

# Underfloor Air Distribution (UFAD) Application Guide



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## General

This document provides application and design highlights for underfloor air distribution (UFAD) systems.

Additional information may be found at the Titus website, [www.titus-hvac.com](http://www.titus-hvac.com).

## Introduction

The interest in underfloor air distribution (UFAD) has increased significantly over the last decade. There is currently several million square feet of access floor air distribution systems being designed across the country.

In 1997 Titus introduced the TAF-R diffuser and the TAF-G grommet, which were installed in the Owens Corning World Headquarters. Since then, Titus, ASHRAE, and the engineering community have continued to learn about UFAD systems.

In the decade that Titus has participated in UFAD designs in the US, we have continued to introduce new products to meet the needs of this unique application.

## UFAD System Overview

UFAD systems utilize the space under an access floor as an air plenum. Properly designed UFAD systems take advantage of thermal stratification.

ASHRAE recommend that, for comfort, the temperature in the occupied zone be between 73° and 77°F, relative humidity be between 25 - 60%, and the maximum velocity in occupied zone be 50 fpm in cooling or 30 fpm in heating.

The key to successful access floor systems is the ability of the access floor diffuser to rapidly mix room air into the supply air at low velocities. Because supply air is introduced directly into the occupied zone, it is important that the supply air reach the ASHRAE recommended temperature and velocity, mixing of the supply air into the space should happen rapidly.

The typical application for a UFAD system is the open plan office. Floor space is at a premium in a cubicle so a smaller clear area around the diffuser will allow more usable space in the cubicle. The UFAD diffuser manufacturer defines the required clear area that their diffuser needs to achieve the ASHRAE recommended temperature and velocity.

Originally UFAD systems were for computer rooms. The design intent was to cool computer equipment and not to provide comfort. The computer room design concept typically provides too cold of a space for comfort.

There has been a growth of UFAD systems used in offices and headquarters in U.S. It is estimated that 10% of U.S. construction will utilize access floors within few years.

The growing interest in UFAD systems is primarily due to companies' need to easily rearrange office layouts, information and communications based offices, economics of ownership, and green building programs such as LEED.

## Design Basics

### Plenum Design

The raised floor office can be supplied with conditioned air from below the floor in two ways – pressurized plenum or neutral plenum.

## Pressurized Plenums

The pressurized plenum (the area between the slab and the raised floor) is essentially a large duct maintained at a constant pressure differential to the room above; typically between 0.05 and 0.10 in. pressure (w.g.).

This pressure is maintained through the supply of conditioned air from a number of supply duct terminations. The spacing and location of these ducts are dependent on the air supply requirement and the plenum depth, with shallow plenums and / or high air quantities requiring more air supply duct outlets under the floor. UFAD diffusers are specially designed grilles with a user adjustable damper to regulate flow.

Sealing the underfloor plenum is critical to optimizing the operation of a UFAD system. Air leaking through the floor tiles into the occupied zone is of minimal concern because it is leaking into the occupied space. Air leaking into the space between the walls, however, is wasted energy. All knockouts and holes in the drywall below the raised floor must be sealed during construction.

The advantages of pressurized plenums include low first cost and easily changed layouts. This is the most commonly used plenum design.

## Neutral Plenums

With the neutral plenum design, the same layout as the pressurized plenum may be used, but the pressure difference between the plenum and the room is kept as close as possible to zero.

Floor diffusers either contain integral fans, are ducted from a central source, or both. In many cases, these closely resemble conventional ceiling supply systems.

Advantages include the possibility of multiple small zones (as with multiple tenants) and insensitivity to construction details. Disadvantages include higher first costs due to ducting and/or fan connections under the floor, lower flexibility as the grilles are individually ducted, and potentially higher noise levels.

This design is rarely used, but may be effective in tenant buildings where the utilities will be paid by the tenant.

## Plenum Details

Plenum heights typically range from 14" to 18", occasionally going as low as 12". The plenum height is usually determined by the height requirements of other equipment that will be located under the floor. The number of inlets required to supply the plenum with sufficient air to run the diffusers is dependent upon the plenum size and the number of diffusers, which in turn is determined by the 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 50-65 feet. Distances longer than this are subject to thermal losses and the discharge temperature of the diffuser may be too high.

If zone control is desired from the underfloor plenum, the plenum can be partitioned into separate zones. The zones in the underfloor plenum should correspond to building zones having similar load requirements. However, it is not necessary to partition the underfloor plenum into zones and doing so can make future office layout changes more difficult. If an office layout must be changed, the partitioned plenum will need to be changed to match the new layout.

Because of the special heating and cooling requirements of the perimeter of the building, it may be necessary to create a perimeter zone in the underfloor plenum to run a separate perimeter system. Typically only the perimeter is zoned from the core. The perimeter will be discussed in more detail next.

## Perimeter Systems

The perimeter is typically the most difficult area of an underfloor system to design. The perimeter is often handling much larger loads and require the most equipment. In the past, the best way to handle the perimeter was to use fan powered terminals with reheat ducted to linear bar grilles.

There are a couple challenges with this design concept. The throw of a linear bar grille ducted to the discharge of a fan powered terminal is very long, possible as long as 15-20 feet. Designing long throws at the perimeter contradicts the concept of stratification in a UFAD system. Not only does the long throw from the grille mix the air above the stratified layer into the occupied zone, wasting energy, but it also may roll up the glass and across the ceiling, where it drop into the

occupied zone causing discomfort for the occupants.

Although the concept of UFAD systems is to be modular, the function of handling perimeter loads is not modular. Those loads come with the building envelope, which is always a line of some sort. The TAF-L Perimeter System was designed to address all of these considerations.

## **Perimeter Cooling**

The perimeter cooling system should combine induction, buoyancy and displacement ventilation models, handles high thermal loads such as 225 CFM per 4' length at 0.07" wg, engage the occupied zone, but not the stratified ceiling layer. This avoids occupant complaints from air rolling back, dumping into interior space and saves energy by not mixing the warm ceiling air into the occupied zone.

The TAF-L perimeter system provides this ideal air pattern. The TAF-L system consists of a modular cooling plenum, the TAF-L-V, and heating plenum, the TAF-L-W, designed to be integrated with the CT-TAF-L multi-deflection linear bar diffuser.

The TAF-L system provides a continuous look around the perimeter. The TAF-L-V cooling plenum used with the CT-TAF-L has an engineered throw pattern that never breaks through the stratification layer created by the UFAD diffusers in the core. The dual aperture plate design allows the TAF-L-V / CT-TAF-L assembly to maintain this engineered throw pattern while modulating the airflow volume.

## **Perimeter Heating**

Perimeter heating cannot be accomplished with the same system as the interior load cooling system. Ideally, since ASHRAE 90.1 states that you should not simultaneously cool and heat, the perimeter heating system should be completely independent of the cooling system. Separate ducting of hot or reheated air, hydronic systems, or perimeter fan powered systems are often used to condition the skin load on the building.

The TAF-L-W, self contained fin tube perimeter heating plenum utilizes room air to heat the perimeter instead of supply air. The TAF-L-W heating plenum also uses the CT-TAF-L to create a continuous linear look from the occupied space.

The TAF-L-W works by allowing the denser cold air to flow down a window or exterior wall into the TAF-L-W plenum while also inducing room air into the plenum. A finned tube heater in the plenum reheats this cold air and room air, returning the warmer air to the window or exterior wall through natural convection.

Typically the TAF-L-V, cooling plenums, and TAF-L-W, heating plenums are alternated as needed throughout the perimeter.

The TAF-L system allows you to remove the fan powered terminals, and their associated energy and maintenance costs, from the UFAD system. However, in the event where the system cannot achieve consistent plenum pressure, a fan powered terminal may be necessary.

The PFC was designed to be used as a booster unit for perimeter applications. The PFC fan powered terminal unit is designed to be installed between the pedestals in an underfloor system and installed in a floor 12" to 18" in height.

The PFC is usually ducted to linear bar diffusers, such as the CT, or diffuser and plenum units, such as the TAF-D. The airflow of the diffusers is directed at the glass like a typical ceiling system.

Modulating the fan speed to vary the amount of air supplied to the zone is the most common control sequence used for the PFC. The PFC controller will determine the speed of the fan based on zone temperature. For example, the fan would run 100% when the zone is 75°F and modulated down to 30% as the zone approaches 70°F.

## **Conference Rooms & Other Areas of Varying Load**

Much like the perimeter, conference rooms must be handled separately to adjust for the varying load conditions. The LHK fan powered terminal was designed for this application. Like the PFC, the LHK fits within the modular pedestal systems of the raised floor and is available in various heights to fit under 12" through 18" raised floors.

With the exception of its unique dimensions, the LHK is like any other series fan powered terminal. The LHK has a supply inlet with a damper modulated by a controller and actuator. The LHK has an induced air inlet which pulls air from the underfloor plenum or from the room depending on how the LHK is applied.

The LHK supply inlet would be open to the plenum with the induced air inlet ducted to the room as the return. The discharge would then be flex ducted to TAF-R's in the room.

## ***Return Air***

Due to the upward air flow, returns should be located at the ceiling or on a high side wall. This allows the heat from ceiling lights to be returned before it is able to mix with the conditioned air in the occupied zone. There will also be a small amount of "free cooling" due to the natural buoyancy of hot air.

If the system must use 55°F supply air for humidity reasons, some of the return air can be recirculated from the ceiling to the underfloor plenum to raise the temperature of the air to 63°F to 68°F.

Another option is to take the return air back to the air handling unit where it can be filtered and dehumidified before re-entering the underfloor plenum. With this option, you can more accurately control the air temperature at the diffuser and you gain the cost benefits of the warmer supply air temperature.

## ***Humidity Issues***

A potential problem with the higher supply temperatures used in underfloor supply systems is the higher potential moisture content of the warmer supply air used in these systems.

The supply system must reduce relative humidities to less than 60% to meet IAQ concerns, and this requires dew points less than 65°F. This implies either reheat or blending of air to achieve a 65°F supply, 55°F dew point condition.

System designs utilizing condenser water reheat, run-around coils, face & bypass, and other strategies can be employed to solve these potential design problems. Other possible solutions include the use of a separate system to dry outside air or the use of desiccant dehumidification.

Climate and building operation are important considerations when designing a UFAD system. In humid climates, it may be necessary to operate the HVAC system 24 hours a day to maintain acceptable humidity levels in the building.

## ***Sizing Jobs***

The optimum design point for the TAF-R is 80 - 100 CFM when a 10°F room / supply differential is used. At this point, the noise is negligible and the pressure required is less than 0.10".

Throw will be less than 6 ft., preserving the desired ceiling stratification layer. Our testing shows that there is 100% mixing in the occupied zone under these conditions.

The stratification in this installation results in a supply - exhaust  $\Delta T$  similar to the typical 18°F to 20°F  $\Delta T$  common in most conventional systems.

For example, with 64°F supply air in a 74°F room, the room exhaust, at the ceiling, will probably be about 82°F, for an 18°F  $\Delta T$ .

This means that one diffuser can handle:

$$18^{\circ}\text{F } \Delta T \times 100 \text{ CFM} \times 1.08 = 1944 \text{ BTUH or} \\ 1944 \text{ BTUH} \div 3.41 = 570 \text{ watts of internal load.}$$

Lights are typically 0.75 W/sq.ft, but with ceiling stratification are probably not a part of the room load (but are seen by the air handler). If computers and printers supply about 1W/sq.ft. load and occupants add about 1.2 W/sq.ft, this translates to:

$$1.0 \text{ W/sq.ft. (computers and printers)} \\ + 1.2 \text{ W/sq.ft. (occupants)} \\ = 2.2 \text{ W/sq.ft. (room load)}$$

This corresponds to one TAF-R every:

$$570 \text{ Watts of internal heat} \\ \div 2.2 \text{ W/sq.ft. room load} \\ = 260 \text{ sq.ft. floor space sensed interior zone load.}$$

As a general rule, one TAF-R should be provided for each occupant.

## ***System Economics***

The main economic considerations for a UFAD system are reduced first costs & installation costs, higher HVAC equipment efficiency, lower horsepower fans, better heat and pollutant removal, quick to install and easy to rearrange office layouts, and lower life-cycle building costs.

## First Costs & Installation Costs

UFAD systems can be designed with plenum returns using the same floor to floor height as conventional systems by shifting the occupied zone up into where the ceiling plenum would normally be.

The cost of the raised floor, typically \$5-7 per sq.ft., is offset by the fact that less ductwork is required. The installation costs are usually lower because the HVAC and data / power work is done at floor level.

In a conventional system, ductwork must go to every diffuser. UFAD systems use a pressurized plenum to supply each diffuser, so less ductwork is required. In a UFAD system, the only ducting in the underfloor plenum is the ductwork required to supply the diffusers that are more than 50-65 feet away from the dampers or the separation for the perimeter.

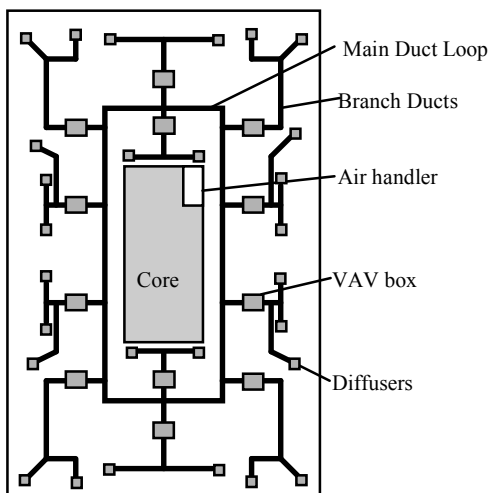


Figure 1. Conventional system ductwork

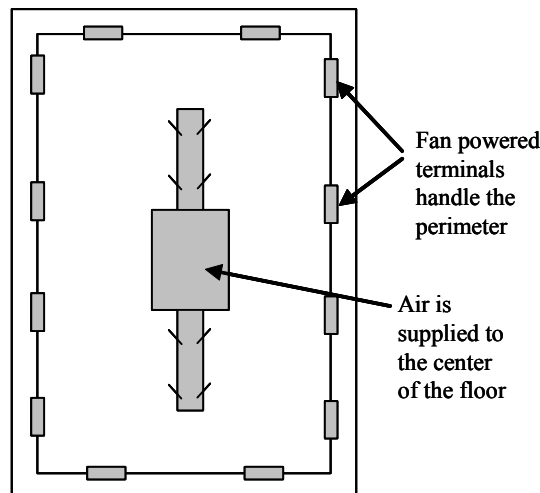


Figure 2. UFAD system plenum

A 1996 study in Building Design & Construction magazine showed a \$2.13/sq.ft. first cost savings using UFAD systems.

## Higher HVAC Equipment Efficiency

In an UFAD system, supply air enters directly into the occupied zone at the floor level. In a conventional system, the supply air temperature is usually 55°F because it must mix with the warm air at the ceiling before it enters the occupied zone.

UFAD systems typically use 63-68°F supply air temperatures. This warmer supply air can reduce energy consumption of the HVAC equipment. Some DX equipment cannot supply air at this high temperature, so this must be considered when selecting the HVAC equipment.

## Lower Horsepower Fans

UFAD systems move a larger volume of air with overall lower pressure drops. The diffusers used in UFAD systems operate with less than 0.1" wg, so lower horsepower fan can be used, reducing energy costs.

## Better Heat and Pollutant Removal

Heat from overhead ceiling lights is removed before it enters the occupied zone and lateral mixing in the occupied zone is reduced. A

Lawrence Berkeley National Laboratory field study found that pollutant removal efficiency for carbon dioxide was 13% higher than expected in a space with well-mixed air, suggesting a 13% reduction in exposures to occupant generated pollutants.

## ***Easy Installation and Relocation***

UFAD diffusers are installed through the floor panel after flooring and carpet installation is complete. Little attention needs to be placed on diffuser location until office furniture layout is finalized.

Typical churn in an office is 33%, meaning that everyone moves every three years. Diffusers are rearranged by moving entire floor panel to a new location. This reduces the time and labor costs of relocation and renovation in an office.

## ***Lower Life Cycle Costs***

Several factors of the UFAD system contribute to potential life cycle savings. The building should have an energy savings from the use of lower horsepower fans. The owner should see reduced costs for office layout changes.

In addition to these, the concrete structural slab can be used to lower peak cooling demand. The use of the underfloor plenum as a supply duct allows the use of the thermal mass of the structure as an energy “flywheel”.

By ventilating the underfloor plenum with cool air at night, the structure can be cooled to the point where the load during the early part of the day is significantly lowered. A number of strategies can be employed to take advantage of the potential for stored “cool”, resulting in lowered energy use and off-peak energy use. However, there is a potential for overcooling the occupied space during the night requiring addition morning warm up, costing energy.

There are also costs savings associated with increased thermal comfort for occupants. Because the diffusers are occupant adjustable, the facility staff should see fewer complaints about thermal comfort.

Increased employee satisfaction potentially results in increased productivity. Labor costs are typically 10 times the cost of property. A 1% productivity improvement is the equivalent of 22 hours, or almost three days, of gained productivity.

For a company with 115 employees earning \$35,000 a year, 30 employees earning \$60,000 a year, and 5 employees earning \$80,000 a year, a 1% improvement would worth be almost \$70,000. This is a substantial payback for a building owner.

## **UFAD and LEED**

The United States Green Building Council (USGBC) developed the Leadership in Energy & Environmental Design (LEED™) Green Building Rating System™. The LEED council is a voluntary, consensus-based national standard board for developing high-performance, sustainable buildings. USGBC members represent all segments of the building industry and update the program continuously.

The growing interest in green buildings and LEED certification has increased the interest in UFAD systems. The table below shows the LEED credits that could be achieved with UFAD systems.

Criteria Classification	Points
<b>Energy &amp; Atmosphere</b>	
▪ Credit 1 - Optimize Energy Performance	Up to 10
<b>Materials &amp; Resources</b>	
▪ Credit 1 - Building Reuse	1 – 3
<b>Indoor Environmental Quality</b>	
▪ Credit 6 – Controllability of Systems, Thermal Comfort	1
▪ Credit 7 – Thermal Comfort	1

## ***Optimize Energy***

Credit 1 is 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 underfloor system. An underfloor 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.

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

The energy savings of an underfloor 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 for the Optimize Energy Performance credit. The ECM motor has efficiencies of up to 70% across its entire operating range (300-1200 rpm) and 80% over 400 rpm. The ECM motor is available in the Titus LHK and PFC UFAD fan-powered terminals. See the ECM Application Guide, AG-ECM, for more information.

## **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 surface area, of 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 nets a maximum of three points for the Material & Resources section.

Utilizing access floors systems can update a building for meet 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. VAV diffusers, such as the Titus T<sub>3</sub>SQ would also qualify for this credit as well as access floor diffusers such as the TAF-R.

## **Abbreviations**

The following table lists abbreviations used within this document.

<b>Abbrev.</b>	<b>Term</b>
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
UFAD	Underfloor Air Distribution
LEED	Leadership in Energy & Environmental Design
USGBC	U. S. Green Building Council