How the Commissioning Provider Can Facilitate a Successful Underfloor Air Distribution Project

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Synopsis

Underfloor air distribution (UFAD) has become increasingly common in commercial construction over the past 5 years. However, there are numerous aspects of the design, construction, and testing of these systems that have been poorly implemented; the result has been costly troubleshooting, delayed move-ins, poor indoor environmental quality, and unnecessary energy penalties. The problems stem from the fact that UFAD technology requires UFAD expertise in multiple disciplines and – most importantly – that all of these disciplines must work closely together. Mechanical designers are not used to working with the very low UFAD plenum pressures (0.03-0.10" WC) and may not understand the importance of small cracks, proper dehumidification techniques, and common plenum and floor zoning issues. Architects are not experts in detailing building elements (floor, ceiling, and wall spaces) to be pressurized plenums and have trouble providing sufficient direction on the specifications. Construction managers and contractors are not used to managing a system that involves so many players and requires careful planning, coordination, and vigilance over the entire construction period. Contractors rarely have staff that understand all of the UFAD issues and can direct subcontractors to conduct their work at the right time and deliver it with sufficient quality.

Because they have inherent systematic and a holistic approach to the design and construction process, commissioning providers are in a perfect position to assist and facilitate successful UFAD projects. Commissioning providers perform design and specification review, construction submittal review, field observation, and testing. During each of these activities, these professionals can provide valuable input to help team players avoid the many potential pitfalls. One of the key areas commissioning providers can assist with is helping contractors sequence and coordinate the installation of the UFAD elements.

About the Authors

The authors have been personally involved in six UFAD commissioning projects and have consulted on other projects with designers, commissioning providers, and owners concerning UFAD projects and issues.

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Commissioning UFAD Systems per Project Phases

Commissioning and its role are defined by the life cycle of a building project. With UFAD, the implementation of traditional commissioning activities is no different. With careful attention to the following issues and situations, a successful project can be easily achieved.

Design Phase Commissioning

Starting the commissioning process as early as possible during design documentation tends to add value to the project without necessarily adding a large cost. A focused review of not only the traditional energy consuming systems, but of architectural and structural details such as stem walls, window glazing, stairwells, floor, and wall penetrations and other areas of potential leakage will allow simple yet invaluable changes to be made during the design phase that will facilitate the construction of the architectural "plenum" by the contractor.

Design Review

UFAD is by no means standardized design. It might be someday, but today it is not. The commissioner must rely on past experience as much as possible, but be careful not to prejudge a design that is innovative or a little different.

Below is a list of UFAD issues that should be addressed during a commissioning design review:

- **Numerous AHUs operating in parallel to supply air to the same underfloor area.**
  Are the AHU VFDs all controlled by a single static pressure sensor? Could the AHUs end up fighting each other (generally, they should all be controlled by the same sensor, or if there are multiple sensors, they should use a high/low select or averaging routine).
- **Strategically located balancing and barometric dampers.**
  With multiple AHUs in operation, what would happen if one AHU was shut off? If there are perimeter heat modular fan terminal unit (MFTs), are they correctly dampered so that they do not redirect non-conditioned air into undesirable places?
- **Type of sensors.**
  Is the respective sensor capable of accurate readings for the ranges expected of it? For example, air highways may have higher static pressure 0.10-0.15"w.g. where general underfloor sensors should be capable of reading 0.010 to 0.10"w.g. A single 0.00 to 0.25"w.g. sensor will not provide the sensitivity and accuracy required for both areas.
- **Location of sensors, both temperature and pressure.**
  Are temperature sensors located on walls that may have underfloor air leakage problems? Are differential pressure sensors located away from corners, supply dampers, or other obstructions that could produce a venturi effect or other undesired results?
- **Perimeter heating.**
  Does this form of heating make sense for the application it is serving? Is the form of heat (electric, hydronic) insulated so that only the desired air is being heated?

- **Air highways (1).**
  Are there diffusers located in these higher pressure areas (which can be problematic and not recommended)? Are the air highways sufficiently sealed as to not leak air and achieve their objectives?
- **Air highways (2).**
  Are air highways installed so no non-fan-powered floor diffusers are further than 50 feet from the end of a duct?
- **Noise**.
  Are the air highways insulated for sound? Are the floor diffusers correct for the application (diffusers are often located very close to the occupants)?
- **Specifications**

Are there clear requirements in the specifications describing the following:

- An assigned party who will manage the coordination and execution of all trades UFAD work and be responsible to personally make inspections along the way.
- Air sealing.
- Cleaning of underfloor area.
- Inspections (including acceptance criteria).
- Covering of floor panels or joints to prevent dirt from falling between them.
- Carefully marking as-builts with all controllers, valves, dampers, equipment, junction boxes, etc. prior to setting panels.
- Marking panels over which there are valves, dampers and equipment that will need to be accessed by trades.
- Requirements for workers accessing the underfloor after panels are set.
- Mock-up requirements, including a pressure test.
- A full construction checklist.
- Pre-commissioning pressure test.
- Commissioning and functional testing requirements.
- Fine-tuning requirements (holding the contractor responsible to fine-tune floor pressure and temperature resets to enhance air stratification and comfort within the space served).

This is not a comprehensive list of all the design issues that should be reviewed with an underfloor system. Other systems traditionally reviewed by the commissioner should still be reviewed to facilitate a successful project.

Drawing Details

A traditional duct/diffuser system is designed and specified by the mechanical engineer and is primarily built by specialist mechanical contractors. This design and construction has been well defined and dictated by the rules of pressurization and structural restraint. It is the mechanical engineer's responsibility to specify pressurization requirements and inspect construction techniques to ensure that there is minimal system pressure drop and little or no air leakage. Architectural input on traditional ducting systems is generally focused on space coordination (i.e.

providing adequate room for ductwork); and unless the ductwork is exposed and/or considered a "feature", the architect typically has limited design input.

In contract, the raised floor area of a UFAD is not designed by the mechanical engineer but more often by the architect and structural engineer. The same attention to leakage and pressurization detail must be adhered to, but the architect or structural designer may not be familiar with these requirements. Because the UFAD "plenum" is structural in nature, the requirements for construction reside mainly in specification sections other than Division 15. Specification sections such as gypsum board wall construction, stem wall, framing, window framing, wall penetrations, and so forth mostly reside in the architectural, structural, and specialty divisions and sections. Prior to development of UFAD systems, very few of these respective specification sections had *any* sealing or pressurization requirements or details, save those for the waterproofing aspects of window framing sections.

The shift of design responsibilities concerning pressurization has caused a documentation gap that has, in turn, resulted in incomplete construction documentation. The contractor will only scope, bid, and perform according to the design documentation. It has not proven effective to simply require the contractor to "provide an underfloor space capable of holding xx inches of water column." Numerous poorly constructed underfloor projects are proof that this type of performance spec is not sufficient instruction for builders to perform the work.

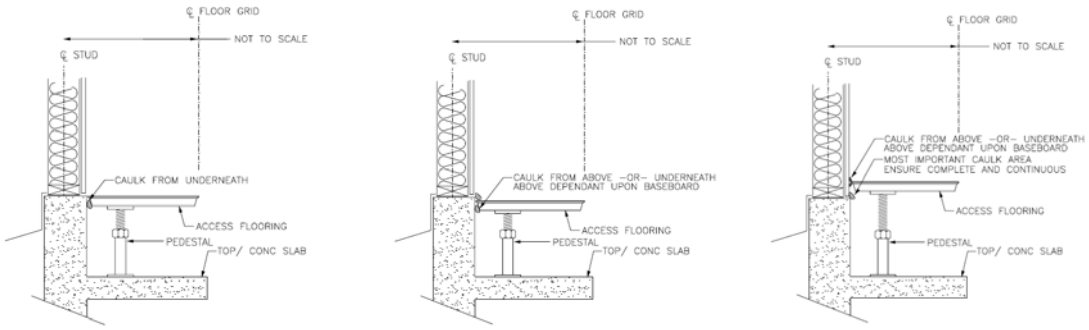
If the commissioning process can actually begin early enough in the design phase, an experienced commissioner can provide input on architectural and structural drawing details with regards to wall joints, wall penetrations, window and door installations, stair details, transitions, and finally, actual raised floor systems and installation. With a focus on air pressurization and the sealing required to maintain that pressurization, the commissioner can recommend enhancements to existing details, and provide additional details and sealing techniques to help the contractor understand the critical nature of the architectural plenum.

The most critical, potentially least expensive (if done in a timely manner) and energy-saving aspect of the details is the correct call out of the sealing requirements and techniques. Usually, the sealing of these detailed areas is a low-cost activity that is conducted early in the construction phase. The rework required to go back and seal these areas after the carpet has been installed, furniture moved in, and substantial completion in the wait can be catastrophic to both owner and contractor groups.

The drawing details should:

- Specifically point out critical issues.
- Draw on your experience and the experience of others.
- Seal with the pressure (like patching a boat or adding sealant to a leaking radiator, use the pressure to enhance the seal, not work against it).

Figure 1: Typical Details



Keep in mind that every corner, stair, elevation change, or transition may be a special case and require the contractor to have at least a comprehensive, if not complete, understanding of the design intent (if pressurization criteria is a global note on the drawings or specifications).

Specifications

As previously stated in the above section, the design and specification requirements of the plenum for UFAD systems have shifted to trades other than mechanical. This shift or gap has made construction trades not only responsible for their respective activities, but for the entire construction of the design intent.

The typical contractor/subcontractor hierarchy has allowed subconsultants to only read and be responsible for the specific specification section that pertains directly to them. “Not in my division” was an acceptable response when sheet rock installers were asked about electrical conduit and electrical and communications installers were asked about sealing sheet rock. These type of “gaps” or questions about responsibilities can be a major cause for the failure of an underfloor to maintain pressure.

To facilitate an “on budget,” “on schedule,” efficiently functioning UFAD project, a well-coordinated specification set needs to be created. The commissioning provider can suggest inserts, or at least refer to sections (related sections) that can hopefully point differing trades in the same direction.

If the designer doesn’t feel qualified to specifically define air sealing details, a commissioning provider can suggest they work with a consultant who does. The system is unlikely to work well if the designer writes a performance specification with the expectation he or she will get shop drawings back from the contractor on how to make the space sufficiently air tight. It is imperative that the contractor have the details of where to seal and how to seal it. It is recommended that specification language state that methods for any areas not detailed be approved prior to application.

Below is some air sealing specification language that may be appropriate for your project.

Sealing Requirements

- Floor area inspected and each opening to wall or floor cavities or to other spaces or zones is verified to be appropriate and all openings that should not be communicating to this floor space are sealed.
- Underfloor perimeter along exterior walls and above unconditioned space sealed absolutely airtight (drywall or sheet metal to concrete deck, vertical and horizontal drywall joints, other penetrations). Overlapping or butting building elements are not acceptable as a seal unless caulked.
- Penetrations from underfloor space into interior walls sealed reasonably airtight, but still caulked (drywall to concrete deck, vertical and horizontal drywall joints, around duct, pipe, conduit, and cabling penetrations).
- Open ends of conduits in underfloor space sealed with caulk.
- Penetrations of ducts and piping and other assemblies through the concrete subfloor or through the raised floor are sealed.
- Floor panels butting walls are *planned* to be gasketed and seal tight.
- The contractor is responsible to make the underfloor area airtight from all interior and exterior spaces, except for penetrating ducts and diffusers.
- The contractor shall follow the intent of the above requirements. The contractor shall follow the drawing details. Discrepancies shall be noted by the contractor and settled by the design engineer prior to proceeding.

Examples of specification sections that need to be tied together, or related:

- Quality Control
- Cleaning
- Cutting and Patching
- Joint Sealers
- Sheet Rock
- Access/Raised Floor
- Structural Steel
- Expansion Joint Cover Assemblies
- Basic Mechanical Materials and Methods
- Mechanical Insulation
- Air Handling Equipment
- Air Distribution
- Testing, Adjusting, and Balancing
- Basic Electrical Materials and Methods
- Conductors and Cables

Each project is different. One of the first commissioning tasks should be to simply go down the list of specifications and highlight the ones that even remotely may have an impact on air tightness. The commissioning provider should then suggest insertions that would tie these together or point to a specification section that defines sealing criteria and requirements.

Construction Phase Commissioning

Traditionally, the commissioning process concentrates on the verification phase of a project. The authors firmly believe that, at least for UFAD, the most important phase of the commissioning process is the mid-construction phase. By paying close attention to submittals, numerous field observations, documenting and resolving construction issues (not just control issues), the commissioning provider should primarily be conducting a documentation exercise during the later part of construction (verification phase).

Submittal Review

The commissioning requirements of the submittal reviews are well defined and required per LEED® and the traditional commissioning process. With respect to UFAD system, these are the other things that the commissioning team should be focused on during the submittal review process:

- **Access or raised floor system.**
  What is acceptable distance between floor tiles? See Figure 2.
  What sealing methods are available for air highway configurations (how can the air highway be sealed to the underside of the floor tile)?
- **Sensor sensitivity and configuration.**
  Are the ranges correct for the application?
  Will temperature sensors be easily influenced by conditioned air coming from the wall cavity or through electrical conduit (if mounted on walls that extend to slab use stand-off type temperature)?
- **Carpeting** (with type or method of adhesion).
  Will the carpeting be an integral part of the sealing method? If so, is the carpet porous (as opposed to rubber backed)?
  Will the adhesive "flow" and fill the spaces between the floor tiles?
  Will the adhesive prevent/hinder carpet removal and access to the plenum?
  Will loss of adhesion over time result in leaks from the plenum?

Field Observation/Inspection

Field observation by the commissioner needs to be more than an exercise in documentation. The more time spent in the field inspecting the work and communicating with the players, the more efficient the process will be. Inspections/observations should be:

- **Frequent**
- **Representative**
- **Documented**

Commissioners should look for:

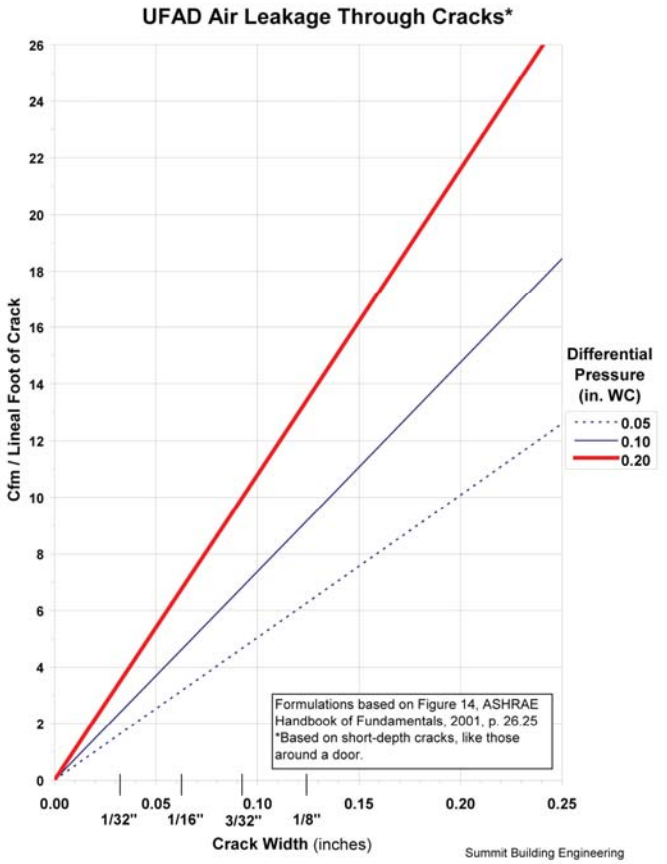
- **Critical sensor locations**
  This is an issue that should be addressed during the design review, but, many times what is installed in the field does not match what is shown (or not shown) in the drawings. A check of the sensor locations during the mid-construction phase will generally negate the need for pulling up carpet at a later date.
- **Cleanliness**
  Save it to the end?
  Everyone's task, but one person's responsibility. Cleanliness should be addressed as to who is ultimately responsible and how clean is clean in the specifications.

- **Airtight**

How tight is tight enough? Contractors (and architects and engineers) too often think that not much will leak through a thin crack under the low pressures experienced by underfloor areas. They also think that the overlapping or butting together of two hard surfaces will constitute a sufficient air seal. This is not the case. Figure 2 illustrates the amount of leakage that will occur through narrow cracks at differing pressures. Providing specific quantifiable data on a project can help resolve disagreements in the commissioner's favor. Below is text from an actual project memo:

Figure 2. UFAD Air Leakage Through Cracks

To put things in perspective, there is about 3,000 lineal feet where the raised floor is adjacent to exterior perimeter walls. The gaps in the current design and construction where the top of the raised floor panels meet the outside wall range from 0 to 3/8". The airflow leaking through those cracks alone would be almost 12,000 cfm, using the assumption that the gaps average 1/16" and that the under floor pressure is 0.10 in. WC. This is about 7% of the total AHU supply air flow. A significant amount of this air would be leaking directly into the exterior wall cavity—a serious energy issue.



The Issues Log

Issues logs are common to every commissioning project. However, not all are managed equally. For UFAD projects, the issues log can be a great help. UFAD projects will have issues that seem to never die, as fingers are pointed back and forth among the multiple trades involved. The commissioning provider can help by maintaining an accurate log of the status of UFAD issues, including responses and non-responses by contractor parties. By vigilantly attending to UFAD

issues, the commissioning provider ensures that issues will be resolved before it becomes too late to optimally address them.

Figure 3: Commissioning Issues Log

Equipment / Group	Dates Entry / Closed	Issue Details and Impacts (list equip tag and zone)	Response or Action by Contractor, A/E, CA or Owner
All AHU's	4/19/06 4/25/06	How the issue was discovered. What problems is it causing? What are the specific equipment Tag Numbers? In your opinion, will there be a schedule impact? In your opinion, willill there be a cost impact?	4/19/06 Issue is OPEN 4/20/06 Who's responsibility is this issue? 4/21/06 Document the proposed solution to this issue. 4/22/06 Who is in the critical path? 4/23/06 Date this issue will be resolved. 4/24/06 Solution is in progress. 4/25/06 Issue resolved and documented. 4/25/06 Issue CLOSED

Underfloor Construction Checklist

A comprehensive and multi-trade document should be issued early in the construction process (hopefully with bid set documents), updated per task completion (not checked off minutes prior to functional testing), and discussed at every commissioning meeting from the construction kick-off meeting onward. The checklist must be managed by a responsible party from the general contractor's camp. Below is a representative list of checklist items that should be included, as appropriate, in a construction checklist. This checklist provides a systematic process in sequence to install UFAD systems so they are sufficiently clean and airtight. The process provides effective and critical coordination guidelines to minimize contractors having to access the floor after initial installation. Note this is not a comprehensive list of all issues and must be tailored to the needs of the specific project.

PRIOR TO SETTING PEDESTALS:

- Meeting held with drywall, electrical, controls, cabling, mechanical, sheet metal, and general contractors, architect, and commissioning authority to go over raised floor protocols and sealing details.
- Concrete floor sealer applied to subfloor, IF specified.
- Pre-installation adhesive field test completed per specifications (set 3 pedestals in adhesive, let cure for 30 days under 25 lbf, apply lateral load at top of pedestal, measure force to fail adhesive bond).

PRIOR TO SETTING FLOOR PANELS:

-MISC.

- All underfloor utilities and work complete (HVAC, plumbing, electrical, data, etc.).
- Carpet glue type and method of application relative to how much it seals panel joints is mocked up and approved.
- Underfloor air plenum dividers located and installed as designed.
- Zone and fire separations installed. Perimeter of every air handler zone is walked to verify it is in place and sealed.
- Shut off valves, sensors, dampers, actuators, fan coil units, filters booster fans be located so they can be accessed later for service and replacement.
- Record drawings submitted showing location of shut off valves, sensors, dampers, fan coil units,

filters booster fans, controllers and other equipment requiring future maintenance or replacement. Submittal required before any panels cover these devices.

- Underfloor temperature sensors in good representative locations away from piping that may affect readings.
- Zone thermostats installed in location to avoid drafts and allow the best available representation of the zone temperature for control.
- Leak and moisture sensors in place, as specified.
- Insulation installed, as specified.
- Floor drains installed, as specified.
- FCU and booster fans mounted to avoid vibration. Duct insulation installed.
- Transfer ducts and extension ducting installed.
- Ducts to terminal devices connected and sealed. Special dampers installed.
- Any piping or other assembly under the floor that is more than 1/ 4 the floor space depth tall and is more than 1/2 the width of a path to an underfloor zone shall be viewed and approved by the designer.
- Electrical conduit and junction boxes and water piping is mounted above the concrete floor to allow for water to flow underneath to a floor drain or at least not backup into electrical equipment in the event of a leak.
- Piping pressure tested and passed and reports submitted.
- Underfloor motorized dampers and valves wired and verified to be functioning properly.

-CLEANING

- The area that panels are to be installed in is closed-in from outside (doors, windows installed and no wall breaches).
- The area that panels are to be installed in is closed-in from other areas in the building that are not closed-in to the outside.
- Prior to applying floor panels, after pedestals are set, sweep the concrete deck, scrape it of mud and vacuum with a pleated filtered vacuum with a brush-ended tool. The area cleaned shall be no more than the area planned to be covered with panels in the following two days.

-AIR SEALING

- Floor area inspected and each opening to wall or floor cavities or to other spaces or zones is verified to be appropriate and all openings that should not be communicating to this floor space are sealed.
- Underfloor perimeter along exterior walls and above unconditioned space sealed absolutely airtight (drywall or sheet metal to concrete deck, vertical and horizontal drywall joints, other penetrations). Overlapping or butting building elements are not acceptable as a seal unless caulked.
- Penetrations from underfloor space into interior walls sealed reasonably airtight (drywall to concrete deck, vertical, and horizontal drywall joints, other penetrations).
- Open ends of conduits in underfloor space sealed.
- Penetrations of ducts and piping and other assemblies through the concrete subfloor or through the raised floor are sealed.
- Floor panels butting walls are planned to be gasketed and seal tight.

DURING SETTING OF CONCRETE OR METAL FLOOR PANELS

- Do not cut and trim floor panels or perform other dust or debris generating work in rooms where floor panels are being installed.
- During installation of the concrete panels, workers have vacuumed any dust and debris on the floor before covering more than four new feet of panel and vacuum any dust and debris that may have accumulated under the panels during installation.
- Within two days of any floor panels being laid, the floor top has been vacuumed and each concrete or metal panel joint taped or covered with overlapping; taped paper or plastic to prevent dirt and dust from falling down the joints between the panels.
- **Inspection.** During panel installation, the owner or owner representative and the contractor have together made visual observations of approximately every 1,000 square feet during panel installation. Observations will be made from the open end of work (not lifting panels). Owner will

approve or reject the cleanliness of that floor section at that time and make visual note of the cleanliness or perform a "white glove test" for later reference.

BEFORE LAYING CARPET TILES
(after setting floor panels)

- When workers access the under-floor after the panels are laid, they shall vacuum up any dust, dirt, or debris they create prior to closing the floor and replace the paper or plastic floor covering.
- When pulling panels, workers shall replace stripped screw heads.
- Floor panels butting walls and pillars are gasketed and sealed tight.
- Each floor box is airtight inside and sealed to floor panel.
- Penetrations into walls above are sealed.
- Plenum dividers located and sealed as designed.
- Junction boxes in exterior or interior walls used for thermostats are sealed to prevent air from space being pushed up past sensor.
- Mark floor panels with a heavy permanent marker indicating location of ALL valves (with ID and tag #), drains, sensors, dampers, control panels, and junction boxes are under the floor.
- Entire floor has been walked and any rocking panels tightened and stripped screw heads replaced.
- Carpet laid so carpet joints are offset from floor panel joints.

AFTER LAYING CARPET TILES

- When workers access the under-floor after the carpet is laid, they shall vacuum up any dust, dirt, or debris they create prior to closing the floor and replacing the carpet tile.
- **Inspection.** Contractor has walked floor with owner or owner representative and lifted up to one panel per 500 square feet and compared cleanliness to observations made during floor panel installation. The floor should be as clean as the earlier observations.
- Additional required under-floor cleaning complete.

The construction checklist is a tool to aid the contractor and subcontractors in assuring the underfloor is sealed, clean, and built correctly the first time. After carpet is laid, furniture installed, and building occupied, underfloor "fixes" become very time-consuming and expensive. Providing a detailed list and requiring it to be properly completed will provide value to a project. The underfloor construction checklist is:

- A "contract document"
- All subcontractors (and ultimately, the general contractor) responsibility
- Ready to test when it is complete – Done, with a capitol "D"

Verification Phase Commissioning

As stated above, if the construction phase commissioning is performed correctly, the verification phase should be a formality.

Functional Testing

Testing should include all the sequences of control of the air handlers and supporting chilled and heating water systems. The condition of the supply air should be checked to ensure proper dehumidification is achieved. The perimeter heating and cooling control systems and any ties to occupancy or lighting controls should also be tested. The tests should include verifying temperature distribution from floor diffusers to ensure there aren't zones with dramatically different supply air temperatures. Room temperature and humidity control should be verified through trending.

One of the driving forces behind adoption of UFAD is the assumption that the design will result in stratified air in open office areas, with improved comfort and energy savings. Testing should be conducted in a few representative locations during summer and winter, and it should verify how much stratification exists. If there is insufficient stratification, the floor pressure may be too high and/or the supply air temperature too high. Too much stratification (too great a temperature gradient) is also not good. A temperature gradient between head and foot greater than 5°F is considered excessive. A gradient of 3.5°F is considered ideal (Energy Design Resources, p. 16). Note that this test will take precision temperature meters or loggers to accurately quantify.

Underfloor Leakage Tests

Balancing Requirements

After the sealing is complete, carpet is installed and controls are operational, require the balancer to measure, the flow going into each floor via duct traverse, and measure the flow from each diffuser. The difference is the underfloor leakage. The underfloor leakage shall be less than 20% based on the central reading in the error band of the balancer's measurements. If leakage is more than 20% or the fans cannot make design underfloor pressure, leakage shall be reduced.

Rationale for 20%: Ducts typically are limited to 10%. Twenty percent is reasonable for an architectural space like UFAD and any more leakage would be considered an excessive energy waste. The duct traverse flow and the diffuser flow readings typically will each have an accuracy of +/- 10%. Therefore, any criteria for leakage less than 20% cannot be verified with the typical measurement accuracy of the balancer.

Leakage Tests During Construction

Mock-up or total floor leakage tests may provide valuable information with regards to the efficiency of the system and quality of construction. However, if the above, described process is followed, an interruptive underfloor leakage test should not be required. If significant leakage is suspected because of poor construction quality or lack of construction details, then a leakage test to flush out sealing issues may be warranted. Unfortunately, getting a true measure of underfloor leakage is very difficult and also can impact schedule dramatically.

Advantages gained by performing a leakage test during construction:

- Somewhat quantifies amount of leakage and will aide in the identification of sources of leakage.
- Will provide an opportunity for adjustments to sealing techniques.

Potential disadvantages to leakage tests:

- Will require all floor tiles to be in place during the test. This means all underfloor work will be interrupted for the duration of this exercise.
- Carpeting may be an integral part of the sealing strategy and may not be fully installed. Installing carpeting prior to the completion of substantial underfloor activities may have schedule impact.

- Unless pressure differential sensors are installed and calibrated, temporary instrumentation will need to be made available. Care must be taken to ensure the readings taken during the test will be comparable to final sensor readings (and placement)
- If supplying 100% outside air is not feasible for the test, LEED™ IAQ requirements may prove difficult.

Facilities Training and Operations & Maintenance Documentation

By the time the functional testing is completed, there are very few, if any, people more familiar with the operation of the newly installed UFAD system and its numerous quirks and idiosyncrasies than the person who has performed the verification of the systems. This knowledge, even if it is well documented, needs to be actively passed on to those who are going to be operating the building.

After the UFAD system has been commissioned, original set points, balance criteria, and even operational design intent may have altered dramatically from when they were originally tested. If this information is not documented, and the reasons for the changes not fully understood by the facilities personnel, the UFAD system performance is likely to quickly degrade. If the changes are not fully integrated into the operations or systems manual (and as-builts), unknowing facilities operators could very easily change one setting back to the original design specifications, and start a cascading effect, which could cause other UFAD elements to be negatively altered.

Warranty Phase Commissioning

UFAD systems are new. Occupants of buildings that are using this new system are not used to it and may or may not like it. Occupants' "opinion" often cannot be anticipated until well after the contractors, designers, and original owner project managers are done and gone. The commissioning provider needs to be aware that there may need to be additional occupant adjustments made that were not anticipated by the owner, architect, or designer.

Again, traditional commissioning tasks during the warranty phase are further complicated by the fact that this is a relatively new and, as yet, non-standard system. As demonstrated by the additional complexities of the functional testing, the warranty phase activities may require more systems retesting and greater attention to changes due to occupant discomfort. This will, of course, require additional time and effort. Fine tuning of supply air temperature reset schedules and floor pressure set points are likely to be required. This will generally be an iterative process. Commissioners should utilize facility staff when possible.

Seasonal Testing

Fine-tuning a UFAD system in one season often requires (as does proper commissioning of any HVAC system) a sanity check during the opposite season. This not only ensures that the commissioned systems are still functioning as they were designed to, but it allows for the task of verifying and adjusting for occupant comfort.

A zone temperature of 70 to 72 degrees F in the winter time may be comfortable for those occupants, but that same zone temperature in the summer time may seem unbearably warm to the same group. With a UFAD system, the supply air temperature reset function is a valuable asset and could be instrumental in occupant comfort.

Other opposite season aspects to look out for include, but not limited to:

- **Closed "salad spinners"**
  In the colder seasons occupants arrive in the morning sometimes coming from less than comfortable outside air temperatures. The last thing they want is cold air blowing on them if they happen to have a floor diffuser near their area. As much as the designers try to have furniture layout in mind to prevent this from occurring, people and furniture move and many times the floor diffusers are not correspondingly relocated. Effected occupants will close the floor diffusers and tend to leave them closed. Even though the correct operation of the UFAD system depends on people opening and closing the diffusers to adjust to comfort, many times this simply does not happen. This problem will occur more frequently in a transient area such as computer labs where the users are not aware that the floor diffusers can be adjusted. First reaction of facilities if warm calls are being received should be to verify that manual floor diffusers are open.
- **Slab effects**
  Heat rises, and in multi-story UFAD buildings, this will have an effect on the performance of the system. Constant heat load should be calculated and compensated for during the design phase of the project. Seasonal changes and how this may affect the floor slabs are sometimes underestimated or missed entirely. If the slab does not have a thermal break from the perimeter of the building, during extreme cold conditions the temperature of the perimeter areas of the slab may approach outside air temperatures. If the night set back or scheduling does not address this issue, occupants may experience very cold conditions until perimeter heat has had a chance to "catch up" to occupied set points. From direct experience, the first reaction of the effected occupants is to go out and purchase space heaters. Once they have them, they are not very willing to part with them. Fine tuning of perimeter heat, night set back, morning warm up and general scheduling issues should be reviewed during the first year of operation.

Systems Operational Review

One year after occupancy, are the fans running at or below design? Are the occupants happy? Comfortable? At least not complaining?

The LEED® requirements are clear on the responsibilities of the commissioner at the 1-year review. The UFAD system, occupant satisfaction, facilities satisfaction, and building efficiency as a whole add another level of complexity and should, in the authors' opinion, warrant a new review requirement.

An occupant summary or survey is a tool that may assist in the commissioning (and ultimately the operation) of a UFAD system. Although this activity will increase commissioning scope of work during the warranty phase, we strongly recommend at least a cursor survey of occupants of their issues, positive or negative, and general comfort. If conducted correctly, the people

responding will tell you what needs to occur to make their space and/or building comfortable. Lessons learned by the designers, contractors, owners will assure that the future of UFAD is positive and not met with skepticism when initially discussed.

Suggestions of survey types:

- **On-line or Intranet survey.**

  Definitely preferred. Depending on the form of the questionnaire and the method of tracking, the results could easily be report as statistics per area, floor or zone. Statistical software could ensure minimal effort after the initial set up of the system.

- **Hard copy survey.**

  Could achieve same results as the on-line survey but increase the amount of effort drastically.

- **Suggestion Box.**

  Most likely, only people with issues will use this receptacle (other than those who use it as a trash can). This could cut to the core of any issues but also leave incomplete results. "Way too hot" or "pretty cold" have limited analytical value.

Conclusion

At this stage, the definition of a successful UFAD system seems to be subjective. We've worked on some projects that, even through the AHU VFDs, are constantly operating near or at greater than 100 percent. These have been considered successful when the majority of the occupants are not complaining. We've also been involved with "successful" projects when all modeled energy savings expectations have been met and exceeded, but facility occupants are nonetheless constantly complaining.

The success or failure of this form of HVAC system can be greatly affected by how the commissioning process is performed and whether lessons learned are forwarded to others.

Again, the right method and manner of commissioning *can* result in:

- Fewer deficiencies
- Faster testing
- Fewer delays from problems

Systems work as intended— from the beginning!

References

Energy Design Resources Design Brief--Underfloor Air Distribution and Access Floors. www.energydesignresources.com.