CHAM

PHOENICS Case Study: HVAC
CFD simulation of Air Flow and Residence Time in a Medical Operating Theatre Environment

Clean rooms (cleanrooms) feature heavily in the semiconductor and pharmaceutical industries. CFD simulation is used extensively for clean rooms and indeed other environments sensitive to contamination, from medical operating theatres to data centres. The primary concern in all cases is to ensure that the clean room retains a high level of ventilation whilst retaining low and controlled level of environmental pollutant (such as airborne particles (dust), gaseous vapours, bacteria and so forth) through filtration.

Depending upon its use, each different category of industrial clean room has a level of acceptable contamination that is defined by the size and number of particles per cubic metre, for which BS, ISO and other international standards exist.

In the example shown below, PHOENICS has been applied to the simulation of air flow within a medical operating theatre. This simulation is concerned with the overall flow regime within the operating theatre and the effectiveness of an additional air curtain immediately surrounding the operating table.

Contamination represents a high-priority concern within medical operating theatres. Whilst every effort is made to retain a high standard of cleanliness within the theatre, the very nature of its operation – involving the continual movement of people and patients and the consequential entrainment of dust and bacteria – can undermine hygiene integrity.

Whilst air filtration systems and other mechanisms within operating theatres operate in a similar fashion to clean rooms, there is little that can be done to prevent the ingress of unwanted pollutants through their wide and often-used doorways. Consequently, an additional level of patient protection can be implemented through use of a highly-filtered laminar flow air curtain surrounding the operating table, designed to reduce the number of infective organisms present in the immediate vicinity of the surgical procedure.

Such air curtains can operate, ie as a single direction horizontal flow or using a vertical flow in a semi-enclosed manner. The air is highly filtered and changed many times per hour. CFD simulation can used to establish the most effective method of air curtain operation suited to the need and the surrounding environment.

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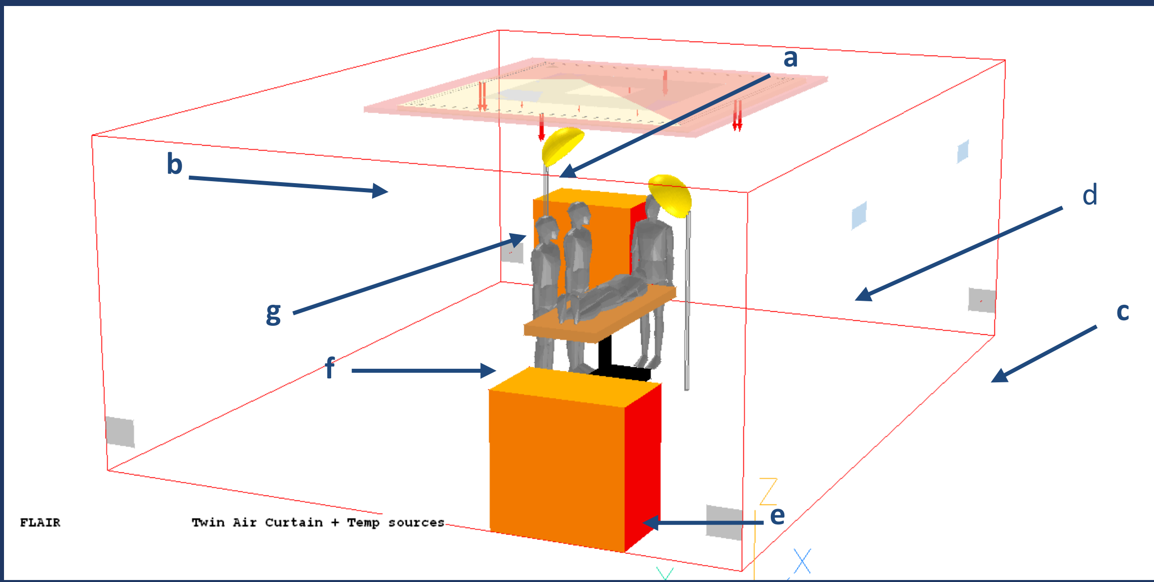
In the example shown, PHOENICS is used to construct a CFD model of an operating theatre with a vertical air curtain consisting of four sets of twin horizontal slots blowing filtered air vertically downwards. These surround multiple air diffusers releasing slightly warmer filtered air at a lower rate to retain patient comfort. Other heat sources, such as lighting and other equipment are not shown in this model.

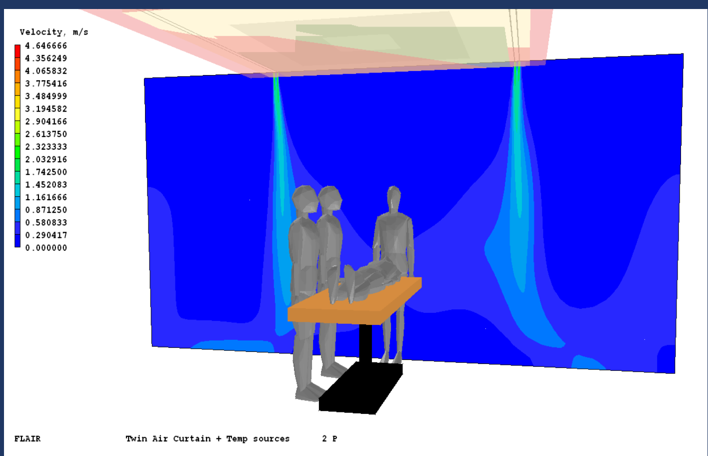


Detail of Operating Theatre

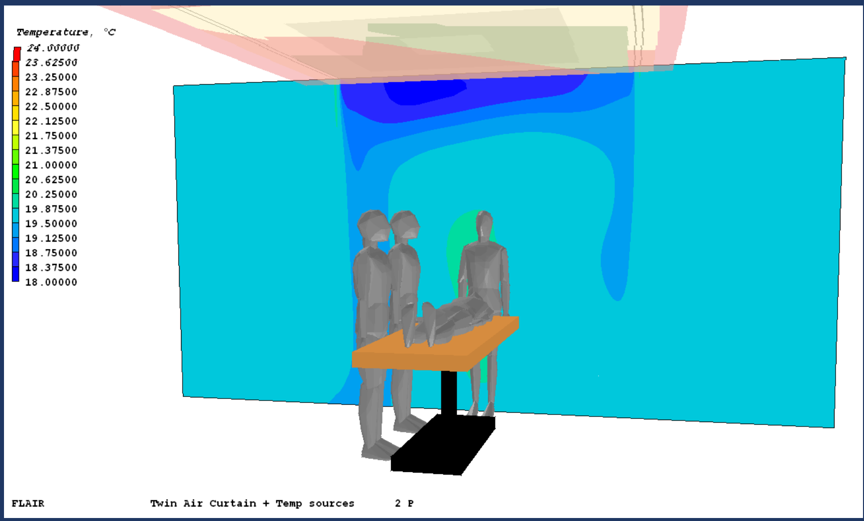
The primary components of the CFD model (shown above) consist of:

A. Laminar Flow Diffusers supplying @ 20.8˚C; [Ambient = 22.0˚C];
B. 4 x 2-slot Air Curtain Slot Diffusers, supplying air slightly angled away from vertical
   a. 2 x 2500 x 2 x 10mm slots, supplying @ 20.8˚C;
   b. 2 x 3000 x 2 x 10mm slots, supplying @ 20.8˚C;
C. Total Expected Air Change Rate = >25 AC/h
D. Extract grilles;
E. Pressure stabilizers to maintain internal pressure;
F. Aluminium equipment storage cabinet @ 28.0˚C;
G. People (Patient + 3 # Surgical Staff) @ 4 x 73W;
H. Lighting domes @ 130W.

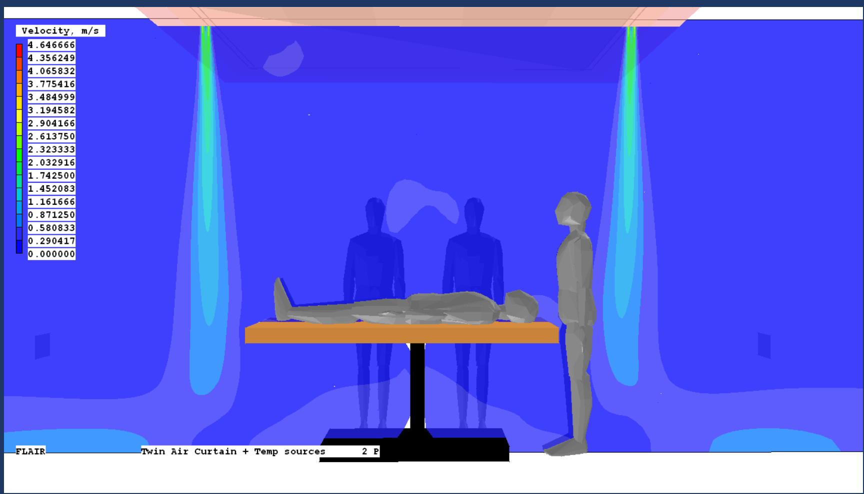
This demonstration case of an operating theatre layout employed ~1.8 million computational cells and ran for 5,000 sweeps, over a weekend (>48 hours) on a 3Ghz single-processor computer. The results are shown below.



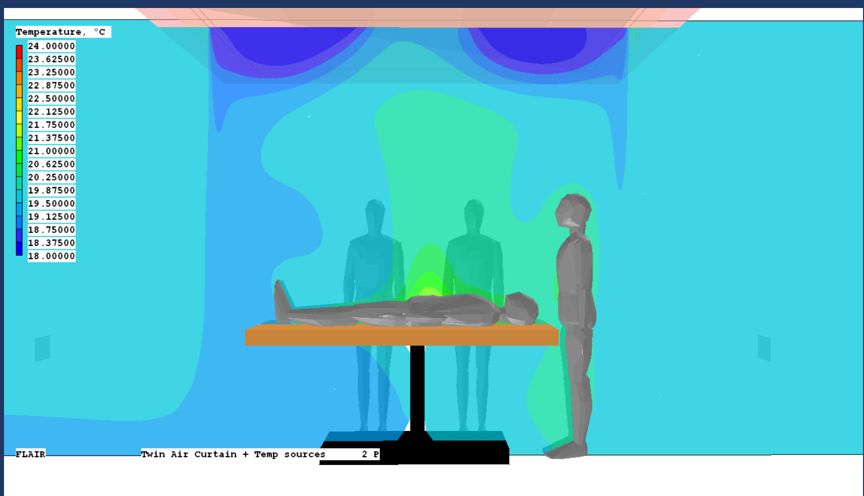
Temperature contours



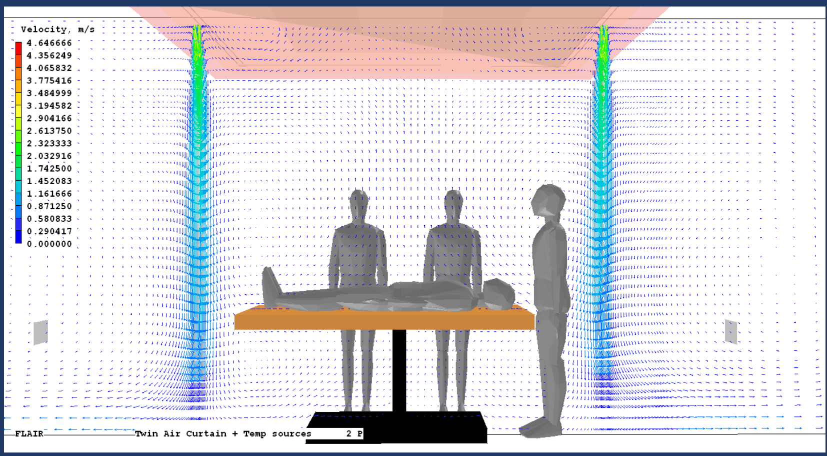
Velocity contours



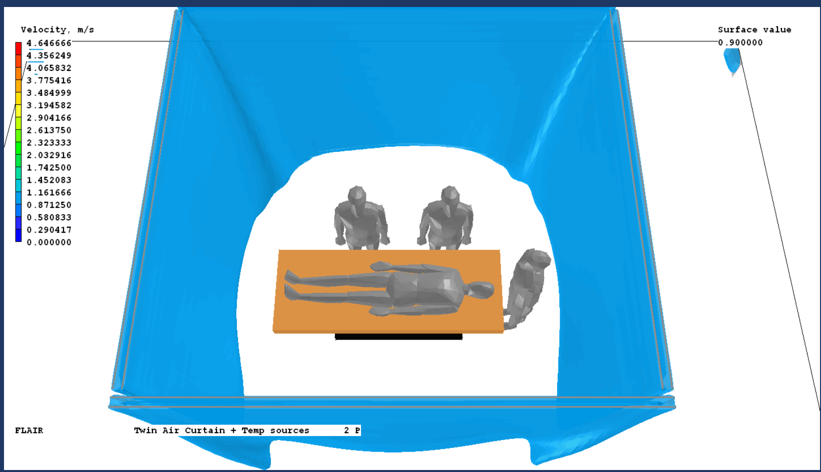
Velocity contours – 60% transparency



Temperature contours – 60% transparency



Velocity vectors



Air curtain Iso-surface at 0.9 m/s

Conclusion

Despite the relative coarseness of the mesh, PHOENICS captures the detail of the air curtain and demonstrates its effectiveness for the conditions specified.

The velocity contours and vectors confirm that the air region within the surgical procedure is effectively contained by the air curtain. Equally, the temperature contours and iso-surface plots indicate that the temperature of the contained air remains contained and separate from its surroundings.

The steady-state model can also be used to predict the mean age of air, track the movement of particulates and plot the dispersion of bacteria concentrations or pollutants.