Thermal characteristics of a partition air supply system at a personal task area

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ABSTRACT
A partition integrated air supply system can provide highly personalized environmental control. The supply air is brought up through raised floors and supplied to outlets located on the partition panels. The purpose of this paper is to find the best design of outlets for optimal occupant comfort within a personal task area.

Real-scale experiments were conducted to allow for comparisons of outlet designs within a personal task area. Experimental results indicate that the location of an outlet is the most critical factor in improving the efficiency of supply air distribution of a personal task area. Thermal characteristic comparisons were made between the under-floor and the partition supply systems. Experimental results suggest that the partition supply system is more efficient than the under-floor supply system in terms of cooling. Such a system allows occupants to personally control their immediate environment, resulting in higher productivity.

INDEX TERMS
Thermal comfort; Air distribution; HVAC system

INTRODUCTION
Conventional HVAC systems of large office buildings supply air from the ceiling. This results in the inability to adjust the volume and direction of the supplied air according to the individual needs of the occupants. Another issue is the inability to remove excess heat generated from office equipment near an occupant's personal task area. Ironically, the environmental controls in an automobile are far superior to those in a building. Although people generally spend 1–2 h per day inside an automobile, these occupants have the ability to control the volume, the direction and the temperature of supplied air.

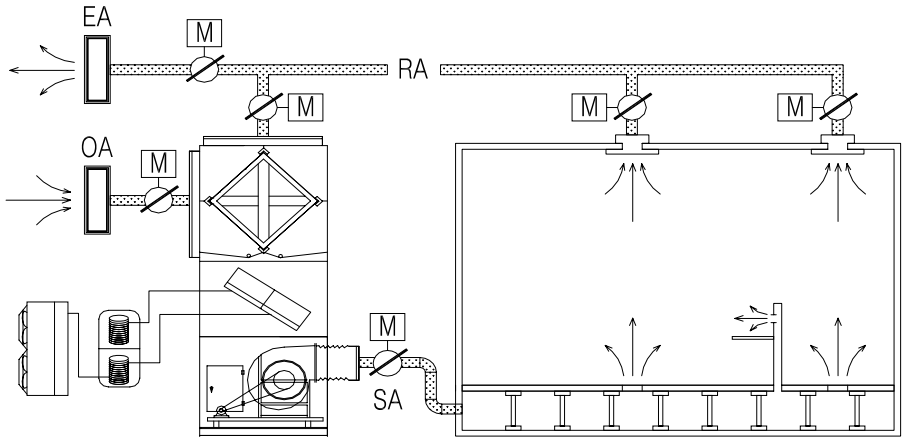
There is a need to develop an individual air distribution control system for a personal task area in office buildings to improve the air and the thermal comfort of occupants, thereby, increasing the occupant's productivity. Based on these concepts, we developed a partition integrated air distribution system to provide an individualized environment.

In the partition supply system, air is supplied to the personal task area through the partition panels by means of a raised floor and returned through the ceiling. This paper aims to find which arrangement of partition panel outlets would best serve the purpose of keeping occupants comfortable within a personal task area. The supply air distribution of the under-floor and the partition air supply systems of a personal task area was measured.

METHOD
All experiments were performed in a controlled environment chamber (CEC) with a 4.4 m by 2.9 m floor and a 2.7 m high ceiling. The CEC resembles a modern office personalized space (Figure 1). A supply air distribution box, located under the floor, draws air from an air-handling unit (AHU) via a flexible duct. After passing through the distribution box, supply air exits through partition panels via outlets located on the partitions. Some air is supplied from outlets on the floor surface. Air was exhausted from the chamber through a ducted return grill on the ceiling (Figure 2). The operational ability of the CEC is given in Table 1.

Table 1 Operational ability of the controlled environment chamber

	Temperature	Humidity
Control range	10–40°C	30–75%
Control accuracy	±0.5°C	±3%
Differences	±0.5°C	±5%



EA: Exhausted Air OA: Out Air
SA: Supply Air RA: Return Air

Figure 1 Concept diagram of a controlled environment chamber.

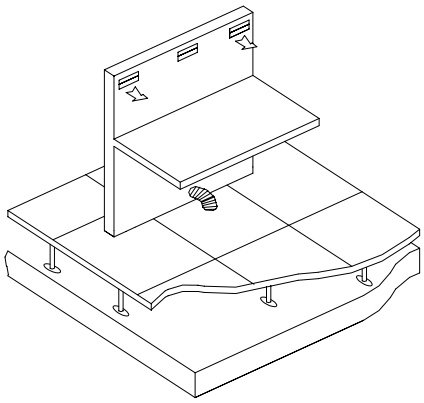


Figure 2 Air distribution of the partition supply system.

Table 2 Experimental conditions

	Case 1	Case 2	Case 3
Supply system	Under-floor	Partition	
Outlets on partition	None	2	3
Initial temperature		30°C	
Desired temperature		24°C	
Humidity		40%	

In this paper, thermal characteristics were measured in order to compare the under-floor and the partition air supply systems. The room temperature was controlled at 24°C after a steady state condition, 30°C, was established (see Table 2). The manikin was seated upright with its face located about 15 cm back from the edge of the desk. Standard office equipment, including a desk with a heat source simulating a PC monitor, was installed. Figure 3 shows the

floor plan of the workstation in the chamber and the location of measurement points.

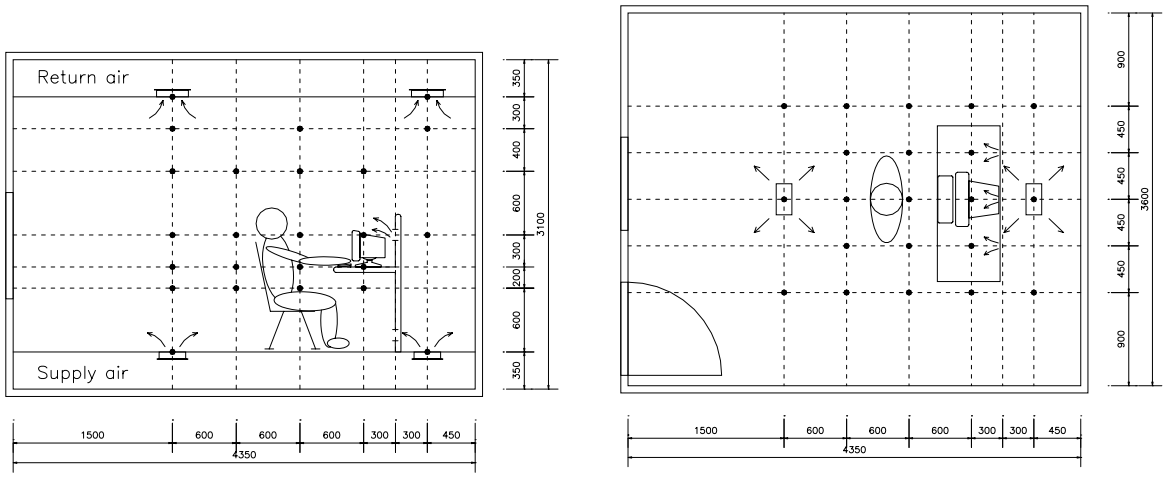


Figure 3 Location of measurement points (mm).

RESULTS

Three different conditioning systems were investigated in the CEC. The supply air distribution between the under-floor and the partition air supply systems for the personal task area were measured.

In the under-floor supply system, the air temperature distribution at a height of 1.1 m ranged from 23.7 to 24.3°C. The temperature on the floor outlet was 21.8°C and was lower than average. The temperature of the manikin's breathing zone was 25.5°C, 1.3°C higher than the average, due to the generation of heat from the manikin. Finally, the temperature above the PC monitor was 30.5°C and was 5.9°C higher than the average because of the excess heat generated from the monitor. This indicates that the under-floor supply system is not sufficient in removing the excess heat generated from office equipment.

The partition supply system supplies air from under-floor to the ambient area and also supplies air from partition to the personal task area. This study compared two outlets and three outlets on a partition panel.

We adjusted temperatures in three cases, equally, when the measurement was started. In comparing the supply air temperature on the floor plane, supply air temperature of the partition supply system (PSS) was higher than that of the under-floor supply system (UFSS). This indicates that the PSS is more effective than the UFSS in meeting the desired temperature and in distributing air to the personal task area. Our findings indicate that the PSS can meet the desired temperature at higher temperatures than the UFSS. This suggests that the PSS is more effective as an energy saving design (see Table 3 and Figure 4).

In order to compare the air distribution to the occupant's breathing zone, three cases were considered—under-floor supply system (UFSS), partition supply system with two outlets (PSS2) and partition supply system with three outlets (PSS3). The air temperature of the manikin's breathing zone was higher than that of other locations due to the heat generated from the manikin. Then, the temperature of the manikin's breathing zone in the PSS was lower than that in the UFSS. This suggests that the PSS is more effective than the UFSS in cooling down the air temperature around occupants within the personal task area.

Also, the air temperature above the PC monitor was higher than at other locations. This was due to the fact that heat was generated from the monitor. The air temperature above the monitor in the PSS was lower than that in the UFSS. This result indicates that the PSS is more efficient than the UFSS in removing excess heat generated from office equipments near an occupant's personal task area (see Table 4 and Figure 4).

Experimental results indicate that the PSS with three outlets is better than the other two systems in removing heated air from the area above the monitor. This is due to the fact that one of the three outlets is placed at the centre location near the monitor. The locations of the outlets are shown to be instrumental in ventilating stagnant air.

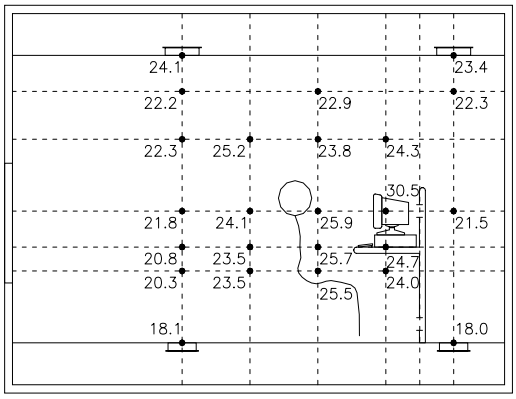
In examining the air distribution from the front partition, we compared cases of panels consisting of two outlets and three outlets. In the case with three outlets, air speed in breathing zone was measured at 0.1–0.7 m/s, higher than the ASHRAE standard of 0.15–0.25 m/s. To further increase the comfort of the occupant, the outlets should consist of operable directional grills that the occupant can control to open, close, and redirect the supply air.

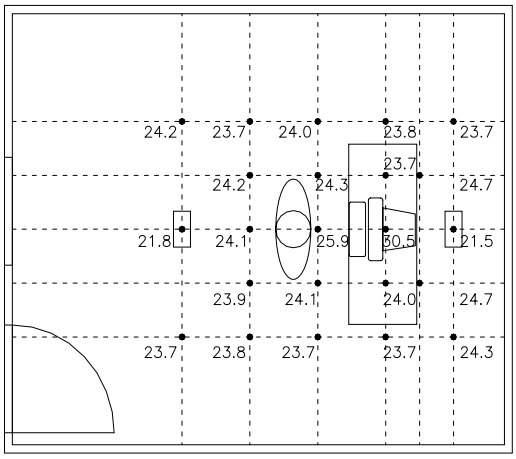
Table 3 Comparison of supply air temperatures (°C)

	Case 1	Case 2	Case 3
Supply system	Under-floor	Partition	Partition
Outlets on partition	None	2	3
Initial temperature		30	
Designed temperature		24	
Supply air temperature on floor	18.1	19.9	19.6
Outlet temperature on partition	23.7	24.5	24.2
Ventilated air temperature on ceiling	None	23.4	23.0

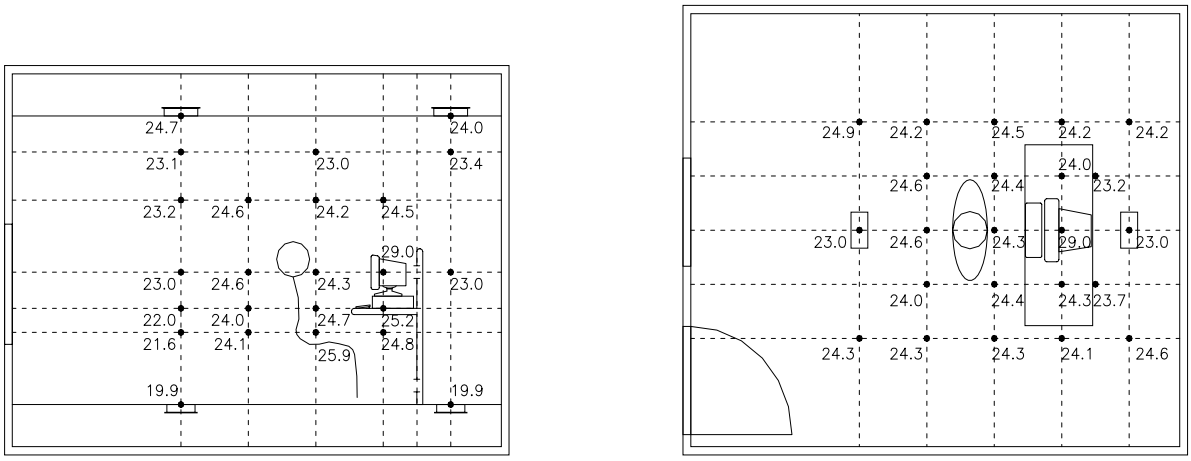
Table 4 Comparison of temperatures in breathing zone and above monitor (°C)

	Case 1	Case 2	Case 3
Supply system	Under-floor	Partition	Partition
Outlets on partition	None	2	3
Initial temperature		30	
Designed temperature		24	
Horizontal temperature on 1.1 m height in task area	23.7–24.3	24.0–24.6	23.8–24.5
Manikin's breathing zone	25.9	24.3	24.2
Temperature above monitor	30.5	29.0	27.8
Supply air temperature on floor plane	18.1	19.9	19.6

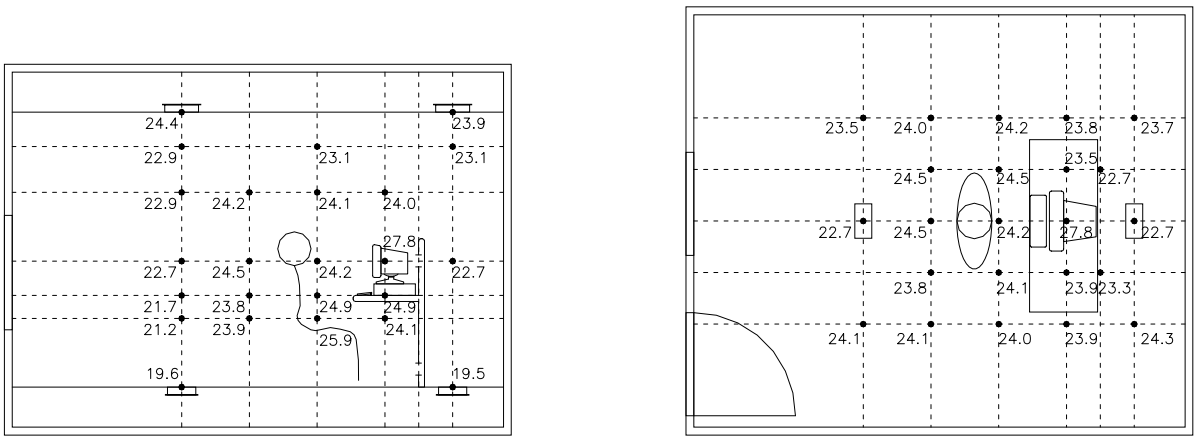




Under-floor supply system



Partition supply system with two outlets



Partition supply system with three outlets

Figure 4 Sectional and horizontal distribution of temperatures.

CONCLUSION AND IMPLICATIONS

In the study, comparisons were made between the under-floor and the partition air supply systems. Experimental results suggest that the partition air supply system is more efficient than the under-floor supply system in terms of cooling. Furthermore, experimental results indicate that the location of an outlet is the most critical factor in improving the efficiency of the supply air distribution of the personal task area.

Air supply control needs to be transferred to the occupants through the use of a partition air supply system. Such a system will allow an occupant to individually control their immediate environment, resulting in higher productivity. We suggest that these outlets should have operable directional grills that the occupant can control for comfort.

Finally, a key issue that remains to be addressed is the fact that the experiments were conducted during hot season. In order for this partition supply system to be feasible, it must demonstrate the ability to efficiently and economically increase occupant comfort throughout the year.

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