Trane Engineers Newsletter Live Series:

High-Performance VAV Systems

Title	Abstract
High-Performance VAV Systems	Variable-air-volume (VAV) systems have been used to provide comfort in a wide range of building types and climates. This ENL will discuss design and control strategies that can significantly reduce energy use and ensure proper ventilation in VAV systems. Topics will likely include: ventilation system design and control, optimized VAV system controls, cold air distribution, and other energy-saving strategies.

Presenters: John Murphy, Dennis Stanke

Viewer learning objectives:

1. Identify ASHRAE Standard 189.1 requirements for VAV systems
2. Summarize how to properly apply air-to-air energy recovery in a VAV system
3. Summarize how to implement optimized VAV system control strategies
4. Summarize how to design and control cold-air VAV systems

Outline:

1) Opening (welcome, agenda, introductions)
2) What does ASHRAE 189.1 (or the IGCC) require for a VAV system?
3) Optimized VAV system controls
    a) Optimal start/Optimal stop
    b) Fan-pressure optimization
    c) Supply-air-temperature reset
        i) Benefits vs. drawbacks, examples
    d) Ventilation optimization
    e) Energy modeling results of optimized VAV system controls
4) Cold-air distribution
    a) Benefits
    b) Tips to maximize energy savings (lower CHW temperatures, more latent cooling, increases reheat energy due to less VAV turndown, fewer economizing hours)
    c) Minimizing comfort problems due to cold air “dumping”
    d) Avoiding condensation on air distribution system components (ductwork, diffusers)
5) Air-to-air energy recovery
    a) Sensible vs. total (enthalpy) energy recovery
    b) Benefits and drawbacks
6) List of other energy-saving strategies (RTVAV and CHWVAV)
7) Share results of example energy modeling analyses
8) Closing

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engineers newsletter live

Presenter Biographies

June 2011

High-Performance VAV Systems

John Murphy, LEED® AP| senior application engineer | Trane

John has been with Trane since 1993. His primary responsibility as an applications engineer is to aid design engineers and Trane sales personnel in the proper design and application of HVAC systems. As a LEED Accredited Professional, he has helped our customers and local offices on a wide range of LEED projects. His main areas of expertise include energy efficiency, dehumidification, air-to-air energy recovery, psychrometry, ventilation, and ASHRAE Standards 15, 62.1, and 90.1.

John is the author of numerous Trane application manuals and *Engineers Newsletters*, and is a frequent presenter on Trane's *Engineers Newsletter Live* series of broadcasts. He also is a member of ASHRAE, has authored several articles for the *ASHRAE Journal*, and is a member of ASHRAE's "Moisture Management in Buildings" and "Mechanical Dehumidifiers" technical committees. He was a contributing author of the *Advanced Energy Design Guide for K-12 Schools* and the *Advanced Energy Design Guide for Small Hospitals and Health Care Facilities*, and technical reviewer for *The ASHRAE Guide for Buildings in Hot and Humid Climates*.

Dennis Stanke | staff application engineer | Trane

With a BSME from the University of Wisconsin, Dennis joined Trane in 1973, as a controls development engineer. He is now a Staff Applications Engineer specializing in airside systems including controls, ventilation, indoor air quality, and dehumidification. He has written numerous applications manuals and newsletters, has published many technical articles and columns, and has appeared in many Trane *Engineers Newsletter Live* broadcasts.

An ASHRAE Fellow, he currently serves as Chairman for ASHRAE Standard 189.1, *Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings*. He recently served as Chairman for ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*, and he served on the USGBC LEED Technical Advisory Group for Indoor Environmental Quality (the LEED EQ TAG).

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High-Performance VAV Systems

engineers newsletter LIVE

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High-Performance VAV Systems
Today's Topics

- ASHRAE 189.1 requirements
- Optimized VAV system controls
- Cold-air distribution
- Air-to-air energy recovery
- Other energy-saving strategies
- Energy modeling results
- Summary

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Today's Presenters

Dennis Stanke
Staff Applications Engineer

John Murphy
Applications Engineer

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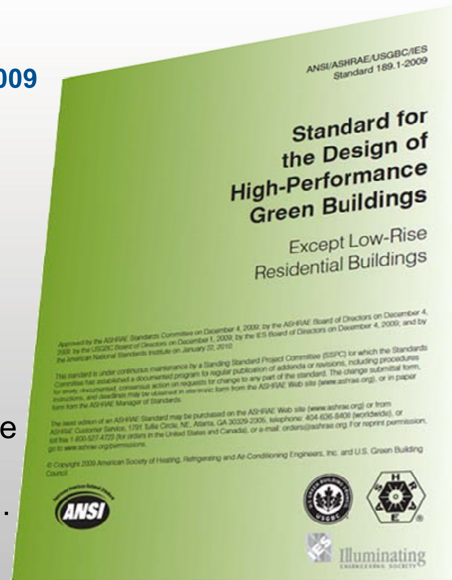
ASHRAE Standard 189.1-2009

- What does the “high performance green building” standard require in a “high performance VAV system?
- For commercial, institutional, and hi-rise residential buildings, the standard covers …



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Std 189.1-2009
HPGB Provisions

- Site sustainability: e.g., site location, heat island, rainwater
- Water use efficiency: e.g., turf, fixtures, once-through, condensate recovery
- Energy efficiency: Std 90.1 compliance **plus…**
- Indoor environmental quality (IEQ): e.g., Std 62.1 all sections, **plus** OA sensing and no smoking, Std 55 compliance, acoustics, daylighting
- Atmosphere, materials and resources: e.g., recycle, reuse, no CFC’s allowed
- Construction and plans for operation

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Std 189.1-2009 and high performance VAV
HPGB VAV-Specific Provisions

- Optimized VAV controls
- Cold air distribution
  - Energy performance modeling shows value of HP VAV cold air distribution
- Air-to-air energy recovery

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	Energy Requirements		
	Std 189.1-2009 Provisions		***90.1-2010***
Topic	***90.1-2007***	***Plus 189.1-2009***	
Optimal start/stop controls	6.4.3.3.3 Controls must automatically adjust start time for 10,000 cfm air handlers, based on space temperature, occupied setpoint and time prior to occupancy	No additional requirements (i.e., same as 90.1-2007)	Same as 189.1-2009
Fan pressure optimization	6.5.3.2 Prescriptive option must reset supply static pressure lower to keep one zone damper nearly wide open	No additional requirements (i.e., same as 90.1-2007)	Same as 189.1-2009
Supply air temperature reset	No mandatory or prescriptive requirements	No mandatory or prescriptive requirements	6.5.3.4 Prescriptive option must reset supply air temperature by approximately 5°F
Demand controlled ventilation	6.4.3.9 Must use DCV in zones >500ft^2 with >40 people/1000 ft^2	7.4.3.2 Prescriptive option must include DCV in zones >500 ft2 with ≥25 people/1000 ft^2	6.4.3.9 Must use DCV in zones >500ft^2 with >40 people/1000 ft^2

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	Energy Requirements		
	Std 189.1-2009 Provisions		90.1-2010
Topic	***90.1-2007***	***Plus 189.1-2009***	
Ventilation reset control	No mandatory or prescriptive requirements	No mandatory or prescriptive requirements	6.5.3.3 Prescriptive option must reset VAV system OA intake based on system ventilation efficiency
Cold-air distribution	No mandatory or prescriptive requirements	No mandatory or prescriptive requirements	Same as 189.1-2009
Air-to-air energy recovery	6.5.6.1 Prescriptive option must recover enthalpy with ≥50% effectiveness in systems with ≥5000 cfm and OA ≥70% of design supply air	7.4.3.8 Prescriptive option must recover enthalpy with ≥60% effectiveness in systems ranging from 1000 to 30,000 cfm and OA ranging from 10% to 80% of design supply air	6.5.3.4 Prescriptive option must recover enthalpy with ≥50% effectiveness in systems ranging from 1000 to 26,000 cfm and OA ranging from 30% to 80% of design supply air

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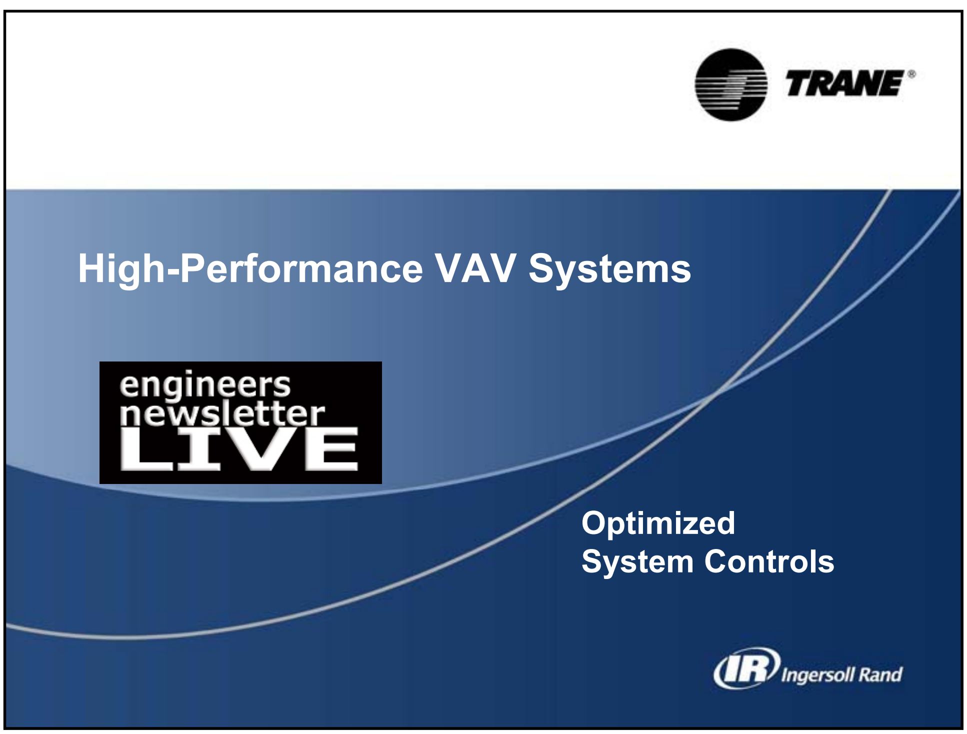

High-Performance VAV Systems
Today's Topics

- ASHRAE 189.1 requirements
- Optimized VAV system controls
- Cold-air distribution
- Air-to-air energy recovery
- Other energy-saving strategies
- Energy modeling results
- Summary

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Optimized VAV System Controls

- Optimal start/stop
  - Time-of-day scheduling
- Fan-pressure optimization
- Supply-air-temperature reset
- Ventilation optimization
  - Demand-controlled ventilation (DCV) at the zone level
  - Ventilation reset control at the system level (TRAQ dampers)

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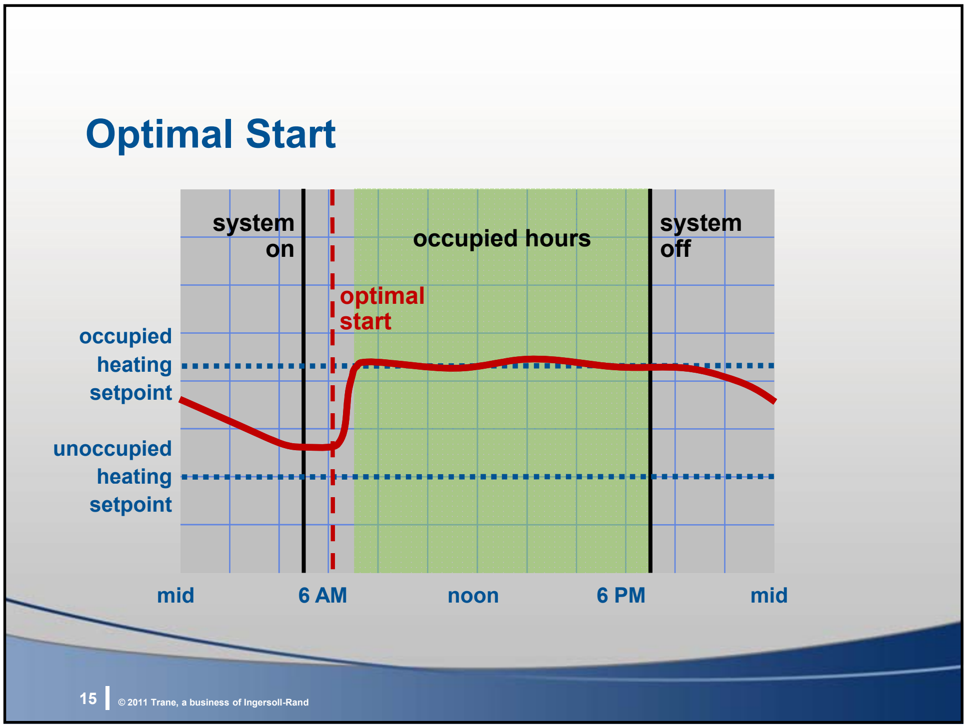
Optimal Start
system on
occupied hours
system off
optimal start
occupied heating setpoint
unoccupied heating setpoint
mid
6 AM
noon
6 PM
mid
15
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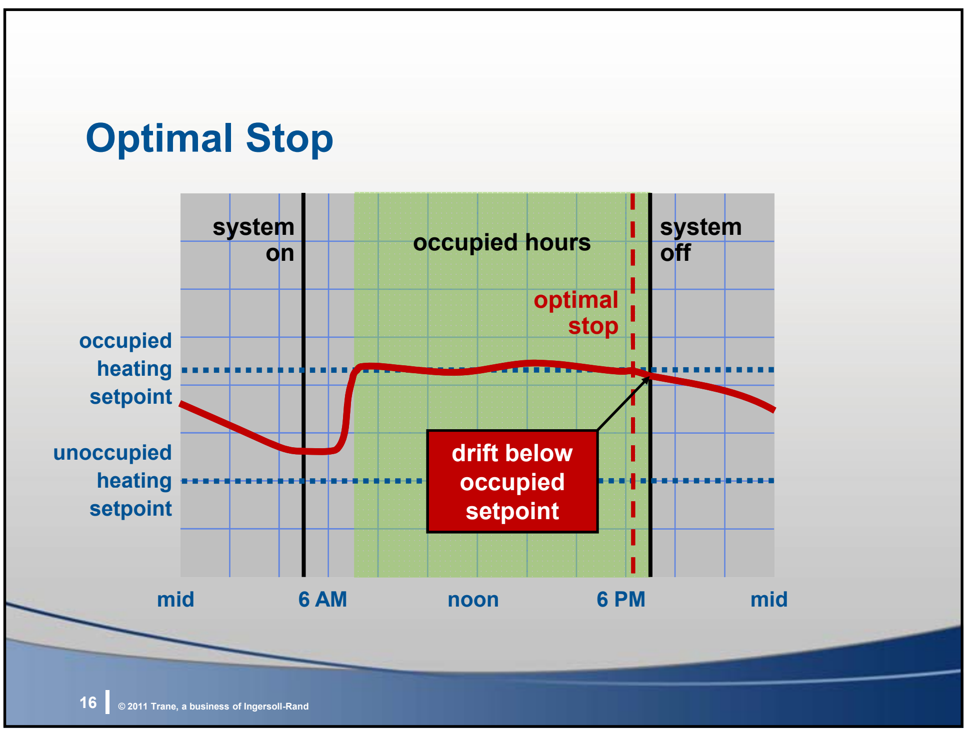
Optimal Stop
system on
occupied hours
system off
optimal stop
occupied heating setpoint
unoccupied heating setpoint
drift below occupied setpoint
mid
6 AM
noon
6 PM
mid
16
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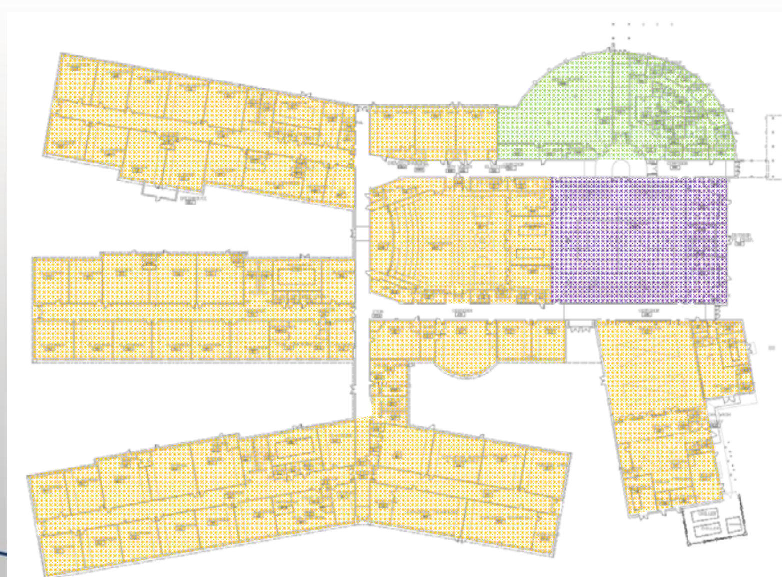
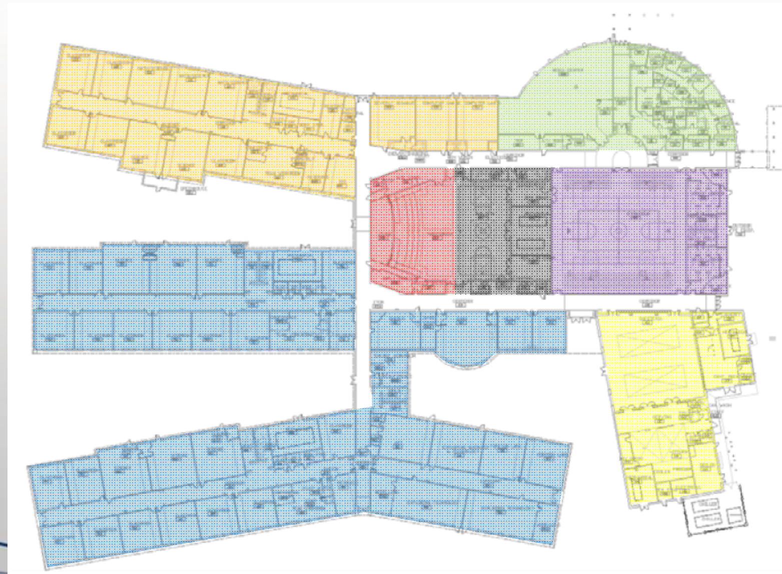
Time-of-Day Scheduling

- Avoid overly-conservative scheduling by including a timed override button on zone sensors
- Use separate schedules for areas with differing usage patterns

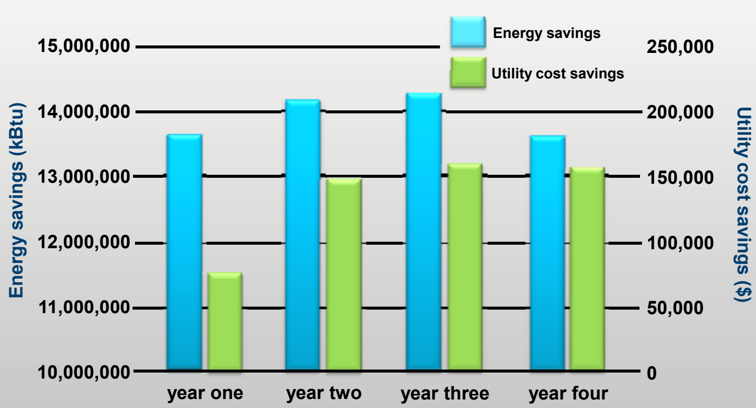




19

measured energy savings for a small school district

Proper Scheduling, Night Setback



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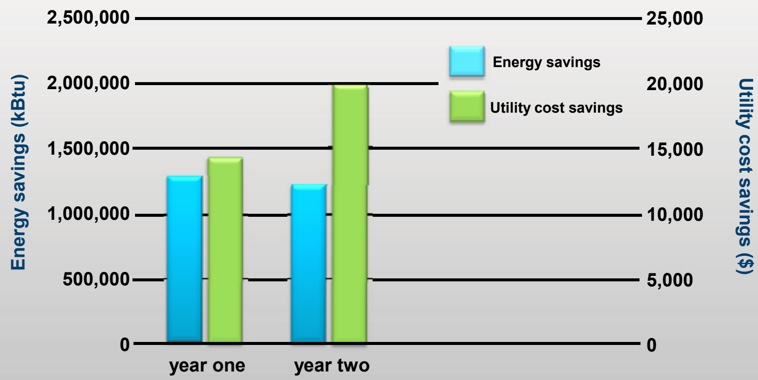
measured energy savings for a government office building

Proper Scheduling, Night Setback



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Optimized VAV System Controls

- Optimal start/stop
  - Time-of-day scheduling
- Fan-pressure optimization
- Supply-air-temperature reset
- Ventilation optimization
  - Demand-controlled ventilation at zone level
  - Ventilation reset at system level (and TRAQ dampers)

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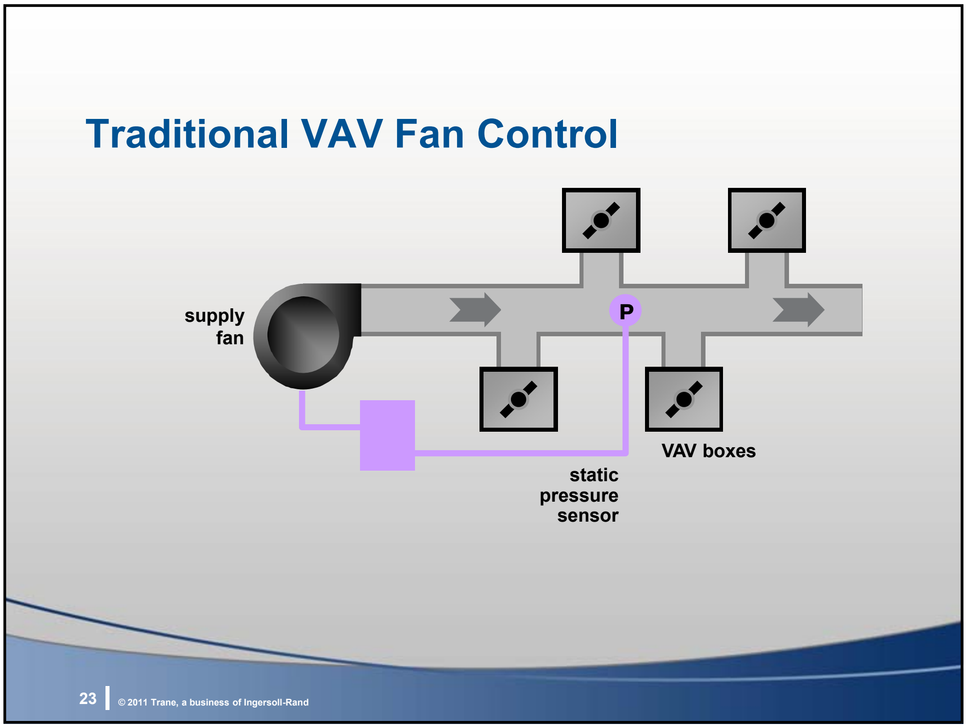
Traditional VAV Fan Control
supply fan
P
VAV boxes
static pressure sensor
23
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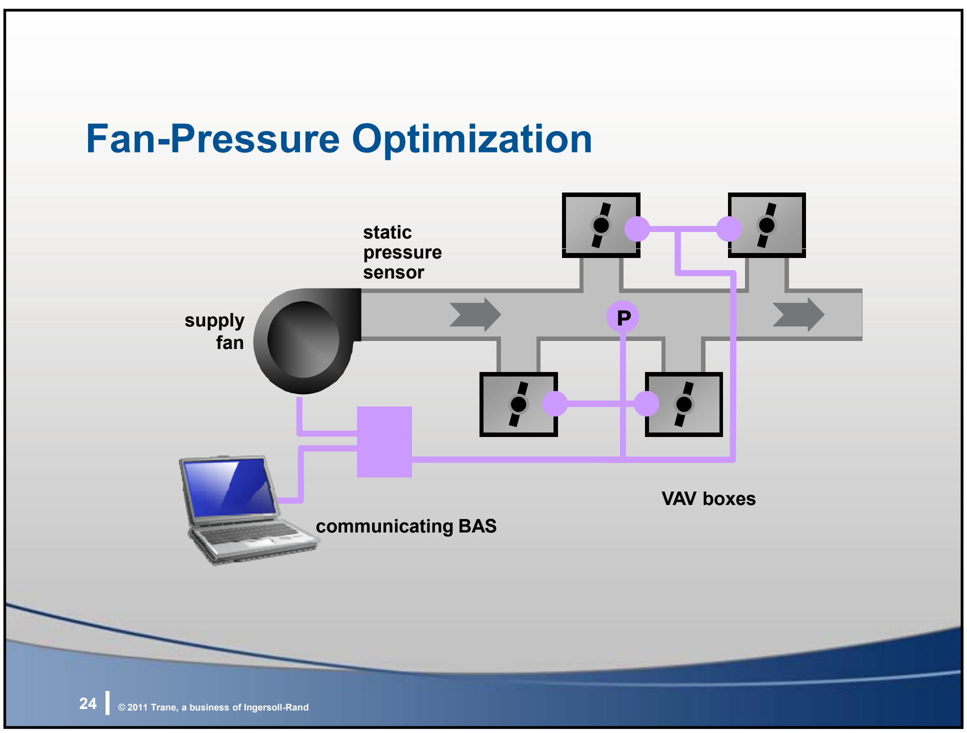
Fan-Pressure Optimization
static pressure sensor
supply fan
P
VAV boxes
communicating BAS
24
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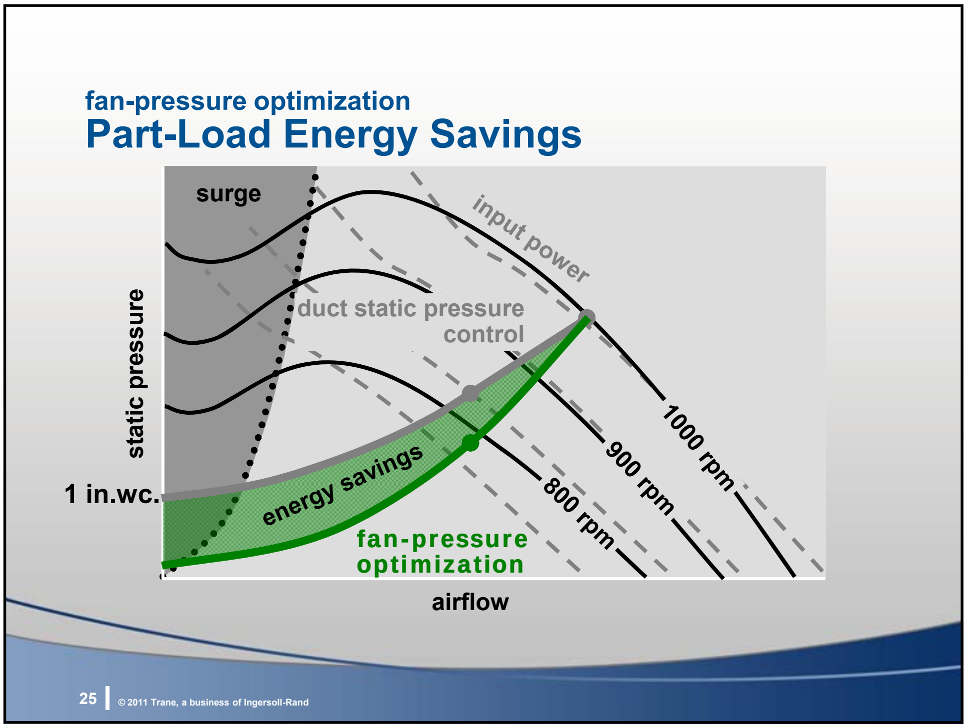
fan-pressure optimization
Part-Load Energy Savings
surge
input power
duct static pressure control
static pressure
1 in.wc.
energy savings
fan-pressure optimization
1000 rpm
900 rpm
800 rpm
airflow
25
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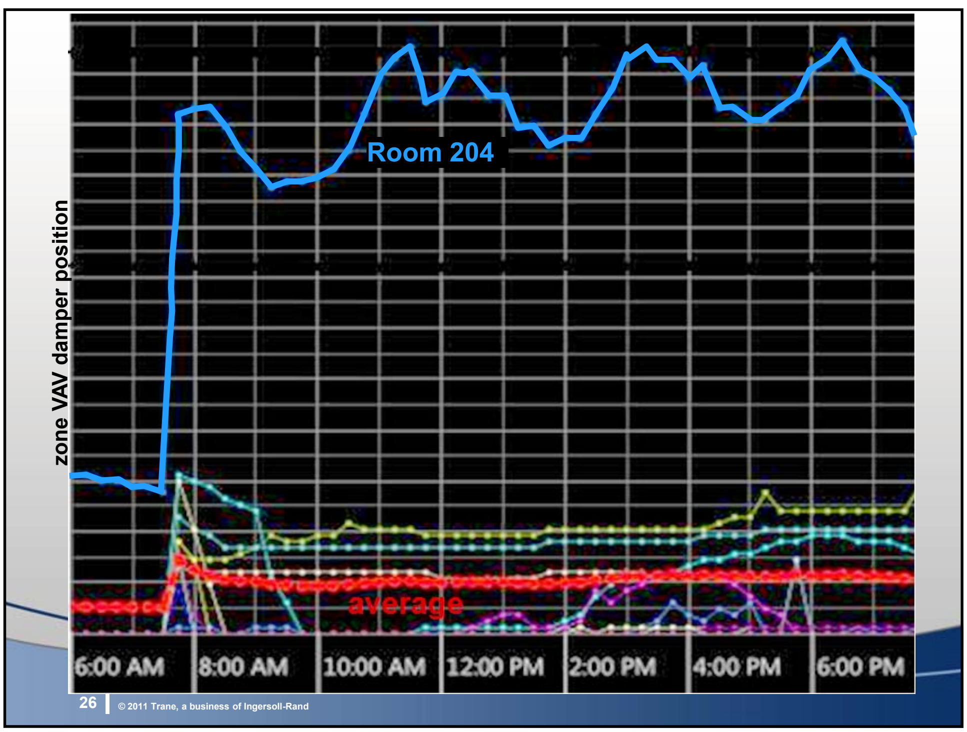
Room 204
zone VAV damper position
average
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
26
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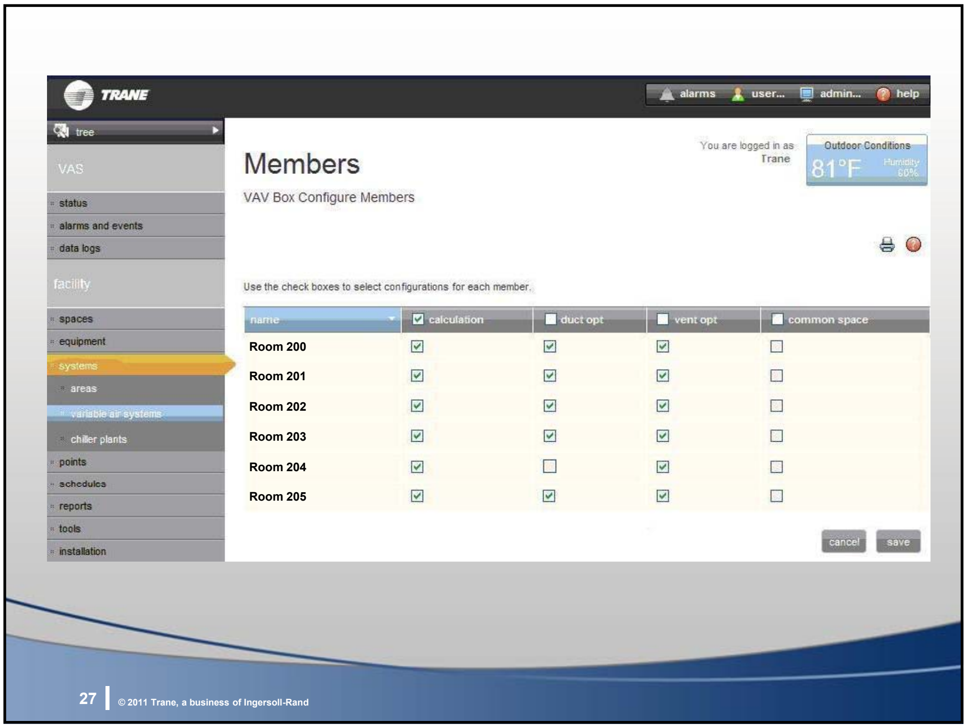
TRANE
alarms
user...
admin...
help
tree
VAS
status
alarms and events
data logs
facility
spaces
equipment
systems
areas
variable air systems
chiller plants
points
schedules
reports
tools
installation
Members
VAV Box Configure Members
You are logged in as Trane
Outdoor Conditions
81°F
Use the check boxes to select configurations for each member.
name
calculation
duct opt
vent opt
common space
Room 200
Room 201
Room 202
Room 203
Room 204
Room 205
cancel
save
27
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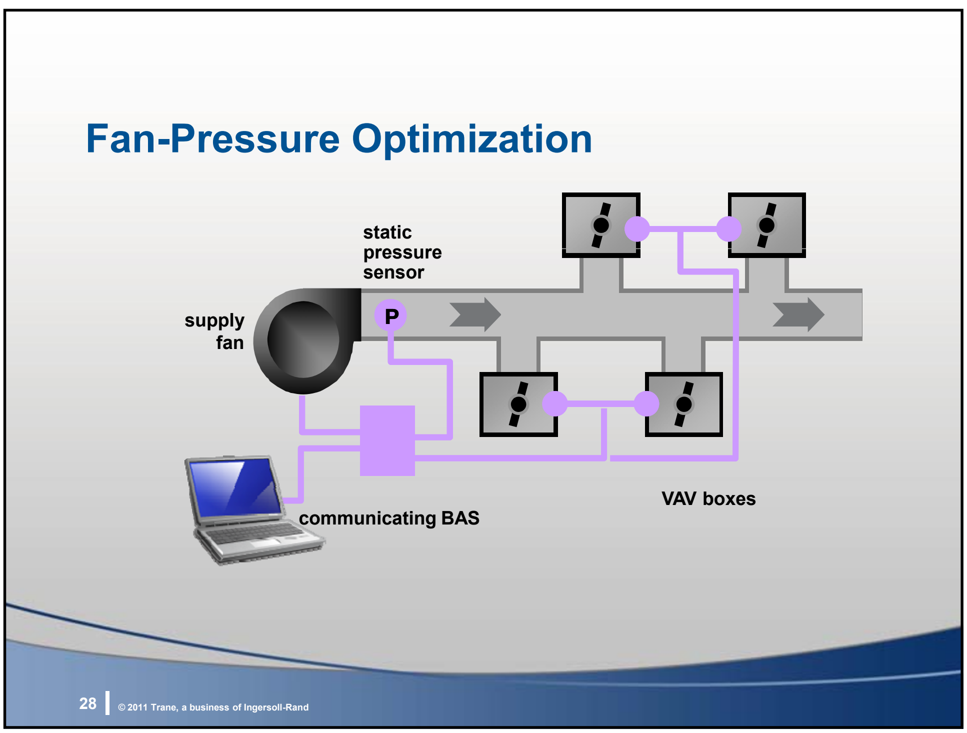
Fan-Pressure Optimization
static pressure sensor
supply fan
P
communicating BAS
VAV boxes
28
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fan-pressure optimization
Benefits

- Part-load energy savings
- Lower sound levels
- Better zone control
- Less duct leakage
- Reduced risk of fan surge
- Factory-installation and -commissioning of duct pressure sensor
- Operator feedback to "tune the system"

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Optimized VAV System Controls

- Optimal start/stop
  - Time-of-day scheduling
- Fan-pressure optimization
- Supply-air-temperature reset
- Ventilation optimization
  - Demand-controlled ventilation (DCV) at the zone level
  - Ventilation reset control at the system level (TRAQ dampers)

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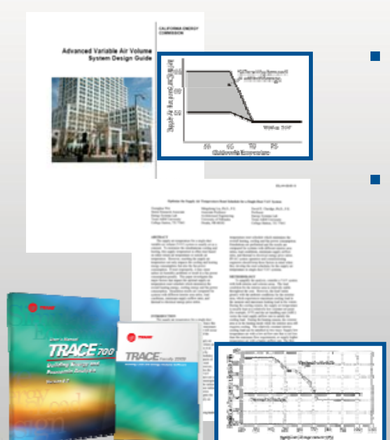
Supply-Air-Temperature (SAT) Reset

- Benefits
  - Decreases compressor energy
  - More hours when economizer provides all necessary cooling (compressors/chiller shut off)
  - Decreases reheat energy
- Drawbacks
  - Increases fan energy
  - May raise humidity level in zones

SAT reset

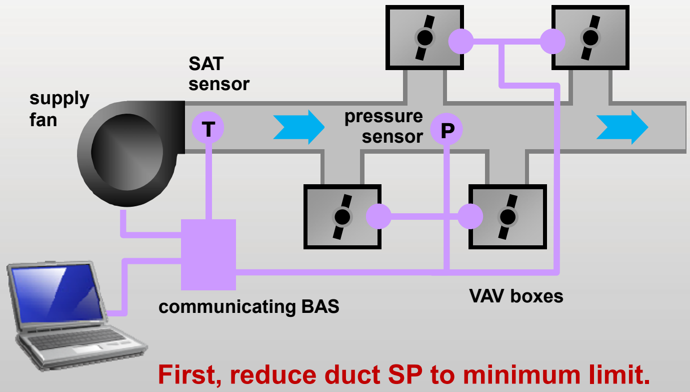
General Principles



- First reduce supply airflow
  - Significant energy savings from unloading the fan
- Raise SAT setpoint when it can enhance airside economizing and/or reduce reheat energy

SAT reset based on VAV damper positions

Example #1



First, reduce duct SP to minimum limit.

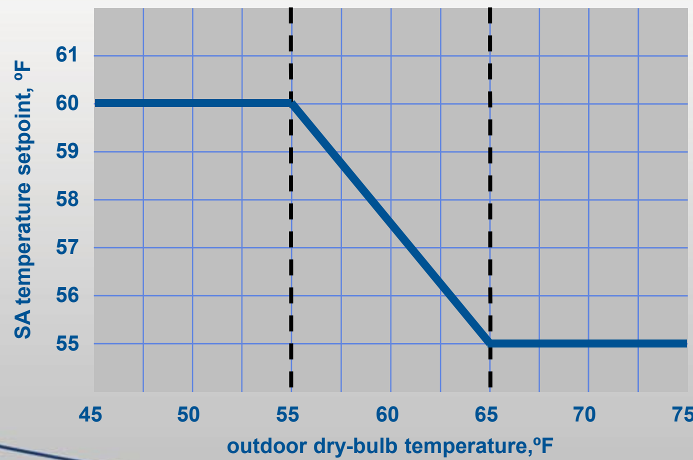
Then, raise SAT setpoint.

SAT reset based on VAV damper positions

Example #1

- Benefits of this approach
  - Maximizes fan energy savings by waiting until you have reset the duct SP as low as possible before you raise the SAT setpoint
  - Ensures that no zone is over-heated (starved for air)
- Drawbacks of this approach
  - SAT setpoint may not get reset upward very often, so might not have much impact on reheat energy use
    - Cooling load in *every* zone needs to be low enough that all VAV dampers are partially closed, even when duct SP setpoint is at minimum

SAT reset based on OA temperature
Example #2



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SAT reset based on OA temperature
Example #2

- When OA temperature > 65°F, no SAT reset
  - When it is this warm outside, the economizer has not likely been activated yet and the cooling load in most zones is likely high enough that reheat is not yet required to prevent overcooling
  - Takes advantage of significant energy savings from unloading supply fan
  - The colder (and drier) supply air allows the system to provide sufficiently dry air to the zones, keeping indoor humidity levels lower
- When OA temperature < 65°F, reset SAT upward (max SAT limit of 60°F)
  - Supply fan is likely significantly unloaded by this point
  - Increases benefit of airside economizer, allows compressors to shut off sooner
  - Reduces any reheat required to prevent overcooling the zones
  - Outdoor air is less humid so the risk of elevating indoor humidity by providing warmer (and wetter) supply air is lessened
- Limiting SAT reset to 60°F allows the system to satisfy cooling loads in interior zones without needing to substantially oversize VAV terminals and ductwork
- Disable SAT reset when outdoor dew point is too high (e.g. above 60ºF or 65ºF) or when indoor humidity is too high (e.g. above 60% or 65% RH)

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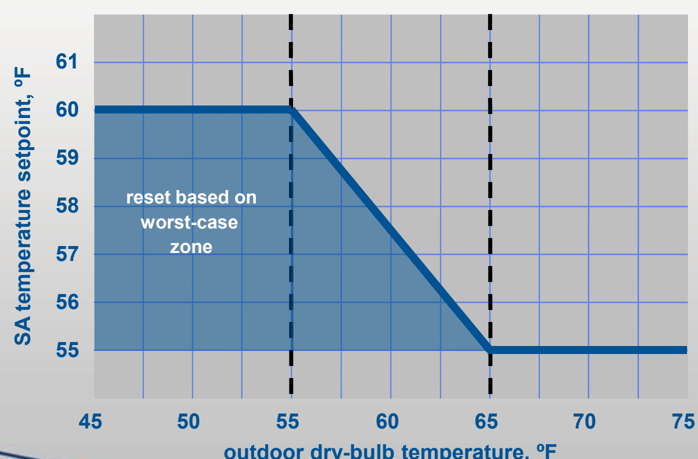
SAT reset based on OA temperature
Example #2

- Benefits of this approach
  - Achieves fan energy savings by waiting until it is cool outside before raising the SAT setpoint
  - May achieve more reduction reheat energy by not waiting for duct SP to be reset to minimum
- Drawbacks of this approach
  - “Open loop” control does not ensure that a zone is not over-heated (starved for air)

SAT reset based on OA temperature and VAV damper positions
Example #3



SAT reset based on OA temperature and VAV damper positions
Example #3

- Benefits of this approach
  - Achieves fan energy savings by waiting until it is cool outside before raising the SAT setpoint
  - May achieve more reduction reheat energy by not waiting for duct SP to be reset to minimum
  - Ensures that no zone is over-heated (starved for air)
- Drawbacks of this approach
  - Both sequences use the same input signal (position of the furthest-open VAV damper), so they require careful coordination

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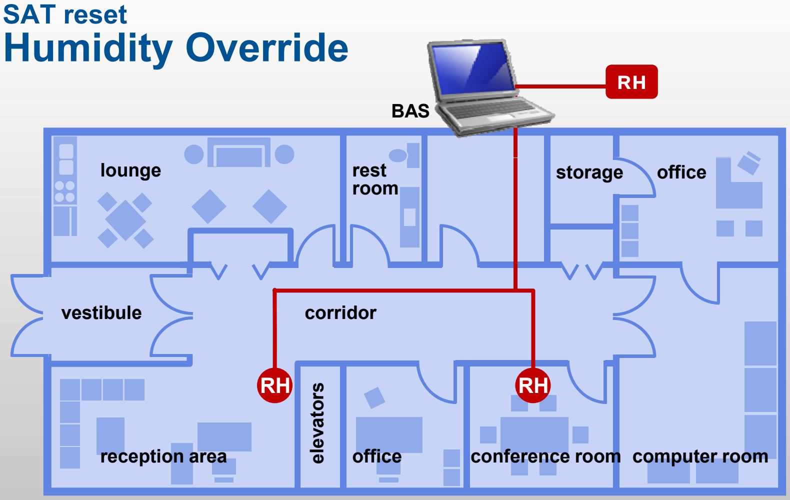
SAT reset
Humidity Override



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SAT reset
Application Considerations

- Will compressor and reheat energy savings outweigh additional fan energy?
- Consider impact on zone humidity
- Design zones with nearly-constant cooling loads for warmer (reset) SAT
  - May require larger VAV terminals and ductwork
  - Allows SAT reset while still providing needed cooling to these zones
- Design an efficient air distribution system
  - Employ fan-pressure optimization

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Optimized VAV System Controls

- Optimal start/stop
  - Time-of-day scheduling
- Fan-pressure optimization
- Supply-air-temperature reset
- Ventilation optimization (dynamic reset)
  - Demand-controlled ventilation at zone level
  - Ventilation reset at system level (and TRAQ™ dampers)

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dynamic reset approaches – zone level

Demand Controlled Ventilation (DCV)

- Estimate current population (*Pz*) based on:
  1. Time-of-day schedule (e.g., when a class is in session)
  2. Occupancy sensors (e.g., motion detectors)
  3. Actual sense population (e.g., using turnstiles, ticket sales, and so on, or changes in CO_2 levels)
- Find required breathing zone OA flow (*Vbz*) using estimated population
- Alternatively:
  4. CO_2-based: Estimate required breathing zone OA flow (*Vbz*) directly based on CO_2 levels

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dynamic reset approaches – zone level

Demand Controlled Ventilation (DCV)

- Estimate the current OA flow required using CO_2 levels
  - Steady state concentration equation

    $$(Cr - Co) = k*m/(Vbz/Pz)$$

  - Typical straight-line proportional controller

    $$Vbz = slope*\Delta CO_2 + offset$$

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dynamic reset approaches – system level
Outdoor Air Intake Flow w/DCV

- For single zone systems:

  $Vot = Vbz/Ez$

- For 100% zone systems:

  $Vot = \Sigma_{all\ zones}(Vbz/Ez)$

- For multiple-zone systems:

  $Vou = \Sigma(Rp*Pz) + \Sigma(Ra*Az)$

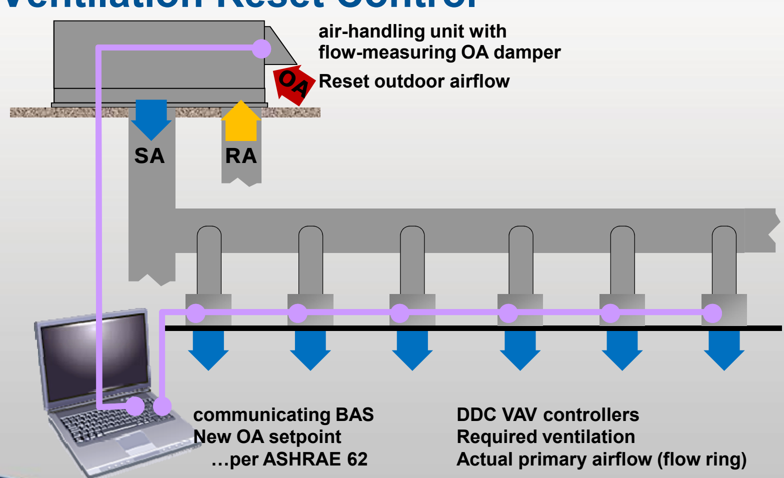
  $Zdz_{critical\ zone} = Vbz/Vdz$

  $Ev = 1 + Vou/Vps – Zdz_{critical\ zone}$

  $Vot = Vou/Ev$

45

dynamic reset approaches – zone/system level
Ventilation Reset Control



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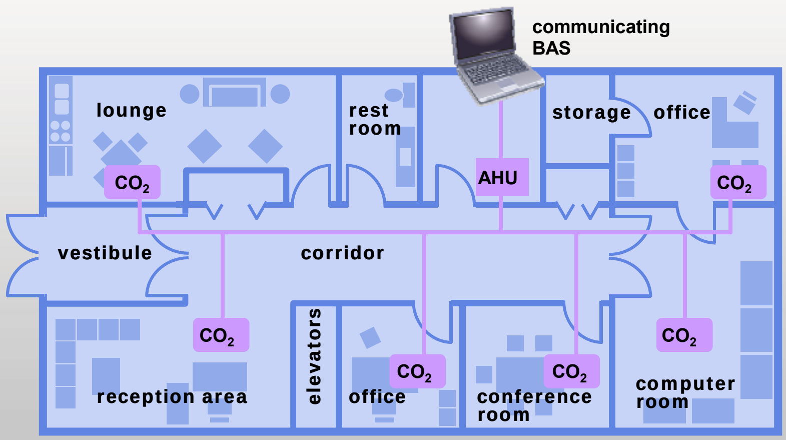
dynamic reset approaches – zone/system level

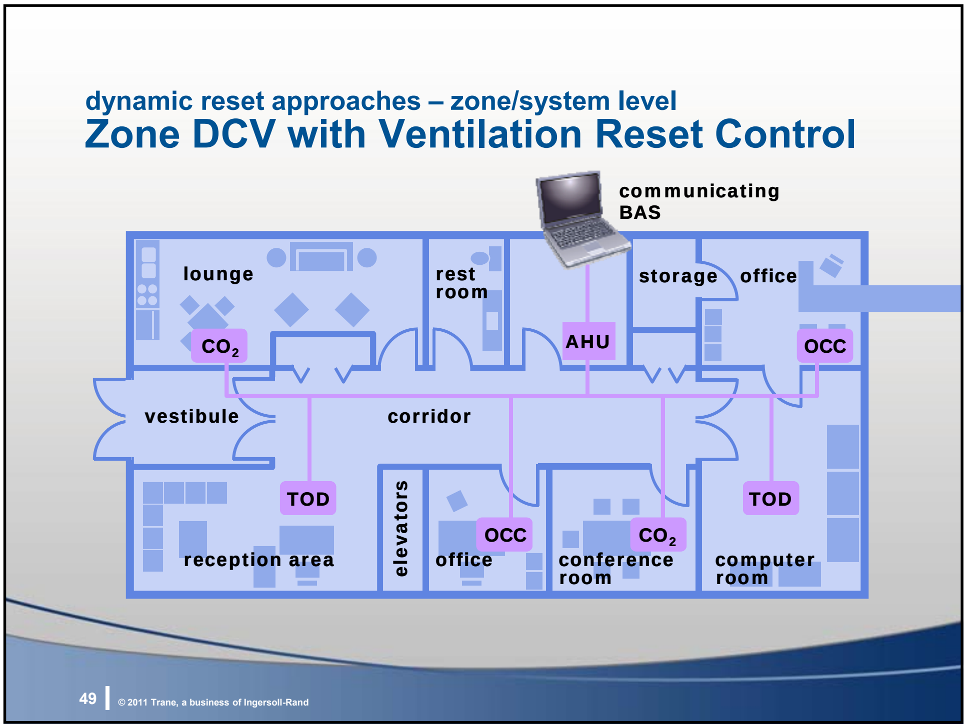
CO_2 Sensor in Every Zone?



CO_2 sensor in every zone

Drawbacks

- Requires a CO_2 sensor in every zone
  - Increases installed cost and maintenance
  - Unnecessary use of sensors (CO_2 level doesn't change much in many of the zones, non-critical zones will always be over-ventilated)
  - Increases risk of over-ventilating or under-ventilating
- Requires BAS to poll all sensors to determine OA damper position
- Requires some method to ensure minimum outdoor airflow


dynamic reset approaches – zone/system level
Zone DCV with Ventilation Reset Control
communicating BAS
lounge
rest room
storage
office
CO2
AHU
OCC
vestibule
corridor
TOD
elevators
OCC
CO2
TOD
reception area
office
conference room
computer room
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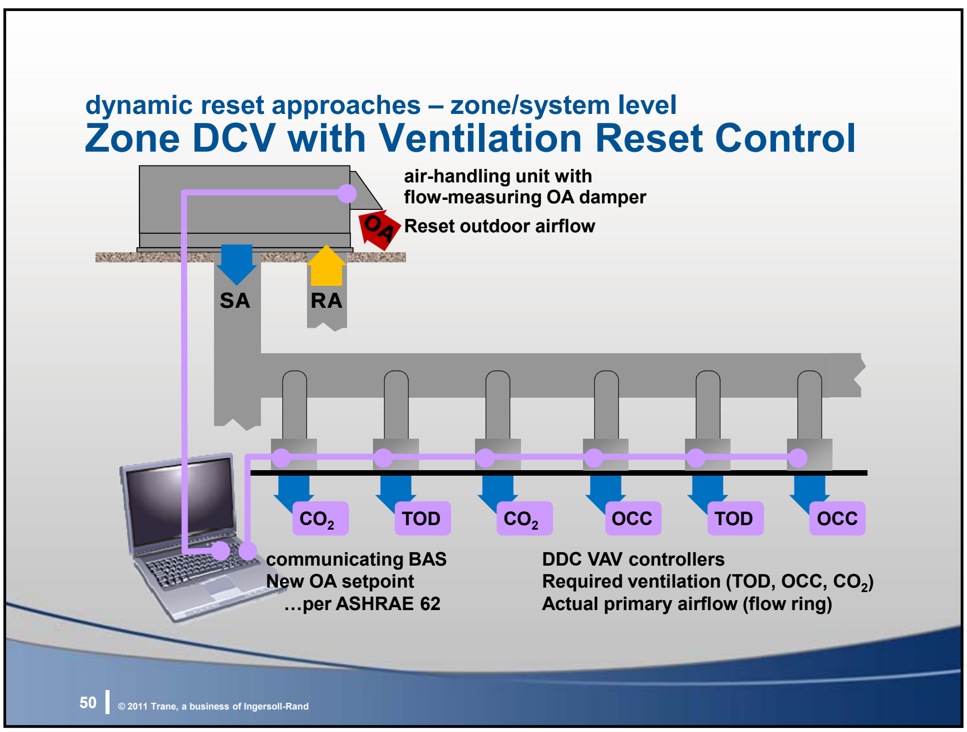
dynamic reset approaches – zone/system level
Zone DCV with Ventilation Reset Control
air-handling unit with
flow-measuring OA damper
OA
Reset outdoor airflow
SA
RA
CO2
TOD
CO2
OCC
TOD
OCC
communicating BAS
New OA setpoint
…per ASHRAE 62
DDC VAV controllers
Required ventilation (TOD, OCC, CO2)
Actual primary airflow (flow ring)
50
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ventilation optimization
Benefits

- Saves energy during partial occupancy
- Lower installed cost, less maintenance, and more reliable than installing a CO_2 sensor in every zone
  - Use zone-level DCV approaches where they best fit (CO_2 sensor, occupancy sensor, time-of-day schedule)
  - Combine with ventilation reset at the system level

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"Occupied Standby" Mode

- Use an occupancy sensor to:
  - Shut off lights
  - Raise/lower zone temperature setpoint by 1ºF or 2ºF
  - Reduce outdoor airflow requirement
  - Lower minimum airflow setting to reduce or avoid reheat

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occupied standby mode

Example

1000-ft^2 conference room
(design occupancy = 50)

	occupied mode	occupied standby mode
Lights	on	off
Zone cooling setpoint	75ºF	77ºF
Outdoor airflow required	310 cfm ($R_p \times P_z + R_a \times A_z$)	60 cfm ($R_a \times A_z$)
Minimum primary airflow setting	450 cfm	225 cfm

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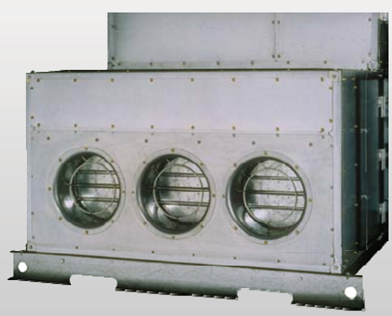
outdoor airflow sensing

Traq™ Damper/Sensor Assembly

- A damper assembly that …
  - Controls airflow by modulating a set of round dampers
  - Measures airflow at all conditions (as required indirectly by Std 62.1 and Std 90.1, and as required explicitly by Std 189.1 and for a LEED credit)



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outdoor airflow sensing
Damper Assembly

- Uses proven flow-sensing technology
  - Flow ring senses differential (total inlet to “wake” outlet) pressure), which can be very low
  - Air doesn’t enter sensing ports, so filtration isn’t needed
  - Transducer auto-calibrates once each minute, to correct for drift due to temperature changes
  - Bell mouth inlet directs air across flow ring to reduce turbulence and pressure drop

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outdoor airflow sensing
Damper Assembly

- Accuracy
  - Tested in accordance with AMCA 610 “Airflow Measurement Station Performance”
  - ± 5% of actual airflow
  - Precision maintained from 100% down to 15% of nominal (design) flow (or down to 5% in some configurations)
- Damper leakage
  - “Low leak” class
  - Meets Std 90.1 requirements

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outdoor airflow sensing

Damper Assembly

For a #25 air-handling unit, 12,500 cfm

Device	ΔP in. wc.	Inlet Velocity
Traq™	**0.30**	1,900 fpm
Blade assembly:		
Filter	0.39	
Sensor	0.00	
Damper	0.25	
Total Assembly	**0.64**	1,200 fpm

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Example TRACE® 700 Analysis

Optimized VAV system controls

- Optimal start
- Fan-pressure optimization
- Supply-air temperature reset
- Ventilation optimization
  - DCV at zone level
  - Ventilation reset at system level

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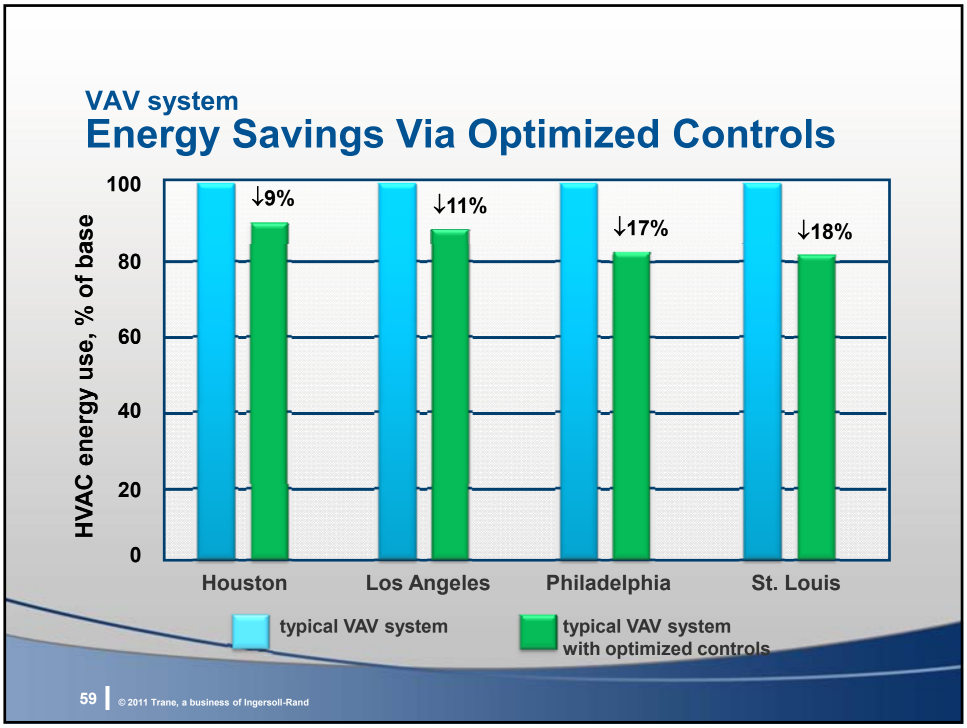
VAV system
Energy Savings Via Optimized Controls
HVAC energy use, % of base
100
80
60
40
20
0
↓9%
↓11%
↓17%
↓18%
Houston
Los Angeles
Philadelphia
St. Louis
typical VAV system
typical VAV system with optimized controls
59
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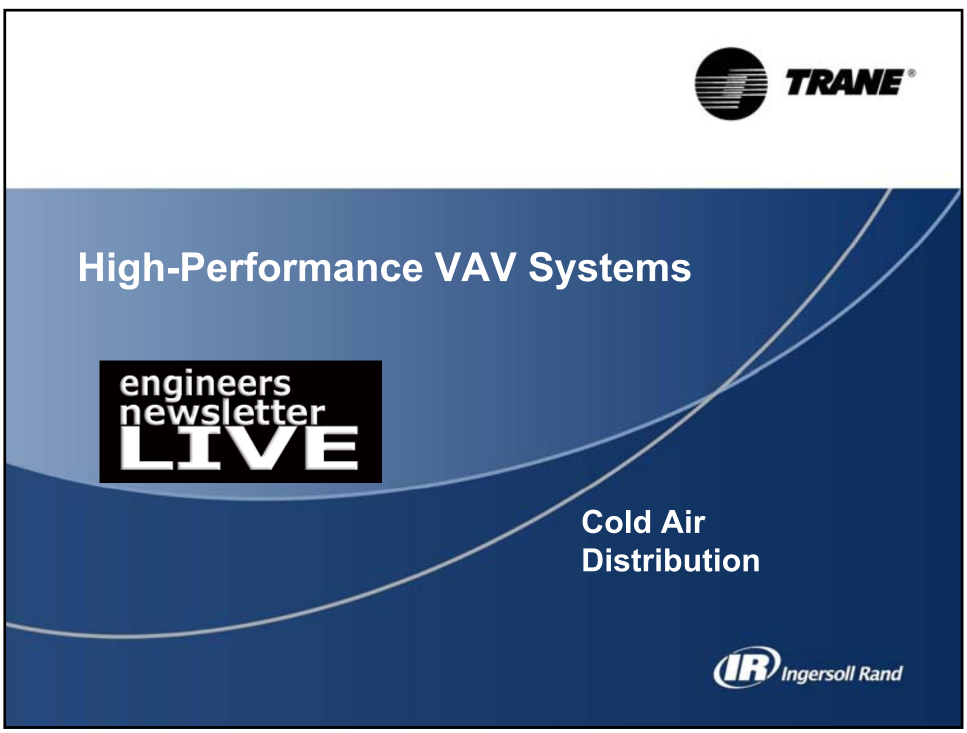
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High-Performance VAV Systems
engineers newsletter LIVE
Cold Air Distribution
Ingersoll Rand

High-Performance VAV Systems
Today's Topics

- ASHRAE 189.1 requirements
- Optimized VAV system controls
- Cold-air distribution
- Air-to-air energy recovery
- Other energy-saving strategies
- Energy modeling results
- Summary

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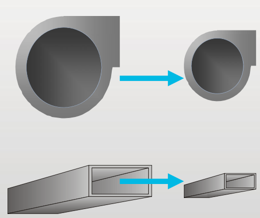
Lower Supply-Air Temperature

Benefits

- Reduces supply airflow
  - Less supply fan energy and less fan heat gain
  - Smaller fans, air handlers, VAV terminals, and ductwork
- Lowers indoor humidity levels



Drawbacks

- Fewer economizer hours
- Increased reheat energy

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lower supply-air temperature

Maximize Energy Savings

- Use supply-air temperature reset during mild weather
  - Maximizes benefit of airside economizer
  - Reduces reheat energy use

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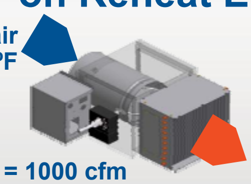
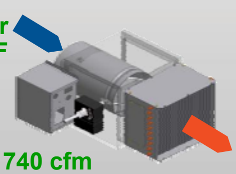
Impact of SAT on Reheat Energy

primary air
55ºF



design primary airflow = 1000 cfm
minimum primary airflow = 300 cfm
(30%) → reheat activated when space cooling load drops below 30% of design

primary air
48ºF



design primary airflow = 740 cfm
minimum primary airflow = 300 cfm
(40%) → reheat activated when space cooling load drops below 40% of design

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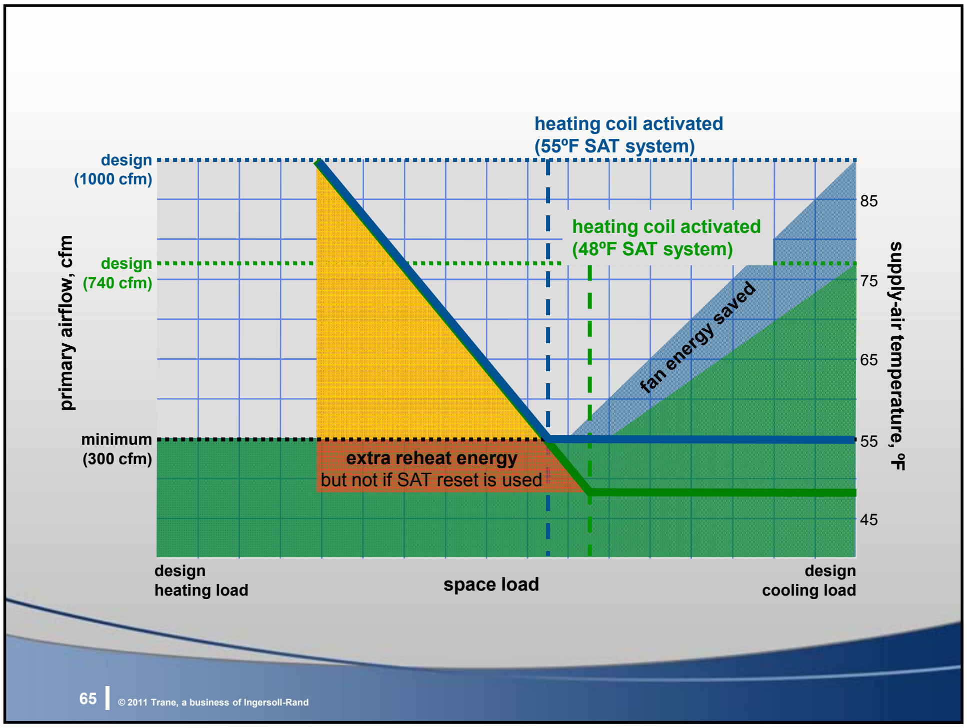

lower supply-air temperature

Maximize Energy Savings

- Use supply-air temperature reset during mild weather
- Raise space setpoint by 1ºF or 2ºF
  - Lower indoor humidity often allows zone dry-bulb temperature to be slightly warmer
  - Further reduces airflow and fan energy use

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lower supply-air temperature

Maximize Energy Savings

- Use supply-air temperature reset during mild weather
- Raise space setpoint by 1ºF or 2ºF
- Keep same size ductwork
  - Further reduces fan energy use
  - Allows SAT reset in systems that serve zones with near-constant cooling loads
  - Capable of delivering more airflow if loads increase in the future

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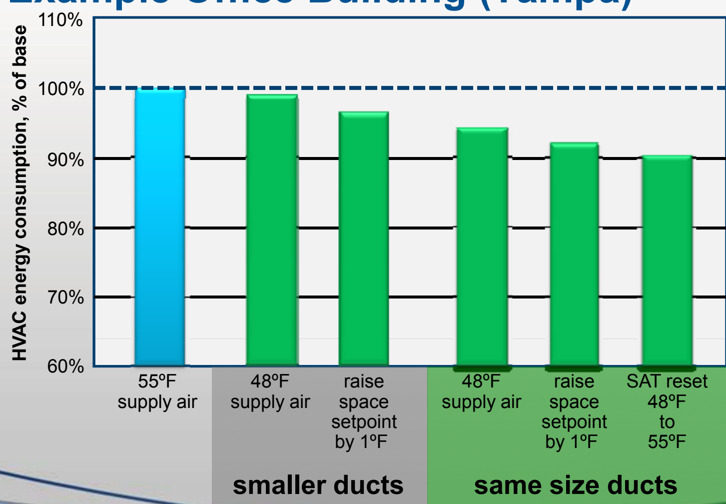
chilled-water VAV system

Example Office Building (Tampa)



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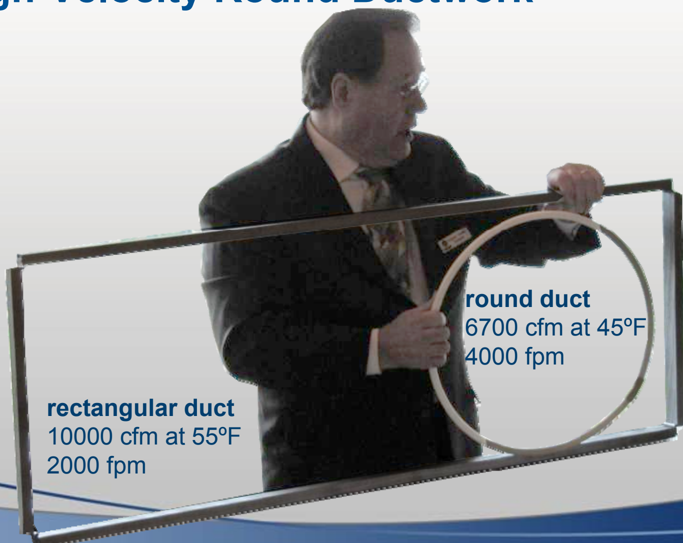
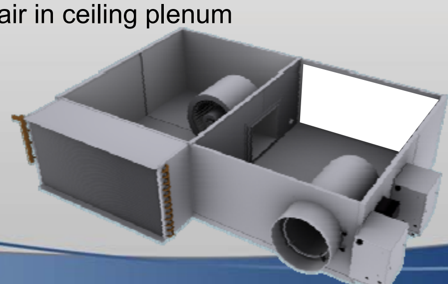
High-Velocity Round Ductwork



lower supply-air temperature

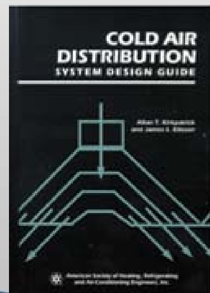
Maximize Energy Savings

- Use supply-air temperature reset during mild weather
- Raise space setpoint by 1ºF or 2ºF
- Keep same size ductwork
- Use parallel fan-powered VAV terminals
  - Reduces reheat energy use by recovering heat from warm air in ceiling plenum



lower supply-air temperature
Challenges

- Minimize comfort problems due to “dumping”
- Avoid condensation on air distribution system components



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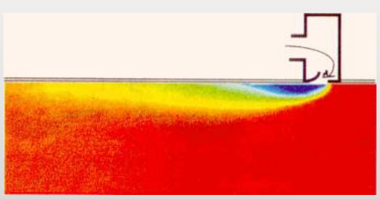
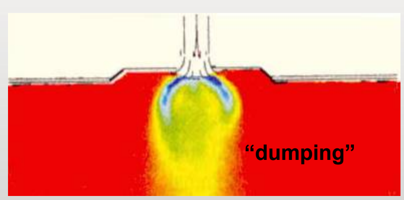
lower supply-air temperature
Minimizing Comfort Problems (Dumping)

- Use linear slot diffusers



linear slot diffuser



conventional concentric diffuser

- Implement supply-air-temperature reset

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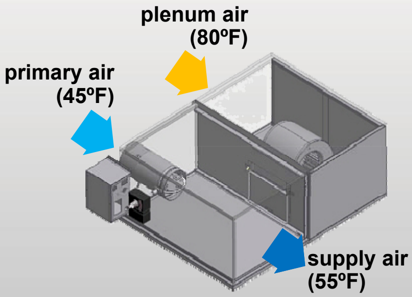
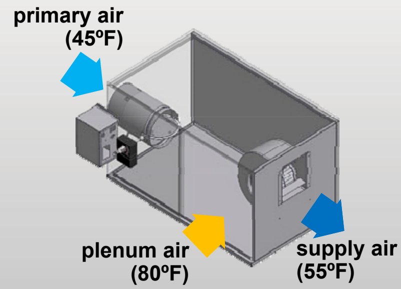
lower supply-air temperature
Minimizing Comfort Problems (Dumping)

…or use fan-powered VAV terminals as "air blenders"



parallel fan-powered VAV terminal



series fan-powered VAV terminal

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lower supply-air temperature
Avoiding Condensation

- Properly insulate and vapor-seal ductwork, VAV terminals, and supply-air diffusers

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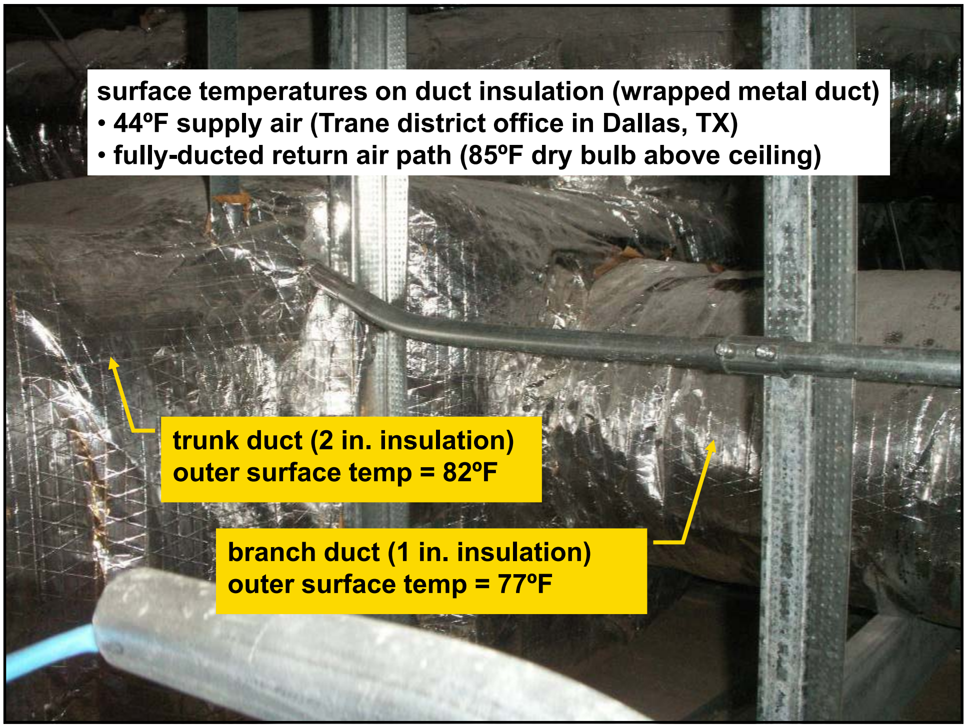

lower supply-air temperature

Avoiding Condensation

- Properly insulate and vapor-seal ductwork, VAV terminals, and supply-air diffusers
- Use an open ceiling plenum return, if possible
- Maintain positive building pressure to reduce infiltration of humid outdoor air
- Use linear slot diffusers to increase air motion
- Monitor indoor humidity during unoccupied periods and prevent it from rising too high
- During startup, slowly ramp down the supply-air temperature to pull down indoor dew point

76

examples
Humidity Pull-Down Sequence

- SAT ramp-down schedule

	supply airflow limit	supply-air temperature
2 hours before occupancy	40% of design	55ºF
1 hour before occupancy	65% of design	51ºF
Scheduled occupancy	no limit	48ºF

Source: ASHRAE *Cold Air Distribution System Design Guide* (pp 138-140)

- SAT ramp-down based on indoor dew point
  ex: SAT = current indoor dew point – 3ºF

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High-Performance VAV Systems

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Air-to-Air Energy Recovery

Ingersoll Rand

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Today's Topics

- ASHRAE 189.1 requirements
- Optimized VAV system controls
- Cold-air distribution
- Air-to-air energy recovery
- Other energy-saving strategies
- Energy modeling results
- Summary

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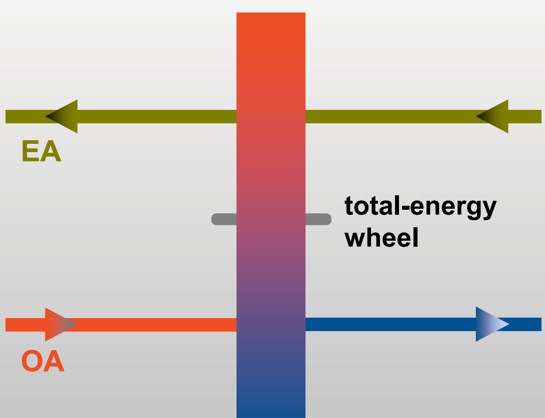
Air-to-Air Energy Recovery



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Air-to-Air Energy Recovery

Benefits

- Reduces cooling, dehumidification, heating, and humidification energy
- Allows equipment downsizing

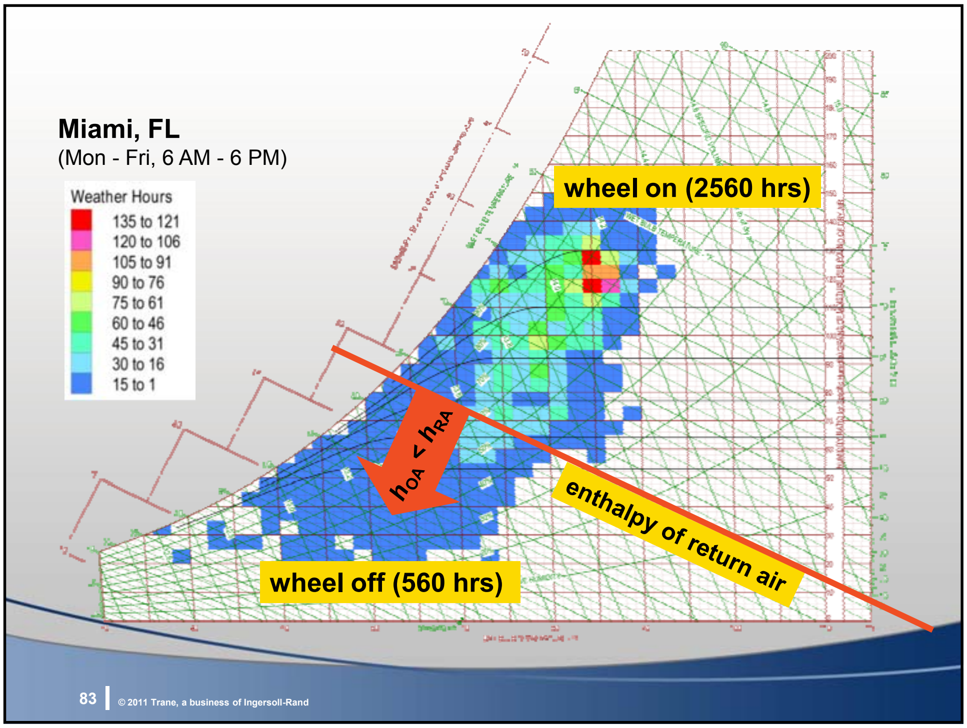
Drawbacks

- Increases fan energy
- Requires exhaust air be routed back to the device

air-to-air energy recovery

Considerations for VAV Systems

- Size energy-recovery device for minimum outdoor airflow required, not economizing airflow
- Strive for balanced airflows
- Ensure that the device is controlled properly
  - Turn off during mild weather to avoid wasting energy
  - Provide a means of capacity control during heating
  - Include bypass dampers for airside economizing


Miami, FL
(Mon - Fri, 6 AM - 6 PM)
Weather Hours
135 to 121
120 to 106
105 to 91
90 to 76
75 to 61
60 to 46
45 to 31
30 to 16
15 to 1
wheel on (2560 hrs)
$h_{OA} < h_{RA}$
enthalpy of return air
wheel off (560 hrs)
83
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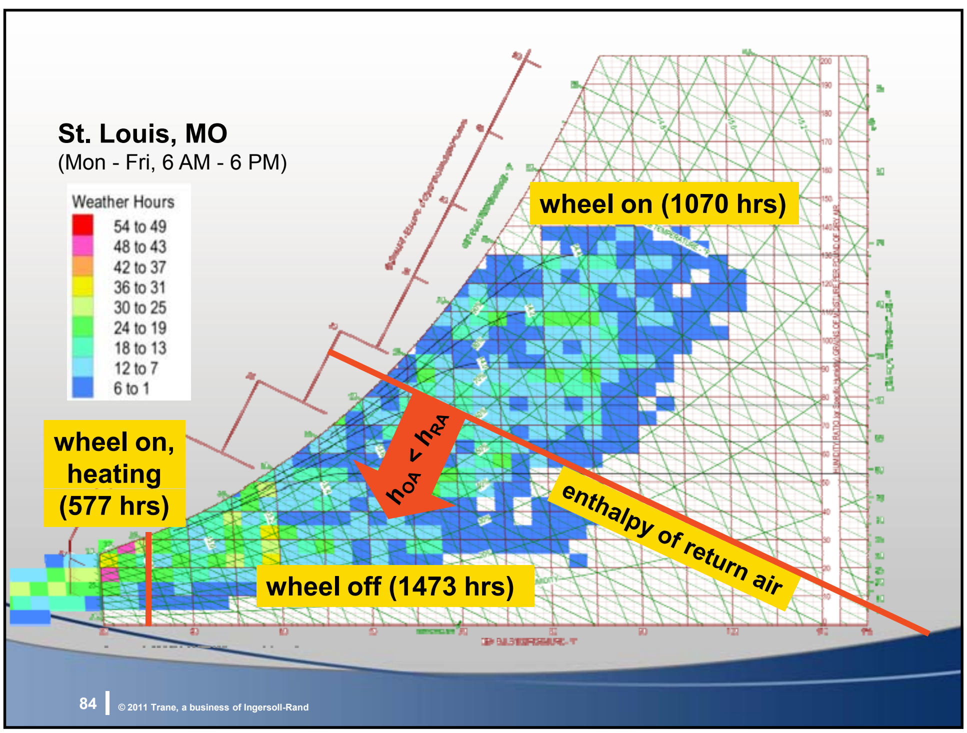
St. Louis, MO
(Mon - Fri, 6 AM - 6 PM)
Weather Hours
54 to 49
48 to 43
42 to 37
36 to 31
30 to 25
24 to 19
18 to 13
12 to 7
6 to 1
wheel on (1070 hrs)
wheel on, heating (577 hrs)
$h_{OA} < h_{RA}$
enthalpy of return air
wheel off (1473 hrs)
84
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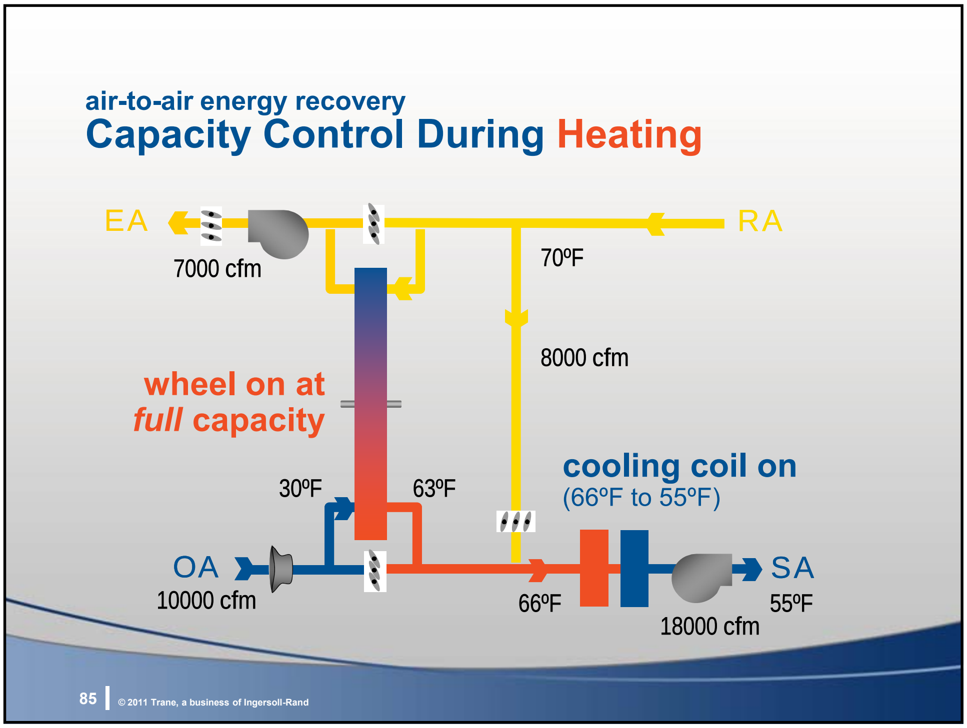
air-to-air energy recovery
Capacity Control During Heating
EA
RA
7000 cfm
70ºF
8000 cfm
wheel on at
full capacity
cooling coil on
(66ºF to 55ºF)
30ºF
63ºF
OA
10000 cfm
66ºF
18000 cfm
SA
55ºF
85
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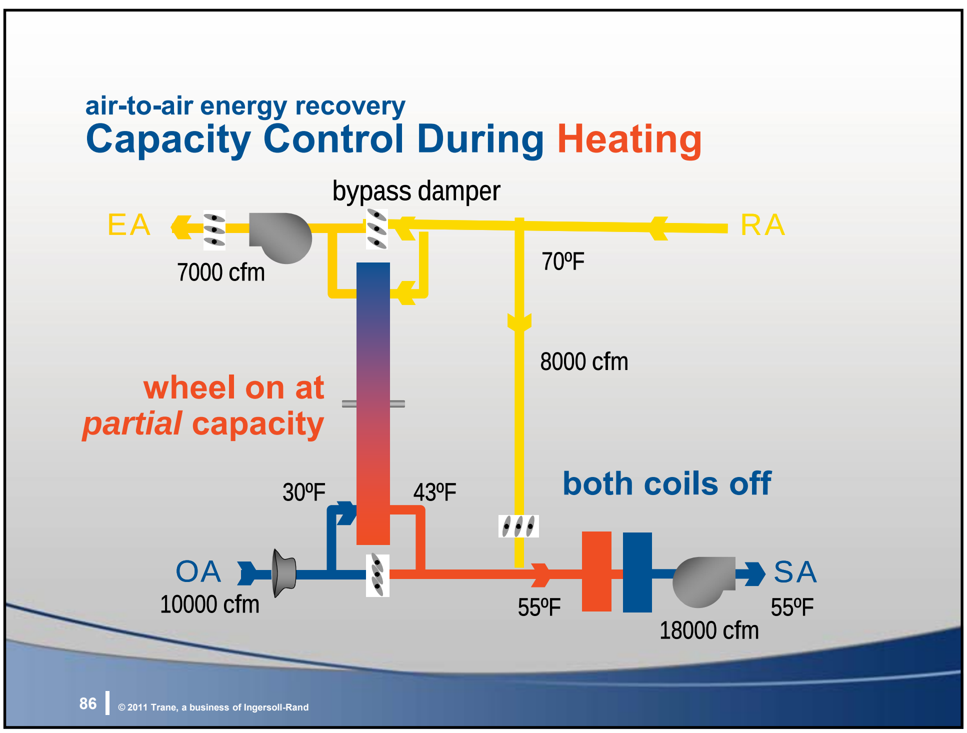
air-to-air energy recovery
Capacity Control During Heating
bypass damper
EA
RA
7000 cfm
70ºF
8000 cfm
wheel on at
partial capacity
30ºF
43ºF
both coils off
OA
10000 cfm
55ºF
18000 cfm
SA
55ºF
86
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air-to-air energy recovery

Considerations for VAV Systems

- Size energy-recovery device for minimum outdoor airflow required, not economizing airflow
- Strive for balanced airflows
- Ensure that the device is controlled properly
  - Turn off during mild weather to avoid wasting energy
  - Provide a means of capacity control during heating
  - Include bypass dampers for airside economizing
- Provide a method for frost prevention in cold climates

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Other Energy-Saving Strategies

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Today's Topics

- ASHRAE 189.1 requirements
- Optimized VAV system controls
- Cold-air distribution
- Air-to-air energy recovery
- Other energy-saving strategies
- Energy modeling results
- Summary

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"High-Performance" Rooftop VAV System

- High-efficiency rooftop
- Evaporative condensing
- Central relief/exhaust fan, rather than a return fan
- Solar hot-water system for reheat

rooftop unit with evaporative condenser

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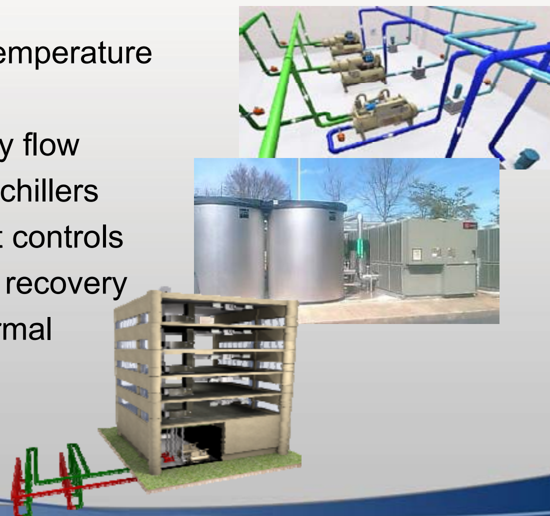
“High-Performance” Chilled-Water System

- Low flow, low temperature
- Ice storage
- Variable primary flow
- High-efficiency chillers
- Optimized plant controls
- Waterside heat recovery
- Central geothermal



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Example
Energy Analyses

Ingersoll Rand

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- ASHRAE 189.1 requirements
- Optimized VAV system controls
- Cold-air distribution
- Air-to-air energy recovery
- Other energy-saving strategies
- **Energy modeling results**
- Summary

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large office building
Example Energy Analysis

"Baseline" chilled-water VAV system

- Per ASHRAE 90.1-2007, Appendix G
- 55ºF supply air

"High-performance" chilled-water VAV system

- 48ºF supply air (no downsizing of ductwork)
- Optimized VAV system controls (ventilation optimization, SAT reset)
- Parallel fan-powered VAV terminals
- Low-flow, water-cooled chiller plant

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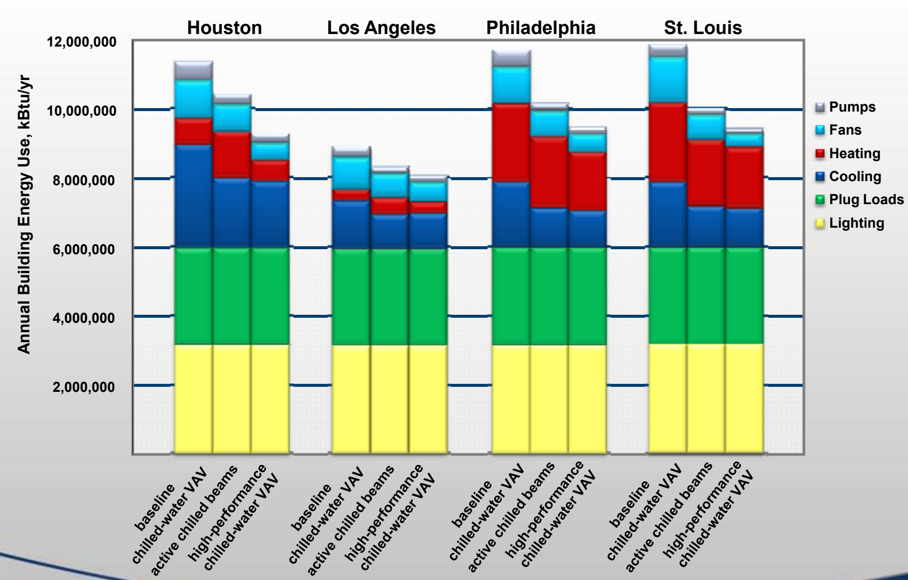
large office building
Example Energy Analysis (continued)

Active chilled beam (ACB) system

- Four-pipe active chilled beams
- Separate primary AHUs for perimeter and interior areas (with airside economizers)
- Water-cooled chiller plant supplying the chilled beams
- Separate low-flow, water-cooled chiller plant supplying the primary AHUs

95



96

small office building

Example Energy Analysis

"Baseline" rooftop VAV system

- Per ASHRAE 90.1-2007, Appendix G
- 55ºF supply air

"High-performance" rooftop VAV system

- High-efficiency, air-cooled packaged rooftop unit
- 52ºF supply air (no downsizing of ductwork)
- Optimized VAV system controls (ventilation optimization, SAT reset)
- Parallel fan-powered VAV terminals

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small office building

Example Energy Analysis (continued)

Variable refrigerant flow (VRF) system

- Heat recovery, air-cooled outdoor units
- Packaged DX dedicated outdoor-air unit with hot gas reheat

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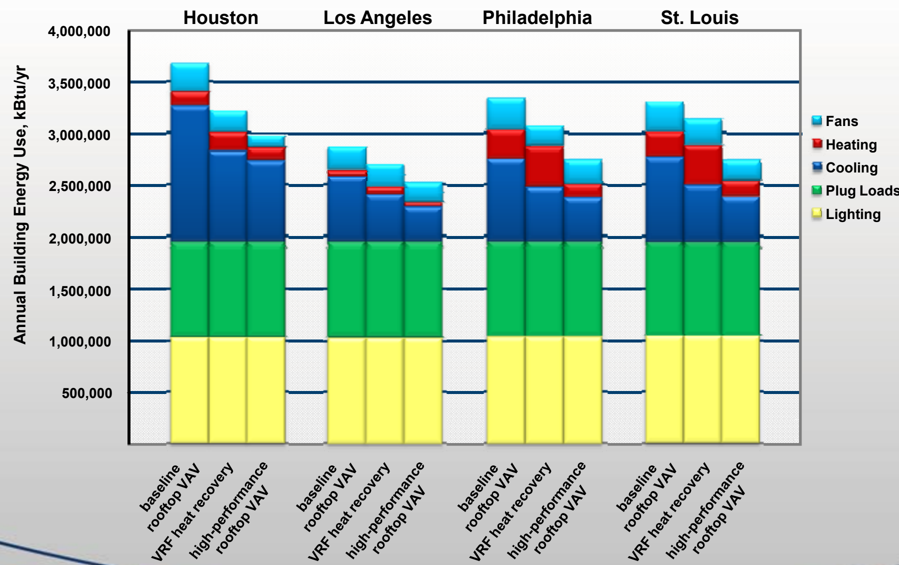

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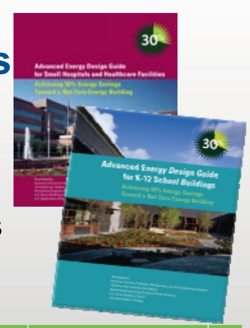
Advanced Energy Design Guides

www.ashrae.org/freeaedg

- Funded by U.S. Dept of Energy
- Climate-specific recommendations for achieving 30% or 50% energy savings (envelope, lighting, HVAC, water heating)
- Based on building energy simulations



Item	Component	Recommendation	How-To Tip	✓
Packaged Rooftop VAV System	Rooftop air conditioner (≥240 kBtu/h)	10.0 EER and 10.4 IPLV	HV5, HV7–8, HV10	
	Gas furnace (≥225 kBtu/h)	80% E_c		
	Gas boiler	85% E_c	HV5, HV7, HV10, HV26	
	Economizer	>54 kBtu/h	HV13	
	Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14	
	Fans	1.3 hp/1000 cfm	HV19	

Item	Component	Recommendation	How-To Tip	✓
VAV and Chiller System	Air-cooled chiller efficiency	9.6 EER and 11.5 IPLV	HV6–8, HV10, HV25	
	Water-cooled chiller efficiency	Comply with Standard 90.1*	HV6–8, HV10, HV25	
	Gas boiler	85% E_c	HV6–7, HV10, HV26	
	Economizer	>54 kBtu/h	HV13	
	Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14	
	Fans	1.3 hp/1000 cfm	HV19	

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Advanced Energy Design Guides

AEDG for Small or Medium Office Buildings

- "High-performance" rooftop VAV systems are included as an option to achieve **50%** energy savings

AEDG for K-12 Schools

- Both rooftop VAV and chilled-water VAV systems are included as options to achieve **30%** energy savings

AEDG for Small Hospitals and Healthcare Facilities

- Both rooftop VAV and chilled-water VAV systems are included as options to achieve **30%** energy savings

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summary

High-Performance VAV Systems

- Optimized VAV system controls
- Cold-air distribution
- Air-to-air energy recovery
- Other energy-saving strategies

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- Air distribution
- Refrigerant-to-air systems
- Control strategies
- Industry standards and LEED
- Energy and the environment
- Acoustics
- Ventilation
- Dehumidification

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- ASHRAE 90.1-2010
- Energy Saving Strategies for Rooftop VAV Systems
- Air-Handing Systems, Energy and IAQ
- Central Geothermal System Design and Control
- Ice Storage Design and Control

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- **March**
  Upgrading Existing Chilled-Water Systems
- **June**
  High-Performance VAV Systems
- **October**
  Dedicated Outdoor-Air Units

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