UFAD and Displacement Ventilation

Dan Int-Hout, FASHRAE
Chief Engineer
Krueger
Richardson, Texas

KRUEGER
Excellence in Air Distribution

UFAD and DV Systems, Objectives:

- Understand Differences between: Well Mixed, Partially Stratified and Fully Stratified Air Distribution
- What is Displacement Ventilation (DV)?
- What is Underfloor Air Distribution (UFAD)?
- Why are we considering these alternate systems?

LEED and 90.1

- An objective in LEED NC V3 is to design buildings 30% better than the base line system in 90.1
- The 90.1 base line is VAV overhead, well mixed systems.
- Architects are challenging Mechanical Engineers to come up with designs that meet this goal.
- The actual challenge is in predicting energy consumption with advanced HVAC systems, where there are no proven energy models.

LEED and 90.1

- The long term goal is to provide buildings that are “ZNEB”: Zero Net Energy Buildings.
- While an admirable goal, there is a risk that the building occupants will suffer as a result. Recent surveys all show occupants are typically dissatisfied with the environment we engineers are providing.
- The result, if we are not careful, is likely ZNAB: Zero Net Acceptability Buildings.

Differences between: Well Mixed, Partially Stratified and Fully Stratified Air Distribution:

- **Well Mixed: Overhead air distribution. Temperatures are uniform throughout the space.**

- **Partially Mixed: (UFAD) Air is delivered vertically from the floor with short throw, high mixing rate diffusers. Temperatures are stratified above 6’ from the floor. (Note this is not Displacement Ventilation).**

- **Fully Stratified : (Displacement Ventilation) Air is supplied horizontally at the floor at very low velocities and delta-t’s. Temperatures are stratified throughout the space.**

What is Displacement Ventilation?

Fully Stratified Air Distribution

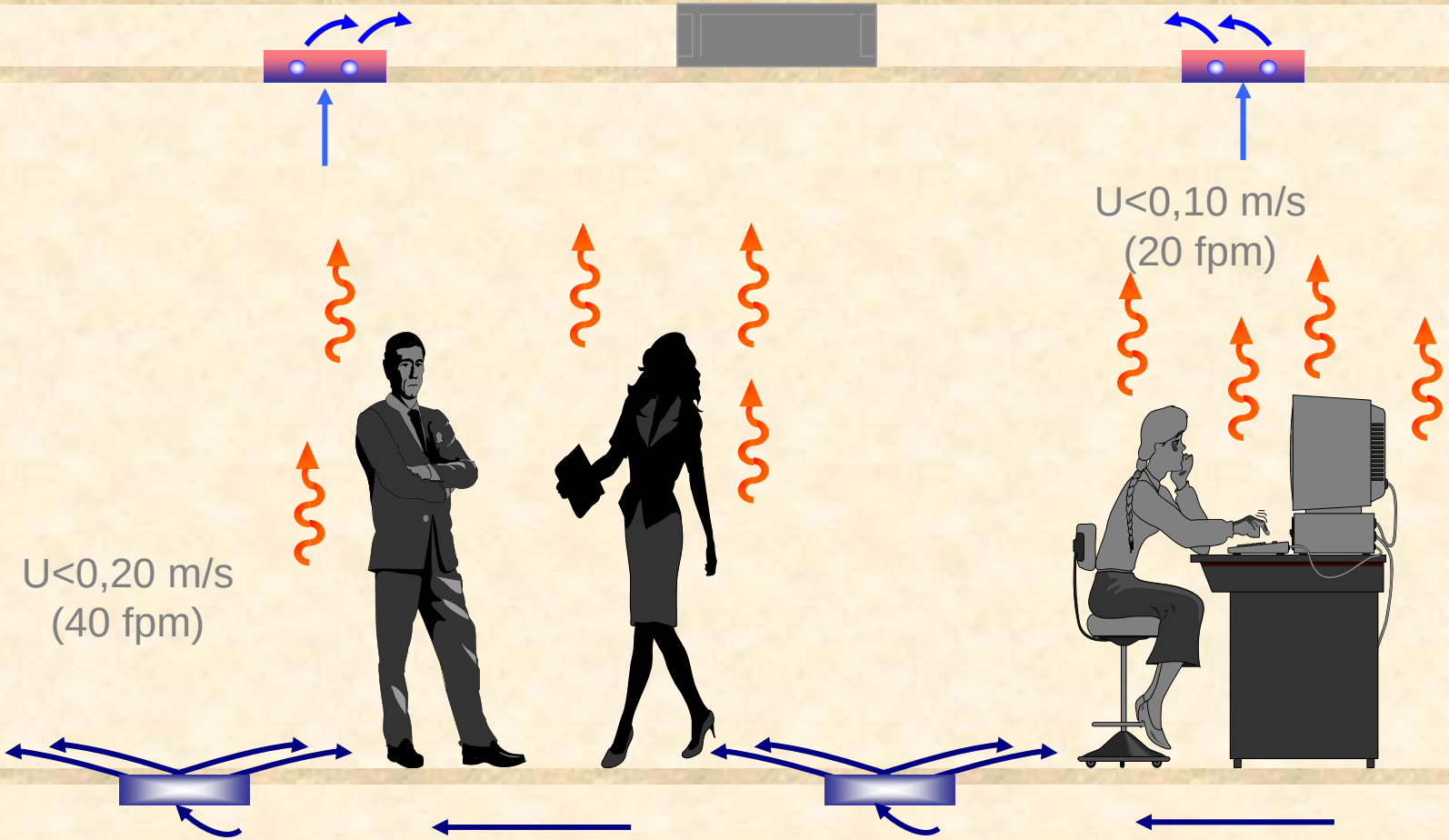
The basic concept:

- **Air is supplied horizontally at the floor at very low velocities and delta-t's (no colder than 65F).**

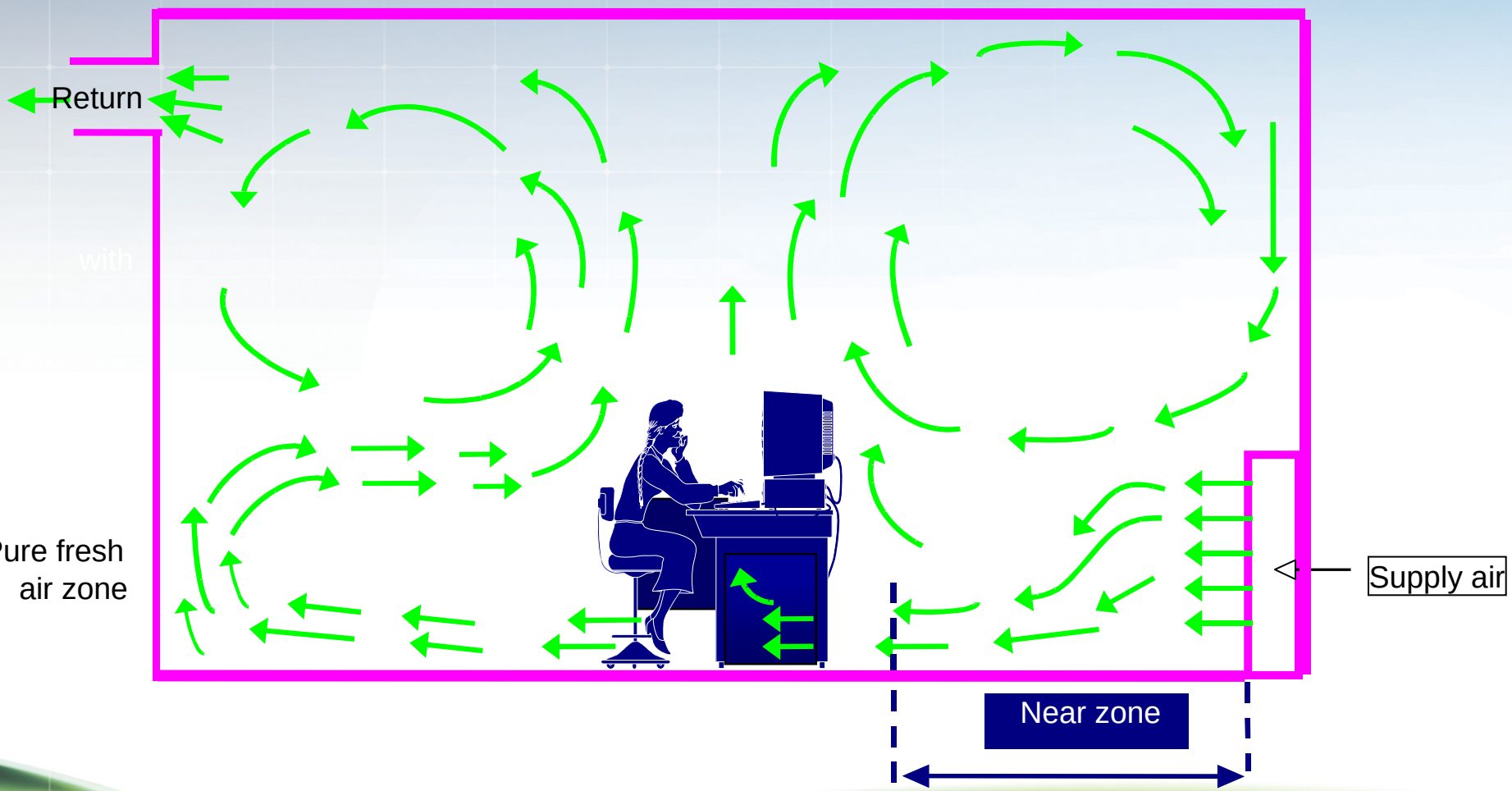
- **Temperatures are stratified throughout the space.**

- **The cool air at the floor is drawn to heat loads (people and equipment) by their vertically created convection currents.**

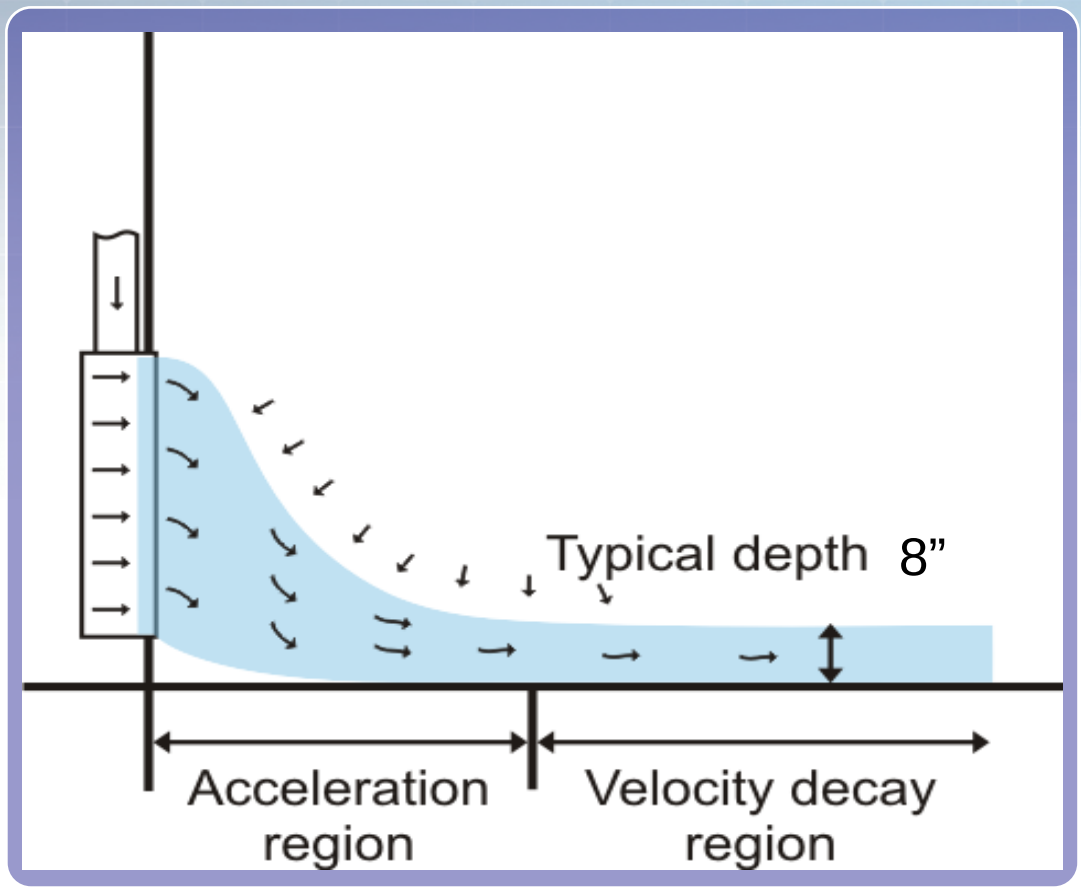
UNDERFLOOR AIR SUPPLY, Horizontal Mixing Diffuser (Displacement)

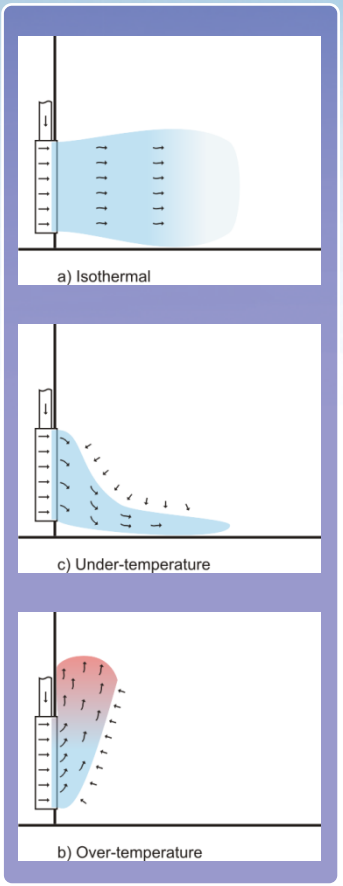


True Displacement Ventilation



Low velocity supply





Applications

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

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
- No ASHRAE 55 vert. temperature calculation method
- Energy Calculations not validated

UFAD
Underfloor Air Distribution

Why UFAD?

Follow the Money!

- Conventional HVAC Costs : $20-$30/sf
- Raised Floor Cost, Installed : $6-$12/sf
- Access Floor Air Delivery System (UFAD):
  - Passive System = $8-$10/sf
  - VAV system = $10-$12/sf
- UFAD May cover 1/2 or more of the raised floor costs.
- Significant tax breaks can be realized with UFAD (faster depreciation)
- Experience has shown that actual construction costs may be higher due to coordination issues with all the building trades involved.

What is Underfloor?

Building Design Elements

Key Design considerations:

- Underfloor plenum
- Perimeter heating
- Supplemental cooling
- Return air
- Humidity treatment
- Potential layouts

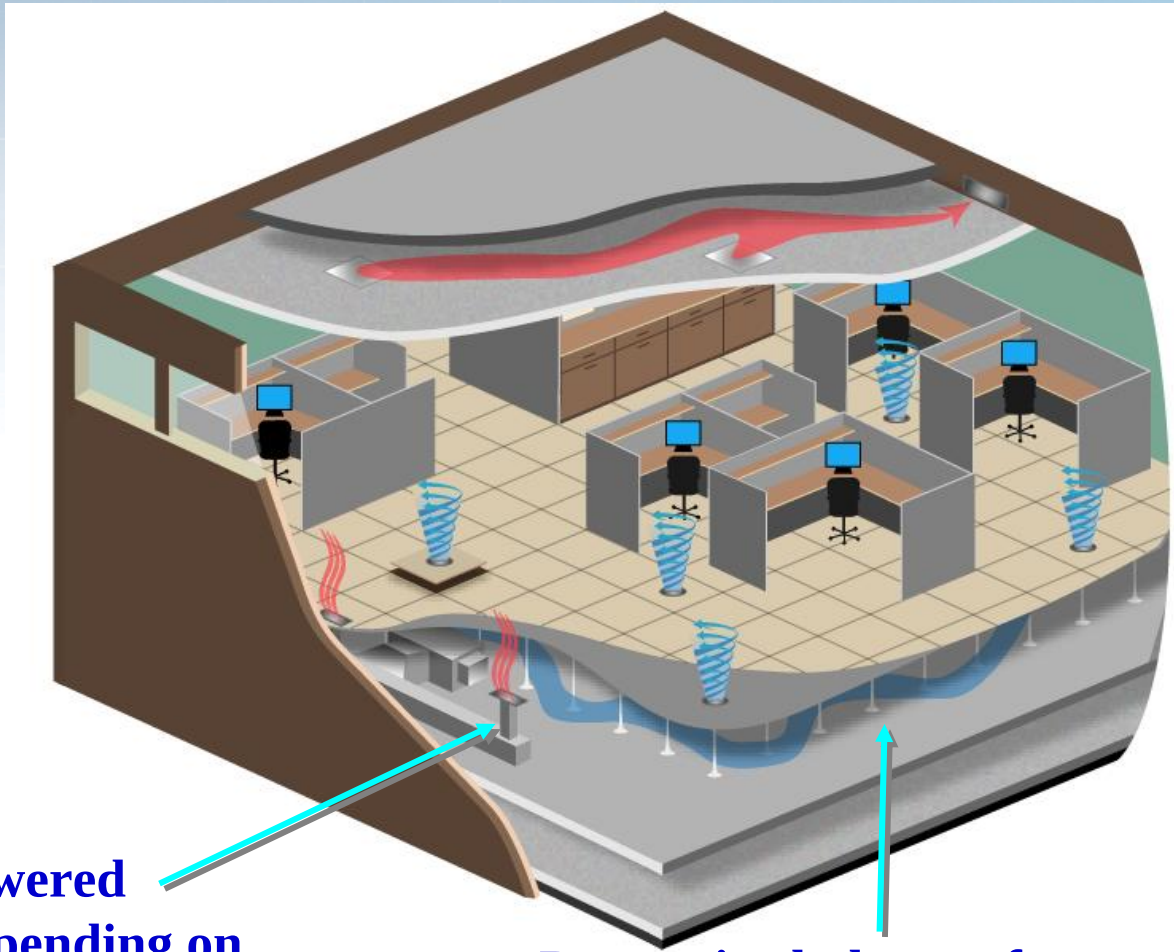
ASHRAE - Comfort Limits

- **Temperatures between 73^{o} - 77^{o} F**
- **Relative humidity between 25 - 60%**
- **Maximum velocity in occupied zone**
  - **50 fpm - Cooling**
  - **30 fpm - Heating**
- **Max temperature gradient from floor to 6’ is 5^{o}F**

courtesy: Amp Incorporated

What is this : The basic concept

- 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

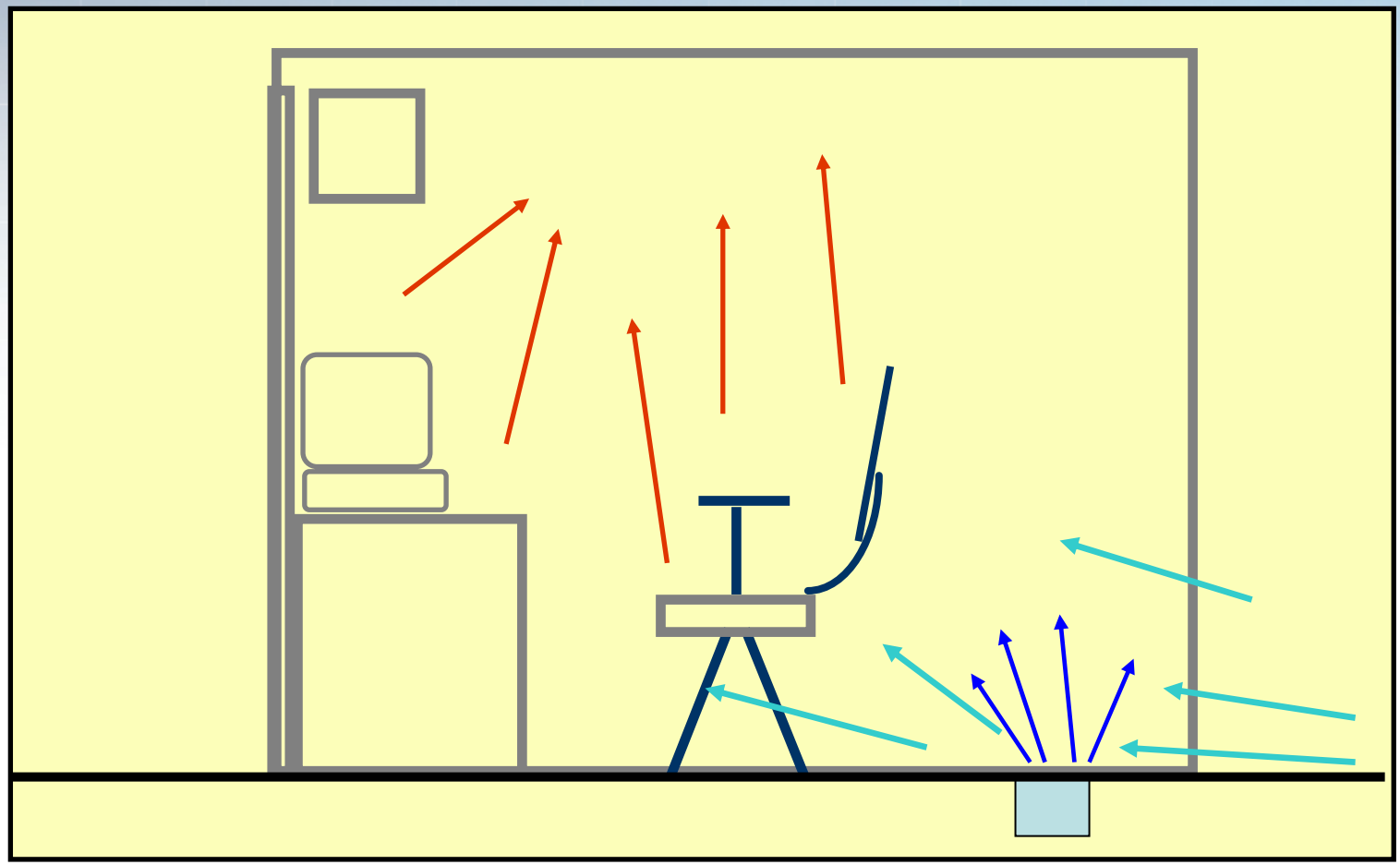
Underfloor Air Conditioning Concerns

- Cold feet
- Drafts
- Humidity control
- Pressure integrity
- Spot cooling demand
- Acoustics

One diffuser per workstation

- Typically, 80-100 cfm / diffuser
- About 1 cfm / Sq.Ft.
- Occupant controlled airflow

One Diffuser per Cubicle



How To Accomplish UFAD

Plenum Design Considerations

- Plenum size:
  - Dependent on the load of the space.
  - Typical plenum depth is 12” to 24, clear”. I recommend 15” minimum clear.
- Number of inlets (air supply to the plenum):
  - Dependent on plenum size and number of diffusers. 75’ to farthest diffuser, 50’ typical. 35’ may be the new rule.
- Zoning:
  - If zone control is desired, the plenum can be partitioned into zones.
  - Zones should correspond to building zones having similar load requirements.
  - Not always necessary and will make office layout changes more difficult.

Perimeter Heating

- Perimeter heating cannot be accomplished with the same system as the interior cooling system.
- Perimeter solutions are the same as in a conventional HVAC system:
  - Ducting of hot or reheated air.
  - Hydronic systems / WSHP’s.
  - Perimeter fan powered systems.
  - Radiant panels.

Perimeter Cooling

Perimeter solutions are the same as in a conventional HVAC system:

- Supply 62^{o}F underfloor air (depending on the load)
- Ducting of 55^{o}F air (if available)
- Perimeter fan powered systems with cold primary air
- Hydronic systems / WSHP's
  - Biggest concern is location of condensate pans!
  - Lowest point on the floor
  - Condensate pump reliability
  - Hidden failure mode

Return Air

- Located at ceiling
- Allows heat from ceiling light to be returned before it is able to mix with occupied zone.
- Small amount of “free cooling” due to the natural buoyancy of hot air.
- If 62^{o}-65^{o}F supply air is used, return air can be brought back to the air handling unit to be filtered and dehumidified.
- If 55^{o}F supply air is used for humidity or other reasons, return air can be mixed with plenum air to achieve 62^{o}-65^{o}F air.

Humidity Issues

- The biggest problem with warmer supply air temperatures is higher humidities.
- The supply system must reduce relative humidities to less than 60% to meet IAQ concerns.
  - Condenser water reheat, run-around coils, or return air face & bypass can be employed.
  - Use of a separate system to dry outside air or the use of desiccant dehumidification.
- One designer proposes to ventilate underfloor, cool and dehumidify from the ceiling.
- Hot and humid climates have special concerns. GSA reports significant condensation on cold slabs during the night.

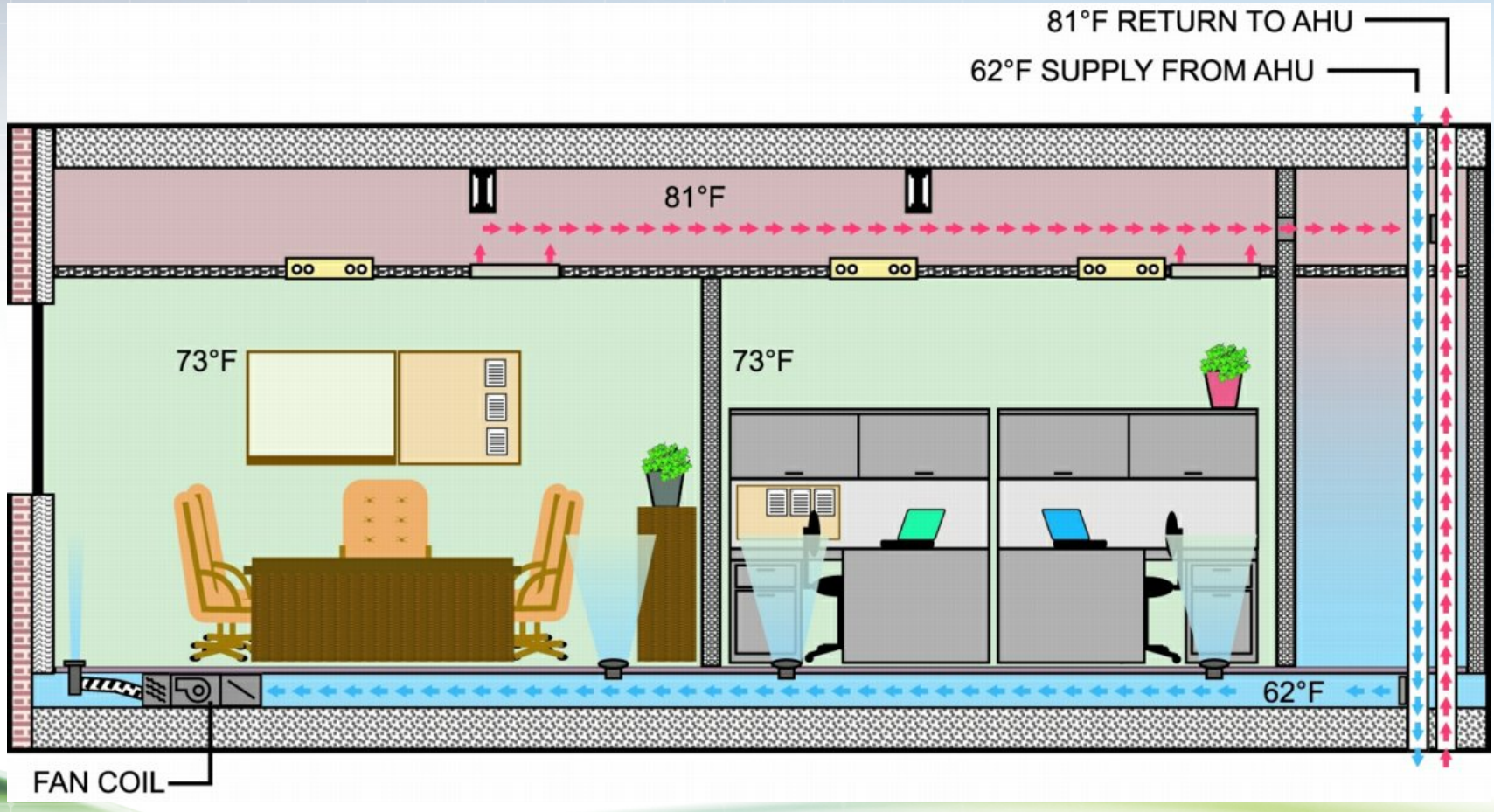
Possible A/H Design Scenarios:

- Plan A: air handler mixes return air with conditioned/dehumidified air to deliver 62-65^{o}F air to the space. Typically a “face and return air bypass” air handler, this is often a custom device (@$2.0-3.0/cfm).
- Plan B: conventional (55^{o}F) air handler, with local mixing near the zone. This is a conventional air handler (@$0./9-$1.2/cfm).

65ºF (Plan A) A/H Design Scenarios:

- Special Air handler to manage dehumidification with 65ºF air.
- VAV or CAV for interior pressure and temperature control.
- Supplemental in floor VAV diffusers / conference rooms.
- WSHP, fan coils at perimeter (typically heating only – see below).
- Cautions:
  - Condensate pans are at lowest point on a floor!
  - Disturbing stratification with high air flows.

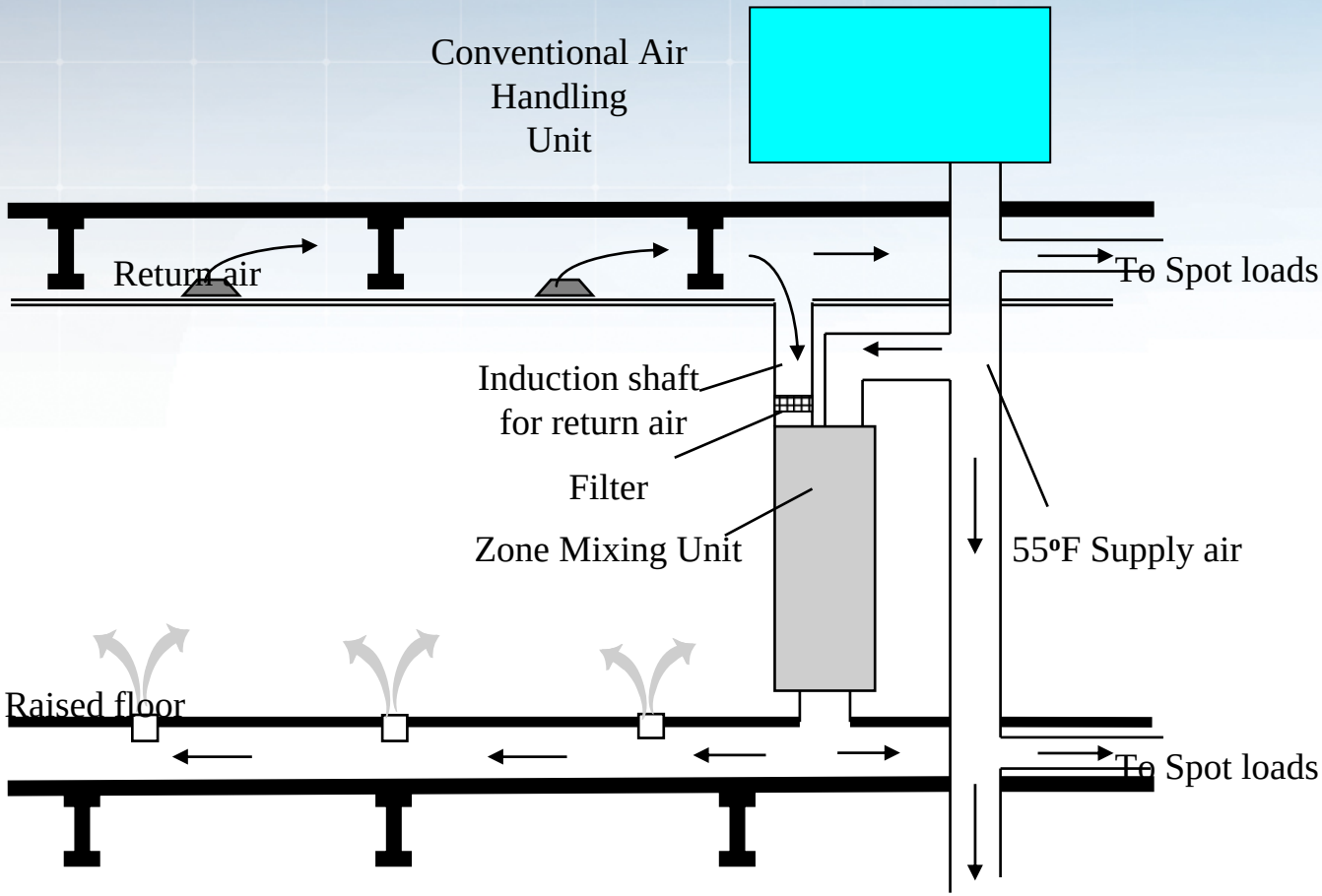
Typical Layout - 62ºF Supply (55ºF Wet Bulb)



Plan B - 55ºF Supply Design Scenarios:

- Conventional Air Handler
- VAV perimeter, underfloor series FPB interior,
- Dual duct with conventional air handlers and fan assisted returns.
- 20K CFM fan-driven (air column) mixing boxes
- Parallel air column fan powered boxes with ECM variable speed induction.

Plan B -
55ºF Supply with local mixing



Plan B -
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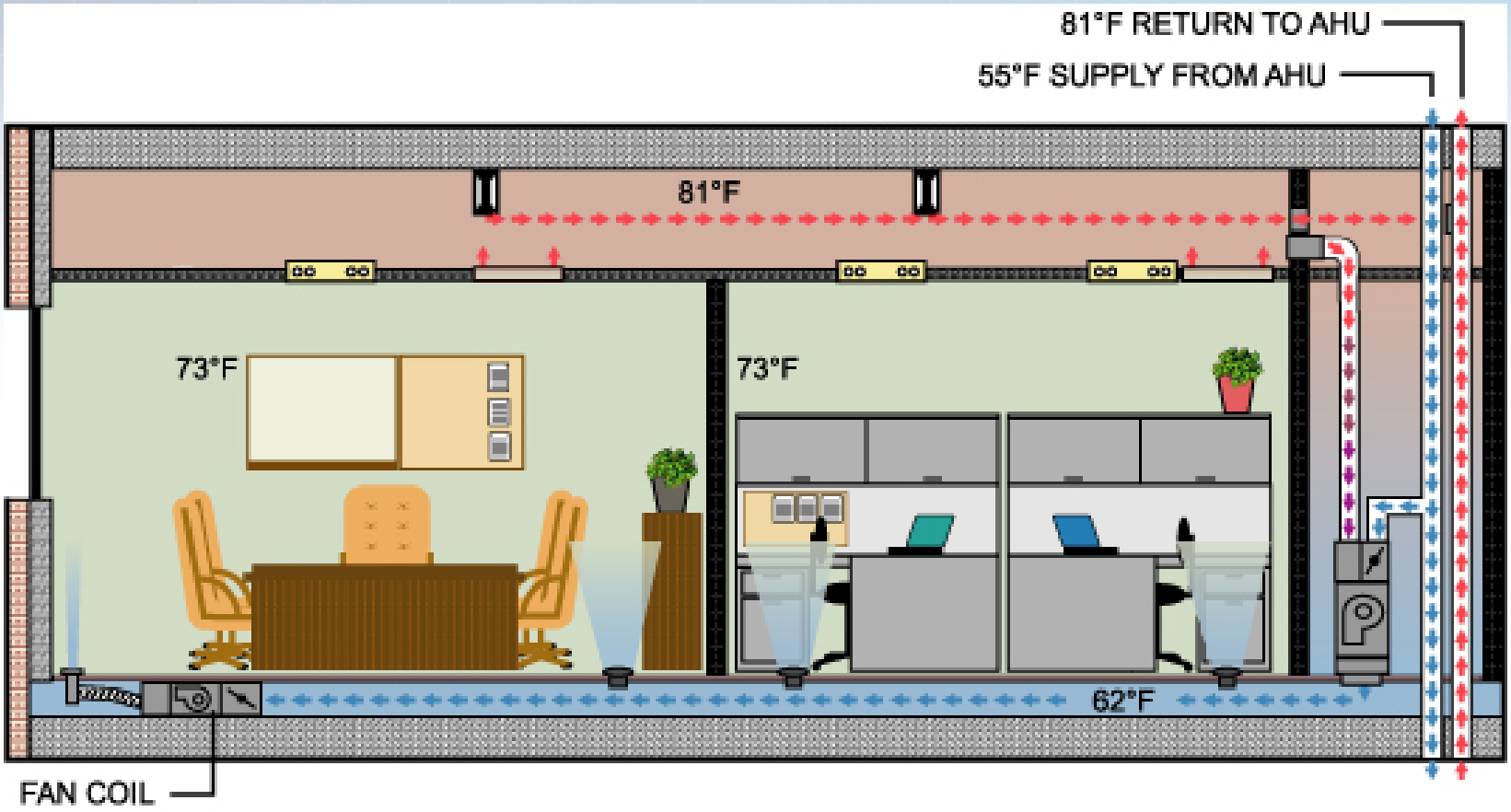
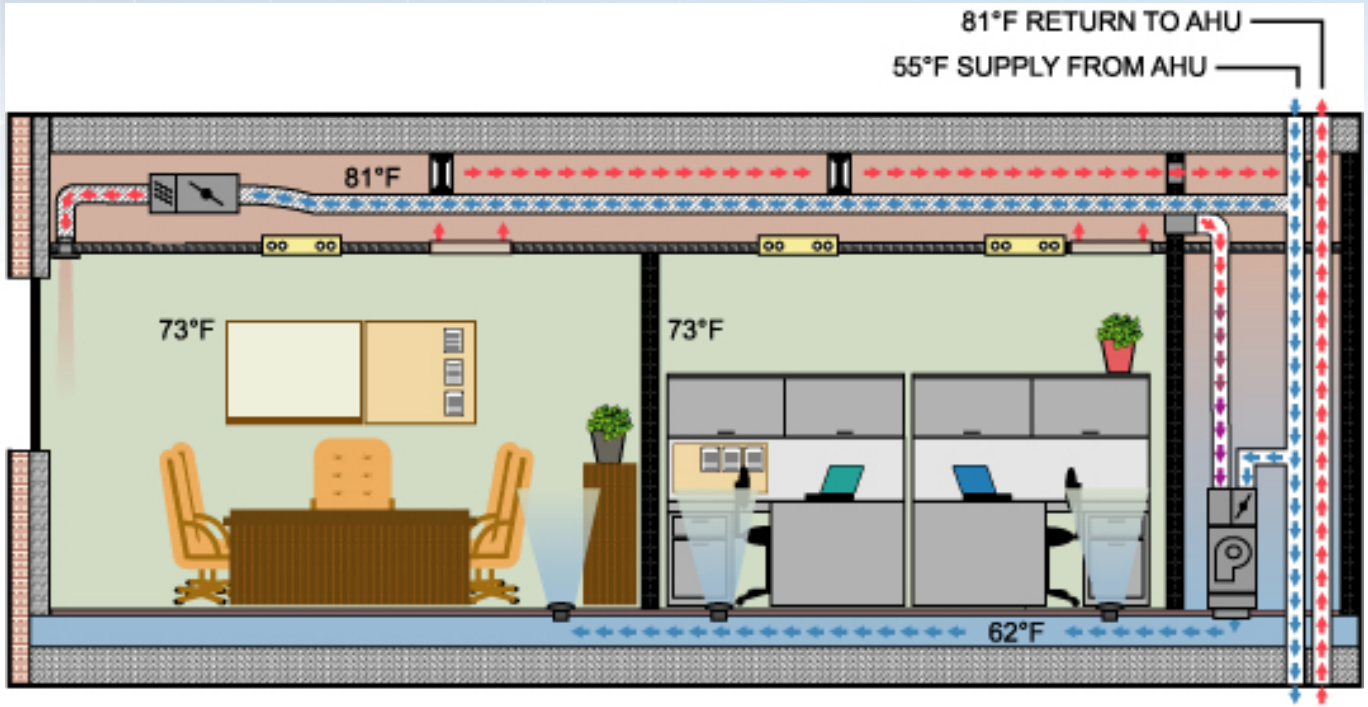


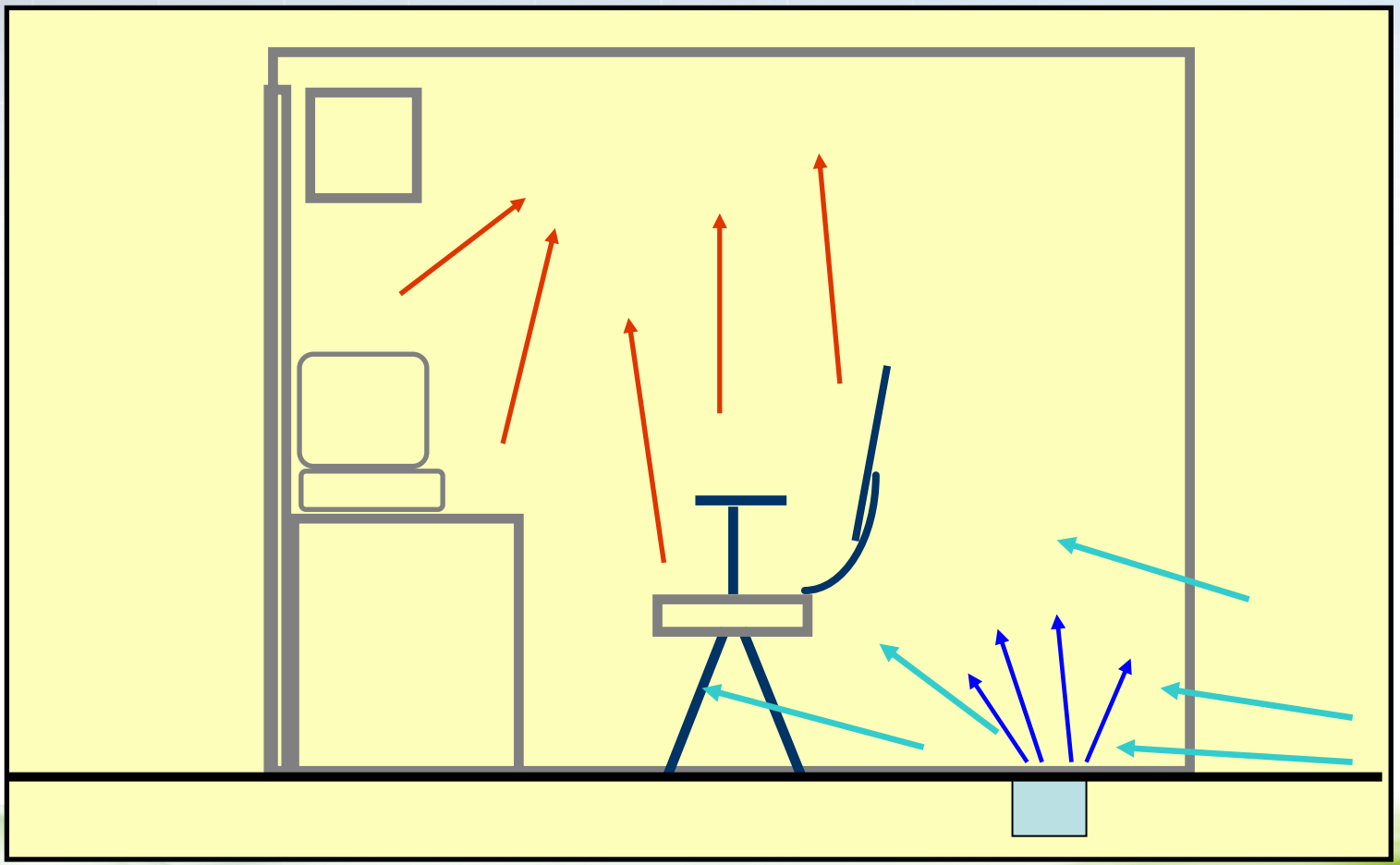
55ºF Supply - Perimeter

- This has the advantage of 55F air being available.
- In this example, a ceiling mounted series box is heating warm plenum air, with 55F air available for cooling.



Reheat example shown with K-Jet nozzles

Recommended approach: One Diffuser per Cubicle

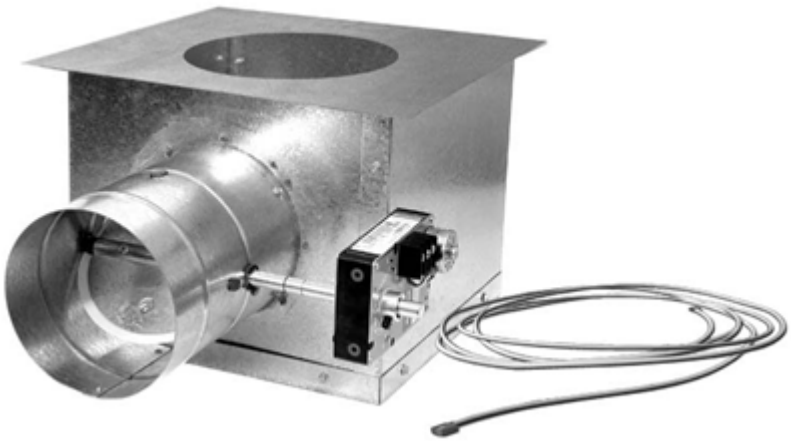


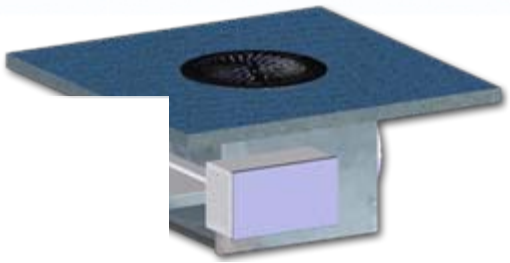
Under Floor Air Distribution Components

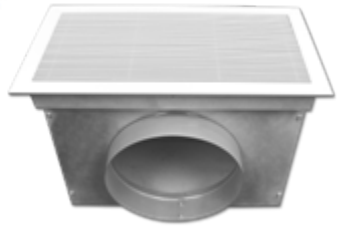
- Diffuser Issues:
  - Plastic vs. steel
  - Fire concerns
  - Scratch concerns
  - High Induction?
  - Passive vs. VAV

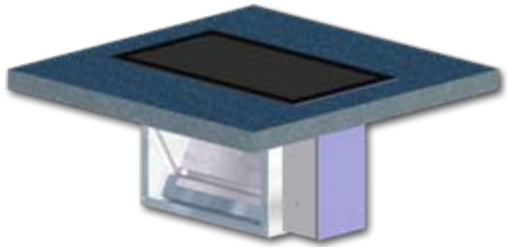
Underfloor System Components

- Ducted and unducted floor diffusers are available
- Some act as a ducted return in heating mode



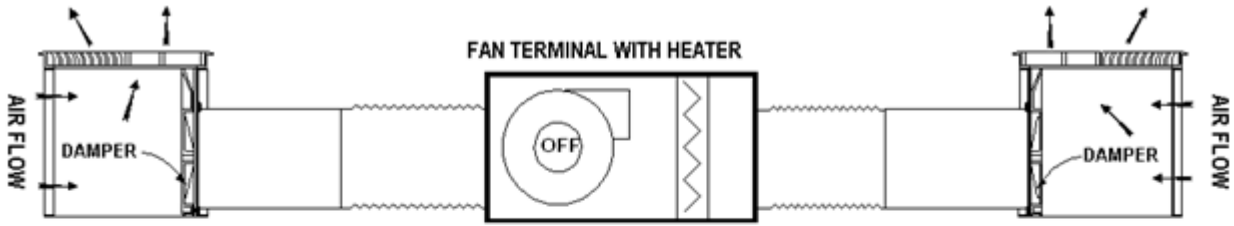




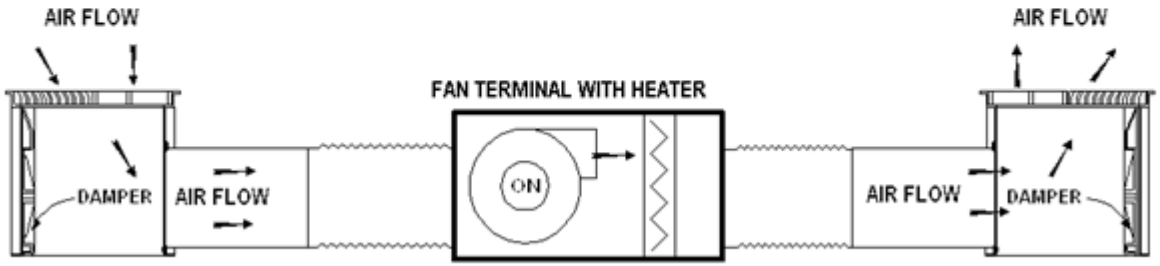


Under Floor Air Distribution Components

- Heating only fan coils
- Underfloor series fan box



(a) Full cooling mode



(b) Full heating mode

LEED Certification

- Many projects now require LEED (Leadership in Energy and Environmental Design) certification.
- Points can potentially be gained with UFAD systems in several areas:
  - Mechanical equipment downsizing.
  - Part load efficiencies.
  - Recyclability of office components.
  - While LEED no longer gives ventilation credit for UFAD systems (because ASHRAE 62 no longer gives ventilation credit for UFAD), there is a proposed change in progress that will allow reduced oudoor air with short throw UFAD outlets.
  - Occupant comfort control. Note: Connecting multiple active diffusers to a single thermostat eliminates “occupant control” LEED point.
- Note: many of these claims have yet to be verified

New ASHRAE UFAD Committee

- The GSA has complained to ASHRAE that it wasn't 'warned' about potential problems with UFAD.
  - Condensation on cold slab
  - High leakage
  - High maintenance costs
  - Poor energy performance
  - Higher than expected installation costs
- ASHRAE has formed a new Technical Resource Group (TRG-7) to look into modifying the ASHRAE UFAD Design Guide.
- Tentatively, a revised design guide will be produced in a year.

Access Floor Review

- Economics (why)
  - System Efficiency
  - Occupant comfort
  - Tax advantages
- Design considerations (how)
  - Perimeter as required by design
  - Return air at ceiling
  - Humidity control is essential in many climates
  - Consider spot cooling load strategies
  - Acoustical issues

UFAD Recommendations:

Every design is unique, but some general recommendations:

- Use pressurized underfloor design (as opposed to neutral pressure).
- Use 55ºF air handler with local mixing designs (to be able to use the cold air where required).
- Use constant volume / variable temperature design (not VAV floor diffusers) for most cost effective solution.
- Be sure the churn requirements are real.
- A suspended ceiling is probably required to meet acoustical concerns.
- This application may not be suited for all situations!

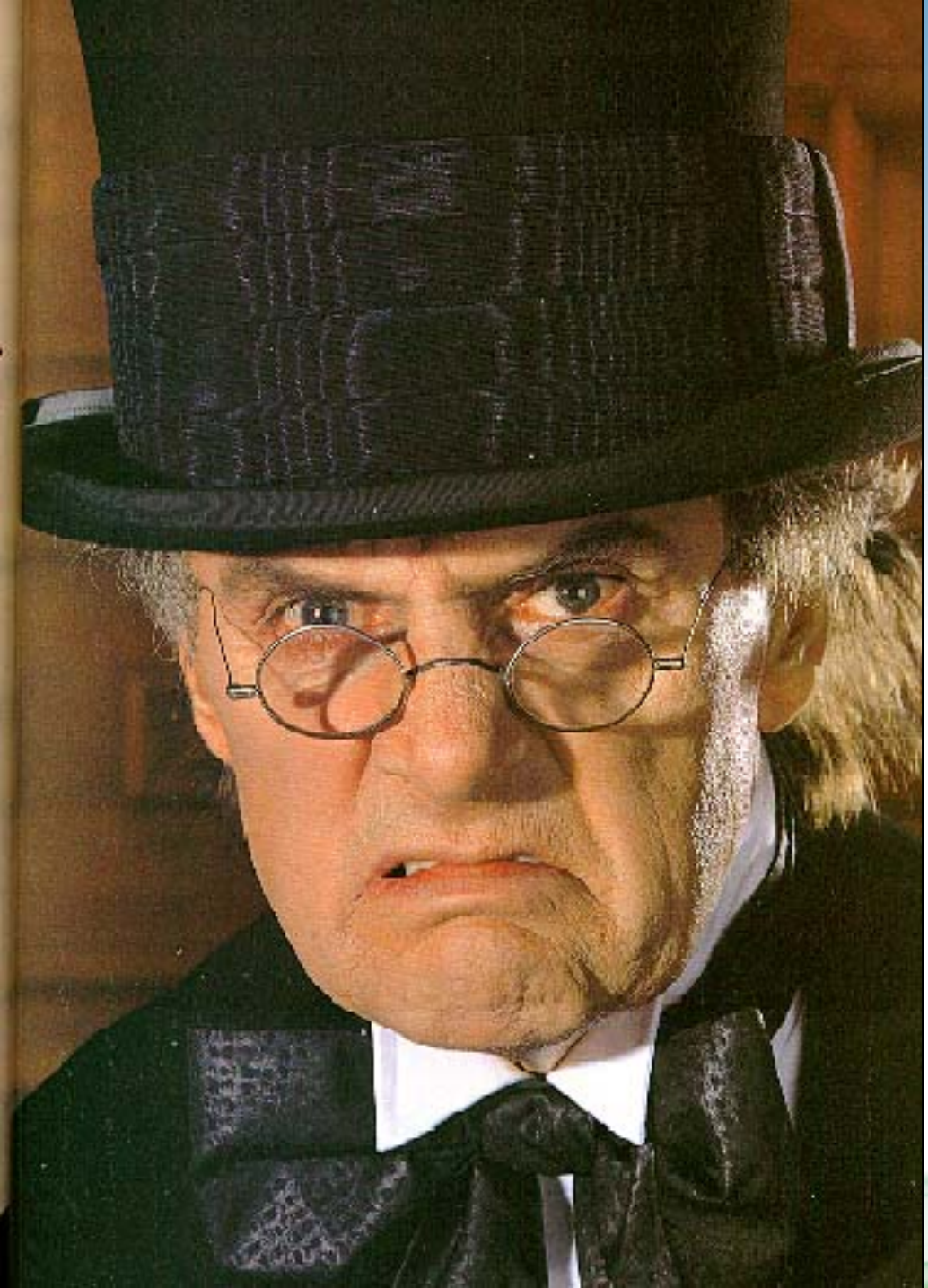
Further Recommendations:

As reported in NYC at the ASHRAE meeting, “Third Generation” designs have some common design elements:

- Use pressurized underfloor design
- Use 55^{o}F DOAS air handler with Air Column designs (to be able to use the cold air where required).
- Use constant volume / variable temperature design (not VAV floor diffusers) for most cost effective solution.
- Several designs use overhead heating and cooling
- A suspended ceiling is required to meet acoustical concerns.

Summary

- Displacement Ventilation (DV) and Underfloor Air Distribution (UFAD) are new technologies seeing increased use in new and existing buildings.
- Both use similar air supply systems and both may well be employed on a single project.
- As with all designs, there are both limitations and advantages to both systems
- The design engineer needs to be fully familiar with any system before utilizing it in a design.



ANY QUESTIONS?