Flow Tracers

Particle Streaks

The commonest flow visualization technique involves the introduction into the flow of small visible particles. By viewing or photographing the pathlines or streaklines of those particles, an image of the fluid motion is obtained. A wide variety of "particles" are used for this purpose. In gas flows, as illustrated in Figure 1, dense smoke is most commonly used for this purpose and, before the advent of more modern techniques, "smoke machines" were a common tool in wind tunnel facilities. Another alternative in gas flows as

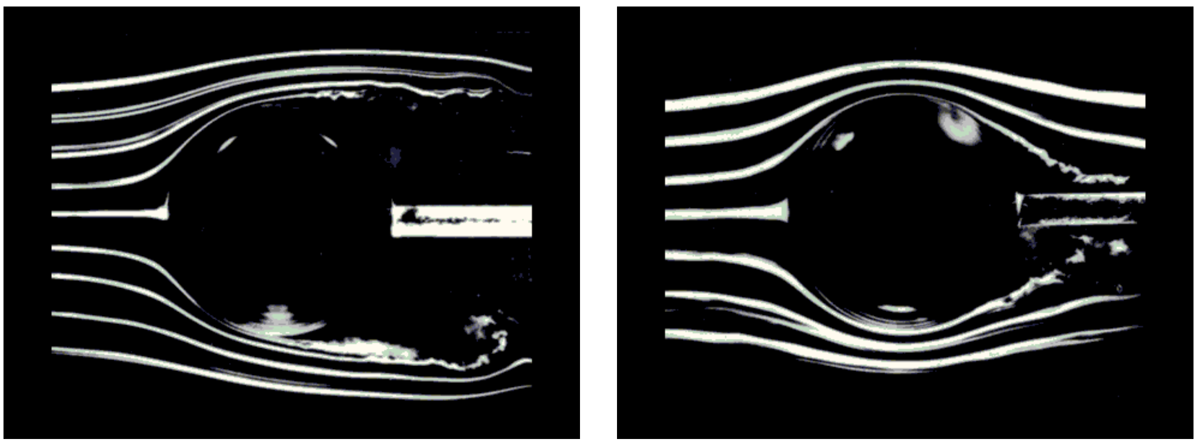

Figure 1: Smoke visualization of steady flows (from left to right) past a sphere showing, on the left, laminar separation and, on the right, turbulent separation. Photographs by F.N.M.Brown, reproduced with the permission of the University of Notre Dame.

illustrated in figure 2 is the use of a very fine mist of oil drops. Corresponding techniques in liquid flows

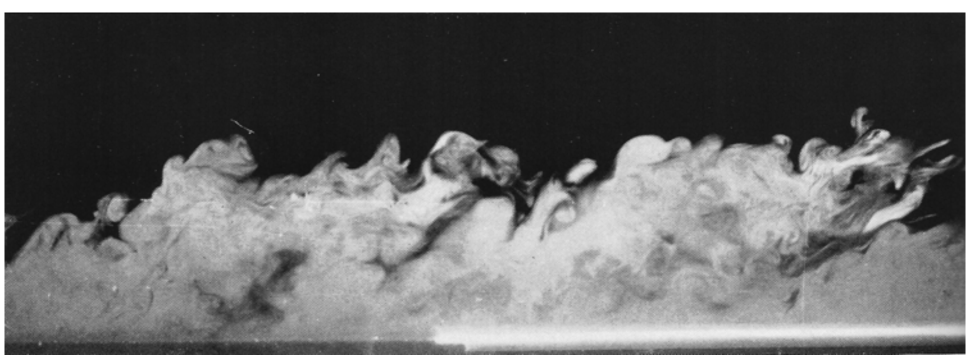

Figure 2: Oil mist flow visualization of a turbulent boundary layer in a wind tunnel. Photograph from Falco (1977).

include injection of a small, concentrated stream of dye (often potassium permanganate or vegetable dye) or colloidal dust (as exemplified in figure 3), the addition to the water of aluminium dust or the injection of very small bubbles (as illustrated in figure 4).

In order to accurately trace out the streamlines of a flow, these methods require two conditions. First the "particles" must accurately follow the flow and to achieve this it is essential that the particles be very small and close to neutrally buoyant. Section (Nej) presents an analysis of the relative motion of particles

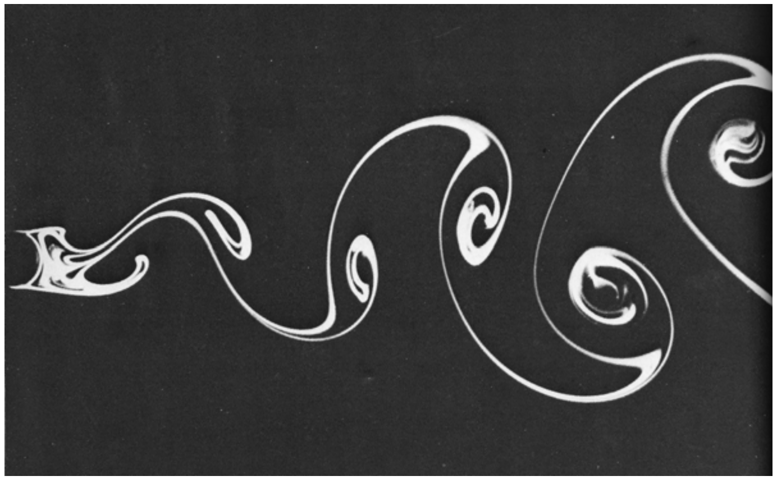

Figure 3: Colloid visualization of the vortex street behind a circular cylinder in water. Photograph by S. Taneda.

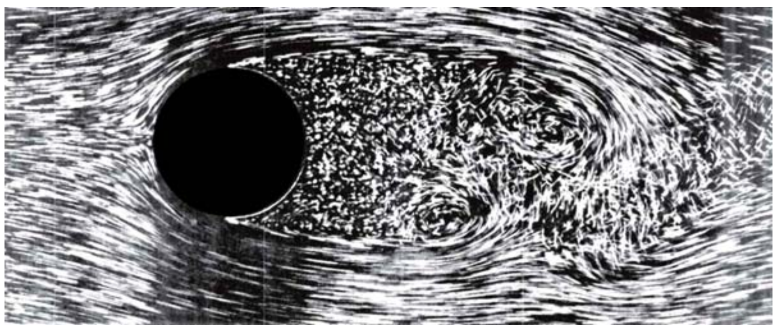

Figure 4: Flow around a cylinder at $Re = 2000$ visualized by air bubbles in the water. ONERA photograph by Werle and Gallon (1972).

in a flow and demonstrates how this requires the particles to be small. The second practical requirement is that the smoke or dye remain visible; turbulent mixing of the smoke or dye can often cause the streak to disappear a short distance downstream of the injection point. Sometimes, this can be overcome by making the initial injection of dye or smoke sufficiently concentrated but this becomes less and less practical in higher Reynolds number flows.

One version of the bubble technique is the use of electrolysis to produce a sheet of very small bubbles distributed across a water flow. A fine wire is stretched taut across the flow upstream of the region of interest and an electric potential is applied between that wire and another metal boundary of the flow (usually the water tunnel wall). Voltage differences used are (typically a few volts), enough to produce a steady stream of small bubbles shed from the wire. Often the applied voltage is a pulse that produces a bubble streak whose length at each lateral location along the wire is therefore proportional to the velocity of the flow at that lateral location. This allows a visible manifestation of the fluid velocity distribution.

Surface Streaks

Frequently, the primary interest is to detect the condition of the flow close to a solid surface. For example, in diagnosing the fluid forces on a vehicle it is often important to determine the location(s) and extent(s) of flow separation from the vehicle surface. One common technique in either wind or water tunnel testing is to attach an array of fine (but visible) lengths of thread to the surface. As illustrated in figure 5 these will indicate whther the local surface flow is in the principal direction of flow or not. Reversed or oscillating threads indicate a separated region of flow and where these threads begin indicates the location of the separation line. Threads or "tufts" of this kind can also be used to indicate whether the local flow is laminar or turbulent, the latter being indicated by unsteady motion of the tuft.

Figure 5: Flow visualization with tufts on an automobile.

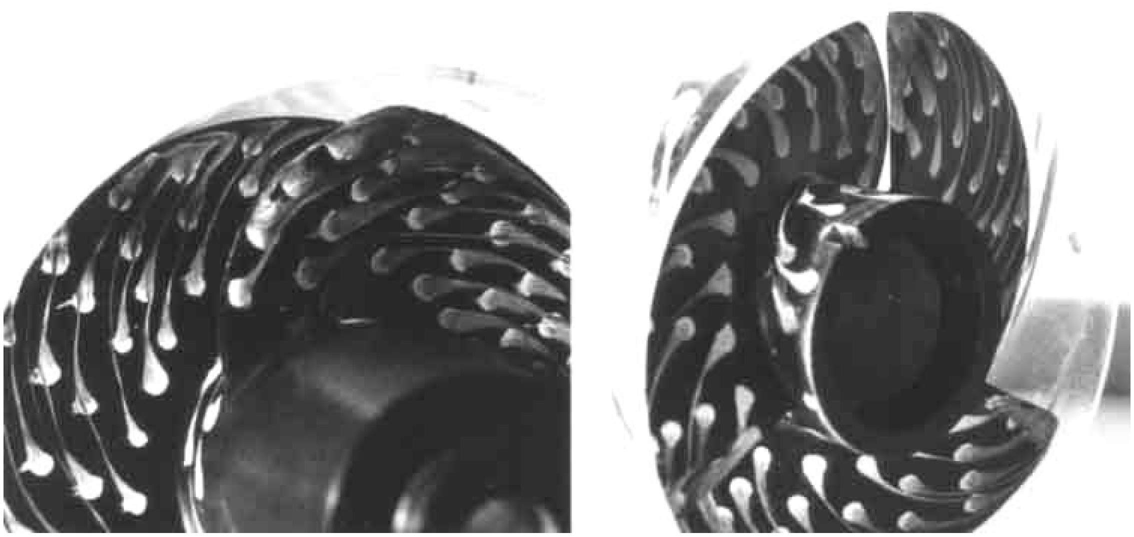

Figure 6: Photographs of a 10.2 cm, 12° helical inducer showing the blade surface flow revealed by the running paint dot technique.

A similar but more rugged technique, illustrated in figure 6, is the "paint dot technique". A trial-and-error mixture of oil paint with some paint thinner is prepared and dots of this very viscous mixture are placed on the surface of a test object (such as a pump impeller) before it is installed in a water flow facility. The object is then run in the facility for some fixed time (chosen again by trial and error) before being removed. Given the right choices the paint should then have run across the object surface indicating the magnitude and direction of the surface flow as illustrated in figure 6. While this technique has the disadvantage of requiring a trial and error procedure, it has the advantage of not requiring visible access during testing and of allowing complete observation of a complex three-dimensional test object.