Jet flows **and good mixing**

OUTDOOR air flows, be they gentle breezes or gale-force winds, are usually easy to detect. Step inside a building though, and the air flows are not so obvious. But just as natural winds affect the movement of pollutants outside, air flows inside buildings affect how pollutants, and temperatures, are dispersed.

According to Murray Rudman from CSIRO's Division of Building, Construction and Engineering, good mixing of air inside buildings is important, because it can speed the dispersion and dilution of pollutants. Good mixing also contributes to more even patterns of heating and cooling.

Rudman uses computational fluid dynamics to study the different kinds of air flows that occur both inside and outside buildings. The information can be used to investigate problems related to air quality.

Many of the situations studied involve a type of air flow known as a jet. Put simply, a jet is a constant source of moving fluid that issues into slowly-moving surroundings. Jets may be any shape. Their flow patterns and mixing properties can vary enormously and depend on factors such as jet shape, background air flow and the geometry of the site. 'Good mixing' occurs when jet fluid and or background fluid are efficiently combined.

A cylindrical jet issuing into a stationary surroundings is one of the simplest jet flows and is a good approximation to a chimney stack on a still day, or a jet exhaust from an aircraft on the tarmac. Such a jet is shown in Figure 1.

The flow is from left to right and the grey surface represents the air that enters the picture inside the jet. The red surface represents regions of low-pressure air. These indicate how the instability is operating in this example. It can be seen that the cylindrical jet travels a short distance then rapidly breaks up due to instabilities. Once the instability takes effect, the jet disperses rapidly.

Parameters such as the velocity of the jet, the jet velocity profile, and how hot the jet is compared with its surroundings, will influence the way the instability operates. The instability, in turn, will influence such things as the noise generated from the jet (if it is flowing very quickly) and the efficiency of mixing that may result from the jet flow.

Another quite common jet type is one that issues into a surrounding air flow that is moving perpendicular to the jet. This is usually termed a jet in a cross-flow. A good example is a chimney stack on a windy day: the wind moves parallel to the ground and the jet moves vertically. Other examples are smoke plumes from fires, exhaust fans on the sides of buildings, air-conditioning ducts issuing into draughty rooms and junctions in air-conditioning ducts.

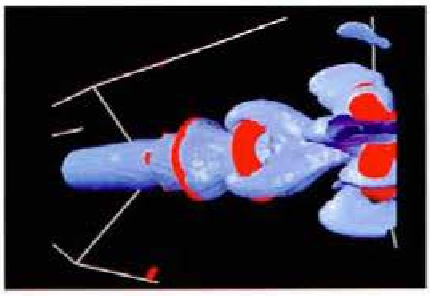

Figure 1. A cylindrical jet issuing into stationary surroundings.

Figure 2. A jet in a cross-flow.

Figure 2 shows an example of a jet in a cross-flow. The jet is similar to that in Figure 1, but in this case issues vertically. The cross-flow is from left to right. Again, the grey region represents air that issued within the jet, and the red and blue regions represent fluid that entered the domain upstream from the jet near the floor. Clearly seen is the bending of the jet by the cross-flow. Instabilities are again evident in the large expansion of the jet downstream.

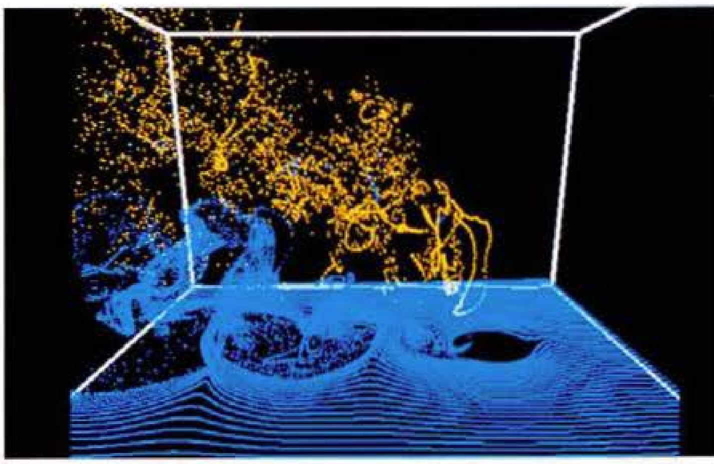

Figure 3. A particle visualisation of the jet in a cross-flow.

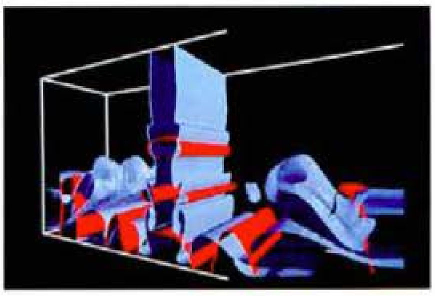

Figure 4. A rectangular jet impinging on a wall.

Of interest in this figure are the red and blue regions of air that can be seen lifting up off the floor. This suggests that this type of flow may mix air from near the floor into the jet.

Another way of visualising this flow is to seed the edge of the jet with particles and follow their progress as they move with the jet. This type of visualisation is much like simulating smoke dispersal from a chimney stack.

A particle visualisation of the jet in a cross-flow is shown in Figure 3, with the yellow particles entering the flow in the jet and the blue particles entering in the cross-flow near the bottom wall. The yellow particles are dispersed quickly, and spirals of blue particles that have been lifted off the floor are beginning to mix with jet particles at the right of the figure.

The mixing of this jet flow is experimentally observed to be considerably better than that of a standard jet, and is a result of different instabilities that operate in the jet in a cross-flow. The mixing in this case is also dependent on the relative speeds of the jet and the cross-flow, whether or not the jet issues through a hole in a flat plate of through a chimney, and whether the jet is at the same temperature as the surrounding air.

A third example of a jet is one that issues into still surroundings, but then hits or impinges on a wall. This jet flow is sometimes called an impinging jet. Examples of impinging jets are air-conditioning vents that exhaust from the ceiling and hit the floor, or vents that exhaust sideways in a corridor and hit the opposite wall.

An example of a rectangular jet impinging on a wall is given in Figure 4. Once again, the grey surface represents fluid that issues inside the jet and red represents regions of low pressure. The jet flow is from top to bottom. Different instability mechanisms operate in the impinging jet, and a variety of behaviours can be seen, depending on factors such as distance from the jet exit to the wall and speed and temperature of the jet.

Clearly the presence of the wall will have a large influence on the direction in which the air may travel. Mixing in the impinging jet can be good, and recirculation currents are set up by the jet and its subsequent diversion by the wall.