

Chapter 6 • Viscous Flow in Ducts

P6.1 An engineer claims that flow of SAE 30W oil, at 20°C, through a 5-cm-diameter smooth pipe at 1 million N/h, is laminar. Do you agree? A million newtons is a lot, so this sounds like an awfully high flow rate.

Solution: For SAE 30W oil at 20°C (Table A.3), take $\rho = 891 \text{ kg/m}^3$ and $\mu = 0.29 \text{ kg/m-s}$. Convert the weight flow rate to volume flow rate in SI units:

$$Q = \frac{\dot{w}}{\rho g} = \frac{(1\text{E}6 \text{ N/h})(1/3600 \text{ h/s})}{(891 \text{ kg/m}^3)(9.81 \text{ m/s}^2)} = 0.0318 \frac{\text{m}^3}{\text{s}} = \frac{\pi}{4} (0.05 \text{ m})^2 V, \text{ solve } V = 16.2 \frac{\text{m}}{\text{s}}$$

$$\text{Calculate } Re_D = \frac{\rho V D}{\mu} = \frac{(891 \text{ kg/m}^3)(16.2 \text{ m/s})(0.05 \text{ m})}{0.29 \text{ kg/m-s}} = \mathbf{2500} \text{ (transitional)}$$

This is not high, but **not** laminar. *Ans.* With careful inlet design, low disturbances, and a very smooth wall, it might still be laminar, but **No**, this is *transitional*, not definitely laminar.

P6.2 The present pumping rate of North Slope crude oil through the Alaska Pipeline (see the chapter-opener photo) is about 600,000 barrels per day (1 barrel = 42 U.S. gallons). What would be the maximum rate if the flow were constrained to be *laminar*? Assume that Alaskan crude oil fits Fig. A.1 of the Appendix at 60°C.

Solution: From Fig. A.1 for crude at 60°C, $\rho = 0.86(1000) = 860 \text{ kg/m}^3$ and $\mu = 0.0040 \text{ kg/m-s}$. From Eq. (6.2), the maximum laminar Reynolds number is about 2300. Convert the pipe diameter from 48 inches to 1.22 m. Solve for velocity:

$$Re_D = 2300 = \frac{\rho V D}{\mu} = \frac{(860 \text{ kg/m}^3) V (1.22 \text{ m})}{0.0040 \text{ kg/m-s}}; \text{ Solve for } V = 0.00877 \frac{\text{m}}{\text{s}}$$

$$Q = VA = (0.00877 \text{ m/s})(\pi/4)(1.22 \text{ m})^2 = 0.01025 \text{ m}^3/\text{s} \times 3600 \times 24 =$$

$$= 886 \text{ m}^3/\text{day} \approx \mathbf{5600} \text{ barrels/day } \textit{Ans.}$$

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Albert A Gayle



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