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 $0.004 \mathrm{~m}^{3} / \mathrm{s}$. The density of water is $998 \mathrm{~kg} / \mathrm{m}^{3}$ and the kinematic viscosity is $1.005 \mathrm{e}-6 \mathrm{~m}^{2} / \mathrm{s}$.


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fluid discharges into the atmosphere
cast iron pipe
diameter $=5 \mathrm{~cm}$
length $=125 \mathrm{~m}$

Solution:
Apply the Extenced Bernoullis Equation from (1) to (2):

(2) $\frac{\uparrow^{z}}{\pi!}$

$$
\begin{aligned}
& \left(\frac{p}{\rho g}+\frac{v^{2}}{2 g}+z\right)_{(2)}=\left(\frac{p}{\rho g}+\frac{v^{2}}{2 g}+z\right)_{0}-h_{L}+h_{S} \\
& p_{2}=p_{1}=p_{\text {atm }} \\
& V_{2}=\frac{Q}{\left(\frac{\pi D^{2}}{4}\right)}=\frac{0.004 \mathrm{~m}^{3} / \mathrm{s}}{\left(\frac{\pi\left(5 \times 10^{-2} \mu\right)^{2}}{4}\right)}=2.04 \mathrm{~m} / \mathrm{s} \\
& V_{1}=0 \\
& z_{2}=0 \\
& z_{1}=40 \mathrm{~m} \\
& h_{L}=K_{V} \frac{V_{2}^{2}}{2 g}+K_{\text {entrance }} \frac{V_{2}^{2}}{2 g}+K_{\text {value }} \frac{V_{2}^{2}}{2 g} \\
& =\left(f\left(\frac{L}{D}\right)+K_{\text {entrance }}+K_{\text {value }}\right) \frac{V_{2}{ }^{2}}{2 g} \\
& \text { where } \\
& \begin{array}{l}
L=125 \mathrm{~m} \\
D=5 \times 10^{-2} \mathrm{~m}
\end{array} \\
& \left.\begin{array}{l}
K_{\text {eatrace }}=0.5 \\
K_{\text {value }}=10
\end{array}\right\} \begin{array}{l}
\text { from } \\
\text { table }
\end{array} \\
& R_{e}=\frac{V D}{\nu}=\frac{(2.04 \mathrm{~m} / \mathrm{s})\left(5 \times 10^{-2} \mathrm{~m}\right)}{1.005 \times 10^{-6 \mathrm{~m} / \mathrm{s}}} \\
& =101500 \\
& \begin{array}{l}
\varepsilon_{\text {cast }}=0.26 \times 10^{-3} \mathrm{~m} \\
\text { (from table) }
\end{array} \quad \operatorname{lof} 2
\end{aligned}
$$

SOLUTION...

$$
\begin{aligned}
& R_{e}=\frac{V D}{2}=\frac{(2.04 \mathrm{~m} / \mathrm{s})\left(5 \times 10^{-2} \mathrm{~m}\right)}{1.005 \times 10^{-6 \mathrm{~m}^{2} / \mathrm{s}}}=101500 \\
& \varepsilon_{\substack{\text { cat } \\
\text { iron }}}=0.26 \times 10^{-3} \mathrm{~m} \quad \text { (from table) } \\
& \quad \Rightarrow \frac{\varepsilon}{D}=\frac{0.26 \times 10^{-3 / \mathrm{m}}}{5 \times 10^{-2} \mathrm{~m}}=0.0052
\end{aligned}
$$

Using Moody Chart $\Rightarrow f=0.032$

$$
\begin{aligned}
\Rightarrow h_{L} & =\left(0.032\left(\frac{125 \mathrm{~m}}{5 \times 10^{-2} \mathrm{~m}}\right)+0.5+10\right) \frac{(2.04 \mathrm{~m} /)^{2}}{2\left(9.81^{\mathrm{m} / \mathrm{s}^{2}}\right)} \\
& =19.2 \mathrm{~m} \\
h_{S} & =\frac{P}{\dot{\mu} g}=\frac{P}{\rho Q g}=\frac{P}{\left(998 \mathrm{~kg} / \mathrm{m}^{3}\right)\left(0.004^{\mathrm{m} / \mathrm{s}}\right)\left(9.81 \mathrm{r} / \mathrm{s}^{2}\right)}
\end{aligned}
$$

$$
=\frac{P}{39.2^{k_{3}^{3}-3}}
$$

$$
\begin{aligned}
& \Rightarrow \frac{V_{2}^{2}}{r \mathrm{~J}}=z_{1}-h_{L}+h_{s} \\
& \Rightarrow \frac{(2.04 \mathrm{~m} / \mathrm{s})^{2}}{2\left(9.81^{\mathrm{m} / \mathrm{s}^{2}}\right)}=40 \mathrm{~m}-19.2 \mathrm{~m}+\frac{P}{39.2 \frac{\mathrm{k}}{\mathrm{~s}^{2}} \mathrm{~m}} \\
& \Rightarrow P=-807 \mathrm{~W}
\end{aligned}
$$

807 W extracted from the fid

