AMCA International

Building Loads and Dedicated Outdoor Air Systems

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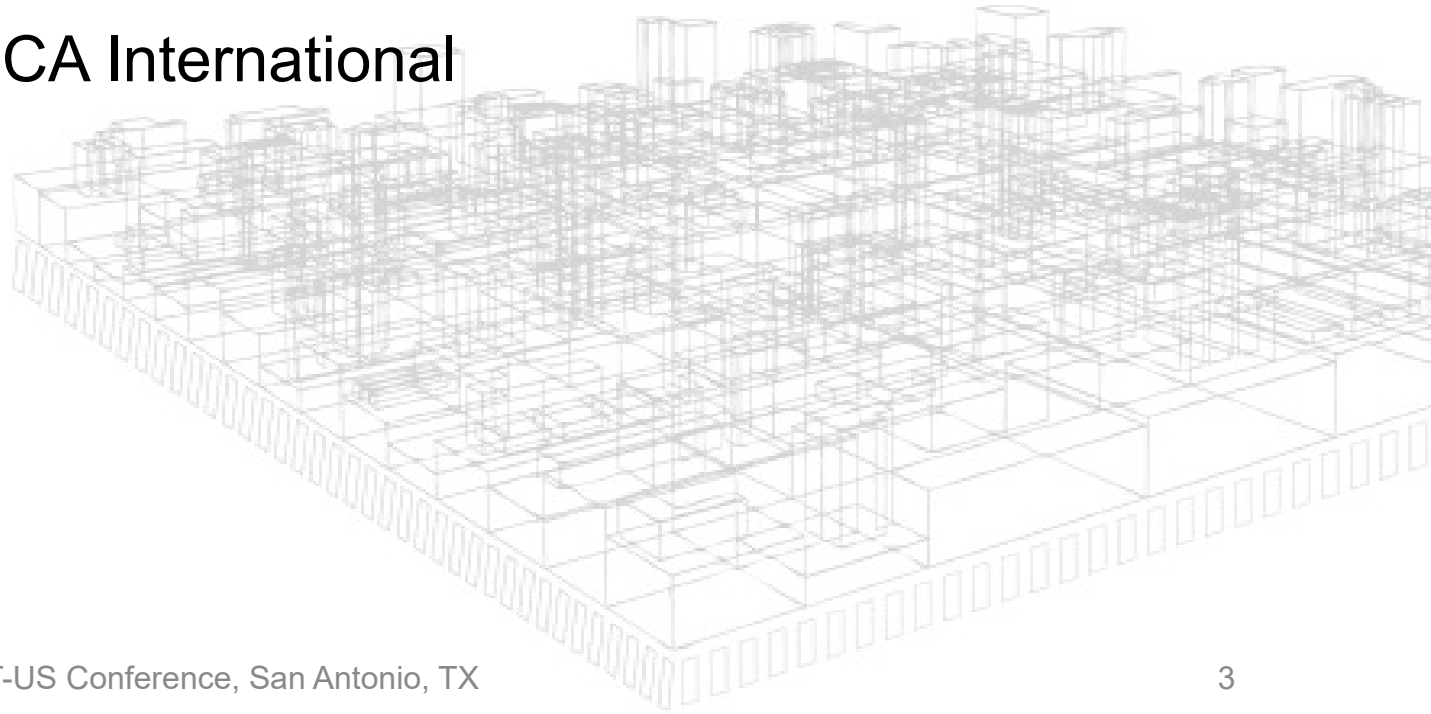
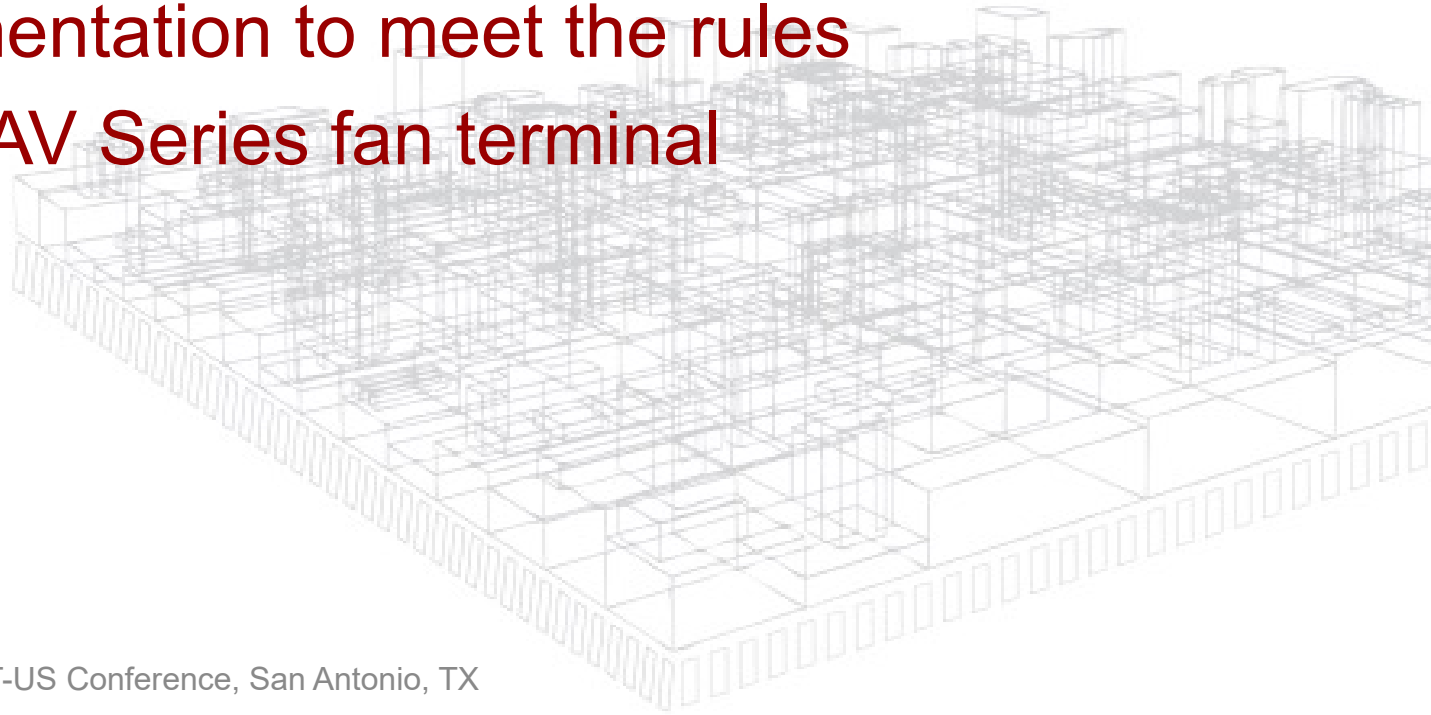


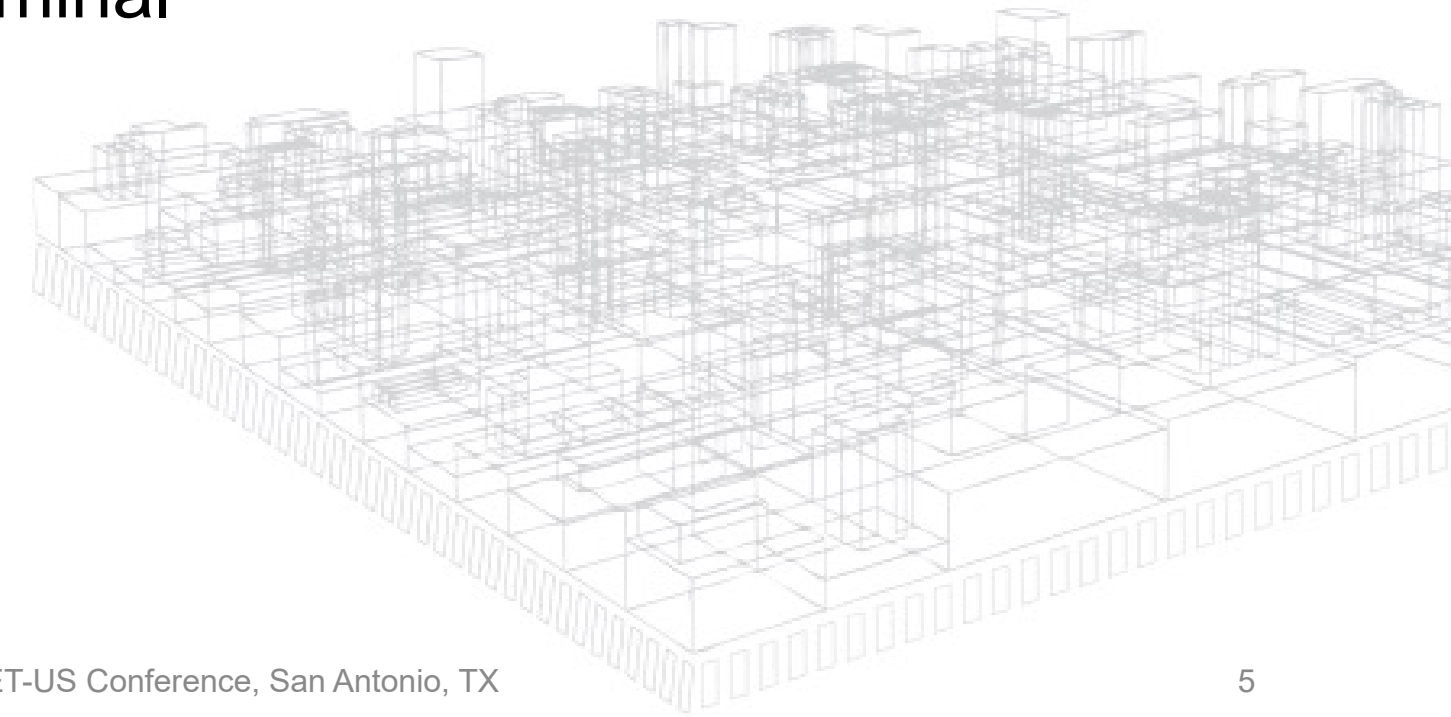
Learning Objectives

- Relevant ASHRAE Research on loads and efficiency
- The Rules (Air Distribution Codes and Standards)
- Methods of implementation to meet the rules
- The Chilled and VAV Series fan terminal



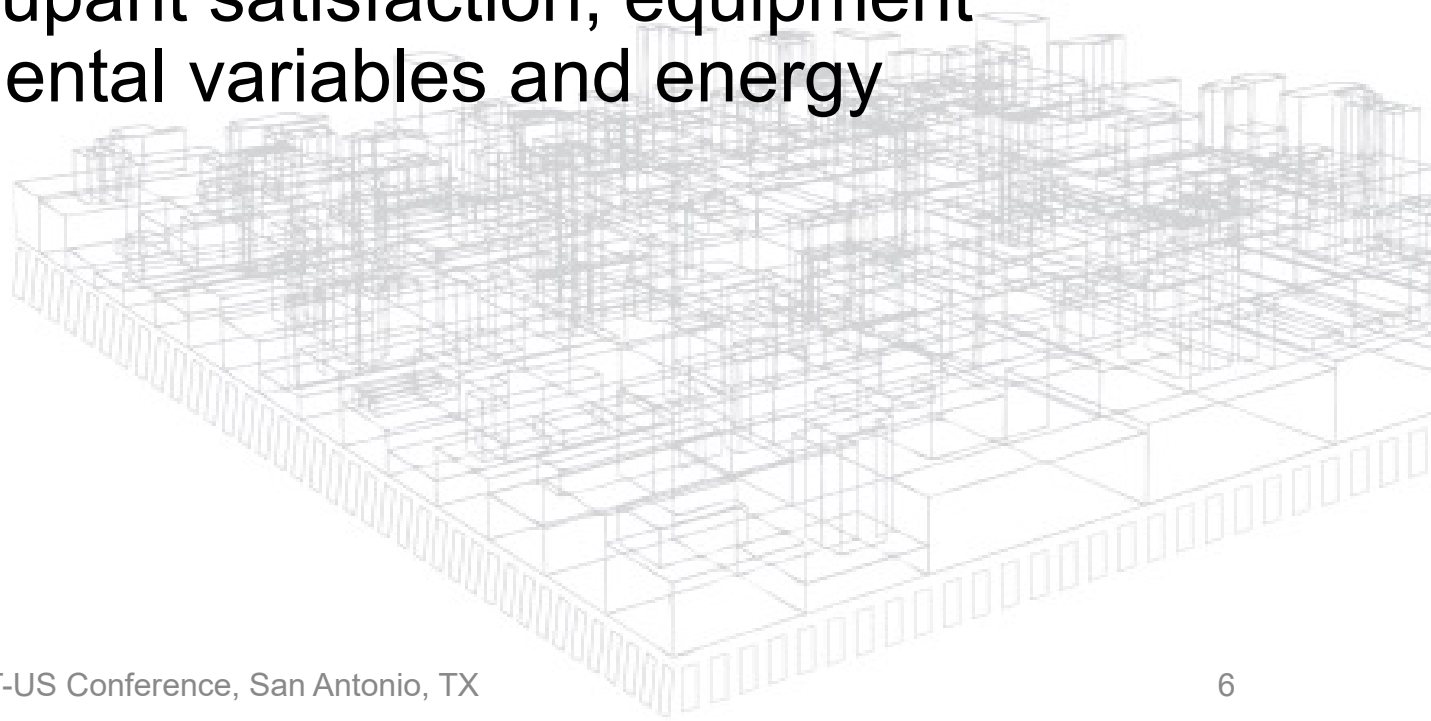
Agenda

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



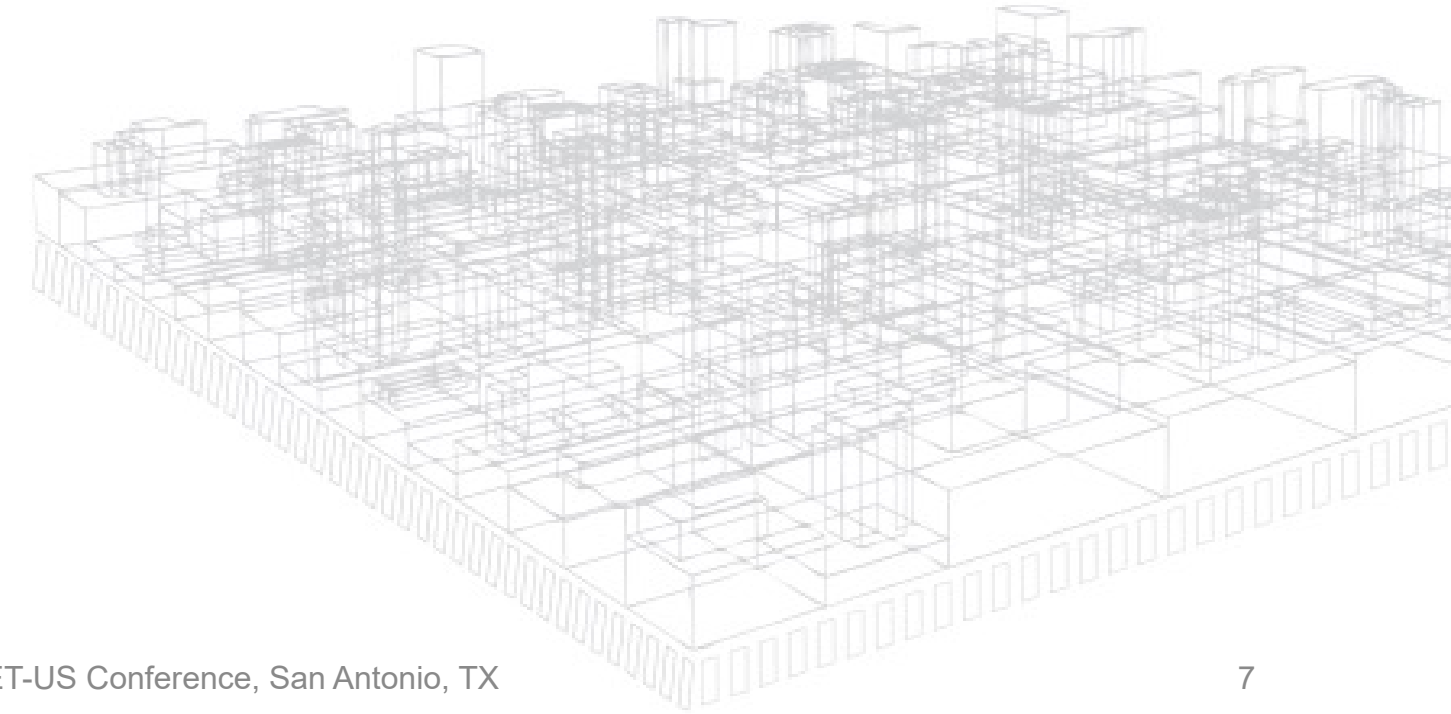
RP 1515

- ASHRAE sponsored a research project in California a couple years ago.
- Subject was the Yahoo campus (1m sq.ft.) and a couple other buildings
- They measured occupant satisfaction, equipment operation, environmental variables and energy use.



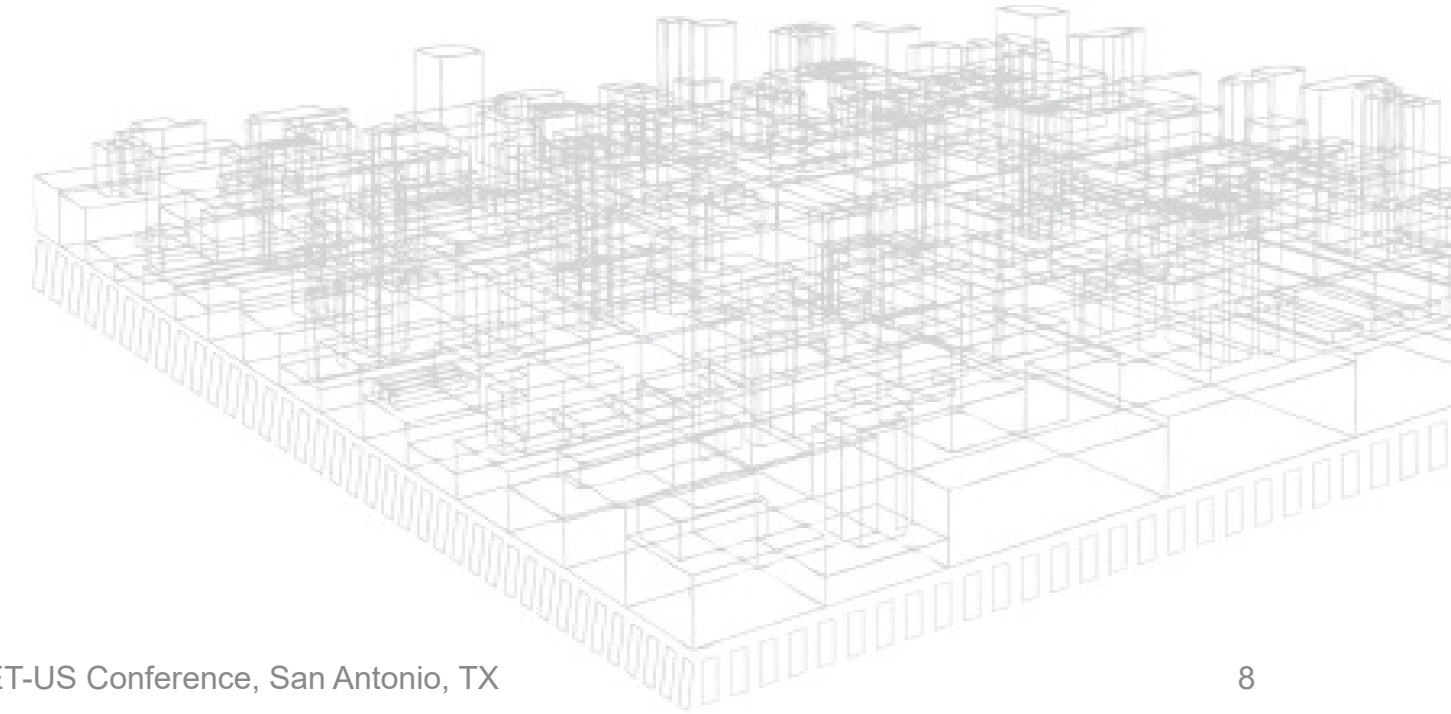
RP 1515

- Yahoo System was DDC Single Duct VAV reheat.
- Interior airflow was set a 1 cfm/sf, 30% turn down
- Diffusers were plaque-type.



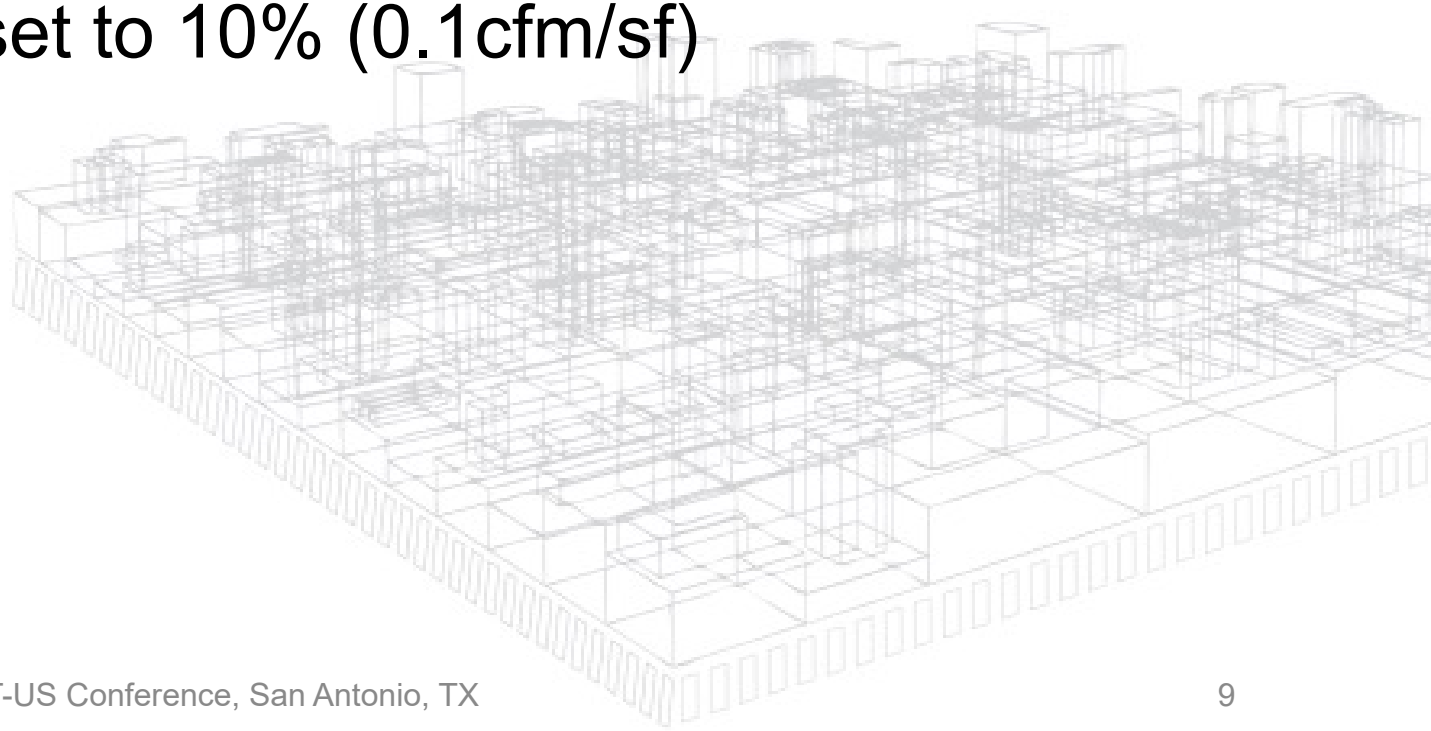
RP 1515 Observations

- Initial Occupant satisfaction was low, below 40%
- Boilers were operating in summer (only use for boilers was reheat coils)
- Space temperatures were 68F by late afternoon, while set at 73F



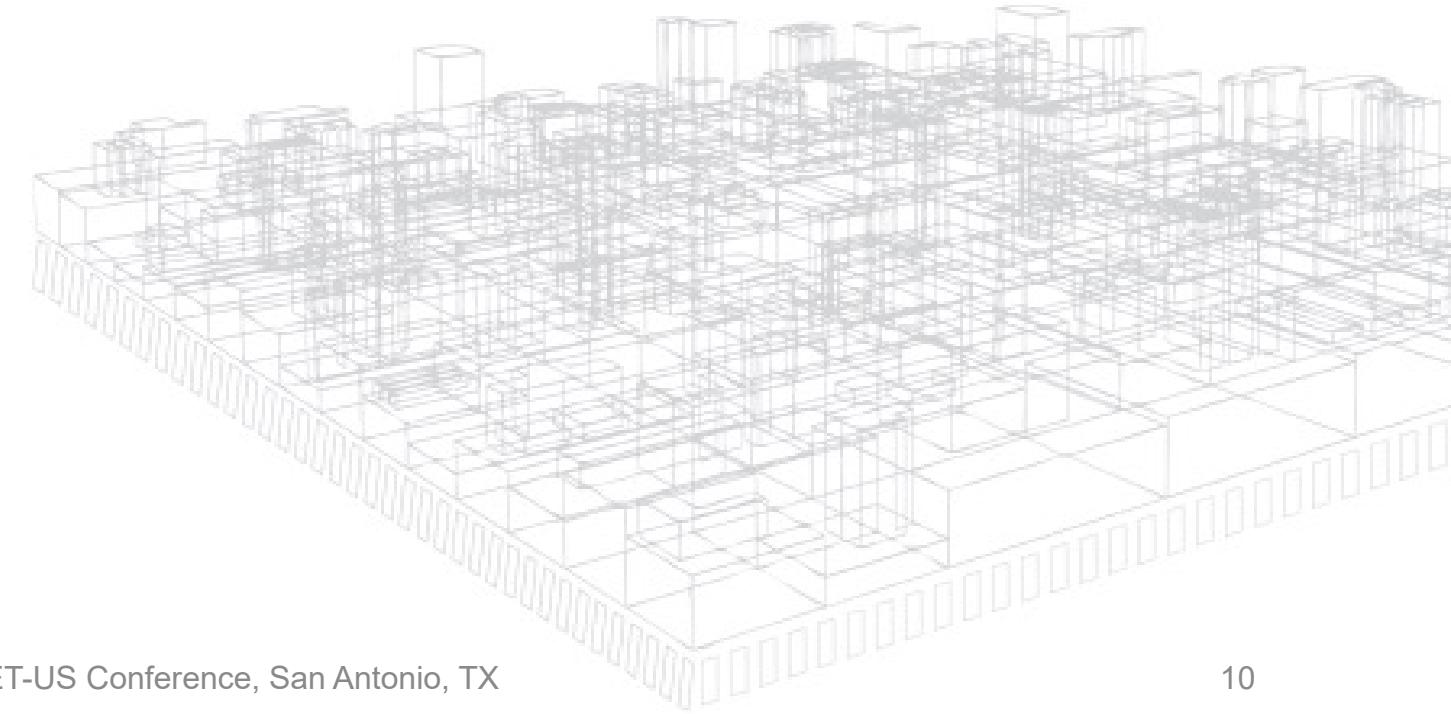
RP 1515 Diagnostics

- At 30% of max interior airflow, space was getting cold.
- When space hit 68F, VAV boxes went into heating mode, with 68F setpoint (per Calif code)
- Space was maintained at 68F till end of day.
- VAV boxes were reset to 10% (0.1cfm/sf)



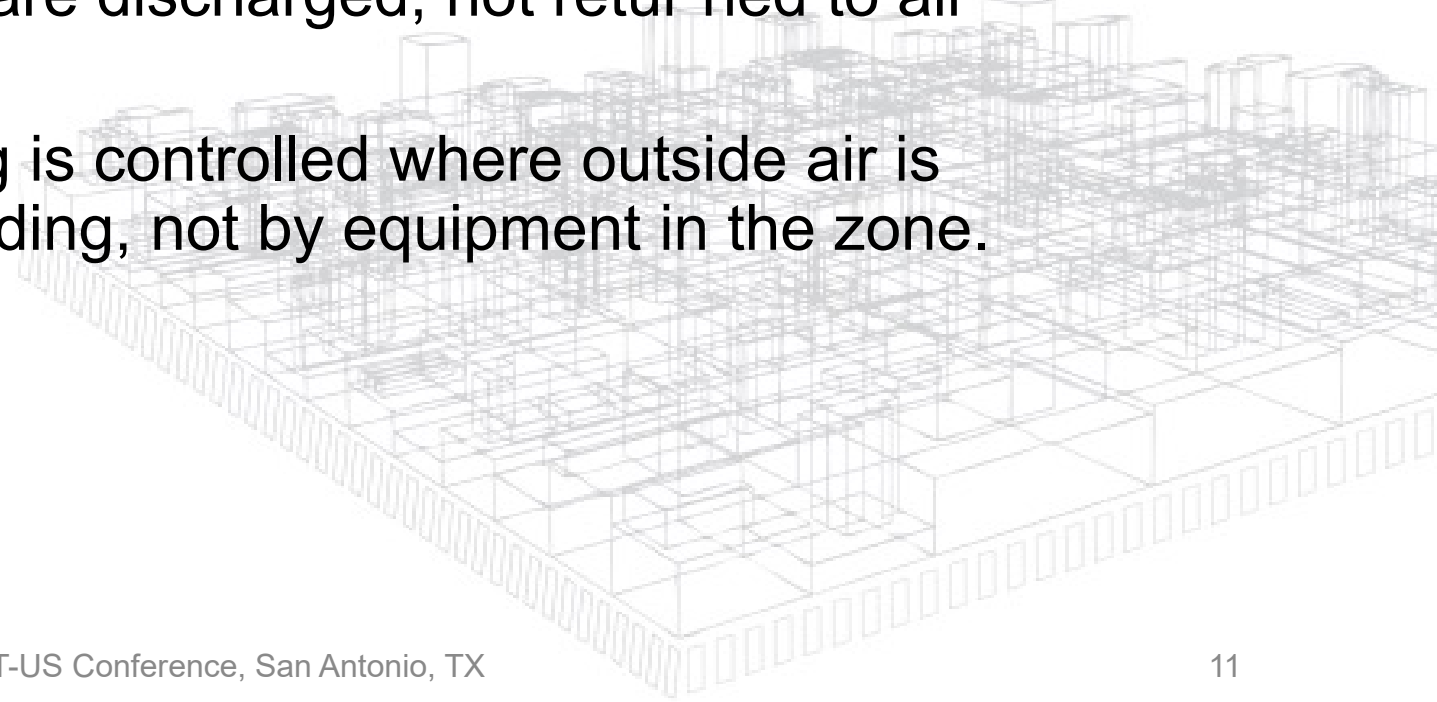
RP 1515 Diagnostics

- System settled at 0.22 cfm/sf (= minimum ventilation rate per Title 24)
- Occupant satisfaction soared as space maintained 73F
- Boilers shut down.



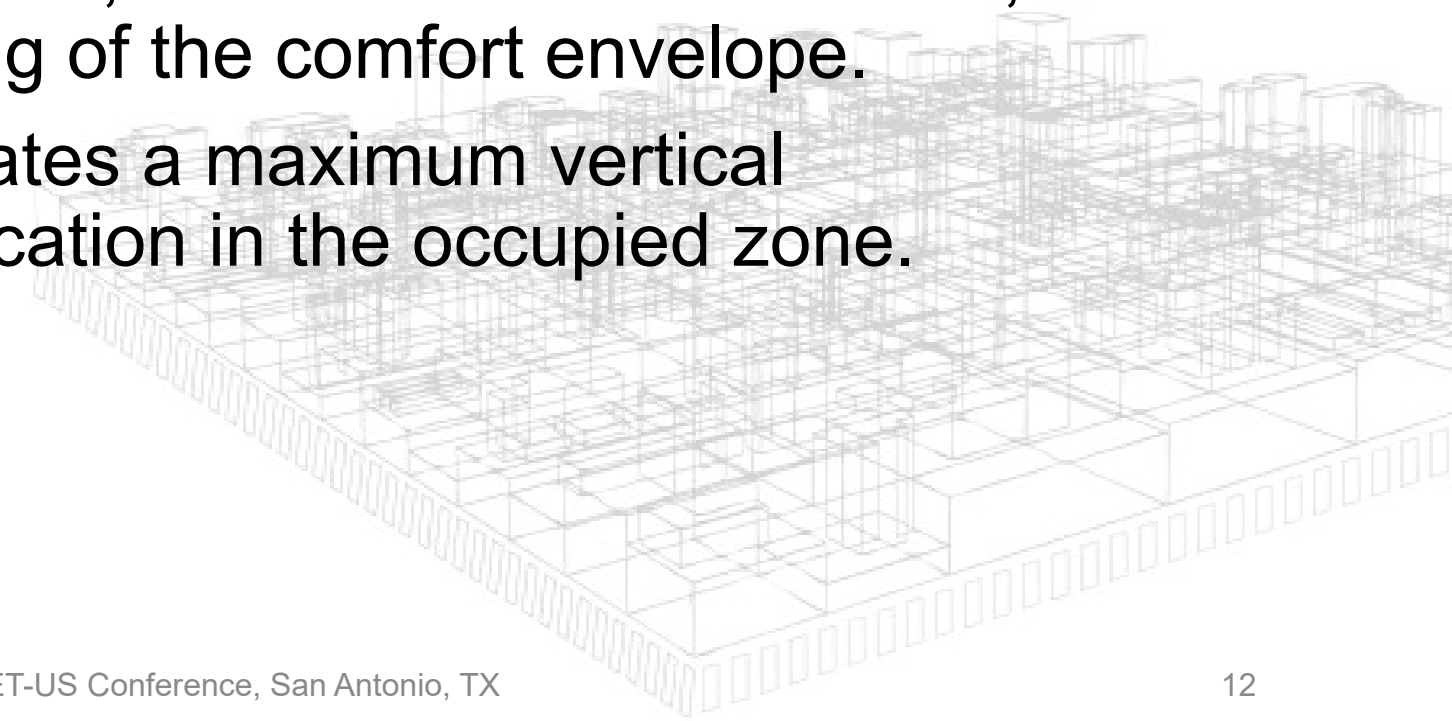
RP 1515 Conclusions

- Interior loads are far less than 1 cfm/sf (the national average).
- Occupant satisfaction above 80% can be achieved at 0.22 cfm/sf (with good diffusers)
- Interior loads are close to 100% outside air, meaning 100% of interior loads are discharged, not retur ned to air handler.
- The load in the building is controlled where outside air is introduced into the building, not by equipment in the zone.
- PS: This is Huge!



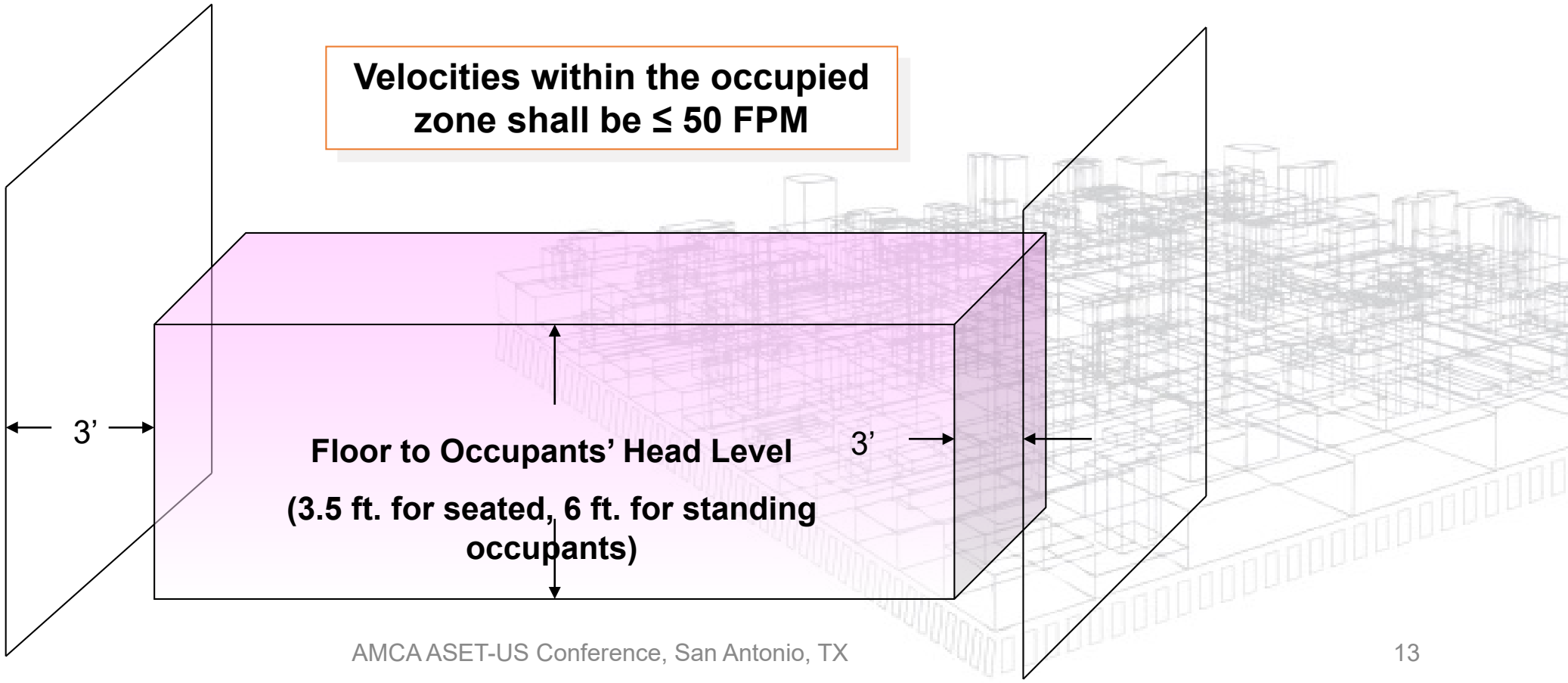
Thermal Comfort

- Thermal Comfort Standard: ASHRAE 55
- ASHRAE Fundamentals, Chapter 9.
- PMV (Predicted Mean Vote) is a single number rating.
- A program is available, based on the ASHRAE 55, which allows plotting of the comfort envelope.
- Standard 55 mandates a maximum vertical temperature stratification in the occupied zone.

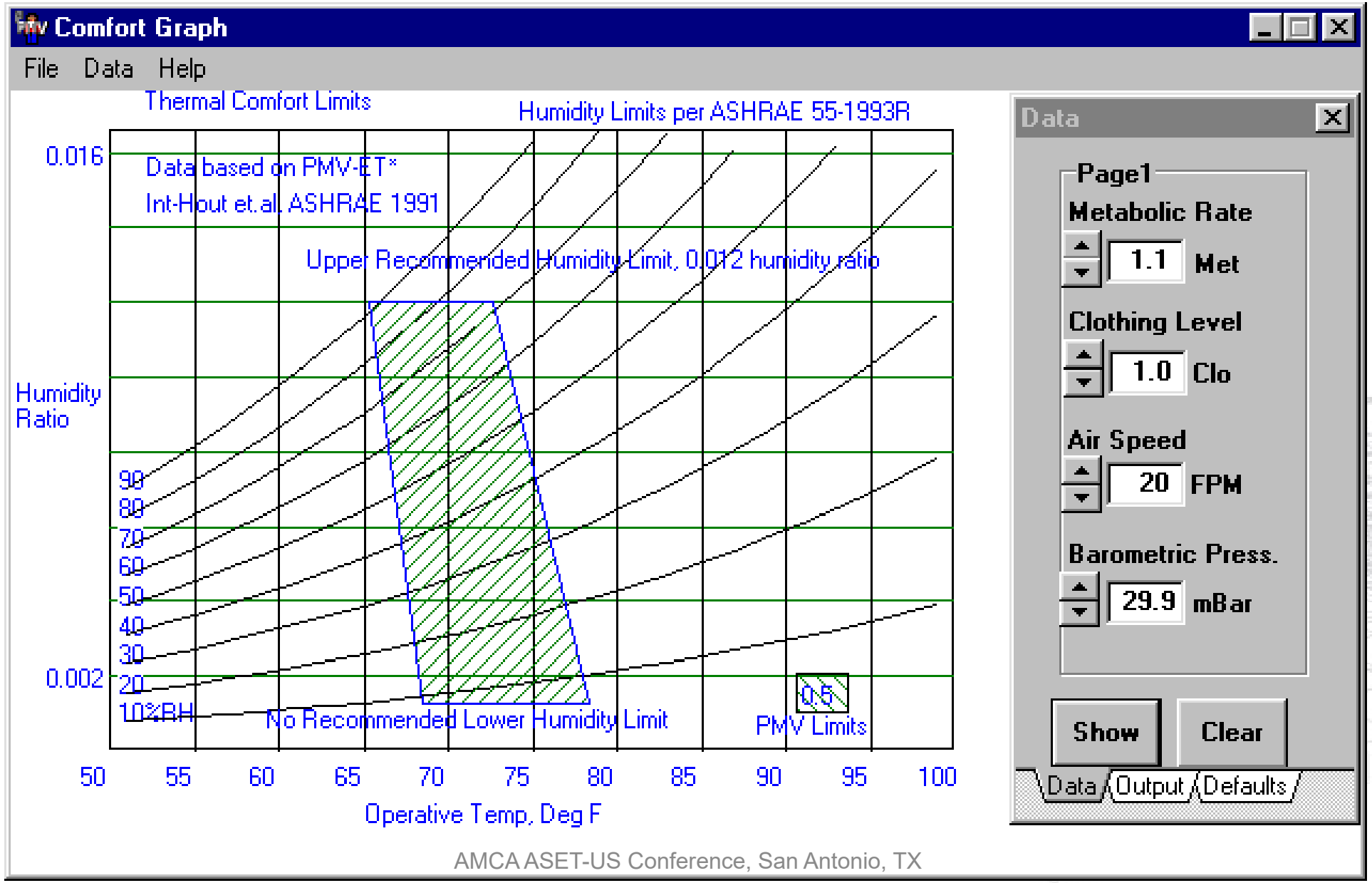


Thermal Comfort

ASHRAE Standard 55-mandates a maximum 5ºF vertical temperature stratification in the Occupied Zone.



Thermal Comfort / Graphical Solution



Comfort Economics

ASHRAE Journal, June 2008

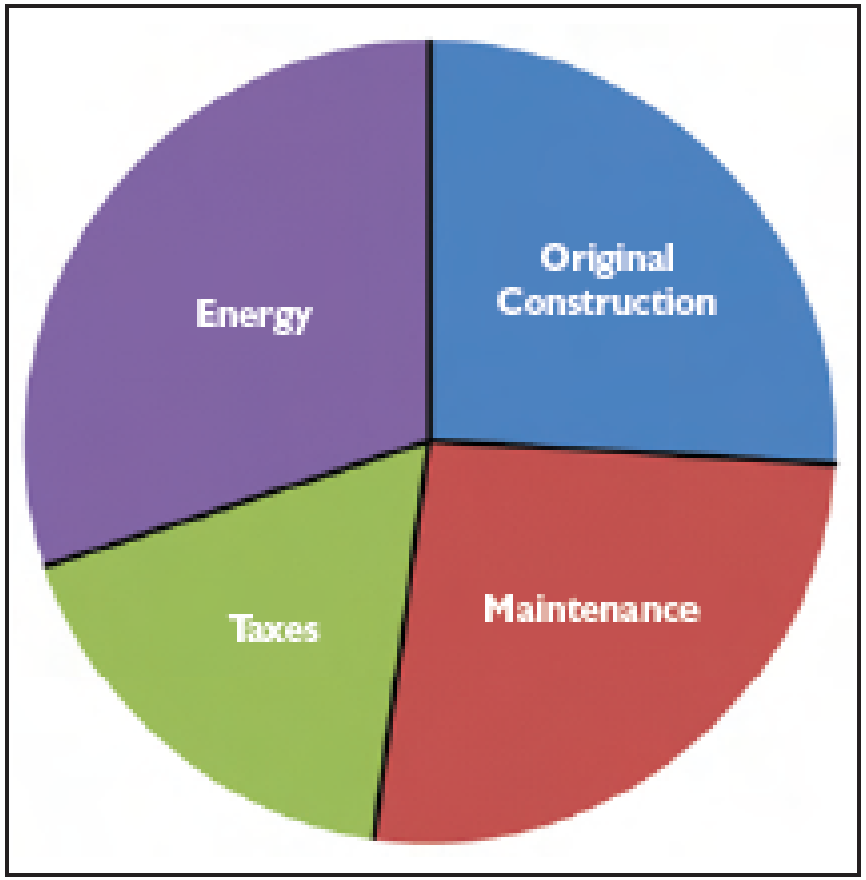


Figure 1: Life-cycle building costs breakdown.

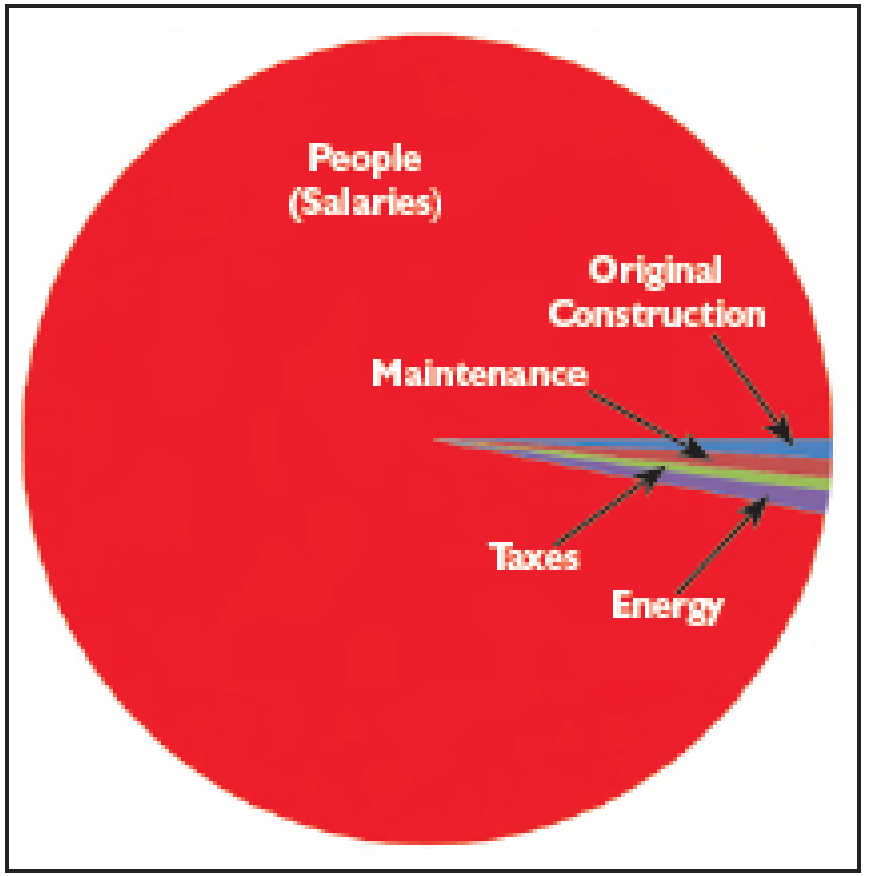


Figure 2: Life-cycle building costs breakdown with people (salaries).

Standard 55 Compliance

- Predicting compliance at the design stage is tricky
- Documenting clothing and met rate allows design temperature to be established, which is the input for most load calculation programs.
- Determining other variables is more difficult.

Standard 55 Compliance

- Vertical stratification can be proven using ADPI, per the new Standard 55 user's manual.
- ADPI can be predicted from an air outlet's throw, outlet separation, and room load, per the ASHRAE Handbook
- The ADPI data was updated in 2014 through an ASHRAE research project.
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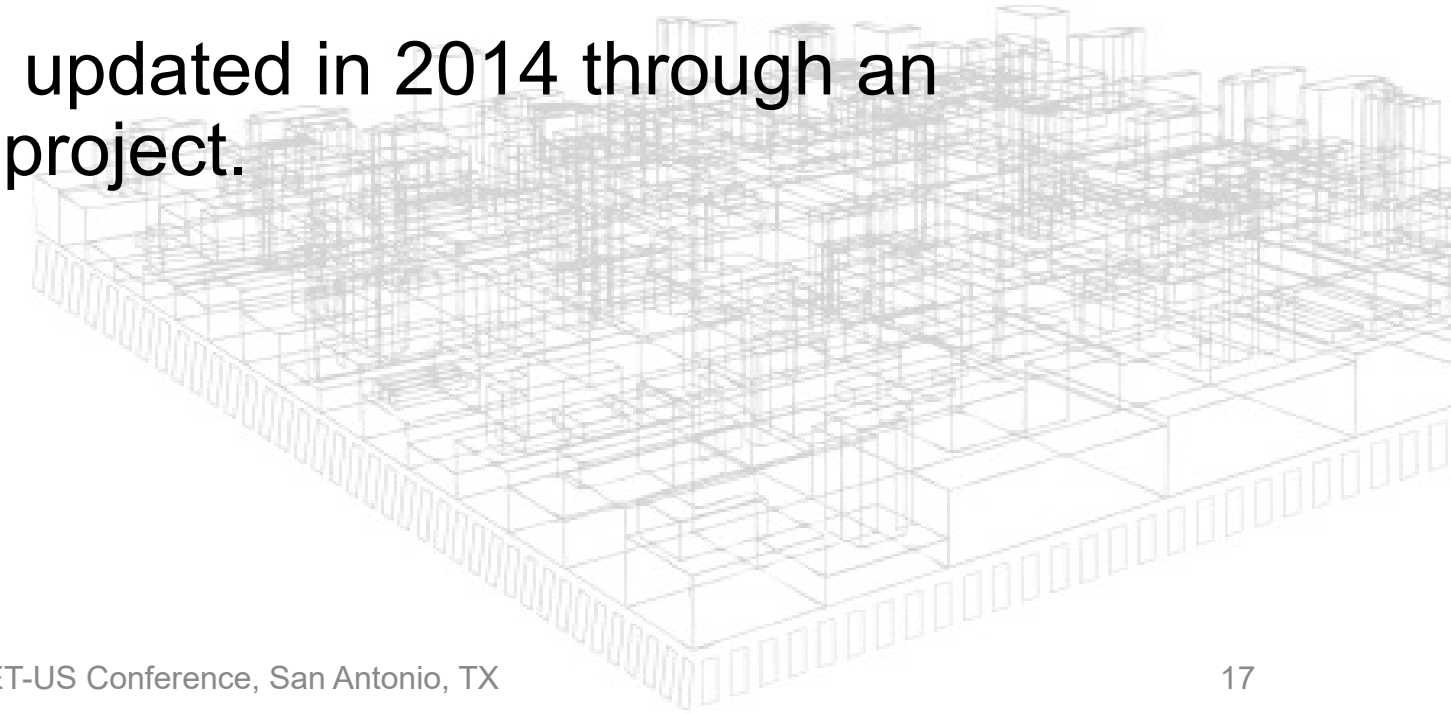
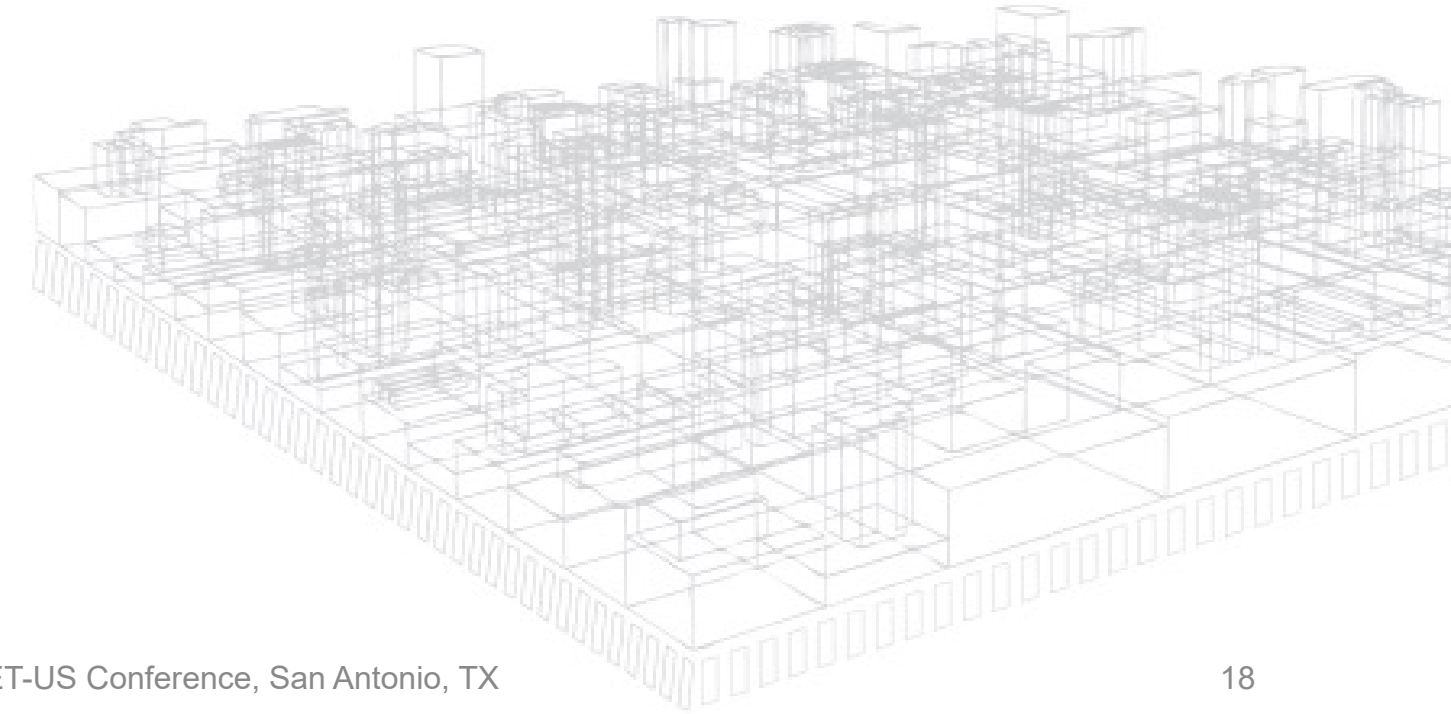


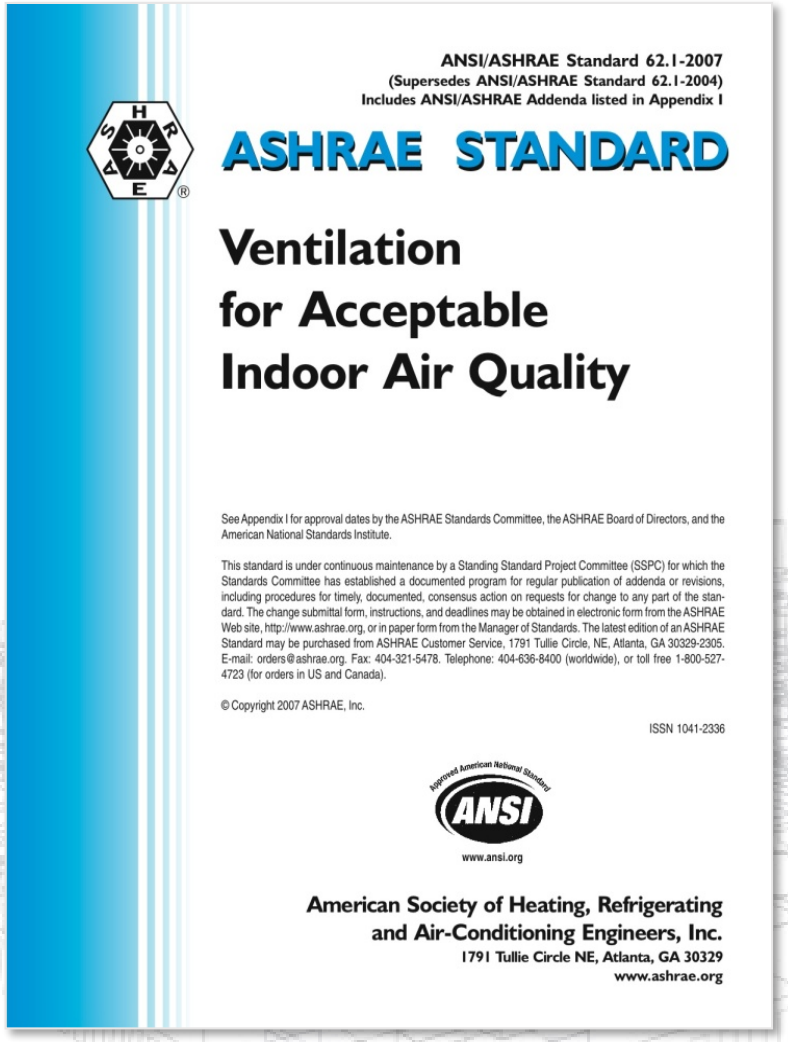
Standard 55 Compliance

- It is debatable whether any but all air systems employing ceiling diffusers can be shown to comply with the vertical stratification requirements of Standard 55.



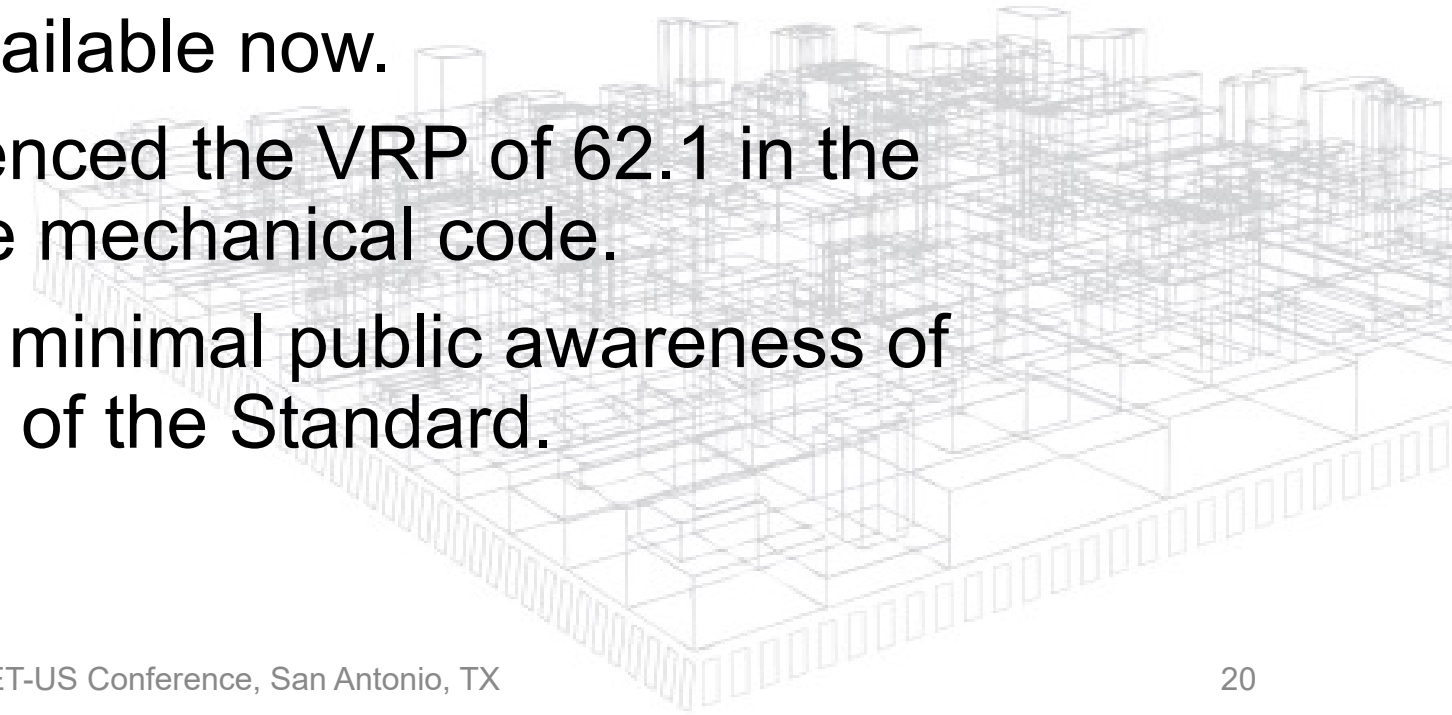
Indoor Air Quality

- Standing Standard Project Committee 62.1.
- Residential Committee is 62.2.
- Current Standard is 62.1-2016.
- The addenda for the 2013 version are included in the 2016 version



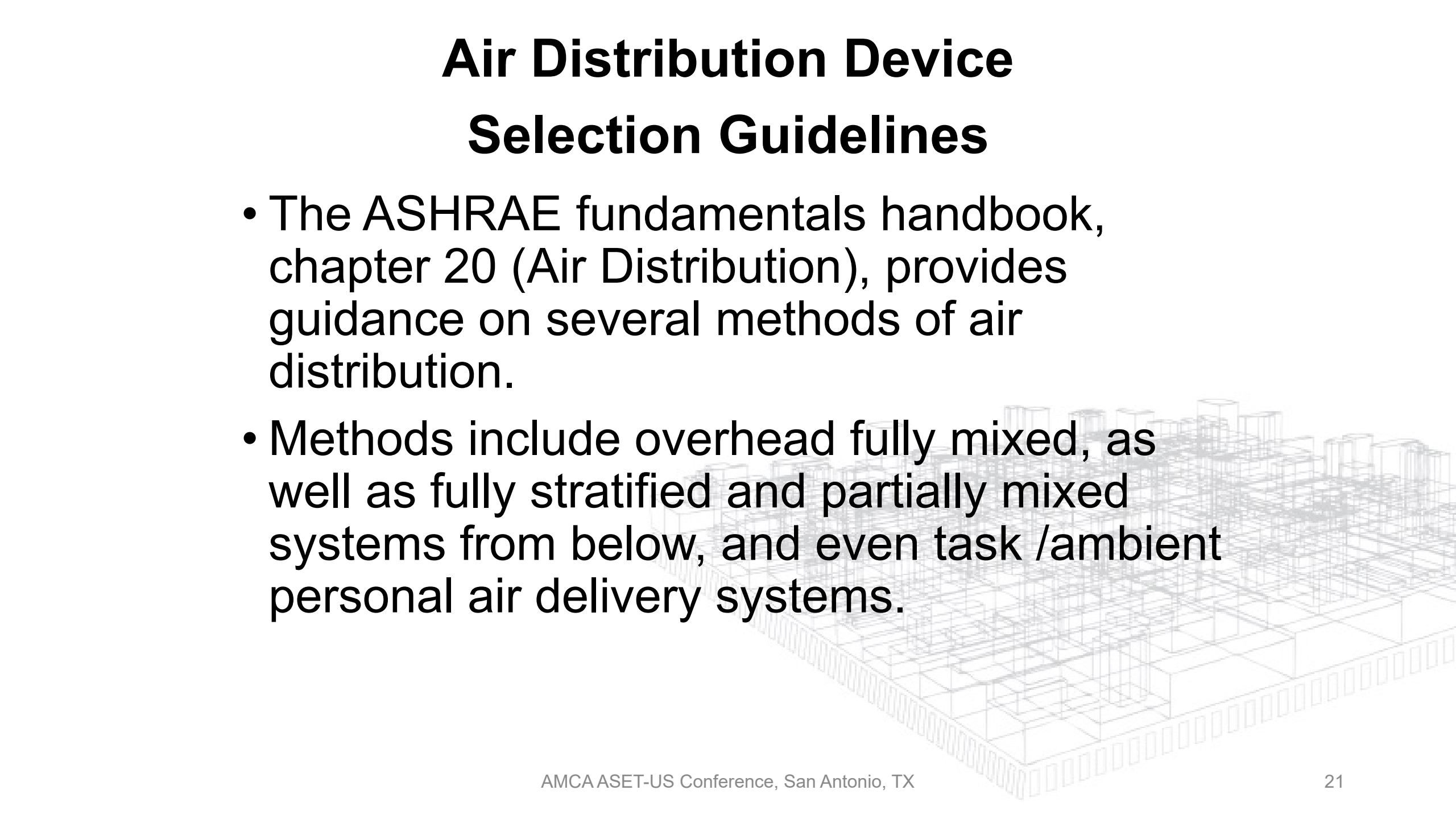
IAQ Standard

- Standard 62.1 is on continuous maintenance.
- Continuous and incremental changes are in progress.
- It will attempt to be in coordination with building codes.
- Users Manual is available now.
- The IMC has referenced the VRP of 62.1 in the latest release of the mechanical code.
- There seems to be minimal public awareness of the dynamic nature of the Standard.



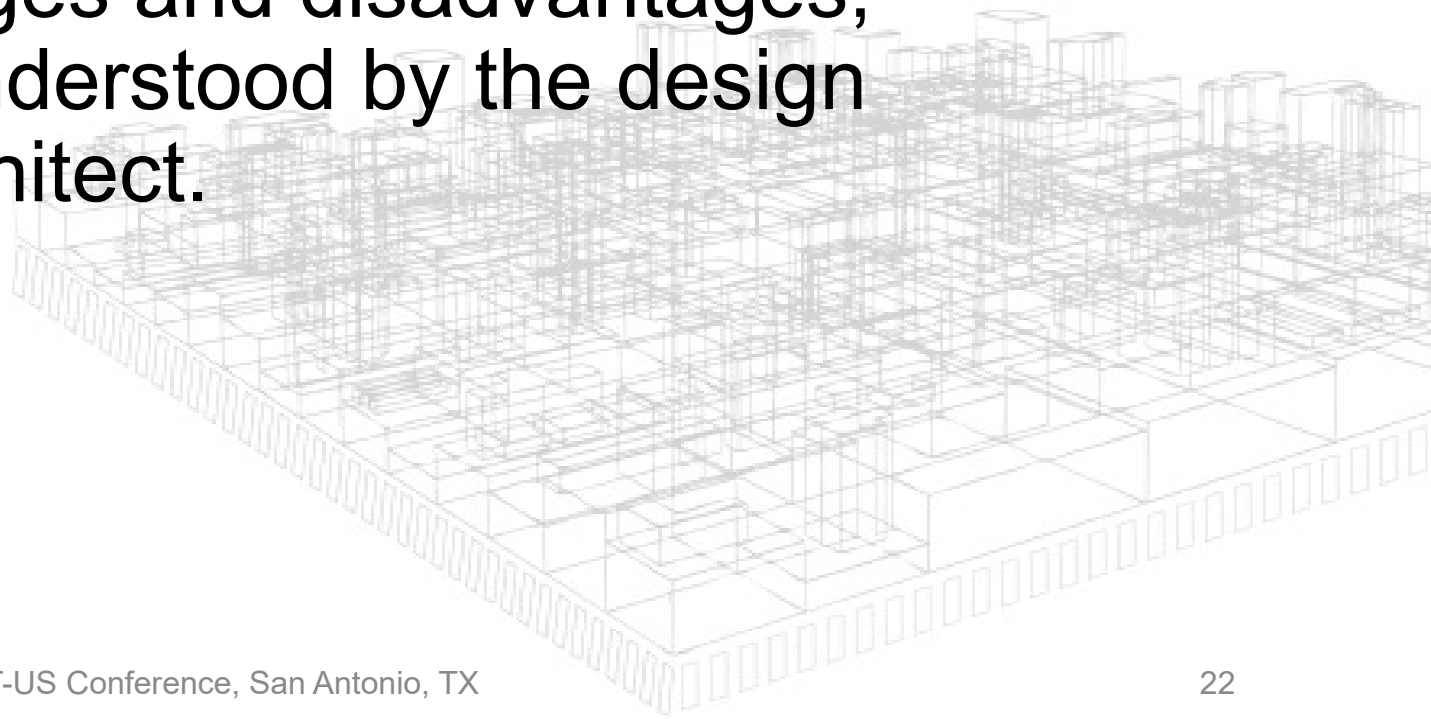
Air Distribution Device Selection Guidelines

- The ASHRAE fundamentals handbook, chapter 20 (Air Distribution), provides guidance on several methods of air distribution.
- Methods include overhead fully mixed, as well as fully stratified and partially mixed systems from below, and even task /ambient personal air delivery systems.

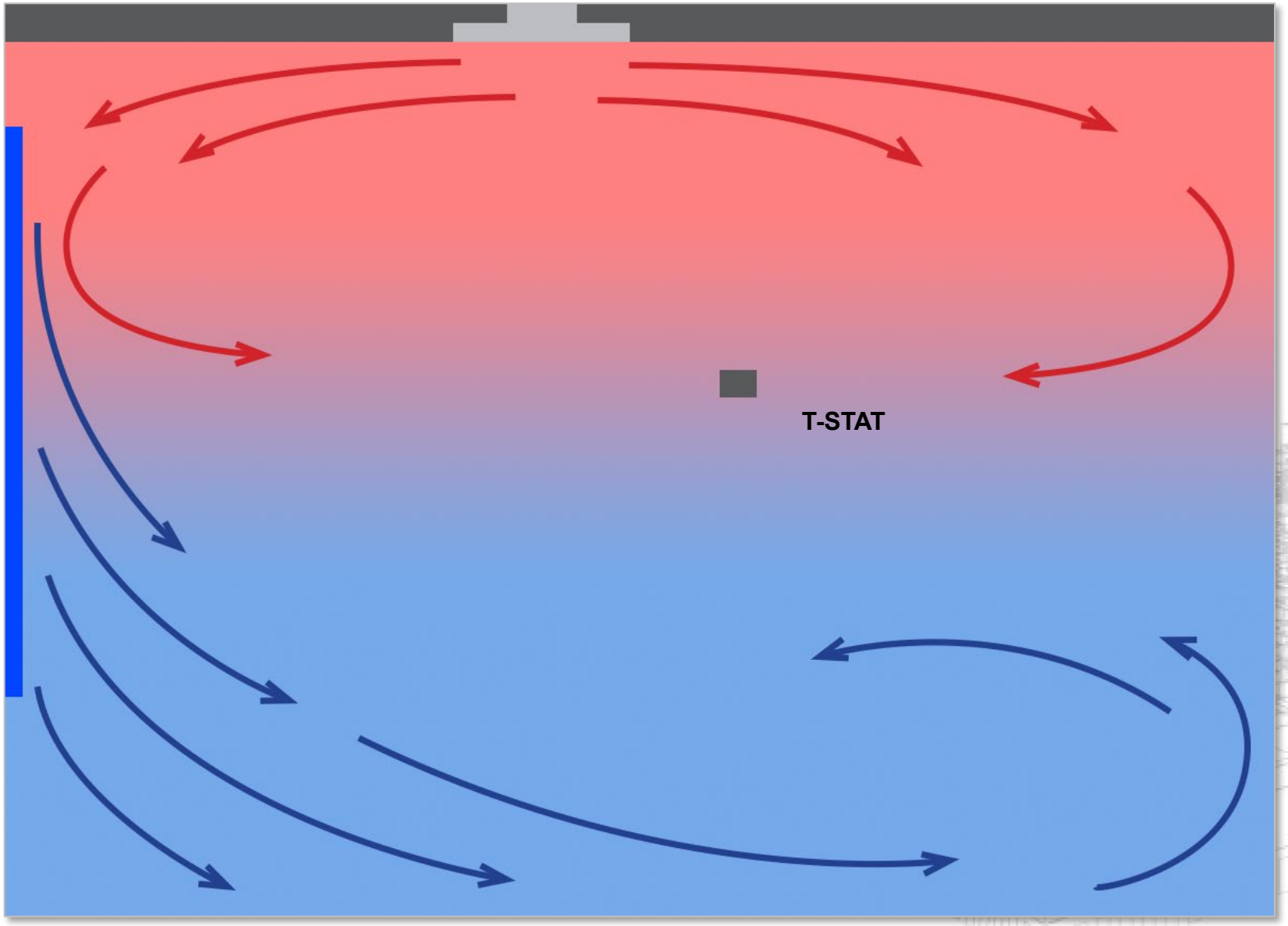


Air Distribution Device Selection Guidelines

- Described delivery systems include constant and variable volume, UFAD, displacement ventilation and chilled beam systems.
- All have advantages and disadvantages, which must be understood by the design engineer and architect.



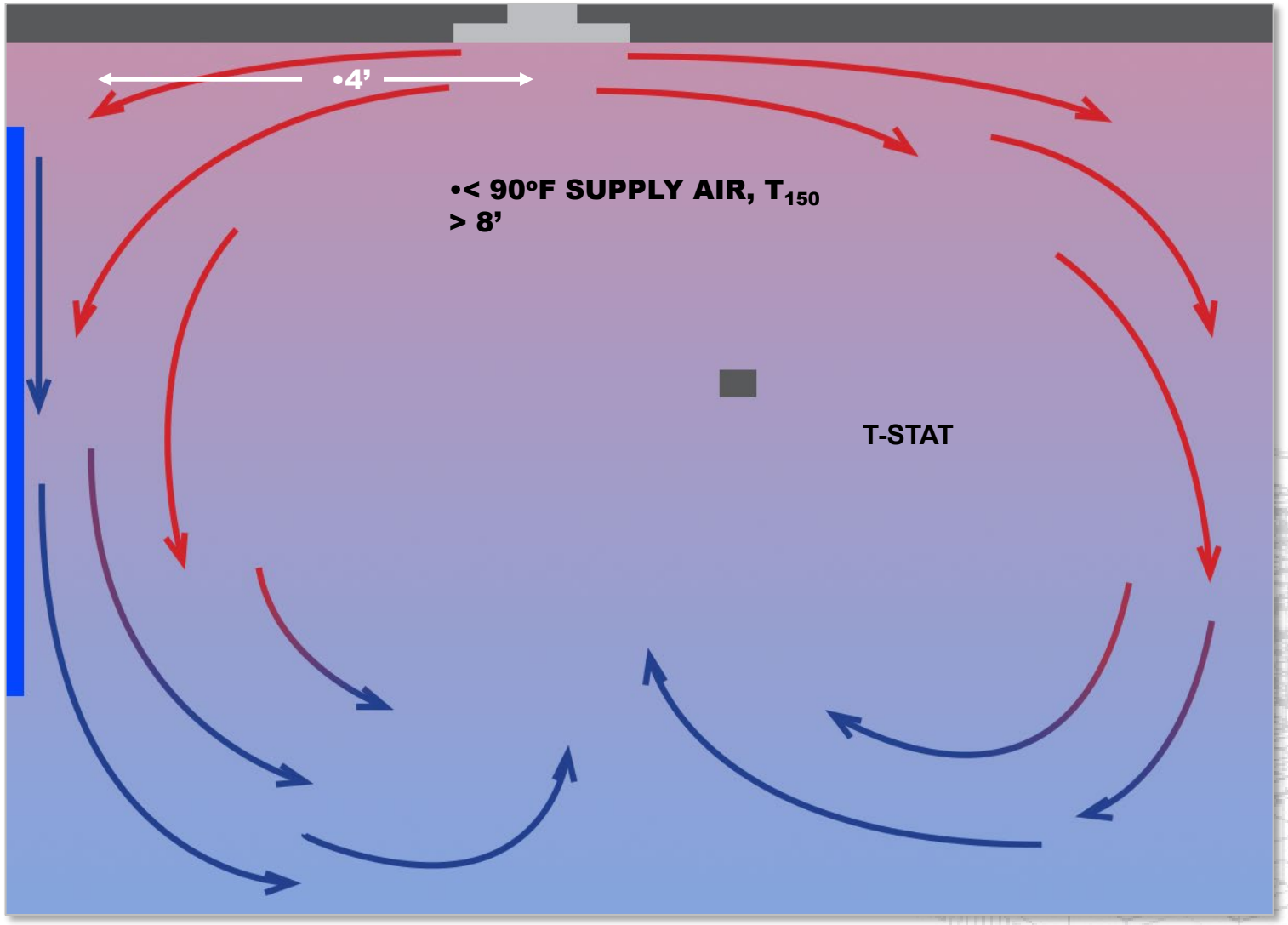
Common Overhead Heating Design



Overhead Heating
Perimeter Considerations

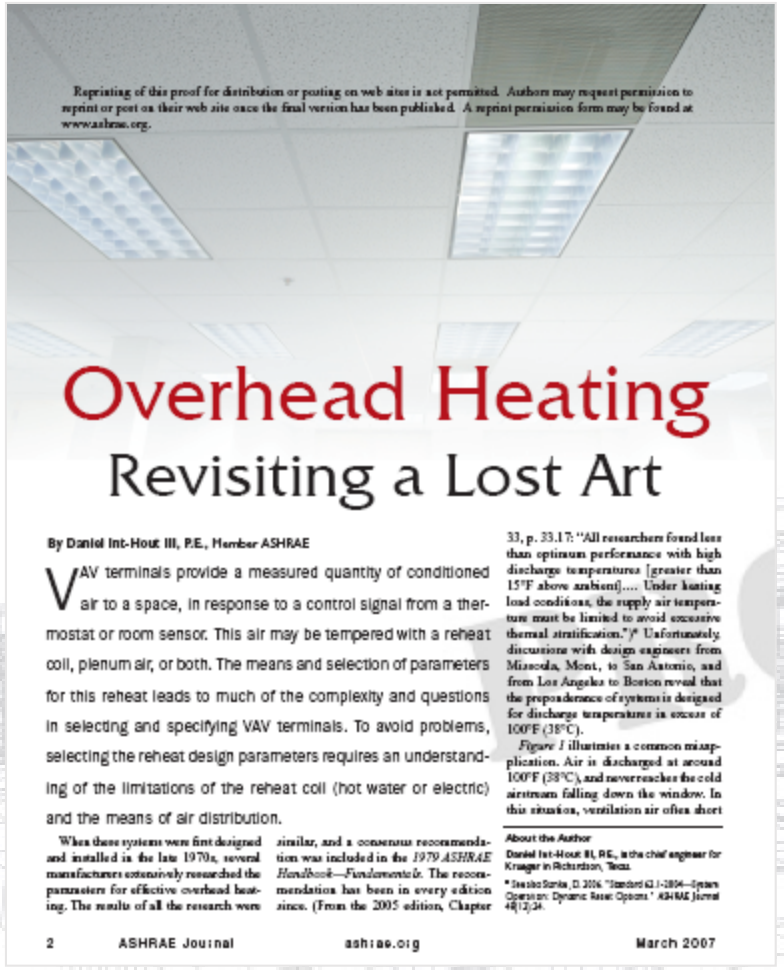
- Maximum Delta-t for effective mixing when heating from overhead, per ASHRAE handbook = ?
- = 15°F (90°F discharge), continuous operation.
- 150 FPM should reach 4-5 feet from the floor.
- ASHRAE 62.1 requires that ventilation be increased by 25% when heating, if the above rules are not followed.
- 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/sq.ft.
- Locate a return slot above the window for solar heat gain.

Proper Perimeter Example



Perimeter Considerations

- The requirements for overheating are discussed in an ASHRAE Journal article, from 2007.
- Nothing in this article was not known in 1979.



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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

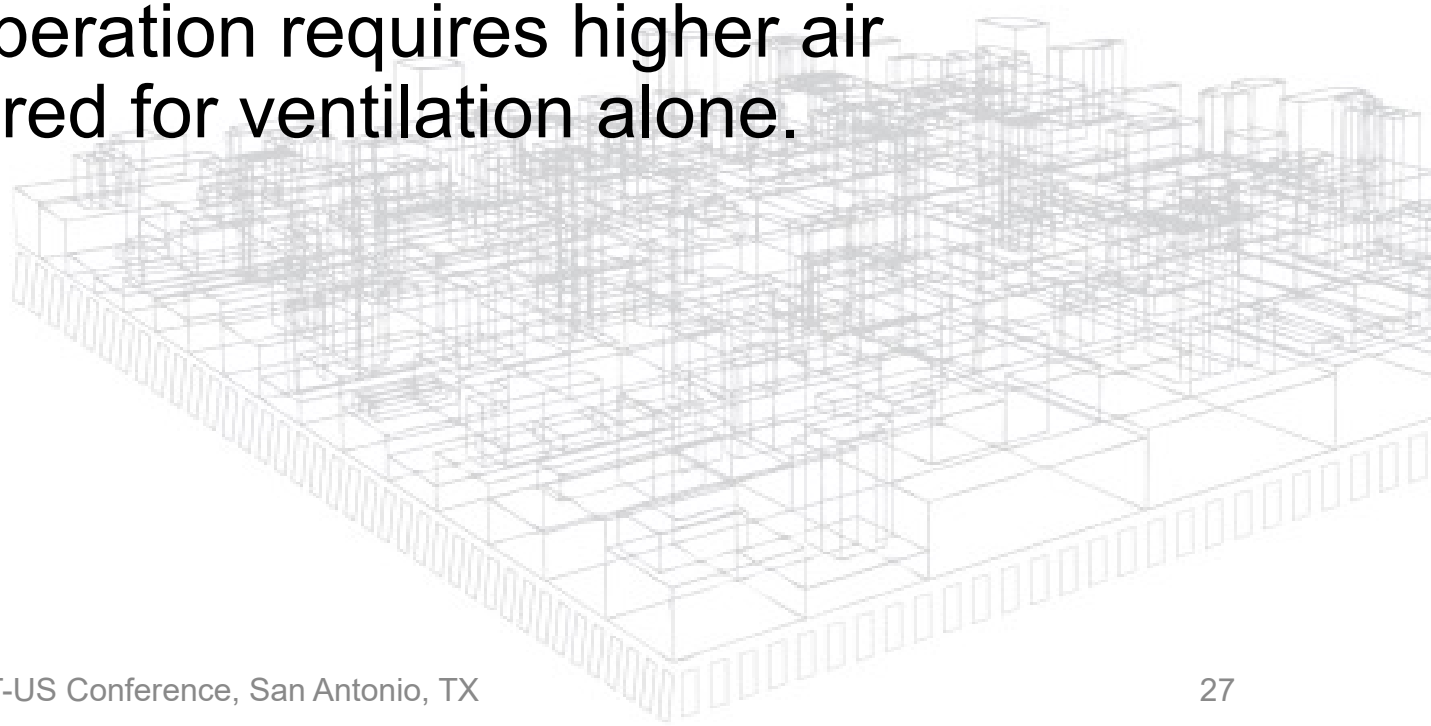
Daniel Int-Hout III, P.E., is the chief engineer for Krueger in Richardson, Texas.

* Standard Series, D. 2006. "Standard 62.1-2004—System Operation: Dynamic Reset Options." ASHRAE Journal 48(12):34.

2 ASHRAE Journal ashrae.org March 2007

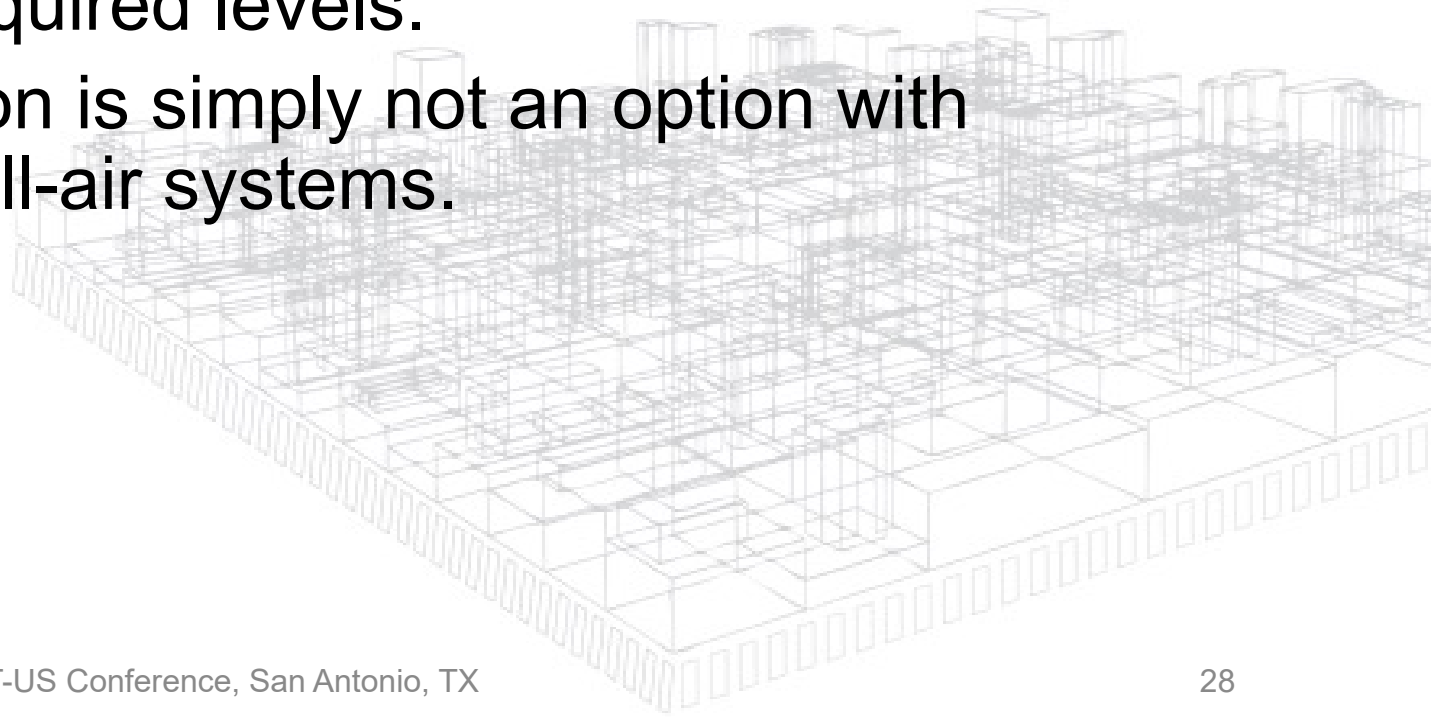
The Value of Economizer

- Economizer, when properly supplied, can be a huge energy saver (but is climate dependent).
- Ventilation can be correlated to productivity.
- Providing effective Economizer operation requires controlling both comfort and humidity.
- Often Economizer operation requires higher air quantities than required for ventilation alone.

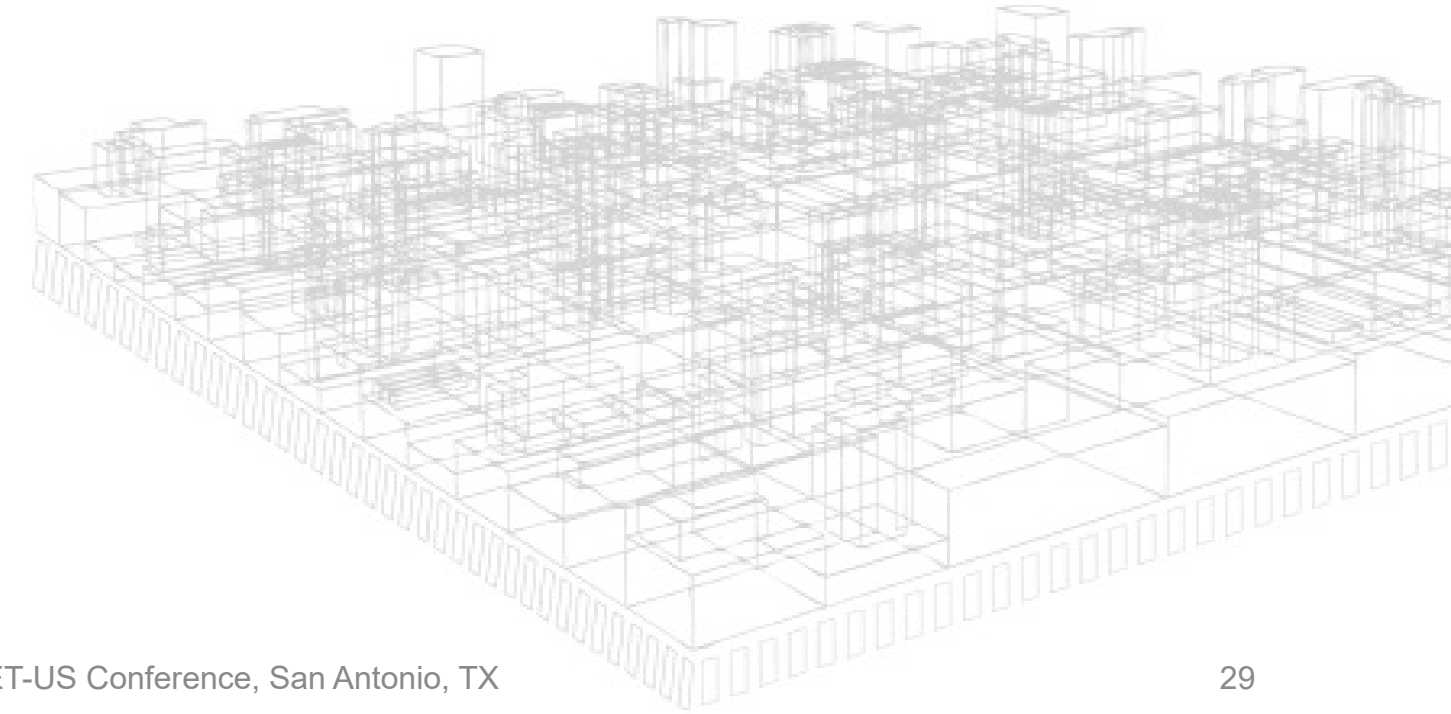


The Value of Economizer

- Often Economizer operation requires higher air quantities than required for ventilation alone.
- This implies a dynamic control of ventilation air quantities to all zones.
- LEED will grant a point for increasing ventilation beyond minimum required levels.
- Economizer operation is simply not an option with many types of non all-air systems.

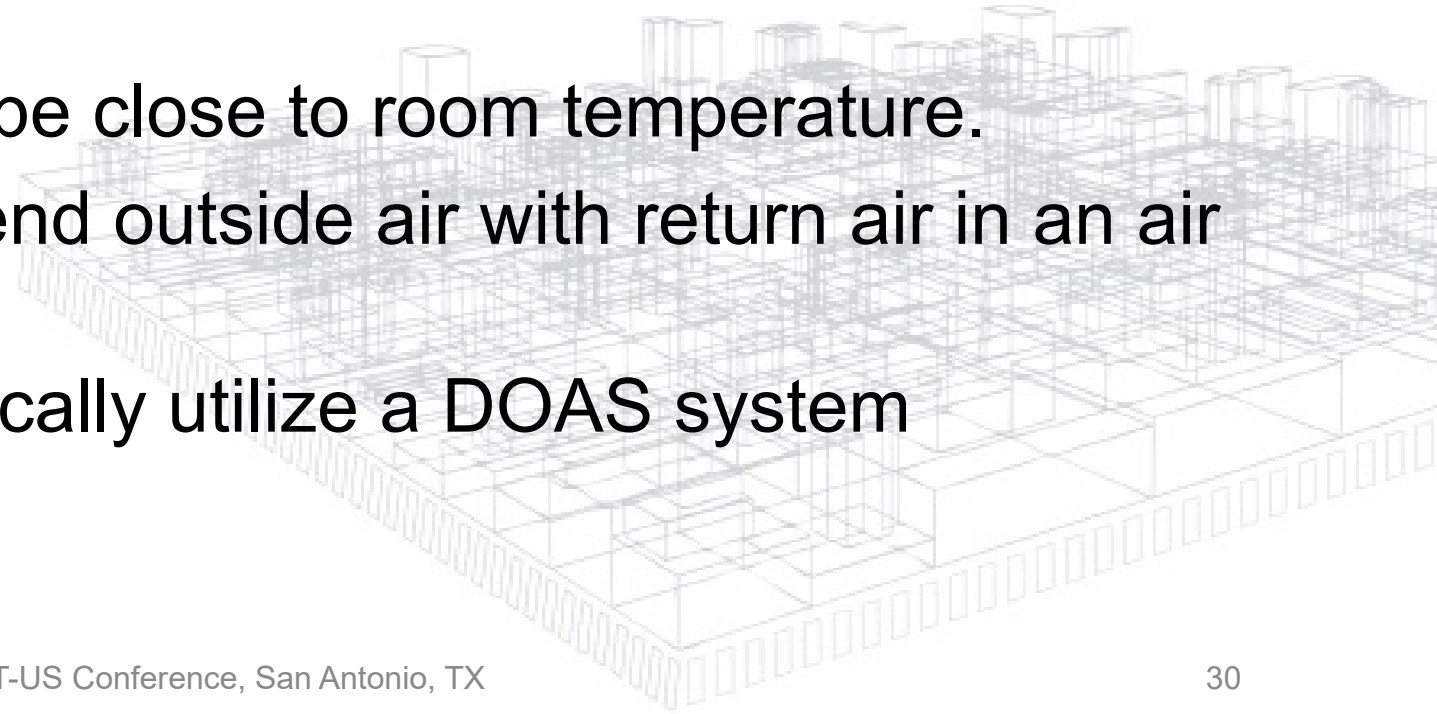


Meeting Current Codes and Standards



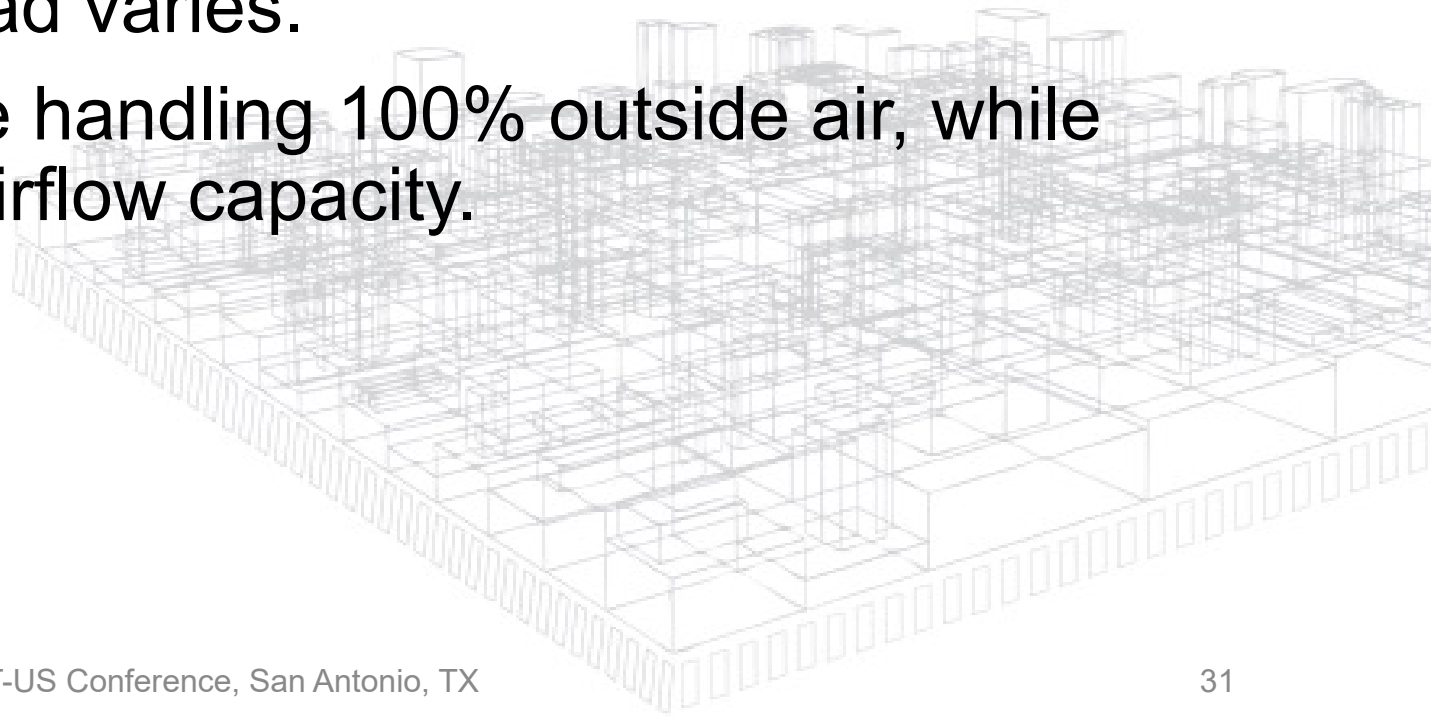
All HVAC Systems Need to Comply with 62.1

- VRF, WSHP and Fan Coil systems need to have source of ventilation air.
- It may be introduced separately, or into the suction side of the units
- In most cases, it needs to be close to room temperature.
- All air systems typically blend outside air with return air in an air handler
- Chilled Beam systems typically utilize a DOAS system



VAV Air Handlers

- Typically, a VAV air handler is designed to condition 30% of it's rated capacity with outside air, mixing it with building return air.
- If operated properly, the outside air component remains fairly constant as the building load varies.
- At low loads, it may well be handling 100% outside air, while delivering 30% of design airflow capacity.

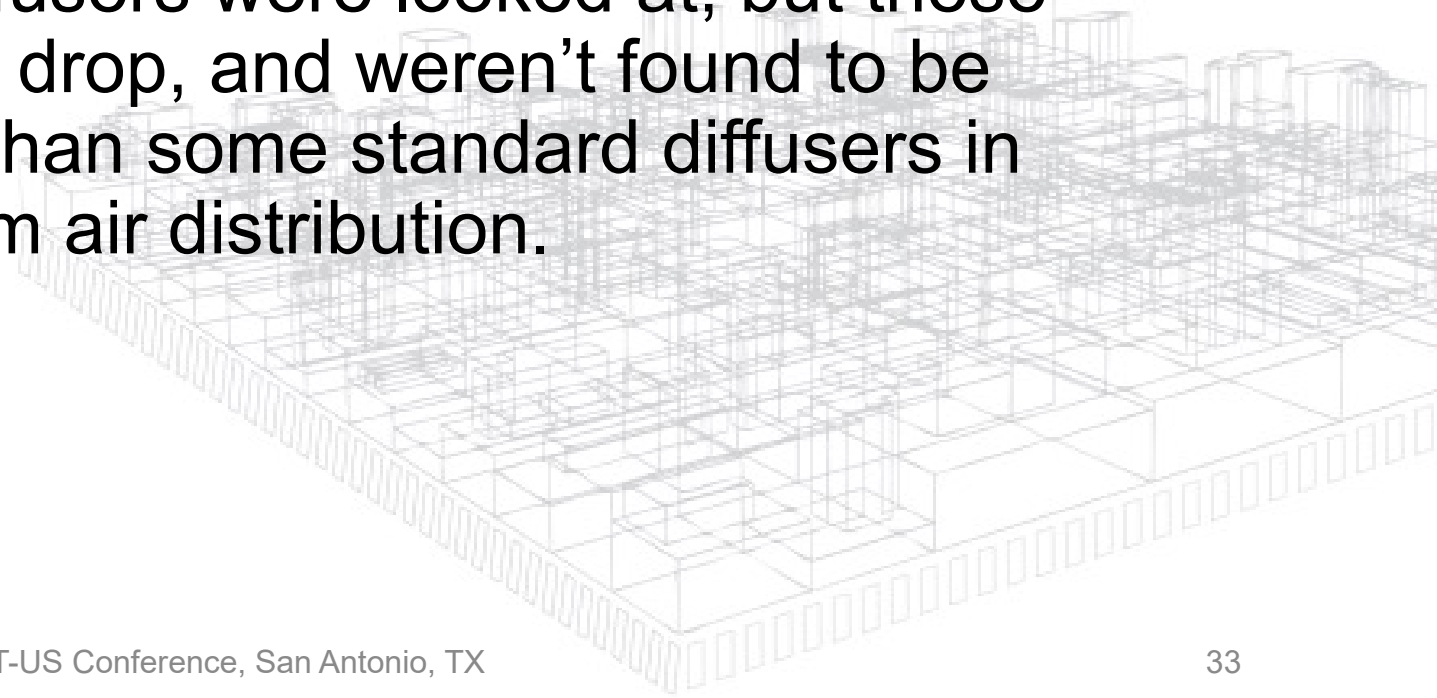


Low-Load Considerations

- At low loads, the ductwork approaches a “plenum” condition, with very low velocity pressures
- The air handler sees two benefits, reduced external static as well as reduced fan HP requirements
- As a rule, fan energy is reduced proportional to airflow, but to the square of pressure reductions.
- Duct leakage is also reduced by the square of the pressure drop.

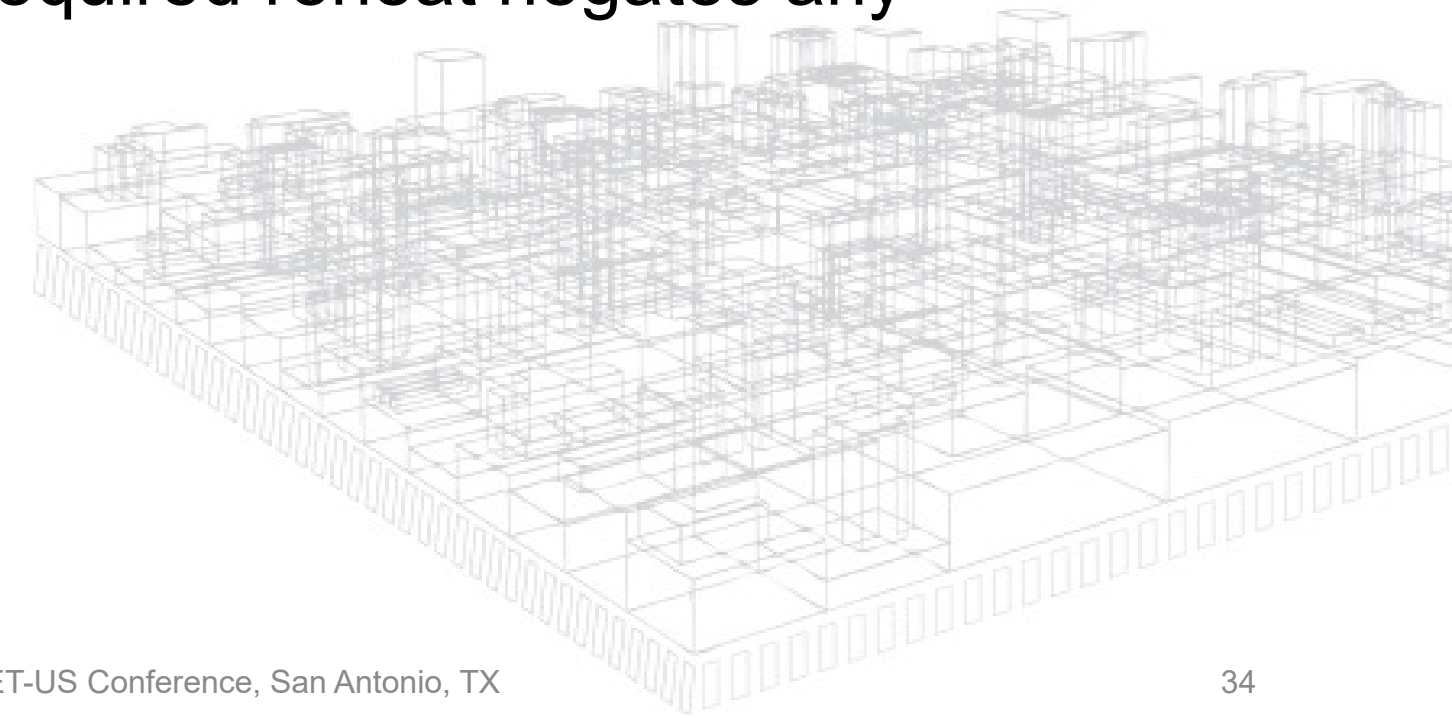
Cold Air Distribution

- Research was conducted for EPRI in the 90's on the delivery of cold air.
- Concerns were "dumping" at low loads with cold air.
- "High Induction" diffusers were looked at, but these have high pressure drop, and weren't found to be significantly better than some standard diffusers in providing good room air distribution.

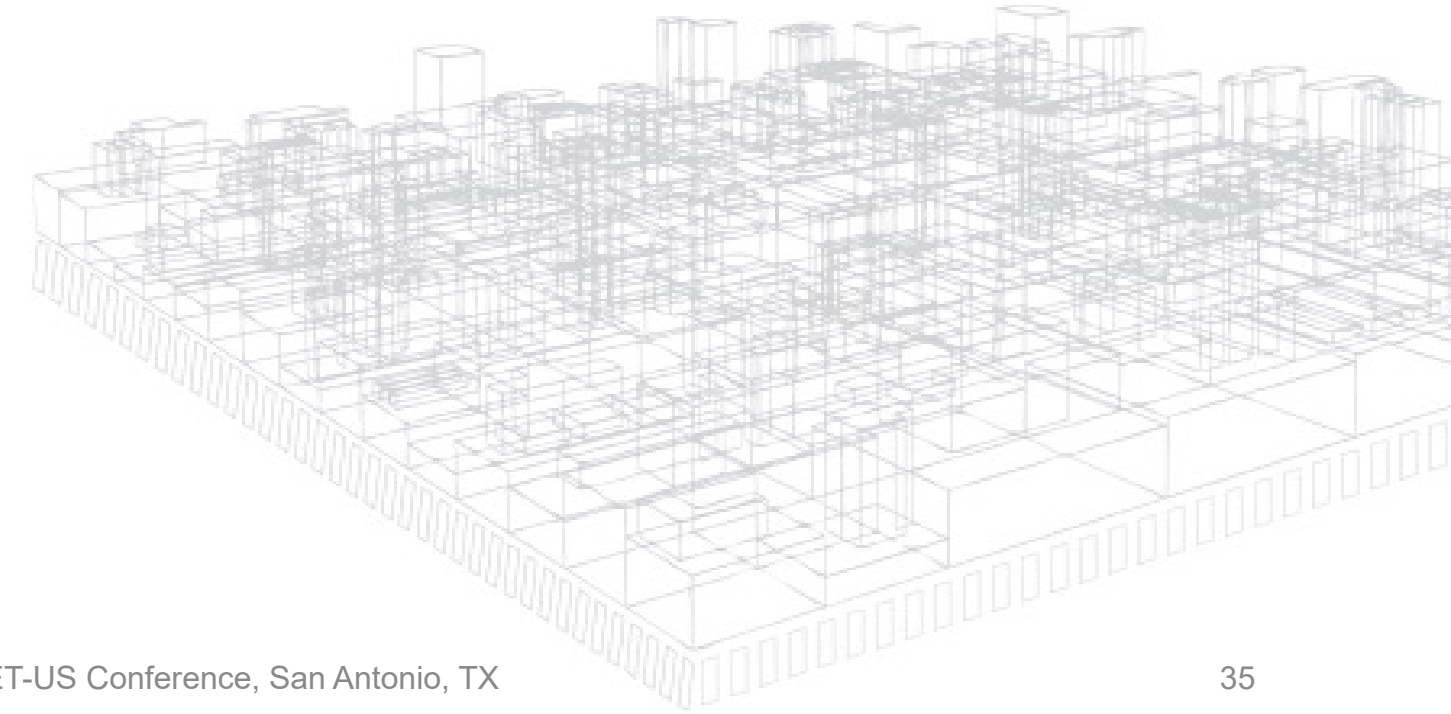


Cold Air Distribution

- The conventional “plaque” type diffuser was found to work well with air as cold as 48F.
- At today’s low interior loads, however, sub cooling is a real issue. The required reheat negates any savings.

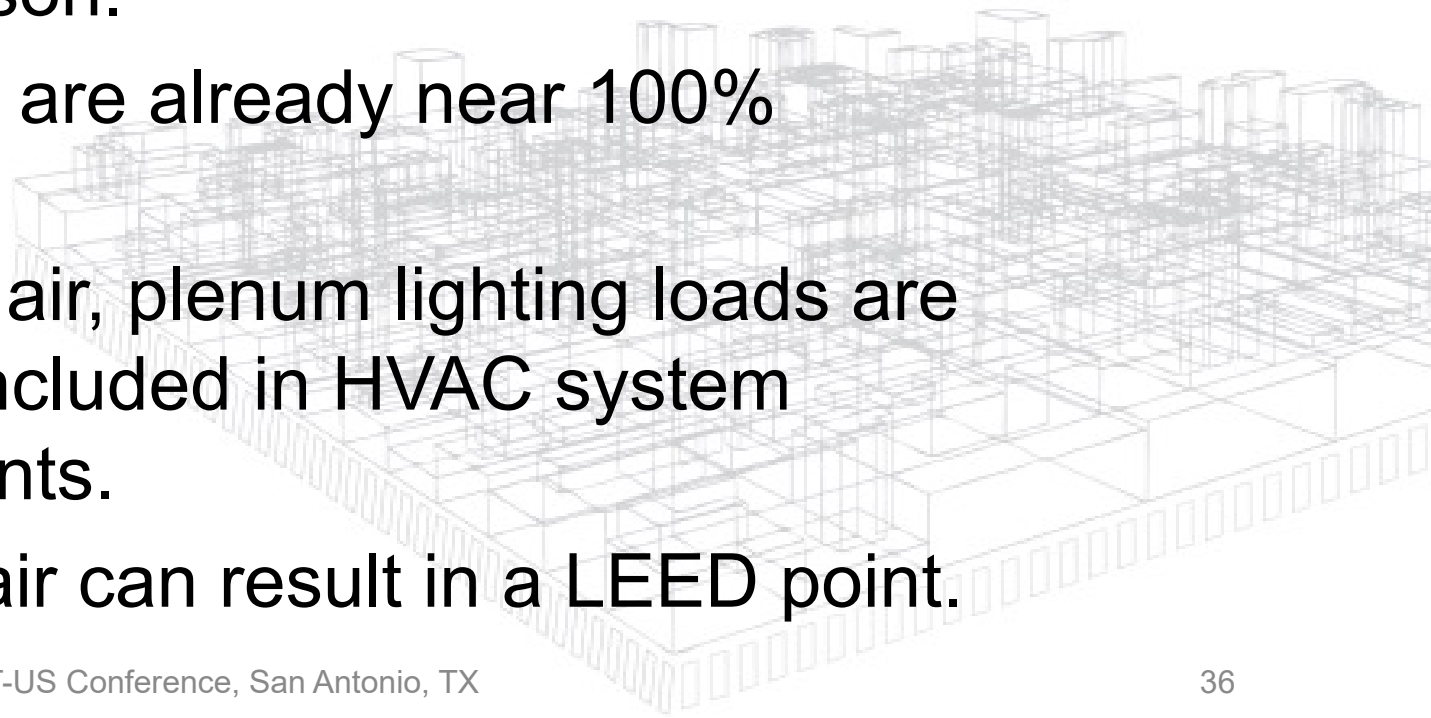


So Where Are We Today?



The Default Ventilation Rate

- The Default Ventilation Rate to meet ASHRAE 62.1 is 17 cfm/person (for offices).
- 17 CFM @ 55ºF 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.

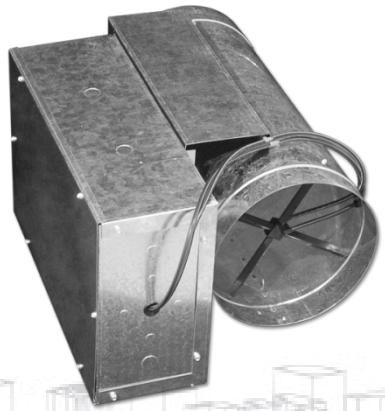


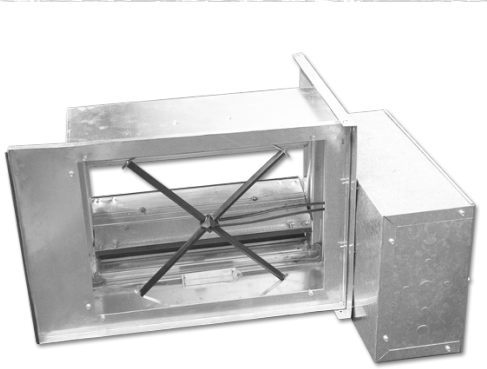
Measurable and controllable ventilation supply should be required

- Ducted ventilation to every zone at design load is a requirement of 62.1 (code in most places)
- Ventilation rates vary depending on several factors
- Changing airflow rate in one zone affects all the others
- Pressure Independent Ventilation supply is a practical and effective strategy.

Pressure Independent Ventilation Dampers

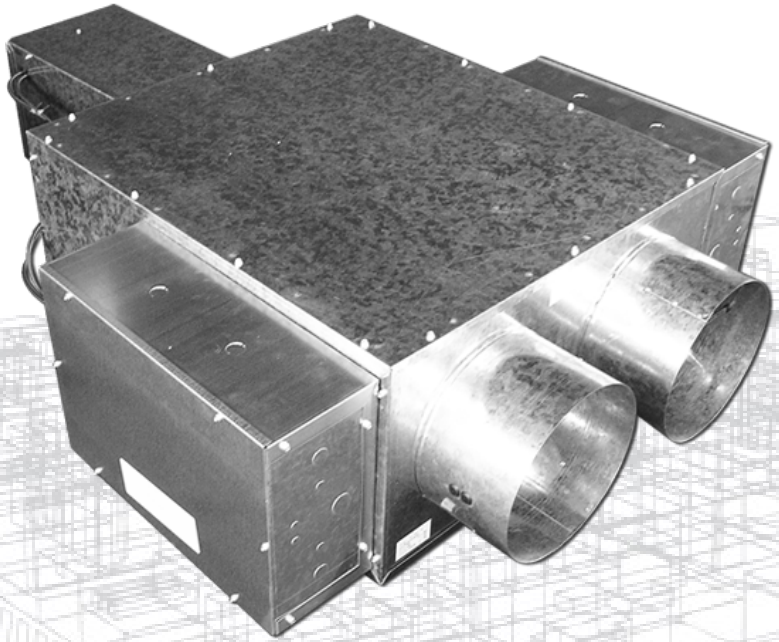
- Round VAV dampers with flow sensors
- Square “slip-in” dampers with flow control
- Electronic actuators with flow transducers
- Analog signals to control ventilation rates





Fresh Air Dual Duct

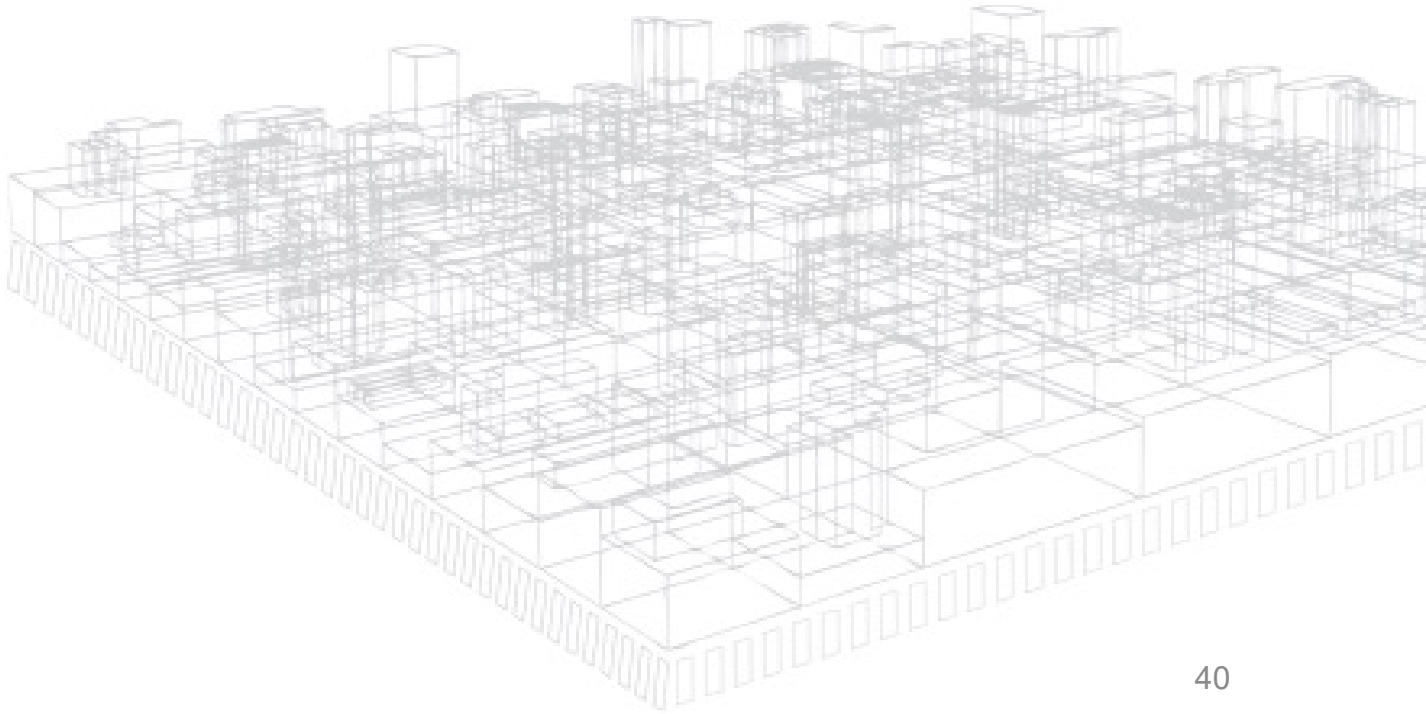
- One inlet provides 100% outside air, dehumidified, typically cold.
- Other duct provides 100% return air, either warm or cold, depending on the season.
- Supplemental reheat coils and even a sensible cooling coil have been considered
- A good mixing baffle should be employed (20:1 Mixing Ratio recommended)



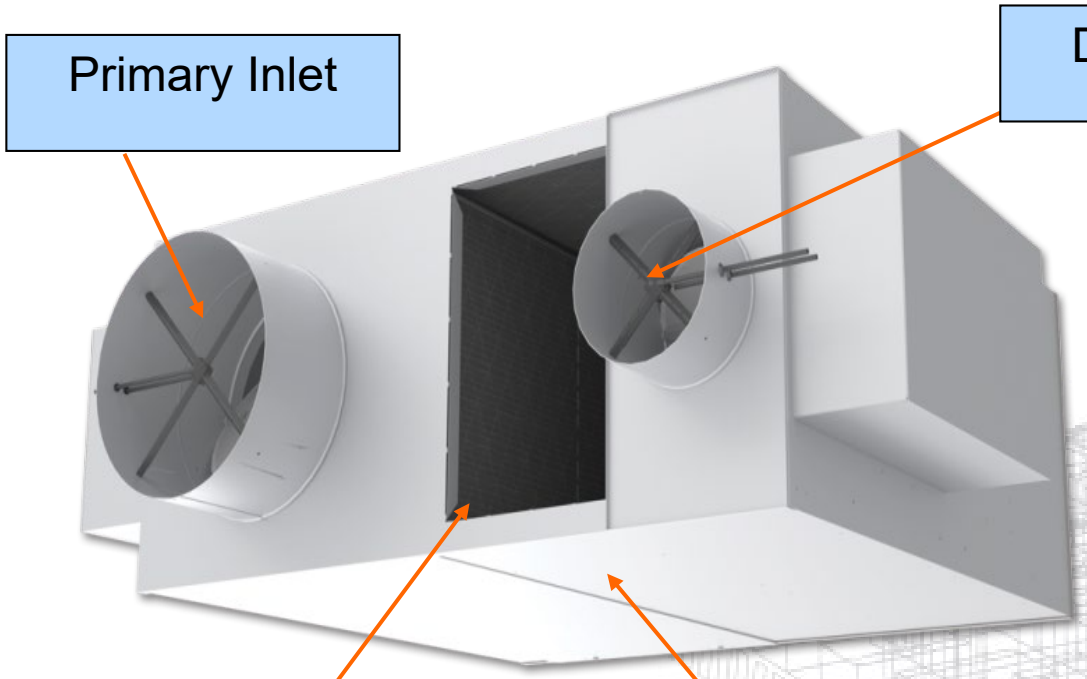
Mixing Dual Duct

Fresh Air Terminal Unit

- Outside air can be supplied to a Series Fan Terminal through a second ducted system.
- This requires two duct systems, but separates ventilation and recirculated air.
- The system allows monitoring of ventilation rates into each zone.

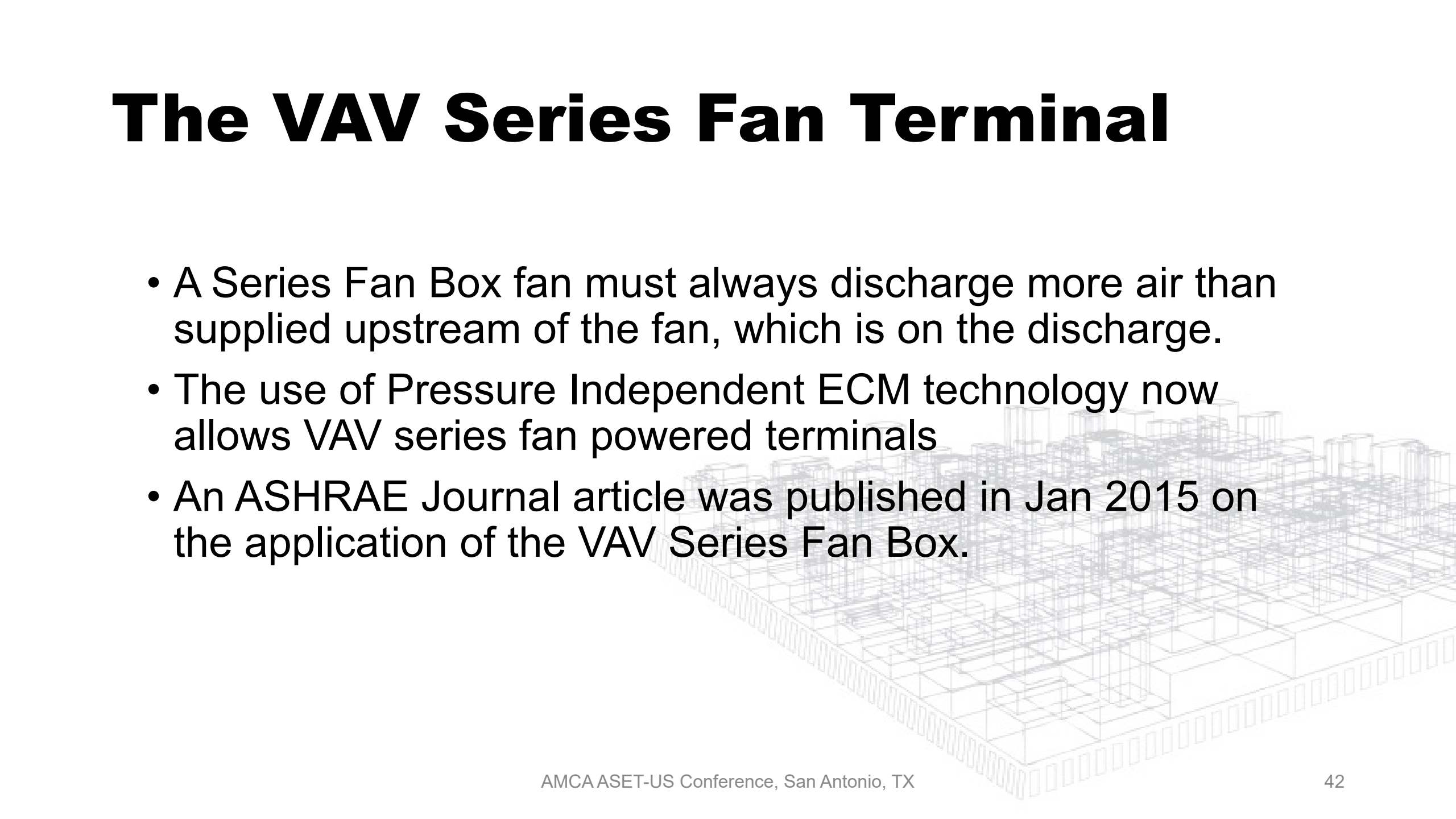


Fresh Air Terminal Unit



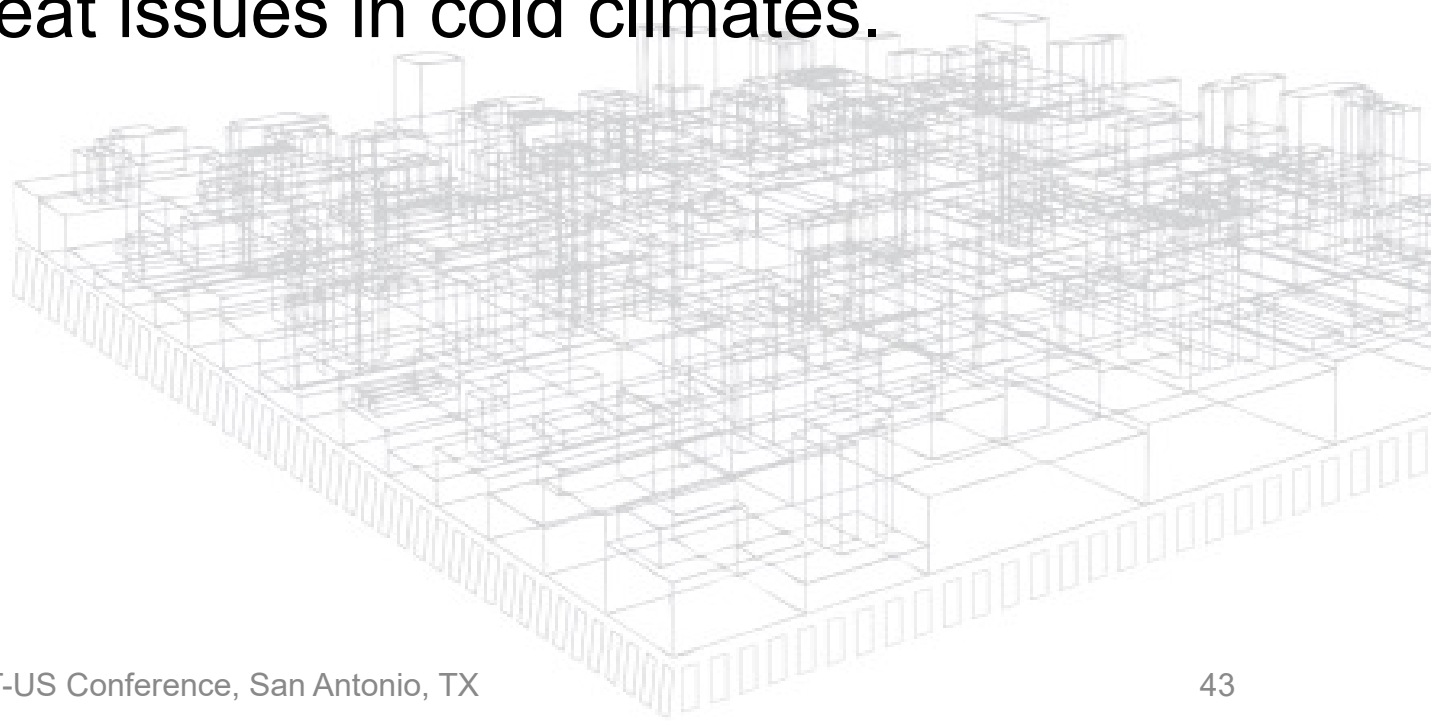
The VAV Series Fan Terminal

- A Series Fan Box fan must always discharge more air than supplied upstream of the fan, which is on the discharge.
- The use of Pressure Independent ECM technology now allows VAV series fan powered terminals
- An ASHRAE Journal article was published in Jan 2015 on the application of the VAV Series Fan Box.



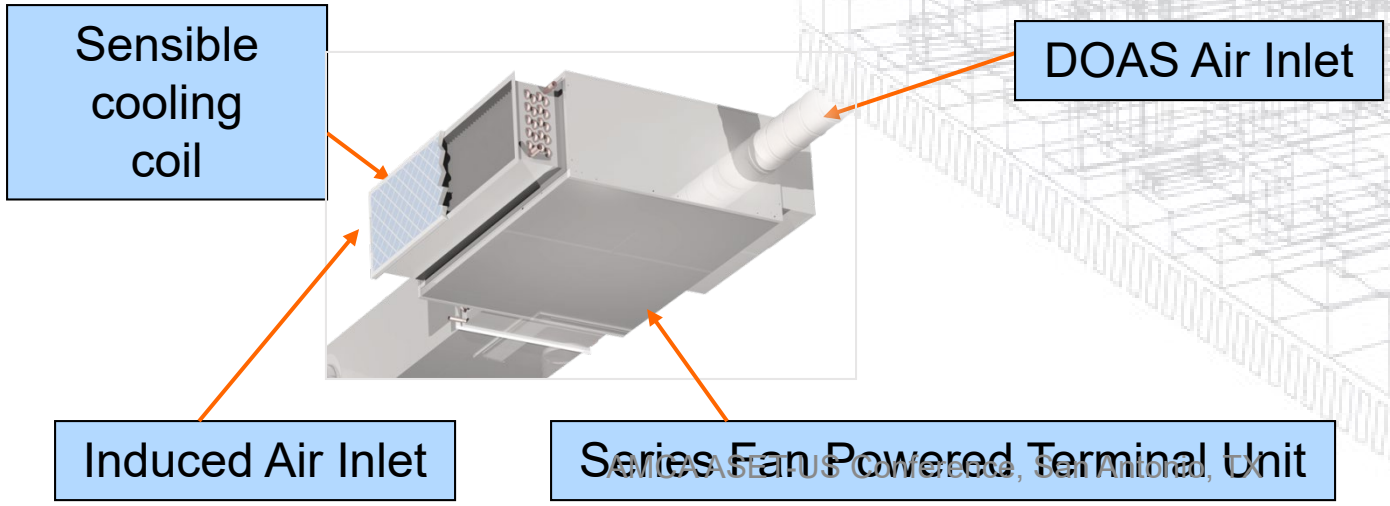
The VAV Series Fan Terminal

- When coupled with a cold air delivery system (CAD) it has an opportunity to significantly reduce building energy while avoiding the need for reheat.
- It also solves overhead heat issues in cold climates.



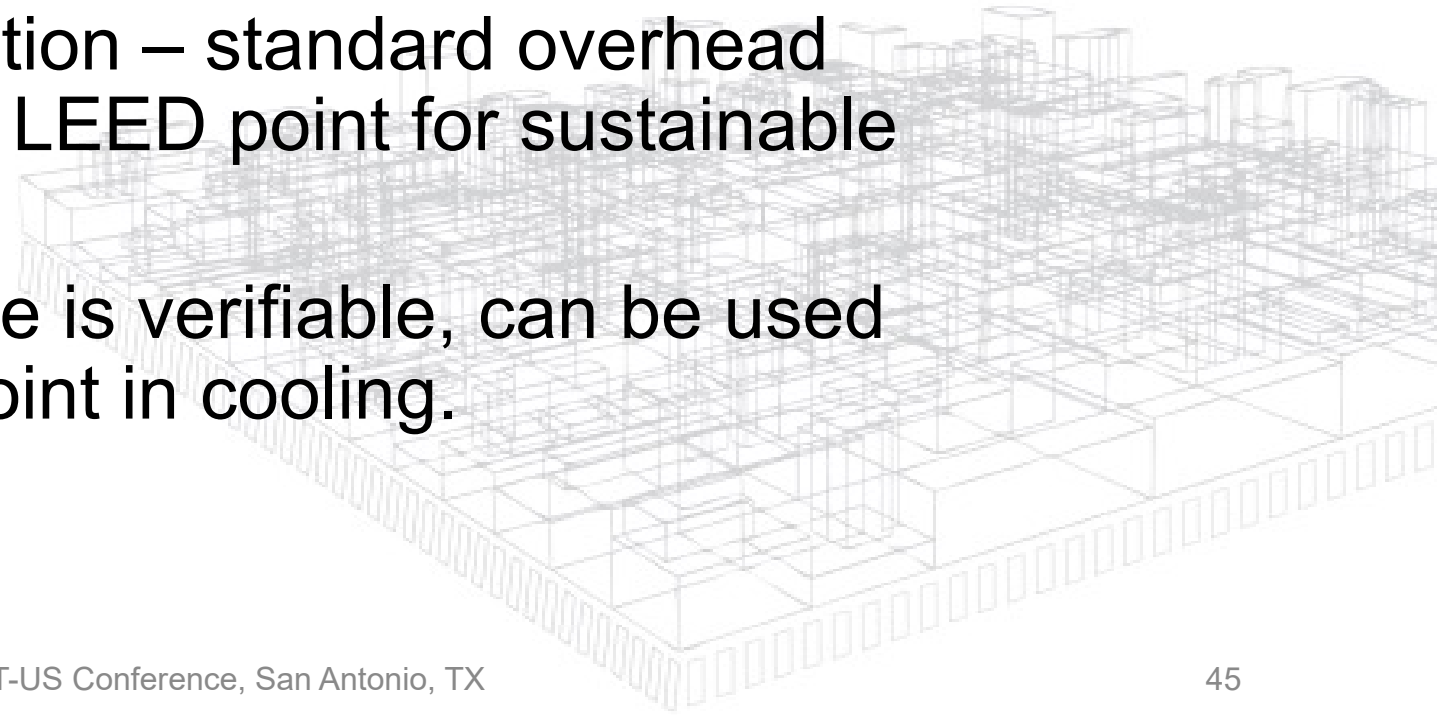
Adding a Sensible Cooling Coil

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



Both the CFB and VAV Unit Features:

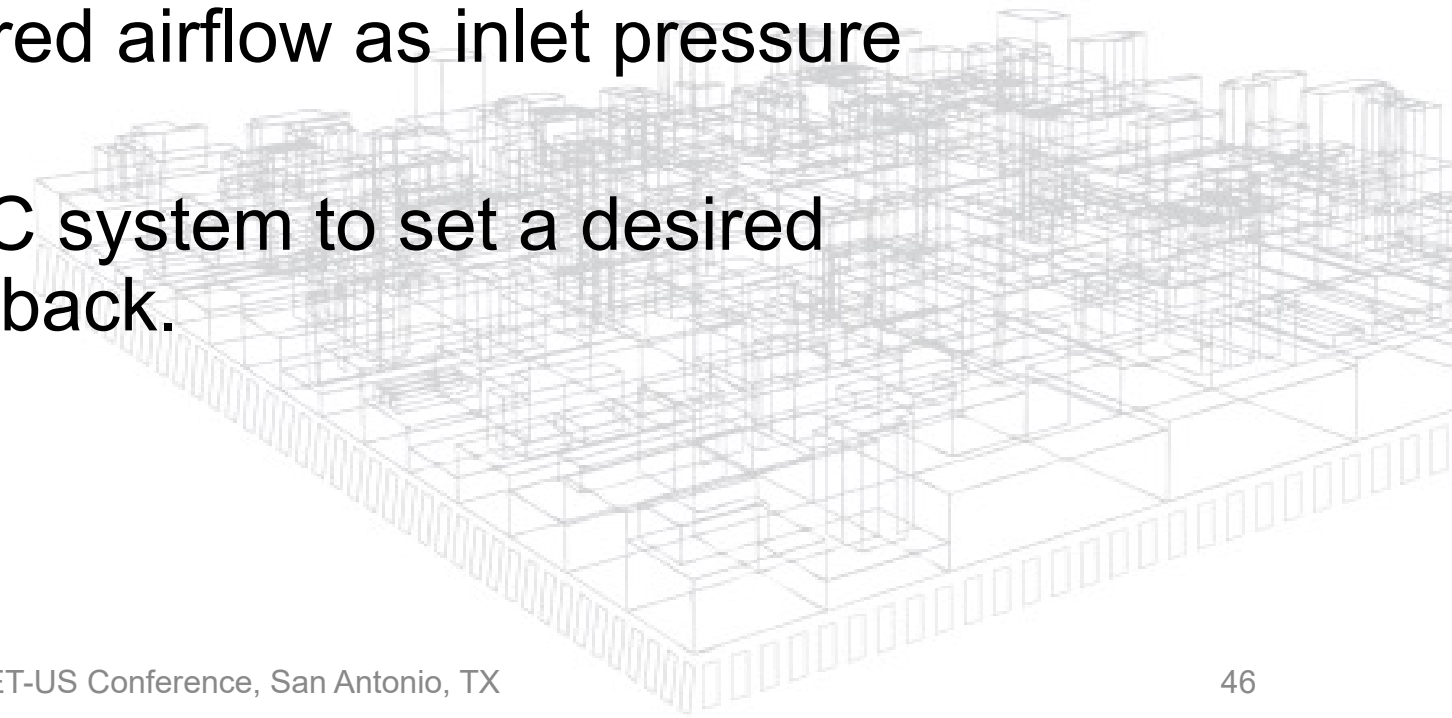
- The Variable Speed Pressure Independent ECM motor/blower allows precise air flow control.
- These units have ARI Certified sound levels, fan performance, power consumption.
- Contractor is familiar with installation details.
- Very flexible installation – standard overhead diffusers – potential LEED point for sustainable design.
- Diffuser performance is verifiable, can be used for LEED comfort point in cooling.



Efficiencies

ECM Motors:

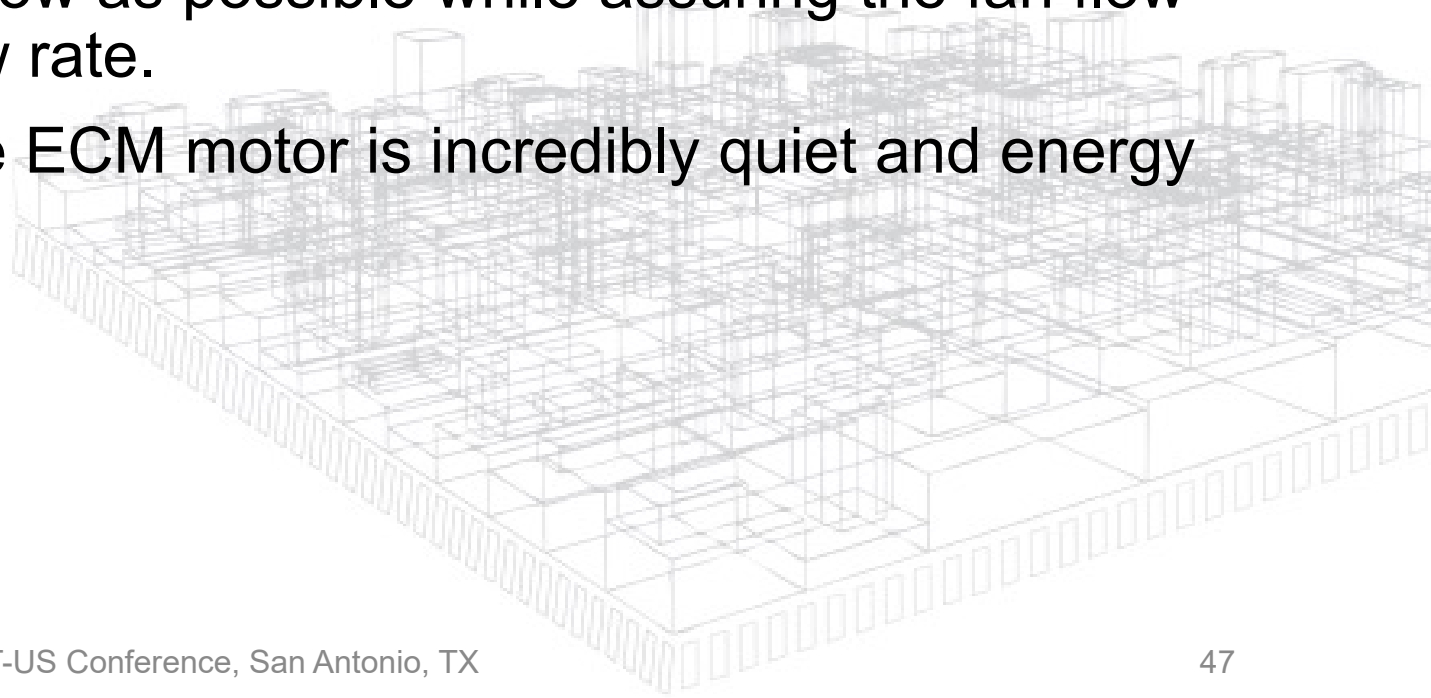
- An ECM motor will typically use far less energy than a the PSC motor it replaces, especially as the air flow is reduced.
- The motor is “pressure independent”, meaning it will maintain a desired airflow as inlet pressure changes.
- This allows the DDC system to set a desired airflow without feedback.



Efficiencies

Reducing Air Flows:

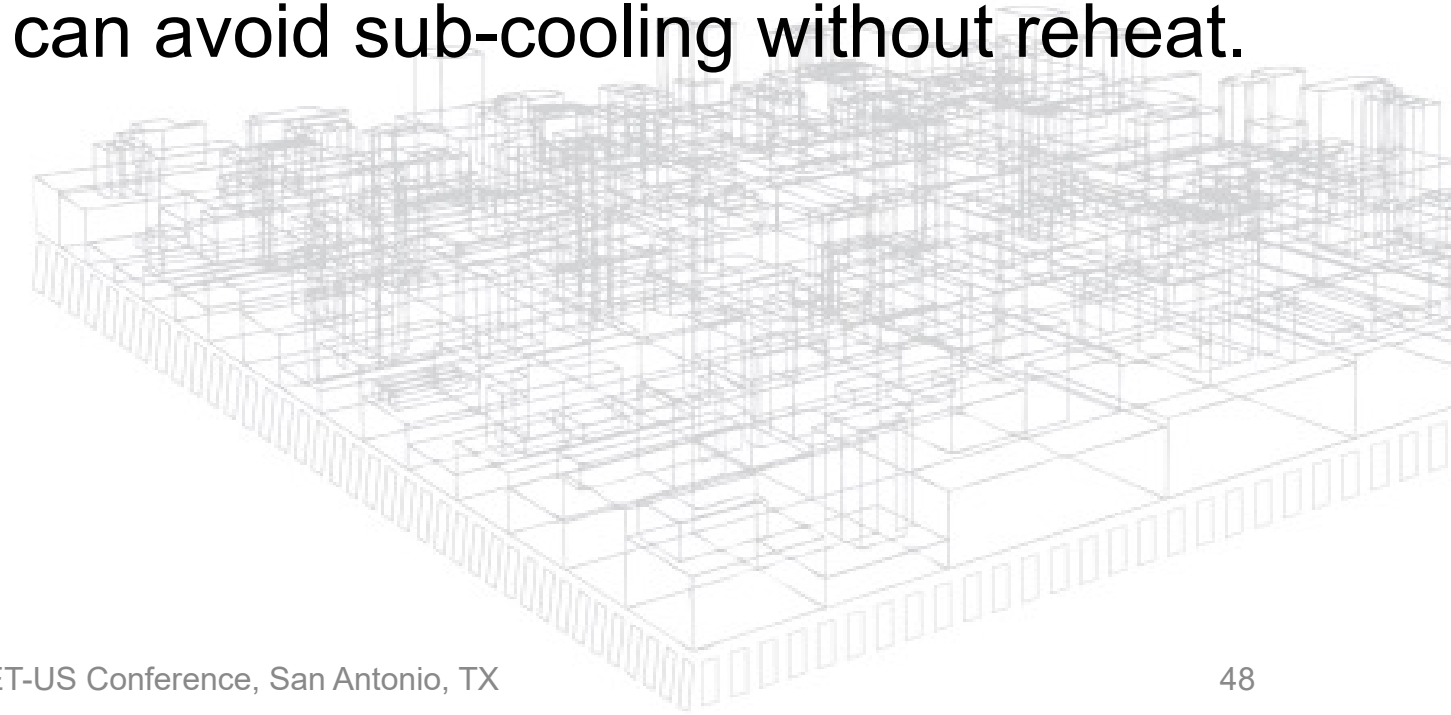
- Recent ASHRAE Research has shown that acceptable environments can be achieved with air flows as low as 0.2 CFM/Sq.Ft.
- Airflows can be maintained as low as possible while assuring the fan flow exceeds the DOAS system flow rate.
- Operating at very low flows, the ECM motor is incredibly quiet and energy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



Efficiencies

Avoiding Sub-cooling:

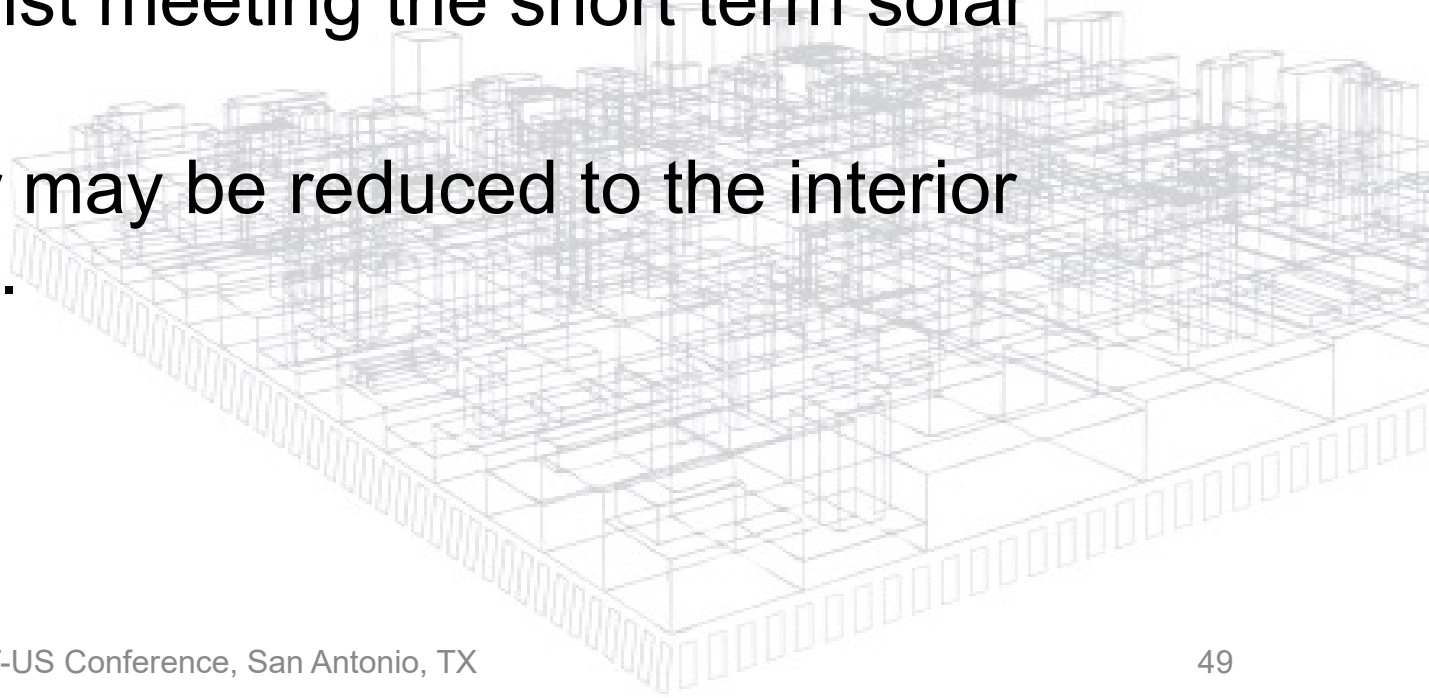
- Sub cooling of interior zones happens when the ventilation rate or dehumidification needs exceed the thermal load.
- Inducing warm plenum air can avoid sub-cooling without reheat.



CFB Unit Efficiencies

Perimeter Solar Loads:

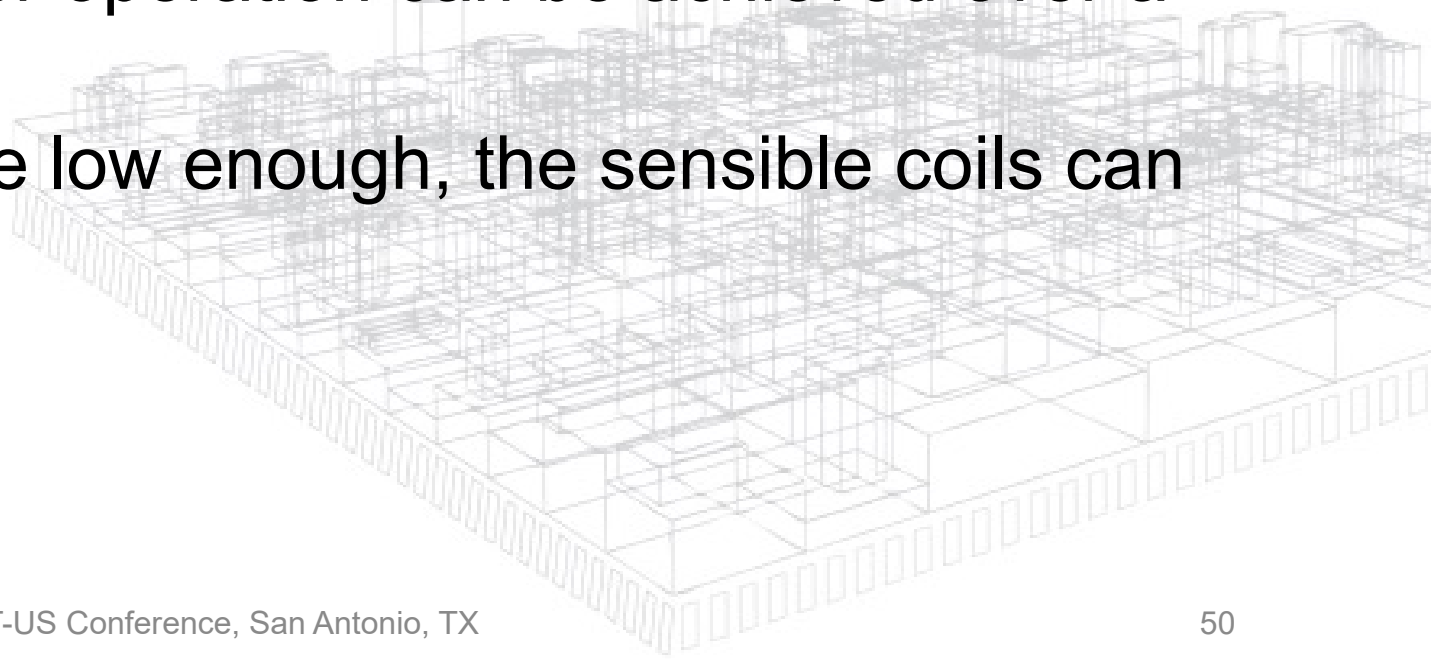
- Solar loads are greatest in early morning and late afternoon.
- Increasing the cold (and dry) DOAS flow rate to these zones can assist meeting the short term solar load demands.
- DOAS Ventilation air may be reduced to the interior during these periods.



CFB Unit Efficiencies

Economizer:

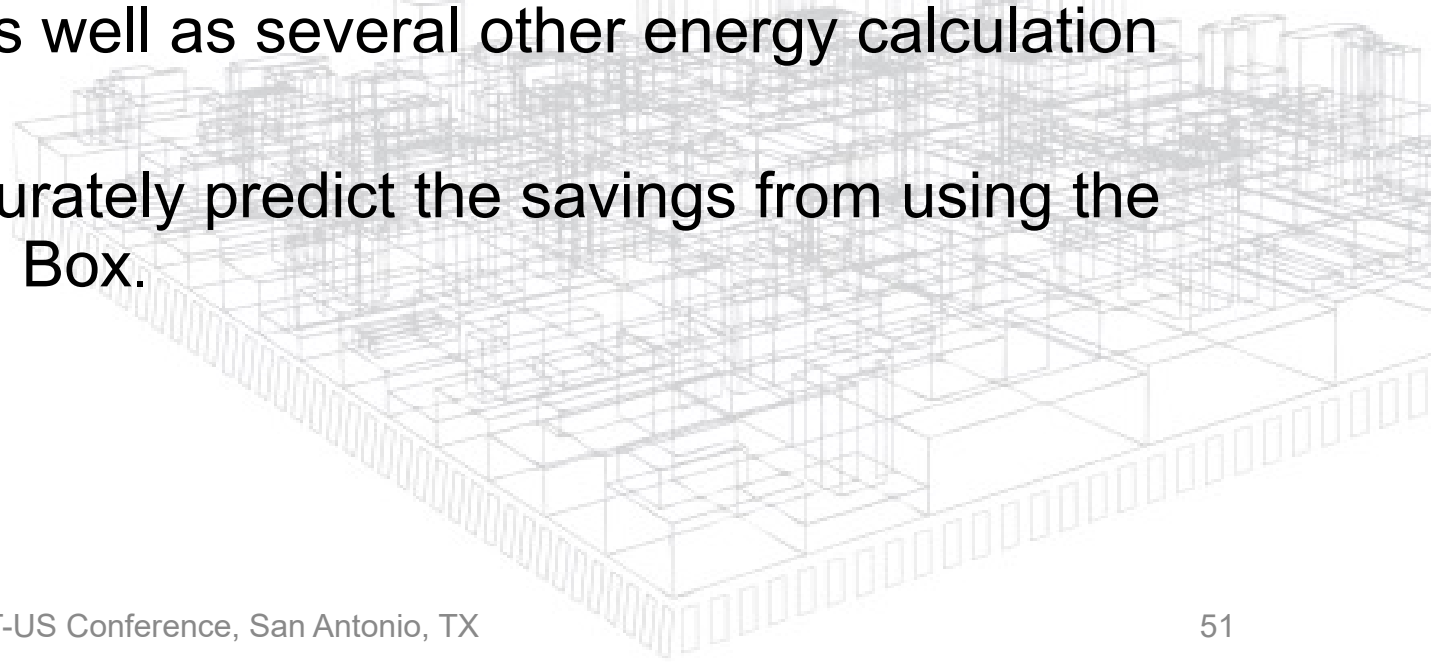
- Economizer operation results in huge energy savings.
- By slightly oversizing the ductwork and inlets to the chilled boxes, effective economizer operation can be achieved over a broad range of conditions.
- If outside air dew points are low enough, the sensible coils can extend this range.



Validation of Energy Use

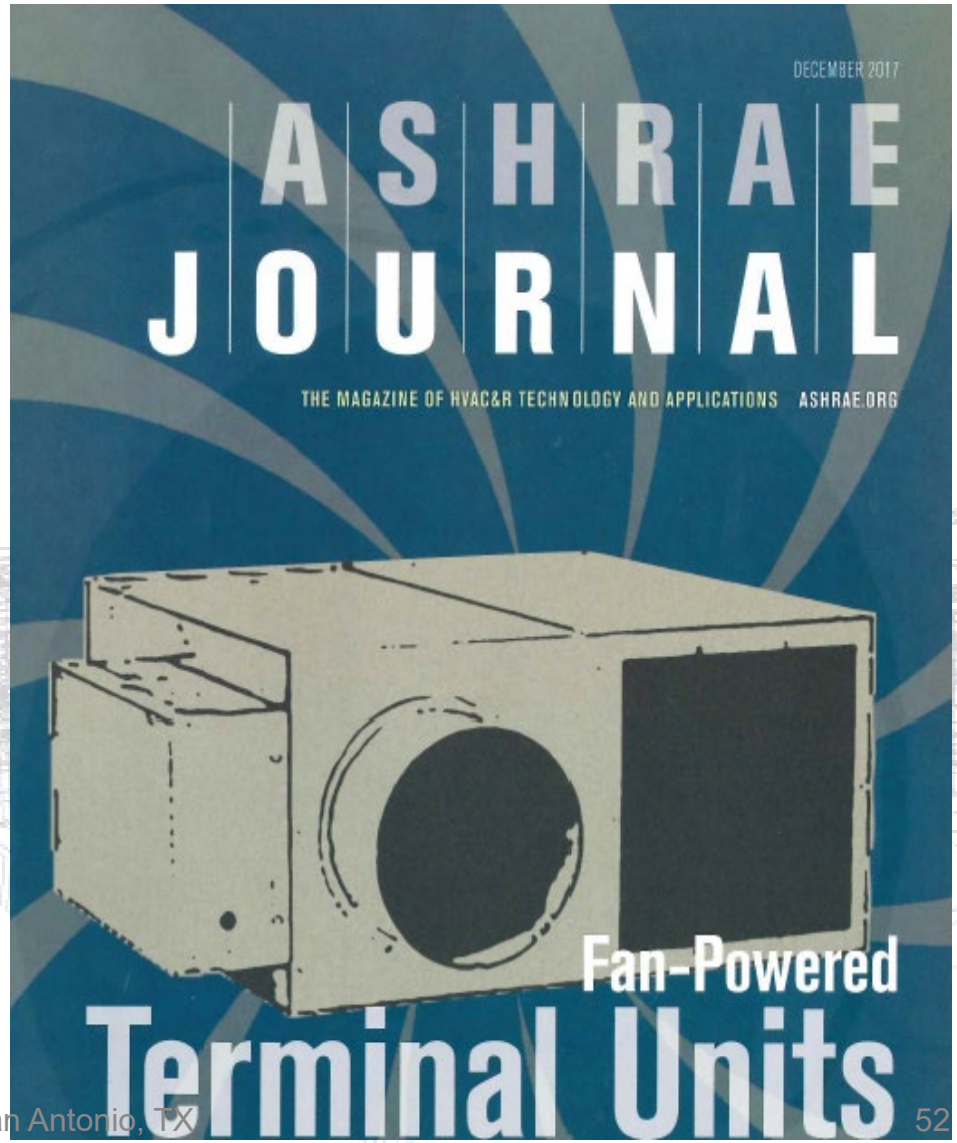
AHRI and ASHRAE sponsored research will allow accurate and validated energy use calculations:

- 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.
- This will allow engineers to accurately predict the savings from using the turn down feature of the Chilled Box.



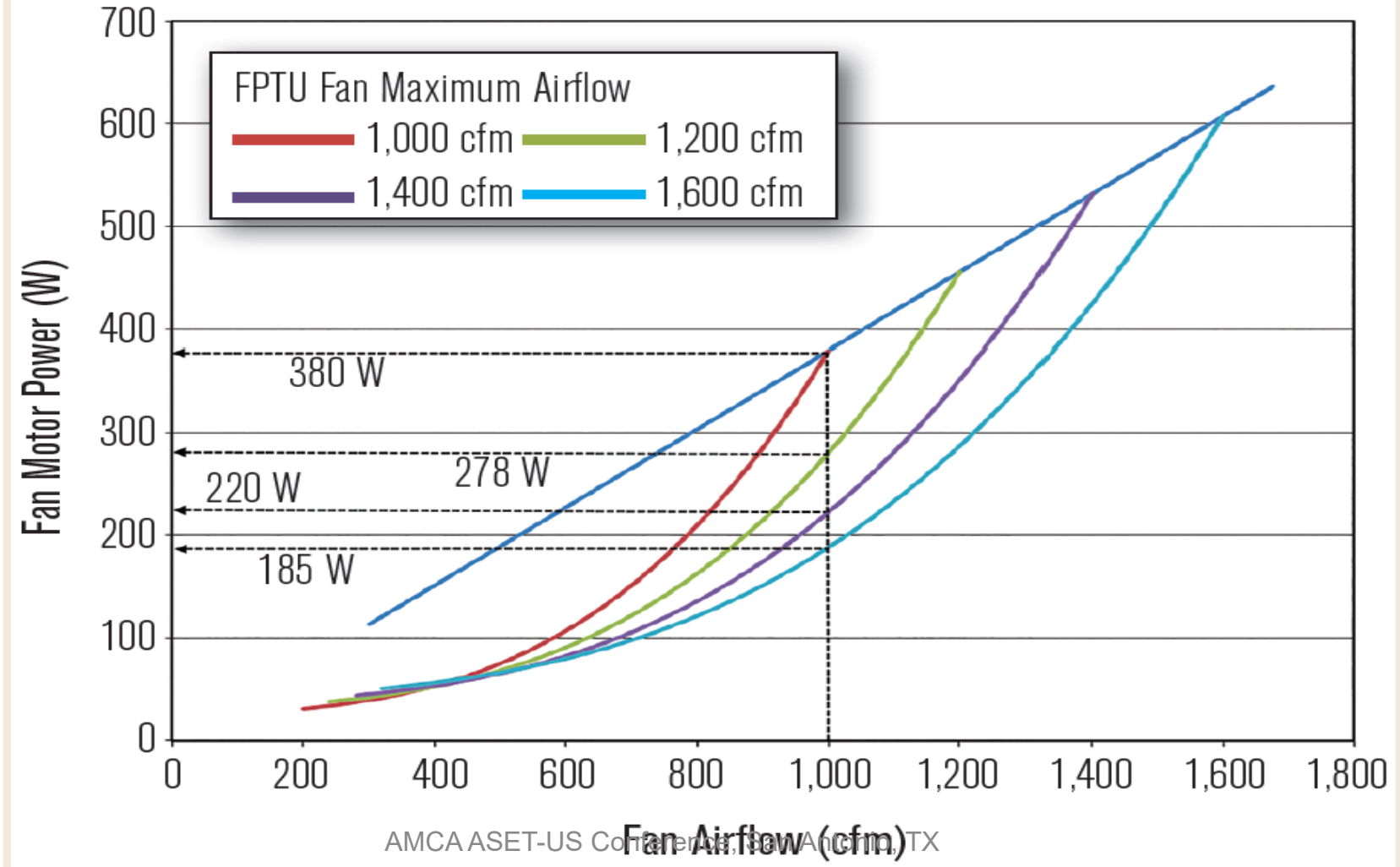
ECM System Energy Use

- 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

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

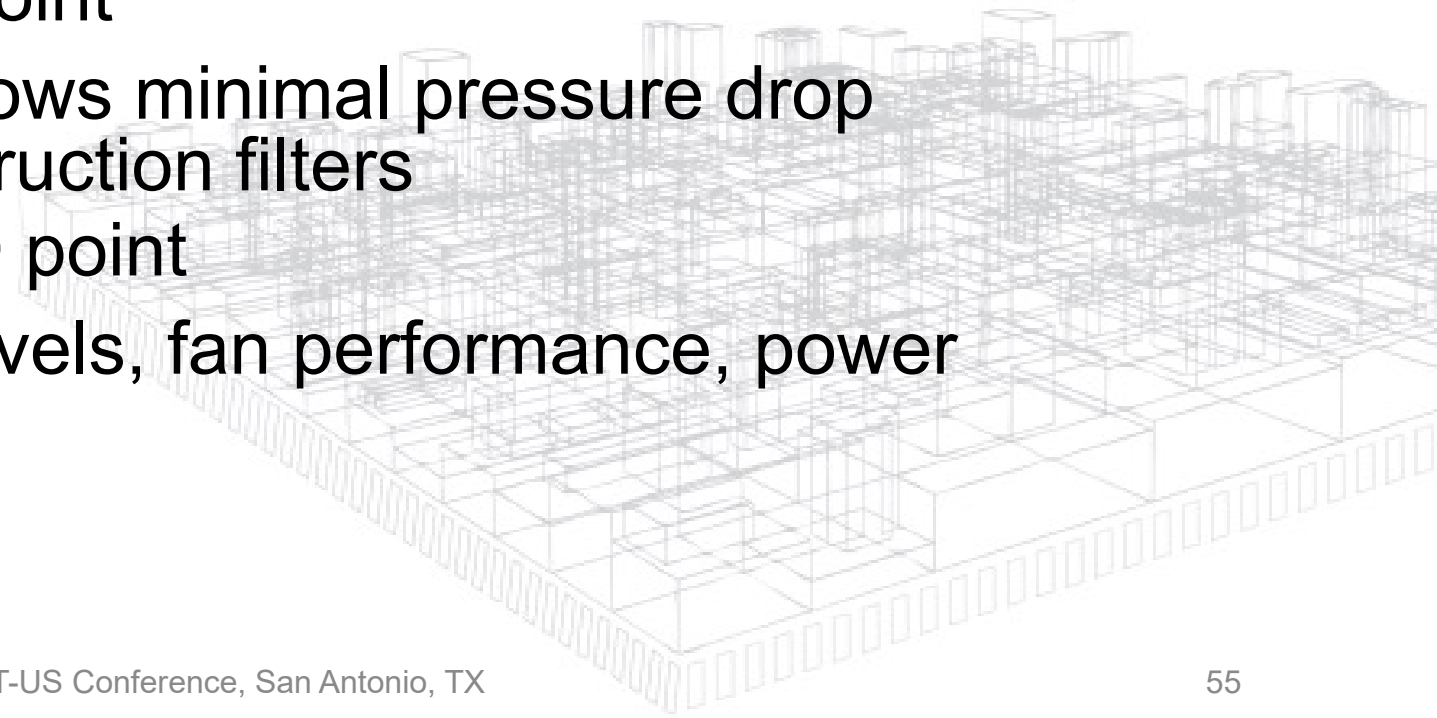


Chilled Box Unit Features

- Unit can be located in non-critical area (away from potential condensation damage).
- Unit can supply 1500 sq.ft. or more, resulting in significant first cost savings over some other systems (not counting cost of additional heating system).
- Replacement parts are readily available.

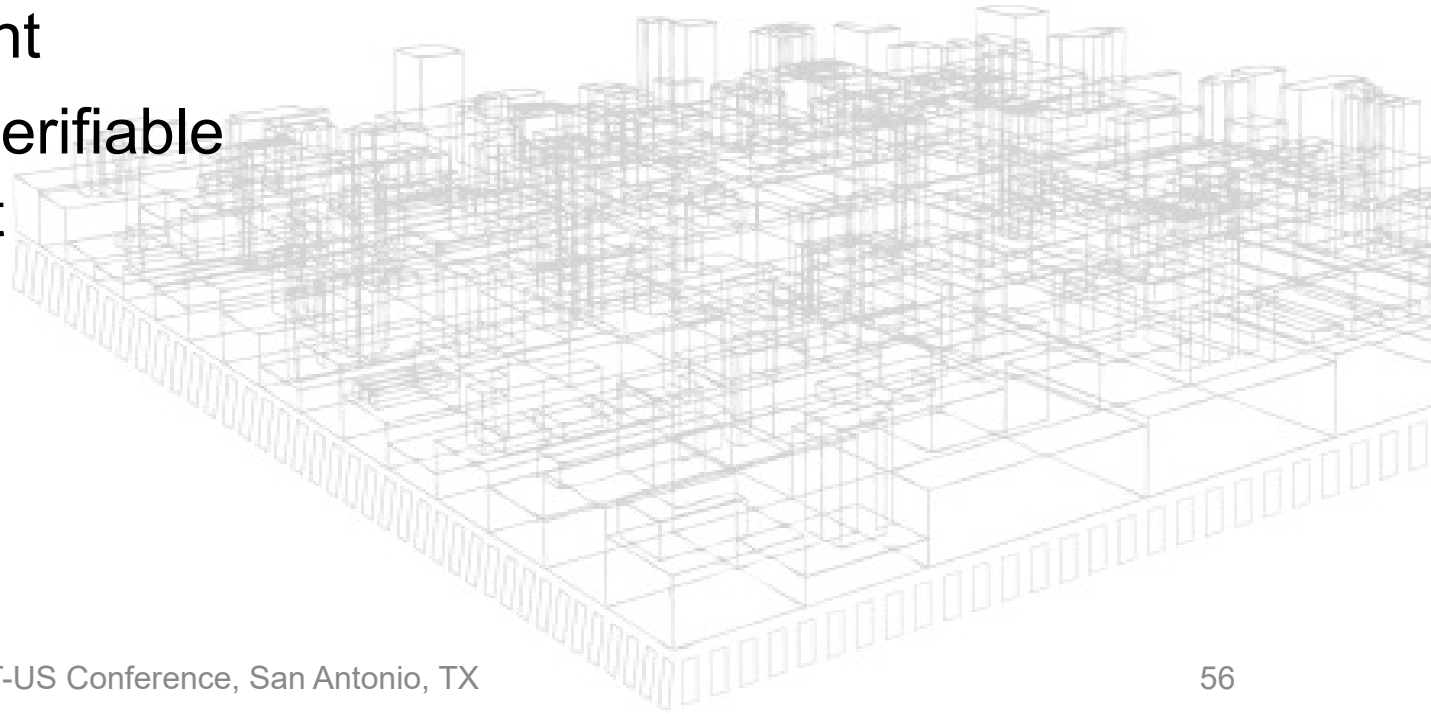
CFB and VAV Series Fan Box Features

- Heat and cool from single unit
- Hot water or electric heat coils
  - LineaHeat w/ discharge temp sensor can help achieve LEED point
- Large filter area allows minimal pressure drop with MERV 8 construction filters
  - Automatic LEED point
- Published sound levels, fan performance, power consumption



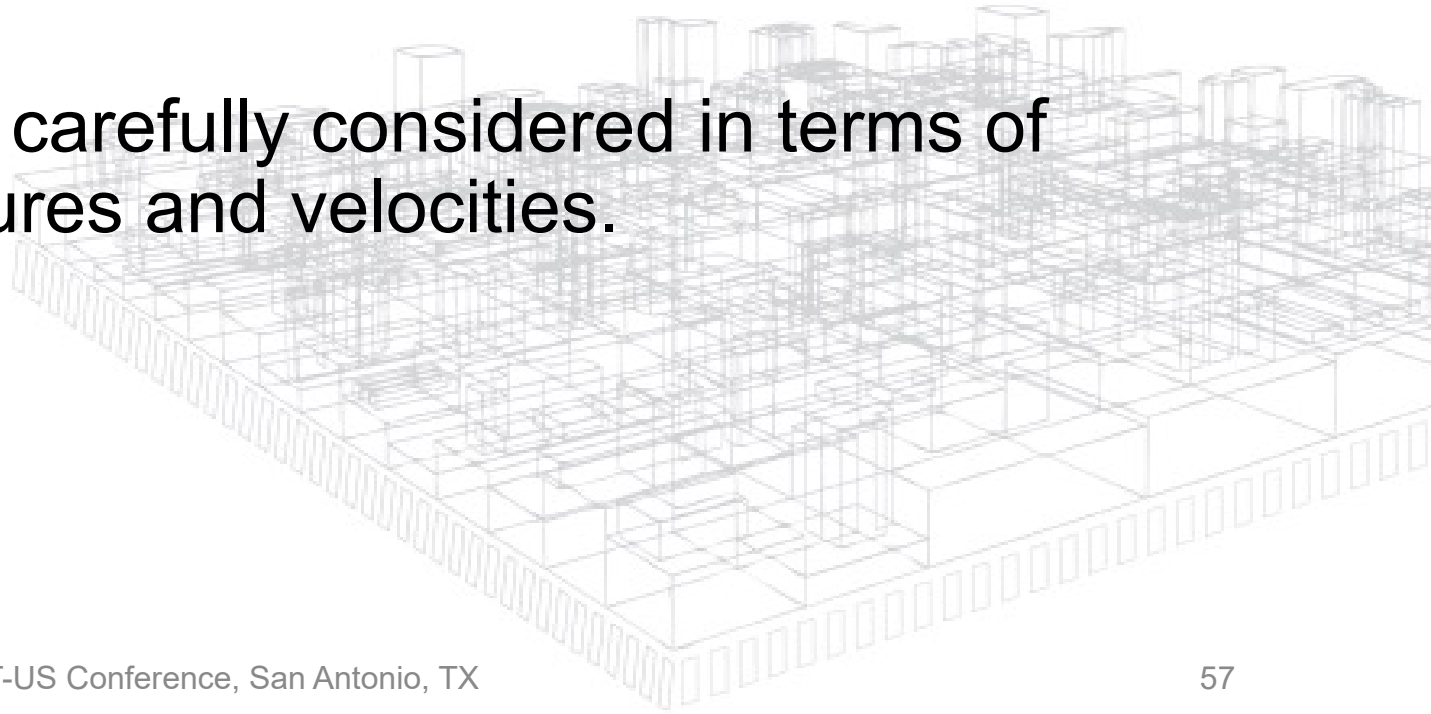
CFB and VAV Series Fan Box Features

- Flexible installation – standard overhead diffusers
  - – Potential LEED point for sustainable design
- Ventilation rate can easily be measured and verified
  - Potential LEED point
- Diffuser performance verifiable
  - LEED comfort point



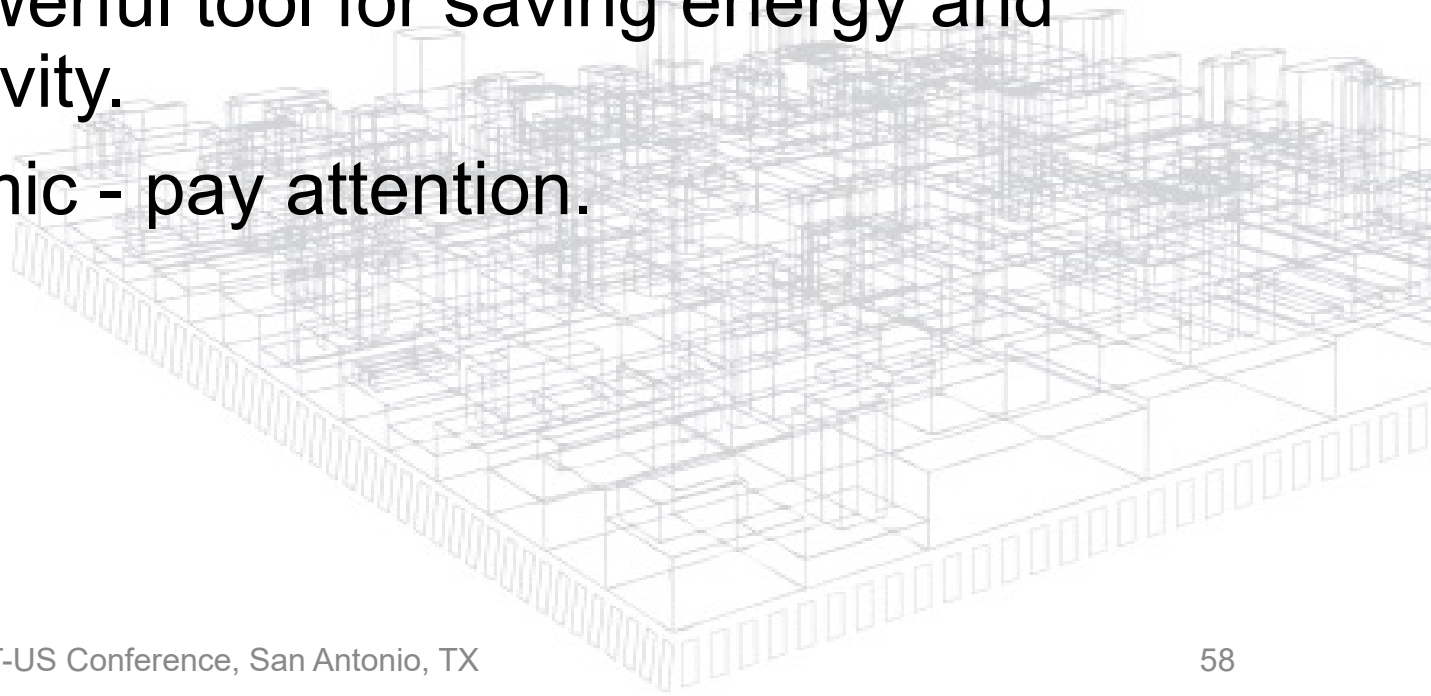
Summary

- 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.



Summary

- 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.



Questions?

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•Read my Air Distribution Blog!

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