coolant 32°F

6in. Ball valve $L_e/D = 150$

all pipes 6in Sched 40 Steel

$A = 0.2006\ ft^2$

$V = 1.11\ ft/s$

$\frac{v^2}{2g} = \frac{(1.11)^2}{2(32.2)} = 0.02\ ft$

$D = 0.5054\ ft$

$\rho = 0.94 \times 62.4 = 57.66\ lb_m/ft^3$

$h_L = h_1 + h_2 + h_3 + h_4 + h_5 \ldots + h_9$

h_L = total loss

$h_1 = K(v^2/2g)$ Entrance loss [square edged inlet]

$h_2 = f_T(L_e/D)(v^2/2g)$ valve (1)

$h_3 = f_T(L_e/D)(v^2/2g)$ two 90° standard elbows (2+3)

$h_4 = f_s(L/D)(v^2/2g)$ faction loss in suction line

$h_5 = f_T(L_e/D)(v^2/2g)$ valve (7)

$h_6 = f_T(L_e/D)(v^2/2g)$ valve (6)

$h_7 = f_T(L_e/D)(v^2/2g)$ 90° standard elbow

$h_8 = f_T(L_e/D)(v^2/2g)$ valve (5)

$h_9 = f_D(L/D)(v^2/2g)$ faction loss in discharge line

Suction and discharge line are the same. Find Reynolds to get friction factor.

$$N_R = \frac{V D \rho}{\mu} = \frac{(1.11)(0.5054)(58.66)}{3.66 \times 10^{-5}}$$

$N_R = 8.99 \times 10^5$ $\quad N_R > 4{,}000$ (turbulent)

$$\frac{D}{\varepsilon} = \frac{0.5054}{1.5 \times 10^{-4}} = 3369$$

$f = 0.0155$

$h_1 = (0.5)(v^2/2g) = (0.5)(0.02\ ft) = 0.01\ ft$

$h_2 = f_T(L_e/D)(v^2/2g) = (0.0155)(150)(0.02\ ft) = 0.046\ ft$

$h_3 = f_T(L_e/D)(v^2/2g) = (0.0155)(2)(30)(0.02) = 0.018\ ft$

$h_4 = f_s(L/D)(v^2/2g) = (0.015)\left(\frac{500\ ft}{0.5054}\right)(0.02\ ft) = 0.29\ ft$

$h_5 = 0.046\ ft$

$h_6 = 0.046\ ft$

$h_7 = (.015)(30)(0.02) = .009\ ft$

$h_8 = 0.046\ ft$

$h_9 = 0.29\ ft$

$h_L = h_1 + h_2 + h_3 + \dots h_9$

$= (0.01 + 0.046 + 0.018 + 0.29 + 0.046 + 0.046 + 0.009 + 0.046 + 0.29)$

$h_L = 0.801$ ft

$h_A = Z_2 - Z_1 + h_L$

$= (23 - 0) + 0.801 = 23.801$ ft

Now calculate Power supplied to the pump

Power $= h_A \gamma Q = (23.801 \text{ ft})(58.66 \text{ lb/ft}^3)(0.7729 \text{ ft}^3/\text{s})$

Power to Pump $= 311.21$ lb-ft/s

$$\frac{311.21 \text{ lb-ft/s}}{1} \times \frac{1.356 \text{ W}}{1 \text{ lb-ft/s}}$$

$$\boxed{P = 421.9 \text{ W}}$$