HVAC Issues - SESSION 047

Challenges and Failures in Green Building Design Using Under-floor Air Distribution

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ABSTRACT

The use of access floors with under floor air distribution (UFAD) systems in new buildings is nothing new; the theoretical benefits have been touted for many years. What was once a special design and construction project is now much more wide spread, and as a result owners, users, operators, designers, and contractors are seeing a system that is wholly new to them. Misconceptions of the system, resulting from discussions of the theoretical benefits with limited to no consideration of the challenges, are responsible for leading many down a path of significant strife and poor building performance.

This paper opens a window into the mind of someone who is in the cautiously optimistic category regarding UFAD and what it can bring a building owner, occupant, and operator. This paper is broken down into four key areas of discussion: access floor and UFAD overview; current challenges and failures with UFAD; steps to overcome said challenges and failures, i.e. what comes next; and finally a quick overview of several case studies demonstrating installed UFAD systems.

Under floor air distribution systems have a significant amount of potential to facilitate reduced energy consumption for a building, while simultaneously helping to create better indoor environmental quality resulting in significantly happier occupants. But without awareness, understanding, application, and mastery, these potential benefits cannot be realized.

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INTRODUCTION

Access floors with under floor air distribution (UFAD) began seeing wide spread use in data centers during the 1970s and 1980s. In these applications the access floor served a dual purpose as a cable management system and as a plenum for the distribution of cooling air throughout the data center space. Cool air was easily introduced low within the data center and natural convection from the heat generating equipment created a once through cooling system. This convective airflow approach allowed the load density (heating density) of the data center equipment to be increased, which matched the increase in computer technology design. Both the cable management system and air distribution were easily modified throughout the space, allowing for significant operator customization beyond the date of construction. Even with its capacity limitations, many data centers are still being constructed with access floors that use UFAD to this day.

Similar to data centers with large high heat producing central computers, office spaces started to fill up with personal workstation computers in the 1980s. Heat loads—in addition to power and data requirements for individual workstation computers—have continued to rise since this time. Just like the data centers before it, the cable management needed to accommodate occupant churn resulted in the application of access floors to general office spaces. In addition to cable management, this access floor could also serve as a plenum for under floor air distribution. Although the space cooling design loads are not nearly as high in office spaces as those found in data centers the UFAD system could be applied in a similar and also smaller way to address these loads, in addition to addressing the outside air ventilation requirements of an occupied office floor. With a smaller load, much lower amounts of air are required, thus the invention (or application) of the low pressure UFAD plenum within general office spaces. This application is also applied to libraries, schools, lobbies, and mixed use facilities, to name a few.

Not long after the application of access floors with UFAD in office spaces, a number of additional benefits— beyond the flexible cable management and occupant churn supportive air systems—became apparent. Some of these theoretical benefits include:

1. Reduced airflow rates with stratified occupied space load profiles;
2. Reduced fan energy as a result of reduced airflow;
3. Reduced fan energy as a result of lower operating duct static pressures (low pressure UFAD plenum vs. high to medium pressure duct);
4. Increased chilled water plant efficiency as a result of higher discharge air temperatures;
5. And greater occupant comfort as a result of expanded control zones.

With this arsenal of benefits it didn’t take long for owners, developers, operators, contractors, and design team members to find many applications for this “new” system. However, along with these benefits come many new challenges.

For the purpose of this paper, all references to access floors with UFAD will be in relation to general office spaces.

MAIN BODY

General Overview

In specific terms an access floor system is a series of removable floors panels set on a grid of adjustable metal support stands. Numerous variations are available with minor construction differences such as panels constructed of light weight concrete or metal, but for the most part all achieve a similar installation using a 24 in. x 24 in. floor grid. These access floors can be installed at a variety of heights to create a difference in plenum volume. The specific height is usually best determined by the design team when factoring in the ultimate use of the access floor plenum. However, some general rules of thumb for plenum heights are as follows:

Access Floor Height*:

High Density Cooling (Data Centers) w/UFAD: 24 in. to 48 in.
General Office Space w/UFAD: 10 in. to 20 in.
Data / Power Only: 3 in. to 8 in.

* The floor heights indicated are general rules of thumb. Specific requirements should be verified with the selected manufacturers, and take into consideration installed equipment and design requirements.

The first access floor plenums used in data centers moved a high volume of air and the tonnage of cooling load per square foot of access floor area was quite high. This high amount of airflow is very forgiving, but is absolutely not appropriate for a general office space. Compared to data centers, general office space requires low airflows over a very large area (due to a lower cooling load than a data center) with considerations for occupied space noise levels. As such, general office space access floor systems with UFAD are often designed to have a low pressure plenum. A low pressure plenum is a type of UFAD that utilizes a low design pressure for outlet airflow. Typical design pressures range from 0.03 to 0.10 in.w.c. The UFAD plenum is maintained at these design pressures by modulating the supply air fan and/or discharge dampers. Throughout the design process, it is important to remember that a low pressure plenum deals with small amounts of nearly static air. These low airflows and low pressures, which are necessary to support the system benefits, do not give much margin for error in the design process. See Figure 1 below for a typical office access floor plenum being cleaned during construction. This particular access floor plenum provides 17” of clear plenum space.

Figure 1 - Typical Office Access Floor (lobby installation shown)

Although not specific to the access plenum design itself, every UFAD design must account for a supplemental form of heating and cooling for the building envelope (known as a perimeter HVAC system). Addressing this building envelope proves a key factor in the success or failure of the UFAD system design. This perimeter HVAC system addresses the highly diverse heating and cooling loads associated with the building envelope. Generally, the UFAD system itself is intended to address internal cooling loads such as lights, computers, miscellaneous equipment loads, and people. For the most part this internal cooling load tends to remain very static loads and as such the UFAD system is usually not designed to respond quickly to such a load. The perimeter on the other hand can see a wide range of loads. For instance in the Colorado region, a building can experience temperature swings in excess of 40°F within a single occupied period (7am to 7pm). This means a building perimeter HVAC system can require heating at one point, then switching to cooling, or vice versa.

With these perimeter factors in mind almost all UFAD systems are supplemented by a semi or fully-decoupled perimeter system. In all cases the perimeter system is zoned for building directional exposures using traditional design techniques. A number of perimeter systems have been applied to this scenario:

1. Semi-decoupled Series Fan-Powered Variable Air Volume Terminal Zone Controllers with either electric or hot water reheat. Often located in the UFAD plenum, these systems utilize the UFAD air for cooling and, when

needed, heat this air for heating. In certain applications a “heat recovery” system is applied to these units. While in heating mode, these units to pull air from the overhead return air plenum instead of the UFAD plenum. This decreases the temperature change necessary for heating, thus decreasing the energy requirements and possibly eliminating a re-heat scenario.

2. Decoupled Variable Air Volume Terminal Zone Controller with either electric or hot water re-heat. Typically a completely separate system from the UFAD, it is essentially a traditional overhead air distribution system.

3. Hot Water Baseboard and Chilled Beams. This simple system uses a traditional hot water baseboard to provide perimeter heat. This proves very effective because the hot water baseboard can often be recessed within the access plenum. Similar to the hot water baseboard, passive chilled beams can be located overhead to provide perimeter cooling. However, be conscious of the capacity limitation of passive chilled beams and the area of influence that they can cover.

4. Heat Pumps – Variable Refrigerant Flow (VRF). Working in a manner similar to traditional heat pumps, a variable refrigerant flow system illustrates another possibility for perimeter heating and cooling. In lieu of a condenser water loop for energy transfer, variable refrigerant uses refrigerant to transfer energy between terminal fan coils and external condensing units. See Figure 2 for a window sill mounted VRF fan coil decoupled from the adjacent access floor UFAD system.

Figure 2 - Decoupled Perimeter Variable Refrigerant System

5. Heat Pumps – Geothermal (or tower/boiler loop). Although not typically seen, it is possible to provide adequate perimeter heating and cooling using a traditional water-to-air heat pump system. This unit could provide either overhead or below window air distribution.

6. Four-Pipe Fan Coils with chilled water and hot water. Although not typically seen it is possible to provide adequate perimeter heating and cooling using a traditional 4-pipe fan coil.

Again the perimeter systems briefly described above represent just a few ways to address the envelope. Each approach presents a number of pros and/or cons, some more cons than others. It is important that the design team understand the limitations of each option and adequately apply them to the building at hand.

UFAD is often desired because of the theoretical benefits that may possibly be achieved with respect to the mechanical HVAC system, such those listed in the introduction. Additional benefits include a once-through clean air distribution and reconfigurable system installation. However, these benefits can be achieved through intense coordination and system optimization, hence; using these reasons alone to choose an access floor and consequently a UFAD system is not recommended. It generally proves good practice for the owner/operator to have a strong desire for cable management and a high frequency of building churn prior to adopting an access floor system. The modular option for the data and power is one of the best features of an access floor system. It is strongly recommended that the use of an access floor not be driven by the HVAC systems alone; wait until these data and power features are desired. That being said, once an access floor becomes part of the design, using the created floor plenum for UFAD can be highly desirable for a number of reasons already noted.

Challenges and Failures with UFAD

There are a number of challenges that face the design team when incorporating an access floor and UFAD. The two greatest challenges this author has experienced relate directly to plenum leakage and thermal decay. The most problematic of these two challenges, and one of the major contributors to many of the current UFAD failures, is plenum leakage.

Although the plenums are designed for low-pressures—0.03 to 0.10 inches of water column (in.w.c.) —their large size means the cumulative leakage over these broad areas can render the system non-functional. Some amount of leakage is typically designed into the system, generally in the range of 0.10 cfm/sqft to 0.15 cfm/sqft (dependent on tile type and finished surface). To comprehend how much air this “ideal” condition of leakage is, it can in some cases be enough air to handle minimum internal cooling and ventilation.

Leakage from the access floor is typically classified in one of two ways. The first leakage, let's call it Type I, is leakage from the access floor directly to the occupied space. Although uncontrolled, in some cases this leakage can be properly accounted for, and in a "non-ideal" way contributes to space cooling and ventilation. Type I leakage is generally present at penetrations through the top of the access floor. The second leakage, let's call it Type II, is leakage from the access floor that either bypasses the occupied space straight to the return air path to the air handler, or is lost from the building. This Type II leakage provides no cooling and/or ventilation benefits, and places a large burden on the HVAC system to deliver more capacity to the HVAC zones. Type II leakage is generally present through the building envelope, up through internal building walls, up through internal building column enclosures, etc.

Although a system can be designed for an "ideal" leakage rate, it is often not enough to cover the real world conditions such as proper design details are not being provided and leading to poor installation. These "ideal" leakage rates can quickly be superseded by real world conditions. During simple mockup tests, leakage rates have presented as high as 0.75 cfm/sqft. Please note that this distribution rate does not include any design diffuser openings which are typically designed for a typical floor plan to be near 0.80 cfm/sqft. If this high leakage rate is present along with the normal design airflow from the diffusers this condition can require an additional 45% of air to be delivered beyond the system design capacity (it is highly likely that the air handlers and associated equipment cannot compensate for this much system airflow change).

Leakage creates a number of problems within the space such as:

1. Over-cooling of the space beyond setpoint as a result of lost control due to over airing. This occurs in the high leakage zones close to the ducted air inlet to the UFAD plenum.

2. Under-cooling of the space below setpoint as a result of lost control due to under airing. This occurs at zones away from the ducted air inlet to the UFAD plenum.

3. Breakdown of desired stratification zones within the vertical space. This breakdown can create a highly mixed space, which is contrary to UFAD design principles.

4. Excessive fan energy use as a result of compensation for leakage.

5. Excessive supplemental system energy use as a result of additional air being moved through the primary air handlers. Energy use could be chillers, pumps, cooling towers, boilers, etc.

6. Excessive system noise as a result of increased airflow.

Aside from leakage, which can be caused by a number of issues, internal zones on a UFAD system generally present limited problems. If adequate control is provided, whether manual or automatic throughout the load range, the space will generally be satisfied.

Thermal decay introduces another considerable challenge for many UFAD systems. Thermal decay occurs when cold air exiting the discharge points into the UFAD plenum changes temperature prior to being delivered to the occupied zone through floor outlets. For example, if a typical discharge air design temperature is 65°F and thermal decay within the floor plenum is 8°F, the actual supply temperature leaving the floor outlets away from the plenum inlet points will be at 73°F. It is very challenging, if not impossible, to maintain a 75°F occupied space with 73°F supply air temperature. This low differential temperature requires an increased airflow; if leakage is present, providing this additional air to the critical zone may prove impossible with this system.

If the system is already designed and built, the typical field solution to fix thermal decay is to reduce discharge air temperature. In the example above, let's say the discharge air temperature drops to 57°F to compensate for the 8°F thermal decay. This may fix the zone far away from the plenum inlet point for the design condition, but how will this new approach affect the far away zone in off peak conditions? And how will this new lower temperature influence the zone immediately adjacent to the plenum inlet? It will most likely create an overcool condition, i.e. cold feet.

Certain designs innately enjoy a better capacity to absorb the issues associated with thermal decay. Fully decoupled perimeter systems are not affected by thermal decay, while semi-decoupled systems can be greatly affected by thermal decay. For instance, many troubled projects employed the semi-decoupled perimeter under floor fan-powered VAV boxes to provide envelope heating and cooling. These systems work by pulling "cool" air from the UFAD plenum for fan powered distribution along the perimeter zones. Often these systems are designed to handle the high loads of the perimeter using a fixed supply air temperature. If this temperature was intended to be 68°F, yet 72°F is provided due to thermal decay, maintaining space temperature on a design day (the ASHRAE defined system design temperatures for a given climate) will be very difficult if not impossible.

Steps for Successful Implementation of UFAD Systems

As previously stated, numerous challenges exist that face the design team when planning an access floor installation that will provide a life of service to the owner/operator. The two biggest concerns noted are plenum leakage and thermal decay. Let's take a look at how these two challenges can be addressed, starting with thermal decay.

Thermal decay occurs in nearly all operations within the HVAC system: chilled water, hot water, supply air duct, etc. In all these cases thermal decay can be constrained to nearly negligible levels by insulating the process systems. Does this imply that the easy solution is to insulate the access floor plenum? No. The cost benefit ratio of this solution is not practical. However, there are a few key items which can significantly lessen thermal decay problems:

1. Limit the distance between the air handler discharge point into the UFAD plenum and the UFAD plenum outlets. New recommendations call for this length to be as low as 20 to 30 feet. The duct between the air handler and the air handler discharge point should be insulated.

   Where the insulated duct cannot be routed to provide discharge points within 20 to 30 feet of outlets, increase the speed of the air within the access floor. This increased speed can, in certain applications, limit the static time the supply air has to rest against the heated surroundings (which can increase the air temperature). Although higher speeds can limit the time the air spends in the plenum, it can also increase the effective convective heat transfer rate between the air and the surroundings. The air speed can specifically be increased by using under floor ducts or field fabricated high speed areas such as air highways. See Figure 3 for an example of an air highway at the top floor of a vertical chase that is supplied from below. Note that access floor will be installed over this air highway at a later date.

   Because UFAD generally operates at a constant discharge air temperature, say 68°F, locate the air handler discharge points near the higher loads. For instance, if the design includes a semi-decoupled perimeter HVAC system the air handler discharge points should be located close to these high load outlets. Thermal decay will be more acceptable for low load internal spaces.

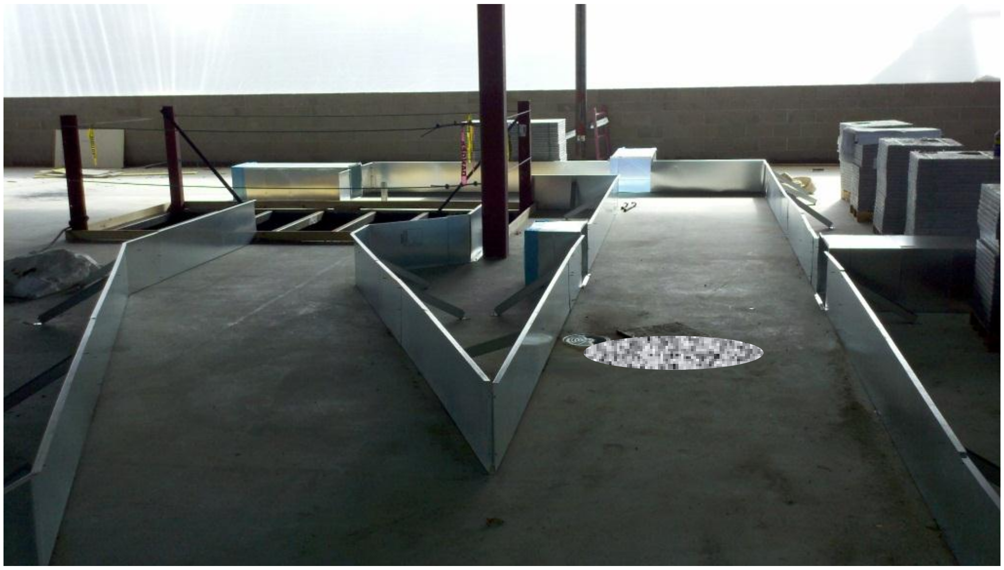

Figure 3 - Air Highway Prior to Access Floor Installation (note vertical chase opening in background)

2. Limit the use of semi-decoupled perimeter HVAC systems, thus eliminating the largest problem areas, i.e. the highly dynamic perimeter zones. Great success has been achieved by fully decoupling the perimeter from the UFAD.

3. Take the building height into consideration when determining the feasibility of a UFAD system. As building height increases, thermal decay begins to compound. Typical thermal decay is driven by the temperature of the structural floor located below the access floor plenum. This higher temperature is driven by the higher return air temperatures located on the floor below. These higher return air temperatures are partially a result of the stratified occupied zone temperature concept associated with UFAD, but also because all the occupied zone loads are routed through the return air plenum. For the first floor, the return plenum might be expected to be around 78° to 80°F. As the number of building floors increase this heat continues to rise up through the building, compounding with each ascent. Ten floors up, the return air temperature could be 83° to 85°F, thus greatly increasing the thermal decay of the floor above. In certain cases floor insulation has been used, though this may not be cost effective.

When contemplating the other challenge, plenum leakage, the design and construction goal is to eliminate all leakage. However, when the number of construction trades that touch the access floor system (sometimes more than 10 different trades) is taken into consideration, eliminating all leaks can be nearly impossible. That being said the plenum leakage must be limited to an acceptable amount that is factored into the UFAD system design. There are a number of steps to minimize plenum leakage:

1. Provide clear documentation on how to seal the plenum. Numerous different conditions require documentation on sealing the plenum. The following areas of plenum sealing should be addressed:

    a. Seal between the access floor and any walls that go down through the access floor. This can be at the perimeter wall or interior walls built through the floor (such as plumbing walls, core walls, elevator/stairwell shafts and structural shear walls).

    b. Seal between the structural floor below the access floor to any walls that make up the boundary of the UFAD plenum. This can be at the perimeter wall or others walls that are built structure to structure.

    c. Seal all vertical column enclosures. Column enclosures can be especially hazardous as they are often an area of excessive Type II leakage (from the UFAD plenum to the return air plenum) if not addressed properly.

    d. Seal all pipe/conduit penetrations through the access floor. This includes those within walls that will sit on the access floor at a later date. An example of this would be electrical conduit serving an outlet within the wall above. See Figure 4 below showing conduit within an electrical room above the access floor; these conduit penetrations need to be sealed air tight.

    

    Figure 4 - Conduit Penetrations through the Access Floor

    e. Seal all pipe/conduit penetrations through the structural floor and sidewall.

f. Seal all data/power outlets leaving the access floor. Do not rely on a onetime application of sealant. The data/power will move sometime down the road, so provide products that accommodate the movement of cables yet still effectively provide a sealed floor. There are many manufacture's products on the market that, through the use of interwoven brushes or flexible rubber, provide this sealed condition.

g. Seal all open-ended conduits within the access floor plenum. The access floor is the pathway for data/power; it is a cable management space. These cables, especially on the data side, are typically introduced into the access floor from data rooms via direct openings or large conduit runs. Direct openings need to be sealed using a specific manufacturer's product (see "f" above). For conduits, the end should be sealed with a removable foam block. See Figure 5 depicting open ended conduits for cable systems within the future access floor plenum. If not sealed, significant leakage will occur. This image also illustrates an area where the access floor ends and traditional flooring begins—in this case at a building loading dock. This stud wall must be sealed to prevent significant leakage up into the wall cavity.

Figure 5 - Open Ended Conduits within the Access Floor Plenum

2. Include the sealing details and specific specified products noted above in the construction documents for all trades working in and/or around the access floor. Maintaining plenum integrity is the responsibility of all trades associated with the access floor.

3. Ensure the finished surface of the access floor helps limit the leakage that can occur directly from the tile seams. A typical installation includes offset carpet tiles which span the UFAD tile seams to reduce leakage. For even further reduction of tile leakage, some manufacturers provide a tile seal.

4. Specify end-of-installation maximum leakage requirements. An understanding of the end of project requirements will help guide the construction team in their efforts. If these goals are not met, energy consumption—or worse, a control issue—will exist that the owner will need to deal with. The end game must be achieved. This requirement is very similar to those maximum leakage requirements placed on pressure pipe and pressure duct used throughout the building.

5. To ensure that the end of installation maximum leakage threshold will be maintained, specify that throughout construction various areas of the access floor shall be mocked up and pressure tested. These mockup locations will provide valuable insight to the performance of the construction team and allow for an opportunity to adjust means and methods (or specific sealing details) to best accommodate the system pressure requirements. See Figure 6 for a sample mockup test setup showing the access floor mockup area with temporary plenum sealing and the pressure testing equipment connection. This particular mockup was designed to test the access floor plenum connection to the building exterior wall. As a result of the test, significant changes were made with the means and methods of sealing the building perimeter.

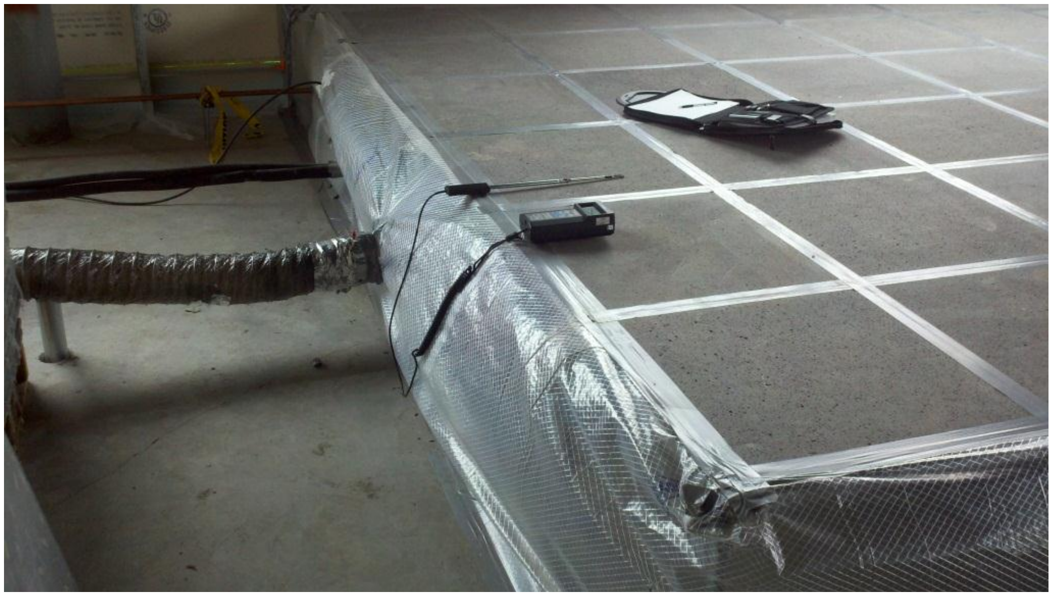

Figure 6 - Access Floor Mockup Pressure Test

6. Train the owner/operators/occupants on the function of the systems. How do the occupants interface with the various manual and automatic floor diffusers throughout the space? How does the owner's I.T. staff work on and modify the cable system located throughout the access floor? These questions must be answered as this is not a traditional building and training will be required. Buildings with UFAD have failed for the simple reason that operators would leave numerous 24x24 panels open throughout the space. This is not a traditional data center access floor; it cannot handle such large leaks. Education is the primary factor in eliminating such simple errors.

CASE STUDIES

Case Study #1 – Lone Tree, CO.

This case study is a six-story, 144,000 gross square foot commercial office space located in Lone Tree, CO. This building design began in 2006 and construction was completed in 2008. This building uses an internal UFAD system fed from packaged rooftop units. In addition to the UFAD system for ventilation and internal cooling, the building uses fan powered electric heat VAV boxes for envelope conditioning. The fan powered perimeter systems pull their air from the adjacent UFAD plenum.

Case Study #1 Operational Issues of Note:

1. As with many UFAD systems that have fan powered perimeter systems, there is limited flexibility in the capacity of these systems when it comes to addressing the perimeter envelope load. The amount of temperature rise between the inlet point of the UFAD plenum (typically at 60° to 65°F) is

fairly unpredictable and can often result with UFAD supply temperatures near 70°F at the building perimeter. The fan powered boxes pull this 70°F air from the plenum and discharge it along the perimeter. Maintaining a space at 72° to 75°F is very difficult with 70 degree air—a high amount of airflow is required. There is not much flexibility for space adjustments with such a high discharge air temperatures. Designers should be cautioned about the temperature change within the access floor and provide inlet points as close to the building perimeter as possible if the UFAD air is to be used for envelope conditioning.

2. There were numerous high velocity floor diffuser layouts along the building perimeter that conflicted with the furniture layout. These would often result in space temperature issues due to reduced effectiveness of the perimeter systems. This proved especially problematic because the perimeter diffusers were located at floor level rather than within a perimeter window sill or other type of raised discharge point. As with any floor distributed air system, caution should be taken to ensure that furniture layouts are carefully coordinated with outlet locations.

Case Study #2 – Golden, CO.

This case study is a five-plus story, 300,000 gross square foot commercial office space located in Golden, CO. The building design commenced in 2005 and construction was completed in 2007. This building has an internal UFAD system fed from packaged rooftop units. In addition to the UFAD system for ventilation and internal cooling this building uses a combination of passive chilled beam and hot water baseboard perimeter system for envelope conditioning, see Figure 7.

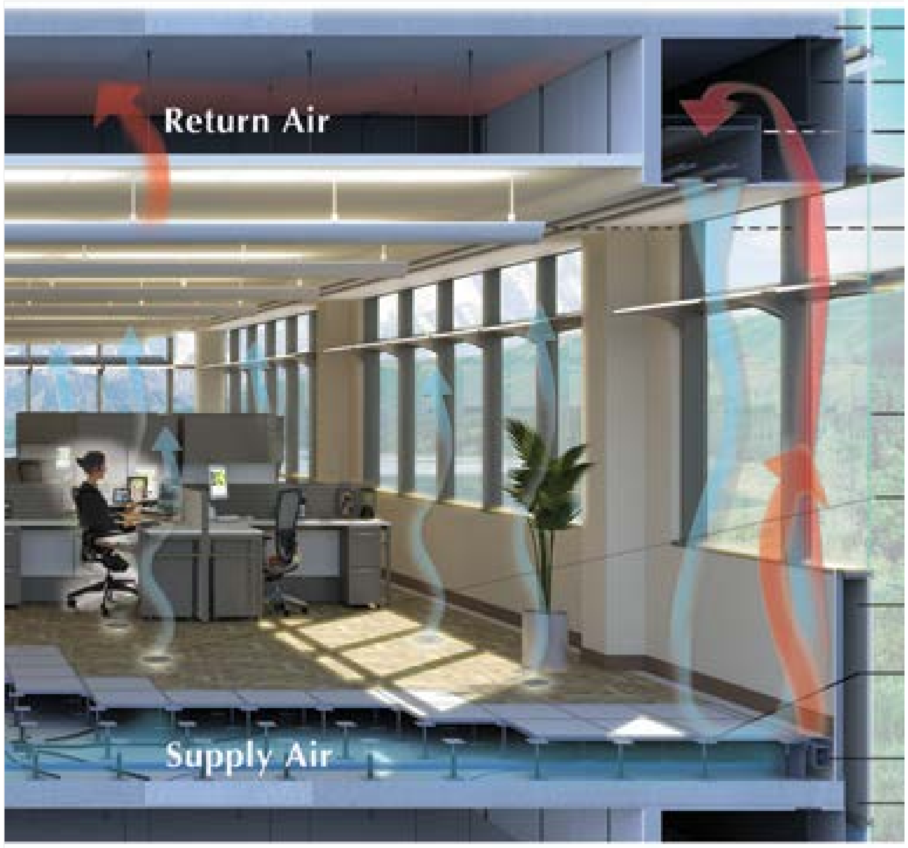

Figure 7 - UFAD with Chilled Beams and Hot Water Baseboard

Case Study #2 Operational Issues of Note:

1. As is popular in many new buildings, this building encompasses a high percentage of exterior glazing area, well in excess of the prescriptive minimums identified in ASHRAE 90.1. As such, a significant amount of cooling was required to address the perimeter envelope loads, especially at and near peak design conditions. The chilled beam perimeter system was designed to address all the envelope convective and conductive loads in addition to radiation loads within a certain vicinity of the building perimeter. During low sun angle conditions (winter months), the radiation load into the building is no longer in the general vicinity of the building perimeter (greater than 10 to 15 feet), and the perimeter-mounted passive chilled beams cannot address those radiation loads. These loads are now required to be addressed by the relatively high temperature UFAD system. Typically the UFAD outlets are only sized for the internal loads (lights, people, and equipment) and are not effective in handling solar radiation loads.

   This operation issue was addressed by providing additional internal UFAD outlets, as needed, to address these loads. Also, less than desirable operation of the window blinds (closed more than preferred) was needed to further address the envelope radiation load.

Regarding the chilled beam perimeter system, a more proper way to address this issue would have been to reduce the quantity of perimeter glazing; this would have needed to be addressed prior to construction. Another approach would have been to significantly change the amount of solar radiation allowed through the glazing to prevent these internal loads. Higher solar radiation reduction typically reduces the amount of visible light which can often create issues with day lighting controls. UFAD systems, unlike internal VAV systems (or other relatively low temperature HVAC systems), do not have the flexibility or quick response to address these perimeter radiation loads which have penetrated deeply into the building.

2. Low temperature supply (below the 65°F desired setpoint) often became an issue as building operators lacking proper system knowledge continually changed the UFAD system set points in an attempt to address other temperature issues. Although these changes may have addressed a few hot spots in the building, the general results of these changes created numerous cold spots throughout the internal space of the building. During design, the building owners are clearly made aware of these issues, however the actual building operators are often not present. This problem is compounded by the fact that most building operators are familiar with more traditional systems with more traditional system set points.

3. Variable occupancy spaces are not suitable for manual control systems. Manual control systems, such as manually operated diffusers, work very well in occupant "owned" spaces like cubicles and offices. These occupants over time understand how and when to operate their manual diffusers. However in variable occupancy spaces like conference rooms, observations show that none of the occupants really take ownership of the manual diffusers. This often results in diffusers being left open in empty conference rooms which quickly results in very cold spaces. Where used, automatic floor diffusers will better address these highly variable spaces.

Case Study #3 – Denver, CO.

This case study is a 22-story, 500,000 gross square foot commercial office space located in Denver, CO. This building design began in 2007 and construction was completed in 2010. This building has an internal UFAD system fed from multiple built-up central station chilled water/hot water air handling units. In addition to the UFAD system for ventilation and internal cooling, this building uses fan powered electric heat VAV boxes for envelope conditioning. The fan powered perimeter systems pull their air from the adjacent UFAD plenum, see Figure 8.

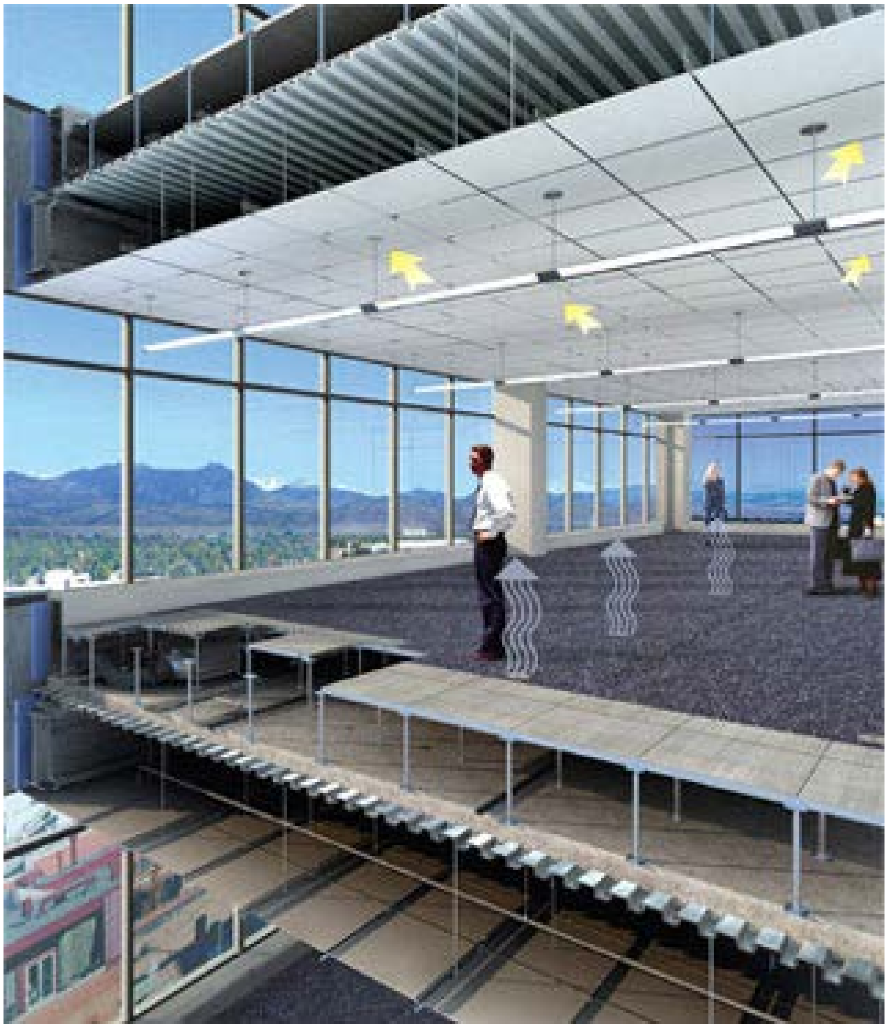

Figure 8 - UFAD with Perimeter Fan Powered VAV Boxes

Case Study #3 Operational Issues of Note:

1. Although this building uses the same perimeter system as that noted in Case Study #1, some additional steps were taken to address the concerns associated with high discharge air temperature as a result of using UFAD air for perimeter conditioning. Air highways within the access floor helped to distribute the air more evenly throughout the plenum in addition to moving this air faster to perimeter, thus resulting in lower temperature changes. Ultimately this provided lower discharge air temperatures at the building perimeter, in the range of 65° to 68°F. Additionally, the building glazing was coordinated to provide very low solar heat gain coefficients to reduce the perimeter cooling loads.

2. Coordinating internal UFAD diffuser placements with final systems furniture layout became a construction issue on this project. Often design

furniture layouts do not match the final installed condition. It seems straight forward enough to have the contractors coordinate minor diffuser placement adjustments with the final layout however scheduling and space turnover generally results in this tasks being a nuisance requiring significant design team intervention. Generally contractors attempt to turn over final space construction prior to furniture installation to avoid possible warranty claim issues as a result of furniture installation. The furniture installers do not necessarily understand the HVAC system layout and sometimes filing cabinets, cubicles walls, etc., over floor diffusers. Designers should be cautioned that special attention must be paid to furniture layout submittals and that floor diffuser placement must be coordinated based on these documents.

Case Study #4 - Denver, CO.

This case study is a two-story, 50,000 gross square foot built-to-suit commercial office space located in Denver, CO. This building design started in 2009 and construction was completed in 2011. This building has an internal UFAD system fed from a direct/in-direct evaporative cooling custom air handler. In addition to the UFAD system for ventilation and internal cooling, this building uses a decoupled variable refrigerant flow (VRF) system for envelope conditioning.

Figure 9 - Case Study #4, UFAD with Decoupled Variable Refrigerant Flow Perimeter System

Case Study #4 Operational Issues of Note:

1. The decoupling of the perimeter system from the UFAD system allows for the issues associated with the relatively high temperature UFAD to be avoided.

2. Similar to Case Study #2, the internal UFAD spaces are not well suited to cover radiation loads from the building perimeter that extend a significant distance from the building perimeter (greater than 10 to 15 feet).

3. Similar to Case Study #3, it is critical for the designer to take into account the careful placement of UFAD outlets with the final shop drawing layouts of the furniture plans.

DISCUSSIONS

The concept of access floors with UFAD is, in theory, a great idea. It provides multiple benefits to the building owner, operator, and occupants. To achieve this, however, requires an understanding of the challenges and putting forth a specific effort to deal with them. Beyond the challenges discussed throughout this paper, there are a number of other issues that the design team must be aware of. The electrical engineer must understand how best to utilize modular power systems. The information technology design team must understand how best to utilizing modular data systems. Can the data and power be routed to common outlets? The hope is "yes" as this will cut down on the number of leakage points. Is the architect working with the structural engineer to provide building components that can be easily sealed against the access floor? Some conditions lend themselves to a simple means and method for sealing; other conditions are nearly impossible. Does the mechanical engineer understand all the special design requirements for the design and implementation of the UFAD system? There are a number of "gotchas" here from humidity control to plenum rated components to special considerations for plumbing within the building.

The key to overcoming the challenges noted throughout this paper, in addition to the individual challenges facing each design group, is to work together and maintain a universal understanding of what is at stake if these challenges are not addressed. There are UFAD buildings that work very poorly; the owner and occupants are not happy. Whenever possible, use designers and contractors who have been exposed to these type of designs in the past. Where certain design members do not have the experience, those who do can help them along.

CONCLUSIONS

UFAD within an access floor in a general office space building can be successful when correctly applied. Numerous challenges face the design team, contractor, owner, operator and users. These challenges must be acknowledged and dealt with. If these challenges are adequately addressed one can achieve a high performance building design.

NOMENCLATURE

Air Highway: A relatively high-velocity (compared to the nearly stagnant air within the remainder of the access floor) air distribution pathway within the access floor plenum. This path allows for air to be more evenly distributed and more quickly distributed throughout the remainder of the access floor, helping to reduce the degree of temperature gain experienced within the access floor.

Churn: The adjustment and change of the occupied space to accommodate owner driven space revisions. An access floor system with UFAD can allow for quick revisions to electrical, information technology and air distribution during these changes.

UFAD: Under floor air distribution. A method of building ventilation and air-conditioning that utilizes an access floor with pressurized supply air plenum in addition to floor air outlets.

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FIGURES

Figure 8 – UFAD with Perimeter Fan Powered VAV Boxes
Figure 9 – Case Study #4, UFAD with Decoupled Variable Refrigerant Flow Perimeter System