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Toward Individual Thermal Comfort and Energy Saving in Open Plan Offices with Chilled Beams

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Cooling demand in commercial buildings is projected to triple by 2050, intensifying the dual challenge of maintaining energy efficiency and ensuring occupant comfort. In open-plan offices, where diverse occupant preferences coexist within shared environments, conventional ventilation systems such as mixed ventilation or displacement ventilation often fail to provide individualized comfort . Recent advances in chilled beam technology, coupled with Precision Ventilation principles to create different air velocity zones, offer a promising alternative. By enabling localized control of air distribution and temperature, these systems can dynamically adapt to varying thermal needs while minimizing energy use. Precision-controlled active Chilled Beams—using adjustable JetCones and sensor-driven control—have demonstrated the ability to create micro-climates for occupants with different metabolic rates while maintaining acceptable PMV and low draught risk, and to raise cooling setpoints without comfort loss (Latif, 2023).

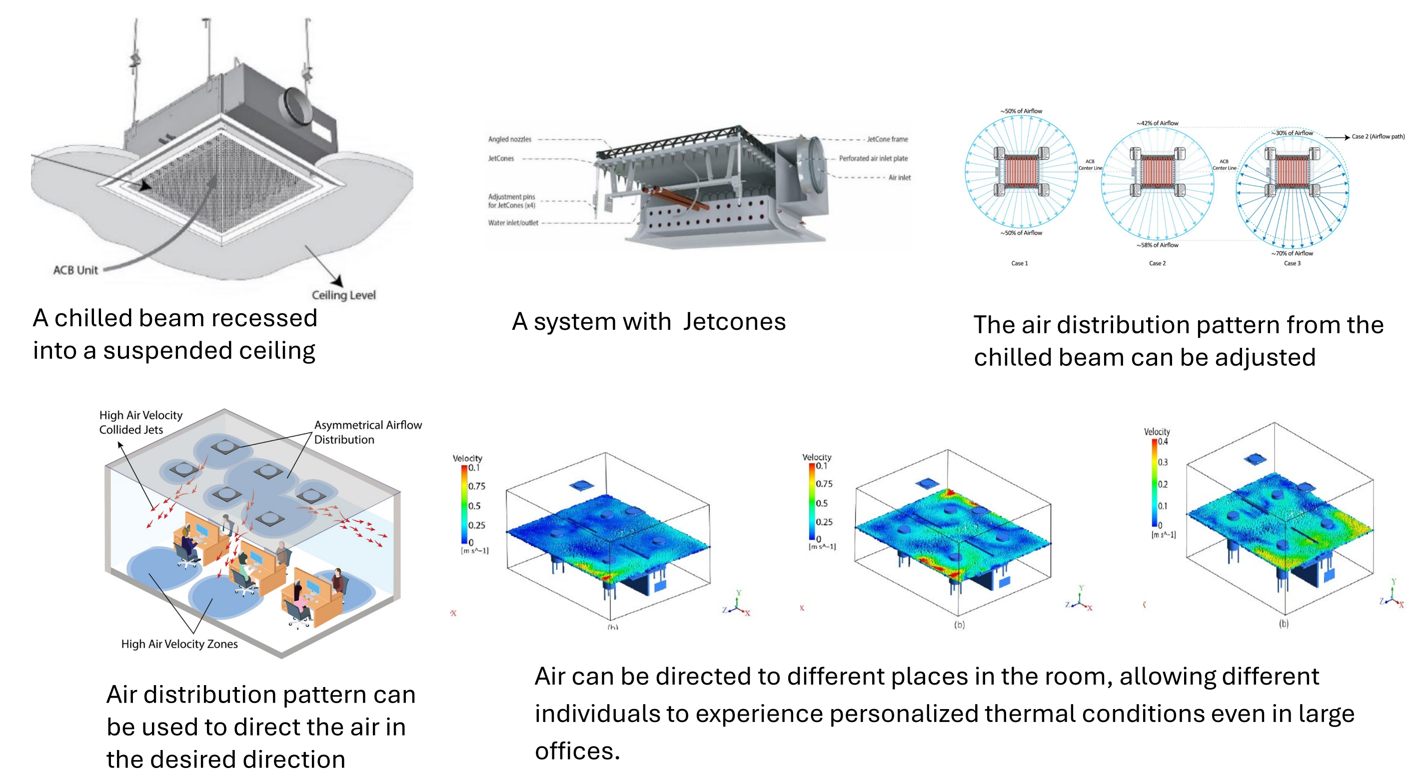

Figure 1. Principle of Precision Ventilation.

Mixed ventilation is currently the most common ventilation principle. The reason for this is that all air can be supplied from the ceiling of the room, without requiring additional ventilation installations that could interfere with the architectural design of the space. Another advantage of this system is its simplicity in both the design and construction phases.

The present article introduces a novel ventilation system so called "Precision Ventilation". The Precision Ventilation system is based on conventional mixed ventilation principles but Chilled Beams /Diffusers are able to supply the air in different directions.

A mixed ventilation system creates an evenly distributed indoor climate for everyone working in a large office. However, different individuals have varying cooling and heating needs that may not be met. Cooling and heating requirements depend on heat transfer from the body, which is mainly determined by the temperature and air speed in the room. To satisfy individuals with lower cooling needs, a higher room temperature or a lower airspeed is necessary. It is desirable to have a higher room temperature, so people with lower cooling needs can be positioned in areas with lower airspeeds, especially during summer when clothing tends to be lighter than in winter. Meanwhile, individuals with higher cooling needs require a certain air speed to compensate for the higher temperature.

Figure 1 illustrates how a smart Chilled Beam can vary both airflow and distribution pattern by moving regulating pins up and down to adjust the outlet area of each nozzle. This movement can be done manually or being controlled by four actuators, one in each corner of the Chilled Beam. The actuators can operate independently, allowing the regulating plate to tilt and direct different amounts of air to different sides.

The Chilled Beam can be controlled by separate sensors, becoming a self-regulating unit that measures the room's air properties, detects presence and absence, and monitors the current airflow. This means that if any part of the ventilation system is modified, all other Diffusers will automatically adjust to the new conditions, eliminating the need for recalibration when changes are made to the building. This ensures a flexible and Precise Ventilation system.

Research conducted at Aalborg University demonstrates how Precision Ventilation provides individualized comfort for people in an open-plan office environment. The results show that satisfactory personal comfort can be achieved while reducing energy consumption by up to 60% during the cooling season by increasing the room's air temperature by 2-3 degrees. Precision Ventilation can in some cases create a satisfactory indoor climate using outdoor air, without the need for a chiller.

The tests were conducted using Chilled Beams, while simulations transferred the boundary conditions of the Chilled Beams to a Diffuser. In other words, the simulations were performed and validated for smart Diffusers (Latif, 2023). The use of Precision Ventilation can be done either Chilled Beam or smart Diffusers.

Air velocities in the occupied zone were measured at 0.1 m and 1.1 m from the floor. Figure 1 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 1 shows a Chilled Beam recessed into a suspended ceiling. This Chilled Beam has the ability to distribute air throughout the room in 360 degrees. Inside the Chilled Beam, there is a system with so-called Jetcones, which can be moved up and down within the nozzles where the supply air is accelerated to create the induction that causes room air to pass through the cooling coil and be cooled.

By moving the Jetcones up and down inside the nozzle, the open area—and thereby also the amount of air discharged from the nozzles—can be varied. The movement is carried out at four independent points. The result is that the air distribution pattern from the Chilled Beam can be adjusted so that one direction receives a larger air volume and thus a higher air velocity, while another direction receives a smaller air volume and lower air velocity. The total air volume from the Chilled Beam can also be adjusted.

In the cooling mode, with supply air at a lower temperature than the room air, the variable air distribution pattern can be used to direct the air in the desired direction. Two Chilled Beams can also be made to interact so that their air jets collide and descend into the room at a desired location. Measurements and CFD simulations show how the air can be directed to different places in the room, allowing different individuals to experience personalized thermal conditions even in large offices.

The evolution from traditional mixed ventilation toward precision-controlled Chilled Beam systems marks a significant transformation in the philosophy of indoor climate design. Conventional mixed ventilation has long been favored for its simplicity, cost-effectiveness, and compatibility with architectural layouts. However, its inherent uniformity overlooks the diverse thermal preferences and metabolic differences among occupants—an issue particularly pronounced in open-plan offices. Precision Ventilation, realized through smart Chilled Beams and advanced Diffuser designs, introduces an adaptive, occupant-centric approach. This shift from space conditioning to individual conditioning represents a critical advancement in reconciling comfort diversity with energy efficiency targets, aligning with the broader goals of carbon neutrality and sustainable building operation.

The implications for energy use are profound. Experimental and numerical studies at Aalborg University have demonstrated that precision-controlled Chilled Beams can maintain high comfort levels while allowing the room temperature to increase by 2–3 °C during cooling operation, leading to up to 60% energy savings for cooling compared with conventional systems (Latif, 2023). By dynamically adjusting air velocity and flow direction based on sensor feedback, these systems create localized microclimates tailored to occupants' needs, all while reducing overall cooling load. When integrated with predictive algorithms and real-time data from occupancy and environmental sensors, Precision Ventilation can operate proactively, minimizing energy use during low-demand periods and maximizing comfort during occupancy peaks.

Despite these advances, several challenges remain before widespread adoption can occur. Integrating sensor networks, actuator controls, and building automation software requires robust interoperability between HVAC, lighting, and monitoring systems. Moreover, retrofitting existing offices with Chilled Beams or smart Diffusers entails financial and logistical considerations that must be addressed through comprehensive life-cycle assessments and standardized performance metrics. Long-term field studies are also needed to quantify user satisfaction, system reliability, and maintenance costs under real operating conditions.

Future research should explore the potential of Precision Ventilation for heating applications, particularly by directing supply air toward cold surfaces or zones during winter to improve thermal balance and occupant comfort. This bidirectional use of the system would allow Chilled Beams and smart Diffusers to serve as all-season climate solutions, optimizing both heating and cooling efficiency. On a regulatory level, the development of comprehensive design guidelines, control algorithms, and performance standards will be essential to ensure consistent implementation across diverse building types. Ultimately, Precision Ventilation represents a pivotal step toward intelligent, low-exergy workplaces that seamlessly integrate technology, comfort, and sustainability—bringing the vision of adaptive, energy-resilient indoor environments for future buildings closer to reality.

Precision Ventilation represents a major step toward reconciling energy efficiency with individualized thermal comfort in open-plan offices. By enabling adaptive air distribution and temperature control, such systems transform traditional HVAC design from uniform conditioning to responsive, occupant-centric operation. Research at Aalborg University has demonstrated that these systems can reduce cooling energy use by up to 60% while improving thermal satisfaction. Yet, large-scale implementation requires new design standards, interoperability protocols, and long-term field validation. Future integration with predictive control, renewable energy sources, and digital twin models could further enhance system intelligence and resilience. As the global building sector advances toward net-zero targets, precision-controlled Chilled Beams exemplify how technological innovation and human-centered design can jointly shape the next generation of sustainable indoor environments.

REFERENCES

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DECLARATION OF INTERESTS

The authors declare no competing interests.