Control of Environmental Tobacco Smoke in Restaurants

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Introduction

Recently, the need to control environmental tobacco smoke (ETS) in restaurants and bars has increased. In Finland, a new law prohibiting ETS states that non-smoking areas must be established and the dispersion of tobacco smoke to non-smoking areas must be prevented. Employees' exposure to ETS must also be limited in restaurants to a reasonable level. In this new situation the existing instructions for designing ventilation in the hospitality industry are inadequate. Therefore, a laboratory study was undertaken to investigate the possibilities of using ventilation systems and interior design to control ETS in restaurants.

Experimental Set-Up

Two different types of test restaurants were constructed. Firstly, a small pub-type single-compartment room (area 38 m^2, height 3 m) was used to study the possibilities to reduce bartenders' and customers' ETS exposure. Secondly, a two-compartment test restaurant was used to investigate the dispersion of tobacco smoke from the smoking area to the non-smoking area. This restaurant included a smoking (35 m^2) and a non-smoking (39 m^2) area connected via an opening (width 2.6 m, height 3 m). The ventilation in both cases was either a mixing or a displacement system. In the single-compartment restaurant a local air supply over the bartender and local exhaust over the smokers at the bar were also studied. The temperature difference between the general supply and exhaust air was maintained at –5 °C, and the number of heated human simulators controlled the difference. These simulators were closed ducts (diameter = 315 mm, height 1350 – 1750 mm) positioned vertically and containing two light bulbs (total effect 100 W). The dispersion of tobacco smoke was simulated with tracer gas. Diluted tracer gas (SF6-air mixture) was released near the human simulators through heated pipes. The tracer gas concentration was measured at several locations and heights within the restaurant by a computer-controlled measurement system and an infrared analyser. The validity of the tracer gas method was verified by measuring the particle mass, nicotine and tracer gas concentrations simultaneously at the same points during tobacco smoke generation. The results indicated that the tracer gas method was suitable for describing the dispersion of tobacco smoke. The tracer gas concentrations were normalized by the C0 concentration on the assumption that the mixing of the tracer gas was complete at an airflow rate of 10 $dm^3 \cdot s^{-1} \cdot m^{-2}$.

Results and Discussion

Single-Compartment Room

In the case of mixing ventilation (airflow rate 10 $dm^3 \cdot s^{-1} \cdot m^{-2}$) (Figure 1a) the tracer gas was dispersed evenly across the room as expected. The use of displacement ventilation and increased airflow rates (Figure 1b) decreased the relative concentration in the bartender's and customers' breathing zone by 70% and 50%, respectively, when compared with the values obtained with the complete mixing method. However, this reduction was achieved when there was no movement or other disturbing airflow that could deteriorate the efficiency of the displacement ventilation during the test. The use of local supply air decreased the bartender's breathing-zone concentration over 80% (Figure 1c-d), although the contaminant release was concentrated at the bar. The wall diffusers used in the mixing ventilation (Figure 1c) may have disturbed the airflow near the bartender more than the low velocity supply units did with displacement ventilation (Figure 1d) and therefore resulted in a higher concentration. However, the use of local supply air increased the concentration in the customers' breathing zone. If the exhaust was focused on the most polluted area, this time at the bar, both the bartender's and the customers' exposure was significantly decreased (Figure 1e). The greatest reduction was achieved when increased airflow rates (total airflow 15 $dm^3 \cdot s^{-1} \cdot m^{-2}$) and the local air supply over the bartender was used in combination with the low velocity supply air distribution and concentrated air exhaust (Figure 1f). In this case the bartender's exposure was decreased about 99% and the customers' exposure by about 75%.

Two-Compartment Restaurant

The results of the relative breathing-zone concentrations in the non-smoking area are shown in Figure 2 for various ventilation configurations. In these tests the airflow rate of the ventilation system was kept constant at 10 $dm^3 \cdot s^{-1} \cdot m^{-2}$. Separating the smoking and non-smoking areas reduced the non-smokers' exposure by about 50% when the opening between the non-smoking and smoking areas was 7.8 m^2, corresponding to 10% of the total floor area (Case 1 in Figure 2). Increasing the exhaust flow rate in the smokers' section and the supply flow rate of the non-smokers' section while keeping the total airflow rates constant further reduced the exposure (Cases 2 and 3). Decreasing the opening to 7% of the floor area reduced the non-smokers' exposure to below 20% when compared with the situation with the complete mixing system (Case 4). An additional decrease in the size of the opening had only a minor effect on the exposure level (Cases 5 and 6). With displacement ventilation the non-smokers' concentration levels were clearly lower (Cases 7, 8 and 9) than with the mixing ventilation system (Cases 4, 5 and 6). The best results were clearly achieved when displacement ventilation was used and a special ceiling exhaust device was installed in the opening (Figure 2). With this configuration the non-smokers' exposure was only 2% of the concentration with complete mixing.

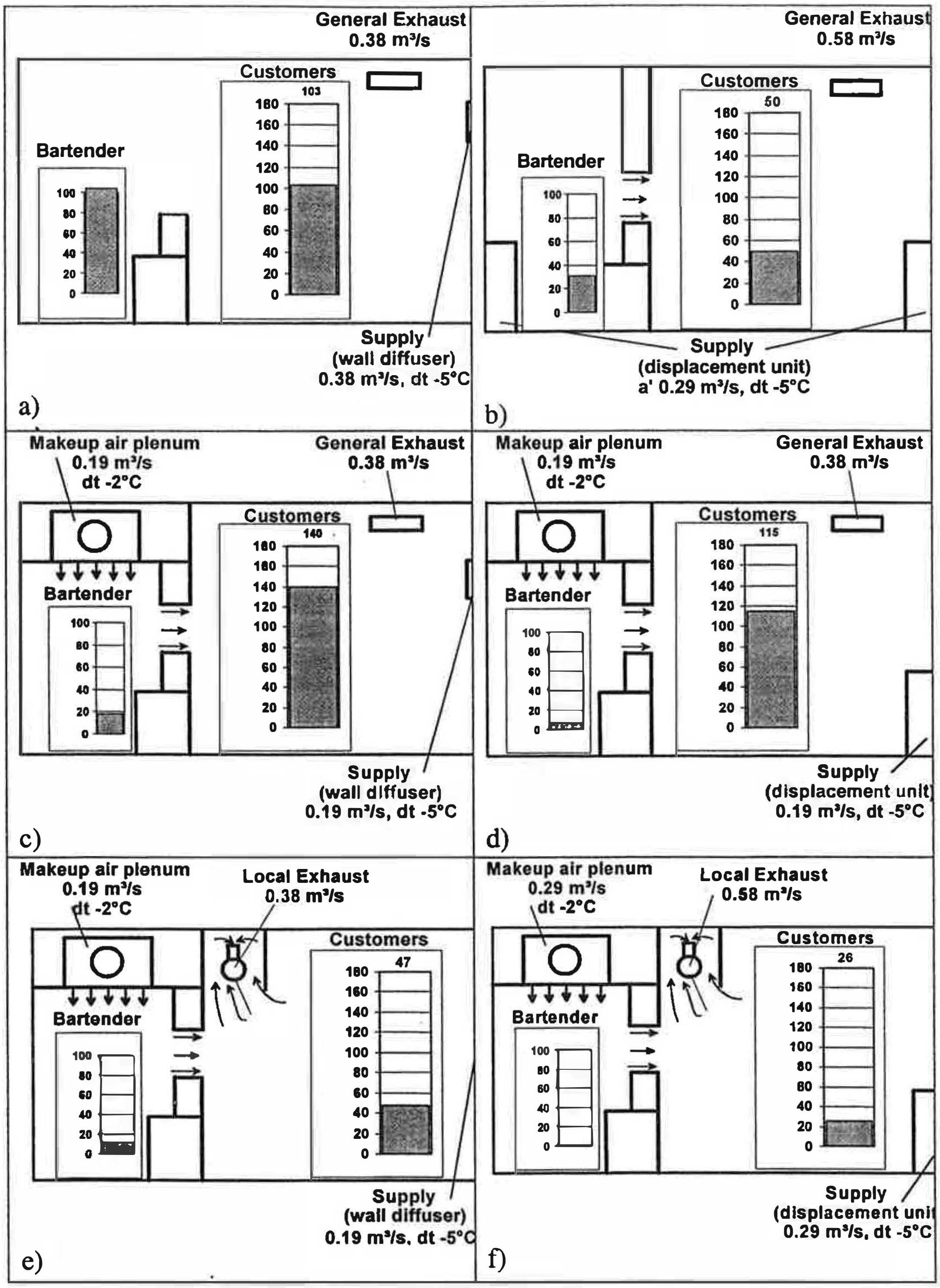
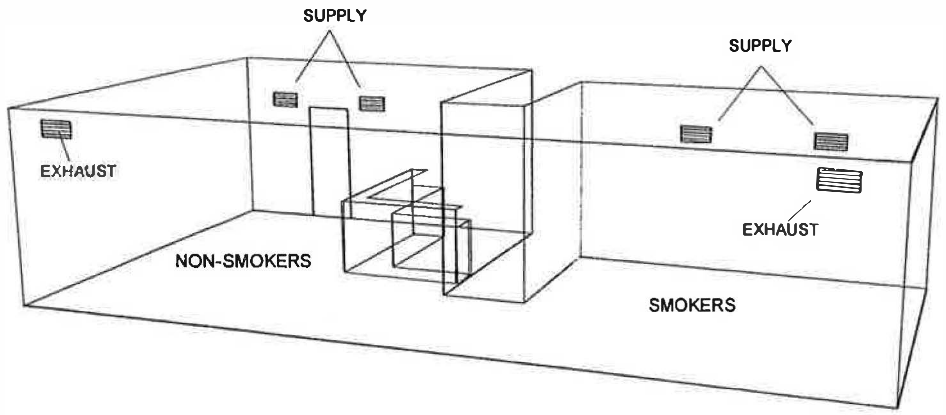
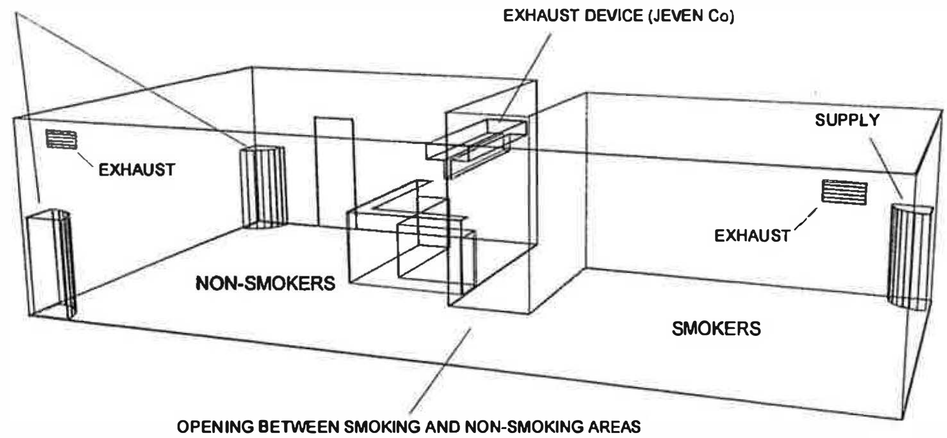


Figure 1. Relative tracer gas concentrations C/C_0 (%) in the bartender's and customers' breathing zone with different ventilation arrangements.

MIXING VENTILATION



DISPLACEMENT VENTILATION



Case	Ventilation system	Airflow rate (m3/s)				Opening size, m2
		Non-smokers		Smokers		
		Supply	Exhaust	Supply	Exhaust	(w x h)
1	Mixing	0.39	0.39	0.35	0.35	2.6 x 3
2	Mixing	0.39	0.17	0.35	0.57	2.6 x 3
3	Mixing	0.57	0.17	0.17	0.57	2.6 x 3
4	Mixing	0.57	0.17	0.17	0.57	1.7 x 3
5	Mixing	0.57	0.17	0.17	0.57	1.1 x 3
6	Mixing	0.57	0.17	0.17	0.57	2.6 x 2
7	Displacement	0.57	0.17	0.17	0.57	2.6 x 2
8	Displacement	0.57	0.17	0.17	0.57	1.7 x 3
9	Displacement	0.57	0.17	0.17	0.57	1.1 x 3
10	Displacement *)	0.57	0.08	0.17	0.46	2.6 x 2.4

*) With Jeven exhaust device, flow rate 0.2 m3/s

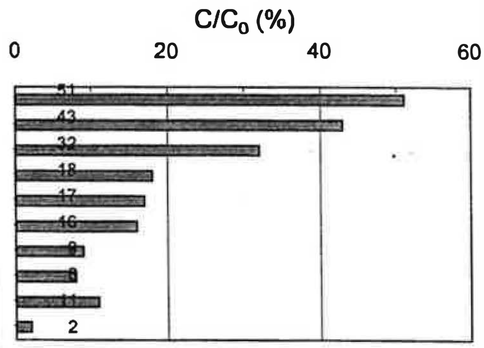


Figure 2. Measured non-smokers' relative concentration with different configurations. C_0 is the breathing-zone concentration with the complete mixing system.

Conclusions

- Bartender's exposure can be significantly reduced in specific areas by separating the work site and using local supply air. The face area of supply air unit must be large enough to cover the contained area.
- Non-smokers' exposure can be reduced by separating the smokers and non-smokers and supplying most of the air into the non-smoking section and exhausting most of it from the smoking section.
- In the case of a two-compartment restaurant the displacement ventilation system is more effective than the mixing one.
- The dispersion of smoke from the smokers' section can be minimized and the non-smokers' exposure reduced if local exhaust with a sufficient flow rate is placed in the opening between the smoking and non-smoking sections.

Acknowledgements

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