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 $\rho = 891$ kg/m³ and $\mu = 0.29$ kg/m-s. Convert the weight flow rate to volume flow rate in S1 units:

$$Q = \frac{\dot{w}}{\rho g} = \frac{(1E6N/h)(1/3600h/s)}{(891kg/m^3)(9.81m/s^2)} = 0.0318 \frac{m^3}{s} = \frac{\pi}{4}(0.05m)^2 V \text{, solve } V = 16.2 \frac{m}{s}$$
 Calculate Re_D = $\frac{\rho VD}{\mu} = \frac{(891kg/m^3)(16.2m/s)(0.05m)}{0.29\,kg/m-s} = 2500 \text{ (transitional)}$

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:

$${\rm Re}_D = 2300 = \frac{\rho V D}{\mu} = \frac{(860 kg/m^3) V (1.22 m)}{0.0040 kg/m - s}$$
; Solve for $V = 0.00877 \frac{m}{s}$
 $Q = V A = (0.00877 m/s) (\pi/4) (1.22 m)^2 = 0.01025 m^3/s \times 3600 \times 24 =$
 $= 886 m^3/day \approx 5600$ barrels/day Ans.

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M Carnoy

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