Precision Ventilation in Open Plan offices – A study of Variable Jet Interaction between Active Chilled Beams





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Abstract: The objective of this study is to utilize a conventional Active Chilled Beam (ACB) equipped with JetCones, enabling a versatile air pattern in various directions and airflow distributions spanning 360 degrees. This approach aims to attain individualized thermal comfort while upholding a stable room temperature. Multiple ACBs are employed to establish adjustable air velocity zones, thereby ensuring occupants with varying thermal comfort requirements experience acceptable levels of comfort. By implementing Precision Ventilation and slightly elevated cooling setpoint temperatures, energy use is decreased by 15%. This comprehensive approach not only improves individual comfort but also enhances energy efficiency in open-plan offices.

1. Introduction

Optimal thermal comfort significantly impacts the well-being and productivity of office occupants [1, 2]. In open-plan offices, the need for individualized control over environmental factors, such as air velocity and temperature, is frequently emphasized [3, 4].

Thermal comfort results from the interplay of personal and environmental factors. Personal factors include variables like metabolic rates (such as muscle mass, diet, health, age, gender, and activity) as well as clothing insulation, while environmental factors encompass air speed, air temperature, radiant temperature, and humidity [5]. Environmental factors wield substantial influence over personal factors, ultimately determining the comfort or discomfort experienced by office occupants [6]. Following the ISO 7730 Standard, a seated office occupant typically sustains a metabolic rate (MET) of 1.2 MET [7], yet this metric can fluctuate based on personal factors [8, 9].

Conventional mixing ventilation systems fall short of achieving personalized thermal comfort, as uniform conditions fail to satisfy individual requirements. This holds true even for traditional ACB systems lacking JetCones, as they mix cold supply air with warmer room air to achieve thermal consistency [10]. Precision Ventilation builds upon the foundation of a conventional mixing ventilation system. However, it innovatively introduces adjustable air patterns in various directions, thereby crafting an environment of personalized thermal comfort.

In contrast, over the past two decades, traditional personalized ventilation systems have been employed within office settings to establish micro-climates around workstations. These systems utilize various Air Terminal Devices to control airflow rates, directions, and temperatures, resulting in localized thermal comfort conditions and substantial energy conservation [11-13]. Some studies have even utilized more than five Air Terminal Devices around a single workstation to ensure precise localized thermal comfort [14, 15]. By elevating the cooling setpoint temperature of the room to as high as 30°C, traditional personalized ventilation systems have exhibited remarkable energy savings, reaching up to 60% [16-18]. While these systems indeed offer significant energy benefits, their implementation necessitates the incorporation of multiple dimensionally modified Air Terminal Devices to establish micro-climates around office workstations [19].

To address the complexity associated with multiple Air Terminal Devices, a modified ventilation strategy is required, one that can establish micro-climate zones without necessitating alterations to the existing office layout. Precision Ventilation [20, 21] emerges as a technique tailored to meet the specific thermal comfort needs of occupants in open-plan offices. This method entails the strategic positioning of high or low-velocity supply jets, effectively creating distinct air velocity zones within the communal office area. Through the integration of JetCones in ACBs, airflow regulation becomes feasible, enabling personalized airflow distribution in alignment with the relevant metabolic rates for each designated zone [22].

Thermal Comfort

Air velocity is one of the most crucial controllable parameters that influence the convective heat transfer between the human body and the surrounding environment [23, 24]. Among building designers, the energy demand perspective has changed and has resulted in an increase in the temperature setpoint to certain degrees [25]. This has left users to increase the room air velocities to compensate for warm room temperatures. This shift of negative discomfort caused by draught to the positive benefits of achieving acceptable thermal comfort by raising air velocities in warm indoor climates has been achieved in various studies as shown in **Table 1**.

As per the EN ISO 7730 Standard [32], a connection exists between air velocities and elevated air temperatures to attain a satisfactory comfort level for occupants, see **Figure 1**.

2. Methodology

The experiments involved ACBs equipped with JetCones, designed to effectively manage airflow in various directions through the use of adjustable regulators, as illustrated in **Figure 2**. The inherent JetCone functionality integrated into the ACBs offers a versatile means of altering supply airflow patterns. The adjustment regulators are marked with numbers ranging from 0 to 9. Each ACB's JetCones can be managed using four adjustment regulators, with the highest airflow achieved when JetCones are positioned at 9 and the lowest airflow at 0, see **Figure 3**. This Precision Ventilation is attained by maintaining a consistent total airflow from the system, all the while creating zones of varying air velocity through the adjustment of JetCones. These JetCones can be fine-tuned either manually or continuously through actuators, rendering Precision Ventilation a fully operational Demand Controlled Ventilation (DCV) System.

Experiments were carried out utilizing varying quantities of ACBs to define distinct air velocity zones tailored to the specific metabolic requirements of occupants. The air temperature emitted by the ACB is cooler by 3.5°C compared to the ambient room temperature, indicative of a heat load approximately around 25 W/m².

***Table 1.** Studies with elevated air temperatures and air velocities.*

References	Air velocity limit	Room temperature limit
[26]	1 m/s	29°C
[27]	1 m/s	28°C
[12]	1.4 m/s	29°C
[28-30]	1 – 1.5 m/s	Up to 31°C
[31]	1.6 m/s	31°C

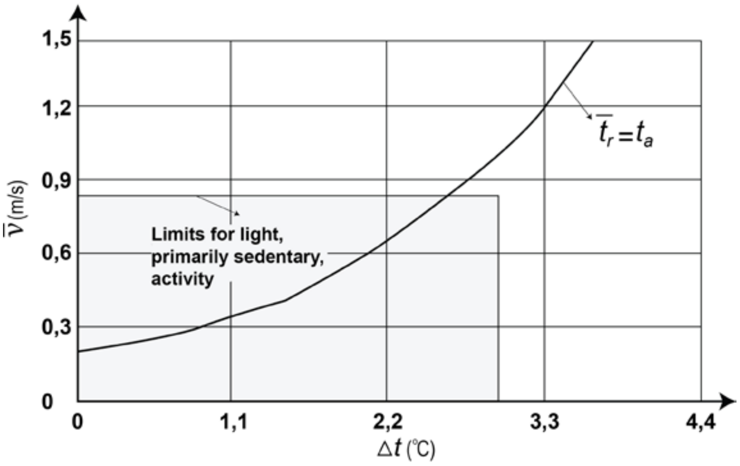


Figure 1. Air velocities required for a temperature rise above 26°C. [7, 32]

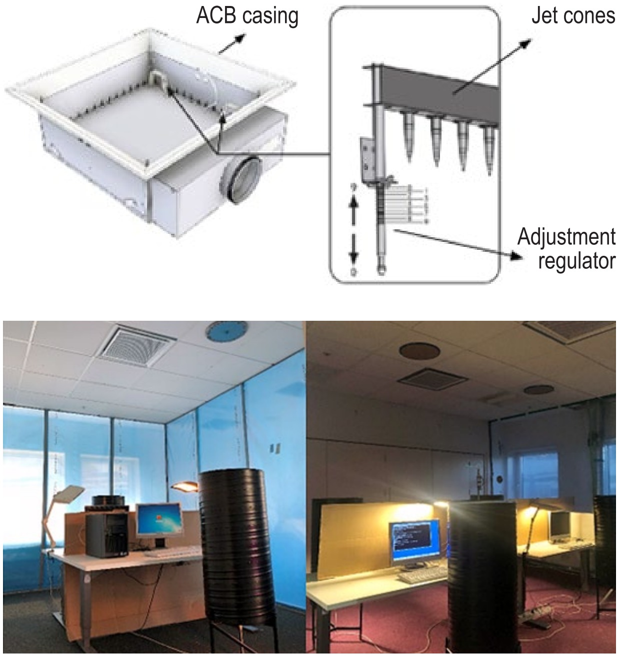


Figure 2. Experimental setup.

The test room's geometry was replicated in SolidWorks 2020 software, mirroring the exact dimensions of the real setup, as depicted in **Figure 4**. The simulated ACB geometry took on a circular form and was partitioned into 16 segments, resulting in radial airflow emanating from the ACB. The air velocities at 16 specific points on the ACB inlets, measured through experimentation, were applied as inlet air velocities for the radial ACB configuration, as illustrated in **Figure 4**. To ensure greater accuracy in dealing with mixed conventional airflows and enhance robustness, the RNG k-ε turbulence model was selected for the numerical simulations, following a successful grid independence test [33].

3. Results

Colliding Jets

In Precision Ventilation, colliding jets are harnessed to establish distinct air velocity zones within open-plan offices, eliminating the necessity for partitions between individual workstations. When these jets collide, a downstream airflow is generated, which is subsequently employed to induce varying air speeds across different regions within the room. The intensity of the jet and the temperature of the supplied air contribute to a stronger downward airflow, resulting in elevated vertical air velocities.

Colliding jets with air velocities of 0.8 m/s and 0.6 m/s, respectively, are directed towards zones with metabolic rates of 1.6 MET and 1.4 MET. These colliding jets established different air velocity zones for different metabolic rate occupants to keep PMV-PPD values within acceptable limits [32].

Variable Air Velocity Zones

Air velocities in the occupied zone were measured at 0.1 m and 1.1 m from the floor. **Figure 5** shows the formation of air velocity zones suitable for occupants with different metabolic rates. The results illustrate four cases as an example of the studied Precision Ventilation technology.

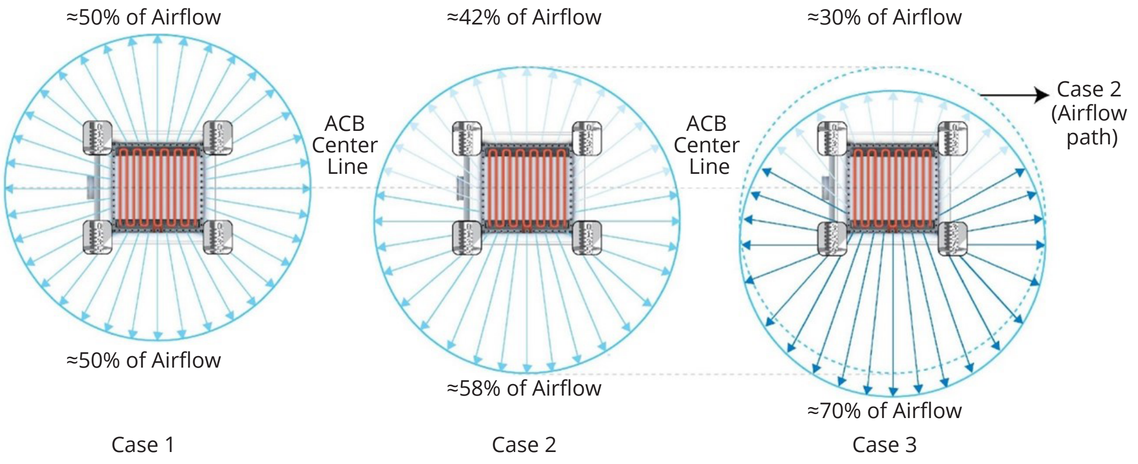


Figure 3. Air pattern out of the ACB.

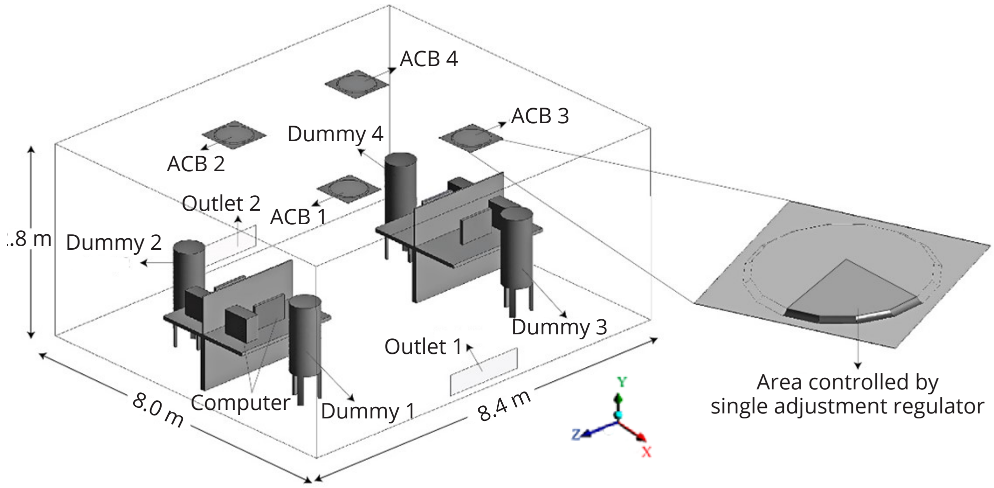
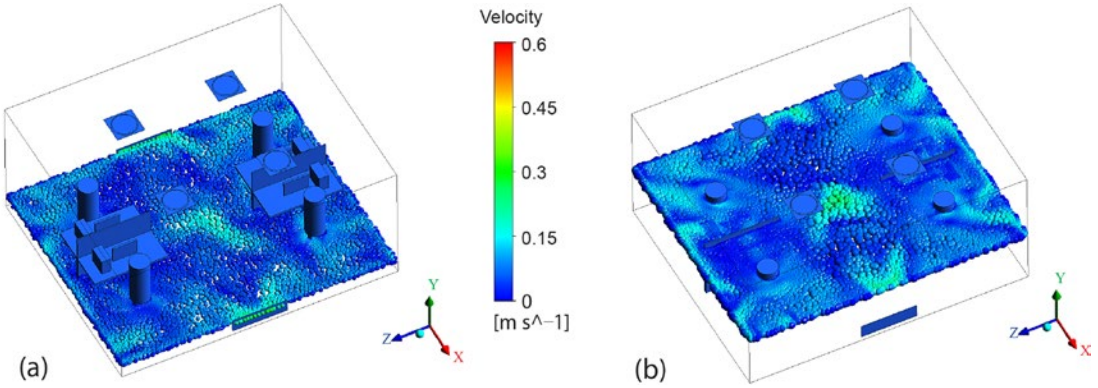
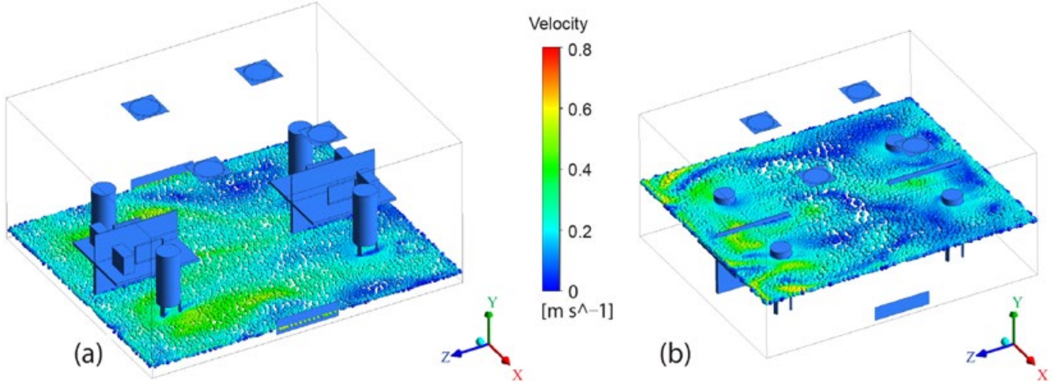


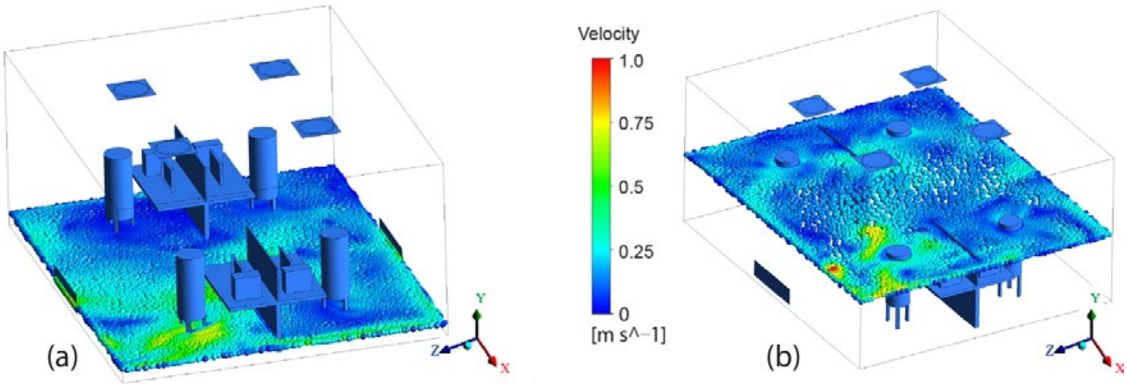
Figure 4. CFD Geometry.



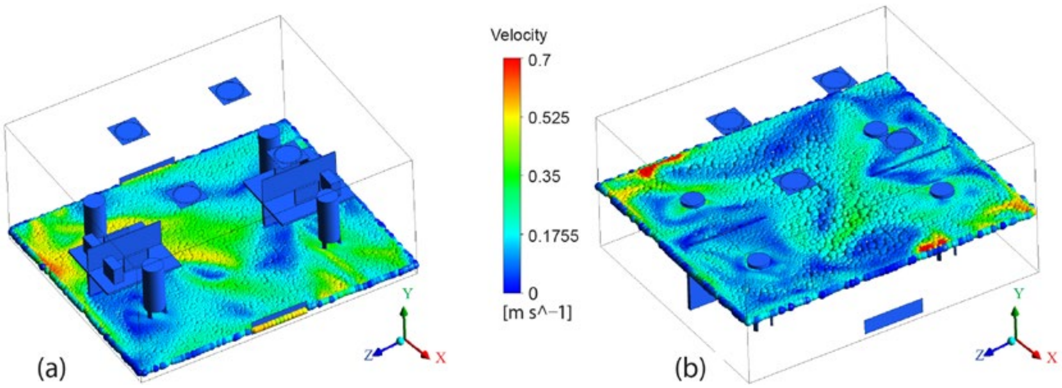
Case 1: Conventional mixing ventilation with uniform air velocity distribution (0.15 m/s).



Case 2: Air velocity distribution (0.45 m/s) for two 1.4 MET occupants in Z-direction and air velocity distribution (0.15 m/s) for two 1.2 MET occupants in the other direction.



Case 3: Air velocity distribution (0.65 m/s) for a single 1.6 MET occupant in the ZX-direction and air velocity distribution (0.15 m/s) for three 1.2 MET occupants in the other directions.



Case 4: Air velocity distribution (0.65 m/s) for a single 1.6 MET occupant in the Z (-X)-direction, air velocity distribution (0.45 m/s) for a single 1.4 MET occupant in X (-Z)-direction and air velocity distribution (0.15 m/s) for two 1.2 MET in the other directions.

Figure 5. Variable air velocity Case 1, Case 2, Case 3, and Case 4. a=0.51 m above floor, b=1.1 m above floor.

Energy Savings

By using precision ventilation during the cooling period, the annual energy savings from heating and cooling were 15% and this was achieved by raising the cooling setpoint by 2°C.

4. Conclusions

The following conclusions can be drawn from the above experimental and simulation study:

1. Precision ventilation can be based on a conventional mixed ventilation system using ACBs.
2. Precision ventilation can act as a new potential ventilation strategy to make the office environment more comfortable and productive for all office occupants.
3. JetCones instead of conventional nozzles brings a novelty in the application of ACBs, which simultaneously achieved low, medium and high-level air velocity zones in a shared office space.
4. The variation in local air velocities with respect to occupants' metabolic rate and room air temperature significantly improved their thermal comfort.
5. Even the occupants with normal metabolic rates, seated together with occupants with higher metabolic rates that were seated in higher air velocity zones remained unaffected and were satisfied.
6. The annual energy savings of 15% were achieved by raising the cooling setpoint by 2°C. ■

References

Please find the complete list of references in the html-version at https://www.rehva.eu/rehva-journal

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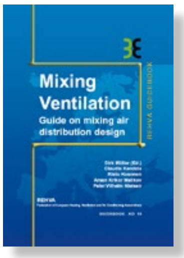
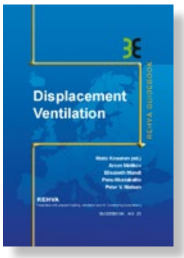
GUIDEBOOK 11 – The scope of Guidebook is to increase the awareness of the role of air filtration in improving indoor air quality. It will help designers and users to understand the background and criteria for air filtration, how to select air filters and avoid problems associated with hygiene and other considerations in the operation of air filters. The Guidebook is mainly applicable to air filters in general ventilation systems. Parts of it may also be applied to any kind of forced ventilation or when air filters are used as a part of a ventilation system in critical applications to protect people, products or the environment.



GUIDEBOOK 19 – In this Guidebook most of the known and used in practice methods for achieving mixing air distribution are discussed. Mixing ventilation has been applied to many different spaces providing fresh air and thermal comfort to the occupants. Today, a design engineer can choose from large selection of air diffusers and exhaust openings.



GUIDEBOOK 23 – The aim of this Guidebook is to give the state-of-the art knowledge of the displacement ventilation technology, and to simplify and improve the practical design procedure. The Guidebook discusses methods of total volume ventilation by mixing ventilation and displacement ventilation and it gives insights of the performance of the displacement ventilation. It also shows practical case studies in some typical applications and the latest research findings to create good local micro-climatic conditions.

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