Greenpaper©

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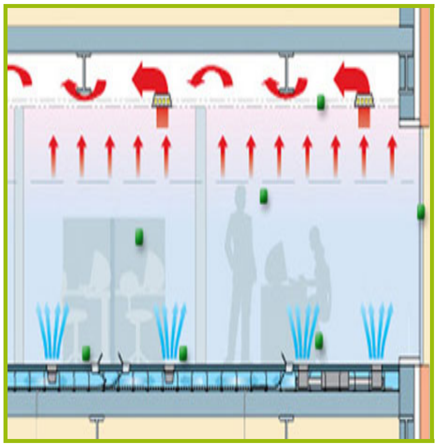
Underfloor Air Distribution



Prepared For:
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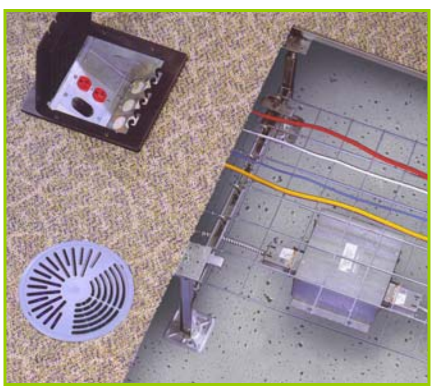


Air Diffuser and Electrical / Data Outlet Box

INTRODUCTION

While this Green Paper discusses primarily the use of raised access floors for air distribution, HVAC integration is only one feature of a raised access floor. In many respects electrical and data distribution is the most important aspect to consider in the evaluation of raised floor. Creating underfloor pathways and using the modular connectors, couplers, flexible wire whips, and outlets available for access floors greatly simplifies installation and subsequent revisions in an office environment. If this flexibility is important, the additional cost of a raised access floor may be justified.

DESCRIPTION OF TECHNOLOGY

Underfloor air distribution (UFAD) takes advantage of the raised access floor to distribute all or a portion of the HVAC conditioning air through a building. A raised access floor consists of square floor tiles supported by pedestals usually 16" or more above the structural floor slab. This floor height is determined by the depth required for HVAC equipment under the floor, wiring needs, and air quantity that must be delivered to the floor. Often, the size of the supply air duct and dampers at the shaft are an important consideration in setting the floor height, particularly since excessive pressure drop at this location can make an UFAD system difficult to control, and excessive air velocity may result in poor air distribution in the floor plenum.

Supply air from the air handling unit is ducted to the access floor, where it is discharged and pressurizes the floor as a plenum. Manually adjustable floor diffusers deliver the air to the space, allowing occupants to control their individual environment. Variable volume floor outlets or booster fans connected to a thermostat can provide automatic zone control for some spaces such as conference rooms. The cool supply air at the floor rises to the ceiling, taking heat and indoor air pollutants with it. At the ceiling, the air travels through the ceiling plenum and back to the air handling unit.

Underfloor air systems by their nature deliver conditioning to a large single zone area. In order to accommodate high density cooling loads or heating, separate zone provisions must be made. There are several options for handling this need including variable volume terminals, water source heat pumps, underfloor booster fans, baseboard heating radiators at the perimeter, and radiant cooling systems. Each has different benefits and liabilities.

While most access floor designs provide all or nearly all of the cooling and ventilation through the floor, another alternative is to use the raised floor plenum to deliver only the required ventilation air. This option assigns the cooling for internal cooling loads and envelope heat gains to a separate system. Passive radiant cooling with chilled beams or panels at the ceiling is an extraordinarily efficient method. This "dual-path" design may permit a reduced floor height of 6"-7".

BuildLACCD


Turbulent Flow Floor Diffuser


Displacement Floor Diffuser


Inclined Flow Floor Diffuser


Square Displacement Floor Diffuser

POSITIVE BENEFITS

There are several advantages of an underfloor air distribution system over a traditional overhead air system.

- Due to higher supply and return air temperatures, the system is able to benefit from extended economizer operation, resulting in significant annual energy savings in the mild southern California climate.
- Underfloor air systems have less ductwork and fewer zone terminal devices. The reduced static pressure required results in air handlers with lower horsepower, first cost savings, and energy savings.
- The uni-directional (bottom to top) airflow pattern removes indoor air pollutants more effectively than a traditional mixing airflow pattern. Indoor air quality is better.
- Evidence seems to indicate that that individual environment control improves productivity and satisfaction while reducing absenteeism and sick time.
- The raised access floor provides excellent flexibility for future reconfiguration of the space. Interior space reconfiguration can be achieved very quickly and with minimal disruption thus reducing losses in productivity and remodelling costs.
- Depending on the choice of lighting and perimeter HVAC system, it may be possible to reduce floor to floor heights.

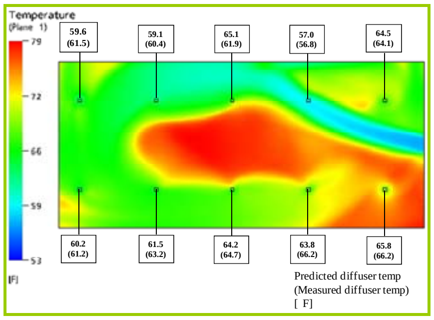
AIR DISTRIBUTION DEVICES

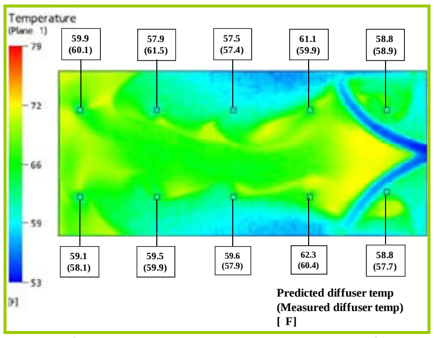
Turbulent flow diffusers create a twist pattern that generates a vertical supply with high induction in the occupied zone. These diffusers work well when located in close proximity to the occupant, but not directly below any overhanging furniture or interior feature.

Displacement flow diffusers create a floor level flow with low induction. These diffusers work well in open circulation areas and where diffuser locations are limited by furniture layouts. In many ways, these are the ideal air distribution device, but they are limited to low air flow quantities and may not be adequate for spaces with high cooling loads such as perimeter areas or conference rooms.

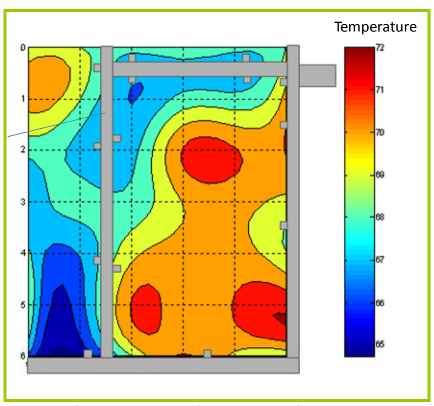
Inclined flow diffusers use a combination of radial and circular discharge jets to create a sloped high induction discharge. The radial slots create a turbulent vertical flow while the circular openings provide a fast mixing angular throw that can be directed towards an occupant. In this way, the occupant can adjust the diffuser rotation to suit their personal preference of air circulation.

Square displacement grilles are designed to supply low velocity air to a space from a floor installation. The grilles utilize the deflection of the core blades in conjunction with directional vanes and an equalization baffle for uniform flow. These diffusers are suitable for lobbies and atria where large volumes of displacement air are required.

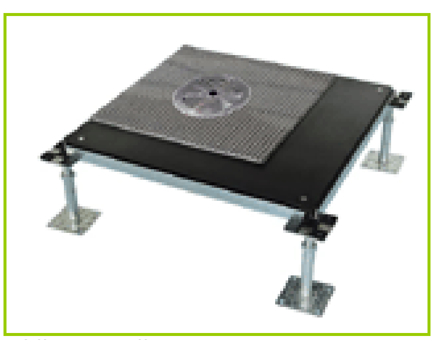




Computational Fluid Dynamics (CFD) models of UFAD to study thermal decay and air distribution in the floor plenum.



CFD Model of an Underfloor Plenum. Grey Areas are Air Highways.



Off-center diffuser installation allows minor location adjustments by rotating floor tile.

To maximize energy savings and air distribution effectiveness, UFAD systems should be designed to operate as a displacement ventilation system. With displacement ventilation, cool supply air flows across the floor and is then drawn upward by thermal plumes that develop over heat sources in the room. Room temperatures become stratified, which allows a significant portion of the internal loads to return to the central air handling system without mixing into the room. Supply air quantities can therefore be reduced which saves fan power, and return air temperatures are higher which increases economizer operation.

The selection of diffuser type is an important factor in how close to the UFAD system operates to this ideal.

ACCESS FLOOR HEAT GAIN

As cool supply air travels in the underfloor plenum, it picks up heat transferred through the structural slab from the floor below. This process is called thermal decay of the supply air. An important design consideration is to limit the amount of thermal decay to acceptable levels for diffusers that are located further away from the plenum inlet. Current estimates for the expected thermal decay, for typical slab temperatures and airflow rates, are approximately 0.05-0.15°F/ft. Applying this estimate in practice is complicated by several variables, including the following: (1) the air may not travel in a straight line between the inlet and the diffuser; (2) the number and location of inlets employed; and (3) the temperature difference between the air and the slab and floor panels. Most designers with experience in UFAD design are using a rule-of-thumb of limiting the maximum distance from the plenum inlet to the furthest diffuser to about 50-60 ft.

Adding additional plenum inlets or an air highway is an approach for improving the thermal uniformity of the airflow distribution within the plenum. However, this must be traded off against the available access points for plenum inlets and the additional cost of the required ductwork.

Underfloor plenums on the ground floor of buildings experience approximately 50% less thermal decay than those on other floors since the ground temperature is relatively stable and less than the return air temperature below the slab for other floors. On the other hand, underfloor plenums above unconditioned spaces, such as parking garages, must be insulated to prevent unacceptably high thermal decay and energy loss. In these cases, a minimum R-19 continuous insulation underneath the slab is recommended.

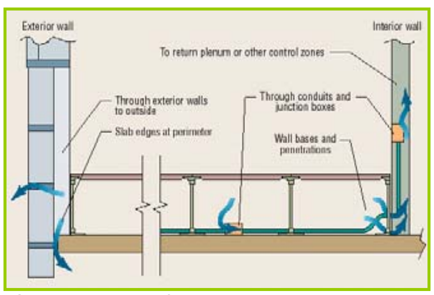
DESIGN AND CONSTRUCTION ISSUES

An underfloor air system requires the design and construction team to address some important issues to ensure a successful installation.

- Areas requiring a hard or continuous surface such as kitchens, locker rooms, and toilet rooms require that a floor slab be created above the structural floor. Typically this topping slab is poured over rigid insulation fill.
- Install floor diffusers off-center in each floor tile to allow flexibility in locating them to avoid furniture.

Raised Floor System during Construction

Raised Floor System during Construction



Common Paths for UFAD Plenum Leakage

UFAD Commissioning with Smoke to Detect Leakage Paths

- Maintain underfloor air velocities at the inlet to 1000 fpm or less to provide good air distribution in the floor plenum.
- Since the air is supplied at 63°F, which is higher than a conventional system, a bypass damper is required at the cooling coil or a secondary coil must be provided to adequately dehumidify the air. Southern California benefits from low summer humidity, which allows this system to work very successfully.
- The supply fans that serve the UFAD system should be provided with variable frequency drives and modulate based on static pressure in the floor plenum. Similarly, the return fans should modulate based on static pressure in the ceiling plenum.
- If multiple air handling units serve a common underfloor plenum, the plenums may be physically separated based on AHU zones to allow off-hours operation of only one unit.
- A night purge control sequence to pre-cool the structural slab is an effective way to utilize the exposed thermal mass in the underfloor plenum and save energy.
- To achieve adequate air-tightness of the underfloor plenum, wall and floor joints must be sealed. This is an especial concern at partition wall penetration of the floor and at the floor connection to the perimeter and core.
- The underfloor plenum must be cleaned and protected from construction debris and dust so that air quality problems do not arise on system start-up.
- Ensuring low plenum leakage is the single most important factor in the successful implementation of a UFAD design. All underfloor plenums should be commissioned and tested for air tightness to meet LACCD standards.

COST CONSIDERATIONS

A detailed first cost comparison of a conventional HVAC system versus an underfloor air distribution system is given on the following page. Excluding furniture costs, the underfloor system is roughly $2.75/sq.ft. more than a traditional overhead distribution system. The annual energy savings has been found to be approximately $0.20/sq.ft., based several built raised floor projects. The energy savings are a result primarily of extended economizer operation and lower fan power.

There are several cost factors that are difficult to estimate but that favor an underfloor air system.

- A raised floor system will result in lower system furniture FF&E costs with the maximum savings being when recycled non-electrified furniture can be used. Savings in this instance could be as much as $20 per square foot.
- The savings from “churn”, or frequent reconfiguring of the space, depend on how often and extensive the changes are made. When frequent changes are required, savings result from simpler reconfiguration of non-electrified furniture, and reduced electrical and mechanical costs from the use of moveable fixtures and diffusers mounted in tiles.
- Although anecdotal evidence is that productivity improves and absenteeism decreases with an underfloor system, such savings have not been documented.

UFAD IN AUDITORIUMS AND THEATERS

Although this Green Paper has focused on UFAD with raised floors in office applications, UFAD is also an excellent system choice in auditoriums and theaters with sloped seating. Many of the same principles discussed above, including displacement ventilation, stratification, energy savings, and underfloor plenum sealing, apply to auditoriums and theaters as well.

ADDITIONAL RESOURCES

Industry Websites

- www.cbe.berkeley.edu/underfloorair/Default.htm
- www1.eere.energy.gov/femp/pdfs/ufad_tf.pdf
- www.peci.org/ncbc/proceedings/2007/English_NCBC2007.pdf

Manufacturer Websites

- www.price-hvac.com
- www.trox.us/usa
- www.titus-hvac.com
- www.tateaccessfloors.com

FIRST COST COMPARISON

Conventional vs Raised Floor Air System

GENERAL CONSTRUCTION	**Conventional ($/sf)**	**Raised Floor Air System ($/sf)**
Architectural:		
Carpet [1]	$1.75	$3.50
Raised Floor	$0.00	$5.05
Sealing of Concrete	$0.00	$0.10
Mechanical:		
Central Equipment	$1.45	$1.45
Supply Air Ductwork [2]	$5.90	$0.90
Supply Air Diffusers [3]	$0.10	$0.75
Skin System (WSHP, Fan Coil Units, etc.)	$0.00	$1.50
Controls [10]	$0.00	$0.00
Electrical:		
Flush Floor Power/Telecom Outlet [4]	$1.68	$0.00
Connection to Furniture	$0.12	$0.00
Access Floor Power/Telecom Outlet [5]	$0.00	$3.60
Telecommunications:		
Non-plenum Cable in Conduit [6]	$4.13	$0.00
Connection to Furniture	$0.10	$0.00
Plenum Cable Under Raised Floor [7]	$0.00	$1.12
Sub-Total	**$15.23**	**$17.97**
Furniture, Fixtures and Equipment:		
Electrified Furniture [8]	$15.00	$0.00
Non-Electrified Furniture [9]	$0.00	$10.55
Total	**$30.23**	**$28.52**

Notes:

1. Assumes equivalent grade carpet.
2. Assumes minimal supply air ductwork in core areas for raised floor system.
3. Assumes one personal air diffuser per workstation, as well as ceiling diffusers in core areas.
4. Assumes four cast bronze flush floor power/tele outlets per bay, with approximately 50 lf connection to core panels and tele/data rooms.
5. Assumes one access floor power/tele outlets per workstation, with approximately 50 lf connection to core panels and tele/data rooms.
6. Assumes four CAT-5 cables per workstation, routed in conduit on slab, with approximately 50 lf connection to core panels and tele/data rooms.
7. Assumes four CAT-5 cables per workstation, laid directly beneath raised access floor, with approximately 50 lf connection to core panels and tele/data rooms.
8. Assumes eight workstations sharing common electrified spine, with spine at $150/lf and non-electrified at $50/lf.
9. Assumes eight workstations, all at $50/lf.
10. Assumes HVAC controls to be similar in both applications due to additional programming and point configurations.