



A Review on Airflow and Temperature Distribution in A Residential Building with an under Floor Air Distribution System

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ABSTRACT

This paper presents the investigation to evaluate an under floor air distribution (UFAD) system existed in a Residential building. Despite the fact that UFAD systems are being applied in the field in increasing numbers, there is a strong need for an improved fundamental understanding of several key performance features of these systems. Recent trends in today's Residential environment make it increasingly more difficult for conventional centralized systems to satisfy the environmental preferences of individual persons using the standardized approach of providing a single uniform thermal and ventilation environment. Under floor 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 under floor 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 is one of the featured characteristic of UFAD system, which allows higher thermostat set points compared to the traditional overhead systems (OH). CFD models have been used to study indoor air quality (IAQ) problems, pollutant distributions, and performance of UFAD systems. The increasing developments of computational fluid dynamics (CFD) in the recent years have opened the possibilities of a low-cost, yet effective, method for improving UFAD systems in design phase, with less experiment required.

Keywords: Under Floor Air Distribution System, CFD, Experimental, Simulation, Residential Building.

I. INTRODUCTION

Under floor 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 [1]. UFAD systems use the under floor plenum beneath a raised floor to provide conditioned air through floor diffusers directly to the occupied zone. Under floor air distribution is frequently used in office buildings, particularly highly-reconfigurable and open plan offices where raised floors .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. The ASHRAE Under floor Air Distribution Design Guide suggests that any building considering a raised floor for cable distribution should consider UFAD. (Airports, Industries, public complexes, recreation, laboratories, etc...)[2].

In recent years HVAC system design has been strongly influenced by increasing emphasis on indoor air quality (IAQ), energy conservation, environmental effects, safety, and economics. The relative placement of system components can significantly affect the thermal comfort and energy performance of the air handling system [3]. To design high-energy efficiency HVAC systems, it is necessary to gather the detailed information about the behavior of the airflow in both the spaces and the rooms of the building. The fundamental information concerning the flow

comprises air velocity, temperature, relative humidity, and species concentrations. All these parameters are important in assessing thermal comfort and indoor air quality. The conventional design of ventilation systems normally relies on valuable know-how, empirical formulas and past experience. Although practical knowledge and basic methods provide successful solutions, this type of engineering cannot take into account specific air flow patterns which are affected not only by the positioning of openings and exhausts in a room, but by the distribution of objects and energy sources as well. Consequences related to the absence of these elements include over-design and unnecessary cost [4].

1.1 Technology Description

A task/ambient conditioning system is defined as any space conditioning system that allows thermal conditions in small, localized zones (e.g., regularly occupied work locations) to be individually controlled by building occupants, while still automatically maintaining acceptable environmental conditions in the ambient space of the building (e.g., corridors, open-use space, and other areas outside of regularly occupied work space)[5].

UFAD systems are uniquely characterized by their ability to allow individuals to have some degree of control over their local environment, without adversely affecting that of other nearby occupants.

The types of diffusers supported, active or passive, further distinguish UFAD systems. Active diffusers (for purposes of this report) are defined as those with local means of volume adjustment (such as an integral variable speed fan or that is amenable to automatic zone control (in addition to means for occupant control)). Passive diffusers, although they may have means for occupant adjustment, are combined with terminal or system elements to achieve zone control. Systems designed with all fan-assisted active diffusers typically utilize zero-pressure plenums. Passive diffusers require pressurized plenums. The majority of UFAD systems currently being deployed have pressurized plenums with either active or passive diffusers [6].

1.2 System Overview

For purposes of introducing the concept of an under floor air distribution system, it is instructive to identify how these systems differ from conventional ceiling-based air distribution systems. Figures 1 and 2 show schematic diagrams of an overhead system and an UFAD system, respectively, for a cooling application in an open-plan office building [7]. Some of the most important advantages of under floor systems over ceiling-based systems occur for cooling conditions, which are required year-round in the vast majority of interior office space in many parts of the United States.

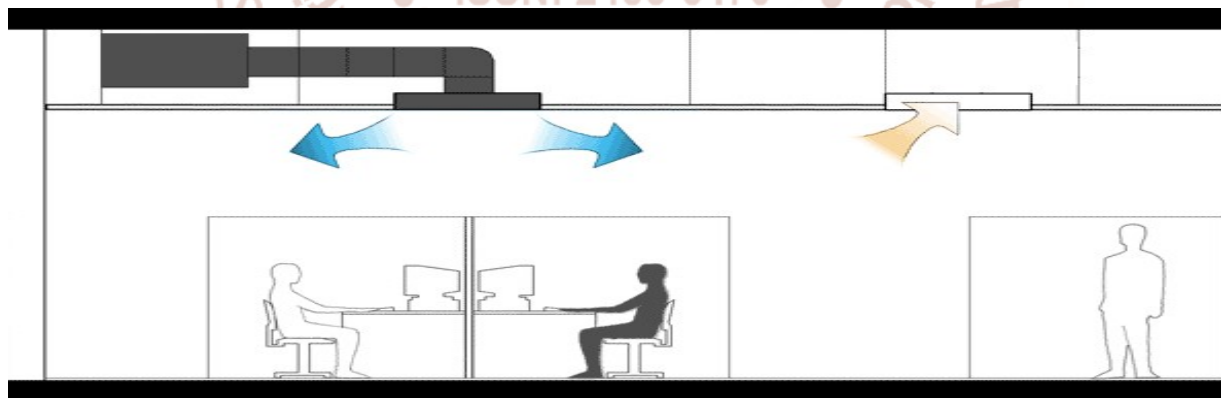


Figure 1

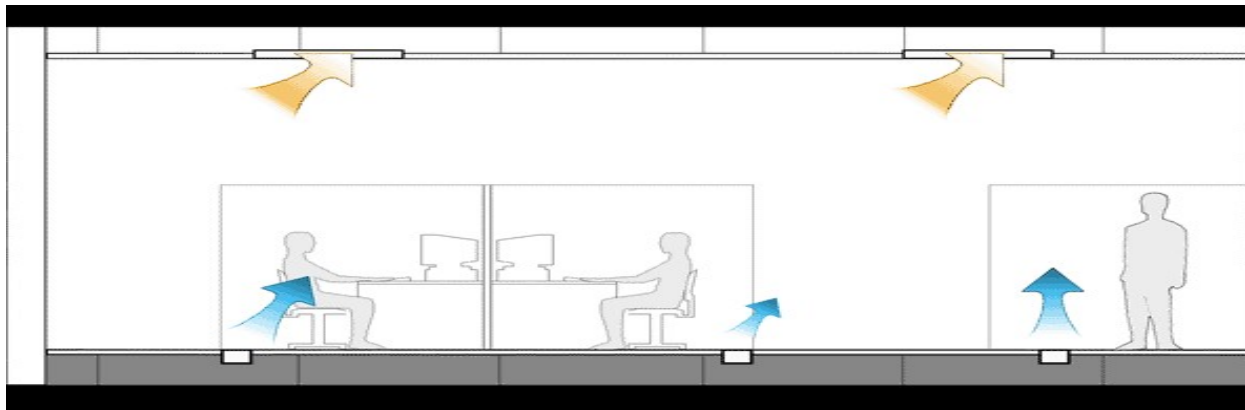


Figure 2

Research evidence is mounting that occupant satisfaction and productivity can be increased by giving individuals greater control over their local environment.

II. LITERATURE REVIEW

Over the past few decades, there were many studies on the CFD analysis and numerical simulations on the indoor environment. According to the previous literature survey, it can be found that the numerical simulation of the UFAD systems mainly focus on the following topics:

- Air buoyancy flow in the room.
- The turbulence model.
- Typical laminar flow in clean rooms Diffuser.
- Air flow simulations in a ventilated room.
- Studies on distribution of contaminants within different HVAC systems.
- General issues on simulations of internal fluid flow and heat transfer inside a room.

CFD models have been used to study indoor air quality (IAQ) problems, pollutant distributions, and performance of UFAD systems (Chow and Fung (2016), Emmerich (2017), Gadgil et al. (2015)). Juan et al. (2013) showed a computational fluid dynamics model on the real environment of computer room. In their study, the geometric model was created using the parametric features of the pre-processor Gambit, in combination with elements created with the Rhinoceros NURBS modeling tool. Joseph et al. (2012) numerically investigated the temperature distribution and air movement within an air-conditioned gymnasium with four different, but

commonly found, exhaust positions in Hong Kong. Hirnikel et al. (2010) investigated contaminant removal effectiveness of three air distribution systems for a bar/restaurant by using CFD modeling. They showed that directional airflow systems could reduce people's exposure to contaminants. Thermal comfort can be predicted based on Fanger's PMV model (2007), which assumes a uniform thermal environment. Based on Rohles and Nevins' work (2006), a thermal sensation index is also widely used for assessing thermal comfort. Relative humidity can be computed by using the procedure recommended in ASHRAE (1997). Son et al. (2005) gives a detailed numerical simulation of thermal comfort and contaminant transport in air conditioned rooms. However, their results are limited to two-dimensional geometry, and the real environment is simplified into regular geometry. Recently, underfloor air distribution (UFAD) systems have become popular design alternatives to conventional air distribution (CAD), such as overhead air distribution systems for thermal and ventilation control (Woods 2004, Webster et al. 2002). This system was first introduced in the 1950s to cool a computer room, and is emerging as a leading ventilation system design in modern commercial buildings. According to Loudermilk (1999), there exist two major advantages of this system. One is that ventilation cool air is certain to reach the occupants (as it is introduced within the occupied zone). Another is that convection heat gains that occur above the occupied zone are isolated from the calculation of the required space supply airflow. The potential advantages of a well-designed UFAD system include (1) improved thermal comfort; (2) improved ventilation efficiency and indoor air quality; (3) reduced energy use; and (4) reduced floor-to-floor height in new constructions. According to Bauman and Webster (2001), there is a higher risk to designers and building owners due to a lack of objective

information and standardized design guidelines. Woods (2004) did a literature review, searches, and field investigations to assess the actual performance of UFAD system in the real world. He showed that there are gaps in available data: valid and reliable field data are not from a sufficient population of existing facilities to conclude that an under floor system's performance is superior to an overhead system; and that designers must be made aware that under floor as well as overhead systems require more care in design, installation, and operations. He also recommended that objective analysis should be made before choosing an HVAC system. Webster et al. (2002) presented a series of full-scale laboratory experiments to determine room air stratification for a variety of design and operating parameters. Fukao et al. (2002) carried out comparative field measurements for both systems in an actual large-scale office building. Webster et al. (2002) presented a study about a building that operated with an UFAD system. They showed little troubleshooting with the system operation, pointing out the positive aspects of using well-designed UFAD systems. Bauman (2001) offered a work presenting a discussion about several advantages shown by the UFAD systems. In the design stage, CFD simulation can play an important role in improving the understanding of any particular system. Ahmed Cherif Megri et al. (2014) demonstrate the use of Computational Fluid Dynamic (CFD) in building applications. In particular, CFD has been used for temperature and airflow predictions of building spaces conditioned using Under Floor Air Distribution (UFAD) System. The space used is an instrumented laboratory room (old daycare center) located at the University of Wyoming.

III. CONCLUSIONS

Ever since global warming became a worldwide environmental concern, scientists have worked hard on finding alternative sources of energy other than fossil fuel, which is the main source of carbon dioxide emissions that causes the global warming. At the same time, other scientists are working seriously on minimizing the amount of consumption of fossil fuel until it is totally replaced by an environment friendly type of fuel.

All of the previous research achievements also show that the increasing developments of computational fluid dynamics (CFD) in the recent years have opened the possibilities of low-cost yet effective methods for

improving UFAD systems in design phase, with less experiment required.

Based on the literature review, the following conclusions were drawn for the modifications to the Throw Room and planned experiments:

- CFD models have been used to study indoor air quality (IAQ) problems, pollutant distributions, and performance of UFAD systems.
- The increasing developments of computational fluid dynamics (CFD) in the recent years have opened the possibilities of a low-cost, yet effective, method for improving UFAD systems in design phase, with less experiment required.
- Lack of data on CFD model on the UFAD system.
- Lack of understanding how UFAD systems work in the real world.
- Improved ventilation efficiency and indoor air quality.
- Improved occupant comfort, productivity and health.
- Reduced energy use.

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