The Upside Of Underfloor Air-Distribution Systems

Part one of a two-part report examines the design phase of a building project using an underfloor air-distribution (UFAD) system

BY JACK GEORTNER

Between 1995 and 2002, a different type of air-distribution system began taking force in the construction of office buildings: raised floors that use underfloor air distribution (UFAD).

Installation of these systems increased approximately 40 percent during this time, which is largely attributed to the benefits UFAD offers over traditional ceiling-based air distribution. These benefits include:

1. Lower churn costs, which allows for fast and inexpensive reconfiguration of office space.
2. Improved IAQ, which supplies conditioned air directly to the breathing zone.
3. Reduced energy need for fans and refrigeration, which lowers energy costs.
4. Potential to reduce floor-to-ceiling heights, which creates cost savings in structural and façade systems

Although UFAD has increased in popularity, application knowledge is not yet widespread, underscoring the need for more information that addresses the design, construction and commissioning phases of the building project.

Determining load calculations

During the design phase, contractors must carefully determine load calculations for the building. These will differ from the calculations for a ceiling-based air-distribution system.

One difference is the amount of a particular load that enters the occupied zone. For a ceiling-based system, the occupied zone is effectively floor-to-ceiling. For UFAD systems, ASHRAE Standard 55-2004 defines the occupied zone as the vertical space from the floor to 6 feet above the floor. This means that some loads never enter the UFAD-occupied zone.

In addition, if return-air grilles are placed close to the building's perimeter wall, convective heat gain occurring there can be carried into the return air before it has an opportunity to enter the occupied zone. Both of these factors can reduce the heat load in the occupied zone. Ultimately, this reduction in space heat gain affects the calculation of cooling airflow in direct proportion, as shown in Figure 1.

Another difference is the room air temperature that is used for load calculations. With a ceiling-based system, the room air temperature is considered to be uniform from floor to ceiling. With UFAD, there is temperature stratification within the space, with heat and pollutants concentrated in the upper levels.

In fact, ANSI/ASHRAE Standard 55-2004 allows a vertical temperature variation of 5.4° F (3° C) between head and ankle levels. If an all-air UFAD system is designed for no stratification in the occupied zone, it will use more airflow, wasting fan energy, as seen in Figure 2.

Because of stratification, it is recommended that contractors use 2° F to 3° F (1° C to 2° C) higher thermostatic temperature for UFAD systems, as compared to overhead distribution. This will also have a direct impact on the cooling airflow calculations.

The third airflow calculation difference concerns the heat transfer from the warm, occupied zone above from the warm, return airway below in multistory buildings into the cool underfloor airway, as shown in Figure 3. This heat transfer, and the resulting thermal decay (loss of supply-air-cooling ability), should be counted as part of the airflow requirement for each zone.

As a rule of thumb, the supply air temperature should not be allowed to rise more than 3° F (2° C) from the time it enters the underfloor airway until it is discharged into the conditioned space through the furthest terminal. If a greater thermal decay is possible because of a large floorplate, then unlined stub ductwork should be used to carry the supply air further into the airway.

Thermal decay is also a good reason to specify a variable-air-volume (VAV) UFAD system. It has been found that the supply air temperature is not uniform in an underfloor airway and will change throughout the day. A properly designed variable-air-volume UFAD system can accommodate these temperature variations, while a constant-air-volume system cannot.

Some believe that placing a manually adjustable diffuser near each occupant will result in greater temperature satisfaction. However, it has been found that most occupants do not understand that they can control airflow in their workspace, and that those who do understand, typically do not make changes anyway. As a result, engineers may find that automatic VAV diffusers provide better comfort than manual ones.

Ensuring minimum ventilation

In any VAV system, ensuring minimum ventilation is always a concern because reduced loads could cause supply air volumes to fall so far that insufficient ventilation is supplied.

To prevent inadequate ventilation in variable-air-volume UFAD systems, some manufacturers offer optional collars to serve as a minimum stop for their dampers. Other manufacturers recommend the use of a series fan-powered VAV box that pulls supply air from the underfloor airway and heats the air as necessary.

Minimum ventilation requirements also may be met if the designer takes into account leakage. Like the ducts in an overhead system, the underfloor airway experiences a small amount of air leakage through the diffusers, the raised-floor panels and the power-voice-data (PVD) boxes. This leakage may meet much, if not all, of the minimum ventilation requirement. This also will affect

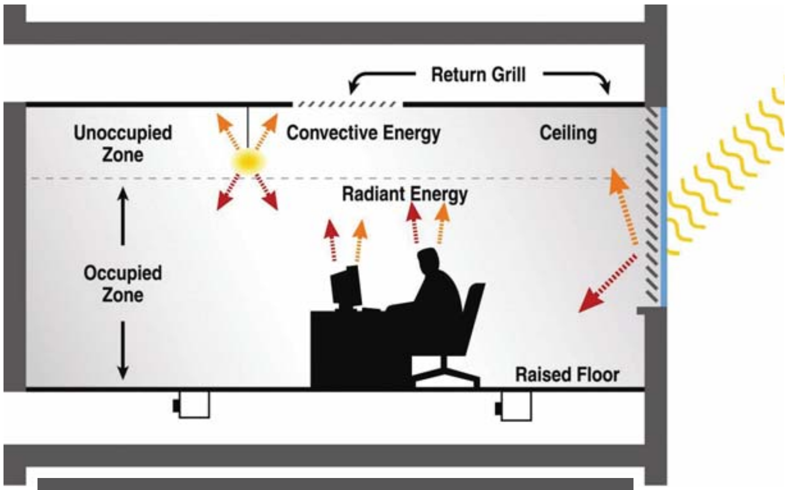

Figure 1 Typical loads in an office, showing how airflow enters the occupied zone.

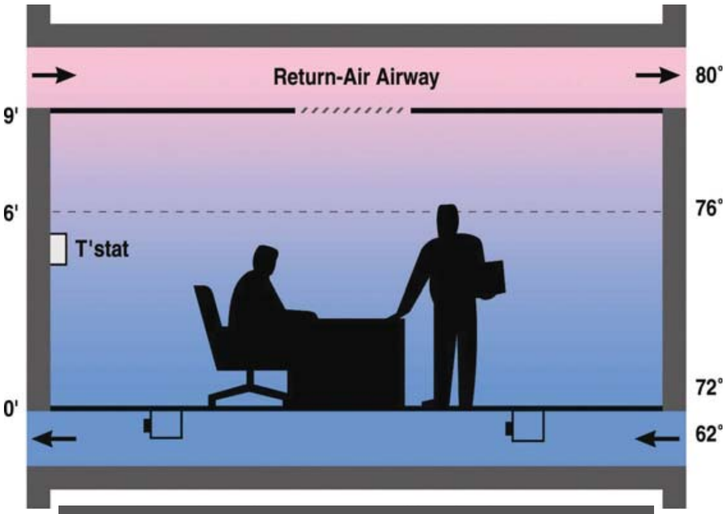

Figure 2 If an all-air UFAD system is designed for no stratification in the occupied zone, it will use more airflow, wasting fan energy.

the amount of diffuser airflow needed to satisfy the space heat gain.

UFAD also may be able to reduce overall ventilation air quantities more than overhead systems, with precise CO_2 monitoring of the room. Rather than having to ventilate the entire floor-to-ceiling space, a UFAD system only requires ventilation of the occupied zone. A CO_2 monitoring system will recognize when the occupied zone is adequately ventilated, regardless of the situation above 6 feet.

Monitoring leakage rates

While a small amount of airway leakage is desirable to handle minimum ventilation requirements, excessive leakage through the floor panels into the space and other uncontrolled airflow can cause comfort problems and waste energy. For this reason, it's important to specify and detail how to ensure a leak-tight airway.

Contractors need to check the intersection of floor slabs with exterior walls and interior shafts (for elevators and risers) to ensure proper sealing. Also, examine furred-in columns, stud walls penetrating the raised floor, and all penetrations for pipes, ducts and cables.

Because the slab will (hopefully) be tightly sealed, you need to consider flood control. The structural engineer should determine whether a flood, caused by a broken pipe or the sprinkler system, would collapse the slab. If that possibility exists, floor drains should be incorporated in the design.

Raised-floor leakage rates vary by manufacturer and floor-covering type/layout. During the design phase, specify an airway leak-rate no more than the minimum VAV airflow and specify a leak test to be performed as part of commissioning. A marginal UFAD system may leak as much as 20 percent to 25 percent of the system's total air volume, but a good system will typically leak no more than 10 percent to 15 percent.

While even 10 percent to 15 percent leakage may seem excessive to some, it's important to remember that overhead duct systems leak an average of 20 percent of their airflow. Plus, leakage flows to the return-air airway and not to the occupied space.

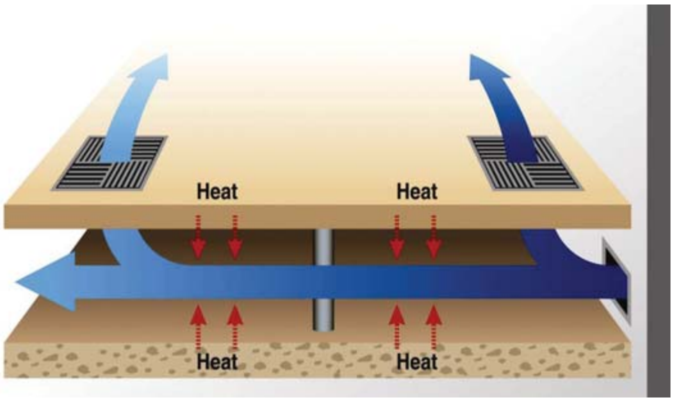

Figure 3 Heat transfer from space above and slab below is shown in the above illustration.

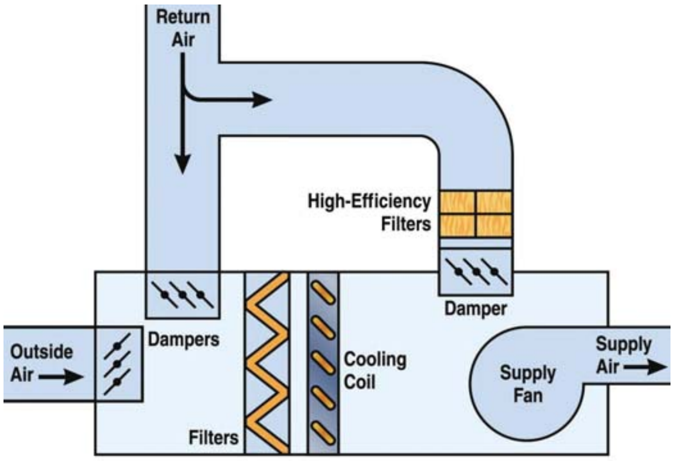

Figure 4 An air-handling unit with return-air bypass used to reheat supply air is shown here.

Airway height, ducts and air handlers

It is important to design enough room for and access to the equipment that needs to be located under the raised-access floor (RAF). Space becomes important when it's time to perform routine maintenance or make repairs or adjustments to the equipment.

UFAD installations typically use 12- to 18-inch RAF. Laboratory testing has concluded that the minimum RAF height is 8 inches for uniform air-distribution. However, RAF height is often driven by the height of the underfloor fan terminals (if utilized) or the size of the floorplate.

Underfloor fan terminals typically range in height from 8 inches to as much as 16 inches for large cooling and heating units. For larger floorplates, the size of the stub-ductwork (typically limited to 22 inches wide to fit between the RAF pedestals) may pose a height constraint.

A UFAD system requires some special consideration of the ductwork. In the room, the return-air intake should be sized for a maximum of 500 fpm and be located above the occupied zone. Air moving any faster will disrupt the stratification effect necessary for a properly designed UFAD system. Combination fire/smoke/control-zone dampers (FSDs) should be specifically designed for modulating control.

As with overhead systems, it is important to take into account the effect of air velocities on noise. It is recommended that air velocity entering the supply airway be limited to a maximum of 1,500 fpm to reduce noise. On the other end of the noise spectrum, it should be noted that noise levels of UFAD systems are typically lower than overhead systems. For this reason, engineers may want to consider the addition of sound masking in low-occupancy areas for acoustic privacy.

The air-handling device provides some or the entire minimum ventilation requirement. The minimum airflow requirement for each device should be displayed on the mechanical schedule.

The air-handling device also should be equipped with reheat capability so it can handle the higher supply-air temperatures (SAT) — about 60° F vs. 55° F SAT — required by these systems without creating a humidity problem in the occupied spaces. In most cases, it is best to use one primary air-handling unit with a return-air bypass, as shown in Figure 4.

The typical face-and-bypass arrangement is not the same as the return-air bypass and will result in unacceptably high humidity levels. More expensive reheat methods include modulating hot-gas, run-around heat pipes or using as many as three fans (not including a return or relief fan) to supply air to perimeter zones.

The minimum airflow requirement for each device should be displayed on the mechanical schedule

Control systems

Controls for an UFAD system are similar to those of an overhead VAV system, except the SAT is designed for a minimum of 60° F dry bulb, and the static pressure (SP) differential between the airway and the occupied space is nominally designed for 0.05 inches wg. Some manufacturers may recommend higher airway SP (up to 0.1-inch wg). However, this will increase uncontrolled leakage theoretically by more than 40 percent.

At light loads, the SAT is typically reset upward and SP downward to prevent overcooling and to maximize free-cooling (economizer) hours. Minimize night setback to maintain proper building control. Morning warmup will not work because of the thermal effects of the building slab.

The control sequence also should have the ability to lower the off-coil temperature, based on the level of underfloor relative humidity (RH), in order to prevent condensation and maintain comfortable humidity levels in the space.

Be aware that UFAD components use a number of different types of controls. By working with component manufacturers, design engineers can secure sequences of operation for the diffusers, actuators and fan-powered units necessary for proper zone control.

Part two in next month's issue will cover the proper installation and operation of an underfloor air-distribution system.◆

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