Solution to Problem 280D:

Using the results for the turbulent skin friction on a flat plate, we estimate the skin friction coefficient, C_{DS}, for the ship:

$$C_{DS} \;=\; \frac{0.074}{Re^{1/5}} \tag{1}$$

where the Reynolds number, $Re = U\ell/\nu$. The residual drag (total drag minus the skin friction drag which is mostly made up of wave drag) is given by

$$C_D - C_{DS} \;=\; \frac{V}{\ell^3}\left(\frac{Fr}{0.35}\right)^3 \tag{2}$$

where V is the immersed volume of the hull and the Froude number, $Fr = U/(g\ell)^{1/2}$ where in the present case $V/\ell^3 = 0.004$. Therefore the skin frcition drag equals the residual drag when

$$\frac{V}{\ell^3}\left(\frac{U_c}{0.35(g\ell)^{1/2}}\right)^3 \;=\; \frac{0.074}{(U_c\ell/\nu)^{1/5}} \tag{3}$$

which needs to be solved iteratively to find the critical velocities, U_c, for various values of ℓ. The results are:

- If $\ell = 1.0000m$ then $U_c = 1.14m/s$.
- If $\ell = 10.000m$ then $U_c = 2.92m/s$.
- If $\ell = 100.0m$ then $U_c = 7.43m/s$.
- If $\ell = 1000.0m$ then $U_c = 18.9m/s$.