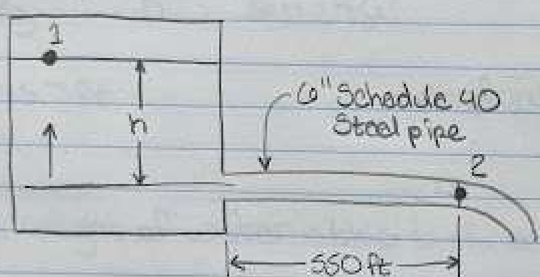
Robert Slade
Homework 5.2

Chapter 8
Problem 33
Purpose
Calculate the tank water height

Drawing



Sources:
Mott, Robert, L; Untener, Joseph A. Applied fluid mechanics 7th - 2015 Reprinted by permission of pearson Education Inc. New York New York

Design Considerations
The following must be assumed
1) Incompressible fluid
2) Isothermal process
3) Steady State

Data and Variables
$L = 550 ft$
$D = 0.5054 ft$
$Q = 2.5 ft^3/s$
$Roughness = 1.5 \times 10^{-4} ft$
$\gamma = 62.2\ lb/ft^3$; $\rho = 1.93\ slugs/ft^3$; $\nu = 9.15 \times 10^{-6} ft^2/s$

Procedures:

Use Bernoulli's equation

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L1,2}$$

Flow Rate equation

$Q = V * A$

Darcy-Weisbach equation

$$h_L = f \frac{L V^2}{D 2g}$$

Reynolds number and relative roughness

$$Re = \frac{\rho V D}{\mu} = \frac{VD}{\mu} \quad \text{Relative roughness} = \frac{D}{\varepsilon}$$

Calculations

$$\cancel{\frac{P_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + z_1 = \cancel{\frac{P_2}{\gamma}}^{0} + \frac{V^2}{2g} + \cancel{z_2}^{0} + h_{L1,2}$$

$z_1 = h$

$$\therefore h = \frac{V^2}{2g} + h_{L1,2} = \frac{V^2}{2g} + f\frac{L V^2}{D 2g}$$

$$V_2 = \frac{Q}{A} = \frac{2.50 \, ft^3/s}{\frac{\pi}{4} * 0.5054^2 ft^2} = 12.46 \, ft/s$$

$$Re = \frac{VD}{\nu} = \frac{12.46\,ft/s * 0.5054\,ft}{9.15\times10^{-6}\,ft^2/s} = 6.88\times10^5$$

$$\frac{D}{\varepsilon} = \frac{0.5054\,ft}{1.5\times10^{-4}\,ft} = 3369$$

from chart $f \approx 0.016$

$$h = \frac{V_2^2}{2g}\left(1 + f\frac{L}{D}\right) = \frac{(12.46\,ft/s)^2}{2*32.2\,ft/s^2}\left(1 + 0.016 * \frac{550\,ft}{0.5054\,ft}\right)$$

$h = 45.7\,ft$

Summary

The height of water in this tank is 45.7 ft

materials

water

Analysis

1) There will always be energy losses due to friction
2) In real systems, the energy losses are almost equal to elevation
3) The minor losses are negligible in this problem.

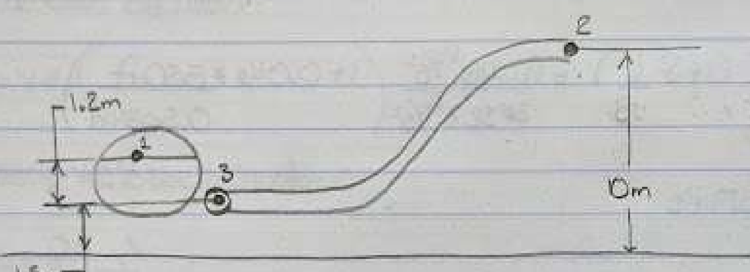
Problem 38

Purpose

a) determine the power delivered by the pump.

b) The pressure at the outlet of the pump.

Drawing



Sources:

Mott, Robert L, Untener, Joseph A, Applied Fluid mechanics 7th - 2015. Reprinted by permission of Pearson Education Inc. New York New York

Design considerations

The following must be assumed.

1) Incompressible fluid

2) Isothermal process

3) Steady state

Data and Variables

Dimensions provided on drawing

$D = 25mm \rightarrow 0.025m$ $\quad P_2 = 145 kPa$

$Sg = 1.10$ $\quad P_1 = 101.325 kPa$

$\mu = 2.0 \times 10^{-3}$

$L = 85m$

$Q = 95\ l/min \rightarrow 0.00158\ m^3/s$

$\rho_{water} = 1000\ kg/m^3$ (from table)

$\gamma_{water} = 9.81\ kN/m^3$

Procedures

Bernoulli's equation (Points 1,2)

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + h_a = \frac{P_2}{\gamma} + \frac{V^2}{2g} + z_2 + h_{L1,2}$$

Reynolds number

$$Re = \frac{\rho V D}{\mu} = \frac{VD}{\mu}$$

Darcy-Weisbach equation

$$h_L = f\,\frac{LV^2}{D2g}$$

Power

$$P = h_a * \gamma * Q$$

Bernoulli's equation (Points 1,3)

$$\frac{P_1}{\gamma} + \frac{V^2}{2g} + z_1 + h_a = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L1,3}$$

Calculations

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + h_a = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L_{1,2}}$$

$$\frac{P_1}{\gamma} + z_1 + h_a = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L_{1,2}}$$

$$h_a = \frac{P_2}{\gamma} - \frac{P_1}{\gamma} + \frac{V^2}{2g} + (z_2 - z_1) + h_{L_{1,2}}$$

$$V_2 = \frac{Q}{A} = \frac{.00158 \, m^3/s}{.00049 \, m^2} = 3.219 \, m/s \qquad A = \frac{\pi D^2}{4} = \frac{\pi (0.025)^2}{4} = 0.00049 \, m^2$$

$$Re = \frac{\rho V D}{\mu} \qquad \rho = 1.10(1000 \, kg/m^3) = 1100 \, kg/m^3$$

$$= \frac{1100 * 3.219 * 0.025}{2.0 \times 10^{-3}} = 44266.125$$

$\therefore f = 0.024$ (moody chart)

$$h_{L_{1,2}} = f \frac{L V^2}{D 2g} = \frac{0.024 * 85 * 3.219^2}{0.025 \; 2 * 9.81} = 43.096 \, m$$

$$\gamma = (1.10)(9.81) = 10.791 \, kN/m^3$$

$$h_a = \frac{140}{10.791} - \frac{101.325}{10.791} + \frac{3.219 \, m/s^2}{2 * 9.81} + (10 - 2.7) + 43.096$$

$$= 3.584 + 0.528 + 7.3 + 43.096$$

$$= 54.51 \, m$$

$$P = h_A * \gamma * Q = 54.51 * 10.791 * 0.00158$$

$$= \boxed{0.929 \, kW}$$

$$\frac{P_1}{\gamma} + \cancel{\frac{V_1^2}{2g}} + Z_1 + h_a = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + \cancel{Z_3}$$

$$\frac{P_1}{\gamma} + Z_1 + h_a = \frac{P_3}{\gamma} + \frac{V_3^2}{2g}$$

$$\frac{101.325}{10.791} + 1.2 + 54.197 = \frac{P_3}{10.791} + \frac{3.219^2}{2 * 9.81}$$

$$64.787 = \frac{P_3}{10.791} + 0.528$$

$$\therefore P_3 = \boxed{704.81\ kPa}$$

Summary

The power is 0.929 kW

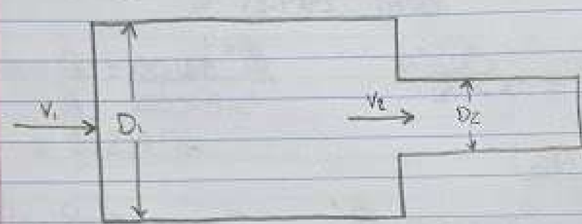
The outlet pressure is 704.81 kPa

material

lawn fertilizer, Plastic hose

Chapter 10
Problem 20
Purpose:
determine the energy loss

Drawing



Sources:
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Design considerations
The following must be assumed
1) Incompressible fluid
2) Isothermal process
3) Steady State

Data and Variables:
DN 125 Schedule 80 = D_1 = 122.3mm → 0.1223m (Table)
DN 50 Schedule 80 = D_2 = 49.3mm → 0.0493m (table
Q = 500 L/min → 0.0083 m^3/s

Procedure:

energy loss

$$h_L = K * \frac{V_2^2}{2g}$$

$$Q = A * V$$

Ratio

$$\frac{D_1}{D_2}$$

Calculations

$$A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4}(0.1223)^2 = 0.012 m^2$$

$$A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4}(0.0493)^2 = 0.0019 m^2$$

$$V_1 = \frac{Q}{A_1} = \frac{0.0083}{0.012} = 0.692 \, m/s \qquad V_2 = \frac{Q}{A_2} = \frac{0.0083}{0.0019} = 4.368 \, m/s$$

$$Ratio = \frac{0.1223}{0.0493} = 2.481 m \quad \therefore K = 0.39 \text{ (from chart)}$$

$$h_L = K * \frac{V_2^2}{2g} = 0.39 * \frac{4.368^2}{2 * 9.81} = \boxed{0.379N}$$

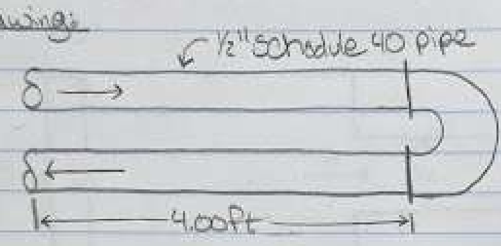
Summary:
The energy loss is 0.379N.

Problem 37

Purpose:

Compute the pressure difference between the inlet and outlet $(P_1 - P_2)$

Drawing:



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Design considerations

The following must be assumed

1) Incompressable fluid

2) Isothermal process

3) Steady State

Data and Variables:

$Q = 12.5 \text{ gal/min} \rightarrow 0.0279 \text{ ft}^3/\text{s}$

$D = 1/2 \text{ sch } 40 \rightarrow 0.0518 \text{ ft}$ (table)

$\nu = 1.59 \times 10^{-4} \text{ ft}^2/\text{s}$ (table)

$\gamma = 68.47 \text{ lb/ft}^3$ (table)

$\varepsilon = 1.5 \times 10^{-4} \text{ ft}$ (table)

$\frac{L_e}{D} = 50$ (table)

$f = 0.026$ (table)

Procedure:

Bernoullis equation

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} - h_f - h_L = \frac{P_2}{\gamma} + \frac{V_2^2}{2g}$$

$z_1 = z_2$
$V_1 = V_2$

$$P_1 - P_2 = \gamma(h_L + h_f)$$

energy Loss

$$h_L = K \frac{V^2}{2g}$$

energy loss (friction)

$$h_f = f \frac{LV^2}{D2g}$$

$$V = \frac{Q}{A}$$

Resistance coefficient

$$K = f \frac{L}{D}$$

Reynolds number

$$N_r = \frac{VD}{\nu}$$

Calculations

$V = \frac{Q}{A}$ $\quad A = \frac{\pi}{4}(0.0518)^2 = 0.0021\,ft^2$

$= \frac{0.0278\,ft^3/s}{0.0021\,ft^2} = 13.24\,ft/s$

$K = f\left(\frac{L_e}{D}\right) = 0.026 * 50 = 1.3$

$h_L = K\left(\frac{V^2}{2g}\right) = 1.3 * \frac{13.24^2}{2 * 32.2} = 3.54\,ft$

~~$N_r = \frac{VD}{\nu} = \frac{1.59 \times 10^{-4} * 0.0518}{13.24} =$~~

$= \frac{13.24 * 0.0518}{1.59 \times 10^{-4}} = 4313.409 \times 10^{3}$

$\therefore f = 0.048$

$h_f = 0.048 * \left(\frac{\cancel{49}\ 48\,(\text{both pipes}) * 13.24^2}{0.0518 * 2 * 32.2}\right) = 20.18\,ft$

$P_1 - P_2 = \gamma(h_L + h_f) = 68.47(3.54 + 20.18) = \boxed{1624.11\ lb/ft^2}$

Summary:

The pressure between the inlet and outlet ($P_1 - P_2$) is $1624.11\ lb/ft^2$ or 11.28 psi