Flow Across Tube Banks

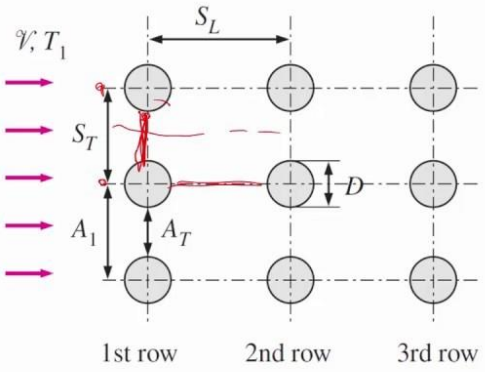
- *For in-line arrangement*
  - The conservation of mass can be expressed as

$$\rho \mathcal{V} A_1 = \rho \mathcal{V}_{max} A_T$$

$$\mathcal{V} S_T = \mathcal{V}_{max}(S_T - D)$$

  - Then the maximum velocity becomes

$$\mathcal{V}_{max} = \frac{S_T}{S_T - D}\mathcal{V}$$



$$A_1 = S_T L$$
$$A_T = (S_T - D)L$$
$$A_D = (S_D - D)L$$

Turbulent Flow in Pipes

Turbulent Velocity Profile

- The velocity profile is parabolic in laminar flow but is much **fuller** in turbulent flow, with a sharp drop near the pipe wall.
- Turbulent flow along a wall can be considered to consist of four regions, characterized by the distance from the wall. The very thin layer next to the wall where viscous effects are dominant is the **viscous** (or **laminar** or **linear** or **wall**) sublayer.