P6.56 The Alaska Pipeline has a design flow rate of 4.4E7 gallons per day of crude oil at 60°C (see Fig. A.1). (*a*) Assuming a galvanized-iron wall, estimate the total pressure drop required for the 800-mile trip. (*b*) If there are nine equally spaced pumps, estimate the horsepower each pump must deliver. $D = 48''$

Fig A.1 + A.2

crude oil 60° C $\rho = 860\ kg/m^3$ $\mu = .004\ kg/ms$

galvanized iron $\varepsilon = .0005\ ft \Rightarrow \varepsilon/D = .0005/4 = .000125$

Convert metric $Q = 4.4E7\ gal/day = 1.93\ m^3/s$

$D = 4' = 1.22\ m$

$V = Q/A = 1.65\ m/s$ $Re_D = \frac{\rho V D}{\mu} = 433{,}000$

equation (6.48) $f^{-1/2} = 2 \log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re_D f^{1/2}}\right)$

$f = .0149$

(a) $\Delta h = h_L = f \frac{L}{D} \frac{V^2}{2g}$ $h = P/\gamma + z$

$\Delta p = 1.85E7\ Pa = 2680\ psi$ $\Delta z \sim 0$

(b) $P = Q \frac{\Delta p}{\eta} = 396{,}000\ W = 5300\ hp$ $\frac{W}{746} = hp$