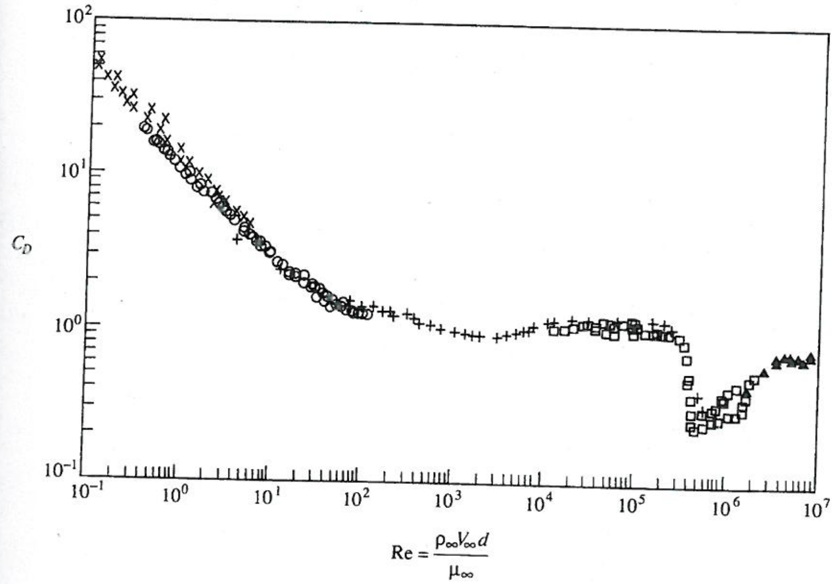

Figure 3.44 Variation of cylinder-drag coefficient with Reynolds number. (*Source:* Experimental data as compiled in Panton, Ronald, *Incompressible Flow*, Wiley-Interscience, New York, 1984.)

layer at the higher values of Re. Why does a turbulent boundary layer result in a smaller C_D for this case? Stay tuned; the answer is given in Chapter 4.

The variation of C_D shown in Figure 3.44 across a range of Re from 10^{-1} to 10^7 is accompanied by tremendous variations in the qualitative aspects of the flow field, as itemized, and as sketched in Figure 3.45.

1. For very low values of Re, say, $0 < \text{Re} < 4$, the streamlines are almost (but not exactly) symmetrical, and the flow is attached, as sketched in Figure 3.45*a*. This regime of viscous flow is called *Stokes flow*; it is characterized by a near balance of pressure forces with friction forces acting on any given fluid element; the flow velocity is so low that inertia effects are very small. A photograph of this type of flow is shown in Figure 3.46, which shows the flow of water around a circular cylinder where $\text{Re} = 1.54$. The streamlines are made visible by aluminum powder on the surface, along with a time exposure of the film.
2. For $4 < \text{Re} < 40$, the flow becomes separated on the back of the cylinder, forming two distinct, stable vortices that remain in the position shown in Figure 3.45*b*. A photograph of this type of flow is given in Figure 3.47, where $\text{Re} = 26$.
3. As Re is increased above 40, the flow behind the cylinder becomes unstable; the vortices which were in a fixed position in Figure 3.45*b* now are alternately shed from the body in a regular fashion and flow downstream.