3.34 A rocket motor is operating steadily, as shown in Fig. P3.34. The products of combustion flowing out the exhaust nozzle approximate a perfect gas with a molecular weight of 28. For the given conditions calculate V_2 in ft/s.

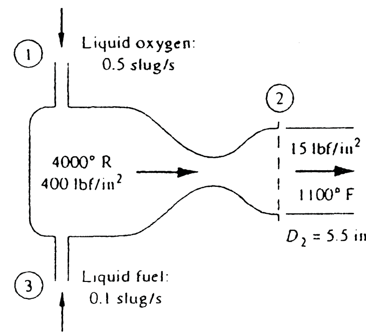

Fig. P3.34

Solution: Exit gas: Molecular weight = 28, thus $R_{gas} = 49700/28 = 1775\ \text{ft}^2/(\text{s}^2\cdot°\text{R})$. Then,

$$\rho_{\text{exit gas}} = \frac{p}{RT} = \frac{15(144)\text{ psf}}{(1775)(1100+460)} \approx 0.000780\ \text{slug/ft}^2$$

For mass conservation, the exit mass flow must equal <u>fuel + oxygen entering</u> = 0.6 slug/s:

$$\dot{m}_{\text{exit}} = 0.6\ \frac{\text{slug}}{\text{s}} = \rho_e A_e V_e = (0.00078)\frac{\pi}{4}\left(\frac{5.5}{12}\right)^2 V_e,\quad \text{solve for } V_e \approx \mathbf{4660\ \frac{ft}{s}}\quad \textit{Ans.}$$

3.35 In contrast to the liquid rocket in Fig. P3.34, the solid-propellant rocket in Fig. P3.35 is self-contained and has no entrance ducts. Using a control-volume analysis for the conditions shown in Fig. P3.35, compute the rate of mass loss of the propellant, assuming that the exit gas has a molecular weight of 28.

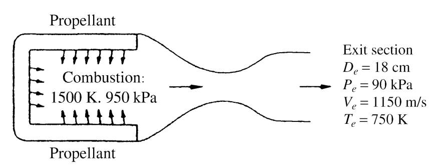

Fig. P3.35

Solution: With M = 28, $R = 8313/28 = 297\ \text{m}^2/(\text{s}^2\cdot\text{K})$, hence the exit gas density is

$$\rho_{\text{exit}} = \frac{p}{RT} = \frac{90{,}000\ \text{Pa}}{(297)(750\ \text{K})} = 0.404\ \text{kg/m}^3$$

For a control volume enclosing the rocket engine and the outlet flow, we obtain

$$\frac{d}{dt}(m_{CV}) + \dot{m}_{out} = 0,$$

or: $$\frac{d}{dt}(m_{\text{propellant}}) = -\dot{m}_{\text{exit}} = -\rho_e A_e V_e = -(0.404)(\pi/4)(0.18)^2(1150) \approx \mathbf{-11.8\ \frac{kg}{s}}\quad \textit{Ans.}$$
