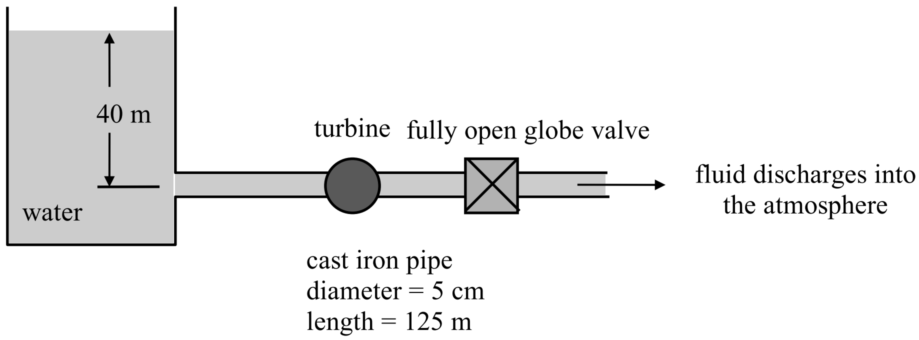
Determine the power, in W, extracted by the turbine in the system shown below. The pipe entrance is sharp-edged and the volumetric flow rate is 0.004 m^3/s. The density of water is 998 kg/m^3 and the kinematic viscosity is 1.005e-6 m^2/s.



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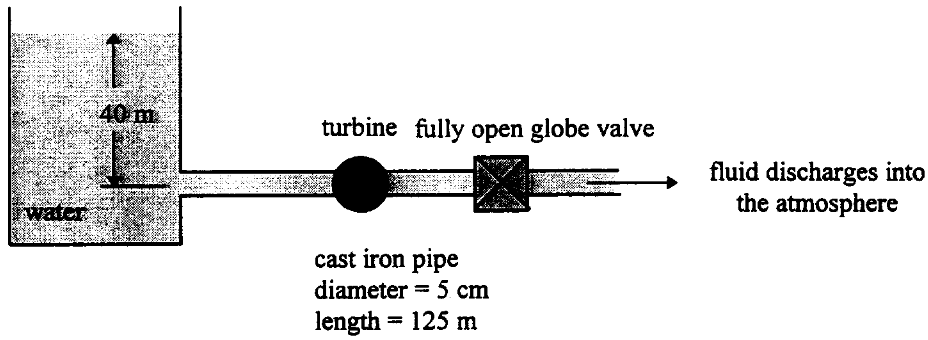
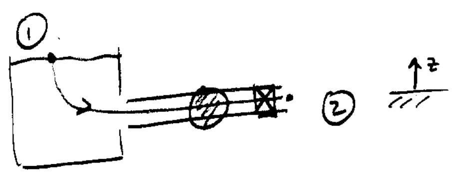


SOLUTION:

- Apply the Extended Bernoulli's Equation from ① to ②:



$$\left(\frac{p}{\rho g}+\frac{V^2}{2g}+z\right)_{②} = \left(\frac{p}{\rho g}+\frac{V^2}{2g}+z\right)_{①} - h_L + h_s$$

$p_2 = p_1 = p_{atm}$

$$V_2 = \frac{Q}{\left(\frac{\pi D^2}{4}\right)} = \frac{0.004\ m^3/s}{\left(\frac{\pi (5\times10^{-2} m)^2}{4}\right)} = 2.04\ m/s$$

$V_1 \approx 0$

$z_2 = 0$

$z_1 = 40m$

$$h_L = K_V \frac{V_2^2}{2g} + K_{entrance}\frac{V_2^2}{2g} + K_{valve}\frac{V_2^2}{2g}$$

$$= \left(f\left(\frac{L}{D}\right) + K_{entrance} + K_{valve}\right)\frac{V_2^2}{2g}$$

where $L = 125m$

$D = 5\times10^{-2} m$

$K_{entrance} = 0.5$ } from table

$K_{valve} = 10$

$$Re = \frac{VD}{\nu} = \frac{(2.04\ m/s)(5\times10^{-2} m)}{1.005\times10^{-6} m^2/s}$$

$= 101500$

$\varepsilon_{cast\ iron} = 0.26\times10^{-3} m$ (from table)

SOLUTION...

$$Re = \frac{VD}{\nu} = \frac{(2.04\ \text{m/s})(5\times10^{-2}\ \text{m})}{1.005\times10^{-6}\ \text{m}^2/\text{s}} = 101500$$

$$\varepsilon_{\substack{\text{cast}\\\text{iron}}} = 0.26\times10^{-3}\ \text{m} \quad \text{(from table)}$$

$$\Rightarrow \frac{\varepsilon}{D} = \frac{0.26\times10^{-3}\ \text{m}}{5\times10^{-2}\ \text{m}} = 0.0052$$

Using Moody Chart $\rightarrow f = 0.032$

$$\Rightarrow h_L = \left(0.032\left(\frac{125\ \text{m}}{5\times10^{-2}\ \text{m}}\right) + 0.5 + 10\right)\frac{(2.04\ \text{m/s})^2}{2(9.81\ \text{m/s}^2)}$$

$$= 19.2\ \text{m}$$

$$h_s = \frac{P}{\dot{m}g} = \frac{P}{\rho Q g} = \frac{P}{(998\ \text{kg/m}^3)(0.004\ \text{m}^3/\text{s})(9.81\ \text{m/s}^2)}$$

$$= \frac{P}{39.2\ \frac{\text{kg}\cdot\text{m}}{\text{s}^3}}$$

$$\Rightarrow \frac{V_2^2}{2g} = z_1 - h_L + h_s$$

$$\Rightarrow \frac{(2.04\ \text{m/s})^2}{2(9.81\ \text{m/s}^2)} = 40\ \text{m} - 19.2\ \text{m} + \frac{P}{39.2\ \frac{\text{kg}\cdot\text{m}}{\text{s}^2}}$$

$$\boxed{\Rightarrow P = -807\ \text{W}}$$

807 W extracted from the fluid