ES-18

7.56

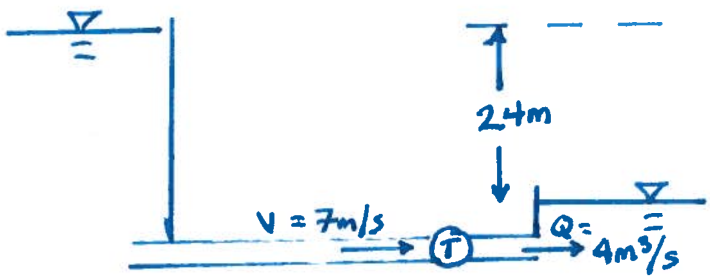
SMALL HYDRO-DAM

$\Delta Z = 24m$

$V_{TURB} = 7m/s$

$Q = 4m^3/s$

FIND P_{TURB} IN K.W.



EQUATION(S)

ENERGY FROM RESERVOIR TO RESERVOIR, POWER = $Q\gamma h$

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_L + h_T$$

0 gage 0   0 gage 0

HEAD LOSS IS EXPANSION LOSS ONLY (pg 271)

$$h_L = \frac{V^2}{2g} \text{ (FOR EXPANSION)}$$

SOLVE FOR h_T

$$h_T = z_1 - z_2 - h_L$$

$$= 24m - \frac{(7m/s)^2}{2(9.8m/s^2)} = 21.5m$$

POWER

$$P = Q\gamma h = (4m^3/s)(9800N/m^3)(21.5m) = 844 \cdot 10^3 \frac{N \cdot m}{s}$$

$$= \underline{\underline{844 \text{ kW}}}$$ ← P

7.61

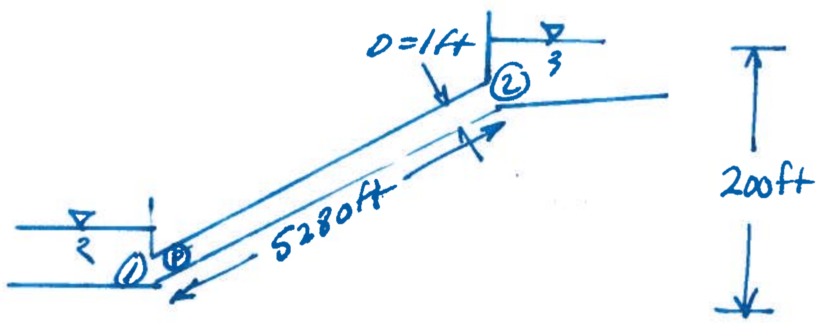
PUMP OIL 1 MILE, 1FT. DIAMETER PIPE @ 3500 GPM.

$\Delta z = 200\,FT$

$\Delta p_{LOSS} = 60\,psi$

$\gamma_{OIL} = 53\,lbf/ft^3$

FIND hp REQUIRED



EQUATIONS

ENERGY; POWER

SOLUTION

ENERGY ① → ②

$$\cancel{\frac{p_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}} + \cancel{z_1}^{0} + h_p = \cancel{\frac{p_2}{\gamma}}^{0} + \cancel{\frac{V_2^2}{2g}} + \cancel{z_2}^{200ft} + h_L$$

$V_1 = V_2$

$$h_p = z_2 - z_1 + h_L$$

$$= 200ft + \frac{\frac{60\,lbf}{in^2} \cdot \frac{144\,in^2}{1ft^2}}{53\,lbf \cdot ft^3} = 363.01\,ft$$

$$P = Q\gamma h = \left(\frac{3500\,gal}{min} \cdot \frac{1\,min}{60\,sec} \cdot \frac{ft^3}{7.48\,gal}\right)\left(53\,\frac{lbf}{ft^3}\right)(363.01\,ft)$$

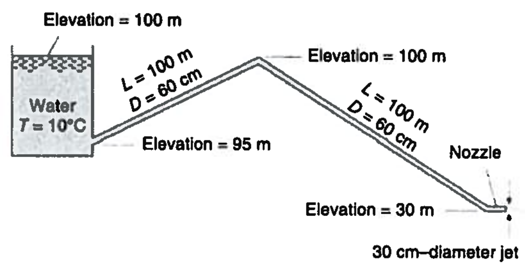
$$= 150044\,\frac{lbf\text{-}ft}{s} \cdot \frac{1hp}{550\,\frac{lbf\text{-}ft}{sec}} = \underline{\underline{272hp}} \leftarrow P$$

~~7.81~~: PROBLEM DEFINITION

Situation:

Water flows from a tank through a pipe system before discharging through a nozzle.
$z_1 = 100\,\text{m}$, $z_2 = 30\,\text{m}$.
$L_1 = 100\,\text{m}$, $L_2 = 400\,\text{m}$.
$D_1 = D_2 = 60\,\text{cm}$, $D_{\text{jet}} = 30\,\text{cm}$.
Head loss in the pipe is given by

$$h_L = 0.014 \frac{L}{D} \frac{V_p^2}{2g}$$



Find:

(a) Discharge.
(b) Draw HGL and EGL.
(c) location of maximum pressure.
(d) location of minimum pressure.
(e) values for maximum and minimum pressure.

Properties: Water (15 °C), Table A.5, $\gamma = 9800\,\text{N/m}^3$.

Assumptions:

Assume $\alpha = 1.0$ at all locations.

SOLUTION

Energy equation (locate 1 on the reservoir water surface; locate 2 at outlet of the nozzle).

$$\begin{aligned}
\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 &= \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L \\
0 + 0 + 100 &= 0 + \frac{V_2^2}{2g} + 30 + 0.014\left(\frac{L}{D}\right)\left(\frac{V_p^2}{2g}\right) \\
100 &= 0 + \frac{V_2^2}{2g} + 30 + 0.014\left(\frac{500}{0.6}\right)\frac{V_2^2}{2g}
\end{aligned}$$

Continuity equation

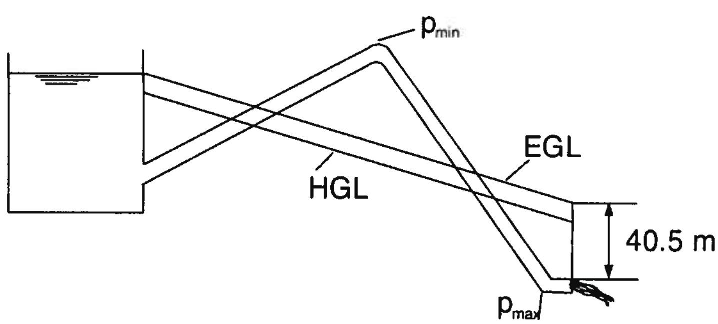
$$\begin{aligned} V_2 A_2 &= V_p A_p \\ V_2 &= V_p \frac{A_p}{A_L} \\ V_2 &= 4V_p \end{aligned}$$

Then

$$\begin{aligned} \frac{V_p^2}{2g}(16 + 11.67) &= 70\,\mathrm{m} \\ V_p &= 7.045\,\mathrm{m/s} \\ \frac{V_p^2}{2g} &= 2.53\,\mathrm{m} \end{aligned}$$

Flow rate equation

$$\begin{aligned} Q &= V_p A_p \\ &= 7.045\,\mathrm{m/s} \times (\pi/4) \times (0.60\,\mathrm{m})^2 \\ &\boxed{Q = 1.99\ \mathrm{m^3/s}} \end{aligned}$$



Minimum pressure. Apply the Energy equation (point 1 on reservoir surface; point 2 in pipe at location of minimum pressure)

$$\begin{aligned} \frac{p_1}{\gamma} + \alpha_1 \frac{V_1^2}{2g} + z_1 + h_p &= \frac{p_2}{\gamma} + \alpha_2 \frac{V_2^2}{2g} + z_2 + h_t + h_L \\ 0 + 0 + z_1 + 0 &= \frac{p_{\min}}{\gamma} + \frac{V_p^2}{2g} + z_2 + 0 + 0.014 \frac{L_1}{D} \frac{V_p^2}{2g} \\ z_1 &= \frac{p_{\min}}{\gamma} + \frac{V_p^2}{2g} + z_2 + 0.014 \frac{L_1}{D} \frac{V_p^2}{2g} \\ 100\,\mathrm{m} &= \frac{p_{\min}}{9800\,\mathrm{N/m^3}} + \frac{(7.045\,\mathrm{m/s})^2}{2\,(9.81\,\mathrm{m/s^2})} + 100\,\mathrm{m} + 0.014 \left(\frac{100\,\mathrm{m}}{0.6\,\mathrm{m}} \right) \frac{(7.045\,\mathrm{m/s})^2}{2\,(9.81\,\mathrm{m/s^2})} \end{aligned}$$

$$\boxed{p_{\min} = \text{-82.6 kPa gage}}$$

Maximum pressure. Apply the Energy equation (point 1 on reservoir surface: point 2 in pipe at location of maximum pressure)

$$
\begin{aligned}
\frac{p_1}{\gamma} + \alpha_1 \frac{V_1^2}{2g} + z_1 + h_p &= \frac{p_2}{\gamma} + \alpha_2 \frac{V_2^2}{2g} + z_2 + h_t + h_L \\
0 + 0 + z_1 + 0 &= \frac{p_{\max}}{\gamma} + \frac{V_p^2}{2g} + z_2 + 0 + 0.014 \frac{L}{D} \frac{V_p^2}{2g} \\
z_1 &= \frac{p_{\max}}{\gamma} + \frac{V_p^2}{2g} + z_2 + 0.014 \frac{L}{D} \frac{V_p^2}{2g} \\
100\,\mathrm{m} &= \frac{p_{\max}}{9800\,\mathrm{N/\,m^3}} + \frac{(7.045\,\mathrm{m/\,s})^2}{2\,(9.81\,\mathrm{m/\,s^2})} + 30\,\mathrm{m} + 0.014 \left(\frac{500\,\mathrm{m}}{0.6\,\mathrm{m}} \right) \frac{(7.045\,\mathrm{m/\,s})^2}{2\,(9.81\,\mathrm{m/\,s^2})}
\end{aligned}
$$

$$\boxed{p_{\max} = 373\,\mathrm{kPa\ gage}}$$

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7.87 TEXTBOOK CE3305 6 OF 7

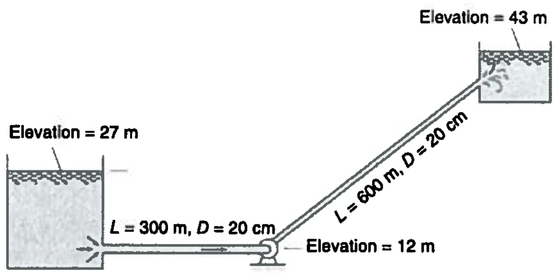
~~7.86~~: PROBLEM DEFINITION

Situation:

Water is pumped from a lower reservoir to an upper one.
$z_1 = 27\,\text{m}$, $z_2 = 43\,\text{m}$.
$L_1 = 300\,\text{m}$, $L_2 = 600\,\text{m}$.
$D_1 = 20\,\text{cm}$, $D_2 = 20\,\text{cm}$.
$Q = 0.1\,\text{m}^3/\text{s}$, $h_L = 0.018\frac{L}{D}\frac{V^2}{2g}$.

TEXTBOOK IS U.S. CUSTOMARY

- METHOD IS SAME



Find:

(a) Power supplied to the pump (kW).
(b) Sketch the HGL and EGL.

Properties:

Water (20 °C), Table A.5: $\gamma = 9810\,\text{N/m}^3$.

PLAN

Apply the flow rate equation to find the velocity. Then calculate head loss. Next apply the energy equation from water surface to water surface to find the head the pump provides. Finally, apply the power equation.

SOLUTION

Flow rate equation

$$\begin{aligned} V &= \frac{Q}{A} \\ &= \frac{0.1\,\text{m}^3/\text{s}}{(\pi/4)\times(0.2\,\text{m})^2} \\ &= 3.2\,\text{m/s} \end{aligned}$$

Head loss

$$\begin{aligned} h_L &= \left(0.018\frac{L}{D}\frac{V^2}{2g}\right) + \left(\frac{V^2}{2g}\right) \\ &= 0.018\left(\frac{900\,\text{m}}{0.2\,\text{m}}\right)\frac{(3.2\,\text{m/s})^2}{2\,(9.81\,\text{m/s}^2)} + \frac{(3.2\,\text{m/s})^2}{2\,(9.81\,\text{m/s}^2)} \\ &= 42.64\,\text{m} \end{aligned}$$

ES-18

Energy equation

$$\begin{aligned}\frac{p_1}{\gamma}+\alpha_1\frac{V_1^2}{2g}+z_1+h_p &= \frac{p_2}{\gamma}+\alpha_2\frac{V_2^2}{2g}+z_2+h_L\\ 0+0+27+h_p &= 0+0+43+42.64\\ h_p &= 58.64\text{ m}\end{aligned}$$

U.S. CUSTOMARY IN FEET HEAD

Power equation

$$\begin{aligned}P &= Q\gamma h_p\\ &= 0.1\,\text{m}^3/\text{s}\times 9810\,\text{N/m}^3\times 58.64\,\text{m}\\ &= 57,526\,\text{N-m/s}\end{aligned}$$

$$\boxed{P = 58\,\text{kW}}$$

U.S. CUSTOMARY WOULD REPORT $\frac{\text{lbf-ft}}{\text{sec}}$ OR HP