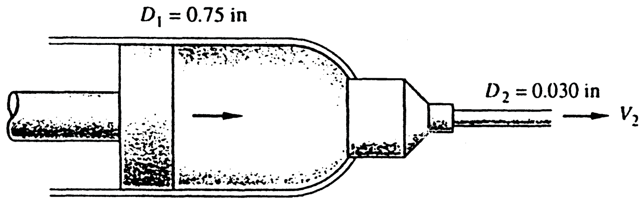


Solution: (a) For incompressible flow, the volume flow is the same at piston and exit:

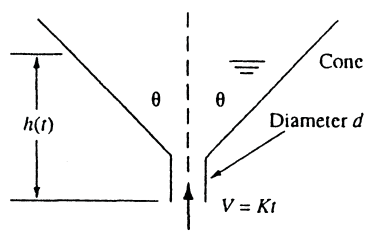
$$Q = 6\ \frac{cm^3}{s} = 0.366\ \frac{in^3}{s} = A_1V_1 = \frac{\pi}{4}(0.75\ in)^2 V_1,\quad solve\ V_{piston} = \mathbf{0.83}\ \frac{\mathbf{in}}{\mathbf{s}}\quad Ans.\ \text{(a)}$$

(b) If there is 10% leakage, the piston must deliver both needle flow and leakage:

$$A_1V_1 = Q_{needle} + Q_{clearance} = 6 + 0.1(6) = 6.6\ \frac{cm^3}{s} = 0.403\ \frac{in^3}{s} = \frac{\pi}{4}(0.75)^2 V_1,$$

$$V_1 = \mathbf{0.91}\ \frac{\mathbf{in}}{\mathbf{s}}\quad Ans.\ \text{(b)}$$

3.24 Water enters the bottom of the cone in the figure at a uniformly increasing average velocity $V = Kt$. If d is very small, derive an analytic formula for the water surface rise $h(t)$, assuming $h = 0$ at $t = 0$.



Solution: For a control volume around the cone, the mass relation becomes

$$\frac{d}{dt}\left(\int \rho\, d\upsilon\right) - \dot{m}_{in} = 0 = \frac{d}{dt}\left[\rho\frac{\pi}{3}(h\tan\theta)^2 h\right] - \rho\frac{\pi}{4}d^2Kt$$

$$Integrate{:}\quad \rho\frac{\pi}{3}h^3\tan^2\theta = \rho\frac{\pi}{8}d^2Kt^2$$

$$Solve\ for\quad \mathbf{h(t)} = \left[\frac{\mathbf{3}}{\mathbf{8}}\mathbf{Kt^2d^2\cot^2\theta}\right]^{1/3}\quad Ans.$$

3.25 As will be discussed in Chaps. 7 and 8, the flow of a stream U_o past a blunt flat plate creates a broad low-velocity wake behind the plate. A simple model is given in Fig. P3.25, with only half of the flow shown due to symmetry. The velocity profile behind the plate is idealized as "dead air" (near-zero velocity) behind the plate, plus a higher