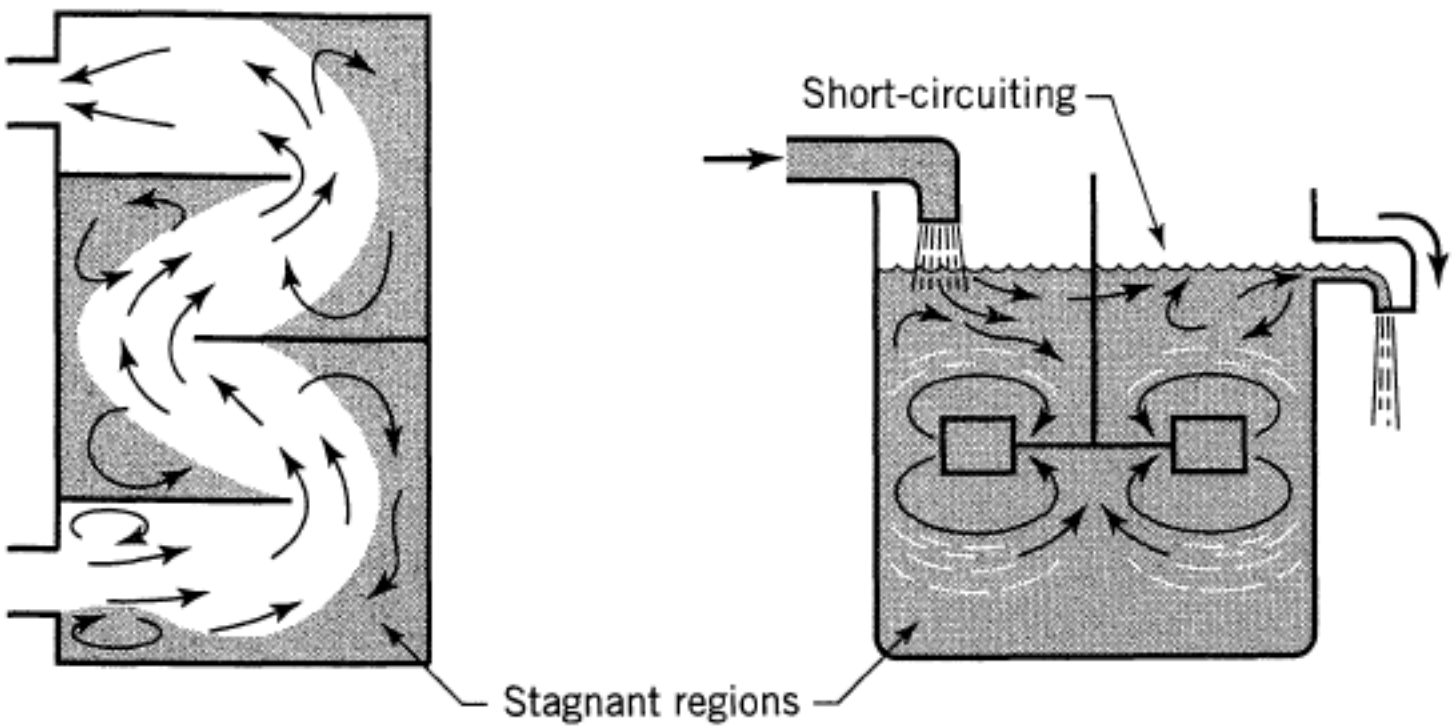
Introduction to Non-Ideal Flow in Reactors

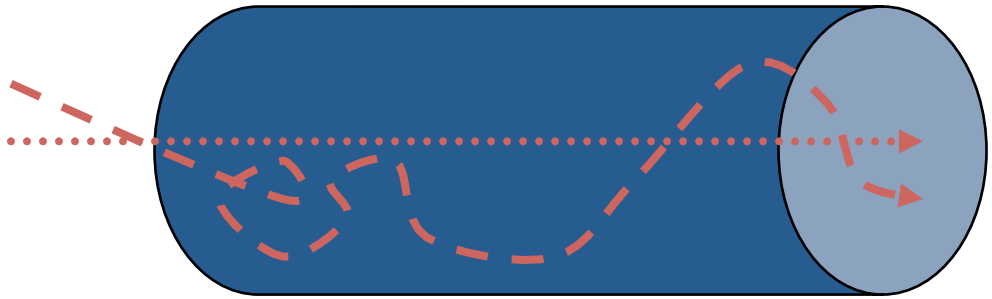

Short-circuiting
Stagnant regions

Residence Time Distribution

- Flow in reactors deviates from ideal flow for various reasons:
  - Channeling of Fluid
  - Recycling of Fluid
  - Stagnant Regions (dead space) in Vessels

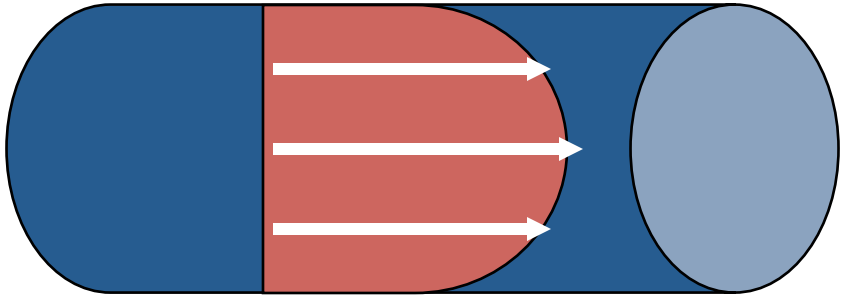
- Non-Ideal flow is accounted for by the Residence Time Distribution (RTD).

RTD: Particle Flow Path



- RTD accounts for the different times that various particles will take to exit the reactor due to the infinite number of paths that each particle can potentially follow.
- For example, a particle that follows the dotted line in the above figure will have a much shorted residence time in the tube than a particle that follows the dashed line.

RTD: Particle Flow (cont.)



- When laminar flow occurs the particles at the center of the stream will move faster than those at the edges. Therefore, they will spend less time in the reactor and have a shorter residence time.

Exit Age Distribution

- E, exit age distribution, is the normalized residence time distribution
- The fraction of the flow exiting the reactor at a given time is described by the E(t) curve.
- Normalized relationship is represented by:

$$\int_0^\infty \mathbf{E}\, dt = 1$$

- Note: The units of E are time^{-1}.

Exit Age Distribution (cont.)

- Graphically, the exit age distribution is represented by:

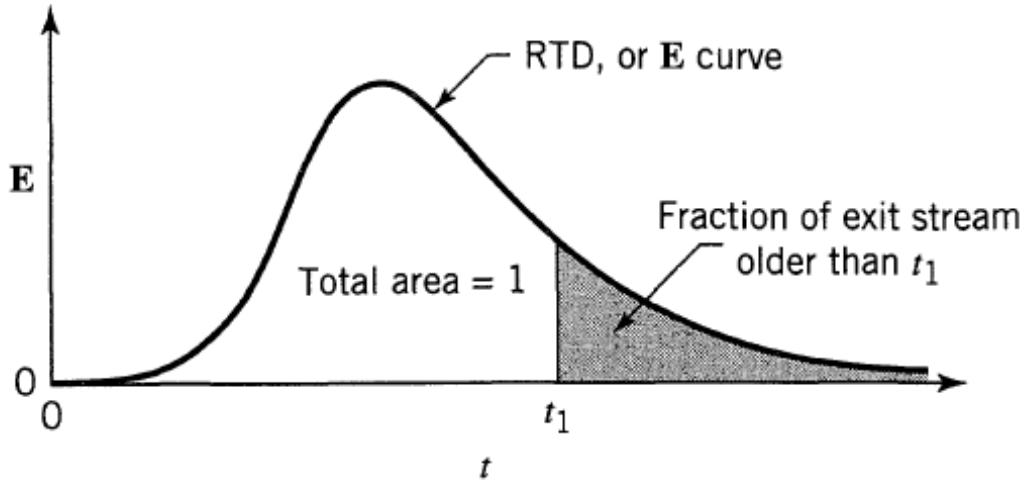
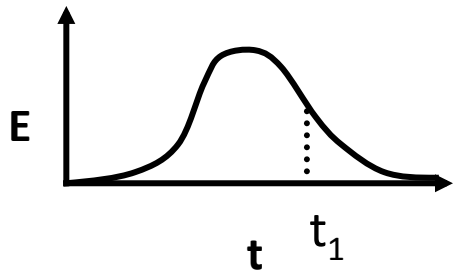


Figure 11.6 The exit age distribution curve **E** for fluid flowing through a vessel; also called the residence time distribution, or RTD.

Exit Age Distribution (cont.)

- Note that the total area under this curve is equal to one.
- The portion of the area to the right of t_1 is the fraction of the exit stream older than the time t_1.
- The area to the left of t_1 is the fraction of the exit stream younger than time t_1.

$$\int_{t_1}^{\infty} \mathbf{E}\, dt = 1 - \int_{0}^{t_1} \mathbf{E}\, dt$$



Food Application of RTD: Thermal Processing

- When a thermal process is designed it is critical that the residence time distribution of the processing device be considered.
- For example, if orange juice is being pasteurized using a heat exchanger it is possible that some particles of the juice will spend a considerably longer period of time in the heat exchanger than others. The end result will be differing degrees of pasteurization within the fluid. For instance, if the particles that have a shorter residence time are harmful microorganisms or spores the product will have a reduced shelf life.