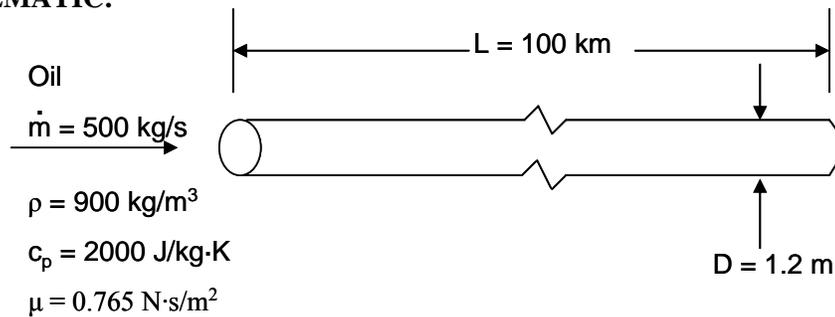


## PROBLEM 8.9

**KNOWN:** Flow rate and properties of oil flowing in pipe. Dimensions of pipe.

**FIND:** Pressure drop, flow work, temperature rise caused by flow work.

**SCHEMATIC:**



**ASSUMPTIONS:** (1) Steady-state, (2) Incompressible flow, (3) Negligible kinetic and potential energy changes, (4) No work *other than* flow work.

**ANALYSIS:** We begin by determining whether the flow is laminar or turbulent. From Equation 8.6

$$Re_d = \frac{4\dot{m}}{\pi D \mu} = \frac{4 \times 500 \text{ kg/s}}{\pi \times 1.2 \text{ m} \times 0.765 \text{ N}\cdot\text{s/m}^2} = 693$$

and the flow is laminar. The friction factor is given by Equation 8.19,

$$f = 64/Re_D$$

and the pressure drop by Equation 8.22a,

$$\Delta p = f \frac{\rho u_m^2}{2D} (x_2 - x_1) = 32 \frac{\rho u_m^2}{D Re_D} L$$

where  $u_m$  can be found from  $\dot{m} = \rho u_m A_c$  :

$$u_m = \frac{\dot{m}}{\rho A_c} = \frac{\dot{m}}{\rho \pi D^2/4} = \frac{4 \times 500 \text{ kg/s}}{900 \text{ kg/m}^3 \times \pi \times (1.2 \text{ m})^2} = 0.491 \text{ m/s}$$

Thus

$$p_{in} - p_{out} = \Delta p = \frac{32 \times 900 \text{ kg/m}^3 \times (0.491 \text{ m/s})^2 \times 100,000 \text{ m}}{1.2 \text{ m} \times 693} = 8.4 \times 10^5 \text{ Pa}$$

$$\Delta p = 0.84 \text{ MPa} \quad <$$

The flow work is then found from its definition (see discussion leading to Equation 1.11d),

$$\dot{W}_{flow} = \frac{\dot{m}}{\rho} (p_{in} - p_{out}) = 500 \text{ kg/s} \times 0.84 \text{ MPa} / 900 \text{ kg/m}^3$$

$$= 0.46 \text{ MW} \quad <$$

Finally, with reference to Equation 1.12d, the portion of the temperature rise due to flow work is given by

$$\dot{m} c_p \Delta T_{flow} = \frac{\dot{m}}{\rho} (p_{in} - p_{out}) = \dot{W}_{flow}$$

$$\Delta T_{flow} = \dot{W}_{flow} / \dot{m} c_p = 0.46 \text{ MW} / (500 \text{ kg/s} \times 2000 \text{ J/kg}\cdot\text{K})$$

$$= 0.46^\circ\text{C} \quad <$$

**COMMENTS:** Despite the long length of pipeline and high viscosity of the oil, which results in a large pressure drop, the temperature rise due to the flow work is quite small.