

Fig. 25.6 • Cross-flow microfiltration through an individual fibre.

through many times. The filtrate, which in this technique is often called the 'permeate', flows radially through the membrane and porous support. The great advantage of this mode of operation is that the high fluid velocity and turbulence minimize blocking of the membranes. Fresh liquid enters the system from a reservoir as filtration proceeds. Because the fluid flow is across the surface, rather than at right angles, this technique is known as cross-flow microfiltration.

The method has been used for fractionation of biological products by first using a filter of pore size sufficient to let through all the molecules equal to or smaller in size than those required, and then passing the permeate through a second filter that will retain the required molecules while passing smaller unwanted molecules. Blood plasma can be processed to remove alcohol and water and prepare concentrated purified albumin using this method. The process has also been used for the recovery of antibiotics from fermentation media.

## Centrifugation

Centrifugal force can be used either to provide the driving force ( $\Delta P$ ) for the filtration process (refer to Darcy's equation above, Eqn 25.1) or to replace the gravitational force in sedimentation processes (refer to Stokes' Law, Chapter 5 and Chapter 6). Centrifuges are often used in the laboratory to separate solid material from a liquid, the solid typically forming a 'plug' at the bottom of the test tube at the end of the process.

## Principles of centrifugation

If a particle (mass =  $m$ , kg) spins in a centrifuge (radius  $r$ , m) at a velocity ( $v$ ,  $\text{m s}^{-1}$ ) then the centrifugal force ( $F$ , N) acting on the particle equals  $mv^2/r$ . The same particle experiences gravitational force ( $G$ , N) equal to  $m \times g$  (where  $g$  = the gravitational constant).

The centrifugal effect ( $C$ ) is the ratio of these two forces, so  $C = F/G$ , i.e.  $C$  indicates how many times greater  $F$  is than  $G$ . Therefore,  $C = v^2/gr$ . If the rotational velocity is taken to be  $\pi d n$ , where  $n$  is rotation speed ( $\text{s}^{-1}$ ) and  $d$  is the diameter of rotation (m), then  $C = 2.01 d n^2$ .

To increase the centrifugal effect, it is more efficient to increase the centrifuge speed than use a larger diameter at the same speed. Larger centrifuges generate greater pressures on the centrifuge wall for the same value of  $C$ , so are more costly to make.

## Industrial centrifuges

Two main types of centrifuge are used to achieve separation on an industrial scale: those using perforated baskets, which perform a filtration-type operation (like a spin-dryer), and those with a solid-walled vessel, where particles sediment towards the wall under the influence of the centrifugal force.

### Perforated-basket centrifuges. (centrifugal filters)

A diagram of a perforated-basket centrifuge is shown in Figure 25.7. It consists of a stainless steel perforated basket (typically 1–2 m in diameter) lined with a filter cloth. The basket rotates at a speed which is typically  $<25 \text{ s}^{-1}$ , higher speeds tending to

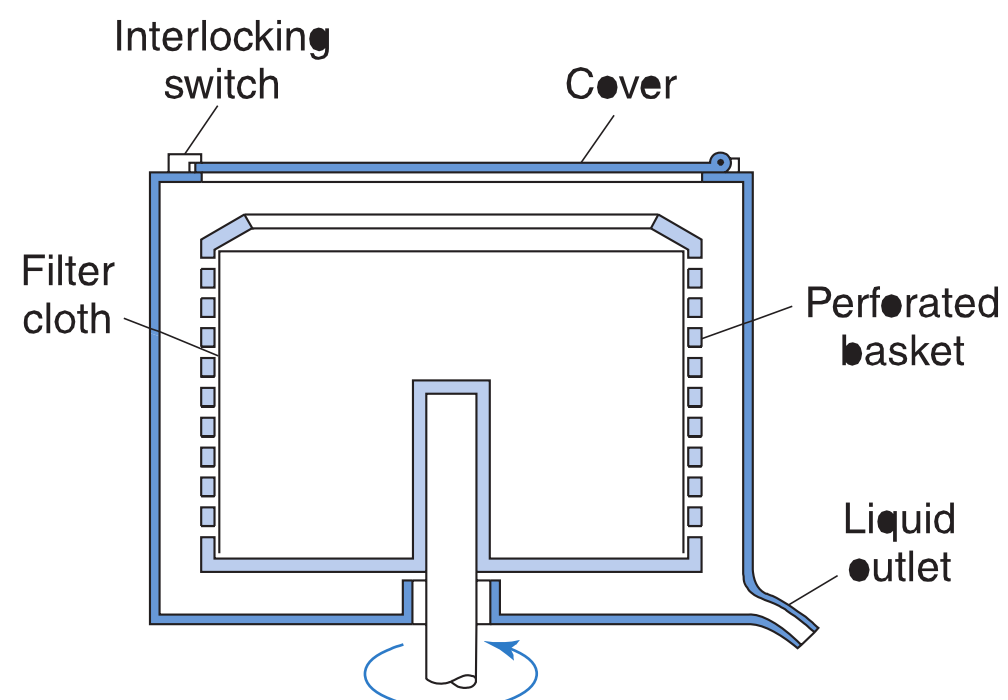


Fig. 25.7 • Centrifugal dewatering filter.