Methods for Effective Room Air Distribution

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KRUEGER
Excellence in Air Distribution

Where We Are Today:

Agenda

- Overview
- LEED issues and Update
- Perimeter
- Acoustics
- Thermal Comfort
- IAQ / Standard 62.1 Update
- Air System Selection
- Summary

LEED:

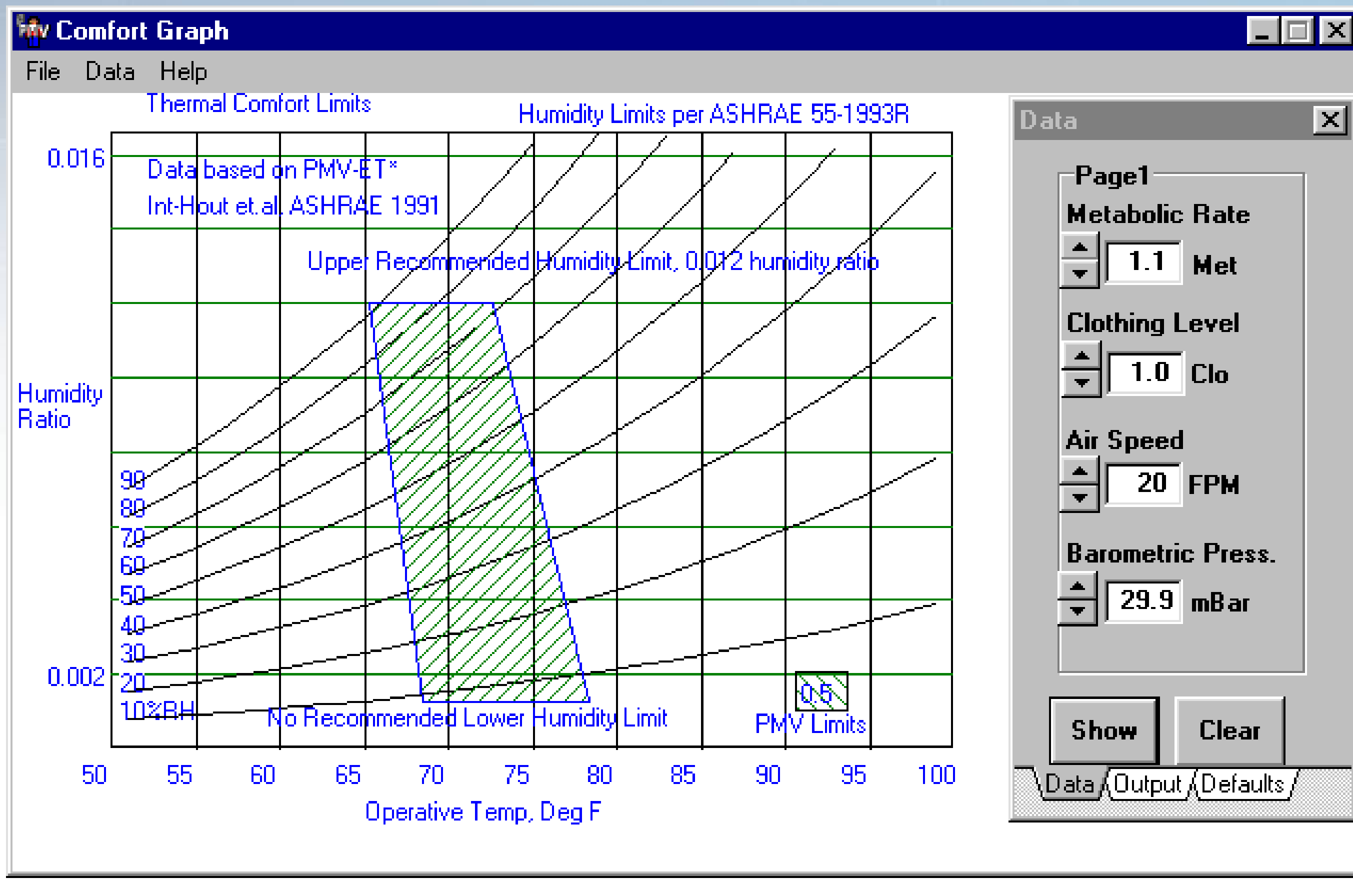
- The challenge from Architects to the Mechanical Engineer is to achieve energy efficiency 30% better than the base systems in ASHRAE 90.1
- The Base System is VAV / Overhead (well mixed).
- As a result, engineers are looking at alternate systems, which include;
  - Underfloor Air Delivery (UFAD)
  - Displacement Ventilation
  - Chilled Ceilings and Beams
- Most Energy Calculation programs, however, have not been validated for systems other than VAV overhead.
- Based on occupant comfort complaints, we still don’t understand how to properly apply overhead VAV systems.

Thermal Comfort

Thermal Comfort:

- Latest THERMAL COMFORT STANDARD: ASHRAE 55-2010
- ASHRAE Fundamentals, Chapter 7
- PMV - predicted mean vote - a single number rating.
- A program is available, based on the new ASHRAE 55-10, which allows plotting of the comfort envelope.
- Standard 55 mandates a maximum 5^{o}F vertical temperature stratification.

Thermal Comfort / Graphical solution



Comfort Economics

- **ASHRAE Journal, June 2008**

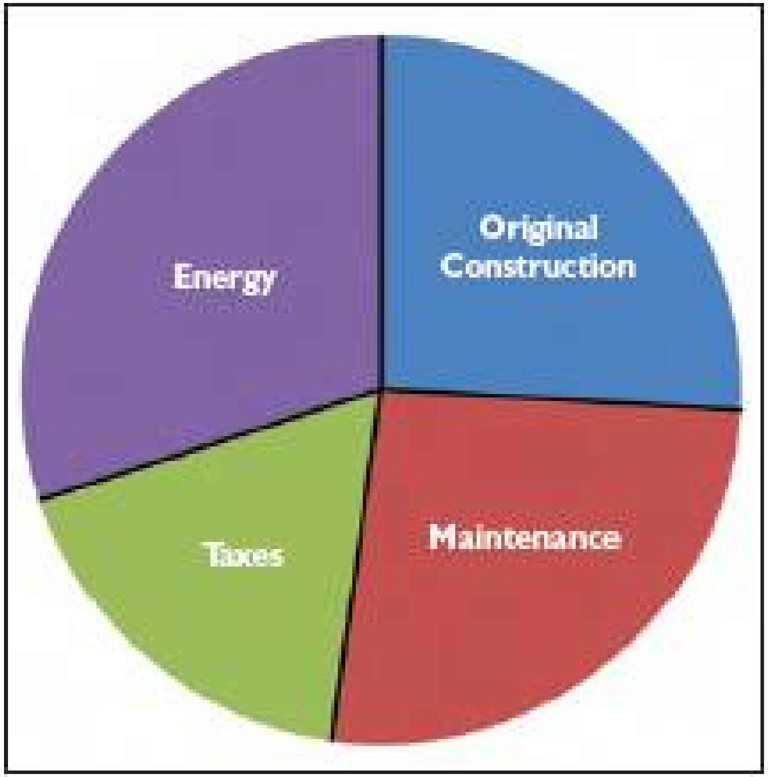


Figure 1: Life-cycle building costs breakdown.

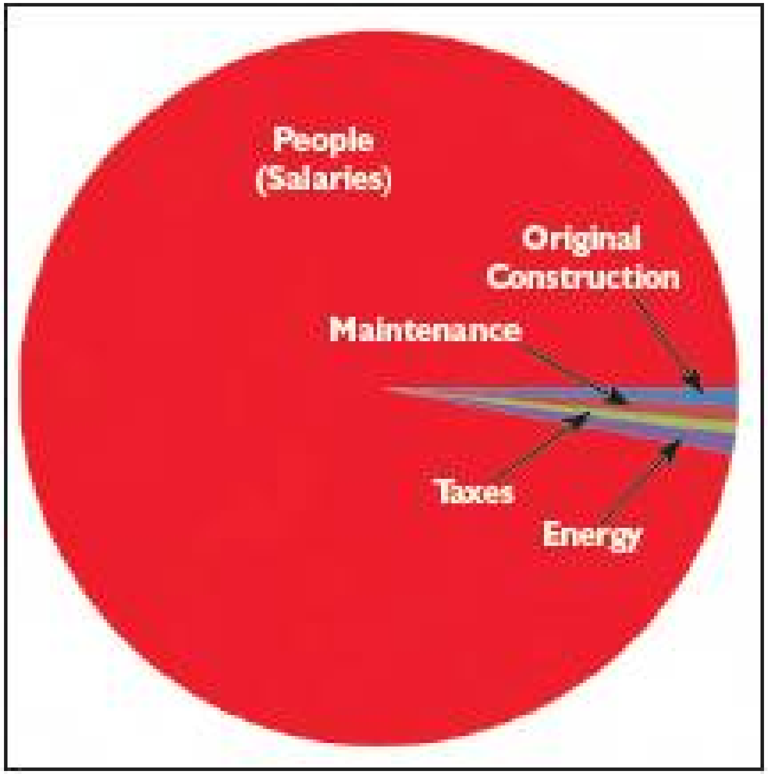


Figure 2: Life-cycle building costs breakdown with people (salaries).

LEED '09 ASHRAE Std 55 Checklist

SAMPLE COMPLIANCE

Based on Standard 55-

COMPLETE SECTION TWO FOR PROJECTS USING THE PMV/PPD METHOD

Weather data used for design calculations

COMPLETE SEC

Assumptions for pers

Space
(i.e.. Office,

SECTION ONE

Local Discomfort Effects

Verify that local discomfort effects have been considered and are not likely to exceed Standard 55 limits. When local discomfort effects are likely to occur, verify that calculations were performed to demonstrate that local discomfort effects are predicted to result in less than 10% dissatisfied occupants.

Local Discomfort Effect	Not Likely	Calculations Performed
Radiant Temperature Asymmetry		
Vertical Air Temperature Difference		
Floor Surface Temperature		
Draft		

Heating M

* Operative temperature includes radiant effects. See Standard 55.

Acoustics

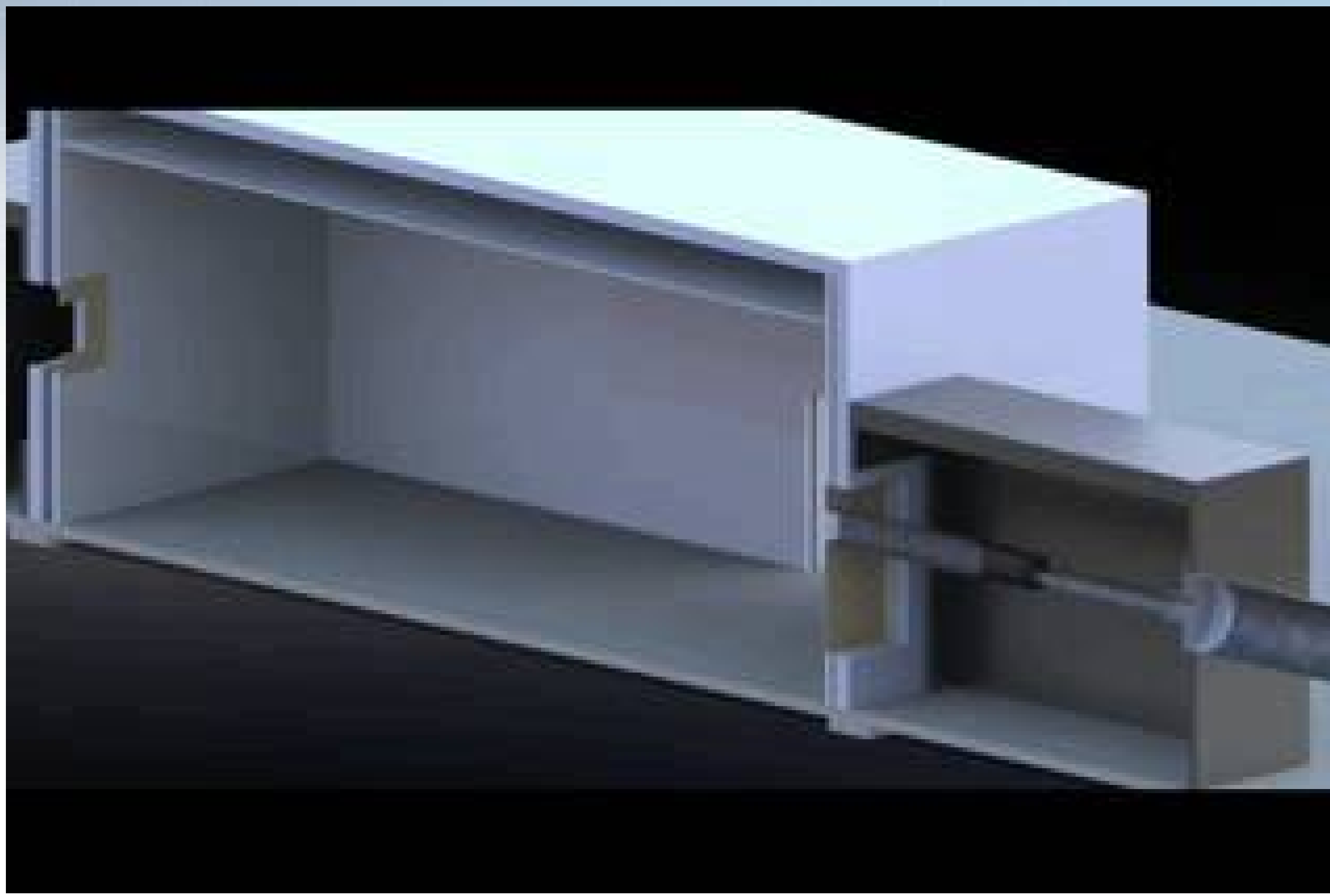
Acoustics:

- AHRI 885-08 acoustical application standard.
- AHRI 880-08 air terminal test standard.
- AHRI 260-01 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 2012 will include acoustical credits and requirements.
- A new ruling by AHRI will change everyone’s discharge sound ratings considerably.

End Reflection

- Low frequency sound traveling down a duct will partially reflect back when encountering a rapid change in area.
- The smaller the duct, the greater the effect.
- It can be as much as 10dB at 125Hz. It is much less at higher frequencies.
- Since NC is usually set at 125Hz, reported NC can go up as much as 10NC.
- Most importantly, Specifying Engineers should be modifying their discharge sound requirements to reflect the new data.

End Reflection



End Reflection

- An end reflection happens when air travels from a main to a branch duct, and especially when it enters a flex duct connection.
- Another happens when a duct terminates at the room, at the diffuser.
- AHRI 885 includes one 8” end reflection in Appendix E.
- This change only affects reported discharge sound power levels.
- Discharge sound is the same, but will be reported a bit louder.
- Engineers will need to update their discharge sound specifications.

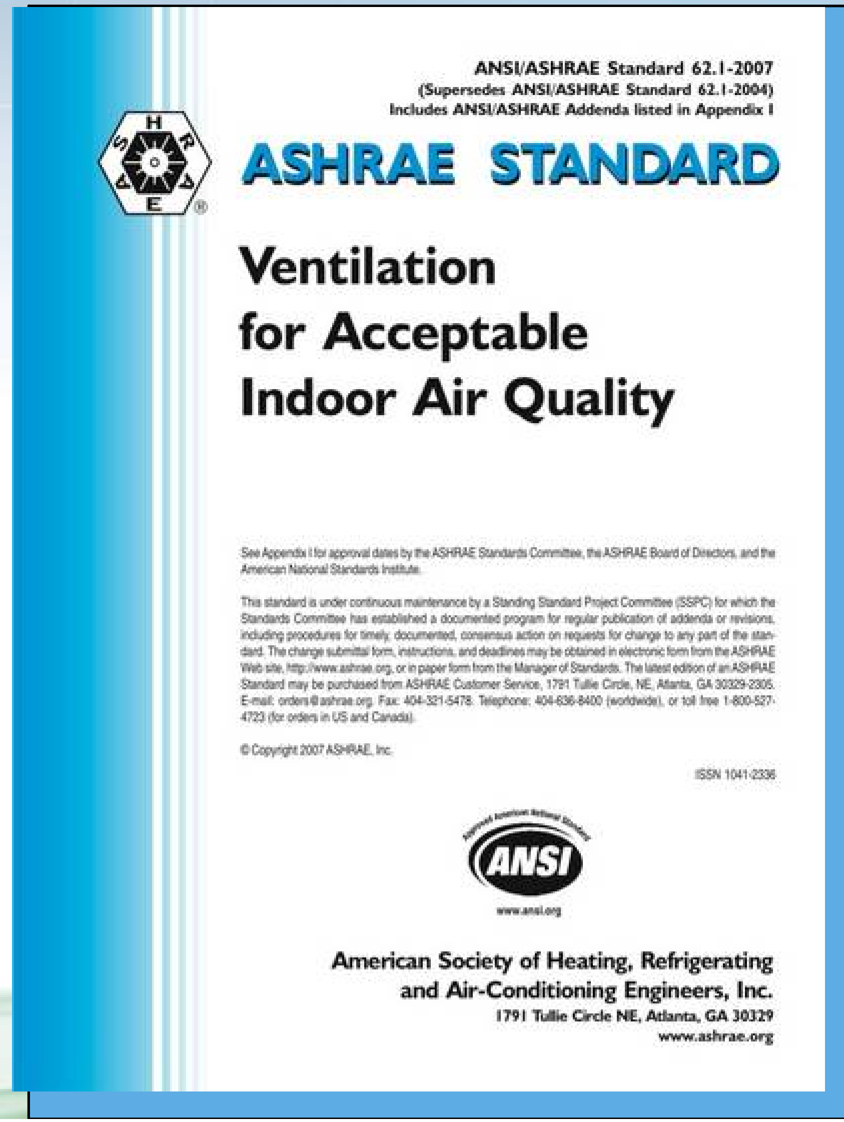
Sound Specifications

- Should be based on clearly stated assumptions.
- Should reflect real project needs, not any manufacturer's data and use currently accepted application factors..
- If duct lining is used – require"NC shall be determined in accordance with AHRI 885-08, Appendix E", otherwise specify octave band sound power.
- Specifications need to me modified to account for the new reported data.
- Over-silencing increases both initial costs and operating costs, and may hinder proper IAQ performance.

Indoor Air Quality

Indoor Air Quality

- Standing Standard Project Committee 62.1
- Residential Committee is 62.2
- Current Standard is 62.1-'10
- One addenda for the '10 version has already been approved



IAQ Standard

- Standard 62 is on continuous maintenance.
- Continuous and incremental changes are in progress.
- It will attempt to be in coordination with building codes.
- A Guideline document for designing systems above minimum requirements is being created.
- Users Manual is available now.
- The IMC has referenced 62.1 in the 09 release of the mechanical code.
- There seems to be minimal public awareness of the dynamic nature of the Standard.

Methods of Air Distribution

Air Distribution Device Selection Guidelines

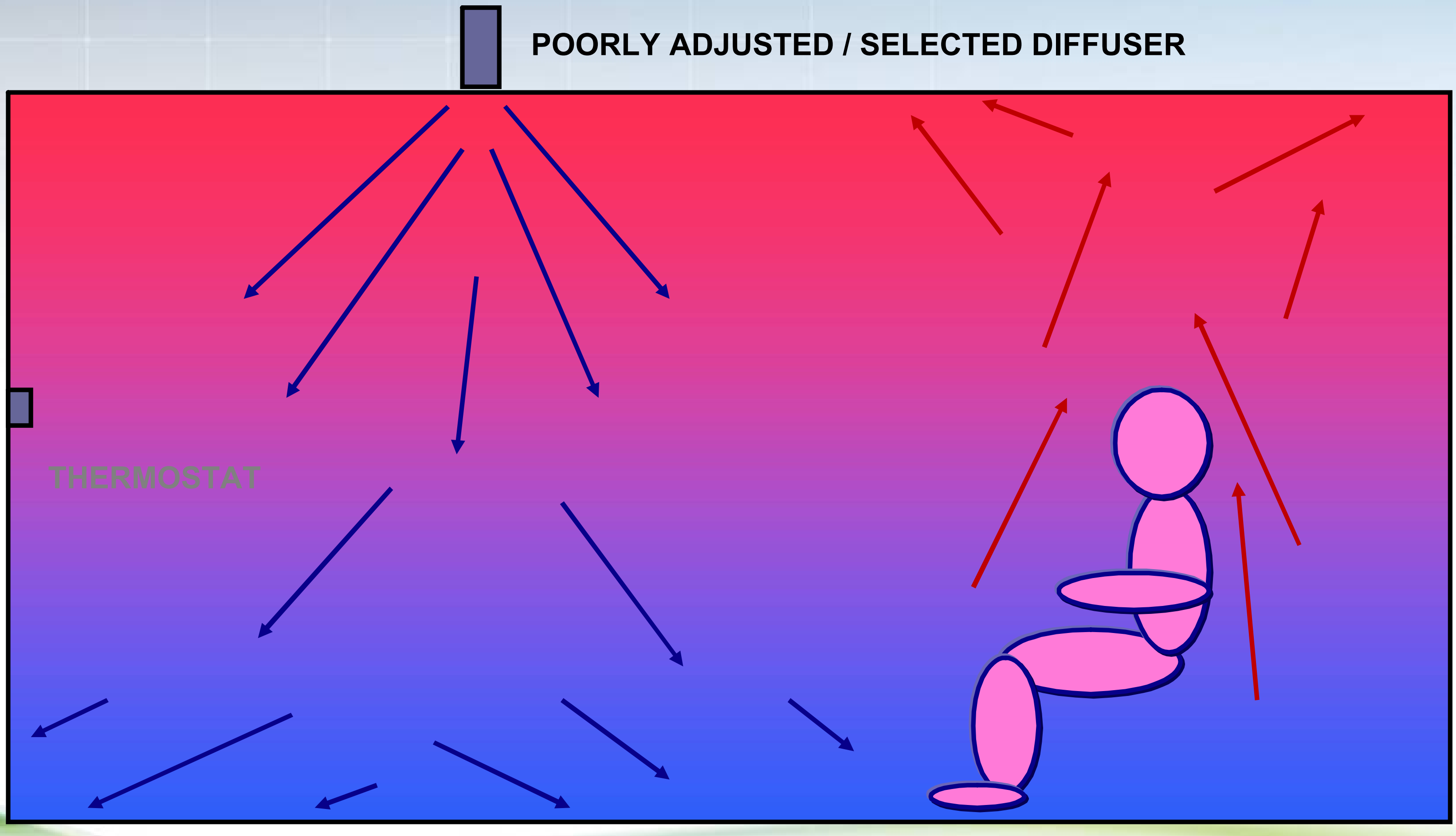
- The ASHRAE fundamentals handbook, chapter 20 (Air Distribution), provides guidance on several methods of air distribution.
- Methods include overhead fully mixed, as well as fully stratified and partially mixed systems from below, and even task /ambient personal air delivery systems.
- Described delivery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

Well Mixed Overhead Air Distribution

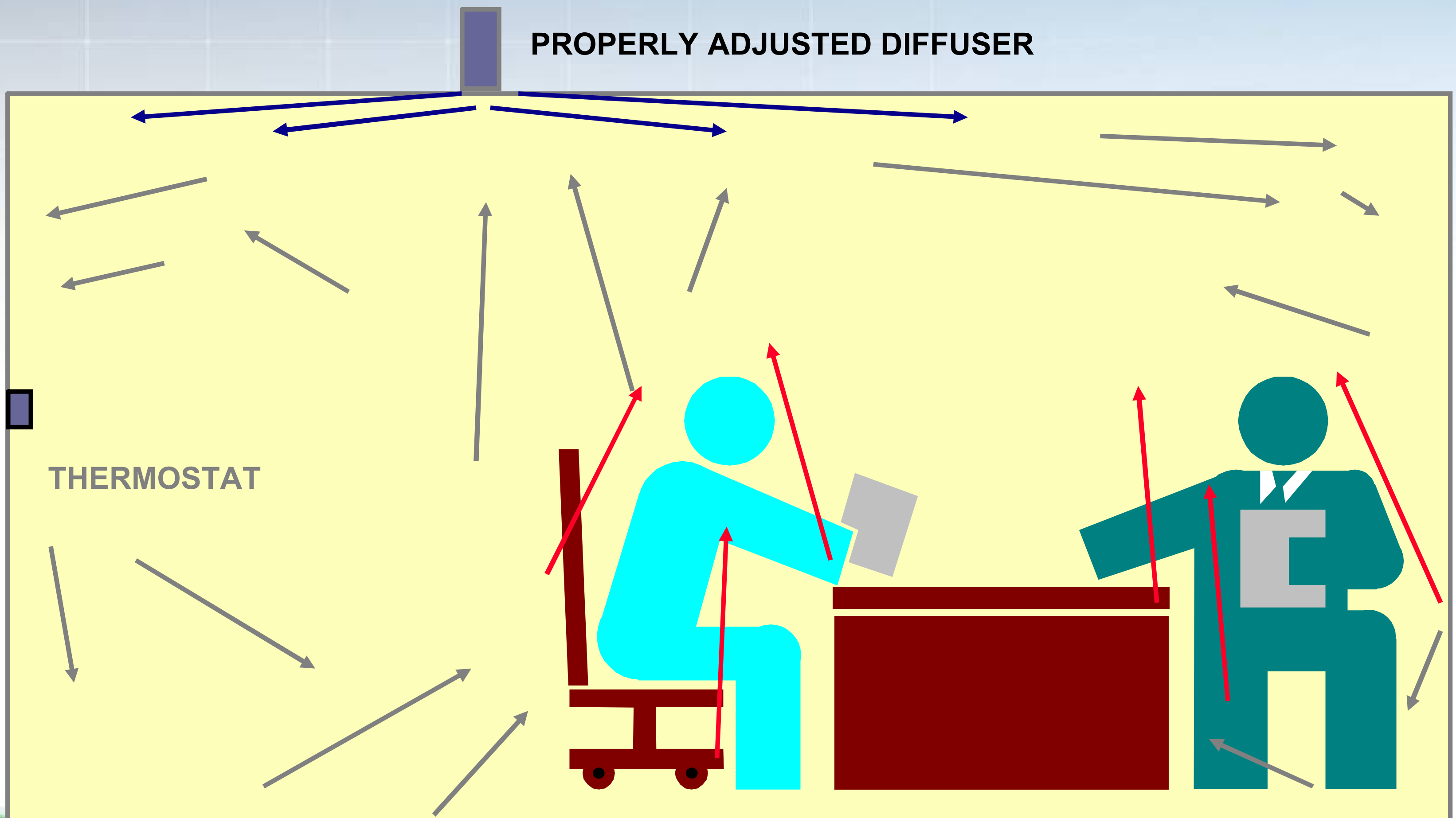
Air Distribution Device Selection Guidelines

- For overhead well mixed systems, one should select a unit with throw at max, and minimum, flow that meets ADPI guidelines based on diffuser spacing and T50 (throw to 50 fpm).
- Additionally, select for maximum mixing:
  - Noise can be good.
  - Dirt on the ceiling is not bad.
- Air Distribution Effectiveness (ADE) is a new term describing room air mixing, and is a parameter with all delivery methods.

Improperly Selected Overhead Air Distribution



Effective Overhead Air Distribution



ASHRAE Journal, 2004, on overhead air distribution selection

Design Issues:

- •Diffuser Selection
- •Perimeter
- •Thermal Comfort
- •Acoustics
- •Ventilation & IAQ

Protection Against Liability For Poor Diffuser Selection

By Daniel Int-Hout III, Member ASHRAE

The manner of achieving an acceptable Air Diffusion Performance Index (ADPI) has been well understood for more than 20 years. Unfortunately, complaints of discomfort abound. It is not uncommon for building occupants who work in the same space to complain that they are "too hot" and "too cold."

Many unconventional designs and new technologies have been used to correct this apparent problem, including displacement ventilation, underfloor pressurized plenum air distribution, occupant task conditioning systems, etc. While all of these strategies assume that conventional overhead air distribution is unable to provide acceptable environments, this appears to be a false premise.

According to data and to technical papers as early as 1976, given a properly selected set of overhead ceiling diffusers, and an HVAC supply system capable of meeting the loads in the space, it is possible to devise a system of either VAV or constant volume air distribution that can respond to variations in localized loads from 20% to 100% of designed maximum loads at a variation in space temperature that most occupants will not notice.[1] This same system also will provide a ventilation effectiveness of 100% (all the ventilation air supplied at the ceiling will be delivered to the occupants). Heating performance with ceiling located diffusers also is well documented.

Int-Hout

So why are building occupants complaining they're uncomfortable? The likely culprit is improper diffuser selection,[2] which can lead to a number of problems. The first is "dumping." At low airflows, diffuser velocities may not be high enough to create the "Coanda effect" necessary to overcome the negative buoyancy of the cold air being discharged. This causes cold air to drop into the space. As a result, it's cold under the diffuser, warm at the midpoint between diffusers, and cold air puddles at the floor creating a vertical stratification in the space. Another problem occurs at very high airflows. Jets collide at the midpoint between diffusers, causing cold airstreams to drop into the space (where it was hot earlier). The increased induction at the recently cold spot under the diffuser now creates an upflow, warming that location.[3]

At the perimeter (where closed executive offices often are located) even worse things can happen. In winter, air is being discharged at 15% of cooling velocities at discharge temperatures of 105°F (41°C).[4] Since the warm jet has too much buoyancy and too little projection to mix with cold air that will spill down the window, there will be an 8°F to 10°F (4.4°C to 5.6°C) temperature difference between 6 in. and 6 ft (0.1 m and 1.8 m) from the floor in the middle of the room (contrary to the minimum requirements of ASHRAE Standard 55, *Thermal Environmental Conditions for Human Occupancy*). In summer, heat rising from the window stratifies at the ceiling. Cold air from the diffuser, which is often set to blow down,[5] stratifies at the floor. In both cases, at 43 in. (1.1 m) above the floor, where the thermostat is located, it is 75°F (24°C).

Problems like these can lead to liability and exposure. Here are just a few examples. In a Baltimore condominium complex with two-story living rooms, the designer supplied air from the ceiling. Since the air was too hot in cold weather, it stratified at the ceiling, resulting in a temperature of 50°F (10°C) at the ankles and 80°F (27°C) at the head. The condominium owners sued the engineer. The case was eventually settled, but not until after the engineer incurred fees and costs for attorneys and experts. A similar problem occurred in a one-story bank in Pennsylvania. This time, the case went to trial and the jury returned a sizeable verdict against the engineer. The expert witness fees alone exceeded the amount in issue in the lawsuit.

Improper diffuser selection can also lead to problems for owners. For example, in an office building in New Jersey, a tenant successfully broke its lease after complaining about comfort problems relating to ceiling diffusers. Indeed, according to the Building Owners and Managers Association, thermal comfort related issues (often misdiagnosed as IAQ problems) were the No. 1 reason for non-renewal of leases in 2002.

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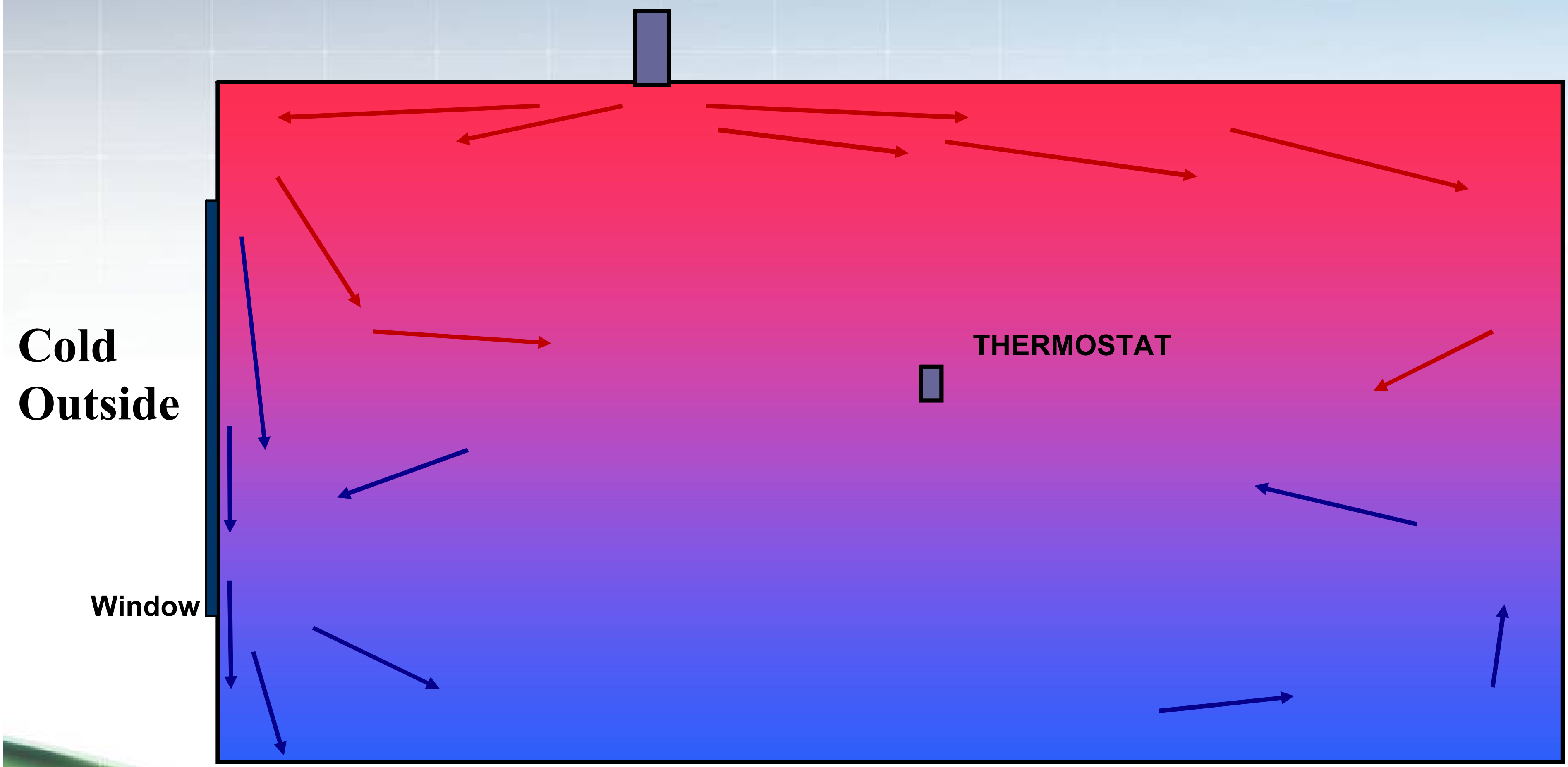
Common Overhead Heating Design



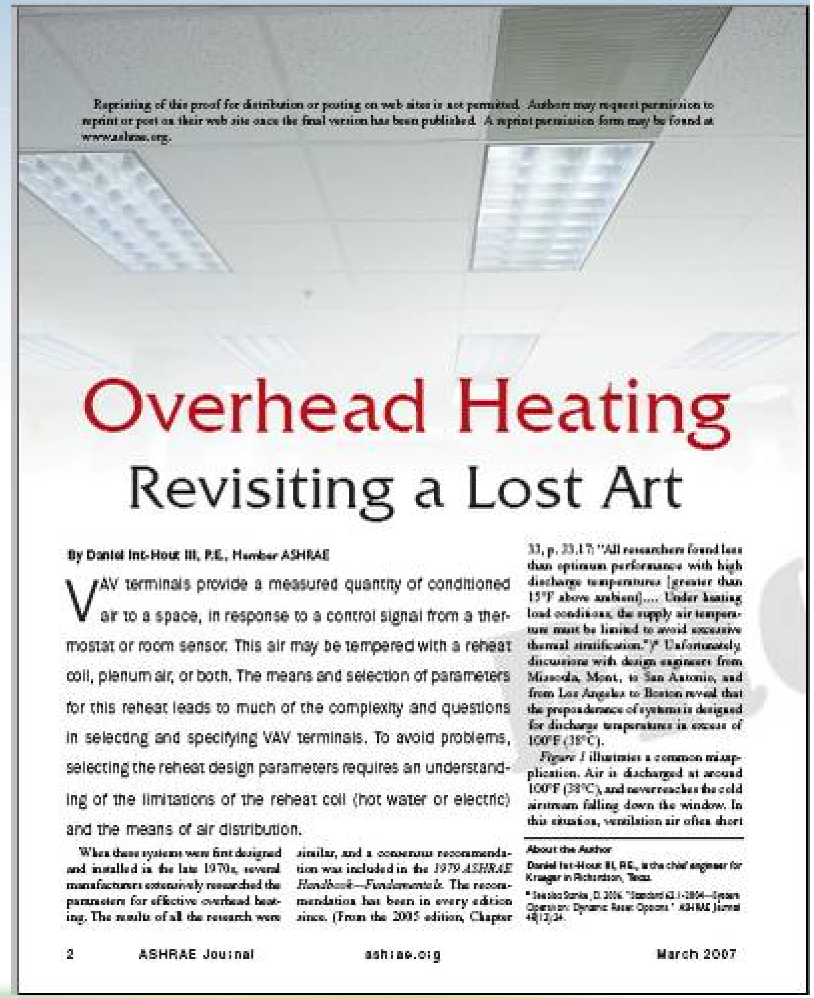
Overhead Heating Perimeter Considerations:

- Maximum delta-t for effective mixing when heating from overhead, per ASHRAE handbook = ?.
- = 15°F (90°F discharge), continuous operation.
- Throw toward and away from glass.
- 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.
- Typical perimeters require only 8°F Delta-t

  @ 1cfm/sq.Ft.

Perimeter Considerations:

See March 2007 ASHRAE Journal:



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

Overhead well mixed Air Distribution - Pros and Cons

Pros:

- Baseline of 90.1 Energy – well documented energy calculation programs
- ADPI can be predicted to validate 55 Vert. stratification
- Well understood construction details
- Heating and cooling commonly accomplished with single system
- Low cost for reconfigured spaces

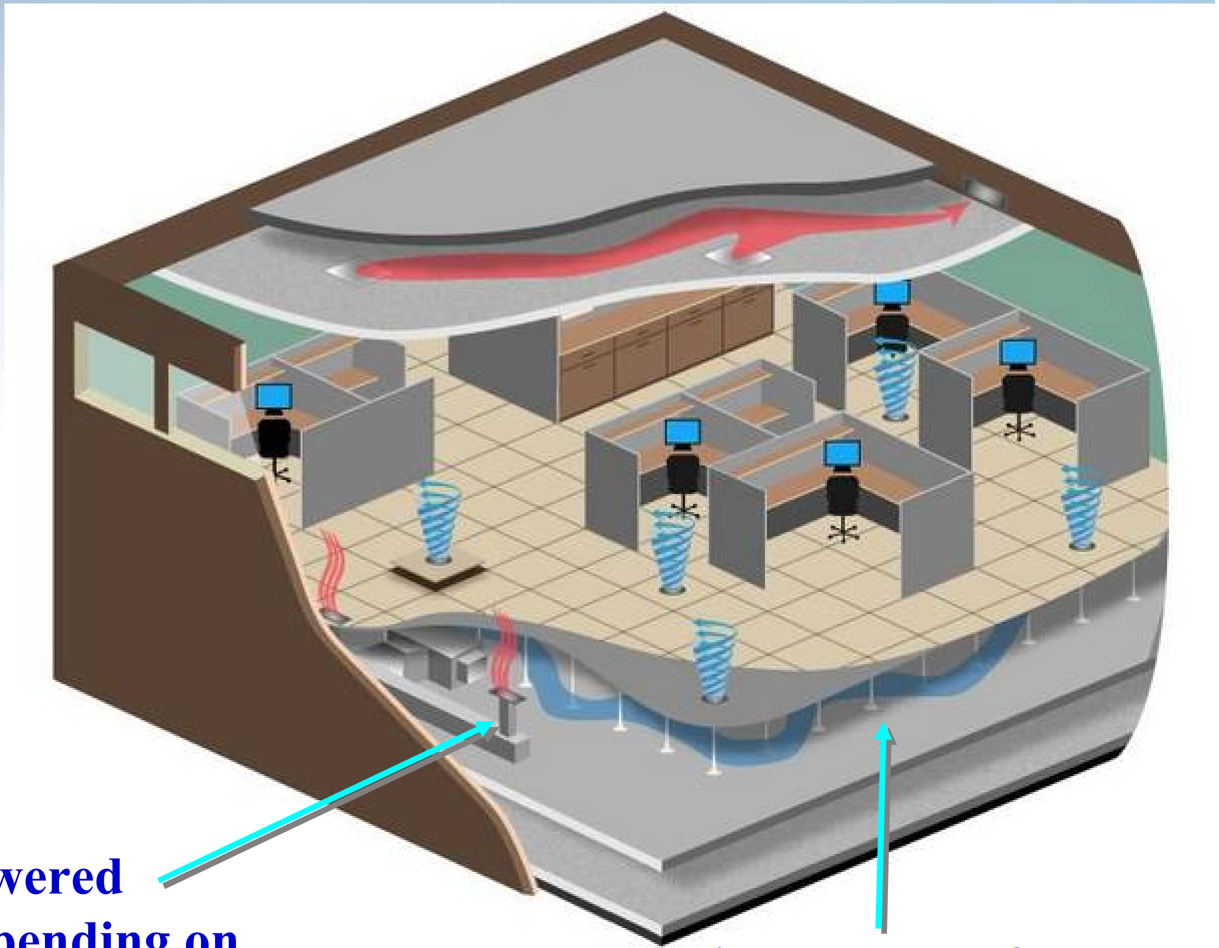
Cons:

- Difficult (but possible) to guarantee 30% more efficient than 90.1
- Ventilation is shared by all
- System acoustics may be objectionable if not carefully designed
- It’s ”Old School”.

UFAD
Underfloor Air Distribution

UFAD: Underfloor Air Distribution

- A raised floor allows electrical and communication circuits to be easily accessed and changed.
- Air may be distributed within this space, without ductwork.



Ducted perimeter with fan powered boxes, or other techniques, depending on climate, glass load, etc..

Pressurized plenum for core

Interior Outlet Selection – 1/workstation

Perimeter outlet selection

- Perimeter solutions vary considerably
- Avoid condensing coils under the floor
- Hydronic coils often leak
- Exhaust at the perimeter to draw heat away
- Best solutions seem to be heat and cool from overhead

UFAD –
Pros and Cons

Pros:

- Potential to save energy due to reduced fan static and higher discharge temperatures
- Silent operation, less than 30 NC
- Relatively simple controls needed
- Occupant control of local environment
- Lowest Churn costs with raised floor
- No Validated Energy Modeling programs

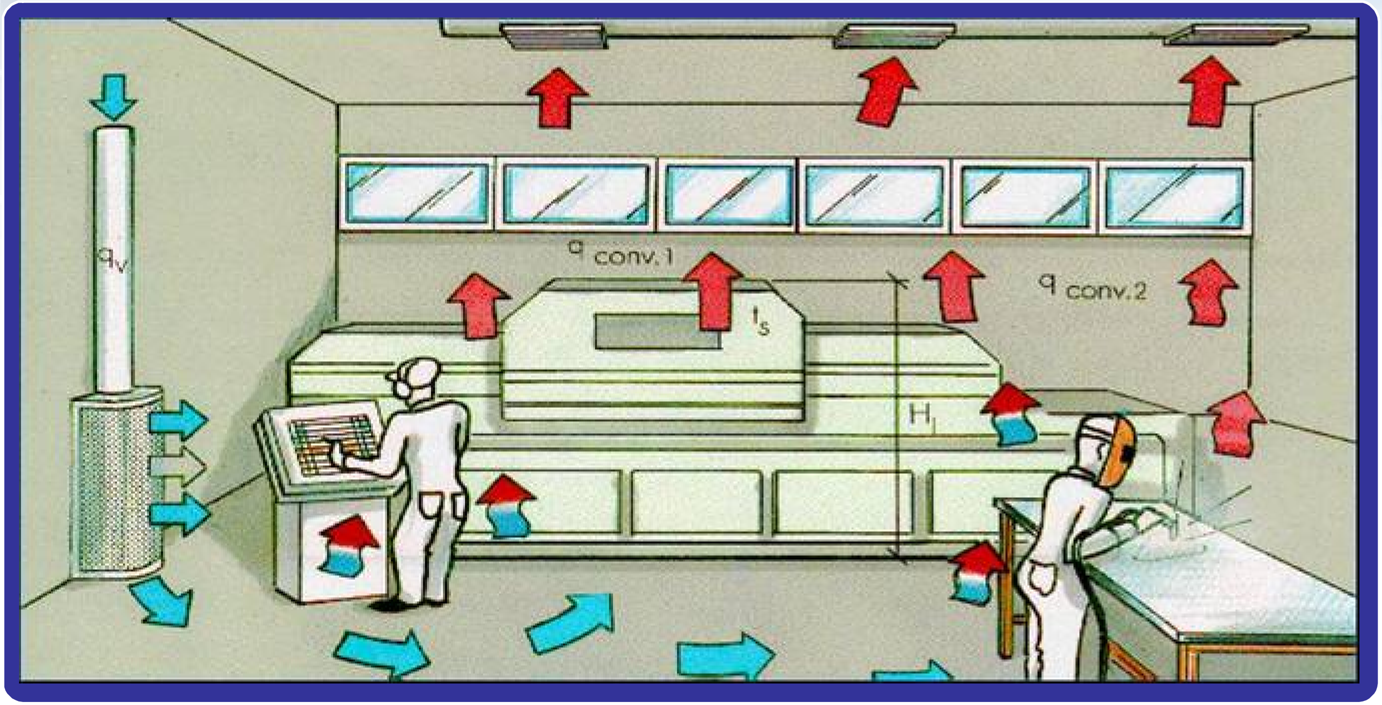
Cons:

- No ASHRAE 55 Vertical Temperature Stratification calculation method (yet!)
- Requires careful building construction to avoid leakage
- Special consideration required in humid climates
- No Validated Energy Modeling programs

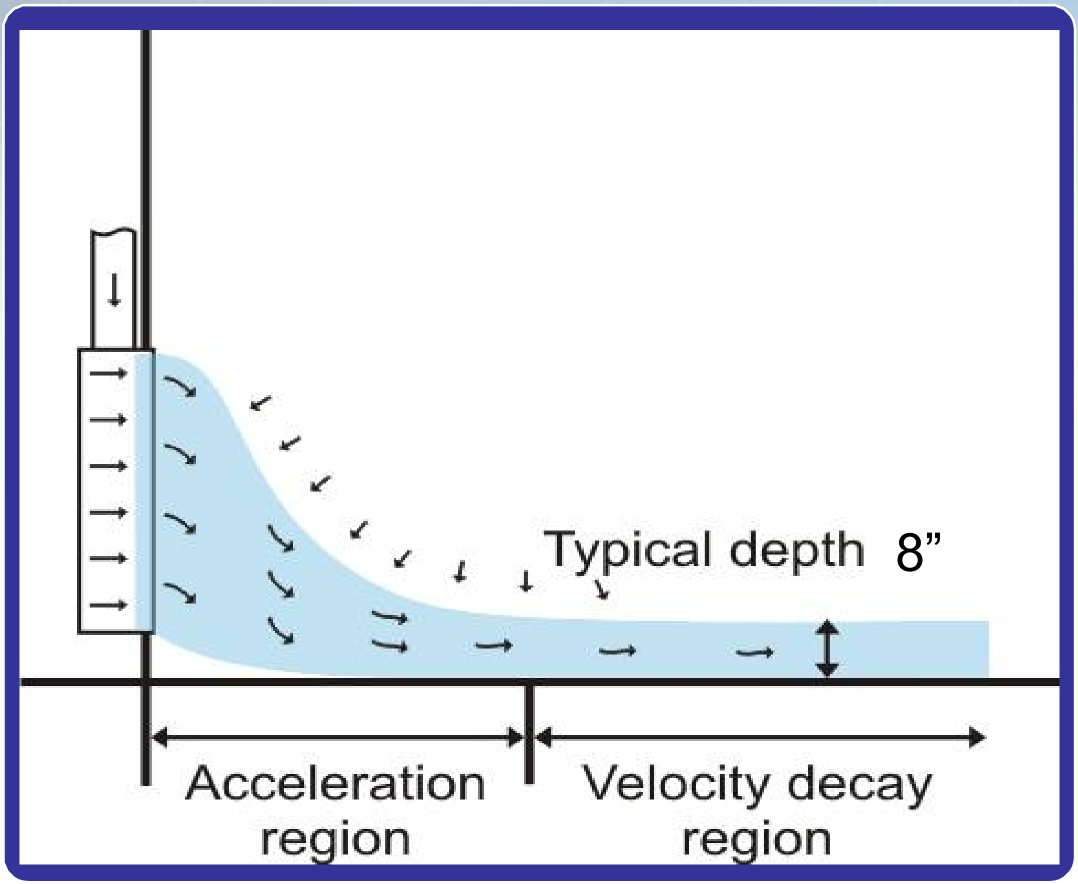
Displacement Ventilation

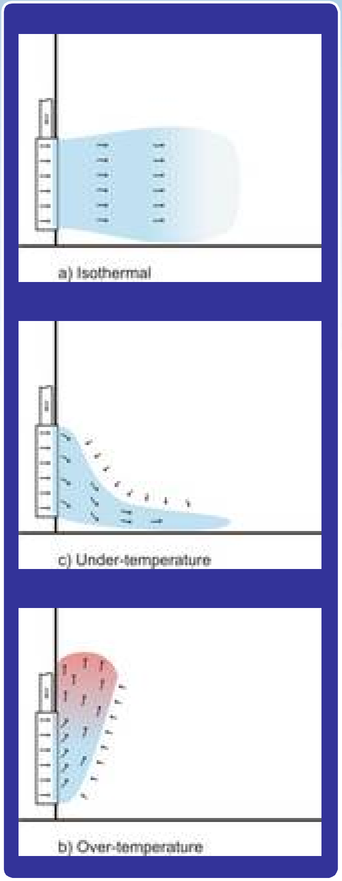
Displacement Ventilation System

- Thermal displacement ventilation is based on cool air supply at low level and stratification of room air temperature and contaminants due to natural buoyancy forces of the heat gains.



Select based on ”near zone”





Applications

Classrooms
Kitchen
Restaurant
Auditoriums
Atriums
Gyms
And more…

Displacement Ventilation – Pros and Cons

PROS

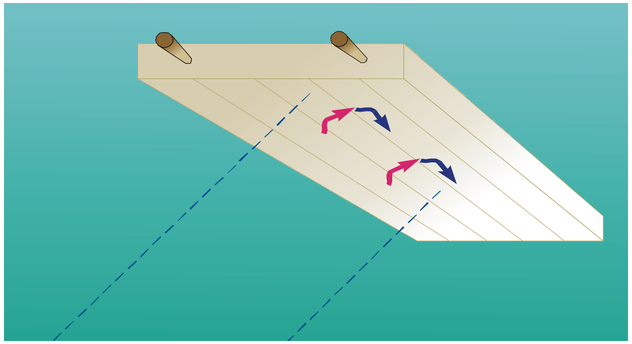
- Less cooling energy may be needed
- Longer free-cooling period, depending on climate because of lower discharge temperatures
- Better air quality / reduced outside air requirement
- Quiet – excellent for classrooms
- Energy Calculations not validated

CONS

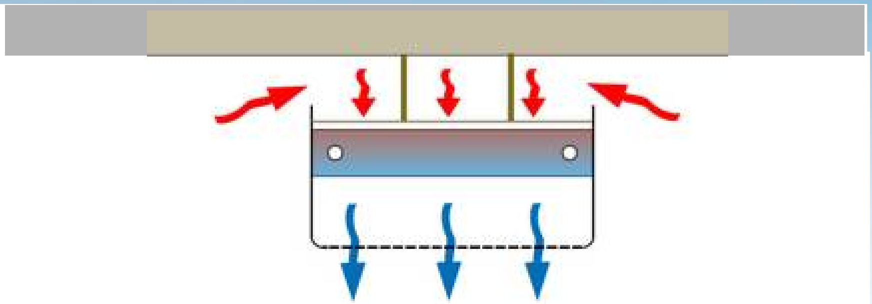
- No advantage if the ceiling height is < 10 ft
- Draft risk near units; velocities should always analyzed
- Enough space for units should be available
- Separate heating system required if exterior walls aren't well insulated
- Must use CFD or other method for vert. Temp. validation.
- Energy Calculations not validated

Chilled Beams

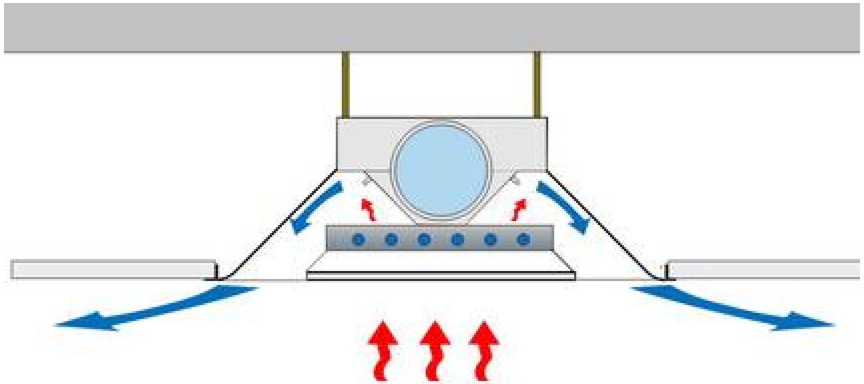
Chilled ceiling systems



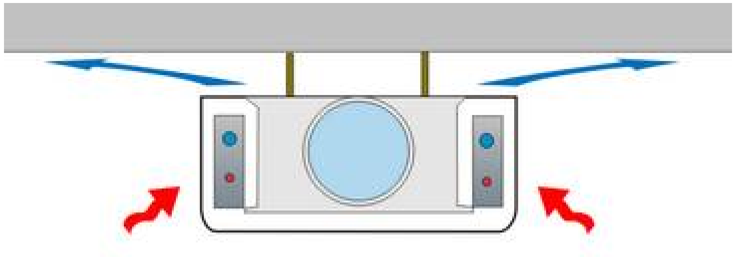
Chilled ceiling



Passive chilled beam



Suspended Ceiling Active chilled beam

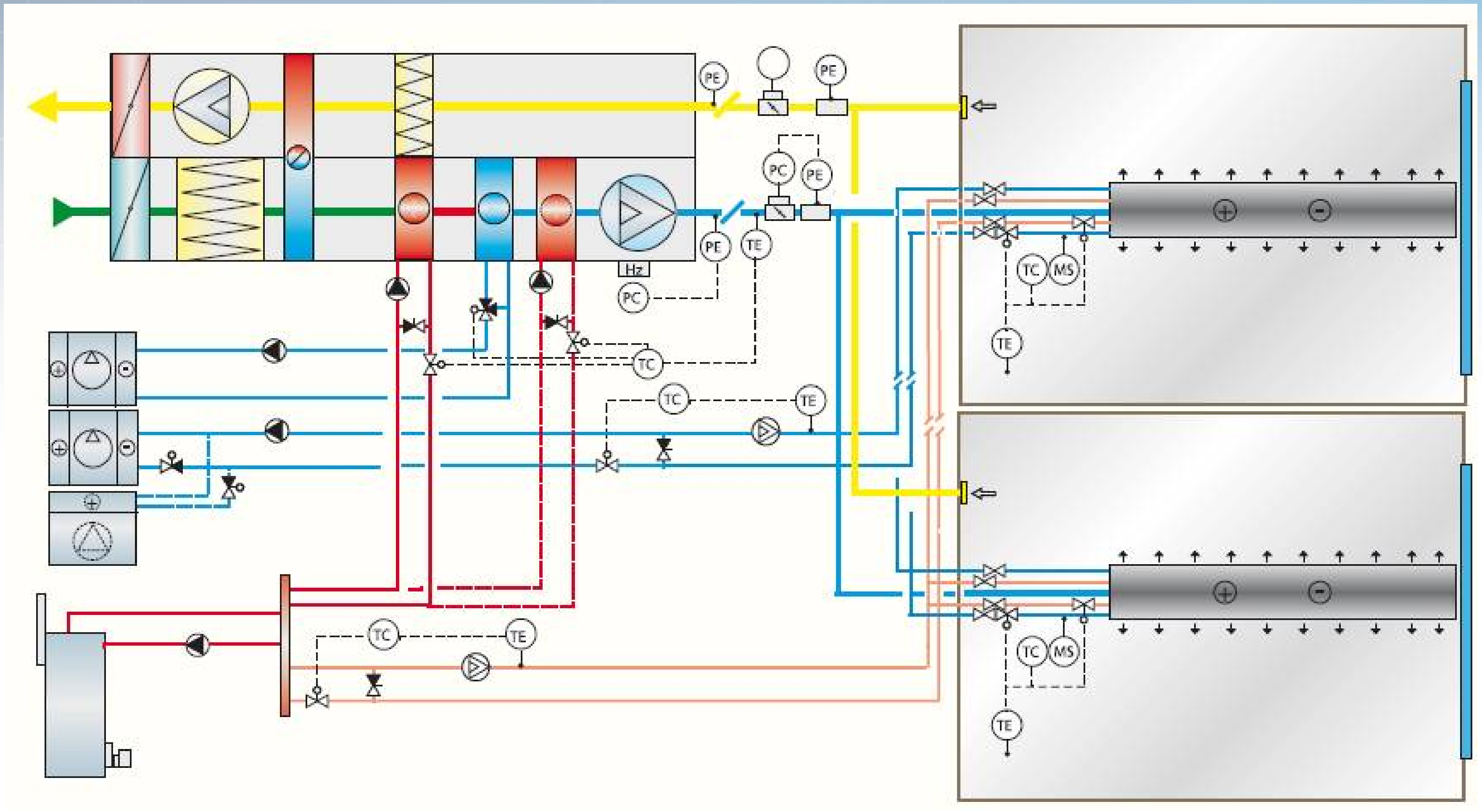


Exposed Active Chilled Beam

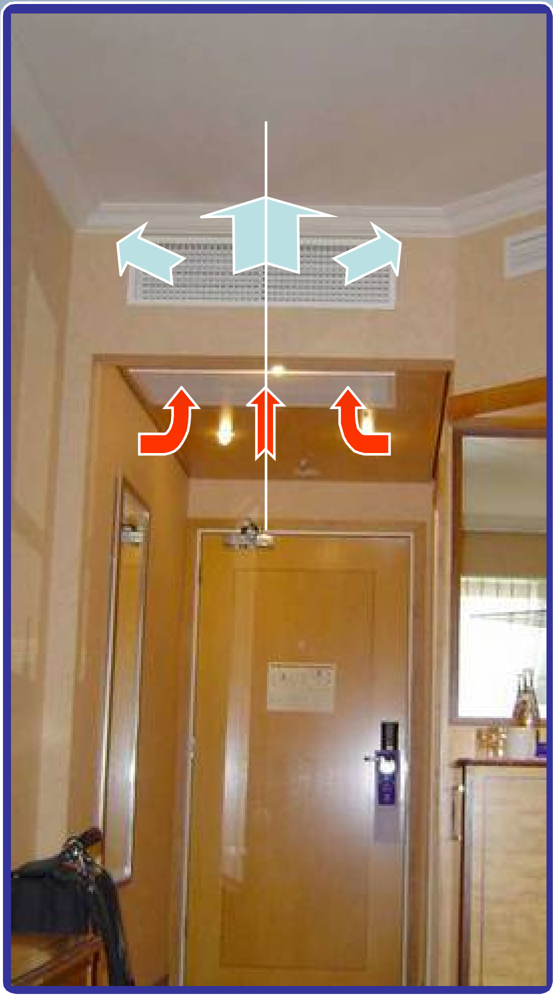
Active Chilled Beams

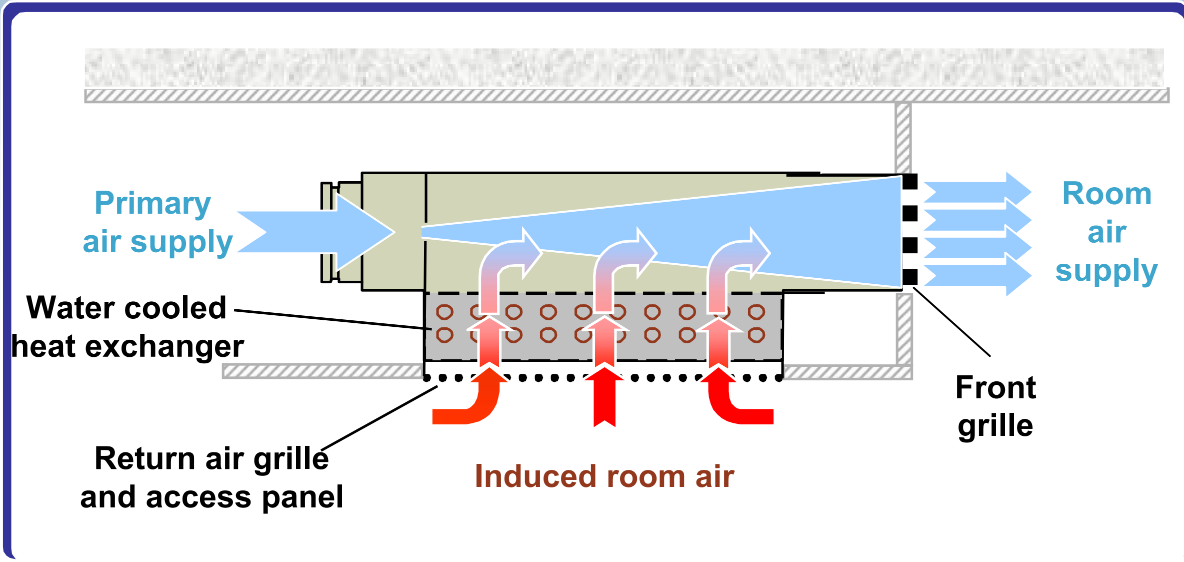
- Remember – they are still diffusers
- The same selection rules apply as for other slot diffusers
- Selecting for maximum capacity reduces cost but raises possibility of reheat at part load
- Beams have limited capability in perimeter applications with poor building evnelopes.

Schematic Diagram of a Chilled Beam System



Beams in Hotel Rooms





Chilled Beams – Pros and Cons

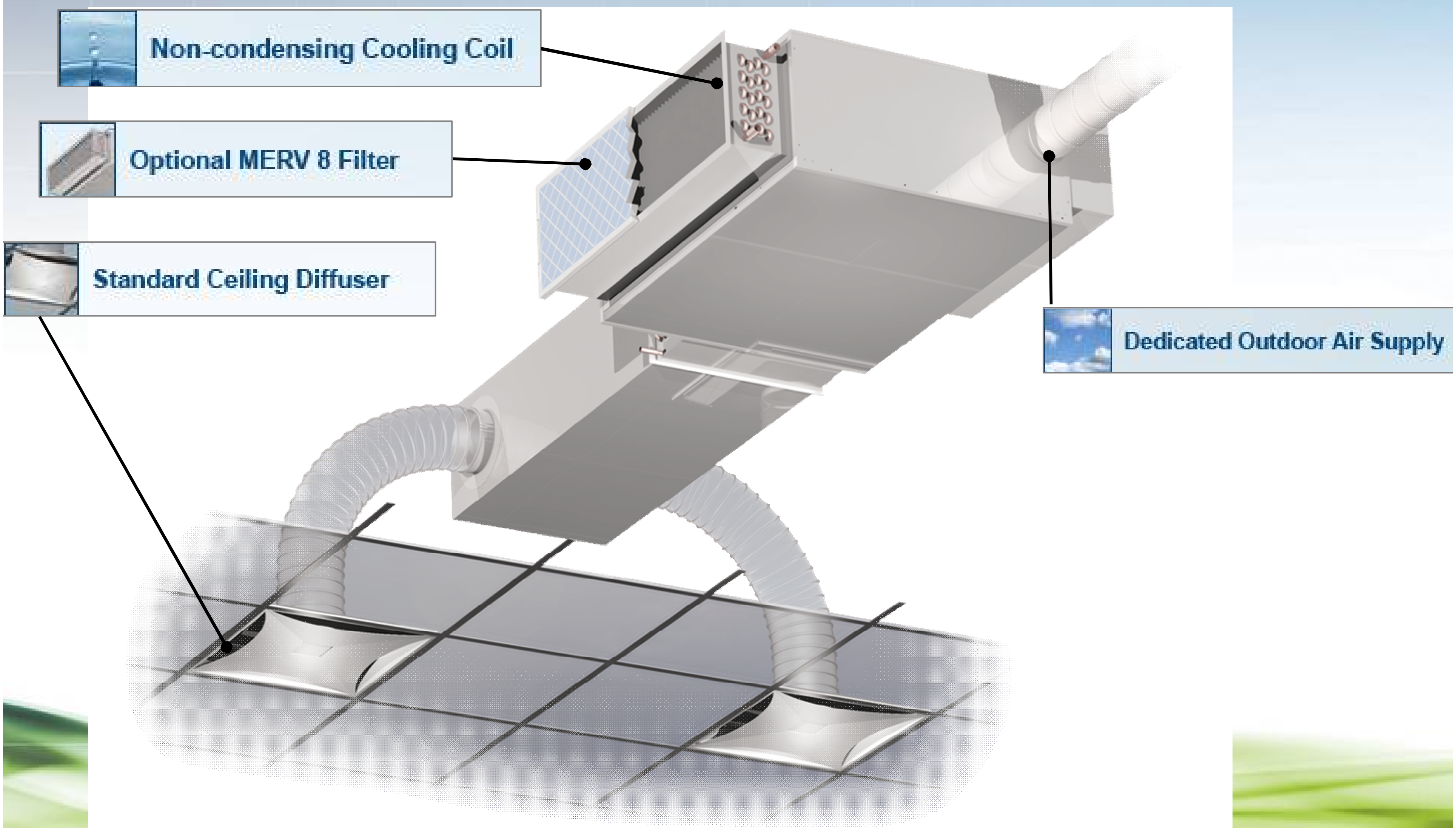
Pros:

- Potential to save energy – For example: To transfer 1 ton of energy with water consumes much less electricity compared to air.
- Low velocities in occupied space, less than 50 fpm
- Silent operation, less than 30 NC
- Lower units save plenum space, may reduce floor-to-floor height
- Radically smaller ductwork – lower fan energy required
- Relatively simple controls needed
- Few (any?) validated energy modeling programs

Cons:

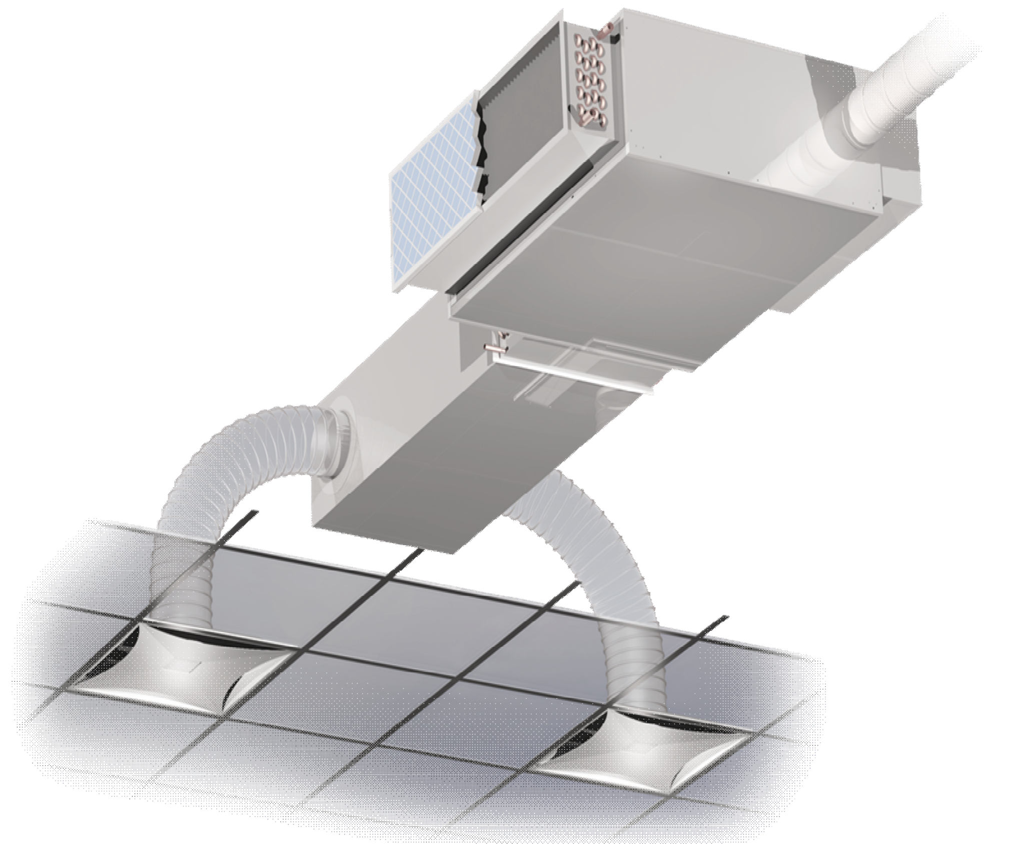
- Requires Excellent Building Curtain Wall Construction to control Condensation, especially in humid climates
- High First equipment and installation costs
- No ASHRAE 55 Vertical Temperature Stratification calculation method (yet!)
- Few (any?) validated energy modeling program

Plan B: The Chilled Fan Box



Chilled Fan Box Summary – Complement to CB

- Increased air distribution flexibility
- Uses same mechanical system as CB
- Complements CB by addressing challenging applications
  - Atria
  - Lobby
  - High humidity locations
  - Higher skin loads
- Minimal Contractor Training
- Guaranteed Performance



Summary

Zero Net Energy Buildings

- ZNEB is a goal that both ASHRAE and the USGBC have set.
- Failure to understand the physics of room air distribution with the different systems now available may, however, result in "ZNAB" – Zero Net Acceptable Buildings.
- We need to understand the pros and cons of the various means available to provide for occupant comfort.

Net Zero Energy Building

Summary

- LEED 2009 (V3) requires meeting Standard 62.1
- ADPI can assure compliance to 55 in the design phase, but only for overhead systems in cooling mode.
- Reheat needs to be carefully considered in terms of discharge temperatures and velocities.
- Acoustics should be specified as maximum allowed octave band sound power.
- DV, UFAD and Beams can supply quiet air in classrooms
- Software is available to assist in selecting the best mix of products.
- Energy Use Calculations of alternate systems needs to be validated.
- The rules are dynamic - pay attention.

Contact

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