Why the "Simple Underfloor Air Distribution System" Isn't Quite as Simple as It Seems

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ABSTRACT

The rapid evolution of modern office technology coupled with high churn or occupant turnover rates has resulted in an increasing use of underfloor supply plenums to support displacement ventilation and underfloor air distribution technologies. In concept, this provides a flexible, sustainable approach to handling the requirements of the modern office environment. However, successful implementation of the underfloor plenum as an air supply and distribution system requires a very persistent and rigorous effort on the part of the design and construction team, as well as the commissioning provider to assure success. Improper application or poor installation of an underfloor plenum can result in significant comfort complaints and energy usage. When commissioning an underfloor air distribution system, the commissioning provider should address the following design, construction, and operational issues:

Design

- Design addresses perimeter vs. internal loads and humidity issues
- Design includes sufficient detail to ensure the plenum will be properly sealed
- Designing systems and equipment to facilitate maintenance
- Designing equipment and systems to deal with catastrophic occurrences such as flooding

Construction

- Maintaining cleanliness during construction and operation
- Constructing an air tight assembly
- Coordinating with various contractors to assure air flow is not impeded
- Maintenance access is not impaired due to installation constraints

Operations

- Maintaining an air tight assembly as systems age and after remodels
- Changes to system layout do not impede maintenance access

This paper looks at design and construction issues from a commissioning and operational perspective and discusses recent field experiences with underfloor plenum systems. The discussion includes the theoretical importance of the issues listed above as well as case study information for projects where these issues came into play in the real world

operating environment. The case studies include a new construction project applying for LEED Gold certification and the renovation of an existing facility.

Introduction

Underfloor air distribution systems have been utilized since the 1950's to serve spaces having high heat loads, such as computer rooms and control centers, but they are still relatively uncommon in an office environment. Most buildings are designed using a conventional overhead distribution system, which generally supplies cold conditioned air (typically 55°F) at the ceiling and relies on complete mixing from floor to ceiling to maintain space temperature. In order to achieve complete mixing, the conditioned air must be delivered through the diffusers at relatively high velocity. The concept behind an underfloor air distribution system is to create a stratified condition from floor to ceiling, rather than mixed, and rely on the natural buoyancy of the air to remove heat and contaminants away from the occupants. Cool conditioned air – typically between 63°F and 68°F – is supplied at floor level through diffusers at very low velocity. The air is then heated by the internal loads of the space and rises to the ceiling where it returns back to the central air handling unit. Potential advantages of an underfloor air distribution system compared to a traditional ceiling-based system include improved thermal comfort, improved air quality, and reduced energy consumption (CBE 2002).

All of this sounds rather simple, but many design issues can greatly influence system performance and success of the application, for example: the type of plenum used – pressurized or non-pressurized, open or partitioned; how interior and perimeter loads are to be met; how humidity will be controlled; and diffuser selection – passive or active. Once the design is complete, the entire system must be constructed, commissioned, and then maintained to ensure that present and future system operation and occupant comfort are sustained.

In the late 1980's a building was designed and constructed utilizing an underfloor air distribution system and the predominant problems identified during commissioning at that time included plenum leakage and contractor unfamiliarity with the design and construction requirements (Arnold 1990). Sadly, many of the same problems still occur over 12 years later. This paper outlines steps that can be taken during design, construction, and operation to achieve a successful project.

Design Issues

Even though more buildings are utilizing underfloor air distribution systems, there is not a comprehensive guideline to aid the designer, contractor, or commissioning provider in understanding the myriad of the details necessary to correctly design, construct, and commission the technology (CBE 2002). In May 1997, the Center for the Built Environment was established at the University of California, Berkeley to gather and disseminate information pertaining to underfloor air distribution technology, including design and construction issues. The Center for the Built Environment (CBE) is currently in the process of developing a comprehensive design guide under a research project for the American Society of Heating, Refrigerating, and Air-Conditioning Engineers. An overview of key design issues is available on their website.

Proper Application

The primary question that must be answered when designing an underfloor air distribution system is – *will this technology work for the current application?* The answer is more likely to be yes for a new construction project than a retrofit application due to possible limitations of existing floor to ceiling heights and mating all non-raised floor areas (i.e. elevator landings and bathrooms) with the new floor (Bauman et al. 2001). If the determination is made that an underfloor air distribution system is acceptable and desired, then numerous decisions pertaining to system layout and configuration must be made. The commissioning provider should assist the designer during design review to ensure many of the issues outlined below are addressed.

Pressurized or non-pressurized. The two most common methods used to deliver air through an underfloor distribution system are pressurized and non-pressurized plenums. In a pressurized plenum, a central HVAC unit delivers air and maintains plenum pressure between 0.05 and 0.2 inch w.c., with respect to the space served. The air can then be introduced to the space by either passive or active (fan-powered) diffusers. The primary advantages associated with a pressurized plenum are: 1) simplicity; 2) lower installation cost; and 3) flexibility. The primary disadvantages are: 1) air leakage from the plenum adversely effects system operation; and 2) removal of a floor panel for an extended period of time can disrupt flow through the rest of the system.

In a non-pressurized plenum, a central HVAC unit delivers air to the plenum at virtually the same pressure as the surrounding space. Hence an additional fan is needed to actually deliver the air to the occupied space, generally either an active diffuser or fan-powered terminal unit. The primary advantages are: 1) Each occupant can have greater control over air delivered to their space through the use of active diffusers; 2) air leakage to and from the plenum is minimized; and 3) floor panel removal does not disrupt flow through the rest of the system. The primary disadvantages are: 1) small fractional horsepower fans are used to deliver air to the occupied space; and 2) perceived added cost associated with all of the extra fans and equipment.

Open or partitioned plenum. The designer must decide whether to have an open or partitioned plenum. An open plenum is simpler to install and makes it very easy to run wires, pipes, and other sundry equipment under the floor, but satisfying differing space conditions can be difficult because all of the air drawn from the plenum is at one temperature and humidity condition. An alternative is to separate the plenum into individual sealed partitions. The air provided to, and drawn from, each partition can be heated or cooled as necessary to satisfy a specific space requirement but now running anything under the floor becomes much more difficult. The decision between designing an open or partitioned plenum becomes important when addressing perimeter and internal loads.

Perimeter and internal loads. Regardless of whether the plenum is open and pressurized, partitioned and non-pressurized, or some variation thereof, the issue of how to satisfy perimeter, interior, and specialty area loads must be addressed. Typically interior loads require constant cooling and perimeter loads can vary rapidly based on outside conditions.

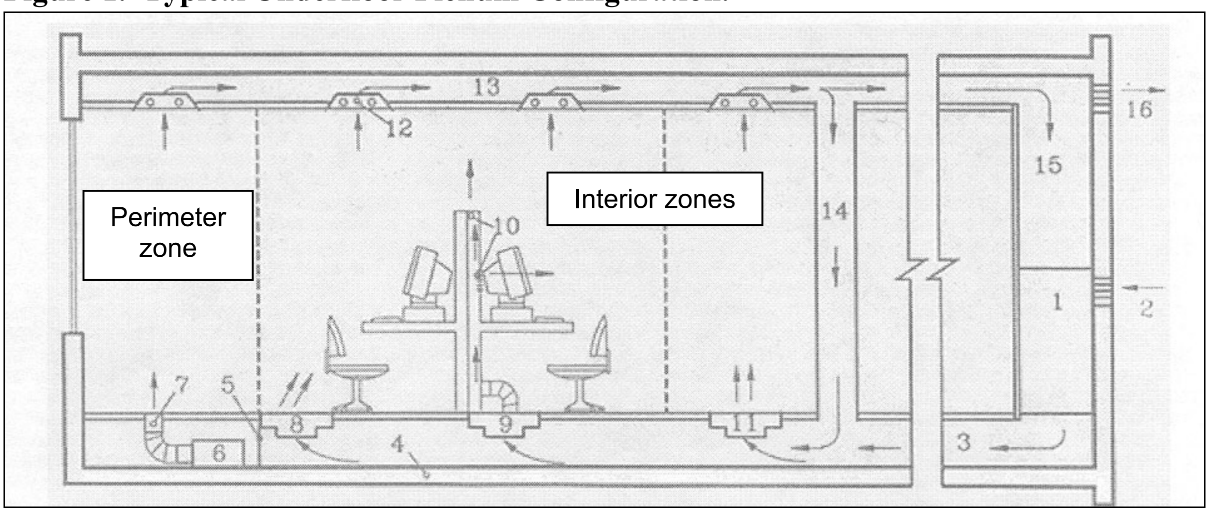
Satisfying this dichotomy is extremely complicated when utilizing only air from an open plenum design.

One solution is to utilize a partitioned plenum to create independent thermal load zones (for example: perimeter, interior, specialty areas) to satisfy individual zone temperature requirements. In concept, it is easy to supply air from a central air handling unit to each partitioned zone and use fan-powered terminal units to control the actual air temperature delivered to the space. Another possibility is to design dedicated HVAC systems for each partitioned zone. The disadvantages of using a partitioned plenum are a significant loss of system flexibility and the system operates similar to a conventional overhead air distribution system.

Another option is to maintain the open plenum, with the interior loads served by either passive or active diffusers and perimeter zones served by fan-power terminal units ducted directly to the diffusers. The advantages of the open plenum configuration with ducts over partitions are more flexibility in reconfiguring the layout (ducts are significantly easier to relocate than sealed plenum partitions) and better system performance and efficiency. Typically most applications will utilize some variation of open/ducted or partitioned plenum and passive/fan-assisted system arrangement.

Figure 1 illustrates a representative underfloor air distribution system with several options.

Figure 1. Typical Underfloor Plenum Configuration.



1. HVAC unit	5. Perimeter zone plenum divider (optional)	9. Personal active diffuser	13. Return air plenum
2. Outside air intake	6. Fan-powered terminal box w/reheat	10. Personal volume dampers	14.Transfer duct (optional)
3. Supply air to plenum	7. Ducted floor diffuser (optional)	11. Passive or active floor diffuser	15. Return air to HVAC unit
4. Underfloor plenum	8. Passive or active floor diffuser	12. Return air path	16. Exhaust air

Source: CBE

A key issue to keep in mind is the difference between total air flow and outside ventilation air flow. If the underfloor plenum is intended to supply only outside ventilation air, then all heating and cooling loads must be satisfied through other means. The volume of air needed to satisfy ventilation requirements is far less than that needed to meet heating and cooling loads (refer to Case Study B for an example of a misapplication).

Humidity control. The typical underfloor air distribution system delivers air to the space between 63°F and 68°F. In humid climates, a discharge air temperature of at least 55°F off the cooling coil will be needed to dehumidify the air, but air this cold cannot be supplied to the space without significant comfort complaints. One option is to use the cooling coil and a face and bypass damper at the central HVAC unit, with the cooling coil and face/bypass damper controlled as necessary to satisfy humidity setpoint and maintain a reasonable discharge air temperature. Another option is to deliver 55°F to the plenum and use return air to temper the supply back to desired air temperature, but this would most likely require the design and installation of transfer ducts between the ceiling and plenum (refer to Figure 1 for an example of a transfer duct).

Passive or active diffusers. The option to use either passive or active diffusers is somewhat determined by whether the plenum is pressurized or not. Active diffusers use small fans to deliver air from the plenum directly to a work station. In a purely open, pressurized plenum, both passive and active diffusers can be used, but only active diffusers should be used in a purely open, non-pressurized plenum. However if the plenum has ducted fan-powered terminal units, then either diffuser style can be used. The main advantage of active diffusers is more individual control, which can increase comfort and productivity (Crockett 2002). The primary disadvantage is that small fractional horsepower fans can be less efficient than a large central fan, however fractional horsepower motor efficiency continues to improve.

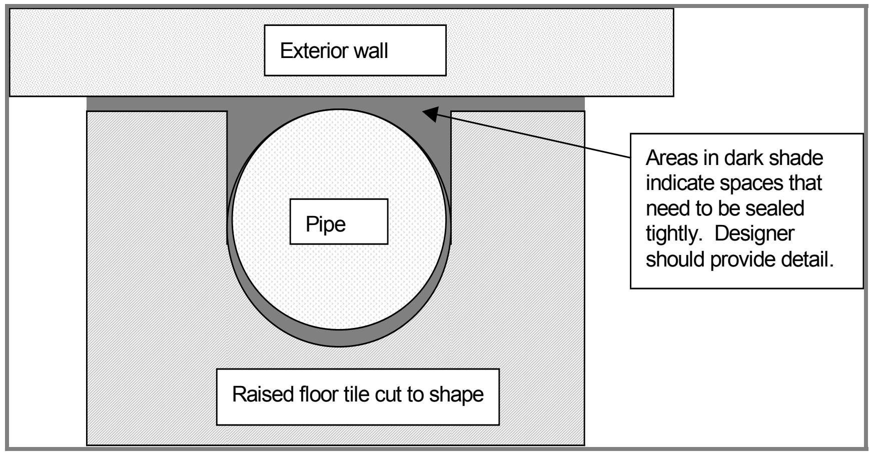
Designing an Air Tight Assembly

Making sure the underfloor plenum is tightly sealed is critical to proper system operation, especially when employing a pressurized plenum. During design-phase commissioning, review the specifications and ensure they clearly state each contractor's responsibility with respect to sealing the plenum. For instance the specifications could include the following requirements:

- Mechanical and plumbing contractors will seal any penetration they create leading to and from the underfloor plenum.
- Electrical and data/communication contractors will seal any exterior penetration they create as well as the inside of conduits to prevent plenum air from migrating into the wall or the occupied space through electrical and communication outlets.
- The raised floor installer will be responsible for providing some form of gasket or seal anywhere the raised floor abuts against a permanent wall.
- Any partitions within the plenum to create independent zones, or walls that penetrate into the plenum, will be tightly sealed between the slab and bottom of the raised floor. This will prevent air from migrating between zones and into wall cavities. The walls are the responsibility of the interior finish contractor (the one furring-out all of the walls). Assigning responsibility for plenum partitions may be more difficult, but it would make sense to include it as part of the mechanical contractor's scope since partitions act the same as ductwork.

In addition, ensure the drawings contain as much detail as possible. For instance if it is known that a water pipe will be located along a perimeter wall and will penetrate into the plenum, it may be worth recommending that the designer develop a drawing detail illustrating how best to achieve a tight seal. Figure 2 shows a drawing detail that could be generated to assist both the designer and the contractor in making sure that all penetrations are properly sealed. It is better to provide as much guidance to the contractors up front as possible, rather than trying to fix problems later.

Figure 2. Floor Penetration Detail



Source: PECI

Designing for Maintenance

Depending on the type of underfloor air distribution technology selected and the loads served, there may be a fair amount of equipment located under the raised floor (i.e. fan-powered boxes with reheat coils). The most important design issue here is making sure there is adequate room and access to perform routine maintenance and repair. Key topics to consider include:

- Equipment access panels should not be blocked by flooring vertical or horizontal structural supports or any other immovable objects.
- Enough room should be available for equipment removal and installation. For example make sure removal and installation of a reheat coil will not be impeded by floor supports.
- Equipment should be located so that filters can be replaced easily.
- Coordinate with interior designer regarding furniture layout. Ensure that mechanical equipment is located in corridors or other open areas where access to the equipment through a floor tile is unencumbered.

Designing for Catastrophic Occurrence

One disadvantage to installing HVAC equipment in an underfloor plenum is – "out of sight, out of mind". This is especially critical when the equipment may be served by chilled and/or hot water. If the unit develops a leak, it is fairly likely that it will go unnoticed for quite some time, unlike an overhead system that starts to drip. The design-phase commissioning should address the following:

- The underfloor slab should be sloped and have adequate drainage to remove any water from the plenum.
- Moisture detectors should be installed on the slab and they should generate an alarm that can contact maintenance personnel immediately.
- The make-up water line valve should be closed and a pressure sensor installed in the water loop. Many times the make-up water valve is left open to keep the loop full should minor amounts of water be lost. However in this scenario there is nothing to stop the water from flowing continually if there was a major leak. Keeping the valve closed and monitoring system pressure, allows the central DDC system to shut down all equipment and generate an alarm if the system loses pressure due to a major leak. The alarm should contact maintenance personnel immediately and require a manual reset before restarting any equipment.

Construction Issues

The old adage – everything looks good on paper – can really be true when it comes to an underfloor air distribution system. Diligence during construction will help mitigate potential operating and occupant comfort problems. The key is to keep an open dialog with the contractors and encourage them to ask questions. Most likely this is the first time they have ever seen anything like this and the learning curve may be steep. The primary construction issues that demand the most attention are outlined below.

Constructing an Air Tight Assembly

Ensure that all trades are fully cognizant of their responsibilities with respect to sealing the plenum in accordance with the specifications and work with individual contractor as necessary to provide guidance. Any instances where the specifications were not clear regarding a contractor's responsibilities must be resolved in the field. In addition, tenacious persistence is required during construction on the part of the construction manager or commissioning provider by way of field inspections to assure the integrity of the plenum.

Cleanliness During Construction

Keep the workspace clean, especially prior to installation of the floor. It is a lot easier to clean everything before the floor is put into place. In order to reduce dust even further, the surface of the slab could be sealed. Using a shop-vac once a week throughout construction to clean up dust and larger debris will extend the life of the initial set of filters, prevent dust from being blown throughout the office when the HVAC system is started for the first time, and prevent larger items from getting in fan units, dampers, or grills.

Coordination Between Trades

It is important to ensure that there is good coordination between all of the trades as construction progresses. It is particularly critical that the mechanical contractor and flooring contractor coordinate the size and location of all HVAC equipment installed within the plenum with the raised floor support legs layout. It is recommended that the mechanical contractor request a template of the actual equipment to be installed and check it against the floor support plan. It is not uncommon for manufacturer's cut sheets to have inaccurate shape and dimensions, which could be disastrous if this were the only information used for coordination. It is also imperative that as much plenum work as possible be completed prior to installation of the floor. One obvious reason is access but more importantly, it is very easy for the screws that attach the floor tiles to the support legs to strip out due to repeated removal and installation. Once the screws are stripped, the floor tiles will not create a tight seal with adjacent tiles and the support legs, which can result in uncontrolled air leakage into the workspace.

Long-term Operation Issues

Maintaining plenum integrity is just as important to future operation and occupant comfort as making sure it works straight away. The key to ensuring a tight plenum over the lifetime of a building is to measure the plenum leakage value when the building was first constructed and use this value as the benchmark for future tests. The plenum leak test includes blocking off all passive and active diffusers, making sure all fan powered terminal boxes are turned off with primary air dampers shut, and the central air handling unit operates to maintain design static pressure within the plenum. Measuring the air flow delivered by the central fan under these conditions will quantify the amount of air leaking from the plenum. A similar plenum leak test should be performed every few years or right after any remodeling or reconfiguration of the underfloor air distribution system. It is imperative that any changes made to the underfloor system or office furniture layout do not impede maintenance access. It is also advisable to keep all of the original specifications and include these same requirements, if applicable, on any new projects. Periodic testing of all alarms is also recommended to ensure the system will respond properly in the event of an emergency.

Case Studies

The following projects highlight issues identified during commissioning with the design, construction, and operation of underfloor air distribution systems. The first case study was a new construction project that was fully commissioned and the second case study pertains to the renovation of an existing office space that was not commissioned.

Case Study A

The following new construction project consisted of a 15,000 SF office space, 25,000 SF training center, and 135,000 SF distribution center. The primary design intent for the building was to achieve a LEED gold rating, hence several innovative design features were employed to improve energy efficiency and indoor air quality, including an underfloor air distribution system and natural ventilation cycle serving the office space. The underfloor plenum was designed to be pressurized to 0.05 inch w.c. with a peak air flow of 14,000 CFM.

Air is delivered to the plenum by a roof-top HVAC system with the supply fan controlled by a variable frequency drive. The plenum is completely open and fan-powered terminal boxes with reheat coils were used to distribute the air to passive diffusers via ductwork. Fan-powered boxes were selected to assist in delivering air to the space during the natural ventilation cycle and to meet perimeter loads during normal operating conditions. The following observations were made during commissioning regarding all aspects of the underfloor air distribution system.

No drains specified. The original design did not include any drains in the underfloor slab. During design review, the commissioning provider recommended installing drains in case a catastrophic failure occurred with any of the hot water lines serving the fan-powered terminal boxes.

Electrical conduit and junction boxes mounted flat on the underfloor slab. During a construction site visit, the commissioning provider noted that the electrical conduit was installed flat against the plenum slab and warned that the conduit could impede water flow should a water leak occur. Since a majority of the conduit had already been installed, the solution was to add shims under the conduit in between lag bolts to raise it off the slab. It was also noted that all junction boxes connected to conduit on the slab were also mounted flat on the slab. Some of the boxes only contained solid wires pulled through them but others enclosed actual wire connection. The concern was that water on the floor could penetrate these junction boxes and cause an electric short. The recommended solution was to mount a second junction box on top of the first box and extend any wire connections into the upper box. This would keep all wire connections at least three inches off the slab in case the slab flooded.

Plenum air leaks. The specifications did not clearly state each trade's responsibility towards maintaining plenum integrity, nor did it define how the plenum was to be sealed. During the construction meetings, the commissioning provider reiterated how critical it was to make sure the underfloor plenum was tightly sealed. Despite the fact that the contractors were very diligent during construction in regards to sealing any penetrations, the underfloor plenum still had a significant amount of leakage, including:

- There was no seal between the raised floor and the exterior concrete wall. It was not in the flooring contractors scope of work to provide a seal and the gap was about 1/16 inch in most places. That may not sound like much, but considering the exterior wall encompassed almost 320 linear feet, that adds up. The recommendation was to apply a bead of caulk before the furred-out walls were installed, but this did not happen.
- Along the 120 linear foot south wall, the furred-in finished wall extended clear down to the plenum slab. It was noted that there was at least a 1/16 inch to 1/8 inch gap between the sheetrock and the slab along the entire length of the wall. This gap was eventually caulked after the first plenum test by crawling around under the floor. It would have been much easier to do this before the floor was put in place.
- The data/communication contractor did not seal the floor penetration or the inside of their conduit, as noted by feeling air blowing out of the wall sockets. The contractor was called back to remedy the situation.

Several plenum tests were performed to determine the amount of air leakage from the plenum. The initial leakage rate was about 4,200 CFM on average at 0.05 inch w.c. plenum pressure, which corresponds to approximately 30% total supply air flow. Several leak sources were identified and sealed with urethane foam and the test was performed again. The second test revealed the overall leakage was reduced to approximately 3,800 CFM on average. The leaks that were known to be entering the workspace and leakage from the natural ventilation dampers were then measured. The leakage into the workspace was deemed acceptable since the air was actually migrating into, rather than bypassing, the occupied space even though this air flow can cause comfort problems and waste fan energy. The leakage from the natural ventilation dampers, however, was not acceptable and had to be fixed (refer to discussion below). In all, the total amount of air leaking completely from the plenum is estimated to range between 16% and 18% of total supply air flow. The designer expected approximately 10% leakage. The excessive leakage increases both fan and cooling energy. Refer to Table 1 for final plenum leak estimates.

Table 1: Plenum Leakage Test Results

Plenum Test Procedure	Low CFM Value	%Total Supply Flow	High CFM Value	%Total Supply Flow
First plenum test	4,000 CFM	29%	4,400 CFM	31%
Second plenum test	3,500 CFM	25%	4,000 CFM	29%
Measured Leaks				
Leaks into work space	920 CFM	6.6%	1,120 CFM	8.0%
Leaks from dampers	380 CFM	2.7%	460 CFM	3.3%
Unknown leakage	2,200 CFM	16%	2,420 CFM	17%
Estimated damper leakage[1]	50 CFM	0.4%	60 CFM	0.4%
Total plenum leakage	2,250 CFM	16%	2,480 CFM	18%

Note: 1 – Estimated damper leakage rate is based on properly operating natural ventilation dampers

Source: PECI

Plenum air infiltrated furred-out walls. It was noted that air from the plenum was infiltrating the furred-out walls, which had a significant impact on the operation of the HVAC system. Many of the temperature sensors used to control corresponding fan-powered terminal units were always reading low because the wall cavity in which they were mounted was approximately 65°F due to the air from the plenum. Hence the space temperature setpoint was never satisfied and the reheat coils continually operated at full capacity. The junction box for each temperature sensor was sprayed with insulating foam to prevent the plenum air from influencing the sensor reading.

Excessive leakage from natural ventilation dampers. A unique design feature at this facility included installing dampers through the exterior wall within the underfloor plenum to allow for natural ventilation into the plenum when outside temperature conditions could meet the cooling loads (passive economizer cycle). Low leakage dampers were specified and installed but it was discovered during the plenum pressurization tests that the dampers had a significant amount of leakage (refer to Table 1 "Leaks from dampers" for measured leakage values). Based on manufacturer's cut sheet, the leakage rate on the dampers is rated at 48 CFM at 1.0 inch w.c. and should be much less at 0.05 inch w.c. The leakage could be attributed to several factors including improper actuator pre-load torque, missing thrust bearing on vertical blades, or leakage around the frame. These dampers directly impact the performance of the underfloor plenum since they are an integral part of the overall design.

Case study conclusion. Due to a concerted effort by the design team, all contractors, and the commissioning provider, many potential problems were identified and corrected early on during construction, which significantly contributed to the successful installation of an underfloor air distribution system at this facility.

Case Study B

The following project included renovating the entire seventh floor (11,000 SF) of an office building to incorporate an underfloor air distribution system. The primary design intent for the project was to provide the occupants with individual control over their thermal environment and to provide flexibility in office configuration. The renovation project was to be used as a pilot to determine whether the concepts could, and should, be implemented as the recommended design for all future renovation projects.

The perimeter loads were served by water-loop heat pumps and only the outside ventilation air was supplied to the underfloor plenum. The outside air handling unit included variable frequency drives on the supply and return fans, both sensible and latent heat recovery, a steam coil for heating, and a direct expansion coil for dehumidification. The plenum was completely open and intended to be maintained at 0.15 inch w.c. of pressure. Both passive and active diffusers were installed at various work stations to deliver ventilation air to the space. Commissioning did not occur during design nor construction. However, a retrocommissioning study was performed on the facility a year later and the following observations were made.

Plenum not sealed. During construction, the plenum was not sealed adequately. There were large holes where the flexible water hoses came from the plenum up to each heat pump. The plenum was also open to the floor below since holes in the concrete slab for conduits were never sealed. As a result the plenum could never maintain pressure and the variable frequency drives operated at 100% speed continually. The recommendation was to seal the plenum as best as possible.

No cooling for interior zones. Most of the work stations were located on the perimeter of the building and the conference rooms were located in the interior of the space. Since the system was designed to only supply outside air ventilation requirements through the plenum, there was inadequate air available to cool the conference rooms. To alleviate overheating, at least two active diffusers were added to each conference room, with the air being extracted from the plenum. Since the air flow from these fans far exceeded total air flow delivered to the plenum by the air handling unit, air from the rest of the space was being drawn into the plenum and distributed back into the space through the conference rooms. Basically the whole space was turned into one big zone. The resolution for cooling the interior zones is currently under review. One option is to add additional heat pumps, which has its own set of problem due to how the existing heat pumps serve the space. Another option is to partition the underfloor plenum and add a small dedicated HVAC unit, but then the design intent of flexibility is compromised.

Diffuser flow rate exceeds available ventilation air. The outside air ventilation HVAC unit was designed to provide 1,500 CFM of outside air to the underfloor plenum but the total capacity for all active diffusers installed far exceed 1,500 CFM, which exacerbates the plenum pressurization problem. The system may never operate as intended if more air can be drawn from the plenum than is provided in the first place. Resolution of the issue is currently under review.

Flooded plenum. The flexible piping connected to one of the heat pumps ruptured and began to flood the concrete slab on a Friday evening. The slab is equipped with moisture detectors, but the alarm was located in the mechanical room and the problem went unnoticed until water began to flood the security station located on the first floor of the building. The problem here is two-fold: 1) the moisture detection alarm is not located where it will be immediately acknowledged; and 2) the water loop make-up line valve was always wide open. The first recommendation is to relocate the existing moisture detection alarm to the security station and add an alarm to the central DDC system that could alert maintenance personnel immediately. The second recommendation is to close the make-up valve and install a pressure transducer to the water loop. Upon a loss of pressure (i.e. a leak), the central DDC system would shut off the circulation pump and send an alarm to maintenance personnel. All of the water in the loop could potentially drain completely from the system and cause some damage but this is a finite volume, not a continuous flow of city water that could feed a leak. The resolution is currently under review.

Case study conclusion. The original design intent of providing flexibility and personalized control of space conditions was not met do to a misapplication of the underfloor air distribution system and numerous construction issues. Had design-phase and construction-phase commissioning occurred, several of these issues may have been identified and addressed, and the chances for a successful project would have greatly increased.

Conclusion

If something is "simple", then it is probably too good to be true. This certainly is the case with underfloor air distribution systems. The concept is simple enough – put air in the plenum between 63°F and 68°F, deliver it at floor level, let it heat up and natural buoyancy will move the air from the floor to the ceiling, and then just bring it back to the central HVAC unit. But once you get beyond the concept, there are numerous design, construction, and operation issues that must be address in order to get the system to function as intended over the life of the project.

This observation was validated through the two case studies presented. Both projects experienced a variety issues but the common theme between them both was plenum leakage. Even in new construction with everyone paying attention to detail in the construction practices, it was difficult to achieve less than 20% total air flow leakage. Increased experience with both design and construction of underfloor air distribution systems should improve the results.

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