The Effects of Ventilation and Sash Handles on the Flow in Fume Cupboards

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Introduction

Two-dimensional numerical simulations have been undertaken for the steady turbulent fluid flow in a room containing a fume cupboard which is attached to a wall and a ventilation duct which is situated in the ceiling of the room, see figure 1. The wall opposite to the fume cupboard is assumed to be porous and a fully developed fluid velocity profile is applied far upstream. The calculated flow is considered to be that which is actually found in the central plane of a practical fume cupboard. The fume cupboard sash is fixed in its maximum opening position at 0.5m, and whilst various positions and fluxes of the ventilation duct are considered, a constant fume cupboard face velocity is maintained by suitably choosing the fluid flow through the porous wall. The fluid flows, both inside the fume cupboard and the room, are obtained using a 2D k-ε turbulence model and the wall function technique within the commercial software package FLUENT. We use the length L to denote the horizontal distance along the ceiling of the room from the wall containing the fume cupboard to the ventilation duct. To improve the convergence of the fluid flow the solution domain was divided into two regions, one inside the fume cupboard, the inner region, and the other outside, the outer region, with an overlap in the vicinity

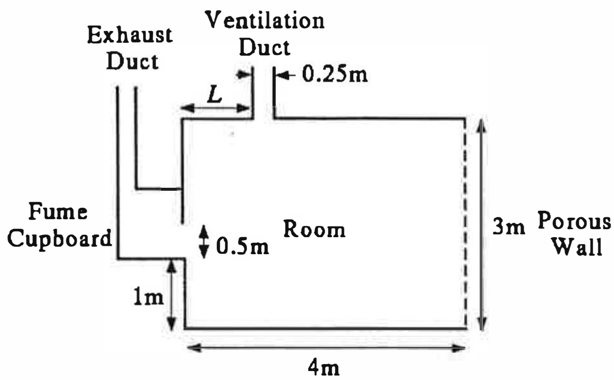
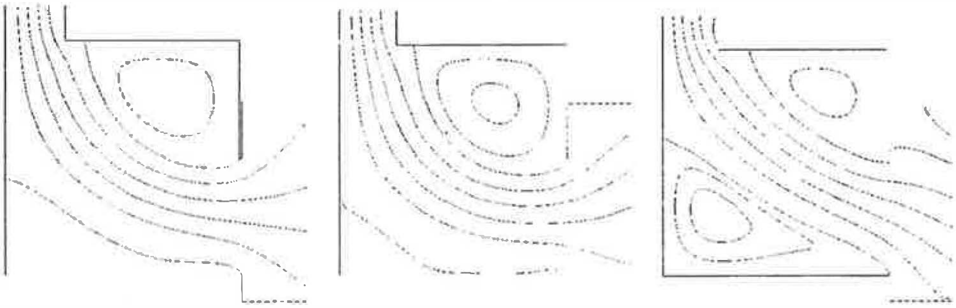


Figure 1. A 2D schematic diagram of the solution domain.

of the aperture. A specific fluid velocity boundary condition was obtained from the outer region, which we were then able to apply as an artificial boundary condition for the inner region. To provide sufficiently accurate results with the inner region reasonably small this artificial boundary was taken as a rectangle of width 0.3m and height 0.9m, with its lower edge fixed at 0.15m below the aperture.

Fluid Flow Patterns



(a) (b) (c)

Figure 2. Streamlines patterns in a fume cupboard with an exhaust flux $0.25m^2s^{-1}$*, where there is (a) no ventilation duct, and (b) and (c) a ventilation flux of* $0.125m^2s^{-1}$*. The length L is 1m in (b) and 3m in (c).*

To gain accurate grid independent solutions a much finer mesh was applied inside the inner region than was utilised in the full domain. When the length L is 1m the main flow approaches the aperture from above, thus inside the fume cupboard the upper recirculation zone increases in size as the ventilation flux increases, with the reverse of this for the lower recirculation zone. When the length L is 3m the main flow approaches the aperture from below, producing the reverse situation to when L=1m. When the length L is 2m the main flow approaches the aperture almost horizontally causing both recirculation zones to remain almost constant in size for a large range of ventilation fluxes, with the resulting formation quite close to the situation when the ventilation duct is absent.

Sash Handles

Sash handles are designed to minimise the leakage near the bottom of the sash while maintaining a practical fume cupboard. Experimental and 2D computational investigations were carried out by Johnson *et al.* (1) and they found that there were large regions of highly concentrated contaminant under the handles if a recirculation zone is present under the handle. A detailed investigation of the various factors which affect the leakage of a fume cupboard was performed by Hu *et al.* (2).

We considered a simple set of sash handles of one grid cell in thickness with a sash thickness of 2 grid cells being 0.01m. We fixed the inner and outer lip widths at approximately 0.0172m and 0.0278m so that the outer lip width was approximately the sum of the inner lip width and the sash width. When the outer lip was raised it was fixed 0.0388m from the bottom of the sash with the aim that a recirculating flow would form under the outer lip and extend close to the bottom of the sash. Globally the effects of the sash handles on the fluid flow are very small but locally the flows are quite different, see figure 3. When the main flow approaches the aperture

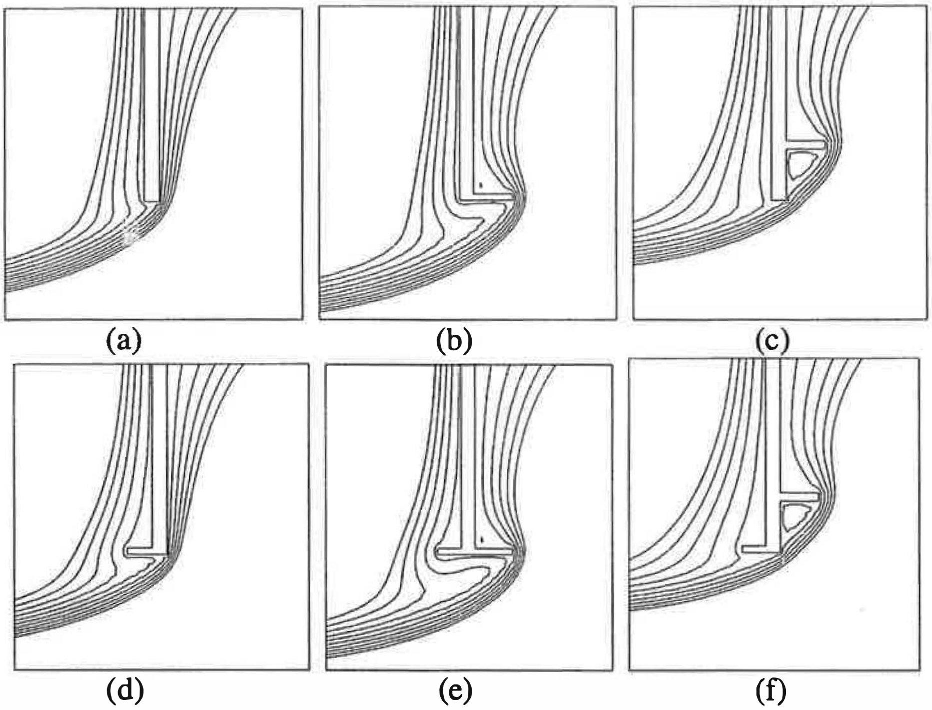


Figure 3. Evenly spaced streamlines when the length L=1m.

horizontally, or from above the horizontal, the following conclusions can be made: (a) Non-raised outer lips proved to be the worst type of handle as they pulled the edge of the upper recirculation zone further out of the fume cupboard and this increases the size of the upper recirculation zone, as well as causing a reversal of the flow under the outer lip. (b) An isolated inner lip decreases the size of the upper recirculation zone. (c) The best results come from the raised outer lip under which a small recirculation region is formed and this promotes a more horizontal flow and reduces the size of the upper recirculation zone. (d) With the addition of an inner lip a slight improvement occurred, which in turn produced the largest magnitudes of the u component of the fluid velocity near the handle, and hence reduced the chance of any leakage occurring in this vicinity. When the main flow approaches the fume cupboard from below then all of the handles very slightly reduced the size of upper recirculation zone and there was no change of sign in the u component of the fluid velocity.

We found that the streamline pattern along with the u component of the fluid velocity at the aperture provide excellent indications as to where high levels of leakages may take place after comparing these factors with a large number of numerical simulations for contaminant concentrations at the fume cupboard aperture.

Conclusions

To minimise leakages from fume cupboards we have found that the ventilation duct should not be placed more than about 2m horizontally away from the fume cupboard so that the main flow approaches the fume cupboard horizontally or from above the horizontal, or the ventilation duct should be absent, then increasing the ventilation flux reduces the size of the lower recirculation zone. The sash handle with the inner lip and raised outer lip produced the smallest leakages.

Acknowledgements

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References

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2. Hu P, Ingham DB, Wen X. Effect of the location of the exhaust duct, an exterior obstruction and handle on the air flow inside and around a fume cupboard. Ann. Occup. Hyg., 1996;40:127–144.