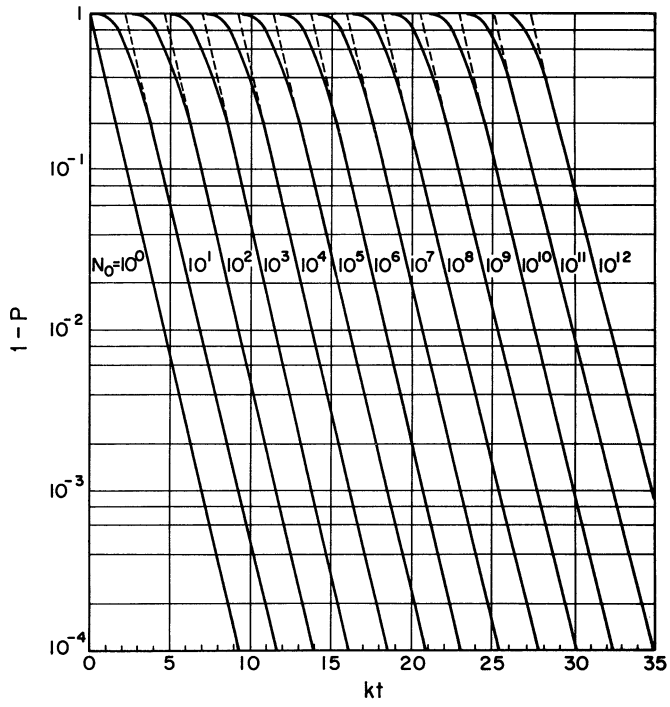

Figure 10.14. Sterilization chart. (With permission, from M. L. Shuler, *Encyclopedia of Physical Science and Technology*, Vol. 2, p. 427, Academic Press, New York, 1987.)

and cool-down periods are very rapid. Continuous sterilization is easier to control and reduces downtime in the fermenters. Two potential disadvantages of the continuous process are dilution of the medium with steam injection and foaming. The flow pattern inside the pipe is critical, since the fluid residence time near the wall can be different from that in the center. The average flow rate and the length of the sterilizing section should be designed to ensure high Peclet numbers (above 500), so that the velocity distribution approaches piston-like flow.

In addition to steam sterilization, process fluids can be filter sterilized. *Filter sterilization* is necessary when the medium contains heat-sensitive materials. An important example of filter sterilization in bioprocesses is the sterilization of medium to support the growth of animal cells. Microporous filters (pore sizes $< 0.2\ \mu m$) are typically used. The filters should be absolute filters; no pores larger than the nominal pore size must exist. A very narrow pore-size distribution is advantageous. The medium may be first prefiltered to remove large particulates that might plug the microporous filter. The actual microporous filter must be sterilized. The equipment that receives the filtered–sterilized fluid is also sterilized.

Filter sterilization is not as reliable as steam sterilization. Any defect in the membrane can lead to failure. Viruses and mycoplasma (small wall-less bacteria) can pass the filter. Consequently, filtered–sterilized medium is usually quarantined for a period of time