A fluid situation

The design of ventilation and room air distribution is critical to the performance of laboratory and process areas. *Geoff Whittle* and *Joe Lam* describe how computational fluid dynamics is being used to evaluate the design of such spaces.

At a fundamental level, computational fluid dynamics (cfd) is all about the solution of equations which describe fluid flow. These equations represent the conservation of physical quantities which include mass, energy and momentum. Solutions of the equations are found at numerous points in the flow, where each point is defined by its position on a mesh.

The information that is obtained on velocity, temperature, pressure etc, at every computed point, builds up a complete picture of the whole flow structure.

Because of the non linear characteristics of the equations, cfd requires a large amount of iterative calculation and has, until recently, been too expensive to employ in the design of indoor environments.

However, with rapid advances in the capabilities and cost-effectiveness of computers, allied to developments both in the underlying numerical algorithms and also in the usability of software, cfd is now being used to assist in the design of a wide range of spaces. Nevertheless the techniques must be used with care in order to get the best from them.

Projects themselves may last from a couple of days (for a small project and an expert user) to a time-scale of weeks where a complex space/system is being considered and detailed optimisations carried out in parallel with this.

CFD is a design tool specifically used to establish the performance of a scheme which has already been proposed. At its best, cfd serves to supplement existing design knowledge and in turn provides a means to evaluate the various design proposals available and also optimise against specified criteria.

In the present context, these criteria are based on several factors, namely safety, air quality and thermal acceptability.

CFD in use

A recent project study involved an assessment of ventilation performance in a pharmaceutical laboratory containing fume cupboards.

Here, the requirements were to condition the space and provide ventilation for the processes going on at the work benches and in the fume cupboards. The need was to maintain comfortable air velocity and temperature conditions while containing, and minimising the spread of airborne pollutants.

The technical issues are complex and, naturally, demand the careful exercise of professional engineering judgement in interpreting and complying with standards and guides.

BS 7258, for example, specifies safety and performance requirements and deals with the installation and maintenance issues for laboratory fume cupboards[1]. In addition, the Health and Safety Executive defines exposure limits to airborne contaminants[2]. The laboratory studied incorporates six fume cupboards and is 16 m by 9 m in plan by 2·85 m high. Supply air enters the laboratory through discrete laminar flow ceiling-mounted supply air diffusers located above work benches. Air is exhausted solely through the fume cupboards, at a design velocity of 0·5 m/s.

Figure 1 shows an outline of the full space, 8 m by 4 m in plan, partitioned off at one corner of the laboratory for use as a write-up area. This is represented by the projection of the computational mesh on surfaces defining work benches (central area) and fume cupboards (on the right along the full room length and on the left along a shorter length).

The write-up area, which was not studied as part of the simulations, is blocked out at the left-rear of the picture. Outline representations of

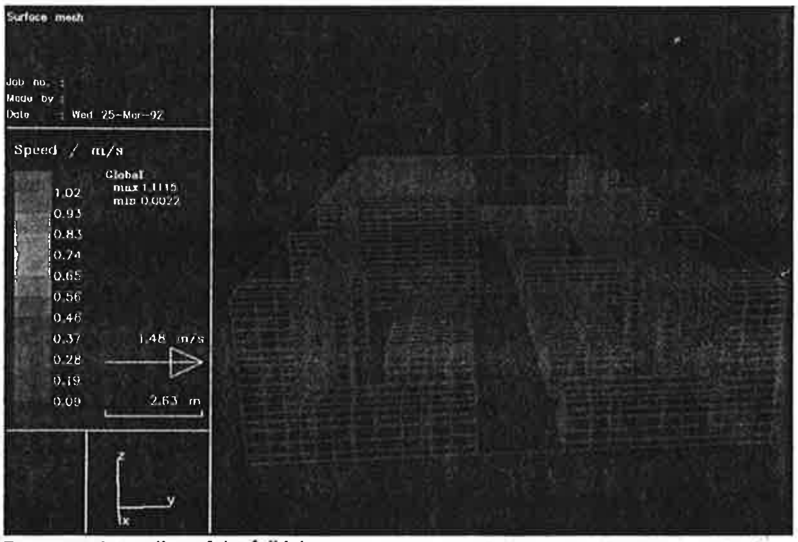


Figure 1: An outline of the full laboratory space.

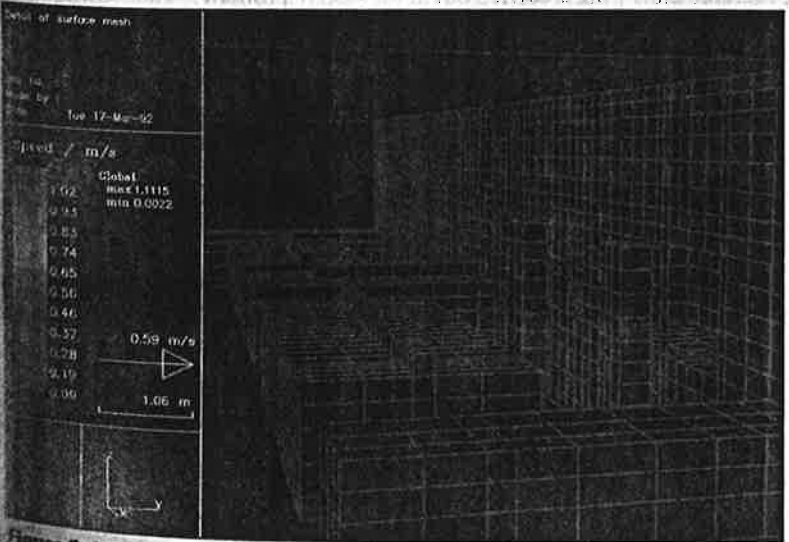


Figure 2: Mesh detail of the laboratory showing the fume cupboard entrances. The laboratory incorporates six fume cupboards in its total area.

operators are shown in front of some of the fume cupboards.

A detail of part of the space is shown in figure 2, where openings into the fume cupboards can be seen to the right of the picture.

More detailed simulations were also performed in a part of the laboratory to focus more strongly on the area around a single and a dual fume cupboard.

As usual with this type of space, more air is exhausted through the fume cupboards than is provided by the supply system, the make-up air being drawn from the write up area and the adjacent corridors via transfer grilles.

Under-pressurisation is necessary to contain any odours and/or chemicals that may be accidentally released into the laboratory.

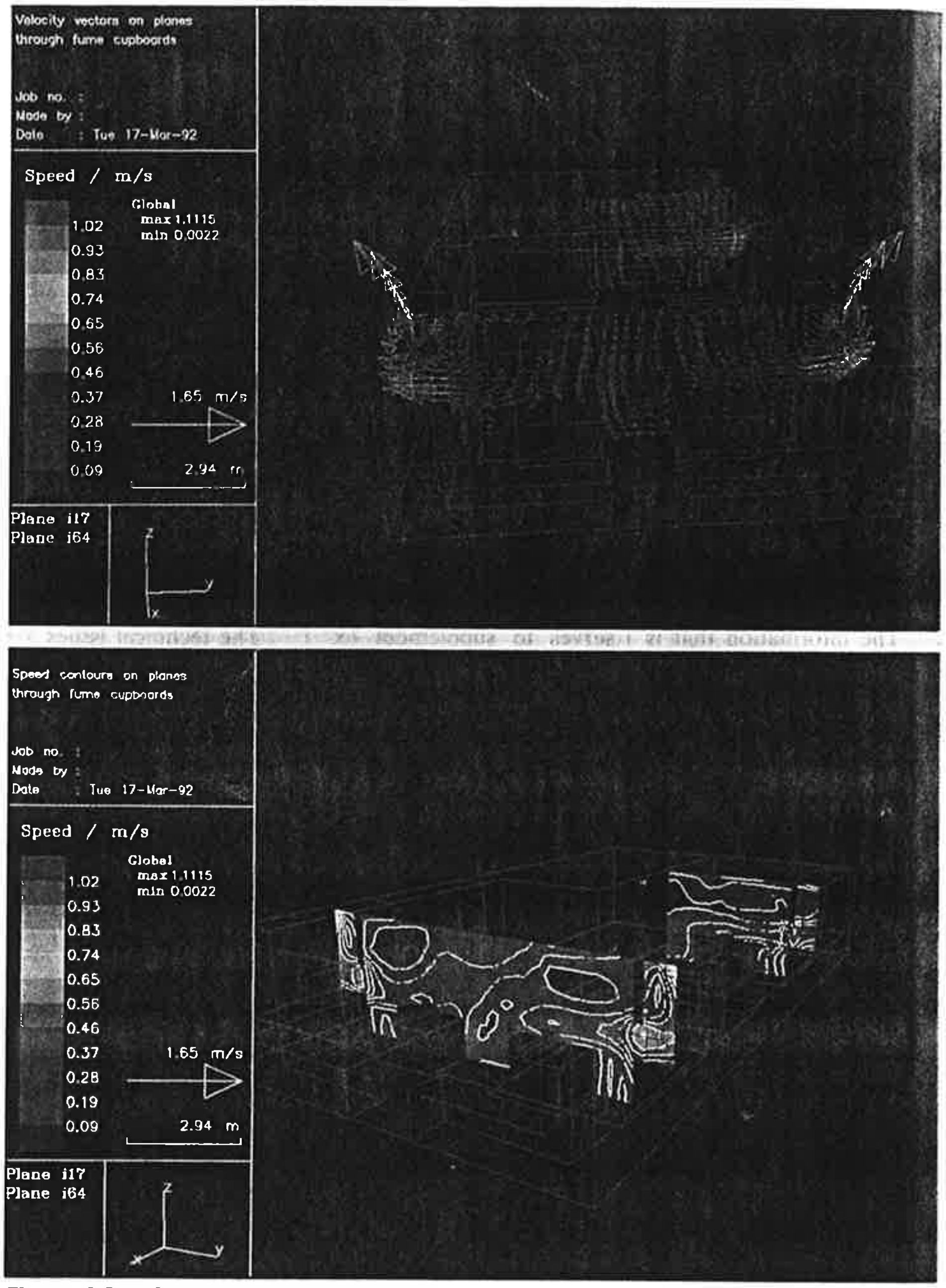
The fume cupboards are of the dual-track, horizontal sliding-sash type. It is claimed they reduce the required face opening area compared with more conventional vertical models of the sliding-slash variety[3].

Therefore less air is needed, giving a potential saving on heating/cooling requirements and on the capital and operating cost of the exhaust fan and motor.

In addition, other factors such as access and total capital cost are important in selecting the type of fume cupboard for any particular application.

The objective of this exercise was to assess the influence of the air supply system on the operation of the fume cupboards.

The CIBSE *Guide* describes ventilation requirements for laboratory spaces and specifies fume cupboard face velocity ranges for different applications[4]. Regarding thermal acceptability, *ISO Standard 7730* defines comfort for moderate thermal



Figures 3 & 4: CFD sample results. Air velocity vectors and speed contours show up as vertical planes through some of the fume cupboards.

environments in terms of air velocity, temperature, clothing and activity level[5].

Broadly speaking, averaged velocities somewhere in the region of 0·15 to 0·25 m/s are appropriate for sedentary activity level (offices), although in laboratory environments, where activity levels are likely to be greater, higher velocities will be tolerable.

However, it is important that room air movement is not so high that it will influence the uniformity of flow into the fume cupboard. The risk from this is that flow interactions will compromise containment ability.

To check for this, *DD 191* describes a procedure where a tracer gas is released inside the cupboard, and monitoring is carried out at the sash plane using a gas analyser[6].

CFD gives the potential for these sort of interactions to be modelled at the design stage to ensure that the system will operate in the manner required.

Sample results are shown in figures 3 and 4. Air velocity in the form of vectors, as well as contours of speed are shown on vertical planes through some of the fume cupboards.

The vectors indicate both direction of flow and speed. These and other results were used by the design team to establish that the laboratory space, the selected air distribution system and the configuration of fume cupboards would function properly, and satisfy the accepted criteria adopted for evaluation purposes.

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References

[1]British Standards Institution, "Laboratory fume cupboards", *BS 7258: 1990*, BSI, 1990.

[2]Health and Safety Executive, "Occupational exposure limits", *HSE Guidance Note EH40*, HMSO.

[3]ASHRAE, HVAC Applications Handbook, Chapter 14 - Laboratories, ASHRAE, 1991.

[4]*CIBSE Guide - Section B2*, CIBSE, 1986.

[5]ISO, "Moderate thermal environments - determination of the PMV and PPD indices and specification of the conditions for thermal comfort", *ISO Standard 7730*, ISO, 1985.

[6]"Method for the determination of the containment value of a laboratory fume cupboard", *DD 191*, BSI, 1990.

Further reading

Patankar S V, "Numerical heat transfer" Hemisphere Publications, USA, 1980.

Whittle G E, "Flow field modelling in buildings", *Building Services*, May 1991, p51-53.