10.60. Points A and B are 3 mi apart along a 24-in. new cast-iron pipe carrying water ($T=50^0F$). Point A is 30 ft higher than B. The pressure at B is 20 psi greater than that at A. Determine the direction and rate of flow.

10.60 Information and Assumptions

from Table A.5 $\nu = 1.41 \times 10^{-5}$ ft²/s
from Table 10.2 $k_s = 0.00085$ ft
provided in problem statement

Find

direction and rate of flow

Solution

$$\frac{P_A}{\gamma} + z_A + \frac{V_A^2}{2g} = \frac{P_B}{\gamma} + z_B + \frac{V_B^2}{2g} + h_f$$

$$h_f = \Delta(p/\gamma + z) = (-20 \times 144/62.4) + 30 = -16.2 \text{ ft}$$

Therefore, flow is from B to A

$$\begin{aligned} \mathrm{Re} f^{1/2} &= (D^{3/2}/\nu)(2gh_f/L)^{1/2} = (2^{3/2}/(1.41 \times 10^{-5}) \times 64.4 \times 16.2/(3 \times 5,280))^{1/2} = 5.14 \times 10^4 \\ k_s/D &= 0.0004 \end{aligned}$$

From Fig. 10.8 $f = 0.0175$. Then

$$\begin{aligned} V &= \sqrt{h_f 2gD/fL} = \sqrt{(16.2 \times 64.4 \times 2)/(0.0175 \times 3 \times 5,280)} = 2.74 \text{ ft/s} \\ q &= VA = 2.74 \times (\pi/4) \times 2^2 = \underline{8.60 \text{ cfs}} \end{aligned}$$

10.69. A pipeline is to be designed to carry crude oil (S=0.93, $\nu = 10^{-5}\ m^2/s$) with a discharge of 0.10 m^3/s and a head loss per kilometer of 50 m. What diameter of steel pipe is needed? What power output from a pump is required to maintain this flow? Available pipe diameters are 20, 22, and 24 cm.

10.69 **Information and Assumptions**

from Table 10.2 $k_s = 0.046$ mm
provided in problem statement

Find

diameter of pipe and pump power

Solution

$$\begin{aligned} h_f &= f(L/D)V^2/2g = f(L/D)(Q^2/(2gA^2)) \\ &= f(L/D)(Q^2/(2g(\pi/4)^2 \times D^4)) \\ &= fLQ^2/(2g(\pi/4)^2 D^5) \\ D &= [8fLQ^2/(g\pi^2 h_f)]^{1/5} \end{aligned}$$

Assume $f = 0.015$

1KM

$$D = [8 \times 0.015 \times 1,000 \times 0.1^2/(9.81 \times \pi^2 \times 50)]^{1/5} = 0.19 \text{ m}$$

Then

$f \to D \to V \to Re$

$$\begin{aligned} k_s/D &= 0.046/190 \simeq 0.00025 \\ \text{Re} &= 4Q/(\pi D\nu) = 4 \times 0.1/(\pi \times 0.19 \times 10^{-5}) \\ &= 6.7 \times 10^4 \end{aligned}$$

From Fig. 10.8 $f = 0.021$. Try again

$$D = (0.021/0.015)^{1/5} \times 0.19 = 0.203 \text{ m} = 20.3 \text{ cm}$$

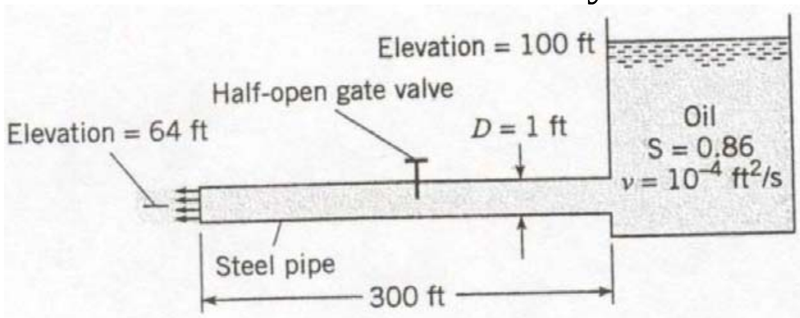
$k_s/D = 0.00023$

Use next commercial size larger; **$D = 22$ cm**. Still assume $h_L \approx 50$ m/1,000 m Then

$Re = 4Q/(\pi D\nu)$
$= 6.27 \times 10^4$
$f = 0.021$

$$P = Q\gamma h_f = 0.1 \times 0.93 \times 9,810 \times 50 = 45,620 \text{ W/km} = \mathbf{45.6 \text{ kW/km}}$$

10.94 Estimate the discharge of oil through the pipe shown below. Also, draw the HGL and the EGL for the System.



10.94 Information and Assumptions

from Table 10.3 $K_e = 0.50$; $K_v = 5.6$ → half open
from Table 10.2 $k_s = 1.5 \times 10^{-4}$ ft → pipe roughness
provided in problem statement

Find

discharge of oil

Energy equation from reservoir water surface to pipe outlet:

$$\begin{aligned} p_1/\gamma + V_1^2/2g + z_1 &= p_2/\gamma + V_2^2/2g + z_2 + \sum h_L \\ 0 + 0 + 100 \text{ ft} &= 0 + V_2^2/2g + 64 + (V^2/2g)(K_e + K_v + fL/D) \end{aligned}$$

Assume $f = 0.015$ for first trial. Then

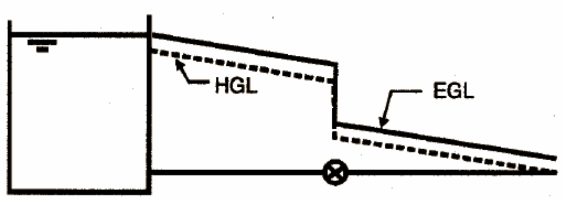
$$(V^2/2g)(0.5 + 5.6 + 1 + 0.015 \times 300/1) = 36$$
$$V = 14.1 \text{ ft/s}$$
$$\text{Re} = VD/\nu = 14.1 \times 1/10^{-4} = 1.4 \times 10^5$$
$$k_s/D = 0.00015$$

From Fig. 10.8 $f \approx 0.0175$.
Second Trial:

$$\begin{aligned} V &= 13.7 \text{ ft/s} \\ \text{Re} &= 1.37 \times 10^5 \end{aligned}$$

From Fig. 10.8 $f = 0.0175$.so

$$Q = VA = 13.7 \times (\pi/4) \times 1^2 = \underline{\underline{10.8 \text{ ft}^3/\text{s}}}$$



HGL ~ hydraulic grade line $\frac{P}{\rho g} + Z$

EGL ~ energy grade line $\frac{P}{\rho g} + Z + \frac{V^2}{2g}$