

# Air Distribution from an Ergonomic Prospective-Delivering Air to People or to Rooms?

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## Mini Review

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## Introduction

Conventional total-volume ventilation theory treats the air in a room as well-mixed. Therefore, to limit the concentrations of contaminants generated in a room, fresh air must be supplied to the room to dilute the contaminants [1]. Because of the so-believed mechanism of dilution, air distribution, i.e., the path of air entering, flowing and leaving the room is of less interest. Under most circumstances, for the conveniences of design and construction, both air supply and exhaust terminals (inlets and outlets) are positioned on the ceiling. Because of the Coandă effect, air short-circuiting between the inlets and outlets often happens. The so-called dilution effect may not be as effective as it would have been expected. In other words, the ventilation efficiencies could be significantly/substantially lower than the predictions. The purpose of control contaminant levels is for the people. The focus should be the air they inhaled, i.e., the indoor air quality in the breathing zone instead of elsewhere in the room.

On the other hand, for a sedentary person, the metabolic heat is mainly generated from the upper body, the head in particular. The conventional total volume ventilation largely bypasses the people in the room resulting in ineffective metabolic heat removal, which could lead to thermal discomfort. Gallup and Hack [2] pointed out that "Brains, like computers, operate best when they are cool." Williams and Chambers [3] worked on removal of metabolic heat by using only local neck cooling in an area superficial to the carotid arteries to determine subjective feelings of thermal comfort. Brown and Williams [4] found that the stabilization of deep body temperature was associated

with an improvement in both head and body thermal comfort. Nunneley, et al. [5] reported that the head was a major determinant of subjective comfort. Possible mechanisms include 1) counter-current exchanges in the neck, and 2) change in sensory output. Supported by the data collected, Cohen, et al. [6] showed the effectiveness of head or neck cooling in increasing subject comfort. Nakamura, et al. [7] revealed that during mild heat exposure, facial cooling was the most comfortable. Human subject tests conducted by Zhang [8] and by Arens, et al. [9] showed that to cool head is the most effective way to maintain people's comfort in warm conditions.

The conventional total volume ventilation is inefficient, in terms of both thermal comfort and indoor air quality [10], because (1) The entire space, including the unoccupied volume is ventilated; (2) Large airflow rate is needed to vent the space, which implies much energy, big systems, and high cost; (3) The contaminants are transported from the unoccupied volume into the occupied zone, i.e., people do not breath clean air because the air supply is far above and away; and (4) The ventilation systems are slow in response and the occupants have very limited control.

The ventilation technology of the next generation should be able to provide:

1. Healthy, comfortable and work stimulating environment (not just one of these elements),
2. Best possible environment for each and every person,
3. Reduction in energy consumption,
4. Increased flexibility in space use, and

5. Reduction of heating, ventilating and air conditioning system size and cost.

These cannot be achieved with the present approach of total volume indoor environment design. Therefore, paradigm shift is needed from the total volume air distribution, which delivers clean and cool air to nobody, to the advanced air distribution, which supplies clean and cool air to everybody. The people in the room must be in the center of the technological development.

People at different locations in a room often require different microclimates. These requirements have not been well satisfied by the conventional ventilation. What really needed is to determine the optimal airflow pattern and supply parameters to meet the requirements. As an effort to solve this problem, advanced air distribution optimizes air supply parameters under a given flow pattern. This new technology determines the optimal supply parameters to meet different parameter requirements in multiple locations and optimizes the supply boundary conditions for accommodating individual preferences.

One solution is task/personalized ventilation, which supplies air through a nozzle located near each and every user, normally at head level. The user can adjust the amount of the supply air. Therefore, this system creates a microclimate desired by the user. As far as the indoor air quality of the breathing zone and personal microclimate are concerned, task/personalized ventilation is the most effective. Nevertheless, it is often difficult to install nozzles and to connect ducts to the vicinity of each and every user in indoor spaces. On the other hand, some people in certain spaces are mobile, e.g., the situation in retail shops.

Another solution is stratum ventilation, whereof air is delivered at head level. A horizontal air layer is formed. Compared with the conventional total-volume ventilation, a greater amount of fresh air enters the breathing zone; the age of the air there is therefore younger. Stratum ventilation has unique airflow characteristics: (1) The typical level of turbulence intensity at the head level is measured at 30% - 70% with around 50% on average, which is helpful for people to feel air movement with low draft risk. (2) The highest velocity and lowest temperature are "sandwiched" at the head level of the users in rooms. At the head level, the power spectrum density of stratum ventilation is significant higher than that of the conventional ventilation. The human body forms a local blocking effect, but the horizontal supply airflow can flow over and around it to reach the back rows. With the body heat from the occupants, the supply air jet penetrates farther [11].

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