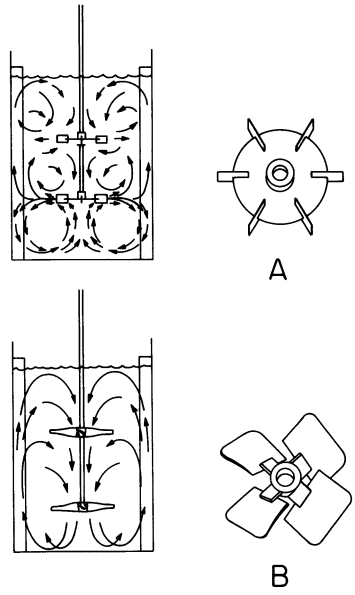

Figure 10.3. Liquid flow in bottled tanks with (A) Rushton radial flow impellers and with (B) axial flow hydrofoil impellers.

Most fermenters are built with a height-to-diameter ratio of 2 to 3, although bioreactors for animal cell cultures tend to be closer to 1. The Rushton impeller diameter is typically 30% to 40% of the tank diameter, while it may reach 50% with the axial flow hydroflow impellers. In large reactors the two main limitations on size are the abilities of the design to provide an adequate supply of oxygen and to remove metabolic heat efficiently. Large reactors usually use either internal coils for heat removal or a jacketed vessel. Although copper coils have better thermal transport characteristics, stainless-steel coils are almost always used, although this choice can depend on the nature of the media and culture. Internal coils provide advantages over jacketed vessels in terms of efficiency of heat removal, owing to the larger surface area for heat transfer. However, in many systems the coils become rapidly fouled by microbial growth, decreasing heat transfer and often adversely affecting mixing. In such cases the jacketed vessel offers advantages.

Another problem often encountered in commercial fermentations is *foaming*. If foam escapes from the fermenter, it can wet filters, increasing pressure drop and decreasing gas flow. Of greater concern is that it provides a pathway for contaminating cells to enter the fermenter. For most products of commercial interest, absolute sterility is required, and contamination may cause the loss of much product, time, and money. Foam can be controlled with a mechanical foam breaker or the addition of surface-active chemical agents. Although such chemicals can be very effective in controlling foam, there are penalties. Foam-breaking chemicals usually lower k_La values, reducing the reactor's capacity to supply oxygen or other gases, and in some cases they can be inhibitory to cell growth. Foam formation is not well understood, but complex media or the formation of high levels of extracellular polymers (e.g., proteins) tend to promote foaming. Foam can limit the ultimate productivity of a fermenter. All stirred-tank fermenters provide head space for the gas to disengage from the liquid. The *working volume* (the amount of culture) in a fermenter is typically about 75% of the total fermenter volume.