HVAC Overview of Underfloor Air Distribution (UFAD)

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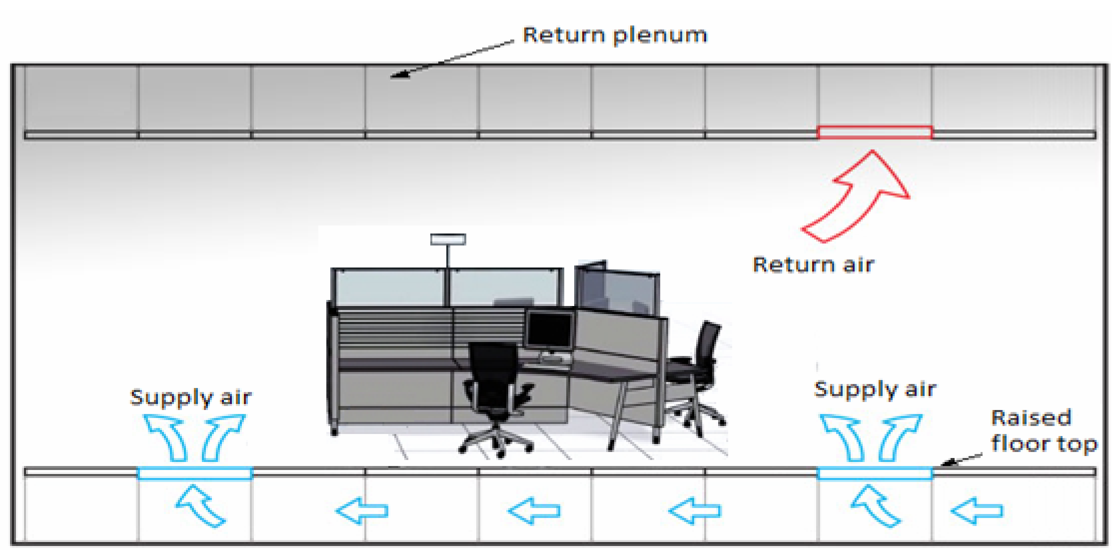
HVAC OVERVIEW OF THE UNDERFLOOR AIR DISTRIBUTION (UFAD)

An Underfloor Air Distribution (UFAD) system uses the open space below a raised floor system to deliver conditioned air to supply outlets located in the floor. It is best to think of an UFAD as an upside down alternative to conventional overhead (OH) air distribution. Since air is supplied in much closer proximity to occupants than in OH systems, supply air temperatures must be usually 63°F or higher and at a much lower pressure. The concept enhances energy efficiency and boosts indoor air quality.

The development of this technology was largely driven by the changing work environment. The advent of computer, communication and internet based technologies, along with advances in flexible interior furnishings, drove organizations to adapt to these new technologies. Today UFAD systems comprise an estimated 58% of new commercial building projects in Japan and about half of all new commercial projects in Europe. In North America, the UFAD technology was introduced in the 1990s, and several buildings have been designed to this technology.



The components of the UFAD system are highly modular making it much convenient and less expensive to reconfigure workspaces during renovation of the building. To better integrate with the raised floor system, electric power, telephone, data cable and other portions of the building's infrastructure are located in the underfloor space. Plug-in electrical boxes, power/data outlet boxes and air diffusers are flush mounted in the floor panels and can easily be moved to accommodate reconfiguration of the workspace or floor plan. UFAD systems allow for the lower costs associated with churn rates when tenants reconfigure, relocate or change the interior of the building.

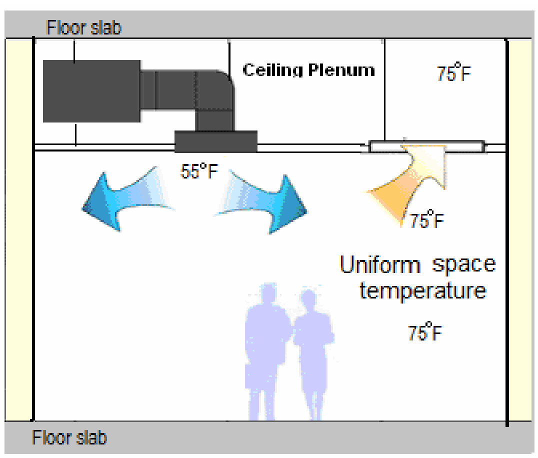
The course will discuss fundamentals of the UFAD design process, the potential benefits, economic issues and the pitfalls. The course is divided into 5 sections:

SECTION -1	Overhead Systems V/s UFAD System
SECTION -2	UFAD System Design Parameters
SECTION -3	UFAD Layout and Components
SECTION -4	UFAD Design Issues
SECTION -5	UFAD & Sustainable Green Buildings

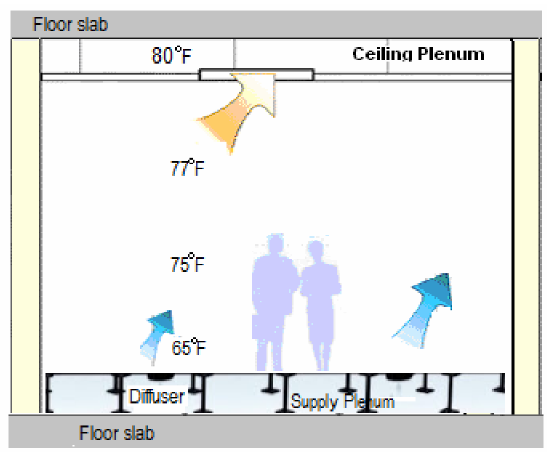
SECTION - 1 OVERHEAD SYSTEMS V/s UFAD SYSTEM

Overhead air distribution (OH) systems supply conditioned air through ducts at the ceiling and typically take return air back through a plenum above the ceiling. The diffusers, or air outlets, connected to the supply duct system are designed to throw the air around the room in such a manner to induce full mixing of the air in the occupied space. For this reason, these systems are called “mixing” systems. The desired result of mixing systems is the complete mixing of supply air with room air, thereby creating a uniform thermal environment across the entire space. The temperature of the uniform environment is controlled with HVAC equipment to a desired setpoint. Typical operating temperatures for overhead mixing systems include supply air temperatures in the range of 55°F to 57°F and thermostat setpoints in the range of 72°F to 78°F.

Underfloor air distribution (UFAD) systems, unlike conventional OH systems, deliver conditioned air at the floor level at low velocities. The air distribution creates an upward flow of air in the space allowing for the effective removal of heat, pollutants and odors. There is typically a large temperature variance between the floor and the ceiling level, where the return air leaves at a higher temperature than the room temperature.



Conventional System



UFAD System

Comparison of Overhead (OH) vs. Underfloor (UFAD)

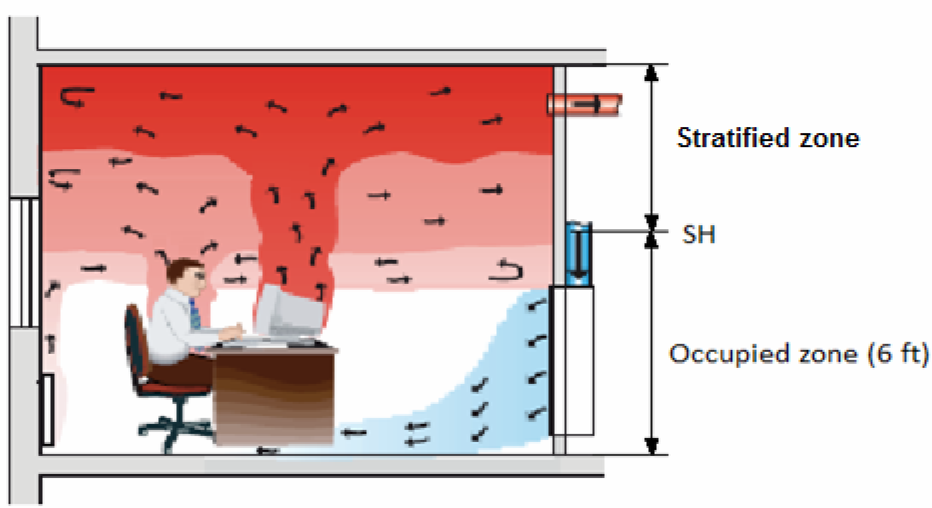
Issue	OH	UFAD
Supply air temperature	~50 to 55 °F supply air	~60 -68°F supply air
Temperature control	- Most uniform - Mixes the entire space	- Commonly cold at the bottom and warm at the top. - Partially mixing in the occupied zone only
Temperature profile	- Uniform temperature - Mixes the entire space - Conditions entire room	- Stratified temperature - Partial mixing in the occupied zone only - Only conditions the occupied zone (the first six feet of the space)
Return air temperature	~75 °F, almost the room air temperature	~77- 85°F, room temperature is higher at ceiling level.
Air delivery	Ceiling diffusers provide high velocity supply air throw.	Air delivered at low velocity and heat sources drive air motion via thermal plume

CLASSIFICATION OF UFAD SYSTEMS

UFAD systems fall in two general categories distinguishable from one another by the temperature and velocity profiles they create in the occupied space. The first type is a displacement ventilation (DV) system and the second is a hybrid UFAD system.

Displacement Ventilation (DV) Systems

Displacement ventilation (DV) delivers supply air low in the space at a lower velocity to minimize mixing and utilizes buoyancy forces generated by heat sources such as people, lighting, computers, electrical equipment, etc. in a room to stratify heat out of the occupied zone.



The temperature profile that develops in DV systems is stratified, i.e. the air at the top of the room is warmer than the air at the bottom occupied zone of the room and has a higher level of contaminants than supply air does.

DV systems create a non-uniform thermal environment. Up to a level called the “stratification height” (labeled SH in the figure), the temperatures increase with increasing height. Above the stratification height, the zone is relatively well mixed and a more uniform temperature profile is created.

A DV system has the following characteristics:

- Air is delivered between 60°F and 70°F;
- Air is delivered at lower discharge air velocity (approximately 50 fpm);
- Air is supplied horizontally into the room low on the side wall;
- There is little mixing of air in the space and the temperatures are stratified throughout the space;
- It uses thermal plumes to promote air movement; and

- It is usually a ducted system that requires slightly higher duct static pressures to operate properly.

A DV system has the following advantages:

1. Better indoor air quality since the ventilated cool air is certain to reach the occupants; and
2. Better energy efficiency since the convective heat gains above the occupied zone are isolated from the cooling load calculation.

A DV system is recommended for spaces where:

1. The ceiling height is more than 12 ft;
2. The occupancy rate or contaminant load is high (as in lobbies, theatres, auditoriums, libraries, and laboratories); and
3. The operations such as soldering, brazing, welding, grinding and machining produce enough heat greater than 30 Btu/ft^2 (industrial and manufacturing facilities).

A DV system has the following limitations:

1. The warm air coupled with the low airflow volumes means that DV systems have a limited cooling capacity that is typically below what is required in modern commercial buildings. As such, DV systems are not in wide use in commercial spaces. These are possibly best served with OH or UFAD systems.
2. Other applications that may not work well with DV systems are those in which the pollutant sources are heavier than air and not accompanied by heat.

UFAD SYSTEMS

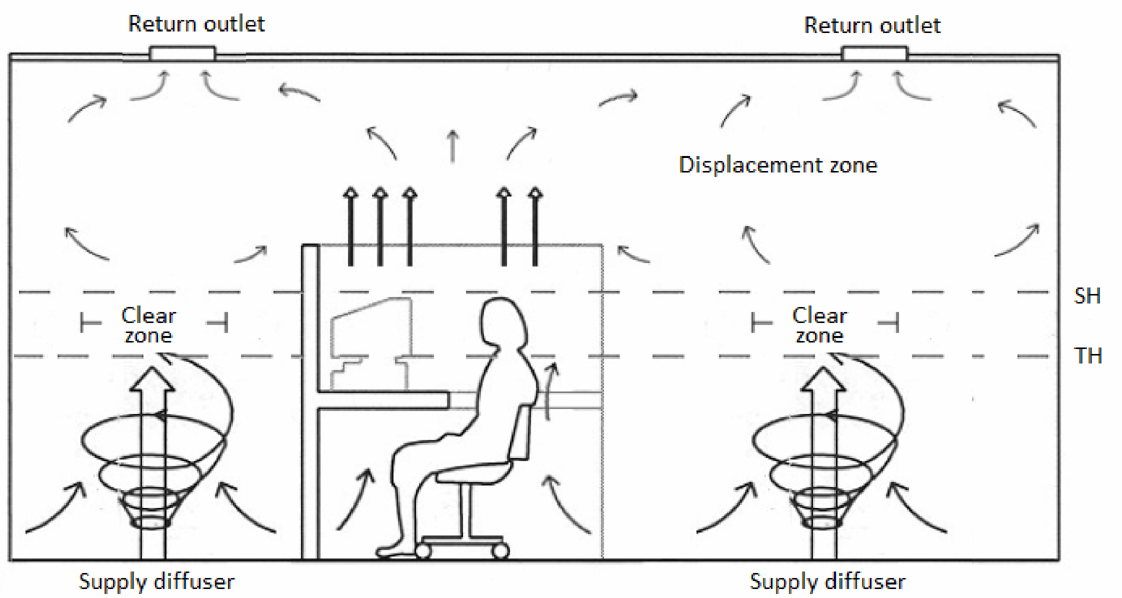
The UFAD system like a DV system attempts to condition only the occupied lower portion of space; however, it differs from a DV system primarily in the way the air is delivered to the space. In an UFAD system, the supply air diffusers are placed on the raised floor tiles above the supply plenum, which discharge conditioned air to the occupied zone through natural buoyancy.

The lower supply velocities typical of UFAD systems result in each thermal zone being subdivided vertically into three vertical zones above the floor: 1) the turbulent mixing zone; 2) the uniformed mixed or occupied zone; and 3) the stagnant upper zone.

1. The turbulent mixing zone is 3 to 4 feet above the floor level. Air is delivered vertically from the floor through short throw rapid mixing swirl diffusers which allow partial mixing with room air.
2. The stratified zone is an upper, unoccupied region from 6 feet above floor height to ceiling height. Heat and airborne pollutants rise naturally into this zone and collect at the ceiling for removal through the return air duct.
3. The occupied zone is an intermediate space between turbulent mixing zone and the upper stratified zone. The air movement in this zone occurs naturally where the air in this zone is at optimal temperature.

Supply velocities are sufficient to support mixing only in the lower, occupied region, leaving the upper, unoccupied region to function as a stratified displacement region. The mixing zone is relatively compact and most of the momentum of the supply air is spent quickly, so that large scale mixing in the room does not develop. Away from the local effects of the supply diffusers, an overall stratified temperature profile develops similar to a DV system.

An UFAD system performance can be seen as a balance between the effects of warm air buoyancy creating a stratified environment and the mixing momentum effects of airflow forced through swirl diffusers. Note that the depths of these three zones are dependent on the ceiling height and the ype of floor outlet (diffuser) used.



Hybrid Underfloor Air Distribution System

The figure above indicates the SH stratification height level just as in the DV diagram. The TH level indicated here refers to the throw height of the diffusers.

Characteristics of Underfloor Air Distribution (UFAD)

- Air is delivered between 63°F and 68°F, midway between those found in OH and DV systems;
- Typical return air temperatures are in the range of 75°F to 80°F, higher than OH systems due to stratification;
- Air is delivered low in the occupied zone through a raised access floor;
- UFAD systems work best when a stratification layer is established at 6 feet above the raised floor;
- Low velocity discharge (usually 250 to 400 fpm) is sufficient to support mixing only in the lower, occupied region;
- Diffusers used in UFAD systems are mixing diffusers similar to OH systems but the mixing zone is relatively compact compared to DV systems; and
- It requires low static pressure and can provide the opportunity for smaller air-handling unit motor horsepower.

Comparison between OH, DV and Hybrid UFAD Systems

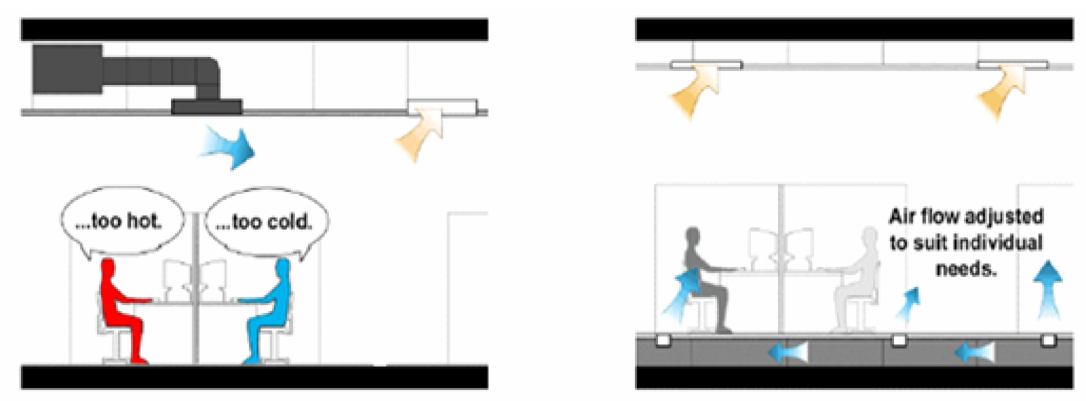
1. **Overhead air distribution:** Characterized as a well mixed air distribution system. Temperatures are uniform throughout the space.
2. **Displacement Ventilation:** Characterized as a stratified, non-mixing air distribution system. Air is supplied horizontally at the floor at very low velocities. Temperatures are stratified throughout the space.
3. **UFAD System:** Characterized as a partially mixed stratified air distribution system. Temperatures are stratified above 6 feet from the floor.

BENEFITS OF UFAD

1. **Improved air quality:** UFAD systems provide a well-mixed zone in the occupied space. The upward direction of air flow from underfloor air removes contaminants and heat directly through ceiling return air systems, thereby reducing the mixing and migration of indoor pollutants throughout the occupied space.

2. **Improved thermal comfort:** UFAD can offer a more comfortable range of air temperatures. Because the air does not need to be pushed down to reach users in the space, the air temperature does not have to be heated or cooled as much. Hence, the plenum temperature can be adjusted to simply allow for the normal variations within occupied rooms and be set closer to typical desired levels. The air temperature ranges are much smaller, thereby allowing for greater thermal comfort.

3. **Temperature control:** Providing adjustable floor diffusers allow users to control both the volume and the direction of the incoming air.



4. **Energy Efficiency:**

   a. The UFAD systems deliver air at around 65°F compared to an average 55°F supply air temperature of conventional OH distribution systems. Higher supply temperature allows a warmer cooling coil and warmer evaporator temperatures, resulting in lower lift across the chiller compressor. This increases the coefficient of performance (COP) of the refrigerant cycle and improves energy efficiency.

   b. Higher supply air temperatures for an UFAD system creates an opportunity to take advantage of free cooling using an air side economizer. As the setpoint of the supply air temperature increases, warmer outside air can be used to meet the load, so the hours required of the mechanical cooling equipment decrease.

   c. The UFAD system is a low-pressure air distribution system requiring only 0.1 to 0.5 inches of static pressure to deliver air through an UFAD plenum compared to 1.5 inch w.g or more with OH systems. The lower static pressure can deliver significant cost savings as a result of downsizing supply air fans. Note that the fan energy consumption is given by the following equation:

$BHP = Q \times SP / (6356 \times Fan_{EFF})$

Where

- BHP = Break Horsepower
- Q = Air flow rate in CFM
- SP = Static pressure in-WG
- Fan_{EFF} = Fan efficiency usually in 65–85% range

The fan power energy savings have been estimated at 5 to 30%.

5. **Flexibility:** The integrated access floor system is engineered to permit fast, easy installation and quick wire and cable changes, thereby enhancing the ability to reconfigure the offices without disrupting power, voice and data services, as well as the air distribution system. Even in workplaces with very low churn rates, the modularity of all components of raised access floor systems can be an advantage in space planning, thereby reducing time and reconfiguration costs. Any spaces that are designed with the "open office plan" are good candidates for UFAD.

APPLICATIONS OF UFAD

The most compelling UFAD applications are large, high spaces like convention centers, airport terminals, auditoriums, theaters, libraries, museums, and converted warehouses, where potentially drafty air flows will be of minor concern to what is a continually transient occupancy. UFAD systems provide good energy-saving opportunities in these applications by promoting thermal stratification. Comfort and improved indoor air quality are maintained in the occupied zone near the floor, while allowing increased temperature and pollutant concentrations to occur at higher elevations in the space. Typical applications where UFAD has been successfully used are:

1. Office buildings
2. Television studios or similar areas with high heat loads that require quiet cooling of occupants at floor level
3. Meeting rooms
4. Conference rooms, theaters, auditoriums, or similar spaces with high ceilings
5. Libraries
6. Spaces with high occupancy and/or high churn rates

7. Spaces with high electrical power and/or data density (ease of cable runs)

UFAD is usually a good choice in the following cases:

1. Contaminants are lighter than the room air
2. Supply air is colder than the room air
3. Room heights are 10 feet or more
4. Low noise levels are desired
5. The space has high churn rates and requires a lot of flexibility
6. Raised floor systems are already in place for other purposes

UFAD is **NOT** a good choice in the following cases:

1. Hospitals (patient and surgical spaces)
2. Secure facilities (jail cells, bank facilities, etc.)
3. Spaces which require wash-down for cleaning
4. Where pollutants or contaminants are heavier than the room air

SECTION - 2 UFAD SYSTEM DESIGN PARAMETERS

The design approach for an UFAD system is similar to the OH system but applied differently. In this section we will discuss the following basic design parameters that make an UFAD system different than the OH system:

1. Comfort Environment
2. Supply and Return Air Temperature
3. Cooling Loads
4. Airflow Rates
5. Ventilation Air
6. Codes and Standards

COMFORT ENVIRONMENT

ASHRAE Standard 55-2010, "Thermal Environmental Conditions for Human Occupancy" specifies the combinations of indoor environment and personal factors that will produce thermal environmental conditions acceptable to 80% or more of the occupants within a space. The environmental factors addressed in the standard are temperature, thermal radiation, humidity, and air speed. The personal factors are those of activity and clothing.

Various studies indicate that individual comfort is maintained when the following conditions are maintained in a space:

- Air temperature maintained between 73 to 77°F.
- Relative humidity maintained is less than 60%.
- Air velocity maintained is ~50 fpm in cooling and ~30 fpm in heating.

The ASHRAE comfort standard suggests that NO minimum air movement is necessary to maintain thermal comfort; provided the temperature is acceptable. To maximize energy conservation, we should attempt to maintain proper temperatures at the lowest possible air speed.

The thermal environment conditions are the requirements for comfort independent of an UFAD or OH system.

SUPPLY/RETURN AIR TEMPERATURES

Conventional OH mixing systems in buildings aim to create uniform thermal environments in each building HVAC zone. Since the UFAD systems are designed to supply air into the lower occupied zone, the conditioned air is usually delivered at warmer temperatures to avoid thermal sensation. ASHRAE 55-2004 Comfort Standard, (section 5.2.4.3) sets a limit for the amount of temperature gradient an occupant can experience between his ankle to neck level at 5.4°F. The condition is generally met in an UFAD system by introducing the air at slightly warmer temperatures and rapidly mixing with room air.

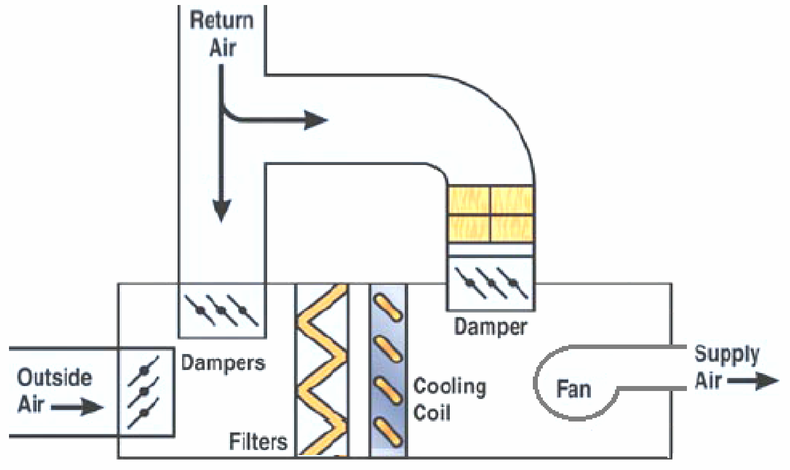
As a comparison, the supply air and return air temperatures for an UFAD and OH system are:

- UFAD Systems: Supply at 63 to 68°F and Return at 77 to 86°F
- Overhead Systems: Supply at 55°F and Return at 75°F.

Warmer supply air temperature for an UFAD system saves energy, but humidity control is a concern. This is because in a cooling system the dehumidification or moisture removal occurs when the moist air contacts the cooling coil surface colder than what is known as dew point of the humid air. The dew point of the air is reached as the air cools down to temperatures less than 55°F, but since the UFAD systems deliver air at much higher temperatures (greater than 63°F), the removal of moisture from the air is inadequate.

One of the earlier approaches to deal with the problem was to first cool the air to less than 55°F leaving the coil and then reheating to the desired supply air temperature greater than 63°F. This is a very energy inefficient approach and is not recommended; many local codes do not permit this.

The other most cost-effective means of accomplishing this is using draw-through air-handling units with integral return air bypass to maintain the supply air temperature. The return air bypass and chilled water coil or DX cooling are modulated to maintain the supply air temperature based on the reset schedule and the return air humidity sensor. When the humidity in the space exceeds 55%, the coil leaving air temperature is dropped and the bypass damper is modulated as necessary to maintain the supply air temperature according to the reset schedule.



Air Handling Unit with Return Air Bypass

This arrangement makes reheat of the air redundant since the desired supply air temperature is achieved by mixing the supply air with recirculated warm air. Such mixing can occur in the floor plenum or directly in the AHU as shown in the figure above. It is best to draw the return air from a high level to benefit from stratification, though some systems draw the air from the occupancy zone (eg from floor level).

COOLING LOADS

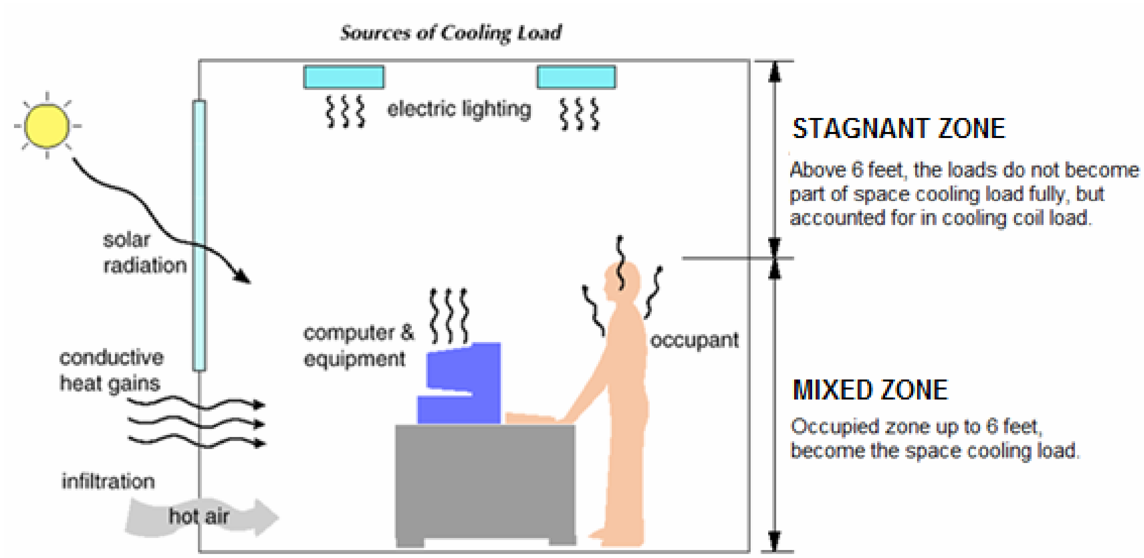
The cooling load for an UFAD system can be calculated in a similar manner as with an OH system (i.e. by summing up all of the net design heat gains and transmissions into the conditioned space). However, the difference is that heat gains within the space do not necessarily participate in loading the lower, occupied air mass. Convective loads originating within the upper displacement region don't mix with the lower occupied air mass, and some fraction of the loads originating in the lower occupied air mass are transported into the upper displacement region via convective plumes without thoroughly mixing with the occupied air mass.

The stratified air flow pattern in an UFAD system allows most radiant heat gains above 6 feet to be assigned directly to the return air and, therefore, not included in the space cooling load. However, it is accounted for in the coil load. The difference between the space cooling load and the cooling coil load is summarized below:

- Space Cooling Load is the rate at which heat must be removed from the space to maintain a constant space air temperature.
- Cooling Coil Load is the rate at which energy is removed at a cooling coil and equals the sum of instantaneous space cooling loads, plus the heat gains moved to the return air,

plus any system loads like the fan heat gain, duct heat gain, and outdoor air heat and moisture brought into the cooling equipment to satisfy the ventilation requirement.

In air-conditioning design, the heat gain is classified by its mode of entry into the space. The mode of entry includes (1) solar radiation through transparent surfaces; (2) heat conduction through exterior walls and roofs; (3) heat conduction through ceilings, floors, and interior partitions; (4) heat generated in the space by occupants, lights, and appliances; (5) energy transfer through ventilation and infiltration of outdoor air; and (6) miscellaneous heat gains.



For UFAD systems, the occupied zone is the 6 feet vertical space above the floor. Experience suggests the following proposed weighing factors:

1. Lighting energy is predominantly radiant; so assign 1/3 of total watts directly to the stratified zone. When return air is taken through the light troffers, a greater portion of the total watts used (up to 50%) can be assigned to the stratified zone.
2. Exterior wall conductive load is predominantly radiant (often over 60%), so 1/3 of the upper wall area load should be assigned to the stratified zone.
3. Solar loading through glazing is 100% radiant, unless internal shading is used. Since manually adjusted shades cannot be counted on when sizing equipment or setting airflows, do not assign any direct solar load to the stratified zone.
4. Solar wall loading becomes over 1/3 convective, so an appreciable portion of this amount can be manually assigned to the upper stratified zone.
5. People loads occur in the occupied zone so always assign 100% to the occupied zone.

6. Equipment loading should not be assigned to the stratified zone unless aggressive thermal plumes will develop and carry a substantial portion of the load into the stratification zone.
7. Infiltration loads always remain within the occupied zone, and outdoor air ventilation loads always remain a part of the central equipment coil loading.

Note that the total cooling load for UFAD systems is not less than OH mixing systems. The load is still present. It's the way in which the load is handled that changes and becomes coil load. Much of the space cooling load is moved to the return air and becomes coil load, unless these loads are exhausted from the building entirely. Engineers have to factor all these variables accurately to arrive at the adequate system performance.

AIRFLOW REQUIREMENTS

<u>How much airflow is needed?</u>

The amount of cooling airflow needed to remove sensible heat loads from a building space is estimated using the following simple steady-state heat balance equation:

$$Q = \frac{h}{1.08 \times \Delta T}$$

Where:

- Q = the airflow moving through a room in cubic feet per minute (CFM)
- h = the heat loads in a room, in Btu per hour
- ∆T = the temperature difference between the room set point and supply-air temperatures in degrees F.
    - o ∆T for an OH system = ~20°F {(75 – 55) i.e. difference between return air and supply air temperature}
    - o ∆T for UFAD system = ~15°F {(80 – 65) i.e. difference between return air and supply air temperature}
- 1.08 = 4.5 (lb per hour) × 0.241 (specific heat of air)

Higher supply air temperatures would suggest that higher supply air volumes are needed to maintain the desired space conditions; but this is not true. This is primarily due to the fact that typical overhead mixing systems are designed to deliver the air from above at higher velocities to mix the heat in the space with the colder supply air, so that the blend of the two, results in maintaining setpoint. The UFAD systems assume that some amount of stratification occurs, which causes the return air temperature to be higher than the OH systems.

Secondly the supply air temperatures may be higher due to “Thermal decay”. Thermal decay is defined as the loss of cooling ability and increase in supply air temperature due to convective heat gain from the concrete slab as it travels through the distribution system. Typical thermal decay is driven by the temperature of the structural floor located below the access floor plenum.

Design supply airflow calculations for the space must account for both the elevated supply air temperature and the redistribution of a portion of the occupant, plug and lighting loads from the space to the return air. Ignoring the high supply-air temperature for UFAD systems will result in an underestimation of supply air volume. Also, neglecting to redistribute a portion of the space loads to the plenum will result in supply air-flow rates that are up to two times greater than the amount required to condition the space. Practical experience indicates that the cooling air quantities for UFAD systems are more or less equal to or lower than that required under the same conditions using OH distribution.

Important!

Thermal decay also occurs in an OH system but adding insulation to the ductwork minimizes this loss. In an UFAD system, adding insulation is not practical so we design the airflows to accommodate the rise in temperature.

VENTILATION AIR

Minimum outside air requirements should be determined according to applicable codes (e.g., ASHRAE Standard 62- 1999), which recommends 20 cubic feet per minute (CFM) per person of fresh air for most environments.

Some improvement in ventilation effectiveness is expected in UFAD, since it provides a continual supply of fresh ventilation air directly to the lower zone where people breath, while warmer/stale air is exhausted towards the ceiling. A good CO_2 monitoring system is recommended to control outdoor air and is typically set up to maintain CO_2 levels in spaces no higher than 700 ppm above ambient CO_2 levels. With precise CO_2 control, the UFAD system may cause reduction in overall ventilation-air quantities and ensure the occupied zone is adequately ventilated, regardless of the situation above the occupied zone (>6ft). Ventilation effectiveness is an important element that can help qualify the building for U.S. Green Building Council LEED® certification.

DESIGN STANDARDS AND CODES

Listed below are few applicable building standards and codes that have important provisions related to the design, installation and operation of UFAD systems.

1. ASHRAE Standard 55-1992: This standard provides the thermal environmental conditions for human occupancy.
2. ASHRAE Standard 62-1999: This standard provides guidelines to the ventilation for acceptable Indoor Air Quality.
3. ASHRAE Standard 90.1-1999: This standard provides guidelines to the energy efficient design of new buildings intended for human occupancy.
4. ASHRAE Standard 113-1990: This standard provides guidelines to the method for evaluating the air diffusion performance of an air distribution system.
5. ASHRAE Standard 129-1997: This standard describes a test method for evaluating the air distribution system's ability to provide required levels of ventilation air to the building occupants.

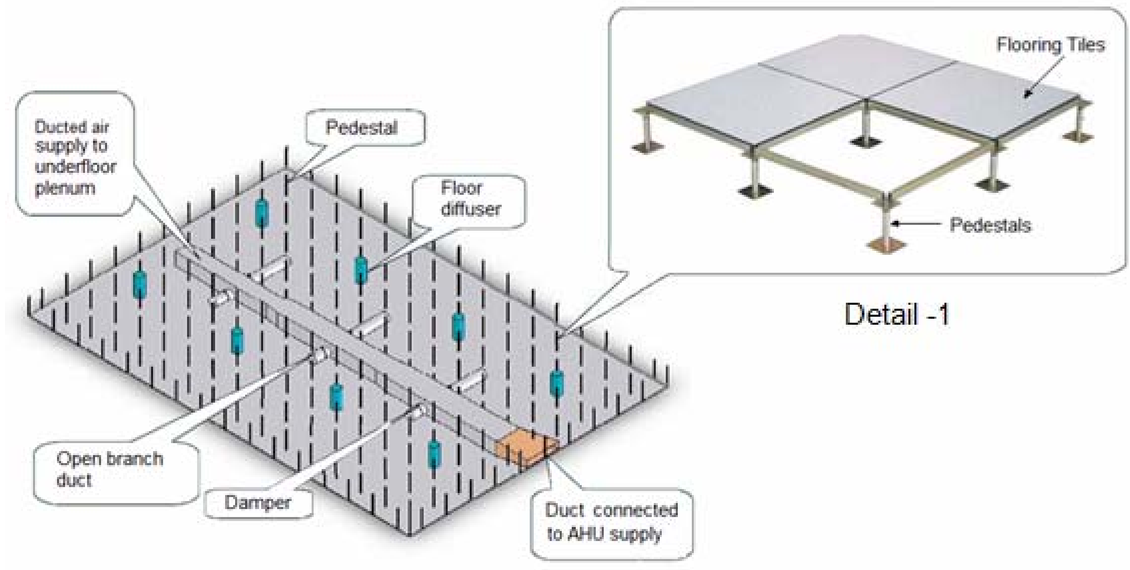
SECTION - 3 UFAD LAYOUT AND COMPONENTS

UFAD systems are quite similar to conventional OH systems in terms of the types of equipment. Key differences arise with the air distribution configuration. In this section we will discuss the following:

1. Types and Variations of UFAD Systems
2. Raised Floor Plenum
3. Supply Air Configuration
4. Return Air Configuration
5. Diffuser Selection and Layout
6. Primary AC Equipment
7. Select and Locate Diffusers
8. Control Strategy

RAISED FLOOR PLENUM

Raised floor is a false floor placed upon a building floor, creating a void for the distribution of building services such as conditioned air, power, voice and data cables. Raised floor plenum consists of a series of removable floor 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. The finished floor surface can be carpet tile, vinyl tile, laminate, finished concrete or natural materials such as wood or cork. (Refer to Detail-1, in the figure below).



The UFAD system often eliminates most of the ductwork and insulation requirements associated with the overhead systems and also enhances mechanical system flexibility because the non-ducted diffusers can be easily removed and relocated. The system is modular with the ability to plug and unplug any of the electrical components in the entire system from the panel board to the receptacle. The major plenum design alternatives include; plenum height, distance from a vertical riser or plenum inlet, pressurization and tightness, plenum subdivisions and ducting, as well as plenum material selection and access.

Airway Height:

Effective plenum heights for underfloor air are pervasively set at 12 to 18 inches, with no penalty for even higher plenums. 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:

- High density cooling (data centers): 24 in. to 48 in.
- General office spaces: 12 in. to 24 in.

Note - Compared to data centers, general office space requires low airflows over a very large area due to lower cooling loads.

Airway height is often driven by the largest HVAC component under the floor. These components can typically be distribution ductwork, fire dampers at plenum inlets, fan coil units, and terminal boxes.

Number of feeders for air supply to the plenum:

The number of feeders required to supply air to the plenum is determined by the cooling load of the space. As a general rule, the longest distance from the supply air outlet in the plenum and the farthest diffuser should not exceed 50 feet. Distances longer then this will affect the performance due to the thermal losses created by thermal conductivity of the return air from the floor below through the slab. Distances of 30 to 40 feet are preferable to ensure no thermal decay and controllable pressure conditions.

PLENUM DESIGN

The raised floor can be supplied air in two ways: **pressurized plenum or neutral plenum**.

A **neutral-plenum design** is an unducted "pull" type system where a central air handler delivers air to the floor plenum at virtually the same pressure as the surrounding space. Hence some local fans are needed to actually deliver the air to the occupied space. Although the fans increase the cost of installing and operating the system, they may be unavoidable if a leaky access floor or building envelope makes it difficult to pressurize the plenum.

The **pressurized-plenum design** is a "push" type system where a central air handler delivers air to the floor plenum, pressurizing it to approximately 0.05 to 0.1 in. wg with respect to the space pressure. The air can then be delivered to the conditioned space through either passive or active fan diffusers.

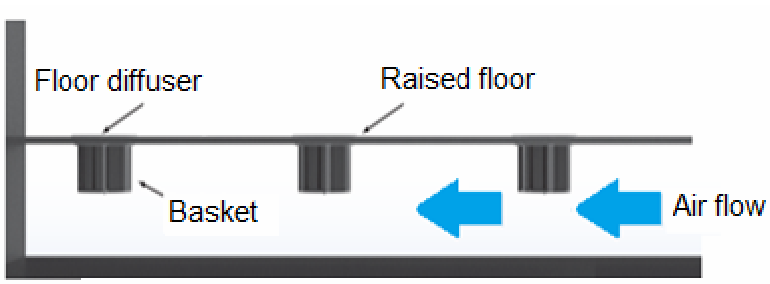
The primary advantages and disadvantages of each system type are:

Pressurized		**Non-Pressurized**	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Additional fans usually not needed to deliver air to the space.	Air leakage is an issue	Occupants have more control over air distributed to their space.	Additional fans needed to deliver air to the space.
System allows for complete "plug and play."	Removing a floor tile disrupts system operation	Renovating a floor tile does not disrupt system operation or impact airflow performance.	Increased initial cost due to active supply outlets.
Lower initial cost		Low plenum leakage	Increased noise level due to small fans.

Plenum Design Variations:

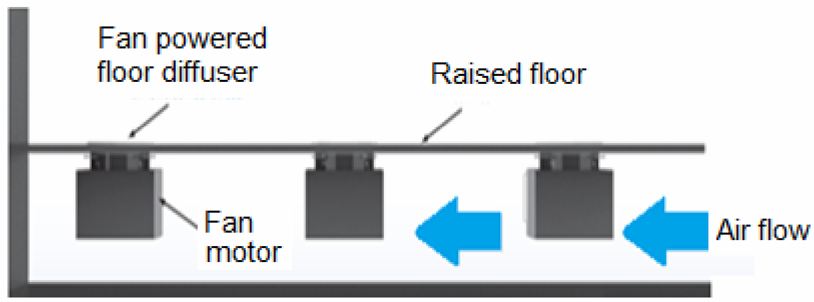
Currently, three common types of UFAD variations are:

Pressurized Floor Plenum System - Supply air is delivered via passive "swirl" type floor diffusers supplied by a pressurized underfloor plenum and central air handler. The scheme is preferred for large interior areas.



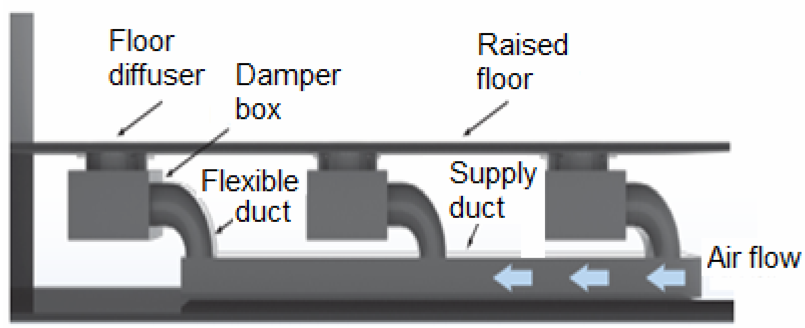
Pressurized floor plenum system

Fan Powered – Non Pressurized System - Supply air is delivered via locally-controlled, fan-powered diffusers (active diffusers) supplied by a very low-pressure underfloor plenum and central air handler. It is recommended for use for perimeter zones. These systems have low air leakage and provide user controllability but will increase fan energy use.



Fan powered non-pressurized plenum system

Ducted System - Supply air is delivered via under floor ducts to terminal devices or supply outlets. Ducted systems solve the air leakage problem but reduce flexibility and user-controllability.



Ducted System

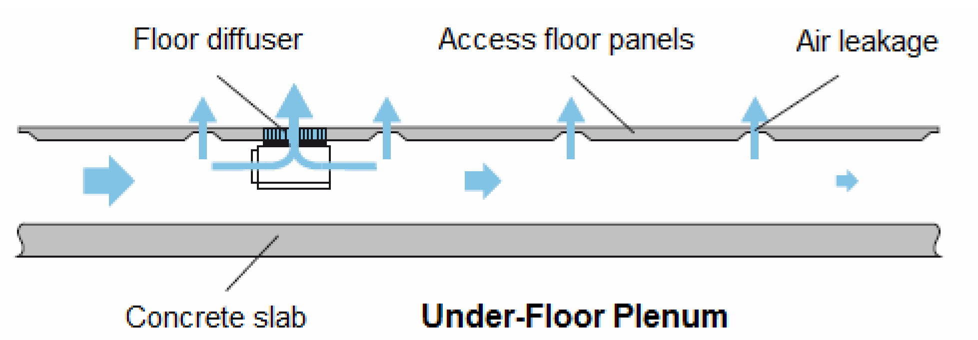
Return Air Configuration

Ideally, return air should be ducted at ceiling level to ensure vertical air flow patterns from floor diffusers for pollution removal and stratification benefits. It supports an overall floor-to-ceiling air flow pattern taking advantage of the natural buoyancy produced by heat sources. A certain portion of return air is mixed with primary air from the AHU to achieve desired air temperatures and humidity, and enable reduced energy costs.

AIR LEAKAGE THROUGH UFAD PLENUM

Air leakage, especially in a pressurized UFAD system, creates a number of problems within the space such as:

1. Over-cooling or under-cooling of the space beyond set point as a result of lost control due to over airing.
2. Breakdown of desired stratification zones within the vertical space. This breakdown can create a highly mixed space, which is contrary to UFAD design principles.
3. Excessive fan energy use as a result of additional air being moved through the primary air handlers.
4. Excessive system noise as a result of increased airflow.



Although the UFAD plenums are designed for low-pressures (0.05 to 0.10 inches WG), their large size could cause very high air leakage due to poor sealing between floor panels or poor construction quality of the plenum. A 1/8-inch gap between the raised floor and exterior wall does not sound like a lot and may seem trivial but over the entire length of the perimeter, the overall area of the gap could be the equivalent of a door wide open. It is imperative that the floor tiles are tightly sealed as well.

The amount of air leakage can be calculated from the following equation:

$Lv = 4005 \times (R_p)^{1/2}$

$L = Lv \times A$

Where

- Lv = Leakage velocity in FPM
- L = Air leakage in CFM

- R_p = Plenum pressure, in-wg
- A = Opening area

Assuming 0.05 in. (WG pressure), the leakage velocity is = 0.223 x 4005 = 895 feet per minute

With a total of 1 sq.-inch opening size, the leakage air volume is = 1 x 895/144 = 6.2 CFM

These amounts can be a substantial fraction of the total required cooling, especially in the interior zones. If access panels are removed for long periods of time or the distance between primary air inlets and supply diffusers is too great, control of air flow will be diminished. A higher plenum pressure in the order of (0.5 inches WG) could result in problems with over-conditioning, lifting of carpets, and problems with diffusers.

It is therefore important to pay close attention to sealing the cracks especially at the intersection of floor slabs with exterior walls and interior shafts (for elevators and risers). Also examine furred-in columns, stud walls penetrating the raised floor, and all penetrations for pipes, ducts, and cables.

Important!

A good system typically will leak no more than 10% to 15% or around 0.10 cfm/sqft to 0.15 cfm/sqft (depending on tile type and finished surface). While even 10% to 15% leakage may seem excessive to some, it is important to remember that overhead duct systems leak an average of 20% of their airflow, and that leakage flows to the return-air airway and not to the occupied space.

AIR DISTRIBUTION OUTLETS

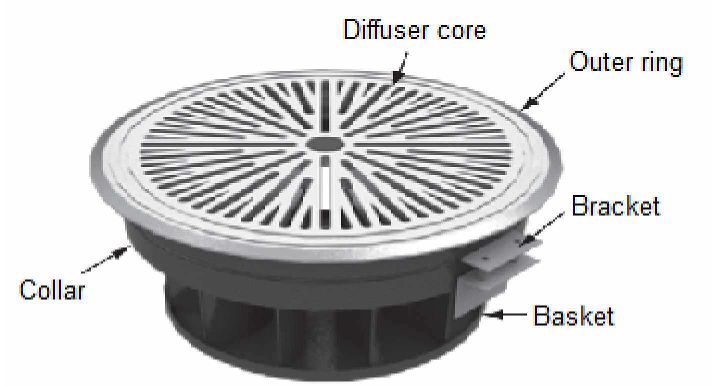
Two types of air distribution outlets used in UFAD are:

1. **Passive diffusers -** Passive diffusers rely on a pressurized plenum to deliver air. Swirl floor diffusers, constant velocity floor diffusers, and linear floor grills are the examples.
2. **Active diffusers** – Active diffusers rely on a local fan to deliver air from the plenum. These are less susceptible to pressure variations and other flow restrictions.

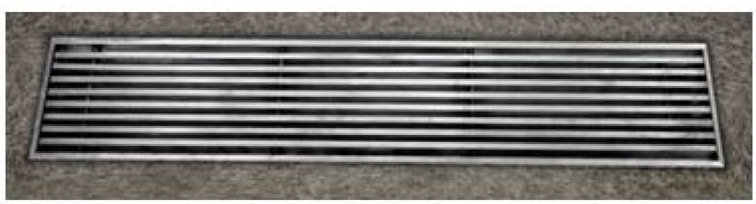
There are three basic styles of diffusers:

1. **Swirl floor diffuser:** Swirl diffusers are passive HVAC elements that have blades arranged in a radial pattern and are designed with an outward throw angle. It discharges

the air into the space in a swirling pattern at a medium face velocity (400 fpm). Because of the swirling pattern, the diffuser does not form a persistent “jet”; rather the turbulence at the discharge promotes rapid mixing with the room air and sheds momentum through smaller scale transient vortices. The design airflow quantity for a swirl diffuser is usually around 75 to 100 CFM at roughly 0.5” pressure drop. Diffusers have no moving parts and can be equipped with optional basket underneath to collect dust and particles.

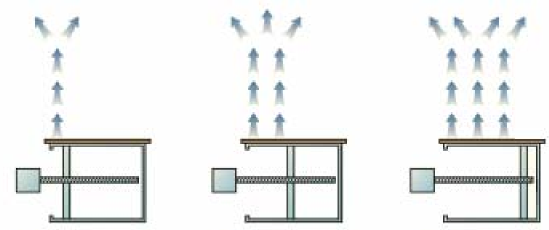


2. **Linear floor grill:** Linear floor grilles are used in perimeter zones and are available in various lengths to match the airflow requirements. Air flow throw pattern is achieved through a 0° or 15° deflection blades. Although linear grilles often have multi-blade dampers, they are not designed for frequent adjustment by individuals, and are therefore not recommended in densely occupied interior spaces.



Linear Floor Grille

3. **Variable Air Volume Diffuser:** Variable air volume diffusers include a motor-driven internal damper to provide variable air flowrates controlled by a thermostat on a zone basis. Alternatively the diffuser can be equipped with a variable speed fan in lieu of a damper to provide variable air flowrates.



Variable Air Volume Diffuser

The table below summarizes the various features and applications of these products.

Diffuser Type	Airflow Pattern	Adjustability	Ideal Location
Swirl diffuser	Swirling upwards, rapid mixing.	Rotate grill or bucket to adjust air flow volume.	Interior and perimeter zones.
Linear bar or floor grilles	Planar sheet, air jet	Multi-blade damper is used to adjust air flow volume.	Perimeter zones
Variable air volume	Multi directional, air jet.	Adjust grill for changes to air flow direction, thermostat for air flow volume.	Interior and perimeter zones.

Notes

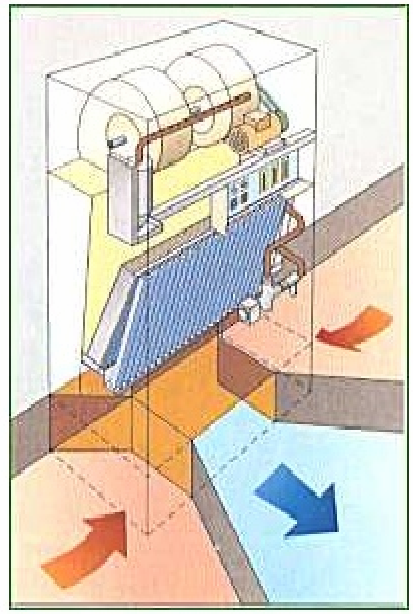
1. Pressurized plenums generally use passive diffusers whereas neutral-pressure plenums use fan-powered diffusers.
2. Fan-powered diffusers provide better local control of airflow rates at the expense of additional fan power, noise and cost.
3. Passive diffusers can generally be converted to an active diffuser by simply attaching a fan-powered outlet box to the underside of the diffuser or grill.

4. Air discharged through the swirl diffuser generally reaches a velocity of 50 FPM somewhere in the range of 4 to 5 feet above the diffuser. This distance is considered the characteristic "throw" of a diffuser.
5. To ensure effective thermal mixing and maintain stratification for energy conservation, swirl diffusers are preferable to jet diffusers for the turbulent mixed flow of supply air and room air in underfloor air systems.
6. *Important:* Changing the density and location of diffusers is the central strategy of UFAD systems to effectively deliver breathing air and cooling to the range of functions and layouts that occur in the dynamic workplace environment.

AIR HANDLERS AND DUCTWORK

The air handler units (AHU's) for UFAD system are usually down blast configuration and are often custom designed to meet the specific requirements. Typically the UFAD AHU must utilize two air streams. The first stream includes all of the ventilation air volume which is chilled to a temperature, such that when mixed with a second stream of bypassed return air, it provides a dewpoint suitable for comfort.

The design and layout of main ducts from the air handler to plenum inlet locations is similar to that of conventional overhead systems except that access must be provided for the ducts to reach the underfloor plenum. The recommended air velocity in the supply ductwork is 1,500 fpm maximum to reduce noise, and the return-air intake should be sized for a maximum of 500 to 800 fpm. Air moving any faster will disrupt the stratification effect necessary for a properly designed UFAD system. Increasing the airflow by increasing the number of supply diffusers (increasing supply area), rather than the velocity, is a good option to increase the cooling capacity. The size of the main ductwork can be reduced using multiple floor-by-floor air handler units closer to the point of use.



System Characteristics

1. The system may be used with chilled water or DX cooling coil.
2. Standard units are available with built-in control consoles.
3. Fan HP is generally lower than OH systems due to lower static pressure.
4. Varying air volumes with variable frequency drive (VFD) on the fan motor is recommended for enhanced system efficiency.
5. High-quality filtration is recommended since a prime consideration of the UFAD system is good indoor air quality.
6. Heat exchange enthalpy type economizer is recommended where local climate permits.

AIR TERMINAL UNITS

Terminal units are used in ductwork to maintain the desired indoor temperature conditions. Basically these units consist of a sheet metal box containing a damper, controls and a sensor, and they are usually connected to a supply header via a flexible circular duct. In their simplest form these units are designated as variable air volume (VAV) boxes. In many climates, fan-powered terminal systems (FPT's), which contain an auxiliary fan to supplement the air delivered from the plenum, is a better alternative for energy efficiency and comfort control.

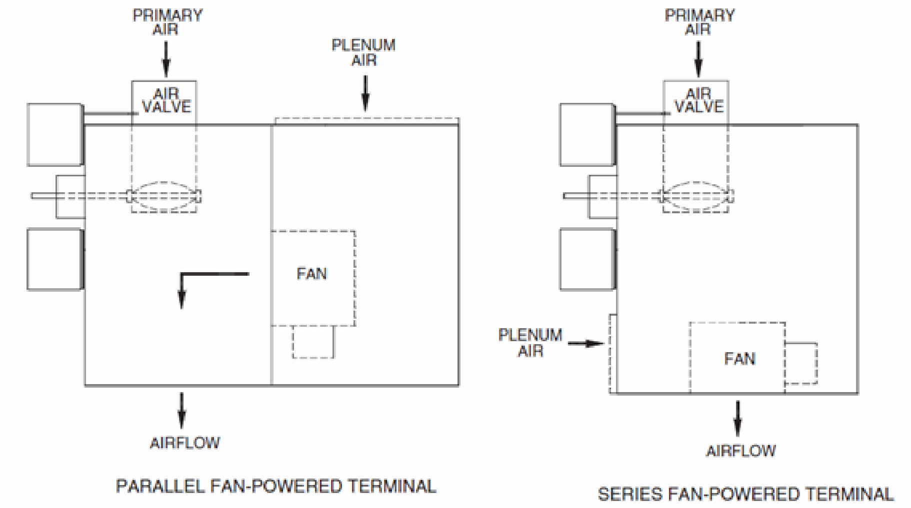
The perimeter and the high thermal load areas are best served by the fan powered terminals (FPT's), which are available in two configurations parallel and series configurations. Each model carries its own characteristics of delivered airflow, energy consumption, and acoustics. For the end user, the designer might consider three goals: a comfortable and productive environment, acceptable installed cost, and low operating costs.

- **Parallel Fan-Powered -** Parallel fan-powered units are commonly used in VAV zones which require some degree of heat during occupied hours, when the primary supply air is cool. The terminal unit fan is in parallel with the central unit fan; no primary air from the central fan passes through the terminal unit fan. The terminal unit fan draws air from the space return plenum.

  Parallel intermittent fan-powered terminal units are very common in perimeter zones or buildings where loads vary during occupied hours. Core zones, which maintain a more constant cooling requirement, are better suited for variable airflow (single-duct) units. Typical jobs combine parallel fan-powered units (exterior) and single-duct units (interior) to provide an efficient system with lowest first cost.

- **Series Fan-Powered -** Series fan-powered terminal units are used commonly in VAV zones that not only require heat during occupied hours, but also desire constant air volume delivery. The terminal unit fan is in series with the central fan. Primary air from the central fan always passes through the terminal unit fan. The local series fan within the terminal unit operates whenever the unit is in the occupied mode. The volume of air delivered to the zone is constant, but the temperature of the delivered air varies. As the zone requires less cooling, the primary air damper closes. As the primary air damper closes, the air mixture supplied to the zone contains less cool air and warmer plenum air. Remote heat or terminal reheat can provide additional local heating.

  Series fan-powered terminal units are used in applications requiring constant air movement, or blending utilize series constant fan-powered terminal units. Conference rooms, laboratories, and lobbies are common applications.



Comparison of Parallel and Series Terminal Unit

	Parallel	**Series**
Fan Operation	Intermittent operation during occupied and unoccupied modes.	Continuous operation during the occupied mode and intermittent during unoccupied mode.
Operation sequence	Variable volume constant temperature device during cooling and constant volume, variable temperature during heating.	Constant volume, variable temperature device at all times. Delivers design airflow regardless of the load.
Terminal fan operation and size	Fan runs during heating load. Size for design heating load. Typically this is 40 to 60% of design primary cooling airflow.	Fan runs continually. Fan sizing should meet the greater of design cooling or heating airflow to the zone.
Static pressure	Sufficient to overcome unit heating coil, downstream duct and diffuser pressure losses.	Sufficient to overcome air valve pressure loss only.

Acoustics	Fan does not run under cooling loads thus offer superior acoustic performance. Under heating loads, the fan operates intermittently – impact can be minimized by use of a ECM (Electrically Commutated Motor).	Produces slightly higher background noise but since the sound level remains constant, it is less noticeable than intermittent fan operation with parallel terminal unit.

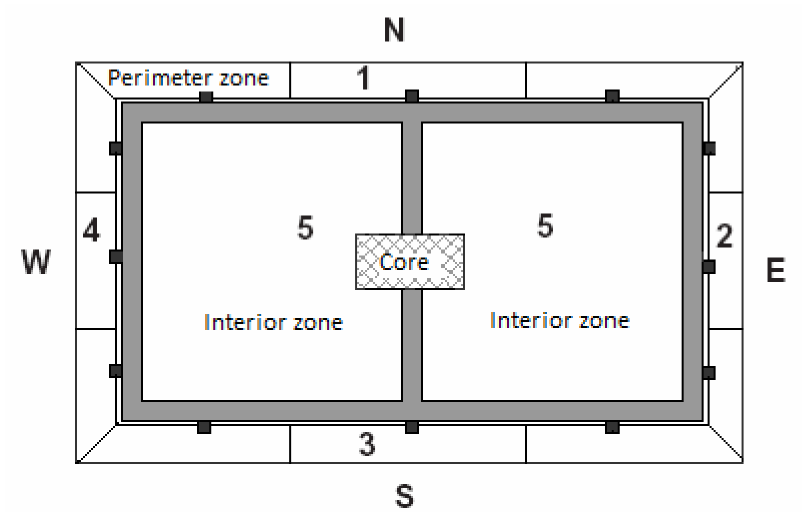
SYSTEM DESIGN & THERMAL ZONING

The efficiency and effectiveness of any air-conditioning installation depends largely on the zoning and control of the installation. HVAC design process starts by dividing the building into thermal zones. A thermal zone is defined as a space or group of spaces in a building that have similar heating and cooling requirements. The concept of thermal zone is important to allow HVAC equipment selection such that it permits independent control of temperature and humidity. It is important to group zones with similar load profiles on the same HVAC equipment and avoid mixing perimeter zones with interior zones on the same HVAC unit as far as possible.

The primary factors to consider when determining the zoning of an air-conditioning system for a building are the building orientation, periods of occupancy, the heat loads due to electrical appliances, fresh air/ventilation requirements, smoke control, etc. The building loads can be categorized in two distinct thermal zones: perimeter zones and interior zones.

Perimeter zones - The perimeter zones are the window-side areas extending 12 to 15 feet away from the outside wall/windows. These spaces are influenced by solar radiations and have variable loads with peaks occurring only for few hours each day. The variables include how the building is oriented toward the sun, its elevation, and the local weather patterns. For example, if a structure's façade calls for high proportions of exterior glass, the result will be a high degree of heat gain during hot summers and heat loss in cold climates.

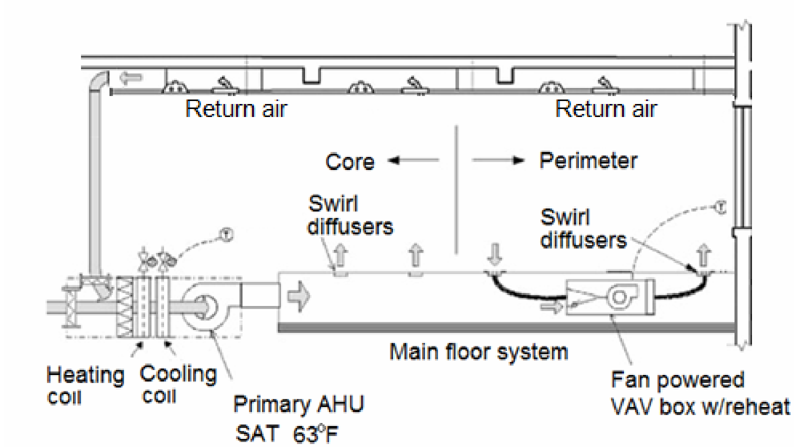
Interior Core zones - Unlike perimeter zones, the interior zones extend further than 15 feet from the exterior walls/glazing and typically exhibit a uniform and steady cooling load throughout. The heat gains in these areas predominantly emanate from people, equipment and lighting which do not vary quickly or significantly. These areas are not influenced by solar loads. Few areas in interior zones may have variable load profile dependent on the level and period of occupancy, for example conference and meeting rooms.



System Design

The heat loads in the interior areas are relatively constant and may not vary significantly As such, the installation of constant air volume (CAV) system using manually adjustable floor diffusers provide a high degree of thermal comfort. Each occupant can adjust their diffuser to their own liking while a constant static pressure is maintained in the floor plenum to prevent the opening and closing of individual diffusers from affecting the airflow delivery to the space. Interior areas with variable load profile such as conference rooms, meeting rooms, etc. can use series fan-powered terminal units along with passive diffusers or use hybrid system comprising both the constant volume type UFAD and the traditional overhead variable air volume (VAV) system. Fan controls and direction control for passive diffusers is recommended.

Unlike interior spaces, loads in perimeter areas may vary significantly and frequently due to external heat gain fluctuations. In particular, heat gains due to solar transmission largely determine the cooling requirements in these spaces. These gains can fluctuate greatly over short time periods as the sun passes in and out from behind clouds. As such, some type of automatic temperature control is required for all perimeter areas. Fan powered terminal units are the popular solution for the perimeter zones when the open airway plenum concept is used for air delivery. FPTs allow for the variable air volume delivery and/or its temperature can be easily varied.



If fan terminals are to be used for perimeter zone treatment, they must be designed to fit within the support structure of the access floor. It should be noted that gaining access to fan terminals is often difficult or impossible once furniture and or partitions have been located on top of the access floor platform. This is a considerable drawback as fan terminals require routine maintenance and have numerous moving parts that are subject to failure.

A return air temperature sensor per supply air plenum is used to employ a supply air temperature reset schedule. The supply air is maintained at 632°F when the return air temperature is 78 to 80°F and 68°F when the return air is below 75°F. This allows the system to be optimized based on the load in the space as well as compensates for any leakage to the space through diffusers, electrical boxes, or the raised access floor. All FPT's are thermostatically controlled by a perimeter zone thermostat.

In the winter season, the air handlers use an electric strip heater or hot water coil that heats mixed air according to the supply air reset schedule if there isn't high enough return air temperature to obtain the desired supply air temperature.

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 the drawback is satisfying differing space conditions because all of the air is delivered or drawn at one temperature and humidity condition.

To satisfy variable loads, the open airway plenum can be partitioned by vertical sheet metal dividers under the raised floor. The dividers create an effective and dedicated thermal load zone as the heated or cooled air can be channeled effectively to interior or perimeter zones, as necessary. The disadvantage, however, is that the system efficiency is compromised and the flexibility of reconfiguring it is lost. Open airways provide better system performance and, when used in combination with FPT's, satisfy the variable loads conveniently.

SECTION - 4 UFAD – DESIGN ISSUES

In spite of the advantages of UFAD systems, there exist some barriers (both real and perceived) to widespread adoption of this technology. Listed below are few of the key design issues, concerns and misconceptions that must be addressed to ensure a successful project.

Concern #1: New and Unfamiliar Technology

One of the biggest worries for UFAD is that it is new and unfamiliar technology. Even though many more buildings are utilizing UFAD systems, there is not a comprehensive guideline to aid the designer, contractor, or commissioning agent in understanding the myriad of the details associated with this type of system. Conventional OH systems on other hand have the advantage of having been used for years, and the design guidelines and tools have been developed, making their application much easier.

While it is true that UFAD designs have been developed through trial and error, significant progress has been made in the past several years. There have been number of studies carried out by CBE, Berkeley, aimed at providing a complete understanding of the underlying fundamental fluid mechanics and thermal issues related to UFAD. Very recently ASHRAE has published UFAD Guide: Design, Construction and Operation of Underfloor Air Distribution (UFAD) Systems, which provide assistance in the planning, construction and operation of UFAD systems.

Concern #2: Perceived Higher Costs

The UFAD system costs more than the conventional OH system.

Although most designers believe that buildings with UFAD systems demand a first-cost premium, study results to date are inconclusive. One study by the U.S. General Services Administration (GSA), indicate that the UFAD systems cost slightly more in first costs and the increase can vary from $2 to $6 per square foot, depending on the scale and the size of the floor plate. Increases in first costs are almost completely attributable to the cost of the raised flooring. However, when analyzed with accurate life-cycle costing and unforeseen contingencies, the UFAD systems can often prove to be very cost-effective. Unlike OH systems, which require extensive ductwork and control dampers, an UFAD design requires very little or negligible ductwork. The first cost difference between an OH system and an UFAD system can be minimized and, in some cases, be completely offset by other variables that include:

- Reduction in HVAC construction sequencing and installation costs

- Reduction in power, data/voice networking installation costs
- Reduction in ductwork, lighter duct materials
- Reduction in HVAC controls
- Lower horsepower fans
- Smaller chillers
- Building height reduction
- Construction time and materials cost savings

Also savings in space remodeling costs over the life of the system can easily pay for the incremental cost. Facility managers can spend less time and money on renovations since changes in electrical and HVAC services are simple and convenient. Churn savings can range from $3 to $5 per square foot; a substantial amount considering the U.S. churn rate now averages 33 percent annually.

Concern #3: Managing Thermal decay

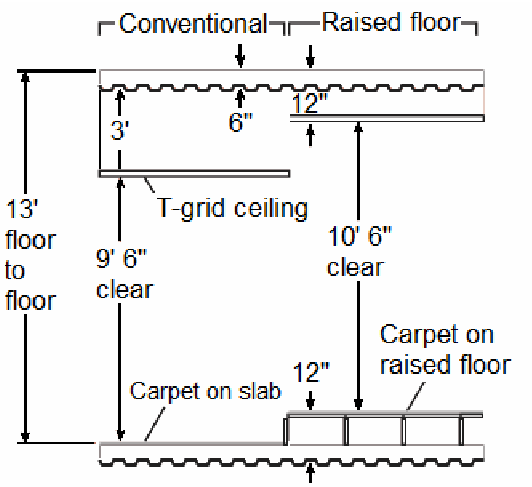
Thermal decay introduces another considerable challenge for many UFAD systems. Thermal decay occurs when cold air exiting the discharge points into the UFAD plenum changes temperature prior to being delivered to the occupied zone through floor outlets. For example, if a typical discharge air design temperature 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. Listed below are a few strategies which can significantly lessen thermal decay problems and minimize slab temperature pickup:

1. Limit the maximum travel distance from the air handler discharge point to the farthest airway outlet to 50 to 60 ft. The shorter the distance the better.
2. Insulate the duct between the air handler discharge point to the airway plenum.
3. Insulate the slab. Minimum R-19 continuous insulation is recommended under the radiant slabs located above unconditioned spaces, such as parking garages.
4. Cover the ceiling with a low-e material. This solution helps to reduce the radiation from the warm ceiling down to the top of the plenum panels.
5. Provide multiple air charging points to large floor plenums. If it is not feasible, try locating the air handler discharge points near the higher loads.

6. Add some plenum dividers and/or run ductwork to reduce temperature gain to the supply air. In certain applications, the air speed can be increased for the airways divided by metallic sheet metal partitions.

Concern #4: UFAD systems require additional height between slab and slab

There is a perception that the height of the UFAD plenum adds additional height between slab and slab. This is not true; rather the UFAD system has the potential to reduce slab-to-slab heights by as much as 6 to 12 inches per floor. UFAD systems can reduce or even eliminate overhead sheet metal ducts that make up conventional ceiling air distribution systems. Smaller ceiling plenums are therefore needed for air return and installing lighting fixtures.



Vertical dimensions of conventional and UFAD systems

Additional benefit is that with much of the HVAC components removed from the ceiling, the building permits a much more open ceiling design, making it easier to include indirect day lighting, light shelves and other design features in the ceiling.

Concern #5: Humidity control

Given the higher supply air temperature (typically 63ºF instead of 55ºF), the humidity control is difficult.

The problem is addressed through the use of a bypass damper at the cooling coil, where the outside air is cooled and dehumidified and part of return air is mixed downstream of the cooling coil.

Concern #6: Difficulties in maintaining pressurization

High air leakage through the floor penetrations and floor panels poses difficulties in maintaining pressurization and affects the air distribution performance. This is potentially due to the high leakage rate through floor penetrations and floor panels.

The air distribution performance capabilities of the system are dependent primarily on the sealing of the plenum cavity. It is important to seal diligently all surfaces in contact with the plenum. This not only maintains the static pressure, but also minimizes moist air exfiltration from the floor plenum into wall cavities, where mold growth can occur. HVAC designers 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. Coordination between the architectural and engineering design disciplines along with sufficient construction oversight is required to insure a sufficiently tight plenum.

The concrete slab in an underfloor plenum shall be sealed with a low-VOC sealant.

Concern #7: Air Quality and Dirt Entering the UFAD Systems

Concern is expressed about the possible spillage and dirt entering directly into the UFAD plenum and contaminating the supply airstream. Few important design considerations must be noted:

- Specify diffusers with catch-basins and traps to capture spills (for example from a typical soft drink spill).
- Seal slabs and floor panels to close tolerances.
- Keep low air velocities in air plenum so that the air does not entrain any dirt or other contaminants from the plenum surfaces into the supply air.
- Establish more-frequent and more-rigorous plenum inspections and cleanup programs.

Concern #8: Moisture Condensation

Condensation can be a concern in UFAD systems, if the cool plenum is suddenly exposed to warm, moist air. Condensation and mold growth can occur on concrete plenum floors when the floor plenum’s supply air temperature is below 63ºF.

To control this condensation ensure that the dewpoint temperature of the air entering the plenum must always be greater than the lowest temperature of any exposed surface within the plenum. This phenomenon can be avoided, if the plenum is well sealed against outside air infiltration, and if sudden step-changes in supply air conditions are avoided. For example, when the fan shuts down at the end of the day, warm and moist air should be blocked from rushing into the cool plenum. Similarly, during occupied hours, if the mechanical cooling abruptly shuts down and the dewpoint of the supply air suddenly rises, the fan may need to be shut off, or the outside air dampers adjusted.

Concern #9: Fire & Smoke Control

Large unducted plenums must have plenum dividers for smoke and fire control. Local fire codes often place restrictions on the size of the plenum to be less than 3,000 ft^2 in area with one horizontal dimension in one direction to be less than 30 ft for effective smoke separation. In some locations, sprinklers are required if a plenum is over 18 inches deep, and in other locations, wiring must be in conduit or plenum rated cables.

Try restricting the plenum depth up to 18 inches and evaluate installing smoke detectors in the plenum. Plenum dividers need to be incorporated to limit the large size of plenums.

Concern #10: 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, volume control dampers, etc.) The most important design issue here is making sure there is adequate room and access to perform routine maintenance and repair. Things to consider include:

- Equipment access panels are not blocked.
- Enough room is available for equipment removal and installation.
- Equipment is located so that filters can be replaced easily.
- Office furniture does not impede access to the equipment.

Concern #11: Designing for Catastrophic Occurrence

One disadvantage to installing HVAC equipment in an UFAD 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 likely that it will go unnoticed for quite some time, unlike an overhead system that starts to drip. The design 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 generate an alarm immediately.
- Do not mount anything directly flush on the floor so that water can flow to the drains unimpeded.
- Identify locations of all shut-off and isolation valves on the as-built drawings.

Keep the make-up water line valve closed and install a pressure sensor in the water loop. The system should shut down on a low pressure alarm.

Concluding:

Virtually all of the issues listed above can be traced to inadequate design, construction, and operating practices that have resulted from lack of knowledge and experience. Many of these issues are actively being researched or have been addressed by various institutes like the Center for the Built Environment, Berkeley California; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE); and other various design and construction organizations.

SECTION - 5 UFAD AND SUSTAINABLE GREEN BUILDINGS

UFAD systems can contribute towards achieving credits towards a LEED certification:

- Optimize energy performance
- Material re-use
- Recycling of access flooring
- Re-use of access flooring components
- Ventilation increases
- Thermal comfort
- Controllability of systems
- Reduced building height and construction materials

There is a nationwide trend toward constructing buildings that are more environmentally friendly, as a response to dwindling resources and increasing energy costs. This trend is reflected in designing and constructing buildings to meet green building or sustainable design construction standards. The LEED-NC™ standard, issued by the US Green Building council, is the best known green building program. The LEED (Leadership in Energy and Environmental Design) standard is based on a voluntary rating system that rates a building design on its environmental impact on the community, site, water, energy efficiency, and indoor quality for the occupants. This standard establishes green building objectives in five categories, with a number of credits which may be accumulated. The rating system, based on the number of points, awards the building a green rating which goes from “Certified” to “Platinum”. There are some prerequisites, but other than that, the points may come from any of the five categories. HVAC related systems account for 40% of the possible points. The points are based on the entire building as a system; no particular product or system is certified by the program, but rather the building in which they are used. Some systems are easier to justify points than others. UFAD systems are one of those systems with potential points in several areas.

Many projects now require LEED (Leadership in Energy and Environmental Design) certification. Points can potentially be gained with UFAD systems in several areas:

1. Mechanical equipment downsizing
2. Part load efficiencies
3. Recyclability of office components

4. While LEED no longer gives ventilation credit for UFAD systems (because ASHRAE 62 no longer gives ventilation credit for UFAD), there is a proposed change in progress that will allow reduced outdoor air with short throw UFAD outlets
5. Occupant comfort control.

   Note: Connecting multiple active diffusers to a single thermostat eliminates "occupant control" LEED point.

The table below shows the LEED credits that could be achieved with UFAD systems.

Criteria Classification	**Points**
Energy & Atmosphere • EA Credit 1 – Optimize Energy Performance	Up to 10
Materials & Resources • Credit 1 – Building Reuse	1 - 3
Indoor Environment Quality • Credit 6 – Controllability of Systems, Thermal comfort • Credit 7- Thermal Comfort	 1 1

Optimize Energy Performance

The intent of this credit is to achieve increasing levels of energy performance above the prerequisite standard to reduce environmental impacts associated with excessive energy use. Credits are based on percentage of reduction and range from 10.5% reduction (1 Point) to 42% reduction (10 Points) for new buildings.

The requirement for optimizing energy performance credit is to reduce the design energy cost compared to the energy cost budget for systems regulated by ASHRAE™/IESNA Standard 90.1-2004. Per LEED, regulated energy systems include HVAC, service hot water and interior lighting.

All LEED projects registering after June 26, 2007 are required to achieve at least two (2) Optimize Energy Performance points. One way to achieve energy optimization credit is with an UFAD system. An UFAD system may have higher HVAC equipment efficiency as access floor air systems use warmer supply air (63 to 68°F) than conventional systems that use 55°F supply air. Raising the discharge temperature of many system types reduces energy consumption.

UFAD systems can move a larger volume of air with overall lower pressure drops. The UFAD plenum needs less than 0.1" WG of water pressure or less for proper diffuser performance. This results in less fan horsepower needed for UFAD systems, and in turn, resulting in lower energy usage.

The energy savings of an UFAD system should be considered as part of the system to receive an Optimize Energy Performance credit. ECM motors are another option that should be considered with fan powered units. The ECM motor has efficiencies of up to 70% across its entire operating range (300-1200 rpm) and 80% over 400 rpm.

Building Reuse

If the project is a renovation, Credit 1.1, 1.2, or 1.3, Building Reuse, may be applicable. Credit 1.1 is for maintaining at least 75%, based on the surface area, of the existing building structure and envelope. Credit 1.2 is for maintaining an additional 20%. Credit 1.3 is for maintaining 50% of existing interior non-structural elements such as interior walls, doors, floor coverings and ceiling systems.

Each credit qualifies for one point; meeting the criteria for all three credits yields a maximum of three points for the Material & Resources section. Utilizing access floor systems can update a building for meeting current technology needs without demolishing the current building structure. In situations where the architect wants to leave an ornamental ceiling open, access floor air distribution may be the perfect solution.

Controllability of Systems

Credit 6, Controllability of Systems, has two parts: 6.1 Lighting and 6.2 Thermal Comfort. The intent of Credit 6.2 is to provide individual comfort controls for 50% of the building occupants to enable adjustments to suit individual task needs and preferences.

The credit states that, "Individual adjustments may involve individual thermostat controls, local diffusers at floor as potential strategies to achieve this credit".

UFAD DO's and DON'T's

1. UFAD systems work best when a stratification layer is established at 6 feet above the raised floor.
2. Airflows need to be closely matched to the loads within the occupied zone so as not to over air the space, losing the partial displacement ventilation effect. Tests have shown an ideal airflow of 0.6 cfm/sqft for good mixing while maintaining the stratification height at 6 feet and keeping the occupied zone temperature gradient below 5ºF.
3. Do not include excess safety factors; it will lead to over airing the zone spaces, thereby resulting in many occupant comfort complaints and loss of the stratification layer.
4. Do not eliminate the suspended ceiling. Shallow up the ceiling plenum and use it as a return air plenum, gaining additional airflow benefits from assigning greater amounts of cooling load directly to the return air.
5. Keep plenum depths below 18 inches to avoid potential requirements for fire sprinklers.
6. Do not use too many zoning barriers in the plenum or you will restrict the ease of future rezoning and running of service utilities to various points of use.
7. If air highways (underfloor sheet metal partitions) are used to channel air and facilitate air distribution, air velocities shall not exceed 1,500 fpm.
8. The maximum air travel to the farthest diffuser should be restricted to 50 to 60 feet.
9. Select diffusers so that throws are around 3 to 4 feet; it will not disturb the stratification zone.
10. Interior areas are best served with constant air volume AHU with manually adjusted swirl diffusers.
11. Perimeter zones are best served with thermostat-controlled airflow via fan powered terminal units (FPT's) connected to floor diffusers or linear bar type grilles.
12. Interior spaces with high variable load zones, such as conference rooms, may use series type fan-powered terminal units, or UFAD can be used in conjunction with traditional overhead variable air volume (VAV) systems. This creates an overall hybrid system that utilizes the best features of both types of systems.
13. Where dehumidification is a concern, use a conventional air handling unit (AHU) with a return air bypass arrangement.

14. Where an air handling unit serves multiple floors, provide motorized dampers at horizontal connections at the shaft on each floor. These dampers shall modulate to maintain underfloor air pressure.

15. Placing returns over heat producing equipment and/or at the outside wall when high solar loads exist, will maximize the benefit of the partial displacement ventilation effect.

16. Device locations

    - Diffusers shall be placed at least 2.5 ft from the occupants with density no less than 1 per 100 ft^2. Typical office spaces shall have a minimum of 1 diffuser per workstation.
    - Avoid placing diffusers in traffic areas where high rolling loads are expected, even though they have a catch basin for incidental spills.
    - If underfloor fan boxes or terminal units are used, they shall be located in accessible aisles and not under workstation furniture.
    - Floor diffusers and electrical box cutouts shall be made off-center in the tile to allow for maximum location flexibility.
    - Electrical and telecom “whips” shall be located to allow a minimum 4-ft relocation distance.
    - Prior to full construction, a mockup shall be built representing perimeter and interior conditions.

17. Access floor commissioning

    - All access floor areas shall be pressure tested prior to occupancy to verify air tightness.
    - The maximum allowed leakage for any area is 10% leakage at 0.10 in.-WG pressure.

Course Summary

Underfloor air distribution (UFAD) is an approach to space conditioning in buildings that have several potential advantages over traditional ceiling-based air distribution systems. UFAD systems have been shown to offer the enhanced level of energy efficiency, comfort, productivity and flexibility. The potential benefits are summarized below:

1. In typical office environments, UFAD systems are able to provide more than three-to-five times the maximum sensible cooling capacity of a comparable displacement system without subjecting occupants to draughts or to an excessive vertical temperature gradient.
2. UFAD systems provide significant energy efficiency advantages due to fan energy savings, extended free cooling, and improved chiller COP, thereby reducing life-cycle building costs.
3. UFAD systems offer higher levels of IAQ in the occupancy zone and improved occupant thermal comfort. Unlike displacement systems, UFAD systems extend these high levels of IAQ to applications with significant movement and/or heating.
4. UFAD systems provide the opportunity for localized control of airflow and direction, further improving individual thermal comfort.
5. UFAD systems provide flexibility. The ease with which UFAD systems can be rearranged to satisfy new office layouts improves flexibility, thereby reducing reconfiguration costs. The modularity of all components of raised access floor systems can be an advantage in space planning, particularly over large open plan areas.

In spite of the significant advantages, there exist some performance concerns that need to be fully addressed. The potential issues are thermal comfort control in relation to widely varying interior functions; maintaining humidity control and the air quality of the underfloor air; fire and security protection in the plenum; and controlling first costs and the overall robustness of the system. Working collaboratively with manufactures and design institutions as well as sharing practical experience of successful installations, especially in Europe and Japan, should be explored towards the widespread adoption of UFAD in the USA.

References

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