

Influence of Air Diffuser Layout on the Ventilation of Workstations

by *C.Y. Shaw*

This Update presents results of research carried out by the Institute for Research in Construction to determine whether differences in supply-air diffuser layout affect the performance of workstation ventilation.

The purpose of ventilation in a building is to supply outdoor air to a space and remove stale air. Ventilation can control the air quality both by diluting the indoor air with less contaminated outdoor air and by removing contaminants produced by building materials, furnishings, equipment and occupants. Sufficient dilution of contaminants is especially important to achieving acceptable air quality. To accomplish this, the supply air, consisting of both fresh and recirculated air, must reach all occupied areas of the building.

In a typical open-plan office, the floor space is divided into small work areas using partitions. However, engineers responsible for the design of a ventilation system rarely know in advance how the office layout will be arranged. Even if the engineers did know, partitions can be added or moved readily to accommodate a change in the use of the floor space.

The Test Facility

For the study, a workstation measuring 2.9 m by 2.6 m was assembled in one of two interconnected rooms in IRC's ventilation test facility (Figure 1). Each room measured 4.9 m by 4.9 m, with a height of 2.9 m. Each was equipped with its own independent HVAC system, two types of return-air inlets and two types of supply-air outlets (recessed air-light fixtures and square ceiling diffusers) (Figure 2).

Designers, facility managers and space planners often follow the practice of locating workstations immediately below air diffusers in the belief that this will ensure good air distribution. This practice may lead to the inefficient use of space. To provide guidance on this issue, the Institute for Research in Construction tested seven air diffuser layouts to observe their effects on distributing supply air in and around a partitioned workstation.

Three characteristics of the ventilation system were measured to assess its overall performance:

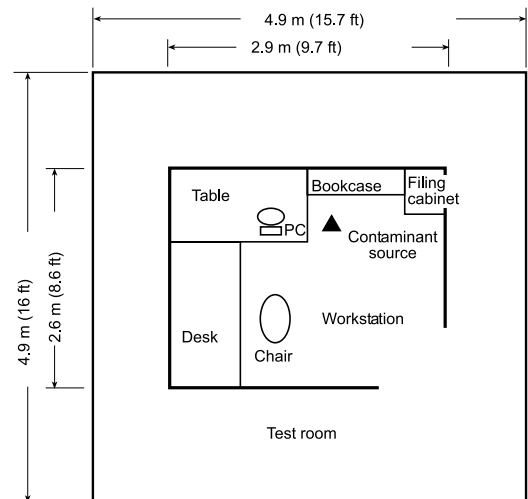


Figure 1. Plan of the test room, showing the layout of the single workstation

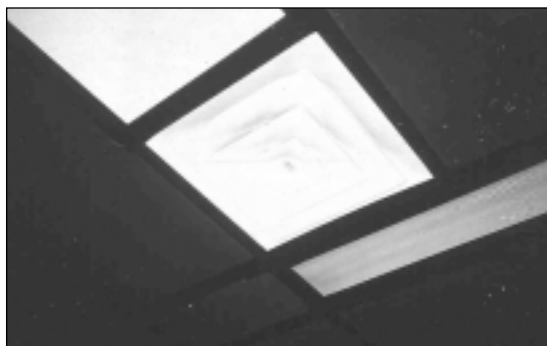


Figure 2. Two types of diffusers were tested: recessed air-light fixtures and square ceiling diffusers.

Air distribution pattern: a measure of how quickly and uniformly the ventilation system distributes the air in a space. It is measured by injecting tracer gas into the supply-air duct, and then taking air samples at four-minute intervals to measure the gas concentrations at 15 locations in and around the workstation and in the return-air duct. How quickly the gas concentrations at all locations reach the same level (indicating that the ventilation air and the indoor air are perfectly mixed) is a measure of the effectiveness of the HVAC system in distributing the ventilation air.

Air change efficiency: a measure of how quickly the ventilation system replaces the air in a space. It is the ratio of the nominal time constant (the volume of the test room divided by the outdoor-air supply rate) to the room mean-age-of-air. The room mean-age-of-air is the average value of the local mean ages of the air (i.e., the average time it takes for air to travel from the supply-air register to any point in a room). The tracer gas technique was used to determine the air-change efficiency.

Ventilation efficiency: a measure of the efficiency with which the ventilation system removes contaminants from a space. It is the ratio between the steady-state concentration of contaminants at the exhaust duct and the mean concentration in the room. A constant flow of tracer gas was used to simulate a single contaminant source on the floor.

Effect of Air Diffuser Layout

All seven diffuser layouts distributed the ventilation air equally well, both inside

and outside the workstation (Figure 3 and Table 1 depict the layouts tested). This was shown by the fact that the tracer gas concentrations inside and outside the workstation were essentially the same.

One air diffuser layout was tested with no workstation in place (Figure 3, Layout 1). It was found that the air distribution pattern was much the same as that with the workstation in place.

The measured values of air-change efficiency in the workstation agreed closely with those in the room as a whole. Any differences due to the diffuser layout were small.

With regard to ventilation efficiency, two of the diffuser layouts showed better results than the other five. In both cases, the supply air diffuser was much closer to the contaminant source than in the other five. This suggests that ventilation efficiency can be improved by directing the supply air towards a contaminant source, thus accelerating the dilution process and achieving a higher ventilation efficiency.

Air Distribution with Dividing Wall Removed

Since no open-plan workstation has four walls around it, the researchers removed the dividing wall between the two test rooms and tested one diffuser layout (see Table 1, "both rooms"). (The HVAC system of the

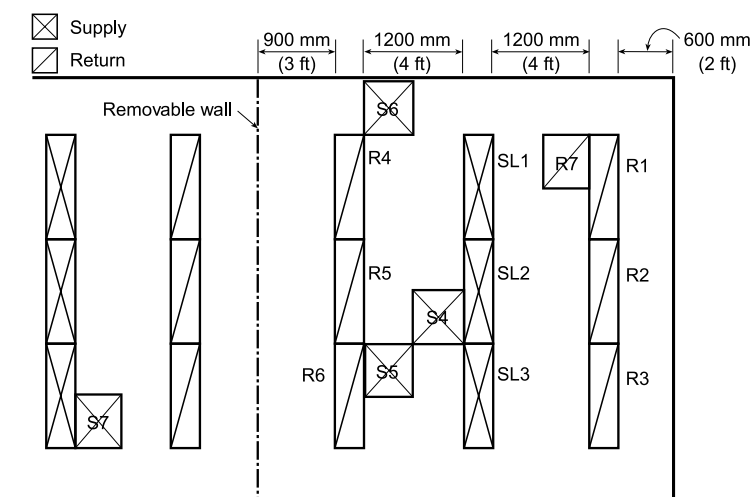


Figure 3. Layout of supply- and return-air diffusers in the two test rooms

second room was not in operation.) Not unexpectedly, the concentration of tracer gas was lower than with the wall in place, as the same supply-air flow rate used for the single room was now being used for the large room. The tracer gas concentration in and around the workstation was almost uniform, indicating that the air was well mixed. The air distribution pattern within the workstation remained essentially the same as when the wall was in place.

Effect of Gap at Base of Partitions

To determine the effect of a gap between the floor and the bottom of the partitions, three tests were carried out: one with no gap, one with a gap of 76 mm and one with a gap of 152 mm. The air distribution pattern was found to be the same for all three situations, suggesting that gap height has no effect on the performance of the ventilation system.

Effect of Supply-Air Flow Rate

To study the effect of the supply-air flow rate, one diffuser layout (Layout 1) was tested three times, each with a different supply-air flow rate: 100 L/s, 50 L/s and 25 L/s. The corresponding outdoor-air rates were 20, 10 and 5 L/s. (The supply air consisted of 20% outdoor air and 80% recirculated air.)

The tests revealed that the mixing time (i.e., the amount of time it takes for the tracer gas concentrations at all locations to reach the same level) increases as the air flow rate decreases. For a rate of 100 L/s, 20 to 40 minutes were required for the supply air to mix thoroughly within the workstation. Decreasing the supply rate to 25 L/s increased the mixing time to more than 4 hours.

Both the air-change efficiency and the mean-age-of-air decreased as the supply-air flow rate increased. A decrease in the

mean-age-of-air would normally be accompanied by an increase in the air-change efficiency, i.e., the younger the mean-age-of-air, the fresher the air in the room. This result suggests that the air-change efficiency criterion is not suitable for comparing ventilation systems with different ventilation rates. The mean-age-of-air appears to be a better indicator of changes in the outdoor-air supply rate in this case.

When the supply-air flow rate was increased from 25 L/s to 100 L/s, the ventilation efficiency decreased, which was contrary to expectations. Close examination of the diffuser layout showed, however, that a lower supply-air flow rate allowed the contaminants to rise in the workstation, resulting in a more uniform mixing with the air both inside and above the workstation. On the other hand, the supply-air rate of 100 L/s was strong enough to disrupt the natural upward movement of the contaminants in the workstation. Instead, it “pushed” the contaminants out of the workstation into the surrounding area. The contaminants then migrated to the return-air ducts, resulting in a greater difference in the concentrations of contaminants between the workstation and the exhaust duct.

Effect of Multiple Workstations

With the common wall removed, three additional workstations and extra partitions were installed at one end of the test room to determine the effect on the performance of the ventilation system (Figure 4). Two partition heights were tested: 1.5 m (tested with no gap) and 1.9 m (tested with no gap and with gaps of 76 mm and 152 mm).

Results showed that the air distribution pattern was similar to that measured for a single workstation: the tracer gas was uniformly distributed throughout the room, and the concentrations of gas within and outside the workstations were the same as in the return-air duct.

As the supply-air flow rate was unchanged, the air-change efficiency was not affected by changes in partition or gap height, by heating or cooling mode, or by workstation location within the room.

The measured ventilation efficiency (contaminant removal efficiency) varied from location to location, however. In general, the closer the contaminant source

Table 1. Supply and return diffuser layouts

Layout Number	Supply	Return
1	SL1, SL2, SL3	R1, R2, R3, R4, R5, R6
2	SL1	R7
3	SL2	R7
4	SL3	R7
5	S6	R7
6	S5	R7
7	S4	R7
Both rooms	S7	R7

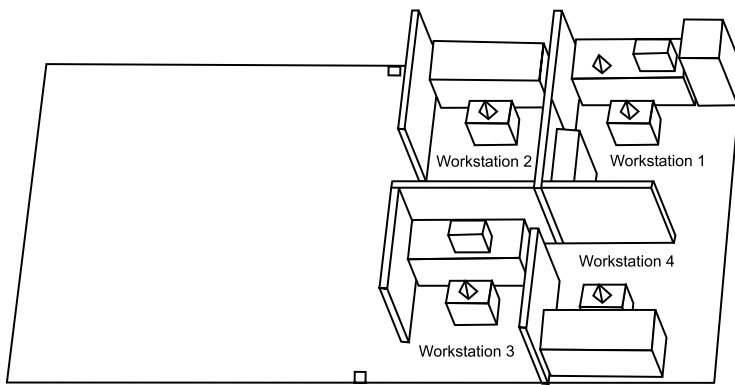


Figure 4. Sketch of the four workstations in the single test room

was to the return-air grille, the less the contaminant would spread in the room.

A gap at the bottom of partitions did not appear to have a beneficial effect on ventilation efficiency, and in some cases the absence of a gap improved efficiency.

With regard to facilitating the removal of contaminants from the workstation, the 1.5-m partition appeared to be superior to the 1.9-m partition.

Summary

IRC tested seven air diffuser layouts to determine their effect on the performance of a ventilation system in a workspace created using partitions.

- All seven diffuser layouts distributed the supply air within and around the workstation area equally well.
- The air distribution pattern within the workstation was not affected by the type of diffuser, the partition height, the gap at the bottom, adjacent workstations, or the location of the supply-air diffusers and return-air grilles relative to the workstation.
- As the supply-air flow rate decreases, the time required for it to mix with the air inside the workstation increases.
- Ventilation efficiency improves when the air diffuser layout directs the supply air towards the contaminant source.
- Increasing the size of the room in which the workstation is located or adding workstations to the space does not affect the air distribution pattern.
- Air-change efficiency may not be a suitable criterion for comparing ventilation systems with different ventilation rates.

Implications

The information presented here will help designers and facility managers make efficient use of valuable floor space in an office environment. Although the research examined ventilation performance in a space 4.9 m by 4.9 m, the results are expected to apply to open-layout offices as well. Further research is needed to confirm these findings for larger offices with multiple workstations.

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National Research Council of Canada
June 2000
ISSN 1206-1220

"Construction Technology Updates" is a series of technical articles containing practical information distilled from recent construction research.

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