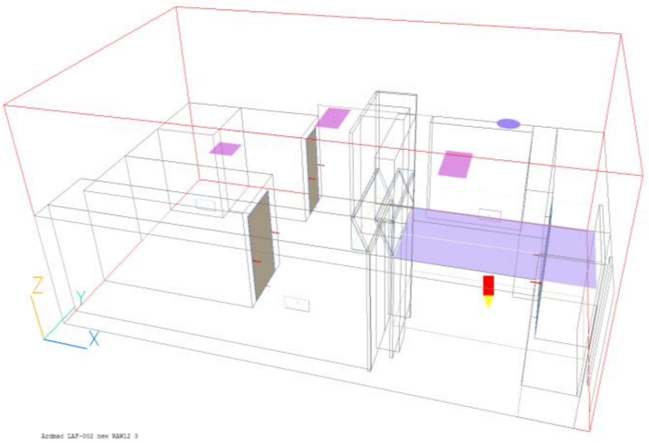
CHAM Case Study: HVAC - Cleanroom Investigation for LAF Unit Optimisation

By Timothy Brauner, CHAM, November 2018 / PH-2018 1.2

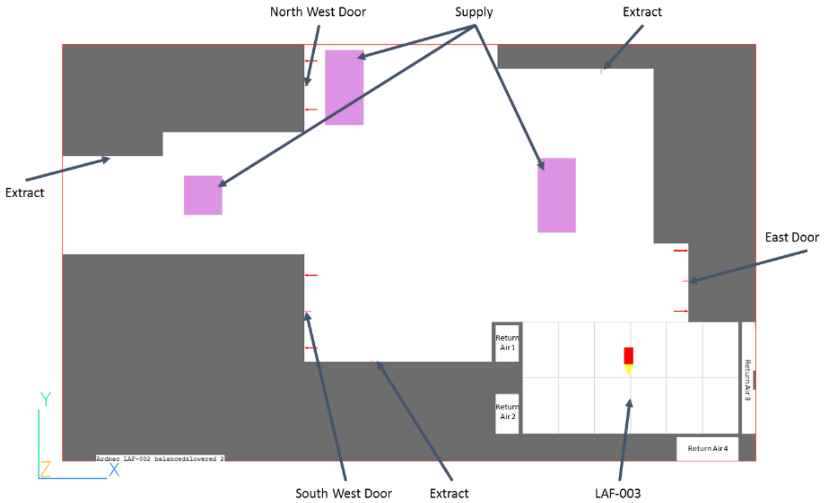
Irish construction company, Ardmac (www.ardmac.com) is a leading provider of high-tech data centre and cleanroom solutions. Required to retrofit Laminar Air Flow (LAF) Units into an awkwardly-shaped cleanroom configuration, Ardmac sought CHAM's assistance to ensure uniform air distribution from each LAF unit to the workbench surface below.



A 3D CFD model was built from 2D CAD plan drawings, provided by the client. The dimensions of the domain containing the LAF unit cleanroom were ~11.5m x 7m x 5m. Figure 1 shows a perspective view and a plan view of the room. Walls, floor and ceilings that obstruct the view have been hidden.

The larger purple panel represents the LAF unit and the three smaller panels the ceiling supplies, modelled as air inlets. The LAF is made up of an array of 2-by-6 filters producing a total flow rate of ~2m^3/s.

Figure 1 – Perspective (top) and plan (bottom) views of the cleanroom

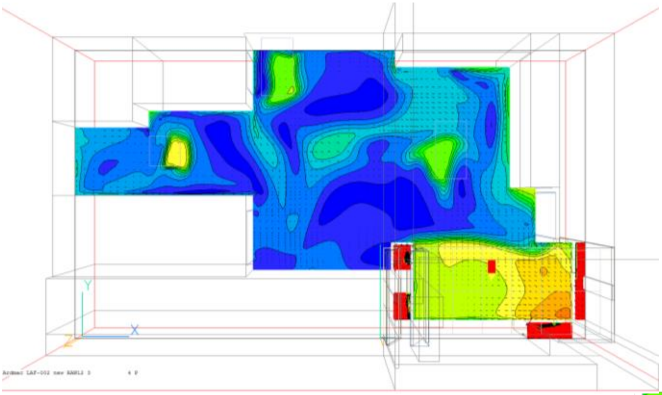


The LAF is supplied via four return air ducts that intake air near the ground directly beneath the LAF and feed it back to a plenum chamber above, supplemented by an additional ceiling supply. The two separate return air ducts located on the right side of the LAF lead straight to the plenum chamber from below, while those on the left follow a path with several bends.

The room has three ceiling supplies: a small supply to the left and two larger ones.

There are three extracts near the ground distributed around the cleanroom. One extract is used to balance the flow leaving/entering the room and thus maintain the room at 30 Pa over atmospheric. The other two extracts operate at flow rates of ~0.3m^3/s. The brown panels represent two doors and a hatch to the cleanroom. The gaps of all doors are modelled as outlets with pressure differences of 7.5 Pa. A 300mm shroud is attached to the ceiling along the edge of the LAF that faces the room. The temperature in the room, assumed to be constant, is not included in the simulation. The computational mesh is refined near walls, inlets, outlets and ducts which produced a total grid size of ~1.8m cells.

The simulation results at work bench height of 1.2m are shown. Contours are presented on two horizontal sections (top-down) and one vertical section (side-on). For clarity the velocity contour scale is limited to a maximum of 0.6 m/s and any "red" areas indicate a velocity of 0.6 m/s or greater.



The yellow and orange region in the bottom right is the dominant flow feature of the room and represents the sinking air beneath the LAF. The red regions around it represent the high velocity air in the return ducts leading to the plenum chamber. The yellow and green regions inside the room represent flow from the three ceiling supplies towards the ground, and flow induced by the supplies and LAF.

Figure 2 – Air velocity at 1.2m height.

Error! Reference source not found. shows a zoomed-in view of the plane directly under the LAF, at work bench height, covering the same area as the LAF. The orange region in the bottom right corner and yellow regions indicate areas with high velocities. In these areas the air is accelerating towards the return air duct intakes, as well as some air spilling out of the LAF into the room. Blue and turquoise indicate low velocity regions round the sides, where interaction with walls and air from the room takes place.

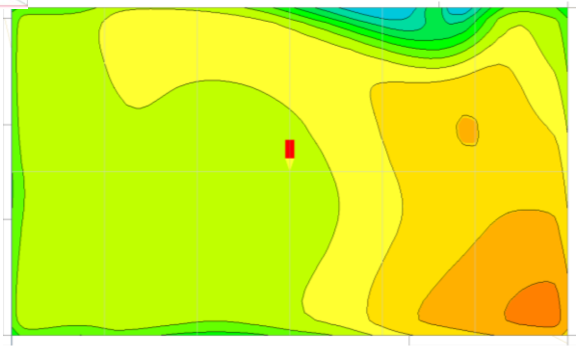


Figure 3 – Zoomed view of velocity at workbench directly beneath LAF unit

It was noted that the lowest velocity appeared to be caused by air from the room's interior encroaching upon the LAF region.

The side view in Figure 4 shows a plane at the centre of the LAF. The air descends uniformly before slowing down closer to the ground with some of it spilling out into the room. The air rotation to the right of the LAF is caused by LAF air and ceiling supply air interacting with the nearby walls.

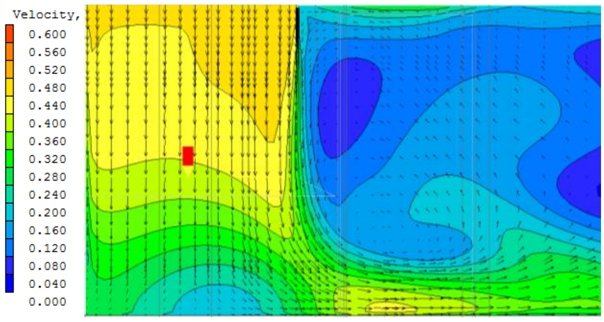


Figure 4 – Side On view showing velocity on a section across the middle of the LAF unit

The contour plots reveal that the air from the LAF initially travels downwards at the specified filter unit velocities and becomes deflected towards the air ducts and the open side of the room. However, there is a notable acceleration towards the bottom right corner, whilst also entraining new air from the room. The plots confirm that air in the clean room nearby to the LAF rotates steadily, having been driven by air leaving the LAF, air from the ceiling supplies, and by their joint interaction with walls. This entrainment and rotation process was considered to be the likely cause of low velocity regions at the surface edge.

To judge the operational efficiency of the LAF unit, it was necessary to ensure that the filtered air reaching the surface of the workbench immediately below the LAF unit was both uniform and within an acceptable velocity tolerance. For this purpose the surface at work bench height was divided into 12 equidistant columns and 8 rows. In each rectangle velocities were spatially averaged and compared to target value. (Numerical values withheld).

A further simulation demonstrated that a small adjustment and repositioning of the ceiling supplies reduced their overall effect upon the cleanroom's central region and consequential influence upon the workbench surface. This change permitted the LAF unit to deliver filtered air to the workbench surface within acceptable tolerances.

The case demonstrates the ability of CFD simulation to confirm whether or not equipment will operate to specification within unusual environmental conditions, and to investigate the effectiveness of remedial actions on a cost-effective basis prior to physical testing of the preferred solution.