REE 307 - Internal Fluid Flow
Sheet 5
Unsteady Flow in Pipes

11. The pipe-line shown in Fig.1 carries 287 gpm (gallon/minute) of water between the two reservoirs under steady flow conditions with the valve wide open (neglect valve and minor losses).

a) If the valve were initially closed, then opened suddenly, how long would it take for the flow rate to reach 99.5% of its steady state value?

b) If the pipe were horizontal and of the same length and same tank levels, what would be the answer to (a)?

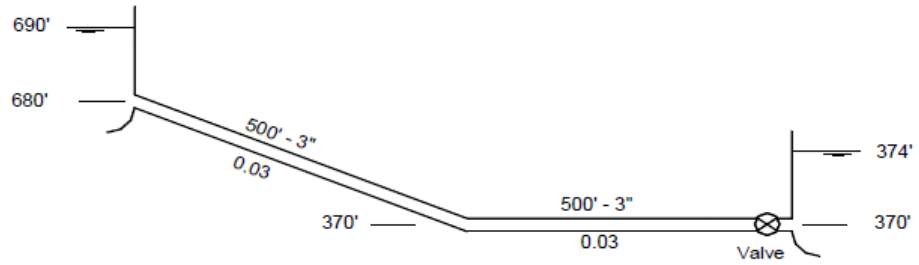


Fig. 1

a] $H_o = H_1 - H_2 + Z_1 - Z_2 = (100 - 4) + (680 - 370)$

$= 316'$

$H_o = \frac{f l v_o^2}{2gd} \longrightarrow v_o = \sqrt{\frac{2gd H_o}{fl}}$

$v_o = \sqrt{\frac{2 \times 32.2 \times \frac{3}{12} \times 316}{0.03 \times 1000}} = 13.02 \text{ fps}$

$t = \frac{l v_o}{2g H_o} \ln\left(\frac{1 + \frac{v}{v_o}}{1 - \frac{v}{v_o}}\right)$

$= \frac{1000 \times 13.02}{2 \times 32.2 \times 316} \ln\left(\frac{1 + 0.995}{1 - 0.995}\right)$

$= 3.83 \text{ sec}$

b] if tank levels are the same 690' & 374'
the time will be the same

2. A horizontal pipe 10000 ft long and 8 ft diameter leaves a reservoir under a head of 60 ft and terminates in a valve. If the Darcy-Weisbach friction factor is 0.030, how long after the sudden opening of the valve will the velocity of flow reach a value 99% of its final value? Neglect minor losses.

$$H_o = 60$$

$$v_o = \sqrt{\frac{2gdH_o}{fl}}$$

$$= \sqrt{\frac{2 \times 32.2 \times 8 \times 60}{0.03 \times 10000}} = 10.15 \text{ fps}$$

$$t = \frac{l v_o}{2gH_o} \ln\left(\frac{1 + \frac{v}{v_o}}{1 - \frac{v}{v_o}}\right)$$

$$= \frac{10000 \times 10.15}{2 \times 32.2 \times 60} \ln\left(\frac{1 + 0.99}{1 - 0.99}\right)$$

$$t = 139.05 \text{ s}$$

3. A horizontal pipe 20000 ft long and 6 ft diameter leaves a reservoir under a head of 100 ft and terminates in a valve. If the steady state Darcy-Weisbach friction factor is expected to be 0.024, how long after the sudden opening of the valve will the velocity of flow reach a value 99% of its final value? Neglect minor losses.

$$H_o = 100'$$

$$V_o = \sqrt{\frac{2g d H_o}{f \ell}}$$

$$= \sqrt{\frac{2 \times 32.2 \times 6 \times 100}{0.024 \times 20000}} = 8.97 \text{ fps}$$

$$t = \frac{\ell V_o}{2g H_o} \ln\left(\frac{1 + \frac{V}{V_o}}{1 - \frac{V}{V_o}}\right)$$

$$= \frac{20000 \times}{2 \times 32.2 \times 100} \ln\left(\frac{1 + 0.99}{1 - 0.99}\right)$$

$$t = 147.5$$

4. The globe valve in the pipe shown in Fig.2 is opened instantaneously, if the loss coefficient for the wide-open valve is 3.0, how many seconds will it take for the flow velocity to reach 99% of its final value?

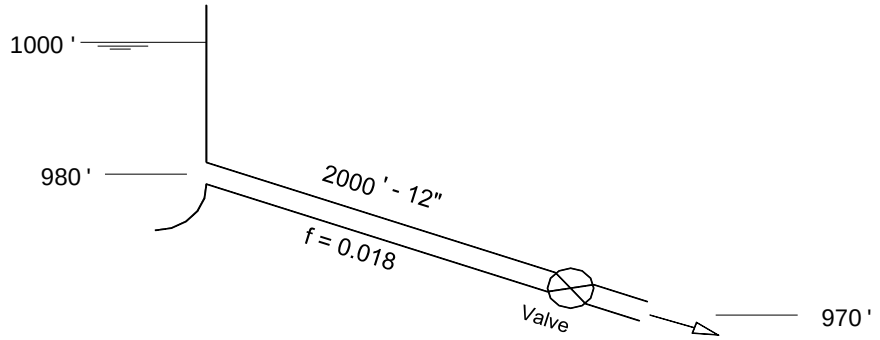
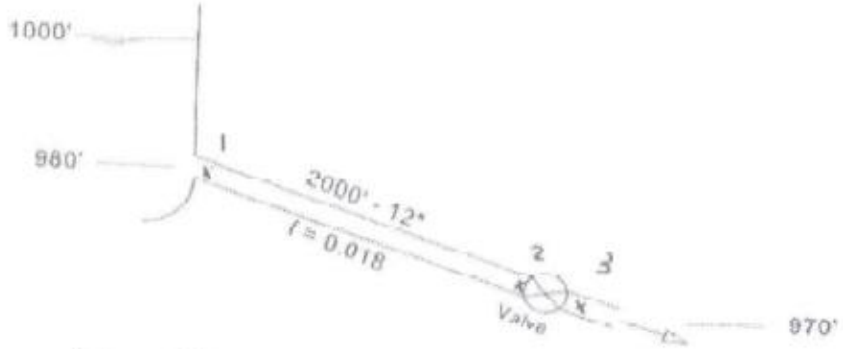


Fig. 2



$$H_o = H_1 - H_3 + Z_1 - Z_3$$

$$= (20 - 0) + (980 - 970)$$

$$= 30'$$

$$H_o = \frac{f l v_o^2}{2gd} + K\frac{v_o^2}{2g} = \left(\frac{fl}{2gd} + \frac{K}{2g}\right) v_o^2 = C v_o^2$$

$$v_o = \sqrt{\frac{H_o}{C}}$$

$$C = \frac{0.018 \times 2000}{2 \times 32.2 \times \frac{12}{12}} + \frac{3}{2 \times 32.2} = 0.606$$

$$v_o = \sqrt{\frac{30}{0.606}} = 7.04 \text{ ft/s}$$

$$t = \frac{l\, v_o}{2g H_o} \ln\left(\frac{v_o + v}{v_o - v}\right)$$

$$t = \frac{2000 \times 7.04}{2 \times 32.2 \times 30} \ln\left(\frac{1 + 0.99}{1 - 0.99}\right)$$

$$t = 38.6 \text{ s}$$

5. The globe valve in the pipe of the previous problem is opened instantaneously to establish flow in the pipe. If the valve's wide open loss coefficient is 6.3, how many seconds will it take for the flow velocity to reach 99.9% of its final value?

$$H_o = 30'$$

$$V_o = \sqrt{\frac{H_o}{C}}$$

$$C = \frac{f\ell}{2gd} + \frac{K}{2g} = \frac{0.018 \times 2000}{2 \times 32.2 \times \frac{1^2}{12}} + \frac{6.3}{2 \times 32.2}$$

$$V_o = 6.76 \text{ fps}$$

$$t = \frac{\ell V_o}{2gH_o} \ln\left(\frac{1 + \frac{V}{V_o}}{1 - \frac{V}{V_o}}\right)$$

$$= \frac{2000 \times 6.76}{2 \times 32.2 \times 30} \ln\left(\frac{1 + 0.999}{1 - 0.999}\right) = 53.2 \text{ s}$$