~~8.44~~ 8.44

8.44

8.44 A 3-ft-diameter duct is used to carry ventilating air into a vehicular tunnel at a rate of 9000 ft³/min. Tests show that the pressure drop is 1.5 in. of water per 1500 ft of duct. What is the approximate size of the equivalent roughness of the surface of the duct?

$$\frac{p_1}{\gamma}+\frac{V_1^2}{2g}+z_1=\frac{p_2}{\gamma}+\frac{V_2^2}{2g}+z_2+f\frac{\ell}{D}\frac{V^2}{2g}, \text{ where } z_1=z_2,\ V_1=V_2, \text{ and} \qquad (1)$$

$$p_1-p_2=\gamma_{H_2O}h=\left(62.4\frac{lb}{ft^3}\right)\left(\frac{1.5}{12}ft\right)=7.80\frac{lb}{ft^2}$$

Also, $V=\frac{Q}{A}=\frac{\left(9000\frac{ft^3}{min}\right)\left(\frac{1\,min}{60\,s}\right)}{\frac{\pi}{4}(3\,ft)^2}=21.2\frac{ft}{s}$

Thus, from Eq.(1) $\quad p_1-p_2=f\frac{\ell}{D}\frac{1}{2}\rho V^2$ or

$$f=\frac{2D(p_1-p_2)}{\rho\ell V^2}=\frac{2(3\,ft)\left(7.80\frac{lb}{ft^2}\right)}{\left(2.38\times10^{-3}\frac{slugs}{ft^3}\right)(1500\,ft)\left(21.2\frac{ft}{s}\right)^2}=\underline{\underline{0.0292}}$$

From Fig. 8.20 with $f=0.0292$ and $Re=\frac{VD}{\nu}=\frac{\left(21.2\frac{ft}{s}\right)(3\,ft)}{1.57\times10^{-4}\frac{ft^2}{s}}=4.05\times10^5$

we obtain $\frac{\varepsilon}{D}=0.0044$ $\quad$ Thus, $\varepsilon=0.0044\,(3\,ft)=\underline{\underline{0.0132\,ft}}$