KRUEGER®

BUILDING LOADS AND DEDICATED OUTDOOR AIR SYSTEMS

ABOUT ME

- Dan Int-Hout
- Chief Engineer
- 43 Years of Experience
- ASHRAE / Designated Lecturer
- Published over 50 articles and technical papers
- Manages presentation of product data and provides advanced application engineering for our sales reps.

AGENDA

- ASHRAE RP1515
- Thermal Comfort
- IAQ / Standard 62.1 Update
- Dedicated Outside Air Systems
- The DOAS Fan Terminal
- Summary

RP 1515

- ASHRAE sponsored
- California, Yahoo Campus (1m sq.ft.)
- Measured
  - Occupant satisfaction
  - Equipment operation
  - Environmental variables
  - Energy use
- Yahoo System: DDC single duct VAV reheat
- Interior Airflow: 1 cfm/sf, 30% turn down
- Plaque diffusers

RP 1515 OBSERVATIONS

- Low occupant satisfaction (< 40%)
- Boilers operating in summer
- Space at 68°F, set at 73°F

RP 1515 DIAGNOSTICS

- Space was cold at 30% of max interior airflow
- When 68°F, VAV boxes went into heat mode, with 68°F setpoint (per California code)
- Space was maintained at 68°F till end of day
- VAV boxes were reset to 10% (0.1cfm/sf)
- System settled at 0.22 cfm/sf (= minimum ventilation rate per Title 24)
- Occupant satisfaction increased at 73°F
- Boilers shut down

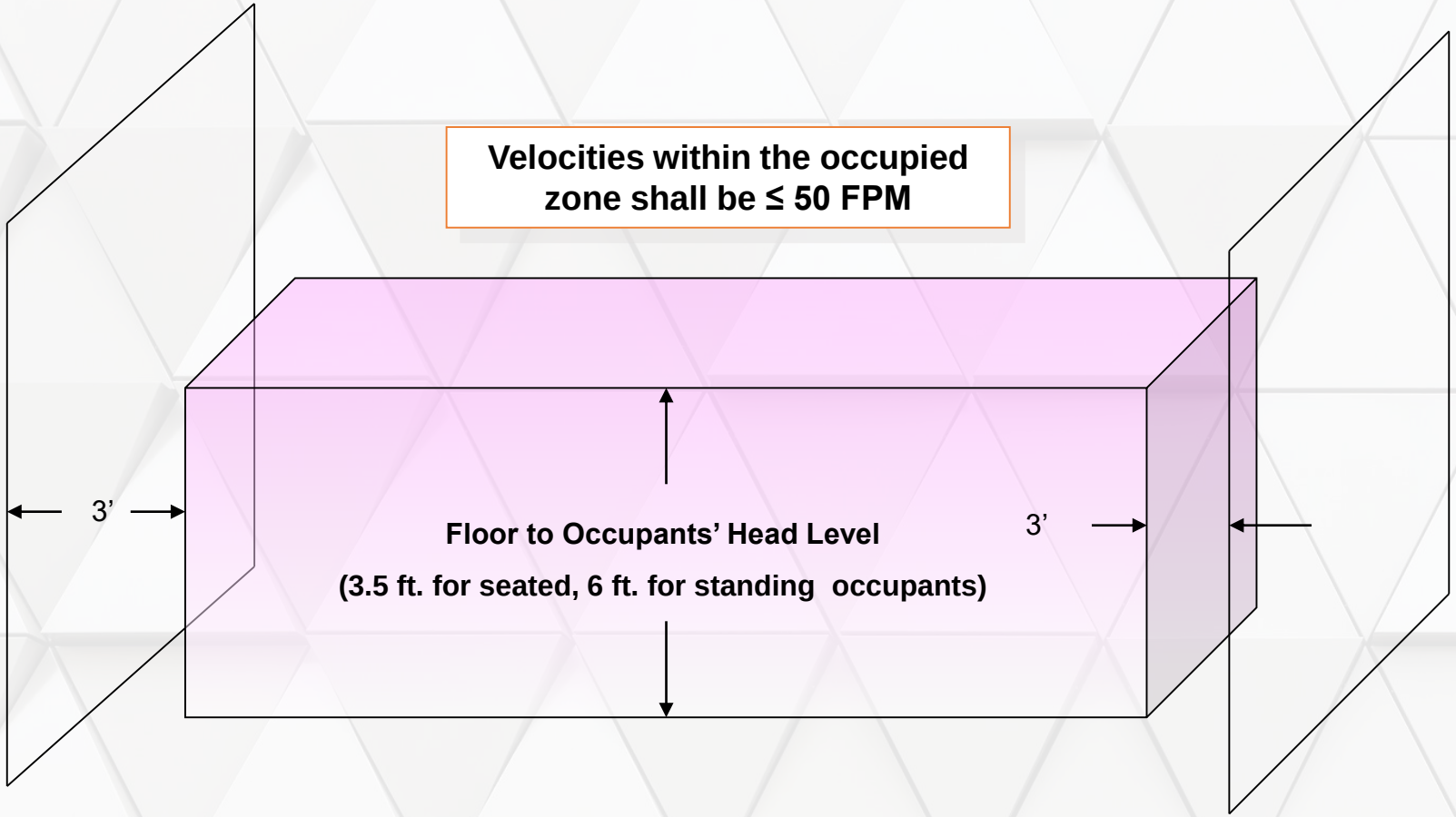
RP 1515 CONCLUSIONS

- Interior loads are less than 1 cfm/sf (the national average)
- 0.22 cfm/sf can achieve occupant satisfaction > 80%
- Interior loads are close to 100% outside air
- Building load is controlled by outside air, not by equipment in the zone
- PS: This is Huge!

THERMAL COMFORT

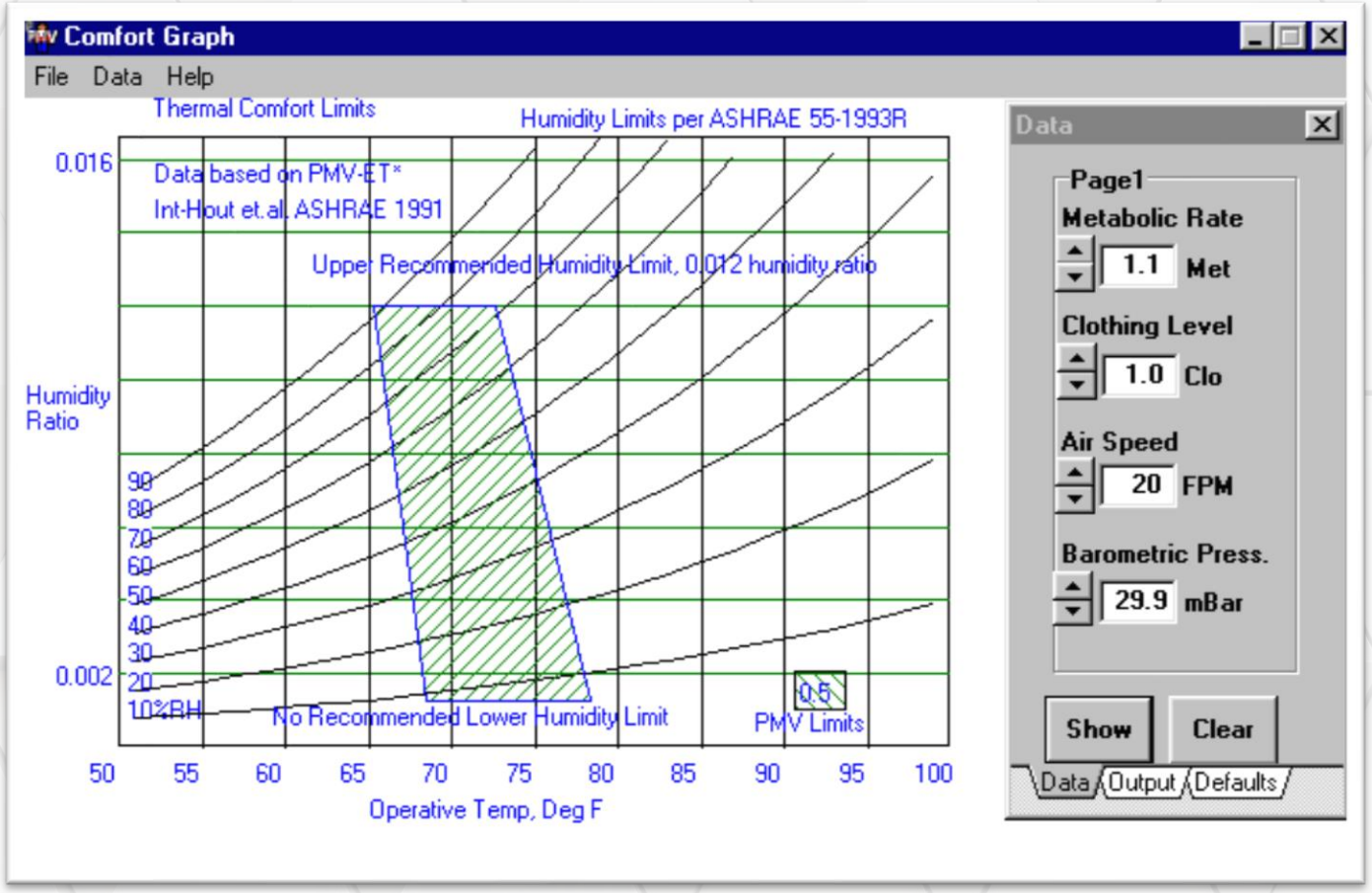
- Thermal Comfort Standard: ASHRAE 55
- ASHRAE Fundamentals, Chapter 9
- PMV (Predicted Mean Vote) is a single number rating
- Program to plot comfort envelope (based on the Standard 55)
- Standard 55 mandates a maximum vertical temperature stratification in occupied zone

THERMAL COMFORT



ASHRAE Standard 55 mandates a maximum 5°F vertical temperature stratification in the Occupied Zone.

THERMAL COMFORT - GRAPHICAL SOLUTION



COMFORT ECONOMICS

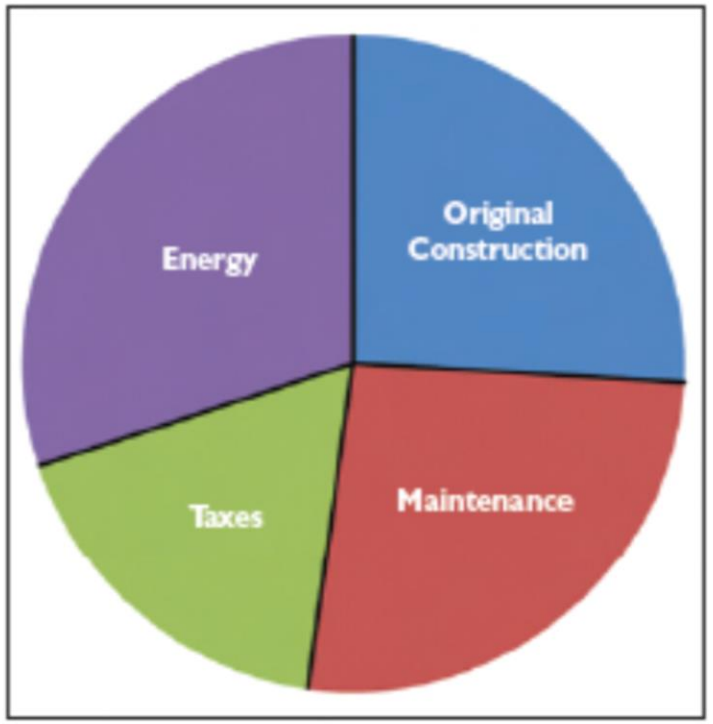


Figure 1: Life-cycle building costs breakdown.

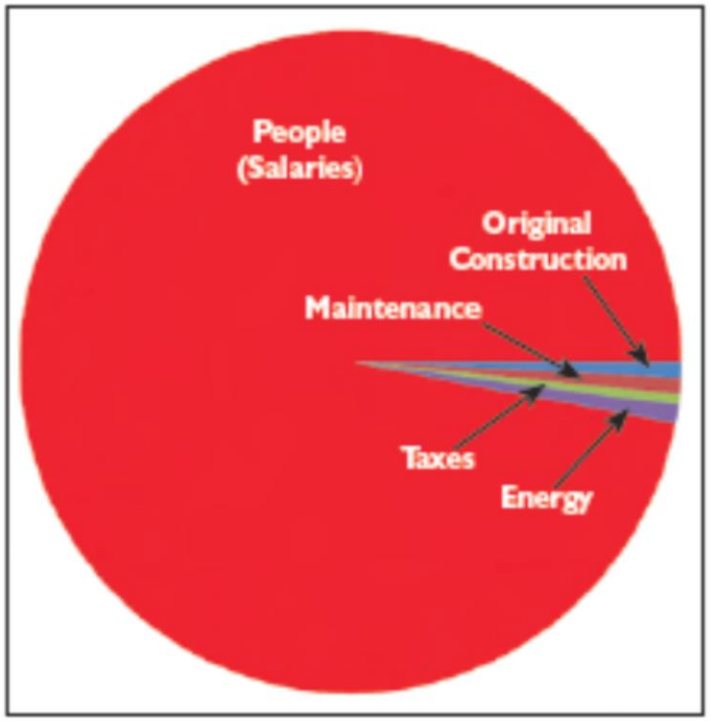
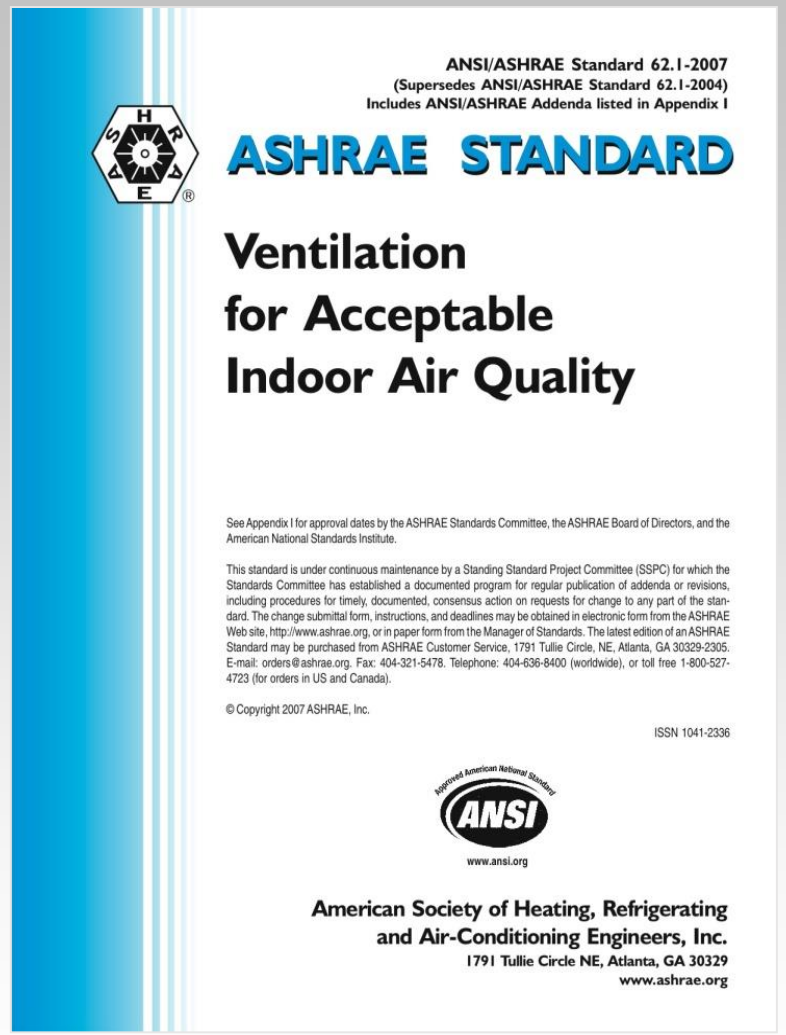


Figure 2: Life-cycle building costs breakdown with people (salaries).

ASHRAE Journal, June 2008

STANDARD 55 COMPLIANCE

- Predicting compliance is tricky
- Establish design temperature with clothing and met rate data
- Vertical stratification can be proven with ADPI
  - Throw
  - Separation
  - Room load
- ADPI data updated in 2014



INDOOR AIR QUALITY

- Standard Project Committee, 62.1
- Residential Committee, 62.2
- Current Standard, 62.1-2016 (includes 2013 addenda)

IAQ STANDARD

- Standard 62.1 is on continuous maintenance
- Coordinating with building codes
- Users Manual
- IMC referenced VRP of 62.1 in latest mechanical code
- Minimal public awareness of the dynamic nature

AIR DISTRIBUTION DEVICE – SELECTION GUIDELINES

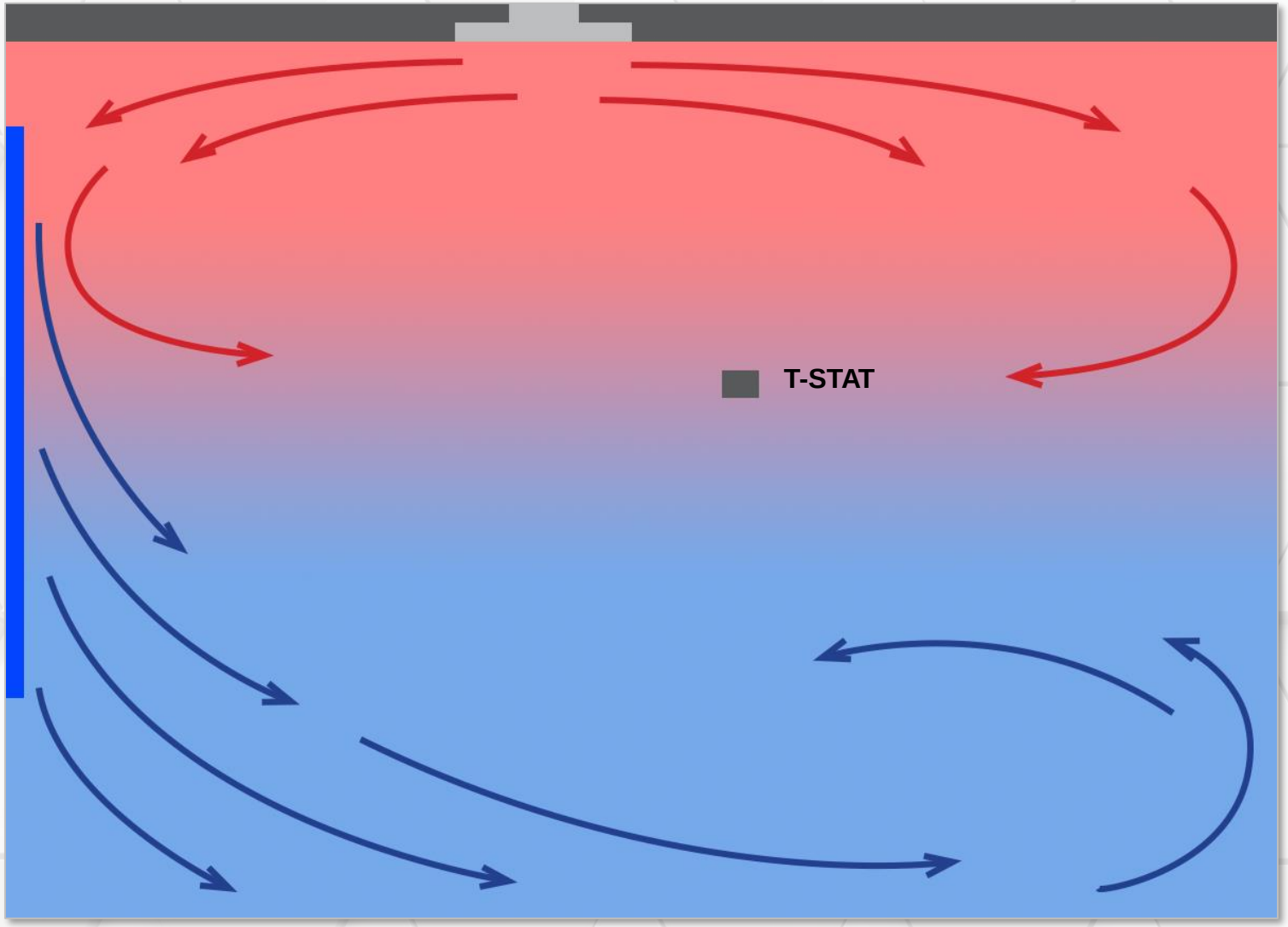
ASHRAE Fundamentals Handbook (chapter 20 – air distribution)

- Methods for overhead fully mixed
- Methods for fully stratified and partially mixed systems from below
- Methods for task /ambient personal air delivery systems

- Constant and variable volume
- UFAD
- Displacement ventilation
- Chilled beams

- All have advantages and disadvantages

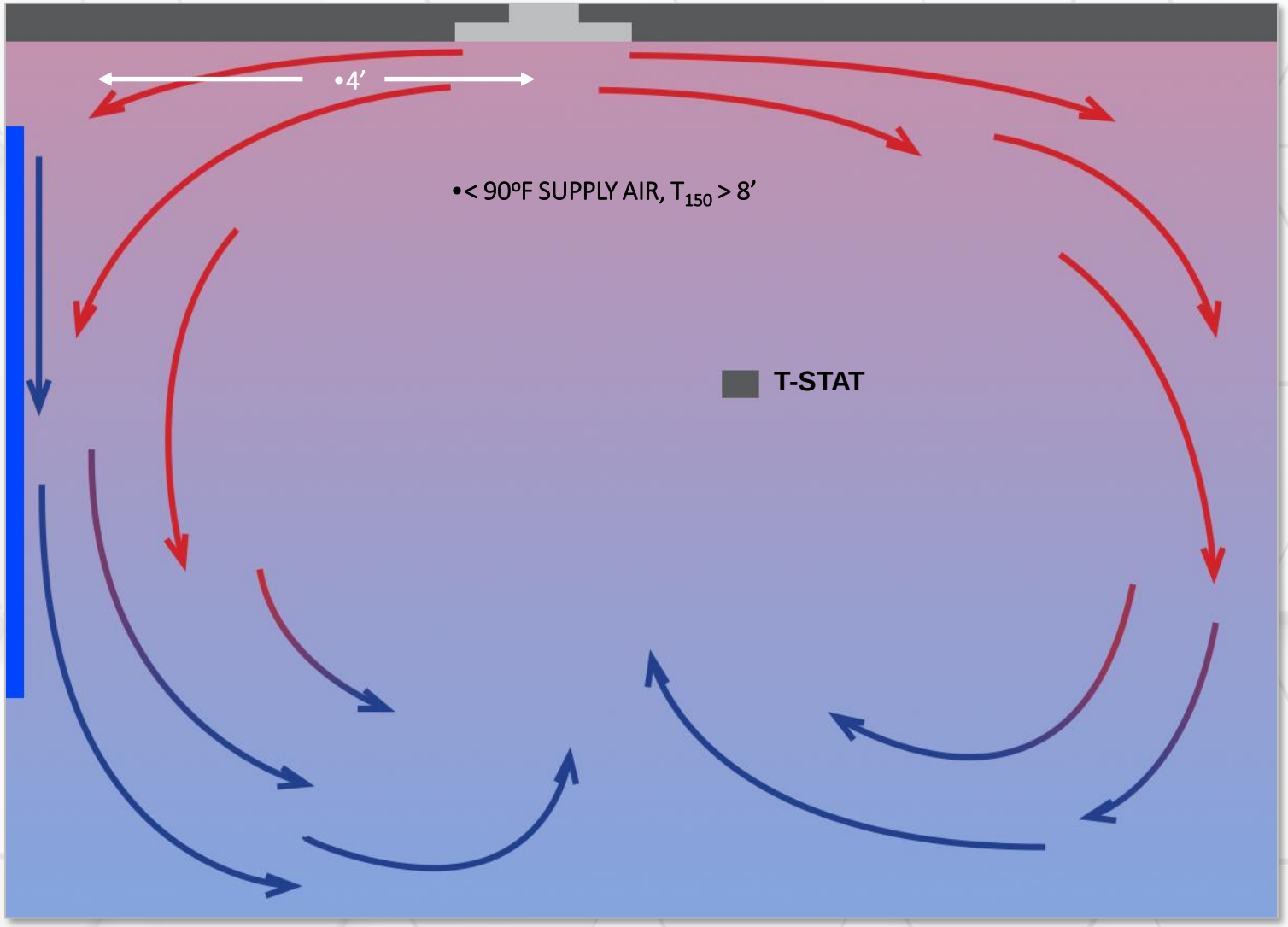
COMMON OVERHEAD HEATING DESIGN

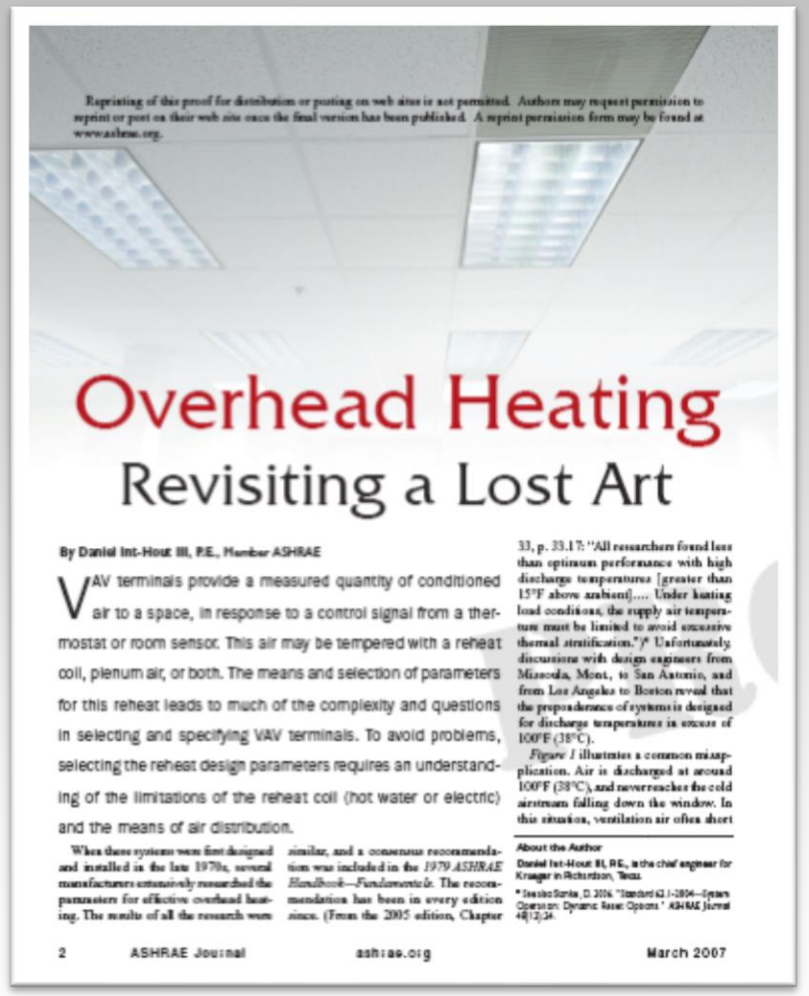


OVERHEAD HEATING – PERIMETER CONSIDERATIONS

- Maximum Delta-t for effective mixing when heating from overhead, per ASHRAE handbook = ?
- **= 15°F** (90°F discharge), continuous operation
- 150 FPM should reach 4-5 feet from the floor
- ASHRAE 62.1 requires that ventilation be increased by 25% when heating, if the above rules are not followed
- The Handbook recommends two-way discharge from an outlet located a couple feet from the window
- Typical perimeters require only 8°F Delta-t @ 1cfm/sqft
- Locate a return slot above the window for solar heat gain

PROPER PERIMETER EXAMPLE





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Overhead Heating

Revisiting a Lost Art

By Daniel Int-Hout III, P.E., Member ASHRAE

VAV terminals provide a measured quantity of conditioned air to a space, in response to a control signal from a thermostat or room sensor. This air may be tempered with a reheat coil, plenum air, or both. The means and selection of parameters for this reheat leads to much of the complexity and questions in selecting and specifying VAV terminals. To avoid problems, selecting the reheat design parameters requires an understanding of the limitations of the reheat coil (hot water or electric) and the means of air distribution.

When these systems were first designed and installed in the late 1970s, several manufacturers extensively researched the parameters for effective overhead heating. The results of all the research were similar, and a consensus recommendation was included in the *1979 ASHRAE Handbook—Fundamentals*. The recommendation has been in every edition since. (From the 2005 edition, Chapter 33, p. 33.17: "All researchers found less than optimum performance with high discharge temperatures [greater than 15°F above ambient].... Under heating load conditions, the supply air temperature must be limited to avoid excessive thermal stratification.")* Unfortunately, discussions with design engineers from Missoula, Mont., to San Antonio, and from Los Angeles to Boston reveal that the preponderance of systems is designed for discharge temperatures in excess of 100°F (38°C).

Figure 1 illustrates a common misapplication. Air is discharged at around 100°F (38°C), and never reaches the cold airstream falling down the window. In this situation, ventilation air often short

About the Author

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* Stanke, D. 2006. "Standard 62.1-2004—System Operation: Dynamic Reset Options." *ASHRAE Journal* 48(12):24.

2 ASHRAE Journal ashrae.org March 2007

ASHRAE Journal article, from 2007.

PERIMETER CONSIDERATIONS

- ASHRAE Journal article outlines requirements for overheating
- Nothing in this article was not known in 1979

THE VALUE OF AN EFFECTIVE ECONOMIZER

- Huge energy saving potential (climate dependent)
- Ventilation can be correlated to productivity
- Requires control of comfort and humidity
- Requires higher air quantities than ventilation alone
- Implies dynamic control of ventilation air quantities
- LEED point for increasing ventilation beyond minimum
- Not be an option with many types of non all-air systems

MEETING CURRENT CODES AND STANDARDS

ALL HVAC SYSTEMS NEED TO COMPLY WITH 62.1

VRF, WSHP, and Fan Coil systems require ventilation air

- Ventilation introduced separately or into the suction side of the units
- Should be close to room temperature
- All air systems blend outside air with return air in an air handler
- Chilled Beam systems typically utilize a DOAS system

VAV AIR HANDLERS

- Designed to condition 30% of its rated capacity with outside air, mixing it with building return air
- Outside air component remains constant
- May handle 100% outside air at low loads, delivering 30% of design airflow capacity

LOW LOAD CONSIDERATIONS

- Ductwork approaches a “plenum” condition (low velocity pressures)
- Air handler benefits
  - Reduced external static
  - Reduced fan HP requirements
- Fan energy is reduced proportional to airflow, but to the square of pressure reductions
- Duct leakage is reduced by the square of the pressure drop

COLD AIR DISTRIBUTION

- Research for EPRI performed in the 90's
- Concerns were "dumping" at low loads
- "High Induction" diffusers were considered
  - Have high pressure drop
  - Were not better than some standard diffusers
- Plaque differs found to work well even at 48°F
- Issue: Low interior loads and sub cooling.
  - Required reheat negates any savings

COLD AIR DISTRIBUTION

WHERE ARE WE TODAY?

THE DEFAULT VENTILATION RATE

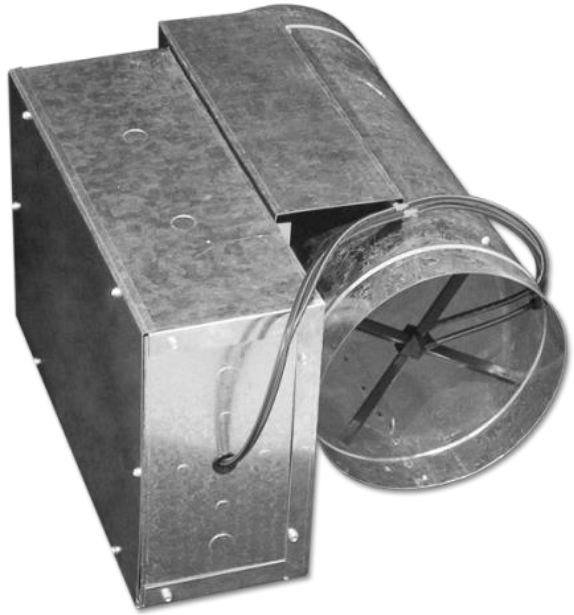
- Default Ventilation Rate = 17 cfm/person (ASHRAE 62.1, for offices)
- 17 CFM @ 55°F is more cooling than required by a sedentary person
- Many VAV systems are already near 100% outside air
- With 100% outside air, plenum lighting loads are expelled, and not included in HVAC system capacity requirements
- Increased outside air can result in a LEED point

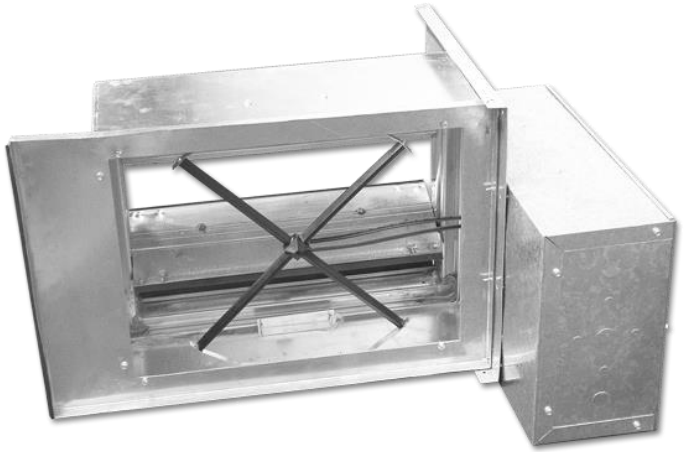
MEASUREABLE AND CONTROLLABLE VENTILATION SUPPLY

- Should be required
- 62.1 Requirement: Ducted ventilation to every zone at design load (code in most places)
- Ventilation rates vary
- Airflow rates affects all zones
- Pressure independent ventilation supply is effective

PRESSURE INDEPENDENT VENTILATION DAMPERS

- Round VAV dampers with flow sensors
- Square “slip-in” dampers with flow control
- Electronic actuators with flow transducers
- Analog signals to control ventilation rates





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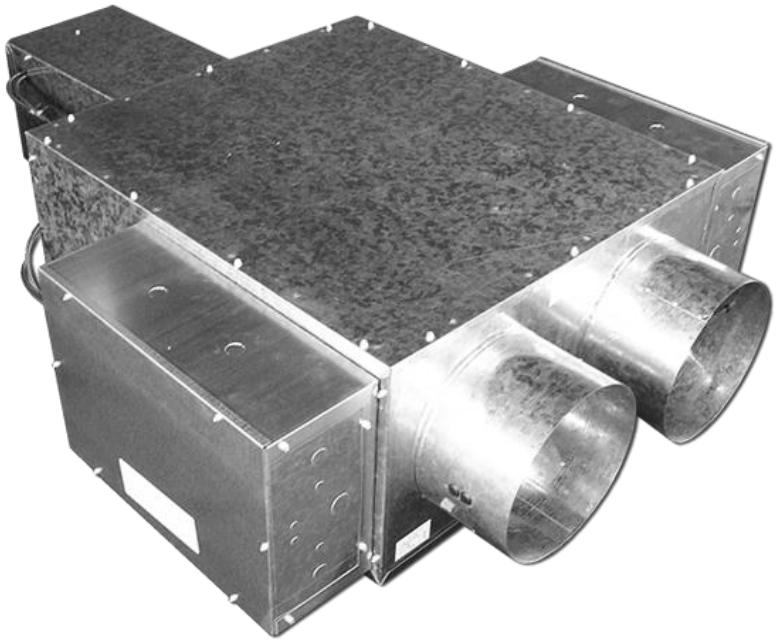
FRESH AIR DUAL DUCT

- 1 inlet provides 100% outside air, dehumidified, typically cold
- Other duct provides 100% return air, either warm or cold
- Supplemental reheat coils / sensible cooling coil have been considered
- Mixing baffle should be employed (20:1 mixing ratio recommended)



Mixing Dual Duct

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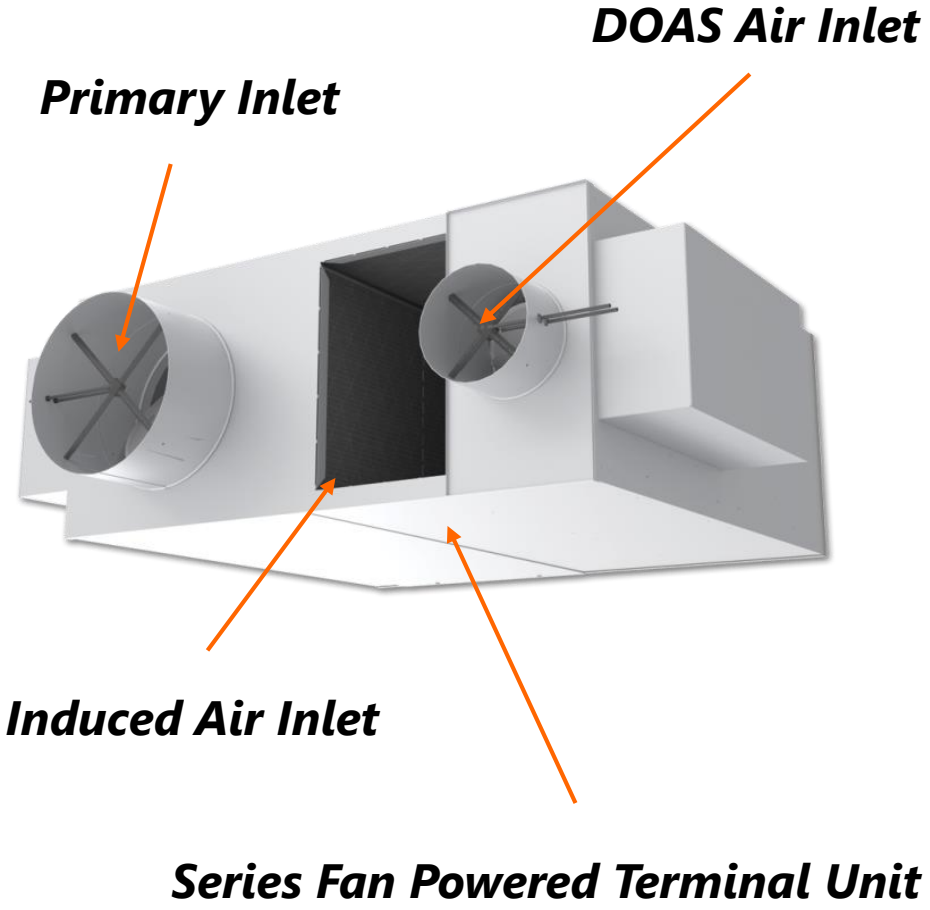
FRESH AIR TERMINAL UNIT

Outside air can be supplied to a series fan terminal by a second ducted system

- Requires two duct systems, but separate ventilation and recirculated air
- The system allows monitoring of ventilation rates into each zone.



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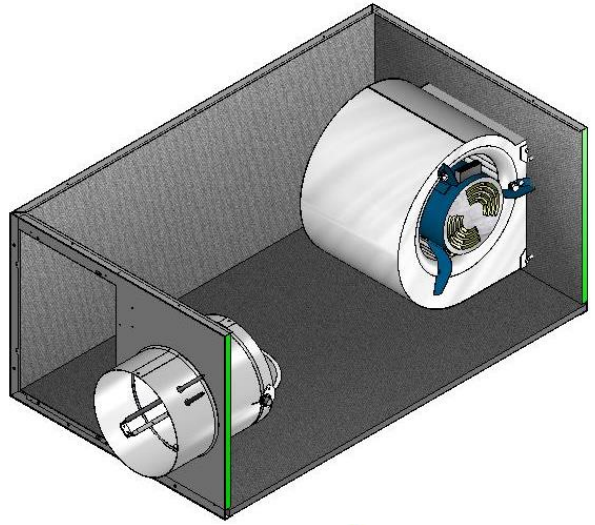
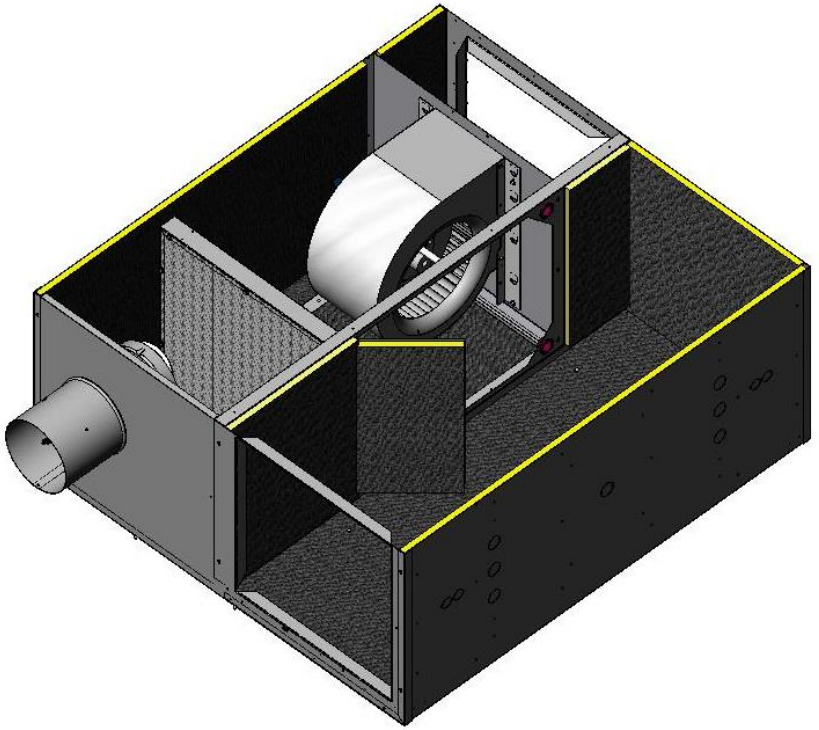
SERIES FAN TERMINAL UNIT

- Must discharge more air than supplied (on discharge)
- Made possible with pressure independent ECM technology
- Reference article in ASHRAE Journal (Jan 2015)
- Reduce building energy and need for reheat when coupled with a cold air delivery system (CAD)
- Solves overhead heat issues in cold climates





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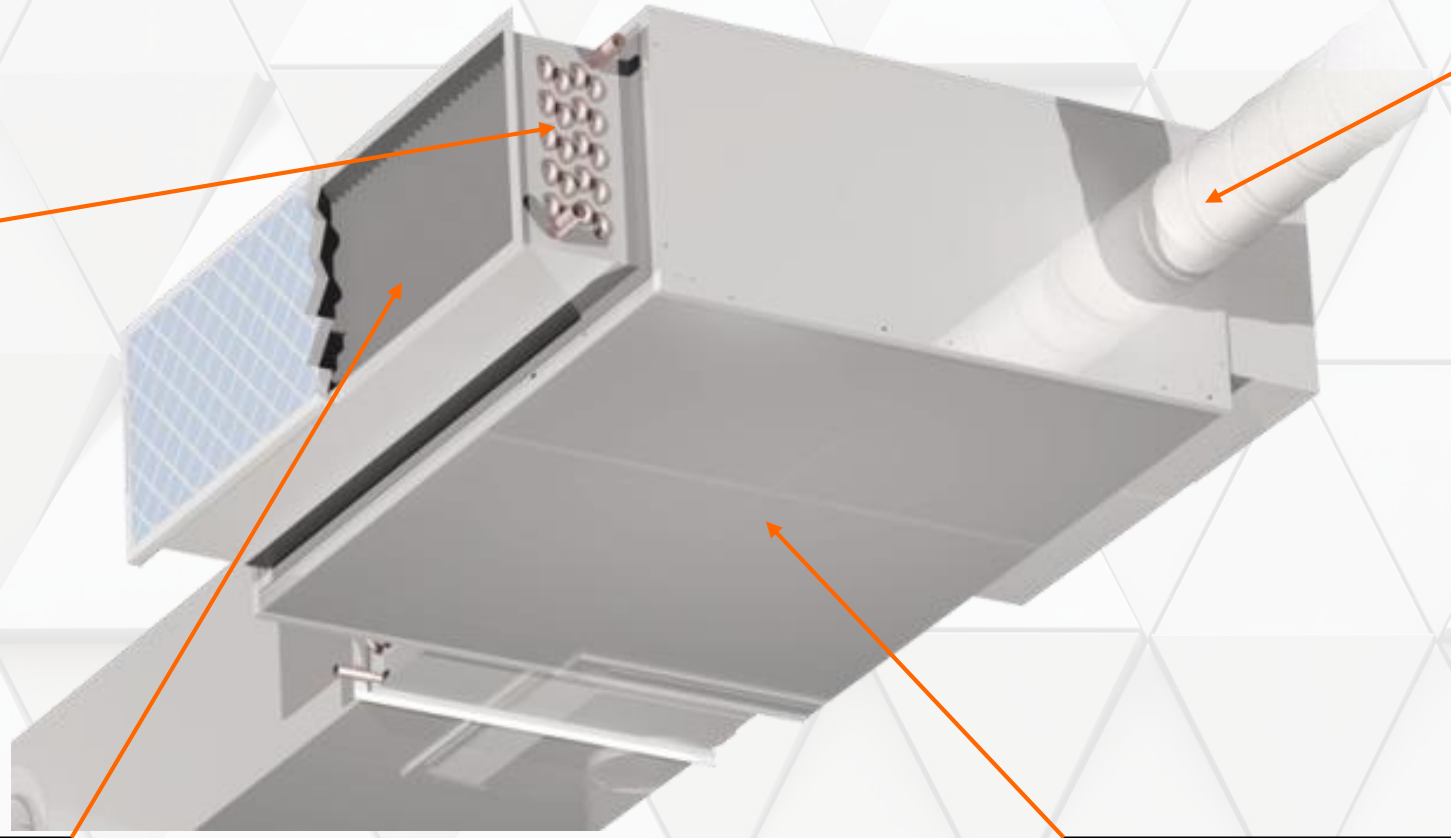
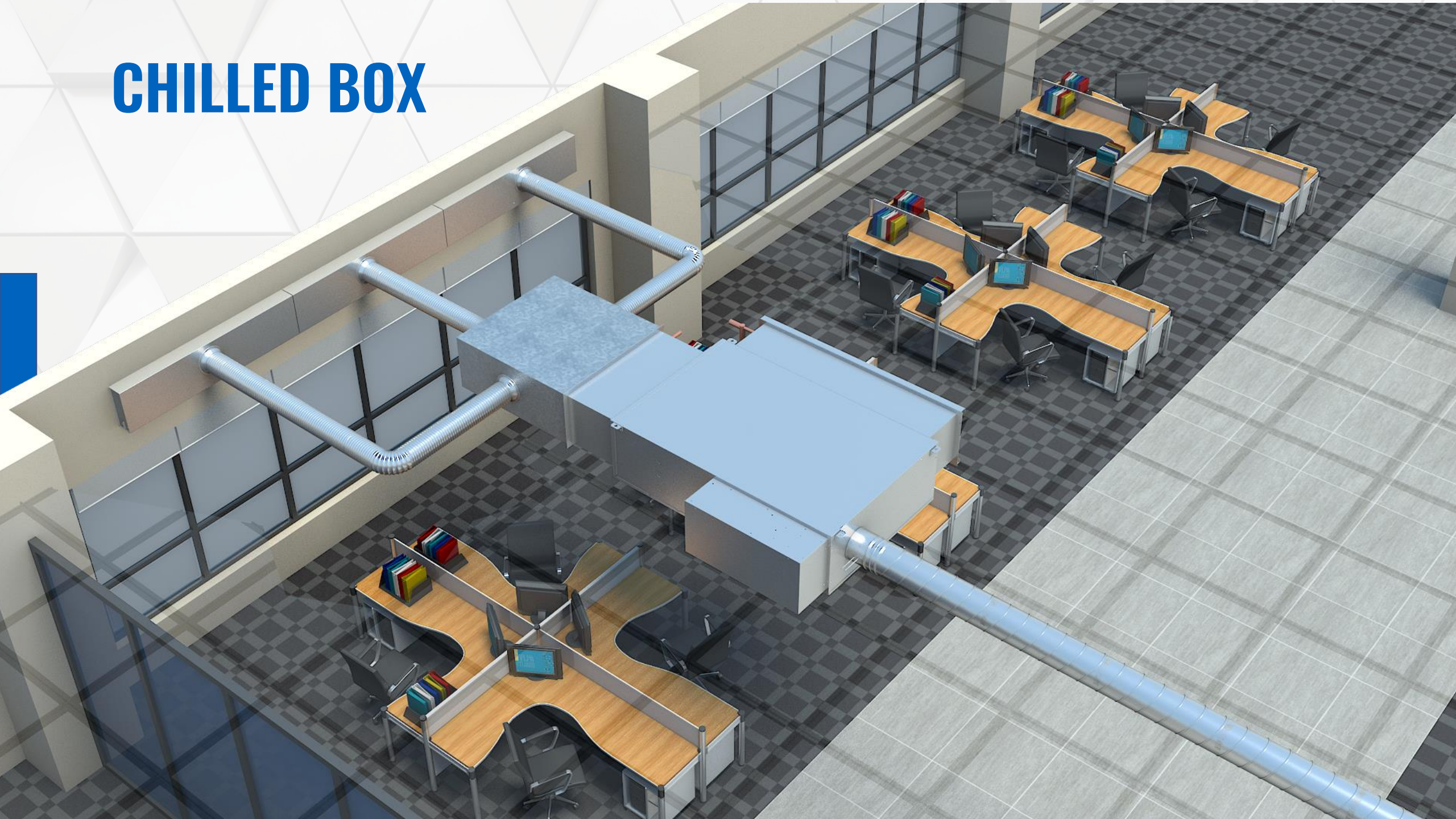
ADDING A SENSIBLE COOLING COIL

- Decoupled outside air can be supplied to a “Chilled Series Fan Terminal” (CFB) through a ducted system, designed to handle ventilation and latent loads
- “Fan assisted chilled beam”
- A sensible cooling coil, on the induced air inlet, cools plenum air for additional sensible space cooling.
- Allows monitoring of ventilation rates into each zone and effective economizer operation
- Reference article in ASHRAE Journal, Aug 2014

CHILLED BOX


Sensible cooling coil
DOAS Air Inlet
Induced Air Inlet
Series Fan Powered Terminal Unit

CHILLED BOX



CFB AND VAV UNIT FEATURES

- Precise air flow control (by variable speed pressure independent ECM)
- AHRI Certified sound levels, fan performance, power consumption
- Contractor is familiar with installation
- Flexible installation (standard overhead diffusers, potential LEED point for sustainable design)
- Diffuser performance is verifiable, can be used for LEED comfort point in cooling

EFFICIENCIES

ECM Motors:

- ECM typically uses less energy than a the PSC motor, especially as the air flow is reduced
- Motor is “pressure independent”, maintaining a desired airflow as inlet pressure changes, allowing DDC system to set a desired airflow without feedback

EFFICIENCIES

Reducing Airflows:

- Recent ASHRAE Research has shown that acceptable environments can be achieved with airflows as low as 0.2 CFM/sqft
- Airflows can be maintained as low as possible while assuring the fan flow exceeds the DOAS system flow rate
- Operating at very low flows, the ECM motor is quiet and energy efficient

EFFICIENCIES

Avoiding Sub-cooling:

- Happens when the ventilation rate or dehumidification needs exceed the thermal load
- Avoid sub-cooling without reheat by inducing warm plenum air

CFB UNIT EFFICIENCIES

Perimeter Solar Loads:

- Greatest in early morning and late afternoon
- Increasing cold (and dry) DOAS flow rate to these zones can help meet short term solar load demands
- DOAS ventilation air may be reduced to the interior

CFB UNIT EFFICIENCIES

Economizer:

- Potential huge energy savings
- Effective economizer operation can be achieved by slightly oversizing the ductwork / inlets to the chilled boxes
- If outside air dew points are low enough, the sensible coils can extend this range

VALIDATION OF ENERGY USE

AHRI and ASHRAE sponsored research will allow accurate and validated energy use calculations:

- ASHRAE Research Project 1292 was conducted at Texas A&M
- A project has started (AHRI 8012) to input the results of this research into Energy Plus, Trace and HAP, as well as several other energy calculation programs
- Allows engineers to accurately predict the savings from using the turn down feature of the Chilled Box

ECM SYSTEM ENERGY USE

- Three ASHRAE Journal articles have been prepared on the A&M Research
- Part 1 (Oct 2017) described the purpose of the research
- Part 2 (Nov 2017) summarized the findings
- Part 3 (Dec 2017) covers what's wrong with Energy Plus and other energy models

MEASURED ENERGY CONSUMPTION

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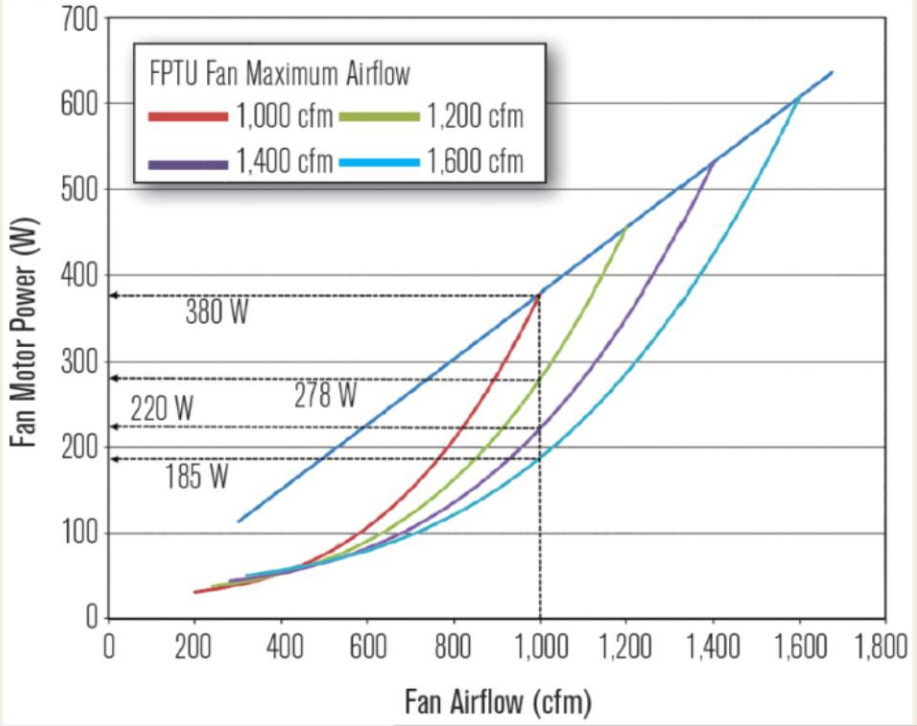
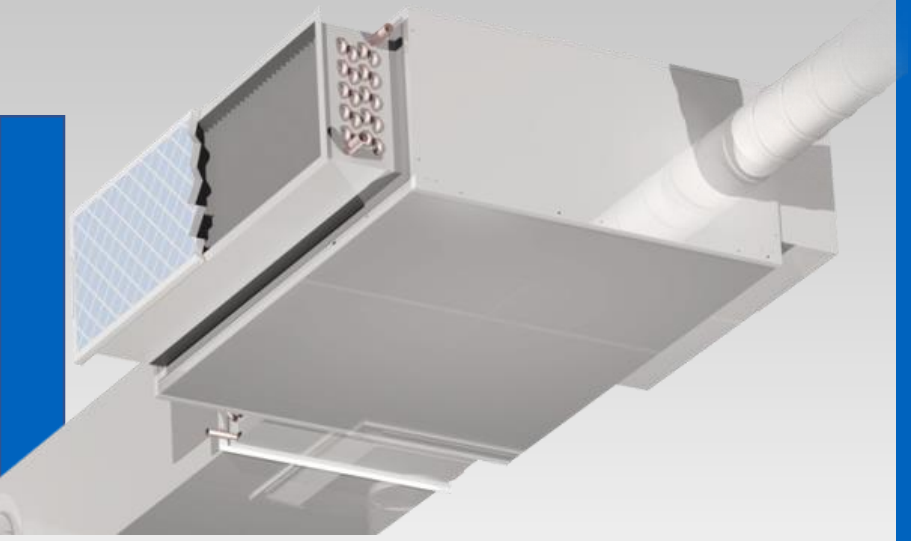
FIGURE 4 Sample plot showing how sizing ECM FPTUs affect fan power.





CHILLED BOX UNIT FEATURES

- Can be located in non-critical area
  - Away from potential condensation damage
- First cost savings over some other systems
  - Unit can supply 1500 sqft or more (not counting cost of additional heating system)
- Replacement parts are readily available

CFB AND VAV SERIES FAN TERMINAL UNIT FEATURES

- Heat and cool from single unit
- Hot water or electric heat coils
  - LineaHeat with discharge temp sensor can help achieve LEED point
- Large filter area allows min pressure drop with MERV 8 constr. filters
  - Automatic LEED point
- Published sound levels, fan performance, power consumption
- Flexible installation – standard overhead diffusers
  - Potential LEED point for sustainable design
- Ventilation rate can be measured and verified
  - Potential LEED point
- Diffuser performance verifiable
  - LEED comfort point

SUMMARY

- ASHRAE'S research project 1515 provided valuable data on building operations and loads
- LEED requires meeting Standard 62.1 VRP
- Documented use of ADPI is the ONLY way to assure compliance to all of Standard 55 in the design phase
- Reheat needs to be carefully considered in terms of discharge temperatures and velocities
- The both the CFB and VAV series fan box can be employed in several different configurations to solve a number of problems
- Economizer is a powerful tool for saving energy and maximizing productivity
- The rules are dynamic - pay attention

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http://www.krueger-hvac.com/public/learn/krueger%20blog