ENGR 335 FALL 2006 HOMEWORK SET 29

THE DRAINING TANK EXPERIMENT

Perform the following analysis of the data obtained from the experiment performed during class.

Data to obtain:

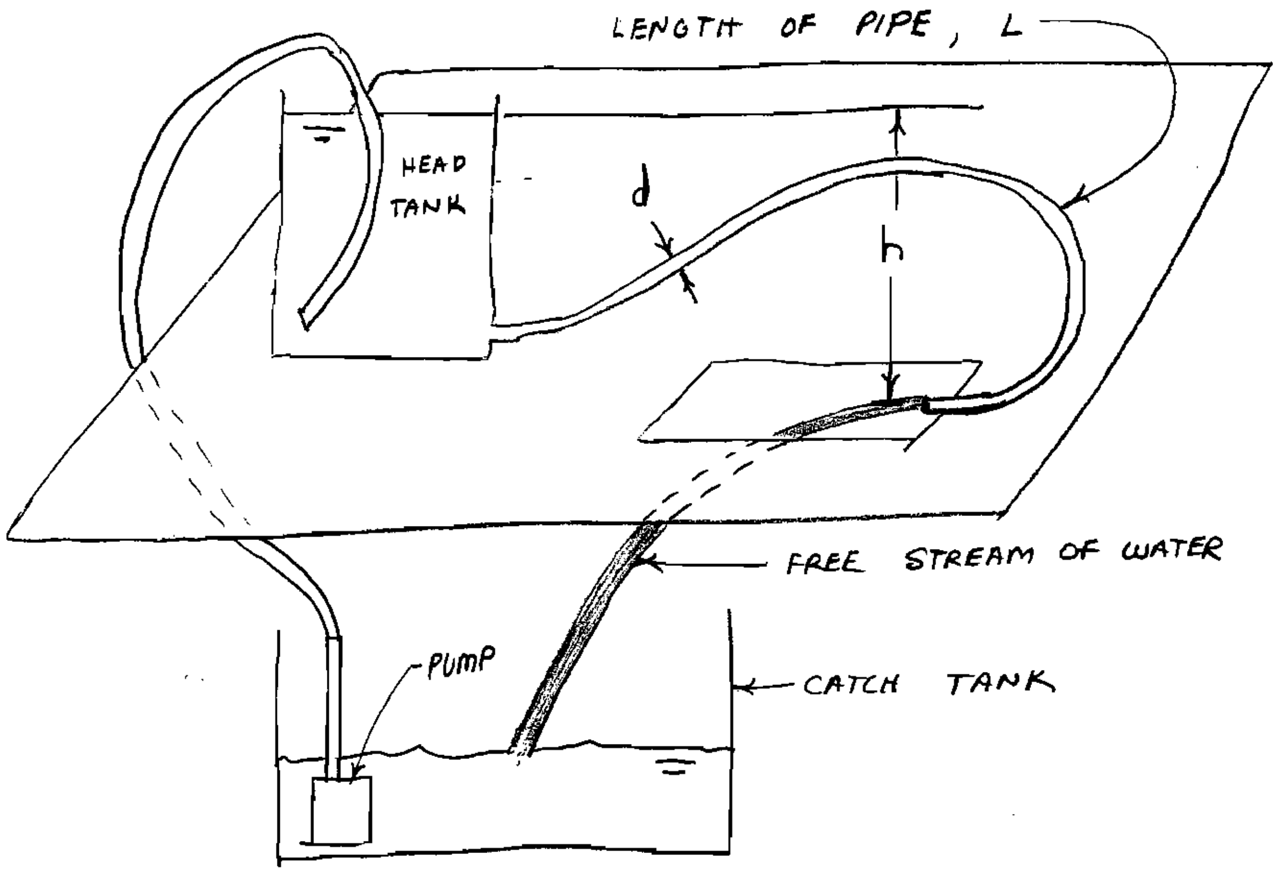
The internal diameter of the exit pipe	d = 3/8 in.
The length of the exit pipe	L = 62 in.
The height of water in the tank	H = 10.5 in.
The volume of water collected	∀ = 950 mL
The time it took to collect the water	t = 16.81 s

(1) Make a sketch of the showing all the components of the apparatus. Carefully draw the dimensions d, L, and H on your sketch.

(2) Calculate the volume flow rate out of the tank from the measurements of ∀ and t. Report your answer in gallons per minute (gpm). Calculate the area average velocity in the pipe in feet per second.

(3) Predict the volume flow rate from the tank using the **Bernoulli** equation. Apply the Bernoulli equation from the free surface of water in the tank to the exit of the pipe. What is the percent difference of the *predicted* value with the *measured* volume flow rate determined in part (2)? Discuss.

(4) Predict the volume flow rate from the tank using the **extended Bernoulli** equation. Include all relevant head losses. What is the percent difference of the *predicted* value with the *measured* volume flow rate determined in part (2)? Discuss.



DRAINING TANK EXPERIMENT

(2)

$$Q = \frac{950\ cm^3}{16.81\,s}\left(\frac{1\ in.}{2.54\,cm}\right)^3\left(\frac{1\ ft}{12\ in}\right)^3\left(\frac{60\,s}{1\ min.}\right)$$

$$Q = 0.120\ \frac{ft^3}{min}\left(\frac{1\ gal}{0.1337\ ft^3}\right)$$

$$\boxed{Q = 0.896\ \text{GPM}}$$

$$\bar{V} = \frac{Q}{A} = \frac{0.120\ \frac{ft^3}{min}}{\frac{\pi}{4}\left(\frac{3}{8}\,in.\right)^2\left(\frac{1\ ft}{12\ in}\right)^2} = 156\ \frac{ft}{min}$$

$$\boxed{\bar{V} = 2.60\ \frac{ft}{s}}$$

(3)

$$\cancel{p_1}^{\,0} + \gamma z_1 + \tfrac{1}{2}\rho \cancel{V_1^2}^{\,0} = \cancel{p_2}^{\,0} + \gamma z_2 + \tfrac{1}{2}\rho V_2^2$$

$$V_2 = \sqrt{\frac{2\gamma(z_1 - z_2)}{\rho}} = \sqrt{2g(z_1 - z_2)}$$

$$V_2 = \sqrt{2\,(32.2)\,\frac{10.5}{12}}$$

$$\boxed{V_2 = 7.51\ \frac{ft}{s}} \qquad \boxed{Q = 2.59\ \text{GPM}}$$

$$\frac{7.51 - 2.60}{2.60} \times 100\% = 189\%$$

WHEN I NEGLECT FRICTION IN THE PIPE I END UP WITH A VELOCITY THAT IS 189% HIGH.

(4) $\cancel{p_1}^{\,0} + \gamma z_1 + \frac{1}{2}\rho \cancel{V_1^2}^{\,0} = \cancel{p_2}^{\,0} + \gamma z_2 + \frac{\alpha_2}{2}\rho V_2^2 + \gamma h_L$

$$V_2^2 + 2g h_L = 2g(z_1 - z_2)$$

ASSUME TURBULENT FLOW FOR NOW.

$\Rightarrow \alpha_2 = 1$ AND $h_L = f\left(\frac{L}{D}\right)\frac{V^2}{2g} + K_e \frac{V^2}{2g}$

$$V^2\left(1 + f\frac{L}{D} + 0.5\right) = 2g(z_1 - z_2)$$

↑ ENTRANCE LOSS COEF.

$\frac{k_s}{D} \simeq 0$ SMOOTH PIPE

GUESS $f = 0.020$

$$V = \sqrt{\frac{2g(z_1 - z_2)}{1.5 + f\left(\frac{L}{D}\right)}} = \sqrt{\frac{2(32.2)(10.5/12)}{1.5 + 0.020\left(\frac{62}{3/8}\right)}}$$

$V = 3.42 \frac{FT}{S}$ @ 60°F

$Re = \frac{(3.42)\left(\frac{3}{8}\right)\left(\frac{1}{12}\right)}{1.22 \times 10^{-5}}$ $\nu = 1.22 \times 10^{-5} \frac{FT^2}{S}$

$Re = 8800$

NOW $f = 0.034 \Rightarrow$ $\boxed{V = 2.81 \frac{FT}{S}}$ $\Rightarrow Re = 7200$

$\boxed{Q = 0.97 \text{ GPM}}$

$$\frac{2.81 - 2.60}{2.60} \times 100\% = 8\%$$

THE VELOCITY IS 8% HIGH. I THINK THAT THE MOST LIKELY CAUSE OF ERROR IS THAT THE FLEXIBLE TUBING DOES NOT HOLD $d = \frac{3}{8}$" TO A CLOSE TOLERANCE.

MATHCAD SOLUTION (NOT REQUIRED)

ENGR335

Tank Draining Calculation

Calculate the exit velocity and flow rate for a 62 inch long pipe.

$H := \frac{10.5}{12}$ $g := 32.2$ $d := \frac{.375}{12}$ $\nu := .0000122$ $L := \frac{62}{12}$ (EG units)

$s(x) := \frac{x^2}{2 \cdot g} \cdot \left(\frac{1.6363}{\ln\left(\frac{d \cdot x}{7 \cdot \nu}\right)^2} \cdot \frac{L}{d} + 1 \right) - H$ Extended Bernoulli Equation with f by Colebrook Correlation

$x := 1$ x is the "guess" for the root solver

$V := \mathrm{root}(s(x), x)$

$V = 2.9317$ V is the exit velocity in feet/second

$f := \frac{1.6363}{\ln\left(d \cdot \frac{V}{7 \cdot \nu}\right)^2}$ $f = 0.0336$ f is the friction factor

$Re := d \cdot \frac{V}{\nu}$ $Re = 7.5096 \cdot 10^3$

$Q := \frac{\pi}{4} \cdot d^2 \cdot V$ $Q = 2.2486 \cdot 10^{-3}$ $Q1 := 448.8 \cdot Q$

$Q1 = 1.0092$ Volume flow rate in gallons per minute