3.143 The insulated tank in Fig. P3.143 is to be filled from a high-pressure air supply. Initial conditions in the tank are *T* = 20°C and *p* = 200 kPa. When the valve is opened, the initial mass flow rate into the tank is 0.013 kg/s. Assuming an ideal gas, estimate the initial rate of temperature rise of the air in the tank.

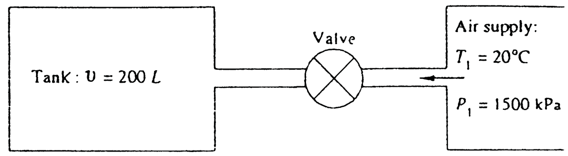

Fig. P3.143

Solution: For a CV surrounding the tank, with *unsteady* flow, the energy equation is

$$\frac{d}{dt}\left(\int e\rho d\upsilon\right)-\dot{m}_{in}\left(\hat{u}+\frac{p}{\rho}+\frac{V^2}{2}+gz\right)=\dot{Q}-\dot{W}_{shaft}=0,\quad \text{neglect } V^2/2 \text{ and } gz$$

$$\text{Rewrite as}\quad \frac{d}{dt}(\rho\upsilon c_v T)\approx \dot{m}_{in}c_p T_{in}=\rho\upsilon c_v\frac{dT}{dt}+c_v T\upsilon\frac{d\rho}{dt}$$

where ρ and T are the instantaneous conditions inside the tank. The CV mass flow gives

$$\frac{d}{dt}\left(\int \rho d\upsilon\right)-\dot{m}_{in}=0,\quad \text{or:}\quad \upsilon\frac{d\rho}{dt}=\dot{m}_{in}$$

Combine these two to eliminate $\upsilon(d\rho/dt)$ and use the given data for air:

$$\left.\frac{dT}{dt}\right|_{tank}=\frac{\dot{m}(c_p-c_v)T}{\rho\upsilon c_v}=\frac{(0.013)(1005-718)(293)}{\left[\frac{200000}{287(293)}\right](0.2\text{ m}^3)(718)}\approx \mathbf{3.2}\ \frac{\mathbf{°C}}{\mathbf{s}}\qquad \textit{Ans.}$$

3.144 The pump in Fig. P3.144 creates a 20°C water jet oriented to travel a maximum horizontal distance. System friction head losses are 6.5 m. The jet may be approximated by the trajectory of frictionless particles. What power must be delivered by the pump?

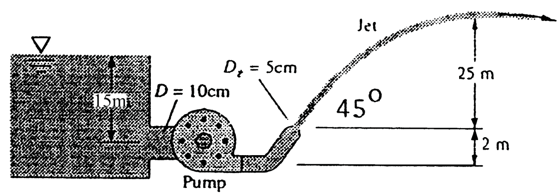

Fig. P3.144

Solution: For maximum travel, the jet must exit at $\theta = 45°$, and the exit velocity must be

$$V_2\sin\theta=\sqrt{2g\Delta z_{max}}\quad \text{or:}\quad V_2=\frac{[2(9.81)(25)]^{1/2}}{\sin 45°}\approx 31.32\ \frac{m}{s}$$

The steady flow energy equation for the piping system may then be evaluated:

$$p_1/\gamma+V_1^2/2g+z_1=p_2/\gamma+V_2^2/2g+z_2+h_f-h_p,$$

or: $0+0+15 = 0+(31.32)^2/[2(9.81)]+2+6.5-h_p$, solve for $h_p \approx 43.5$ m

Then $P_{pump} = \gamma Q h_p = (9790)\left[\frac{\pi}{4}(0.05)^2(31.32)\right](43.5) \approx$ **26200 W** *Ans.*

3.145 The large turbine in Fig. P3.145 diverts the river flow under a dam as shown. System friction losses are $h_f = 3.5V^2/(2g)$, where V is the average velocity in the supply pipe. For what river flow rate in m^3/s will the power extracted be 25 MW? Which of the *two* possible solutions has a better "conversion efficiency"?

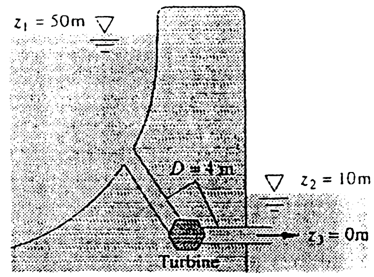

Fig. P3.145

Solution: The flow rate is the unknown, with the turbine power known:

$$\frac{p_1}{\gamma}+\frac{V_1^2}{2g}+z_1 = \frac{p_2}{\gamma}+\frac{V_2^2}{2g}+z_2+h_f+h_{turb}, \quad \text{or:} \quad 0+0+50 = 0+0+10+h_f+h_{turb}$$

$$\text{where} \quad h_f = 3.5V_{pipe}^2/(2g) \quad \text{and} \quad h_p = P_p/(\gamma Q) \quad \text{and} \quad V_{pipe} = \frac{Q}{(\pi/4)D_{pipe}^2}$$

Introduce the given numerical data (e.g. $D_{pipe} = 4$ m, $P_{pump} = 25E6$ W) and solve:

$$Q^3 - 35410Q + 2.261E6 = 0, \quad \text{with roots } Q = +76.5, +137.9, \text{ and } -214.4 \text{ m}^3/\text{s}$$

The *negative* Q is nonsense. The large Q (=137.9) gives large friction loss, $h_f \approx 21.5$ m. The smaller Q (= 76.5) gives $h_f \approx 6.6$ m, about right. Select $Q_{river} \approx$ **76.5 m³/s**. *Ans.*

3.146 Kerosene at 20°C flows through the pump in Fig. P3.146 at 2.3 ft³/s. Head losses between 1 and 2 are 8 ft, and the pump delivers 8 hp to the flow. What should the mercury-manometer reading *h* ft be?

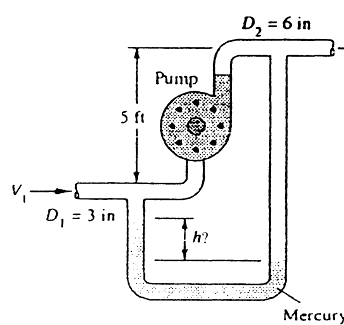

Fig. P3.146

Solution: First establish the two velocities:

$$V_1 = \frac{Q}{A_1} = \frac{2.3 \text{ ft}^3/\text{s}}{(\pi/4)(3/12 \text{ ft})^2}$$

$$= 46.9 \frac{\text{ft}}{\text{s}}; \quad V_2 = \frac{1}{4}V_1 = 11.7 \frac{\text{ft}}{\text{s}}$$