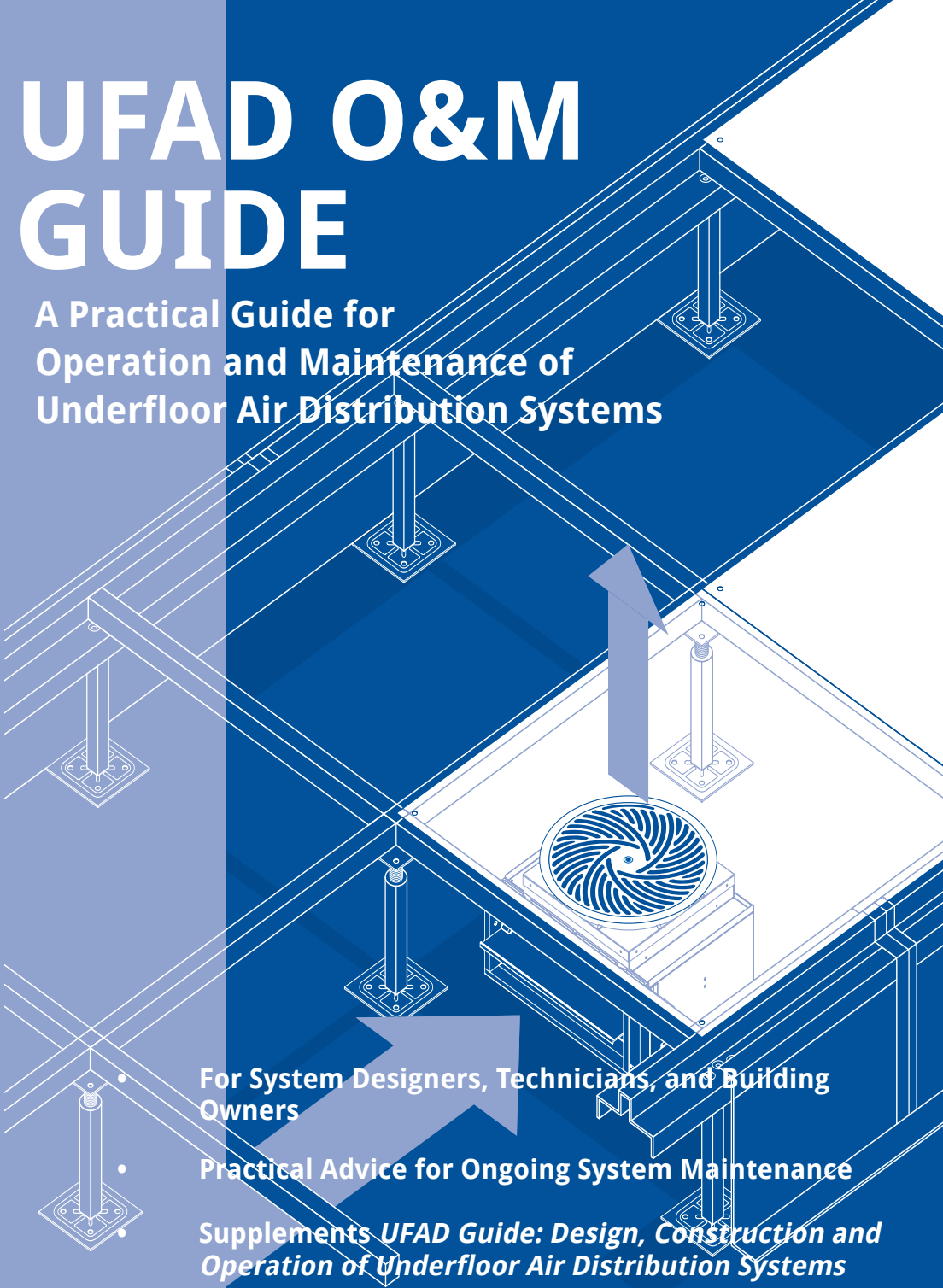
UFAD O&M GUIDE

A Practical Guide for Operation and Maintenance of Underfloor Air Distribution Systems



- For System Designers, Technicians, and Building Owners
- Practical Advice for Ongoing System Maintenance
- Supplements *UFAD Guide: Design, Construction and Operation of Underfloor Air Distribution Systems*

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UFAD O&M GUIDE

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O&M GUIDE

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Underfloor Air Distribution Systems

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W. Stephen Comstock

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The focus of this guide is to expand on issues related to operations, maintenance, and troubleshooting of underfloor air distribution systems that additional research and field experience has uncovered since the 2013 publication of the *UFAD Guide*.

James E Megerson, PE, LEED AP
Chair
November 2016

The following members contributed to this document

James E. Megerson, PE, LEED AP, Chair Design Mechanical, Inc.	Peter Strapp Tate Access Floors
William Reynolds Tate Access Floors	Jerry M. Sipes, PhD, PE Price Industries Inc.
Joseph Hullebusch Airfixture, LLC	Randy Zimmerman Titus
Bob Persechini RDK Engineers	Fred Bauman Center for the Built Environment (CBE)
Matt Bhumbla B.Eng, MBA, LEED® Green Associate Price Industries Inc.	Stefano Schiavon UC Berkeley
Kevin J. Gebke DuctSox Corporation	Kenneth J. Loudermilk, PE Titus

1 General Considerations

1.1 Introduction

Underfloor air distribution (UFAD) is an air distribution strategy for providing ventilation and space conditioning in buildings as part of the design of an HVAC system. UFAD systems use an underfloor supply plenum located between the structural concrete slab and a raised-floor system to supply conditioned air through floor diffusers directly into the occupied zone of the building. Thermal stratification, which is one of the featured characteristics of a UFAD system, allows using warmer supply air than that used with traditional overhead systems. The UFAD cooling load profile is different from a traditional overhead system because of the effect of the raised floor, particularly because systems using UFAD may typically have higher peak cooling loads than those using overhead air distribution. UFAD has several potential advantages over traditional overhead systems, including

- layout flexibility,
- enhanced individual thermal comfort control,
- improved ventilation efficiency,
- improved energy efficiency in suitable climates, and
- reduced life cycle costs.

UFAD is often used in office buildings, particularly highly reconfigurable and open plan offices, where raised floors are desirable for cable management. UFAD is appropriate for various different building types, including commercial office buildings, schools, museums, libraries, etc. UFAD systems have also been used successfully in performing arts facilities and other public meeting venues.

1.2 UFAD System Overview

UFAD systems rely on air-handling units (AHUs) to filter and condition air to appropriate supply conditions before it can be delivered to the occupied zone. Whereas overhead systems typically use ducts to distribute the air, UFAD systems use the underfloor plenum formed by a raised floor. The plenum generally extends 12 to 18 in. (0.3 to 0.5 m) above the structural concrete slab. Specially designed floor diffusers are used as the supply outlets. The most common UFAD configuration consists of a central AHU

delivering air through a pressurized plenum and into the space through floor diffusers. The UFAD configuration may also incorporate fan-powered terminal units at the outlets, underfloor ducts, etc. Refer to the *UFAD Guide* (ASHRAE 2013) for additional information.

1.2.1 Life-Cycle Costs

A properly designed raised-floor system with UFAD can significantly reduce costs associated with frequent changes in office configurations, provided that program requirements do not change. This is a significant factor in life-cycle costs.

Every building has its own set of design constraints and application of UFAD will require evaluation to determine if they are applicable to a specific project. In addition to UFAD, life-cycle cost analysis must consider all components of the system, including electrical distribution (power, voice, and data). It is the consideration of both systems that leads to the ease of reconfiguration that affects life-cycle costs.

Life-cycle cost components include those that accrue over the lifetime of the building. Additional first costs can be offset by the reduction in ongoing costs over the life of the building. How many years of ongoing savings are required to offset additional first costs is left to the owner's judgment.

1.2.2 Energy Optimization and Performance

A performance assessment for a UFAD system should contain the following three primary elements:

1. ENERGY STAR® rating system. This relatively simple procedure uses one year's worth of monthly data for electricity, gas, and water consumption from utility meter records to provide a comparative assessment of the building's energy performance. These data are entered into the EPA Portfolio Manager calculation tool to obtain the ENERGY STAR rating (on a scale of 1 to 100) for suitable buildings. This process compares the building's energy performance with a large database of similar buildings nationwide (see www.energystar.gov/benchmark). If the building type under analysis is not included in the EPA list, it is still worthwhile to calculate the building's energy use intensity with EPA Portfolio Manager.
2. Temperature measurements. It is difficult to fully evaluate UFAD performance without measuring stratification and diffuser discharge temperatures. During a three- to four-day site visit, using a mobile measurement system to collect this data can result in a wealth of insights in how to proceed with adjustments (Webster et al. 2011).
3. Occupant satisfaction survey. This survey, administered via the Internet over a two- to three-week period, provides an assessment by the occupants of the quality of their indoor environment. The survey addresses all major categories of indoor environmental quality, including thermal

comfort, air quality, lighting, acoustics, cleanliness and maintenance, office layout, and office furnishings, as well as satisfaction with floor diffusers. The survey results can be compared to a large benchmark database maintained to assess relative performance (Frontczak et al. 2012).

ASHRAE's *Performance Measurement Protocols for Commercial Buildings* embodies all of these features (and more) and is a good way to evaluate performance (ASHRAE/USGBC/CIBSE 2010).

1.3 UFAD Air Distribution and Stratification

Thermal stratification is the result of processes that layer the internal air in accordance with relative density. The resulting air stratification is a vertical gradient with high-density, cooler air below and low-density, warmer air above. UFAD systems capitalize on the natural stratification that occurs when warm air rises because of thermal buoyancy. In a UFAD design, conditioned air stays in the lower, occupied part of the room, while heat sources such as occupants and equipment generate thermal plumes that carry warm air and heat-source-generated pollutants toward the ceiling where they are exhausted through the return air ducts.

The temperature stratification created by the UFAD system has implication for space set points. Most of an occupant's body is in an area that is slightly cooler than the temperature at the thermostat; therefore, current practice recommends raising thermostat set points compared to traditional overhead systems. The optimal ventilation strategy controls the supply outlets to limit the mixing of supply air with room air to just below the breathing height of the occupied space. The warmer and more polluted air transported by the thermal plumes is above the occupied space, out of the breathing zone. The air that the occupant breathes will have a lower concentration of contaminants compared to conventional, uniformly mixed systems.

Many factors, including the ceiling height, diffuser characteristics, number of diffusers, supply air temperature, and outlet airflow rate, affect the cooling load and ventilation efficiency of UFAD systems. Swirl-type and displacement-type diffusers have been shown to successfully create low air velocity in the occupied zone, whereas improperly applied linear diffusers created the highest velocity in the occupied zone, potentially disturbing thermal stratification and posing a potential draft risk. Additionally, many floor diffusers add an element of personal control within the reach of the occupant, because users can adjust the amount of air delivered by the diffuser. Refer to the *UFAD Guide* (ASHRAE 2013) for additional information on diffuser types and characteristics.

1.3.1 UFAD Design Tools for Zone Airflow Requirements

There are two available design tools for determining zone airflow rate requirements for UFAD systems. One was developed at Purdue University as part of ASHRAE research project RP-1522. The other was developed at the Center for the Built Environment (CBE) at the University of California Berkeley.

ASHRAE RP-1522 (Jiang and Chen 2012) developed a simplified tool available only to ASHRAE members that predicts the vertical temperature difference between the head and ankle of occupants, supply airflow rate for one plenum zone, number of diffusers, and air distribution effectiveness. The tool requires users to specify the zone cooling load and the fraction of the cooling load assigned to the underfloor plenum. It also allows users to input the supply air temperature either at the diffuser or at the location within the plenum where it enters the confines of the zone. The tool allows users to select from three types of diffusers.

The CBE tool predicts the effective cooling load for a UFAD system using the input of the design cooling load calculated for the same building with an overhead system. It also predicts the airflow rate, room temperature stratification, air distribution effectiveness, and plenum temperature gain for both interior and perimeter zones of a typical multistory office building using a UFAD system. The CBE tool allows the user to select from four different plenum configurations (series, reverse series, independent, and common) and five floor diffusers (swirl, square, displacement, and two linear bar grilles). An online version of the design tool is publicly available at the CBE website (www.cbe.berkeley.edu) (Schiavon et al. 2011).

1.3.2 Heat Transfer Pathways in UFAD Systems

Plenum supply air temperatures rise as the supply air travels through the underfloor supply plenum from the plenum inlet to the floor diffusers. This phenomenon is typically known as thermal decay. Plenum air temperature rise is caused by cool supply air coming into contact with the warmer concrete slab and raised floor. Elevated diffuser air temperatures lead to higher supply airflow rate and increased fan and chiller energy consumption. Typical temperature rise is 6.6°F (3.7°C), commonly ranging between 4.3°F and 8.5°F (2.4°C and 4.7°C) (Lee et al. 2012). This rarely happens on the ground floor with a slab on grade has less plenum temperature rise compared to the middle and top floors. Supply plenum air temperature rise thus has implications for the energy saving potential of UFAD systems and their ability to meet cooling requirements with supply temperatures above those of conventional overhead systems. Both energy and thermal performance can be improved in UFAD systems by ducting air to perimeter zones where loads tend to be the greatest. However, critics suggest that such underfloor ducting reduces the benefit of having a low-pressure plenum space, as well as adding design and installation complications when fitting ducts between floor tile pedestals. Decoupled sensible cooling devices such as radiant panels and

chilled beams can also be effective in minimizing in both interior and perimeter area airflow rates.

1.4 UFAD and Energy

The energy assessment of UFAD systems is a not fully resolved issue, which has led to numerous research projects within the building science and mechanical engineering community. Proponents of UFAD point to the lower fan pressures required to deliver air in a building via the plenum versus via ducts. Typical plenum pressures are 0.0036 psi (0.1 inch of water column [25 Pa]) or less. The improvements in cooling-system efficiency inherent in operation at higher temperatures save energy, and relatively higher supply air temperatures allow longer periods of economizer operation. However, an economizer strategy is highly climate dependent and requires careful control of humidity to avoid condensation. Critics cite the shortage of rigorous research and testing to account for variations in climate, system design, thermal comfort, and air quality to question whether UFAD is able to deliver improved energy efficiency in practice. Limited simulation tools, the shortage of design standards, and relatively scarcity of exemplary projects compound these problems.

1.5 Applications

In addition to its frequent use in highly reconfigurable and open plan offices where raised floors are desirable for cable management, UFAD is also common in command centers, IT data centers, and server rooms that have large cooling loads from electronic equipment and requirements for routing power and data cables.

UFAD systems are not recommended for some specific facilities or spaces, such as small, nonresidential buildings, wet spaces (e.g., restrooms, pool areas), kitchens, dining areas, and gymnasiums, because UFAD may result in especially difficult or costly design. UFAD systems should also not be applied in laboratories because of its critical room-pressurization requirements and the potential migration of chemicals into the occupants' breathing zone as a result of their thermal plume formation.