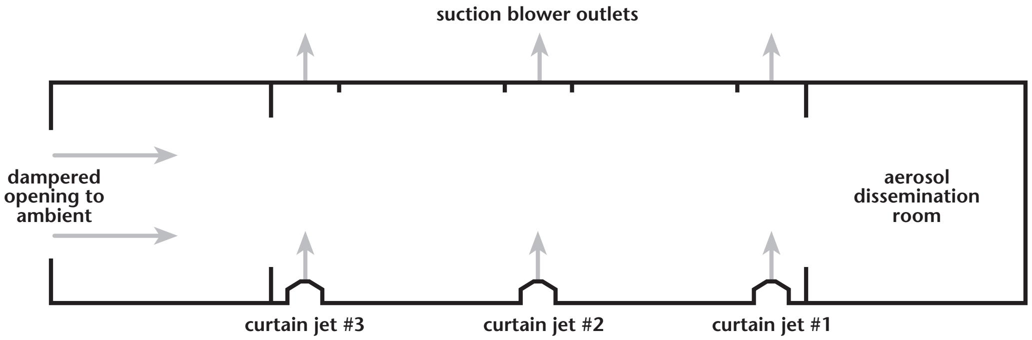
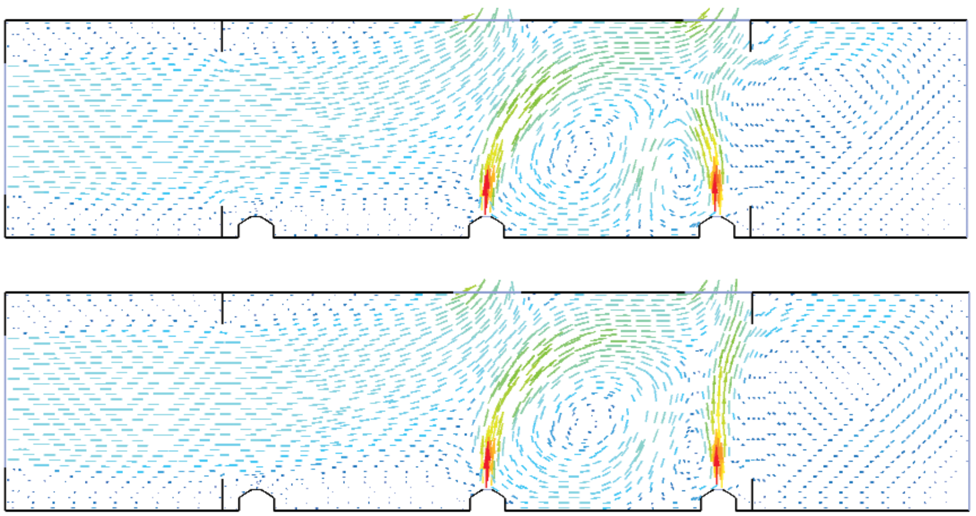
Closing Air Curtains on Aerosols

by Stephen Ricci and James Saunders, Battelle Science & Technology International, Columbus, OH



Schematic of experimental containment facility (top view), 19 m long and 4 m wide; the curtains and filtered blower outlets are oriented vertically (into the page) and are 3 m high; air is drawn in through the dampered opening at left because the blowers draw more air than the curtains emit



In the original arrangement, curtains #1 and #2 oscillate during operation; curtain #1 (right) flaps to the left at one time (top) and to the right at a later time (bottom)

The U.S. Army is building a large test facility to evaluate instruments for the optical detection of chemical and biological agents from 5 km away. The facility will disperse chemicals that optically simulate agents in a chamber to calibrate and test the instruments. The facility is large: the test chamber is 15 x 18 m^2 in cross-section and 135 m long. An optical port 3 m in diameter is located at each end of the chamber. Unfortunately, the optical ports cannot be conventional windows because unlimited optical access is required over a wide range of wavelengths. The simulants, while benign compared to the chemical and biological agents, must still be contained within the chamber and only allowed to exit through filters. Consequently, large air curtains have been put to use instead of windows.

Battelle used CFD and experiments to design the air curtain containment system. To represent one end of the test section, two large rooms are connected by a 9m long air curtain chamber, with a large port between each room and the air curtain chamber. One room serves as a dissemination chamber and is completely enclosed except for the port to the air curtain chamber. The opposite room has an opening to the ambient, simulating the optical port. The air curtain chamber has three air curtains. Opposite each curtain is a large suction blower, which is designed to pull in the air curtain flow and surrounding air, filter it, and discharge it.

The experimental objectives were to demonstrate a five-order-of-magnitude concentration drop from the dissemination chamber to the ambient. The first experiments were promising because the required containment was achieved. However, smoke visualization showed curtain oscillations when more than one curtain was operating, a result that FLUENT predicted accurately.

Physically, the oscillations are caused by the instability that develops when the curtains interact with different surrounding pressure regions and with each other. When curtain #1 fluctuates toward curtain #2, the pressure rises between the curtains, and forces them apart. This is complicated by the colliding secondary flows from the air curtains as they fluctuate toward each other. Curtain #2 is prevented from swinging away from curtain #1 because ambient air is flowing hard into the #2 blower outlet. The pressure rise then pushes curtain #1 away. When it does, the pressure drops between the curtains, drawing the curtains together once again, and the oscillation continues.

Based upon the CFD predictions, Battelle modified the curtain placement to generate a stable vortex pattern between the air curtains. Both model predictions and experiments in the test facility verified the required containment and stable operation. By using the unsteady modeling capabilities of FLUENT to offer insight into the physics of air curtain oscillations, a design that met the performance targets could be found in a cost effective manner. ■