PHOENICS Case Study: HVAC
CFD Simulation of Air Flow and Residence Time in a Clean Room

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.

Typical layout of interconnecting clean rooms in bio-technology site

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 pharmaceutical factory in which several interconnecting clean rooms reside. The simulation is primarily concerned with flow variables such as the resultant velocity, temperature, mean age and mass fraction of air produced by laminar air flow (LAF) units.

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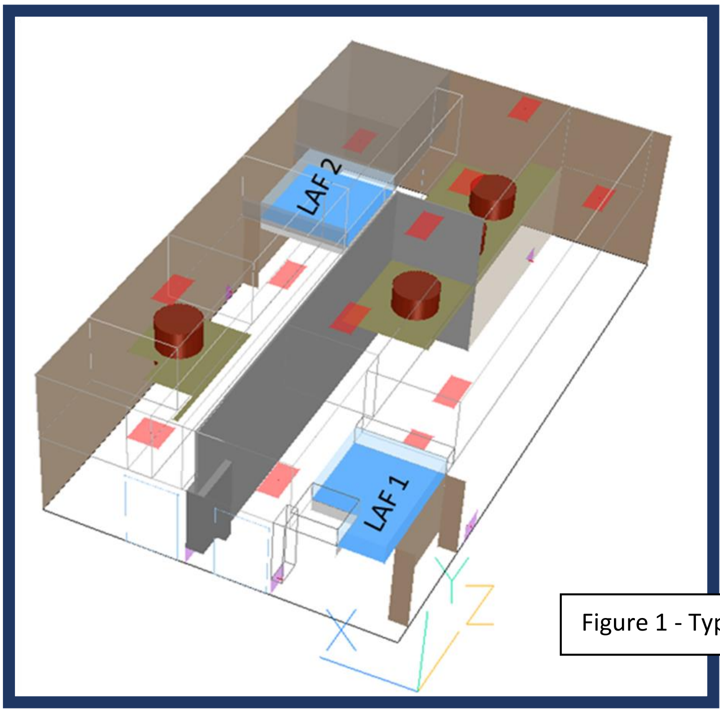

In this example, there is predominantly "new" or filtered air beneath the LAF units that extends down to near-floor level. This LAF air is usually delivered at about 22˚C with air close the ceiling lights becoming a little warmer (~23˚C) and elsewhere in the room about 21.5˚C.

The mean age of air represents the average length of time air has remained in the room, or “residence time”, before it is replaced by "new" or fresh-air. The mean age of air increases away from the influence of inlets and extracts.

Figure 1 - Typical equipment layout in CFD model

Figure 1 above represents the plan view of the ceiling diffusers, extracts, return air, LAF units and lighting arrangement used in the CFD model**.** The ceiling diffusers are represented as a volume flow rate.

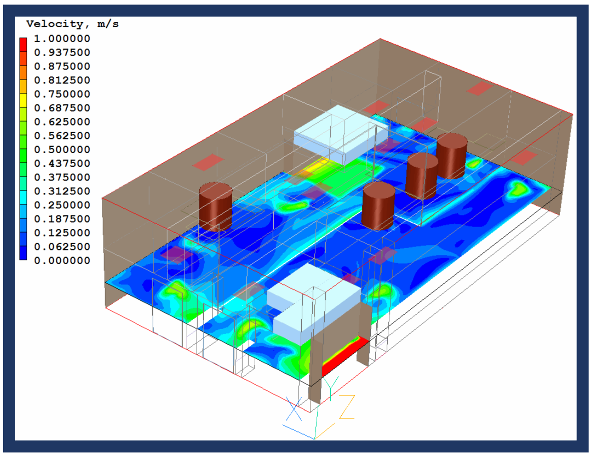

Figure 2 - air velocity @ 1.2m height

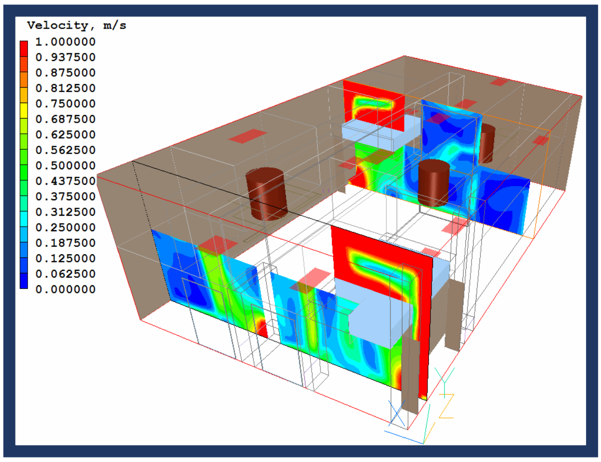

Figure 3 - air velocity @ vertical cross-section

Figures 2 and 3 provide an isometric view of the air velocity across the clean room. Coupled with corresponding plots for mean age of air, this type of image can highlight the regions of high and low circulation and potential for ‘dead’ zones.

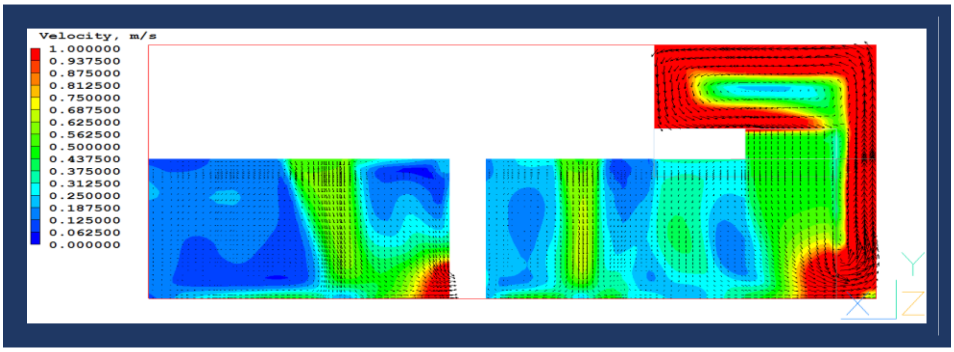

Figure 4 - Velocity Contours [vertical plane]

Figure 5 - Mean Age of Air Contours

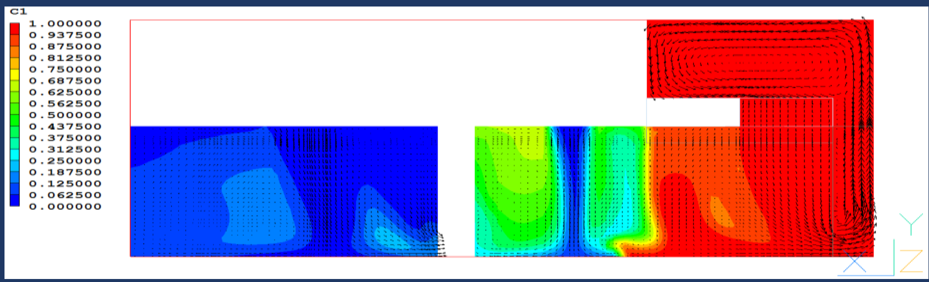

Figure 6 - Mass Fraction of LAF Air Contours

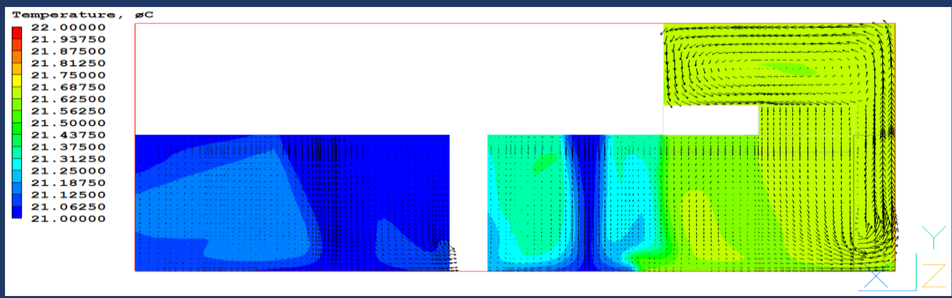

Figure 7 - Temperature Contours

Figures 4 to 7 present plan views of velocity, mean age of air, mass fraction of LAF air and temperature contours respectively at a vertical section. The images demonstrate the relative effects upon the air flow of the two diffusers, the extract and an LAF return duct. The air can be seen returning to the LAF plenum through the return duct showing that the “oldest” air is located between the ceiling diffusers.