets talk about when a facilities guy notices his MAT sensor goes to 0 because the sensor broke, and replaces it.

Let say (real world example) he replaces it with ALMOST the right sensor, but not the exact sensor and so the scaling is thrown off.

At first he might not notice this because Alarms are typically not attached to the MAT sensor

Also, Alarms typically do not consider a temperature sensor's reading with respect to the other AHU sensors and AHU Operating state.

So lets see what happens with the new sensor <click>

Theta is temp error threshold (sensor error).

FDD Implementation - AHU Example

Mixed Air Temperature Fault

$MAT_{AVG} - \theta_{MAT} > MAX\ [(RAT_{AVG} - \theta_{RAT}), (OAT_{AVG} - \theta_{OAT})]$

Variable Name	Example Value
RAT_{AVG}	68 °F
MAT_{AVG}	**71 °F**
OAT_{AVG}	28 °F
θ RAT	2°F
θ MAT	1°F
θ OAT	2°F

(71 - 1) > MAX[(68 – 2),
(28 - 2)]

Is (70) > (66)?

YES, ❖ Fault
(But no Alarm!)

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Theta is temp error threshold (sensor error).

FDD Implementation

Using the Inputs – Average Temperatures

<u>From the GL (and in your specs)</u>
The following values must be continuously calculated by the FDD routines for each AHU:

There is a LONG list. This is just a small portion of it.

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We just saw an example that used the average supply and average mixed air temperatures. Why? Because HVAC systems tend to be dynamic, we don't want to focus on the instantaneous values of any variable. Also, in one particular instance, we may calculate a fault condition, but it may not truly represent a fault. HVAC systems don't respond instantly (ON PURPOSE) and we need to keep that in mind.

Averages have to roll i.e. be continually updated. Once per minute is likely acceptable.

FDD Implementation

Using the Inputs – Average Temperatures

<u>From the GL (and in your specs)</u>

The following values must be continuously calculated by the FDD routines for each AHU:

Five minute (default) rolling averages, one minute samples of the followings point values; operator shall have the ability to adjust the averaging window and sampling rate for each point independently

- SAT_{AVG} = rolling average of supply air temperature
- MAT_{AVG} = rolling average of mixed air temperature
- RAT_{AVG} = rolling average of return air temperature
- OAT_{AVG} = rolling average of outdoor air temperature
- DSP_{AVG} = rolling average of duct static pressure

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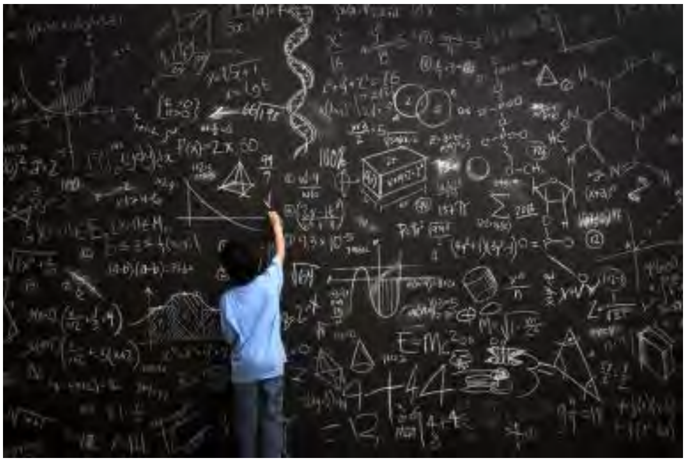
We just saw an example that used the average supply and average mixed air temperatures. Why? Because HVAC systems tend to be dynamic, we don't want to focus on the instantaneous values of any variable. Also, in one particular instance, we may calculate a fault condition, but it may not truly represent a fault. HVAC systems don't respond instantly (ON PURPOSE) and we need to keep that in mind.

Averages have to roll i.e. be continually updated. Once per minute is likely acceptable.

<click> need transition

In conclusion



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In any project you might want to look at ASHRAE Guidline 13 as a starting point because the concepts in there are assumed by Guidline 36 in its current state.

Guideline 36 is still not officially released. We are in public review currently

This is a complicated approach that is mainly software driven and therefore requires a new standard of rigor to verify after implementation.

However given that it is software driven, the implementation costs can be lower than hardware swap out.

http://f.tqn.com/y/chemistry/1/W/s/P/2/168351254.jpg

Questions?

Thank You for attending!

Cx associates LLC

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