5.113

5.113 Water is supplied at 150 ft³/s and 60 psi to a hydraulic turbine through a 3-ft inside diameter inlet pipe as indicated in Fig. P5.113. The turbine discharge pipe has a 4-ft inside diameter. The static pressure at section (2), 10 ft below the turbine inlet, is 10-in. Hg vacuum. If the turbine develops 2500 hp, determine the power lost between sections (1) and (2).

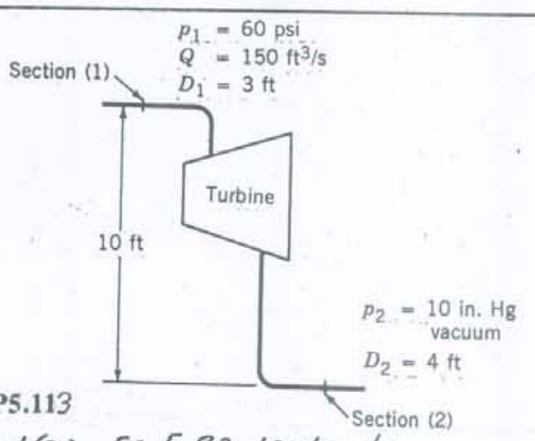

FIGURE P5.113

For flow between sections (1) and (2), Eq. 5.82 leads to

$$\text{power loss} = \rho Q\left[\left(\frac{p_1-p_2}{\rho}\right) + g(z_1-z_2) + \left(\frac{V_1^2-V_2^2}{2}\right)\right] - \dot{W}_{\substack{\text{shaft}\\ \text{net out}}} \qquad (1)$$

From given data

$$p_2 = \frac{(-10\text{ in. Hg})(13.6)\left(1.94\frac{\text{slugs}}{\text{ft}^3}\right)\left(32.2\frac{\text{ft}}{\text{s}^2}\right)\left(\frac{1\text{ lb}}{\text{slug.}\frac{\text{ft}}{\text{s}^2}}\right)}{\left(12\frac{\text{in.}}{\text{ft}}\right)} = -708\frac{\text{lb}}{\text{ft}^2}$$

Also

$$V_1 = \frac{Q}{A_1} = \frac{Q}{\frac{\pi D_1^2}{4}} = \frac{(4)\left(150\frac{\text{ft}^3}{\text{s}}\right)}{\pi(3\text{ft})^2} = 21.22\frac{\text{ft}}{\text{s}}$$

From conservation of mass (Eq. 5.13)

$$V_2 = V_1\frac{A_1}{A_2} = V_1\frac{D_1^2}{D_2^2} = \left(21.22\frac{\text{ft}}{\text{s}}\right)\frac{(3\text{ft})^2}{(4\text{ft})^2} = 11.94\frac{\text{ft}}{\text{s}}$$

From Eq. 1

$$\text{power loss} = \frac{\left(1.94\frac{\text{slugs}}{\text{ft}^3}\right)\left(150\frac{\text{ft}^3}{\text{s}}\right)}{\left(550\frac{\text{ft.lb}}{\text{s.hp}}\right)}\left\{\frac{\left(60\frac{\text{lb}}{\text{in.}^2}\right)\left(144\frac{\text{in.}^2}{\text{ft}^2}\right)+\left(708\frac{\text{lb}}{\text{ft}^2}\right)}{\left(1.94\frac{\text{slugs}}{\text{ft}^3}\right)}\right.$$

$$\left. + \left(32.2\frac{\text{ft}}{\text{s}^2}\right)(10\text{ ft})\left(\frac{1\text{ lb}}{\text{slug.}\frac{\text{ft}}{\text{s}^2}}\right) + \frac{\left[\left(21.22\frac{\text{ft}}{\text{s}}\right)^2-\left(11.94\frac{\text{ft}}{\text{s}}\right)^2\right]\left(\frac{1\text{ lb}}{\text{slug.}\frac{\text{ft}}{\text{s}^2}}\right)}{2}\right\}$$

$$-2500\text{hp}$$

or

$$\text{power loss} = \underline{\underline{301}}\text{ hp}$$