Franklin W. Olin College of Engineering
ENGR 3310: Transport Phenomena

Practice Exam 2

Fall 2004

1. The Trans Alaska Pipeline carries crude oil from Prudhoe Bay on Alaska's North Slope to Valdez, the northernmost ice-free port in North America. The length of the pipeline is 800 miles, and the oil is transported in a 48 inch diameter steel pipe with a relative roughness (ε / D = 0.0007). The pipeline can transport 42 million gallons of crude oil in a 24 hour day. The density of crude oil is 887 kg/m^3 and the viscosity $\mu = 36\times10^{-3}$ Ns/m^2.

a) What is the average velocity in the pipeline?
b) What is the Reynolds number for the crude oil flow? Is the flow laminar or turbulent?
c) What is the head loss due to viscous effects, h_f, in the entire pipeline?

The pipeline has a number of valves along the 800 mile length:

Type of Valve	Number of Valves in Pipeline
Check valve	81
Gate valve	71
Block valve	24
Ball valve	1

d) If all the valves are full open, what are the minor losses, $\sum h_m$, in the entire pipeline? A table of loss coefficients is attached.

e) A drag reducing agent (shown below) is often added to the crude oil to reduce the frictional losses due to turbulence. If the drag reducing agent reduces the friction factor f to 0.001, estimate the total pumping power [Watts] necessary to transport the oil along the entire length of the pipeline. There is an elevation increase of 100 feet along the pipeline. Take major and minor losses into account. You can assume that the inlet and outlet pressures are the same.


Drag Reducing Agent

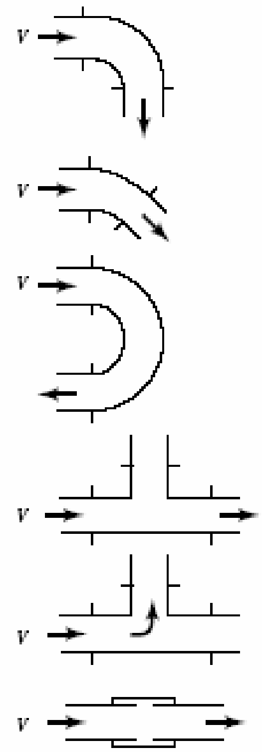
Conversion factors:
1 mile = 1609 meters
1 gal = 3.7854×10^{-3} m^3
1 inch = .0254 m

For more information, see http://www.alyeska-pipe.com/

TABLE 8.2

Loss Coefficients for Pipe Components $\left(h_L = K_L \frac{V^2}{2g}\right)$ **(Data from Refs. 5, 10, 27)**

Component	K_L
a. Elbows	
Regular 90°, flanged	0.3
Regular 90°, threaded	1.5
Long radius 90°, flanged	0.2
Long radius 90°, threaded	0.7
Long radius 45°, flanged	0.2
Regular 45°, threaded	0.4
b. 180° return bends	
180° return bend, flanged	0.2
180° return bend, threaded	1.5
c. Tees	
Line flow, flanged	0.2
Line flow, threaded	0.9
Branch flow, flanged	1.0
Branch flow, threaded	2.0
d. Union, threaded	0.08
***e. Valves**	
Globe, fully open	10
Angle, fully open	2
Gate, fully open	0.15
Gate, $\frac{1}{4}$ closed	0.26
Gate, $\frac{1}{2}$ closed	2.1
Gate, $\frac{3}{4}$ closed	17
Swing check, forward flow	2
Swing check, backward flow	∞
Ball valve, fully open	0.05
Ball valve, $\frac{1}{3}$ closed	5.5
Ball valve, $\frac{2}{3}$ closed	210



*See Fig. 8.36 for typical valve geometry

2. Air flows isentropically in a converging-diverging nozzle with a throat area of 3 cm^2. At the entrance of the nozzle, the pressure is 101 kPa, the temperature is 300 K, and the velocity is 868 m/s.

a) What is the stagnation temperature and pressure in the nozzle?
b) If the flow is choked at the throat, what is the area at the entrance of the nozzle?
c) What is the mass flow through the nozzle?

3. You are late preparing for a party and realize that the cans of soda should have already been put in the fridge. The party starts in 2.5 hours and you want cold soda (T = 5 °C) for your guests. Each can is 6 cm in diameter and 12 cm high and is initially at 20 °C. The air in the refrigerator is at 0 °C, and you estimate $h \approx 4$ W/m^2 K. Assume the properties of the soda can be approximated as density ρ = 1000 kg/m^3, thermal conductivity k = .787 W/m K, and specific heat c = 4195 J/kg K. The can's contribution to the transient is negligible.

a) Determine the estimated time required for a can of soda to reach 5 °C in the refrigerator. Will the soda reach 5 °C by the time the party starts?
b) When you hand a cold can of soda to a party guest, you also give them a koozie (a soda can insulator, shown below). What is the instantaneous (steady state) heat transfer rate to the can with the koozie insulation just as you hand the can to the party guest? You can neglect convection losses from the top of bottom of the beer can, and you can also neglect contact resistance between the can and the koozie. The insulation has a thermal conductivity of 0.1 W/m K and the average heat transfer coefficient is 20 W/m^2 K. The koozie insulation is 1.5 cm thick.

Exhibit 1: The Koozie

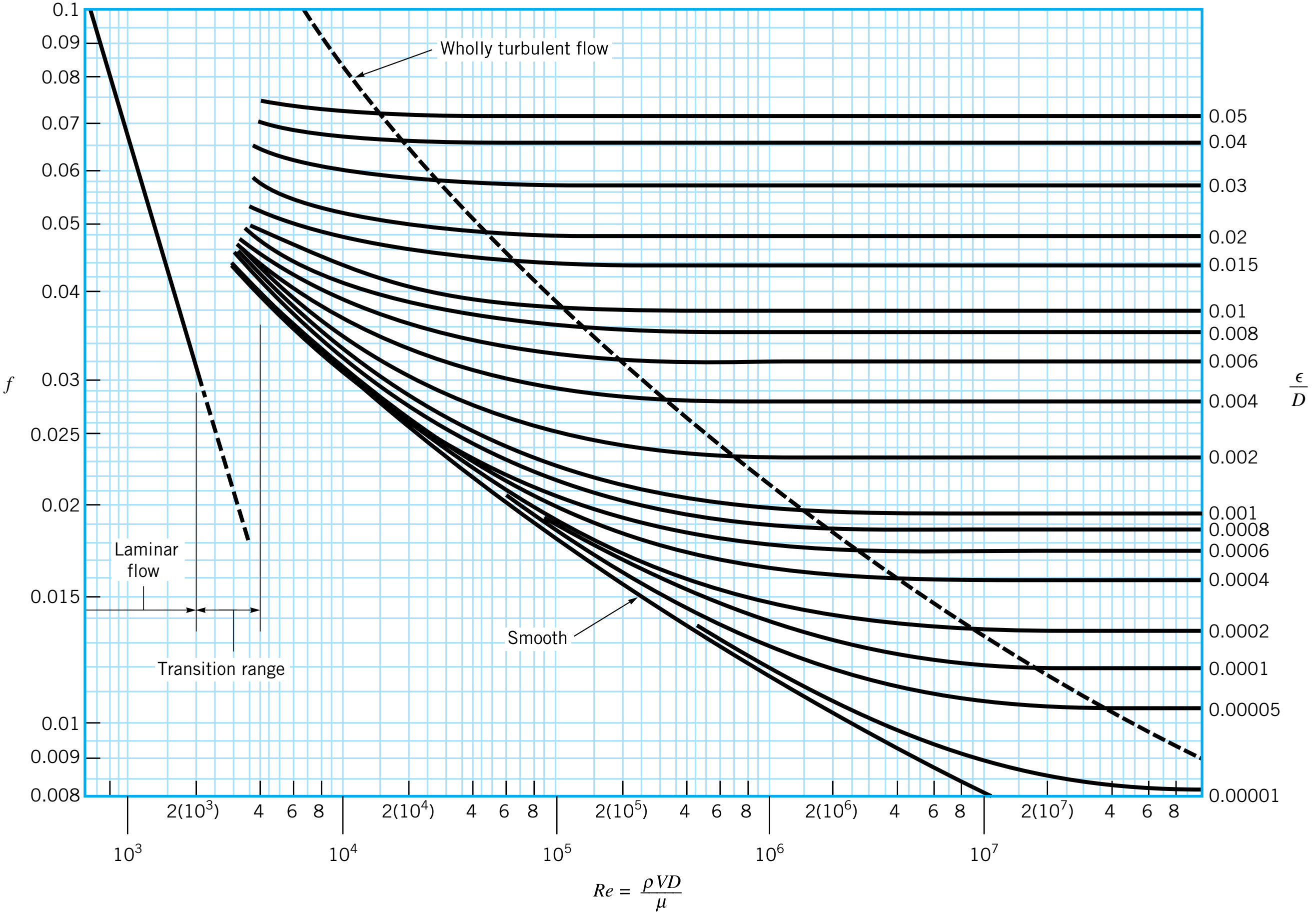


FIGURE 8.20 **Friction factor as a function of Reynolds number and relative roughness for round pipes—the Moody chart. (Data from Ref. 7 with permission.)**