



Under Floor Air Distribution Systems in India

UFAD system under installation for an office in Bengaluru showing the vertical supports for the raised floor, cable tray in the centre and an air distribution duct on the right

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The most critical factor faced in our work space is flexibility to adapt to changes which are driven by technological evolution, and accordingly design our workspaces to forestall obsolescence. In fact, the greatest challenge today in space management is to make work spaces aesthetic, efficient and flexible or, in short, to make them ergonomic.

Under Floor Air Distribution (UFAD) in commercial buildings offers enormous benefits like energy saving, reduced building height, flexibility, improved indoor air quality, etc. UFAD, in conjunction with Raised Access Floor (RAF) system, is the key to flexibility in our workspaces today as the under floor area can provide enough space for existing and future add-on utilities as and when required by the organization, in view of ever changing work flow and employee/ technology related needs.

Sunrise technologies whose benefits

have not yet percolated down to the end user constantly face resistance from the technical and commercial fraternity because of the perceived higher 'risk' when new technology is introduced into a market. People prefer sitting on the fence, waiting for someone else to take the 'risk'.

However, globally, Under Floor Air Distribution (UFAD) is now a proven technology. As far back as the 1950's, UFAD was being used in spaces having high sensible heat loads (e.g. Computer Rooms, Control Centers, Telephone Exchanges and Laboratories), and was subsequently introduced in office buildings in the 1970s.

For more than a decade now the latest concepts in UFAD systems have achieved large scale acceptance in Europe, North America, South Africa and Japan. With organizations in India open to the most contemporary technologies, the time seems ripe for UFAD systems to make their

presence felt in India.

When we introduced this concept in 2008, we came across some UFAD installations carried out in India by innovative engineers; however they were very rudimentary systems put together using existing technology and, although working successfully, had few advantages. This was because there was no company in India which offered the UFAD system using tailored products at that time. We decided to visit some installations and meet occupants of these innovative UFAD spaces.

We received a very positive and encouraging response from the people

About the Author

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Table 1: Details of UFAD projects commissioned in India

Location	Type	Area (Sq Ft)	UFAD system
Bengaluru	A global IT and BPO service provider	25,000	Uses existing AHU combined with rifle ducting, time modulated VAV terminals in the perimeter and constant volume terminals with manual adjustment in the core area
	NOC (Network Operating and Command Center) and office of a global telecommunication giant	9,000	Uses AHU combined with rifle ducting and fan assisted Fan Tile units
	Educational auditorium	3,500	Uses AHU combined with ducting and constant volume displacement terminals
Chennai	Corporate office of a big media house	20,000	Uses AHU combined with time modulated VAV terminals
Delhi	NOC and office of a public utility company	7,000	Uses zonal down flow units combined with Fan Tile units
Mumbai	Our head office	3,000	Uses zonal down flow units combined with Fan Tile units and time modulated VAV terminals

maintaining and occupying these spaces.

- The director of a famous architectural firm in Mumbai, who has a basic UFAD system installed in his office, commented that he felt more comfortable while occupying spaces conditioned by UFAD system compared to his cabin which had a conventional overhead system.
- Maintenance personnel of an installation in Bangalore, running successfully for about five years, mentioned that no maintenance had ever been carried out on the UFAD system. We were astonished and requested them to allow us to visit the site; to our surprise we found that the UFAD terminals were in good condition.

The combination of site visits and user feedback gave us the confidence to get more involved in UFAD systems. We also investigated such applications in similar climates around the world and their suitability for operation in Indian conditions. This experience motivated us to aggressively promote the concept which has resulted in the successful commissioning of six prestigious projects in India with many more in the pipeline. Some of the projects have been functional for nearly a year now without any adverse experience regarding air distribution and quality.

So what made these organizations opt for the UFAD system? In our opinion they could foresee the enormous benefits it offers over a conventional over head system. Some of these benefits are:

1. Improved thermal comfort: Individual comfort preferences can be accommodated by allowing individual occupants to control their local thermal environment.
2. Improved ventilation efficiency and indoor air quality: Improvement in ventilation and indoor air quality at breathing level is achieved by delivering the fresh supply air at floor level near the occupants and returning at ceiling level (Figure 1).

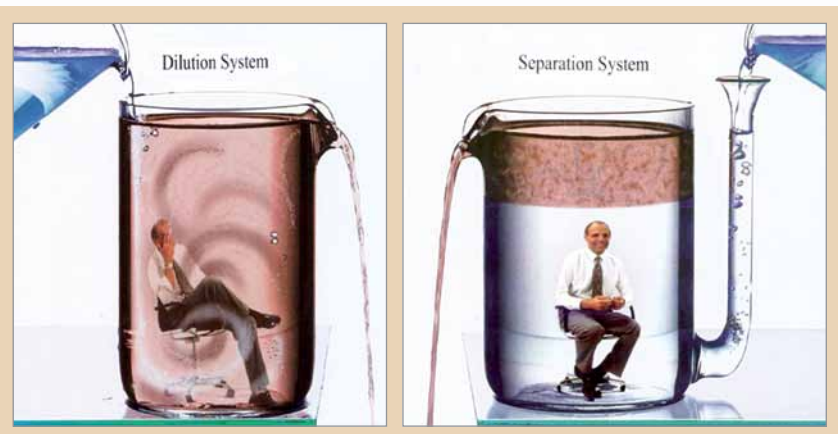


Figure 1: Air distribution in an over head (dilution) system versus UFAD (separation) system

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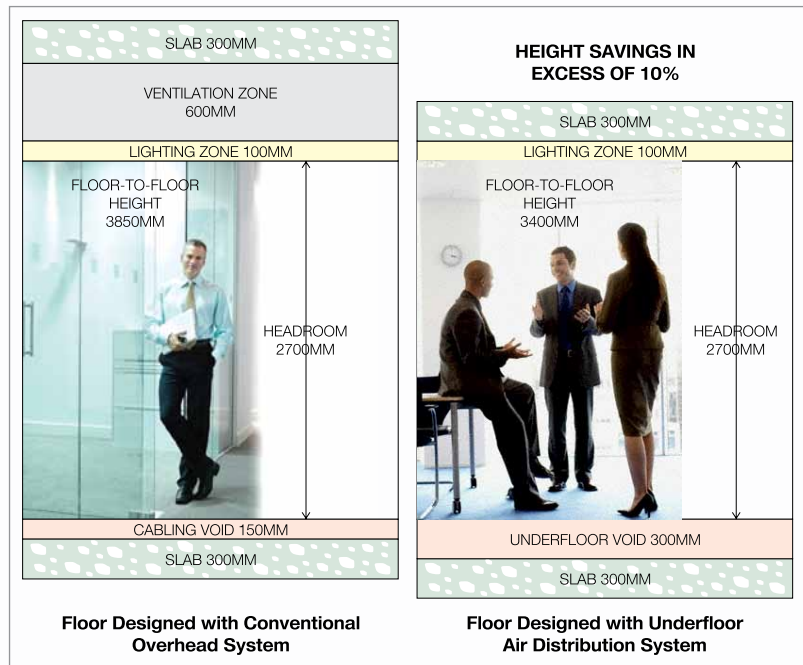


Figure 2: Height saving benefit that can be availed in a UFAD System

Significant progress towards the USGBC LEED 2.2 (IGBC 1.0) requirements can be made with RAF and UFAD. A Green Building has been shown to give the owners a higher Return on Investment (ROI).

How the UFAD Concept Works

Ideal Gas Law describes a basic property of air, which states that hot (less dense) air always tends to rise up and cold (more dense) air settles down. This principle, when applied to air conditioning, can offer tremendous benefits in energy savings compared to the conventional mode of air delivery, as it can limit the cooling requirement to the occupied or breathing zone (up to 1.8/ 2.0 meters height).

Let us now explore the basic difference in air conditioning equipment (high and low side) of a conventional over head system and a UFAD system (Table 2).

This comparison indicates that the equipment used on the high side in both systems remains the same. On the low side, one

Table 2: Basic difference in air conditioning equipment between conventional over head and UFAD systems

Details	Conventional Over Head System	Under Floor Air Distribution System
High Side	Central Plant (Chiller + Pumps + Cooling Tower)	Central Plant (Chiller + Pumps + Cooling Tower)
	Chilled Water Piping	Chilled Water Piping
Low Side	Air Handling Unit	Conventional AHU/ zonal down flow AHU (CAM C/V)
	Ducting	Minimal or no ducting required
	Insulation	Ducting insulation not required as it runs through conditioned space
	Grilles	Terminal Options: Passive: Constant volume, VAV with time modulation Active: Fan Tile units

can utilize conventional AHUs for larger areas and zonal down flow AHUs or Conditioned Air Modules (CAMs) for smaller areas.

UFAD Using Air Handling Units

Conventional AHUs deliver conditioned air through rifle ducts* (please see box) into the floor plenum formed between the top of the slab and bottom of the raised floor to maintain the required temperature in the breathing zone (human height or up to 1.8/ 2.0 meters). The hot contaminated air above the breathing zone rises up due to stratification and returns to the AHU via the open space or false ceiling. Rifle ducts ensure that the supply air temperature rise from the slab is reduced. By using UFAD pressurized plenums, nearly 60-70% of the overhead ducting can be eliminated.

* Rifle ducts are rectangular ducts installed below the raised floor, not connected to any terminals, and are used specifically to channelize conditioned air to the required zones and to eliminate temperature gain from the slab.

Factors to be considered while designing UFAD system with conventional AHU (Figure 3)

1. Different locations across India have some potential days during the year when the outside air temperature drops down to the desired temperature to be maintained in the conditioned space, and which can provide "free cooling". To avail the free cooling option the AHU must have an actuated fresh air damper capable of supplying the total CFM requirement of the AHU. The damper actuator should be controlled via a thermostat that will continuously monitor ambient temperature conditions.
2. To elevate the supply temperature to 16–18°C, the AHU should have the provision to bypass filtered return air (27/ 28°C) and mix it with the coil leaving air (12/ 13°C) through a modulated damper in the fan chamber. A temperature and humidity sensor mounted in the supply plenum will modulate the bypass damper to maintain the supply temperature to above 16°C. You will be surprised to know that about 20-25 percent air is bypassed to elevate the temperature. This eliminates

the need to reheat the supply air by using other means like electric heaters or hot water coil, thereby saving energy.

3. Installing raised flooring needs planning in the initial stage. The floor can be included in a new building design by the architect, or ramps and steps can be planned for existing floor plates. Raised flooring height should be generally between 200-350 mm to house all the services and for cable management.

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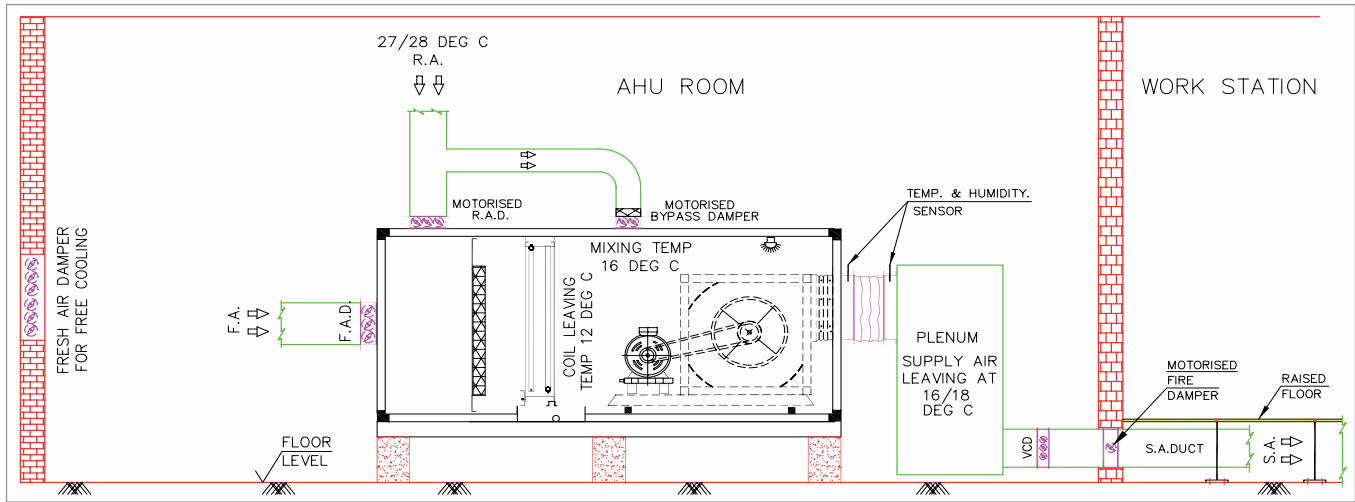


Figure 3: A typical AHU arrangement required with a UFAD system

4. Understanding the limitations of the raised flooring size, rifle ducts should be designed to fit between the pedestal and direct maximum air volumes in the perimeter zone. Each area needs to be specially evaluated to eliminate problems related to supply air temperature rise due to heat gain through the slab.
5. Terminal options can be selected depending on the criticality of the areas. Terminal types are covered later in this article.

UFAD Using Zonal Down Flow AHUs or Conditioned Air Module (CAM)

Use of zonal down flow or CAM units can eliminate the need for an AHU room. The CAM unit can be positioned at any convenient location in the workplace. These units are intelligent compact AHUs which house air filter, cooling coil, optional electrical heaters or hot water heating coil and inverter driven blower. The unit is available in different sizes depending upon the air volume or cooling load requirements. It can be a model V (Variable Speed - Figure 4) that supplies the air through the raised floor plenum and takes the return air using the false ceiling or open space, or a model C (Constant Speed - Figure 5) which has the capability to supply and take the return air through the raised flooring using a physical partition called a baffle. These units can cater to a maximum area of 3500 sq ft and do not require any ducting.

Floor Terminals

Floor Terminals can be broadly classified as follows

- I. Depending upon placement : Floor cooling and Task or Desk cooling terminals
- II. Depending on plenum pressure : Active and Passive terminals
- III. Depending upon throw pattern : Displacement or Well Mixed terminals

Floor cooling terminals are installed in the raised flooring. These terminals are available in square, round or rectangular shapes. They are made of plastic or die cast aluminum and should have the same load-bearing

capacity as the raised flooring. The metal air terminals can be powder coated to the color specified by the architect. These terminals feature a dust collection tray to retain heavy particles which can be cleaned by periodic vacuuming.

Task or desk cooling terminals are installed in the furniture on the desk (Figure 6). A flexible duct connects the terminals to the floor plenum, which can be integrated with the fixtures for aesthetics. These terminals provide the user leverage to adjust air volumes or

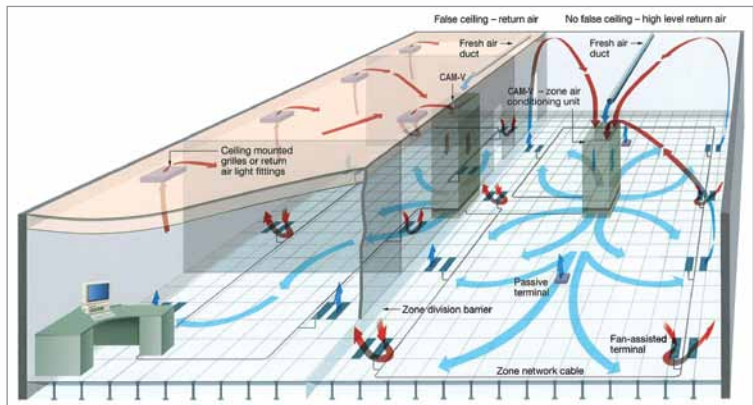


Figure 4: Air movement in a CAM V floor supply and ceiling return system

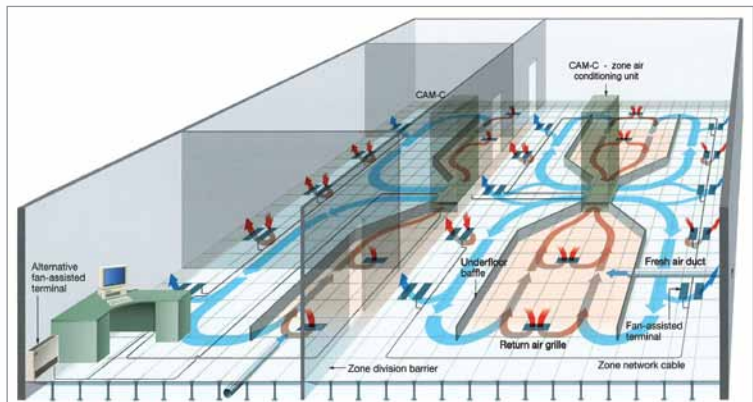


Figure 5: Air movement in a CAM C floor supply and floor return system

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Figure 6: Task or Desk cooling terminal

direct the air towards or away from him. By using these terminals, the user body temperature preference can be maintained (say 24°C) and his surround zone temperature can be elevated a little (say 27°C). This elevation of zone temperature without affecting the comfort of an individual can offer tremendous energy savings.

Active terminals (Figure 7) are fan assisted intelligent terminals featuring DC or EC motors, which can be easily installed in the area occupied by a raised floor tile, and hence they are sometimes called Fan Tile units (FTU). These terminals can operate at very low pressures (0-20 Pascal) in the floor plenum. The FTU comprises the blower, on-off damper, temperature sensors, optional heater and a smart controller.



Figure 7: Active Fan Tile Unit (FTU)

The FTU has two temperature sensors: one monitors the room temperature and the second monitors the supply temperature. Based on the set point for the zone, the FTU opens the damper and introduces supply air into the room to maintain the set temperature. When the set temperature is reached, the FTU closes the damper and recirculates the air in the room. Notably, in the recirculation mode, the unit always takes some supply air to meet fresh air requirements.

The enhancement in the active tiles is such that some of the terminals also offer the user remote adjustment to their temperature and air volume requirements at the click of the mobile.

Passive Terminals (Figure 8) depend on plenum pressure to deliver conditioned air into the space to be conditioned. The required plenum pressure is 0.05 inch (12.5 Pascal). These terminals can be constant volume or variable air volume terminals.

Displacement terminals introduce conditioned air into the space at a very low velocity. When cooling, the supply air is normally introduced into the space at 18/19°C (64.4/66.2°F) and 0.5m/s (100fpm). The diffuser throws the air about one meter in the shape of an inverted cone. After this, the flow of



Figure 8: Passive VAV and constant volume terminals

air is maintained by convective forces. The air is attracted to heat plumes such as people and IT equipment due to the simple fact that hot air rises as it becomes less dense and new colder air replaces it. In doing so it cools the equipment and people. It continues to rise as it is attracted to lighting before being extracted from the space at high level.

Well mixed terminals force the cool air into the space through terminal fans or the main AHU fan when using passive terminals. This being a mechanically controlled action, the systems are not dependant on the location of heat sources such as people and IT equipment to maintain the required breathing zone conditions. The time modulated VAV terminals ensure equal air distribution in the breathing zone (1.8/ 2.0 meters) during part load conditions as well.

Challenges Encountered in the Field

Initially it was quite challenging to get the entire team, including project management and different service contractors, on the same wave length. We conducted several meetings with key members of the entire project team and made presentations, but observed that the required details were not percolating down to the labor at site. UFAD installations need a high quality of workmanship and constant monitoring. With multiple trades involved in the interfaces, early planning and attention to detail is the key.

You will appreciate that in India the "will do" or "chalta hai" attitude is quite pervasive. It is not that the labor or the teams are not aware of the correct processes, but they usually resort to short cuts. This can also be due to the pressure of deadlines. To address this challenge, we had to depute a full time technical expert to monitor the activities and educate the service contractors. The critical factor in the entire UFAD installation is plenum integrity and to maintain a plenum pressure of 0.05 inch or 12.5 Pascal.

Systematic Installation is the Key to Success

The following procedure was employed to install an UFAD system successfully:

1. Install and finish all fire-rated boundary walls, ceilings and ceiling systems.
2. Complete the floor slabs, seal them as dictated by building codes and project specifications and check that they are level. Normally, a level difference of 50 mm in the slab finish can be taken care of by adjusting the height of the raised floor pedestals.
3. Mark the raised-access floor (RAF) pedestal support grid layout on the floor slab, ensuring that the grid lines match with the main supply and branch ductwork.
4. Install and prepare all fan-powered units and any associated ductwork before the RAF is installed.
5. Install pressure control dampers and fire/ smoke/ control-zone dampers (FSDs), fan terminal ductwork and branch ductwork while the RAF is being installed, to ensure proper room for the ductwork.
6. Clean and vacuum the slab before cabling is installed. A clean airway prevents dust from being blown throughout the space during the initial start up.
7. Install all wiring systems on the slab and coordinate the systems with the floor-pedestal marks.

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8. Set up a workstation to install the UFAD terminals in the RAF panels, expediting the installation of floor pedestals, panels and power voice-data (PVD) boxes. Overlay the wiring (preferably plug-and-play cabling) on the UFAD drawings. Unique tag numbers are often unnecessary for UFAD drawings because there are typically only a few types of terminals used.
9. Install the RAF pedestals and panels, including those with UFAD terminals and PVD boxes. It is recommended that UFAD terminals or control items not be installed along known partition lines or under furniture.
10. Install Passive UFAD terminals in the correct orientation in floor panels and RAF panels to ensure that airflow patterns match the drawings.

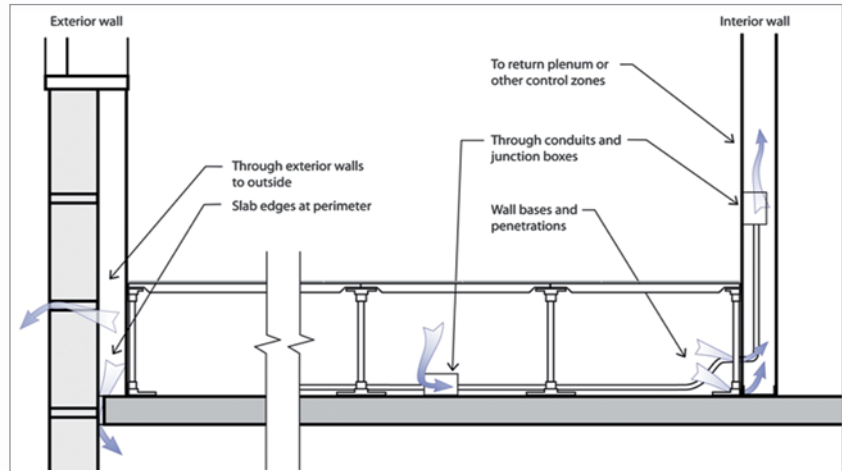


Figure 9: Different types of internal and external leakages

11. In larger floor plates, when the diffusers are located within 15 feet of the supply duct, try to install the terminals with the inlet facing away (if possible, because some diffusers have inlets on all sides and do not allow this) from the air supply to avoid a velocity effect from the ductwork.
12. Orient directional grilles to provide the desired airflow pattern. At the perimeter, airflow should be directed along and/or away from the exterior walls, while grilles in the interior should create an outwards circular pattern. Commission the controls and check all cabling at this time (before carpet, partitions, etc. are installed).
13. Construct partition walls on top of the RAF, covering the floor and any openings or air distribution terminals to keep construction debris from entering the floor airway.
14. Apply finish to the walls.
15. Remove the covering from the RAF and vacuum.
16. Lay carpet on the RAF panels. Depending upon the size of carpet, it can be laid creating aligned or offset pattern with raised flooring tile. The aligned pattern promotes more flexibility whereas the offset pattern reduces the possible leakages between the raised flooring tiles.
17. Install furniture.
18. Ensure all plug-and-play cable connections are properly connected and engaged in mating connectors. (This can be accomplished earlier when the RAF is installed, depending on the sequence of the trades.)
19. Vacuum all construction debris in the diffusers. (This is not necessary if diffuser protective sheets were utilized earlier.)
20. Commission the mechanical systems.

After a successful and critically monitored installation, the system is now ready for commissioning and handing over.

The sequence for commissioning and handing over should preferably be as follows:

1. The commissioning engineer should ensure, before start up of the system, that the required controls and electrical connections are properly in place.

2. Primary fans should be initially tested keeping the terminals in closed or minimum open position.
3. There are two types of leakages from the floor plenum (Figure 9), in addition to the leakage from the raised flooring. The first, which is more critical, is the leakage from the floor plenum to the external atmosphere; the second is from the floor plenum to the internal conditioned space.
4. Identify and seal the leakages.
5. After correction of leakages, retest and balance the primary fans and rifle ducts.
6. The static pressure test determines if the system can provide the required air volumes to the terminals.
7. Typically, one terminal per zone can be tested and the zone controllers can be verified for proper functioning.
8. Balance all terminals, if ducted.
9. Monitor temperatures and humidity in the conditioned space and maintain them as per design.
10. Prepare as-built drawings indicating all the UFAD components like routing of rifle ducts, locations of dampers, controls, plug-and-play wiring.
11. Provide training to the maintenance team regarding the operation of UFAD system.
12. Explain to them the important benefits of the system like flexibility, energy saving, comfort and better IAQ.
13. Stress the importance of periodically cleaning the floor plenum and dust collection trays.
14. Explain to the maintenance team the modifications possible in the terminals to meet individual preference.

Conclusion

Buildings designed with UFAD systems need more inputs in the design phase, particularly when it is a new concept for the team members. Once they have some experience working with UFAD systems, they start appreciating this concept. With implementation of best construction practices and proper coordination, UFAD projects can be much more convenient than conventional projects.

Many innovators have stated that UFAD systems may one day go mainstream replacing the conventional ceiling-based systems. ❖