8.31

8.31 Water at 60 °F flows through a 6-in.-diameter pipe with an average velocity of 15 ft/s. Approximately what is the height of the largest roughness element allowed if this pipe is to be classified as smooth?

Let h = roughness height. Thus, $h = \delta_s$, where $\delta_s = \frac{5\nu}{u^*}$ with $u^* = \left(\frac{\tau_w}{\rho}\right)^{1/2}$ and $\tau_w = \frac{D\Delta p}{4\ell}$. Since $\Delta p = f\frac{\ell}{D}\frac{1}{2}\rho V^2$ we obtain $\tau_w = \frac{\rho f V^2}{8}$ or $u^* = \sqrt{\frac{f}{8}}\,V$

For a smooth pipe with $Re = \frac{VD}{\nu} = \frac{(15\ \frac{ft}{s})(\frac{6}{12}\ ft)}{1.21\times10^{-5}\ \frac{ft^2}{s}} = 6.19\times10^5$ we obtain from Fig. 8.20 $f = 0.0125$

Thus, $u^* = \left(\frac{0.0125}{8}\right)^{1/2}(15\ \frac{ft}{s}) = 0.593\ \frac{ft}{s}$

or $\delta_s = \frac{5\nu}{u^*} = \frac{5(1.21\times10^{-5}\ \frac{ft^2}{s})}{0.593\ \frac{ft}{s}} = \underline{\underline{1.02\times10^{-4}\ ft}}$