You Can’t Afford Discomfort

Dan Int-Hout
Chief Engineer, Krueger
Richardson, Texas

KRUEGER
Excellence in Air Distribution

Where We Are Today:

So You Want To Save Money?

Things to consider:

1. First Cost
2. Energy cost
3. Occupant Salary costs
4. Life Cycle Costs

First Cost

- Today’s typical first cost for HVAC is at or exceeding $35/Square Foot in a high end open office.
- Costs are much higher for HealthCare facilities
- Even strip malls and low end offices are costing over $20/sf

Energy Costs

- A typical office building in the US costs about $2/square foot/year to heat and cool.
- It is of course higher in places with high utility rates (like New York City!)
- It is lower in places where economizer can be utilized a significant part of the time.

Occupant Salary Costs

- On average, assuming about 150 sf/occupant, salary costs no less than \$200/sf/y, as much as \$500/sf/y
- With higher occupancy, this can be much more.
- Health Care is even higher.

Thermal Comfort Economics

- **ASHRAE Journal, June 2008**

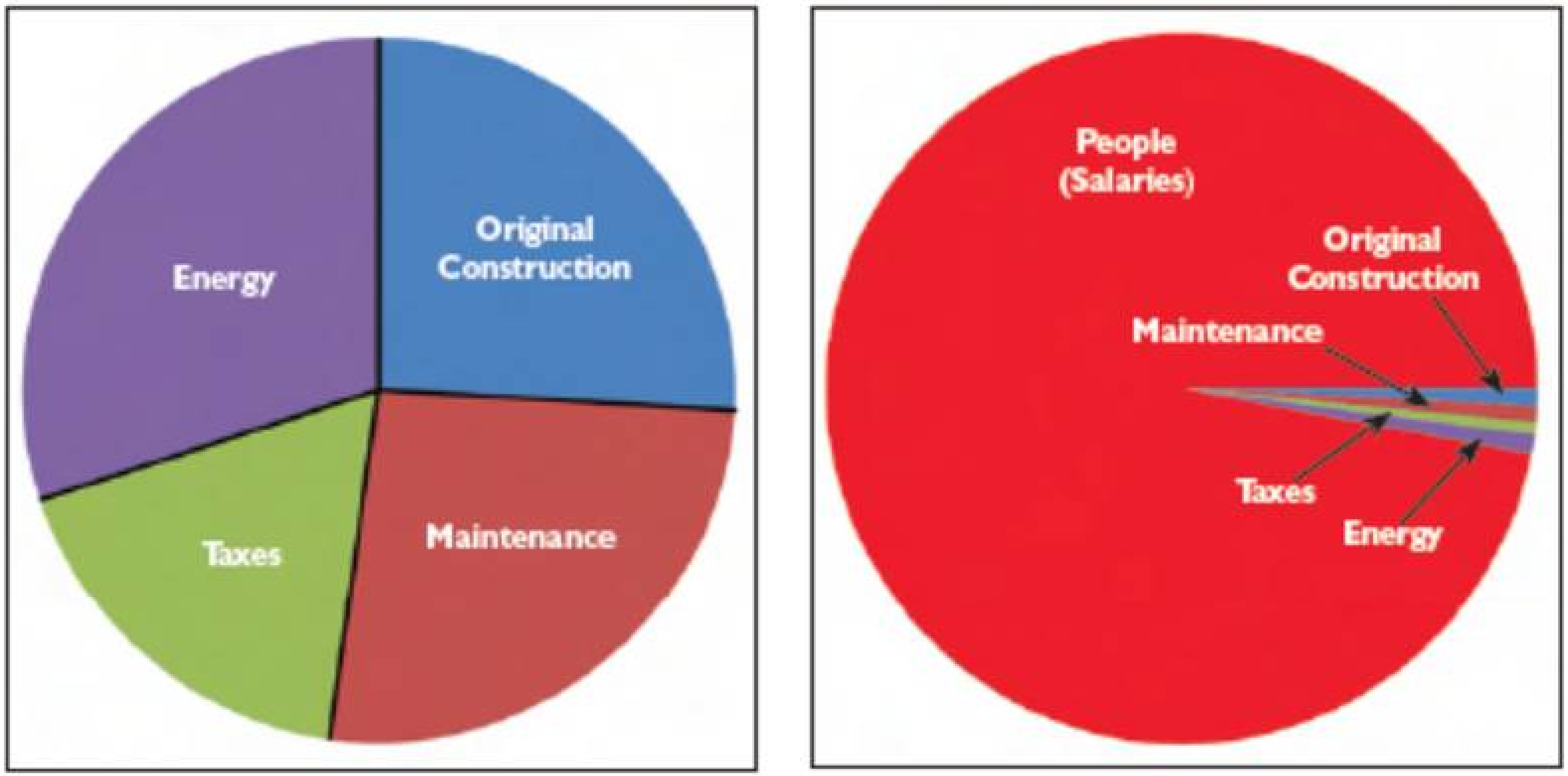


Figure 1: Life-cycle building costs breakdown.

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

What is the reality?

- Energy costs are often much higher than predicted.
- BOMA (Building Owners and Managers Assn) once reported “Occupant dissatisfaction with the thermal environment” is the #1 reason for not renewing the lease in high rise buildings.
- Renovation costs aren’t always considered when spaces are designed.

So what about energy cost predictions?

- Loads are not what engineers think they are.
- Energy use computer programs don’t have inputs for many emerging technologies.
- Validation of energy models is seldom accomplished
- Building operators have no clue how the system is supposed to operate to ensure both comfort and energy efficiency.

So What is the result?

- Spaces are often too cold
- Acoustics are poor (typically too quiet)
- Energy bills are higher than predicted
- Productivity suffers.
- Tenants don't renew the lease.

Spaces are often too cold

- In order to control humidity, and still meet minimum ventilation requirements, spaces are often sub cooled.
- Reheat, while a solution to the comfort issue, is expensive.
- Perimeter zones, in winter, are often severely stratified, with it being very cold near the floor and near exterior walls.
- All too often, space heaters are found throughout the interior, increasing loads significantly.

Acoustics are poor

- In order to achieve a good acoustical environment, it is almost always necessary to add background sound masking.
- Asking the HVAC system to provide that noise is very expensive.
- Poor acoustical treatment of surfaces compound the issue. Open ceilings, while often desired by architects and owners, often result in poor acoustical privacy.

Energy bills are higher than predicted

- Systems have difficulty controlling humidity at low loads
- Poorly adjusted or selected air outlets don’t allow thermostats to sense room temperatures correctly
- Operators don’t know how to run the system efficiently
- Opportunities for free cooling or heat removal aren’t utilized.

Productivity suffers

- Occupants have high absenteeism from poor environmental controls
- Lack of Acoustical Privacy reduces ability to concentrate
- Inability of management to provide comfort reduces employee morale
- Increasing ventilation is proven to improve productivity (and can gain a LEED point).
- See my ASHRAE Journal article(July ‘13)!

Let's look at some of the issues:

- Interior loads: the reality vs the "rule of thumb".
- The cost of comfort
- The need to select and adjust air outlets properly
- Designing for low interior loads
- Taking advantage of "free cooling"
- Making overhead heating work. (and meet code)
- Predicting and Controlling Acoustics

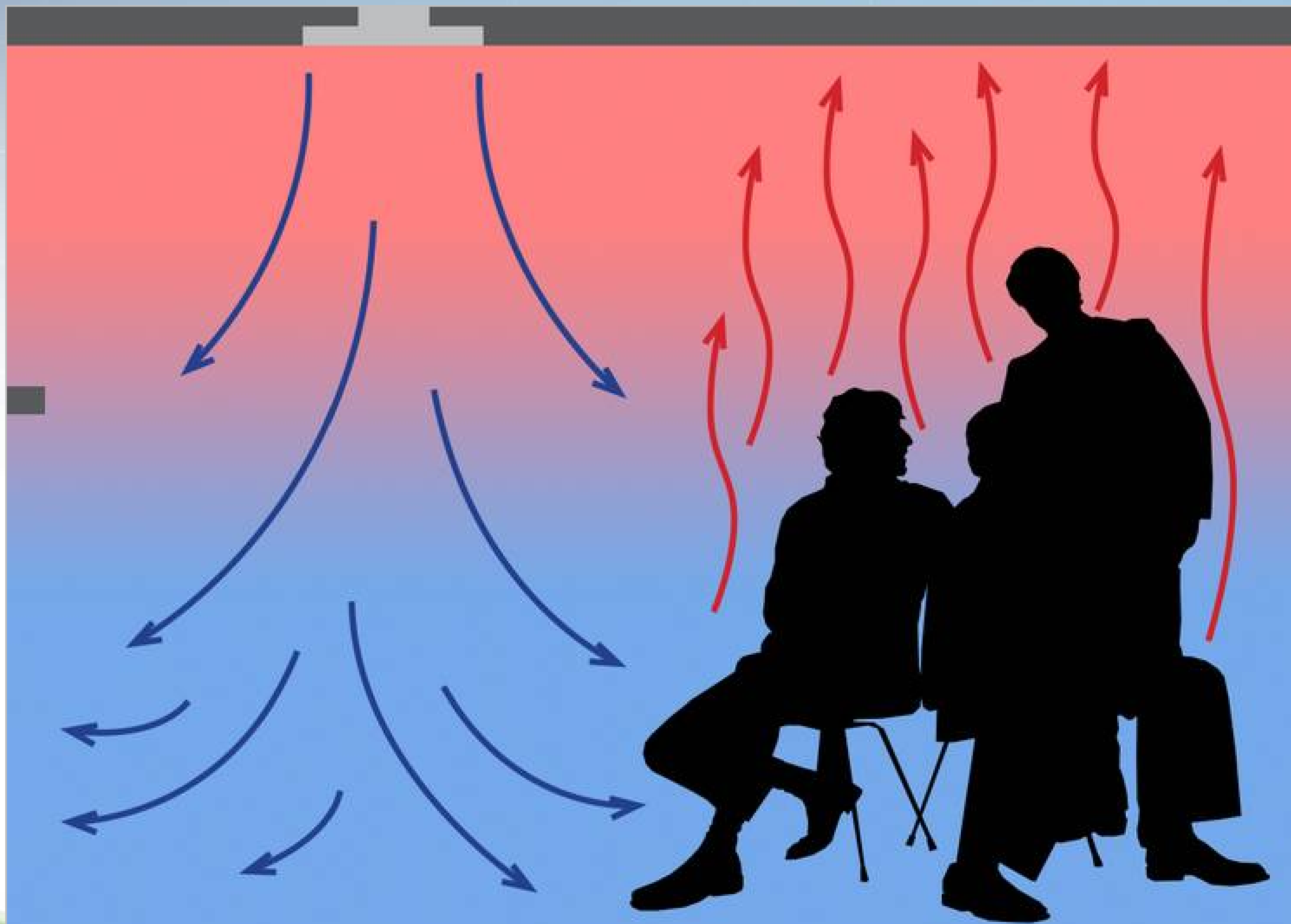
Interior loads:
The Reality vs the “Rule of Thumb”

- I find almost all interior designs assume 1 cfm/sf (23BTUH/SF) for the air loading.
- Actual loads, as we have seen in many research projects, is closer to 0.3cfm/sf (7 BTUH/sf)
- When asked, many engineers respond with “I’ve never been sued for having too much capacity”.

The need to properly select and adjust air outlets

- The ASHRAE handbook suggests selecting diffuser to achieve an 80% ADPI at all air flow rates.
- Most diffuser layouts have diffusers too close together, resulting in drafts at full flow
- Some diffuser designs work better than others at low flows – a plaque-type is a good choice. Perforated and swirl diffusers not so much.
- The new ASHRAE Standard 55 Users manual says compliance can be proven using ADPI.
- ASHRAE RP1515 proved high occupant satisfaction can be proven at 0.25 cfm/sf, as predicted using ADPI.

Air Distribution, Poor Pattern



Designing for low interior loads

- The default minimum ventilation rate in offices is 17 cfm/person. With 150sf/person (per above example) that equals 0.22 cfm/sf
- A person generates about 350BTU of cooling demand (100w).
- At a supply air temperature low enough to provide latent heat removal (<55^{o}F), the minimum ventilation rate provides 370 BTUH of cooling.
- Not much more is required for today's laptops and flat panel monitors.
- 1 cfm/sf is probably 5X too much cooling after morning cool down, even on a design day!

Taking advantage of “free cooling”

- Where is the highest cooling demand load found in most offices?
- At the perimeter, of course.
- Locate a return opening above the window. Warm air will pass into the plenum without any work by the HVAC system (hot air rises!)
- At low loads, most of the air in the plenum is discarded (to maintain building pressures) taking perimeter heat with it.

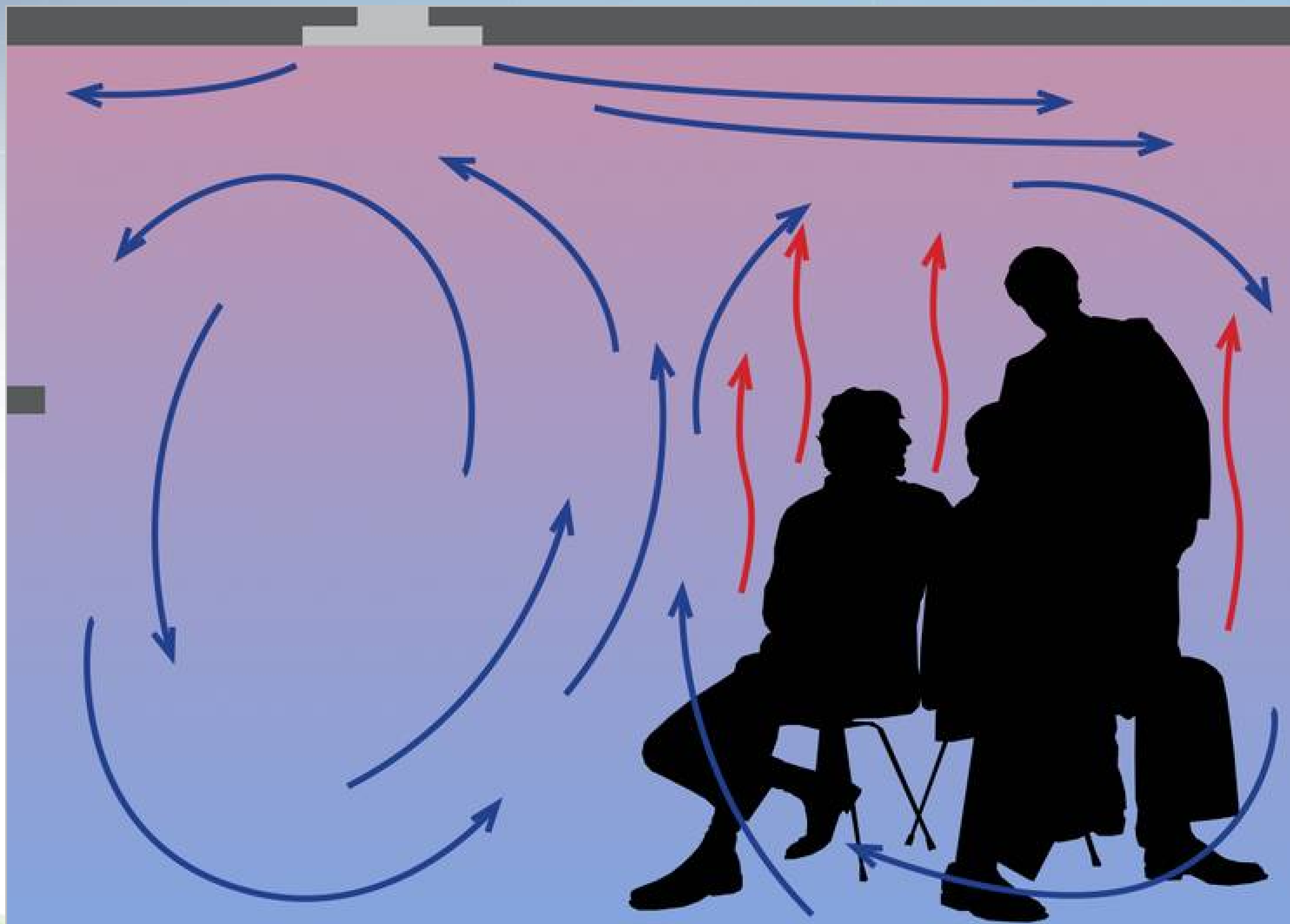
Making overhead heating work. (and meet code)

- Overhead heating is the most popular means of heating an office space.
- A number of technical papers were presented in the late 70’s outlining the relationship between diffuser location, outlet temperature and perimeter heat loss.
- The results were included in the 1981 ASHRAE Fundamentals handbook.
- They were also included in ASHRAE Standard 62.1, table 6.2.

Overhead Heating Perimeter Considerations:

- Maximum temperature difference between supply air and room temperature for effective mixing when heating, per ASHRAE handbook = 15°F (90°F discharge), continuous operation.
- 150 FPM must reach 4.5 feet from the floor or less.
- ASHRAE 62.1 requires that ventilation be increased by 25% when heating, if the above rules are not followed.
- ASHRAE Handbook says that one should use linear diffusers, with throw toward and away from glass, to get acceptable performance in both heating and cooling.
- Put a return slot above the window to carry away solar heat gain.

Air Distribution, Good Pattern



Predicting and Controlling Acoustics:

- **AHRI 885 acoustical application standard.**
- **AHRI 880 air terminal test standard.**
- **AHRI 260 ducted equipment except air terminals.**
- **ASHRAE 70, air diffuser performance.**
- **Acoustical quality suggests the use of RC (or newer measures) rather than NC. Many acousticians are heading back to dBA!**
- **LEED V4 includes acoustical credits and requirements.**

Indoor Air Quality

- Standing Standard Project Committee 62.1
- Residential Committee is 62.2
- Current Standard is 62.1-’13
- Several addenda for the ’13 version have already been approved

Minimum Ventilation Rates

- At a recent ASHRAE meeting, an interpretation request discussed ventilation rates. It was stated that there are actually three rates:
  1. Occupied Minimums are the sum, of occupant and floor area
  2. Unoccupied (but available) is just based on floor area
  3. Not Occupied means “off”.
- So, we need to have three ventilation rates, not one.
- When one zone changes, all the others need to adjust, suggesting the need for pressure independent, measurable ventilation rates for all zones.
- Washington State just passed a code requiring direct injection of outdoor air (DOAS) into every occupied space.

So, What Can We Do?

- The “Rules” are becoming code, or at least the “Acceptable Standard of Care”.
- Loads are dropping as Ventilation rates are increasing.
- Perimeter loads are becoming less.
- Ventilation rates are not constant.
- The solution starts at the input of outside air.

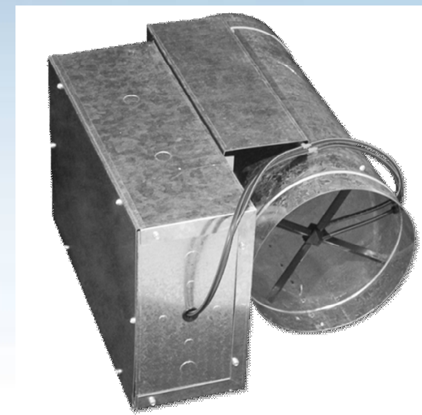
Dedicated Outdoor Air Delivery Systems

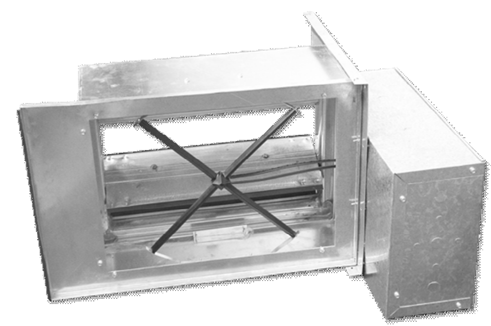
Measurable and Controllable Ventilation Supply is Required

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

Pressure Independent Ventilation Dampers

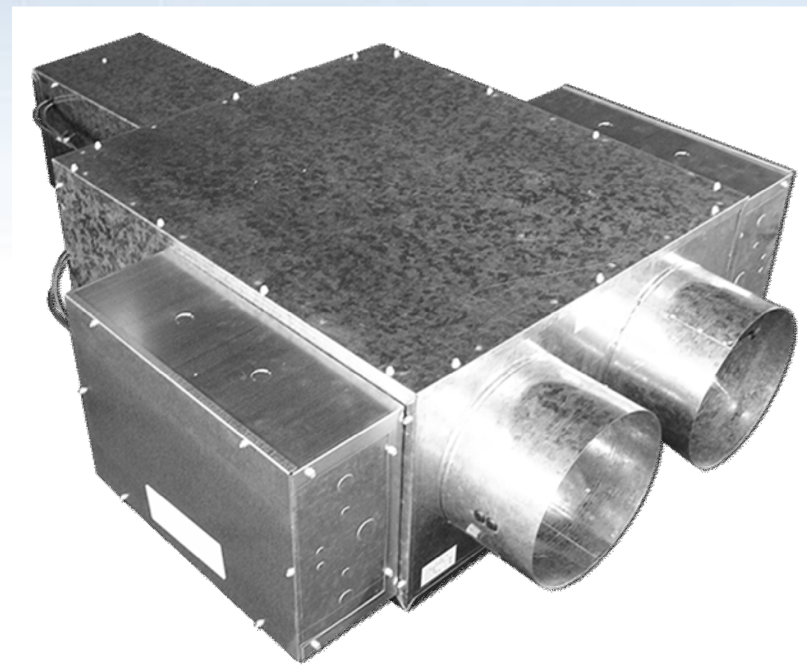
- Round VAV dampers with flow sensors
- Square "slip-in" dampers with flow control
- Electronic actuators with flow transducers
- Analog signals to control ventilation rates





DOAS Dual Duct

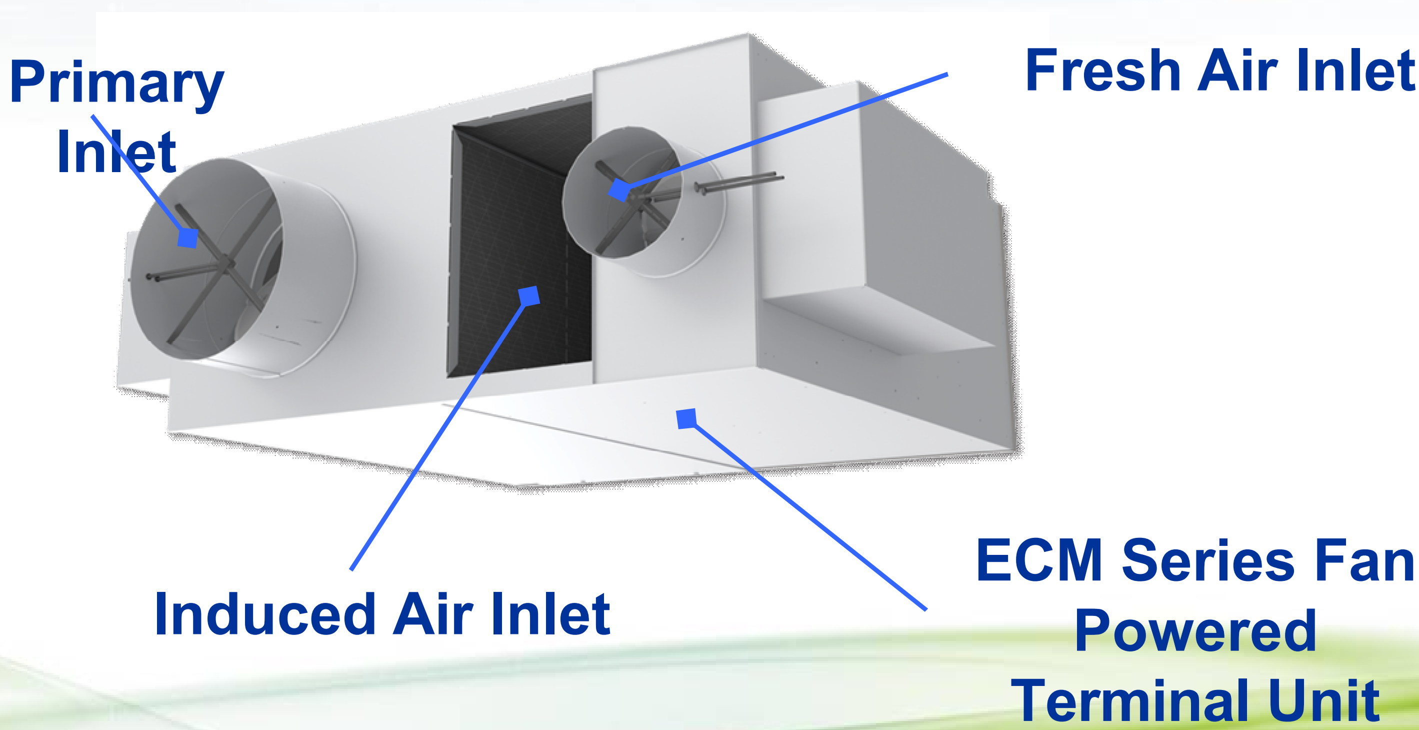
- One inlet provides 100% outside air, dehumidified, typically cold.
- Other duct provides 100% return air, either warm or cold, depending on the season.
- Supplemental reheat coils and even a sensible cooling coil have been considered
- A good mixing baffle should be employed (20:1 Mixing Ratio recommended)



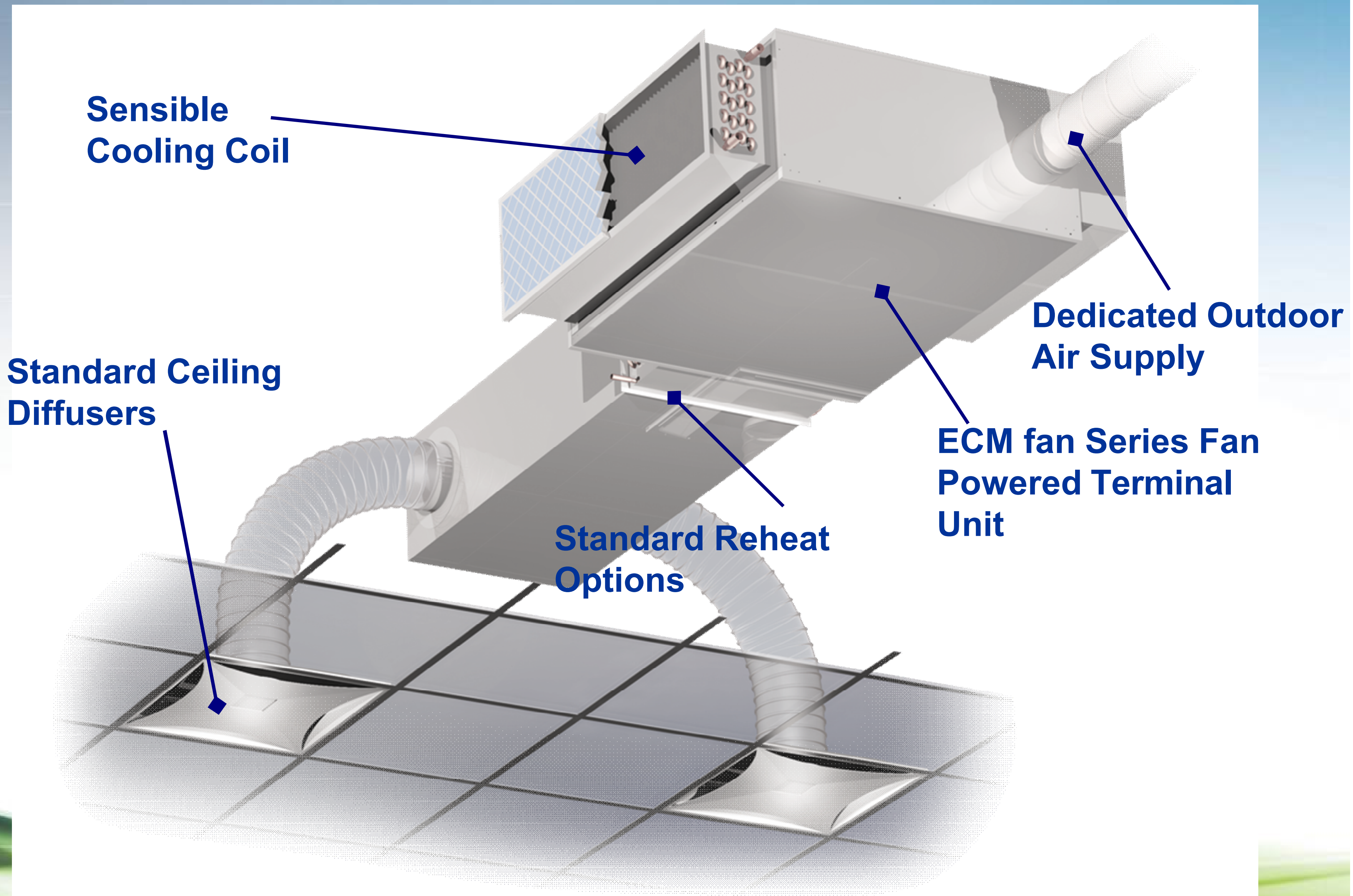
Mixing Dual Duct

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.



The Chilled Box



VAV Series Flow Chilled Box Control Strategies

- Take advantage of the ECM Variable Volume capability, maintaining as low a total flow as necessary (but always greater than primary inlet air flow rate).
- DOAS Ventilation air should typically be as cold and dry as possible.
- Increase fan CFM slightly to bring in warm plenum air as required to avoid sub cooling while maintaining ventilation rates and humidity control.
- Increase primary (ventilation) air during periods of high perimeter cooling demand.
- Run in economizer mode whenever possible

Energy Calculations Research

- Texas A&M has completed an ASHRAE/AHRI study of series, parallel, PSC and ECM fan box whole system energy use
- Data is being input into HAP, TRACE and Energy Plus. Software.
- Users will be able to prove the savings of using VAV ECM Series fan boxes
- See my January 2015 ASHRAE Journal Article

So What have we learned?

- Spaces are often too cold because of vertical stratification (hot air rises!) and/or poor humidity control. Adjustable diffusers need to be adjusted! (who knew?)
- Acoustics are poor (typically too quiet), but we can predict HVAC noise, and manage the acoustical environment.
- Energy bills are higher than predicted because prediction software needs to be validated, and designs don't take advantage of the low loads and free cooling opportunities.
- Productivity can be increased, likely saving both time and money.
- Systems should be operated at as low an airflow as possible, while meeting minimum ventilation rates.
- Designs and products are available that can manage loads, provide ventilation and run in economizer mode.
- And of course….

- **You Can’t Afford Discomfort:**
  - Building occupants are unhappy
  - New construction payback is longer as occupants move out
  - Energy bills are likely higher than “predicted”
  - Building Owners are dissatisfied!

Net Zero Energy Building

Contact

KRUEGER

EXCELLENCE IN AIR DISTRIBUTION

dint-hout@krueger-hvac.com

www.krueger-hvac.com

Read my Air Distribution Blog!

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