Applied Fluid Mechanics

Chapter 7

General Energy Equation

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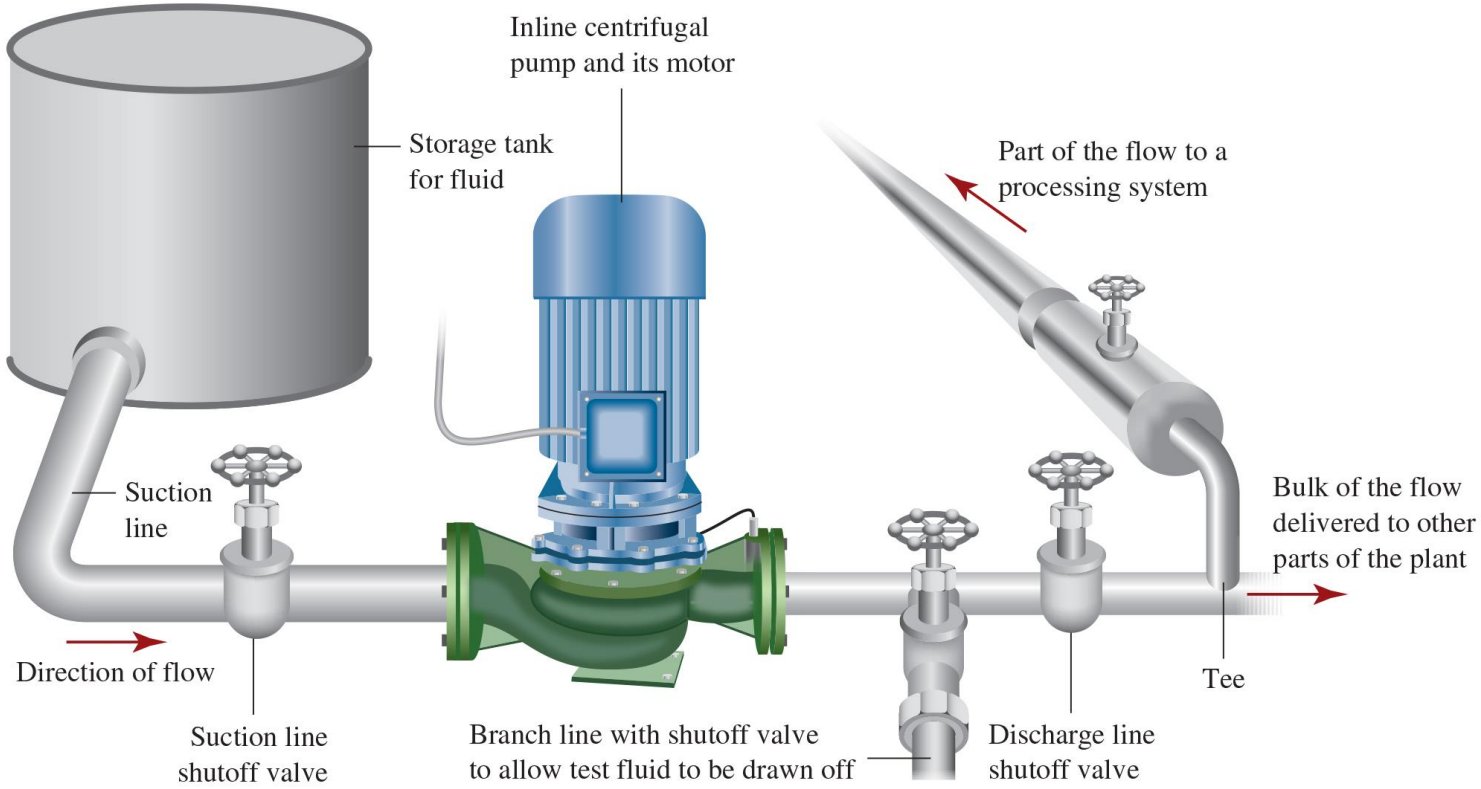
Spring 2022/2023

General Energy Equation

- Bernoulli's Equations applies to two points in a fluid system that have no change in total energy. In many cases, though, we do need to account for a change in energy between two points:
  - If there is a pump between two points, then energy is ADDED
  - If there is motor or turbine between two points, then energy is REMOVED
  - If there is appreciable friction, then energy is LOST

… and in all of these cases, this energy must be accounted for.

Typical industrial pipeline installations include pumps which add energy to the fluid, along with fittings such as valves, elbows, and tees that cause the fluid to lose energy.



We will simply add three new terms to Bernoulli's Equation to account for these changes in energy:

Since energy in Bernoulli's Equation is tracked in the form of *energy per weight of fluid*, or *head*, we will do the same with these three new terms:

h_A = Energy added to the fluid with a mechanical device such as a pump.

h_R = Energy removed from the fluid for some useful purpose by a turbine or fluid motor

h_L = Energy lost from the fluid due to friction in pipes, valves, or fittings.

Add these three to new terms to Bernoulli's Equation:

$$E_1' + h_A - h_R - h_L = E_2'$$

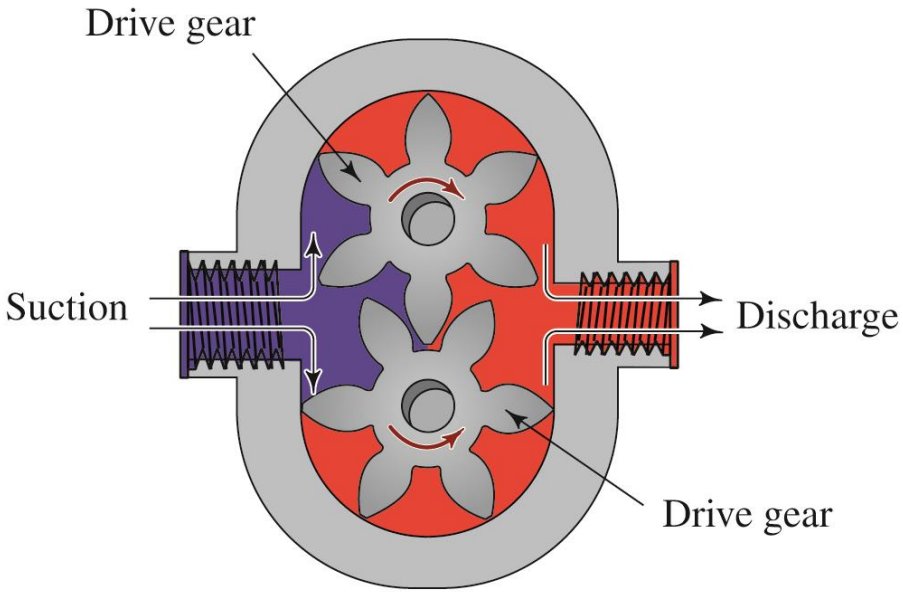
$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_R - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

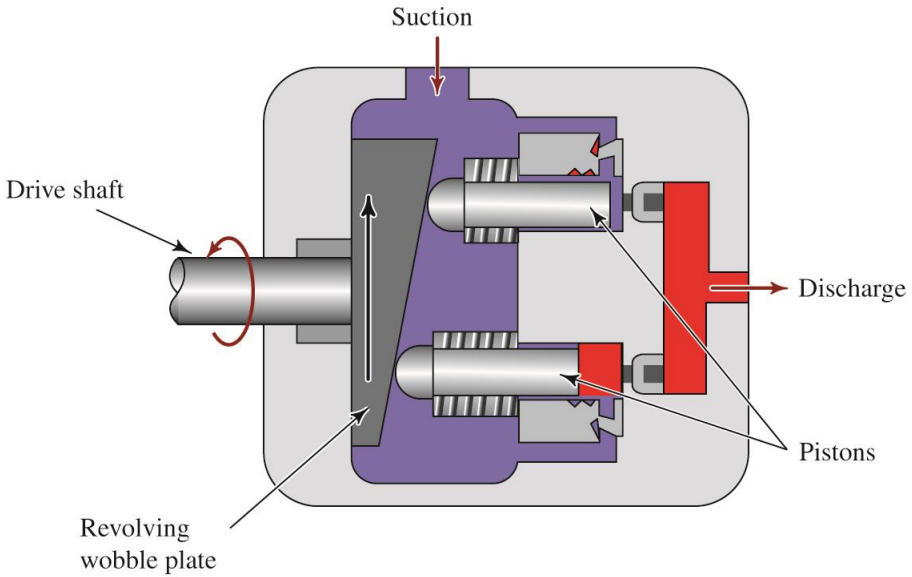
Just as in Bernoulli's Equation, eliminate terms that do not apply to the two points chosen for analysis, determine values, and solve for the unknown.

$$\frac{p_1}{\gamma}^{0} + z_1 + \frac{v_1^2}{2g}^{0} + h_A^{0} - h_R^{0} - h_L = \frac{p_2}{\gamma}^{0} + z_2 + \frac{v_2^2}{2g}$$

$$z_1 - h_L = z_2 + v_2^2/2g$$

Pumps are mechanical devices that take mechanical energy from a rotating shaft and give that energy to the fluid. Pumps transfer mechanical energy from an external source, to the fluid in the system.





Power Added to a Fluid by a Pump

$$P_{\mathrm{A}} = h_{\mathrm{A}} W$$

Because $W = \gamma Q,$

we can also write

⇨ **Power Added to a Fluid by a Pump**

$$P_A = h_A \gamma Q$$

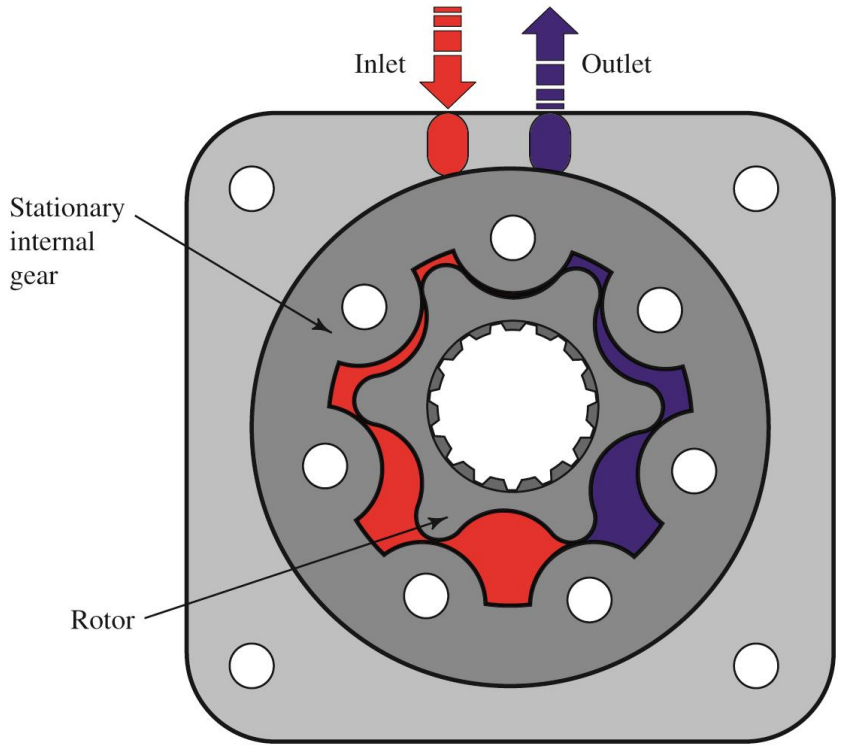
Mechanical Efficiency of Pumps

There are mechanical losses that occur within the pump's internal components.

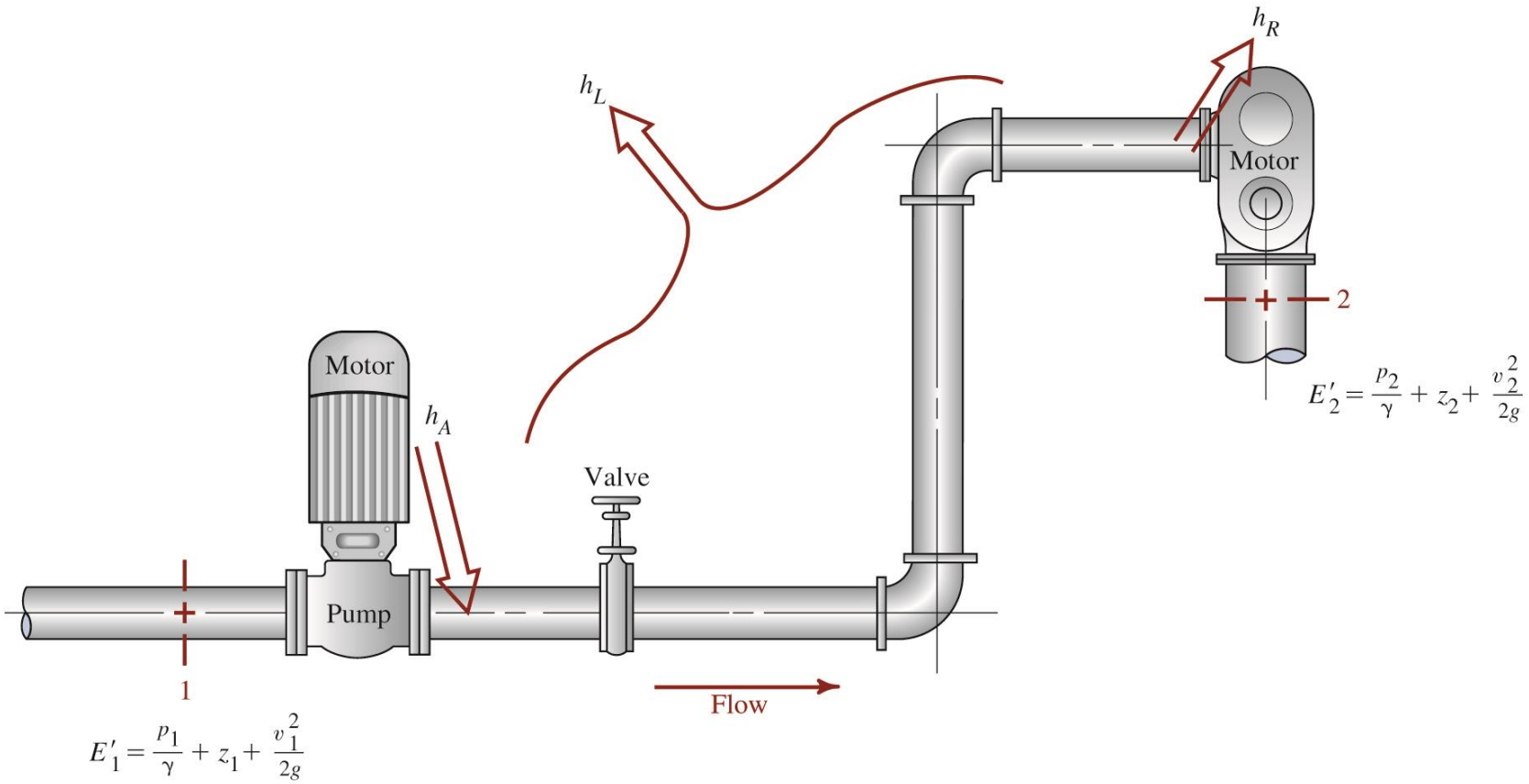
$$e_M = \frac{\text{Power delivered to fluid}}{\text{Power put into pump}} = \frac{P_A}{P_I}$$

The value of e_M will always be less than 1.0.

Hydraulic motors are the opposite of pumps; they remove energy from the fluid and deliver that energy to an external operation, via a rotating shaft, to do work externally.

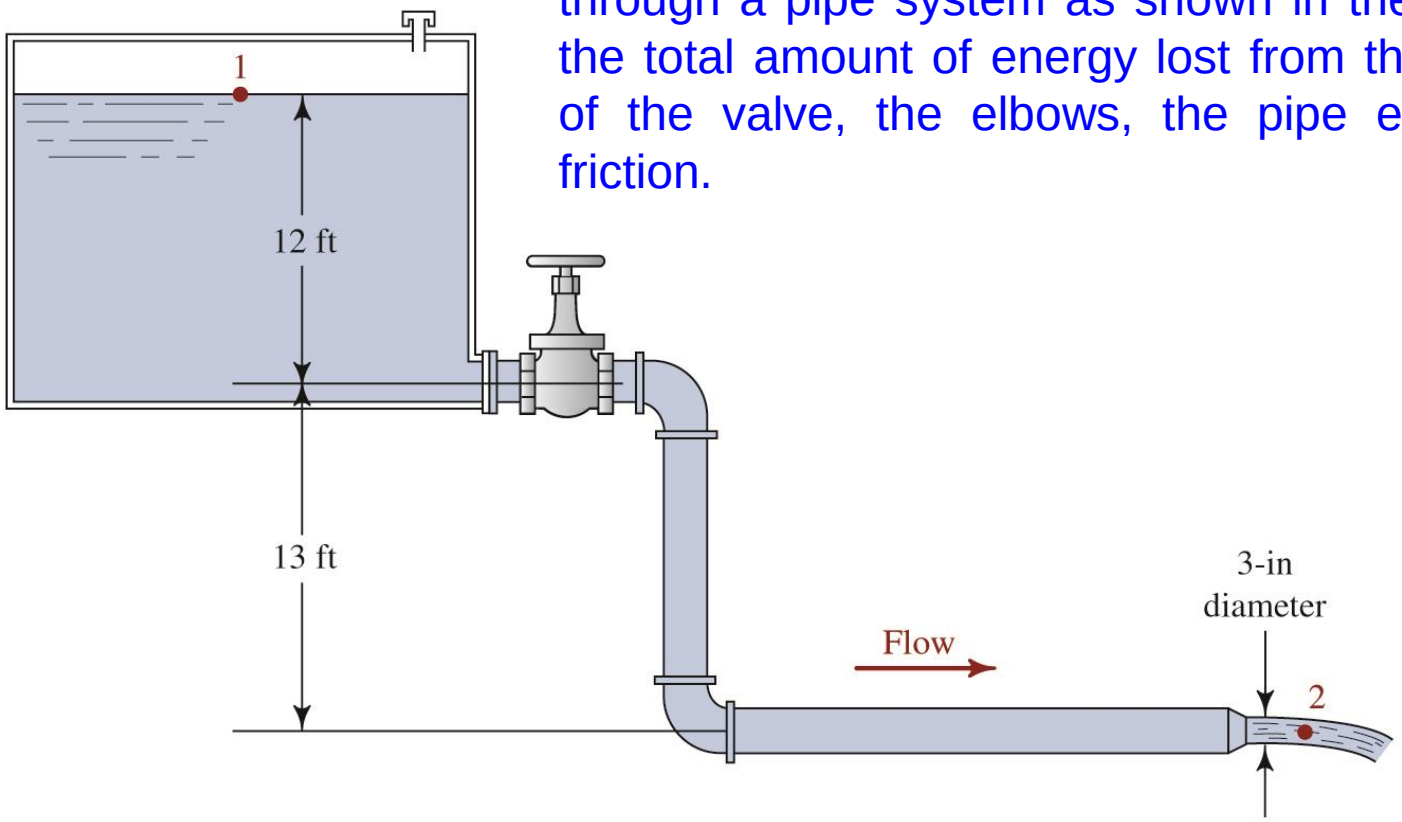


Fluid flow system illustrating the general energy equation



Pipe system for Example Problem 7.1

Water flows from a large reservoir at the rate of 1.20 ft^3/s through a pipe system as shown in the Figure. Calculate the total amount of energy lost from the system because of the valve, the elbows, the pipe entrance, and fluid friction.

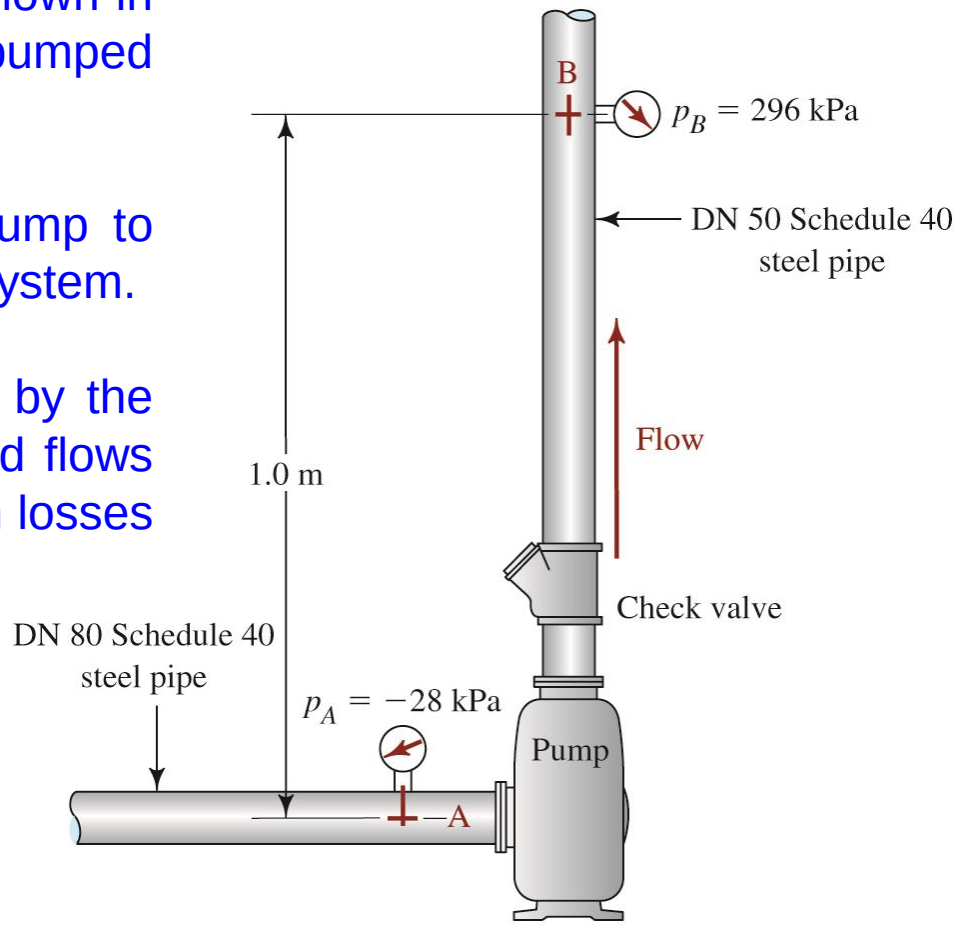


Pump system for Example Problem 7.2

The volume flow rate through the pump shown in the Figure is 0.014 m^3/s. The fluid being pumped is oil with a specific gravity of 0.86.

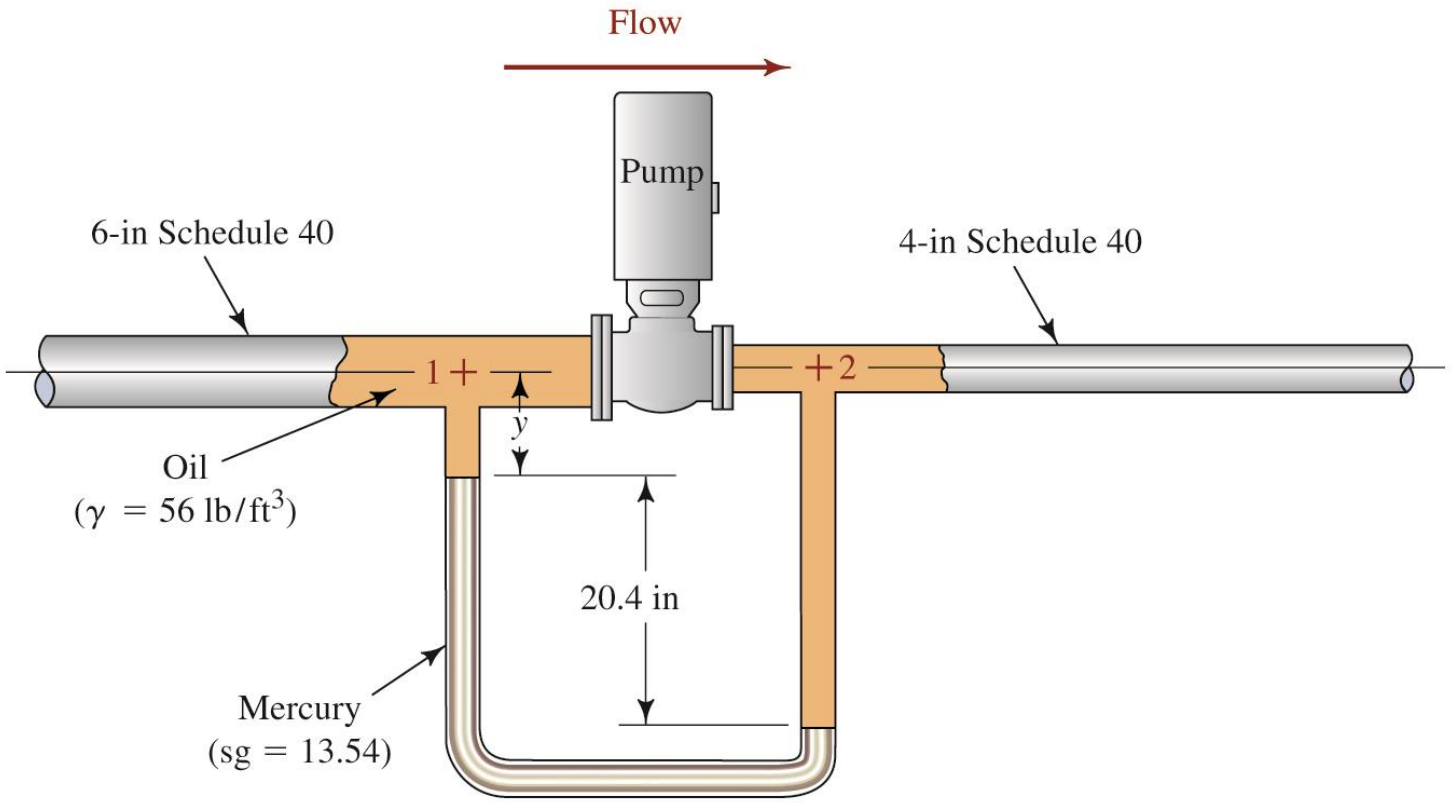
Calculate the energy delivered by the pump to the oil per unit weight of oil flowing in the system.

Energy losses in the system are caused by the check valve and friction losses as the fluid flows through the piping. The magnitude of such losses has been determined to be 1.86 N·m/N.

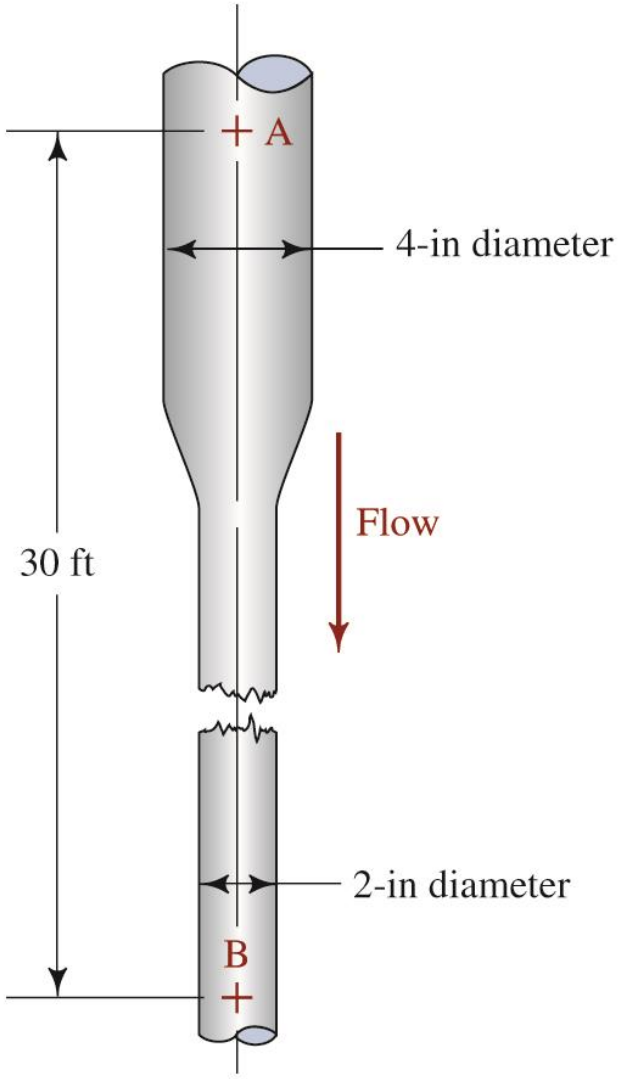


Pump test system for Example Problem 7.3

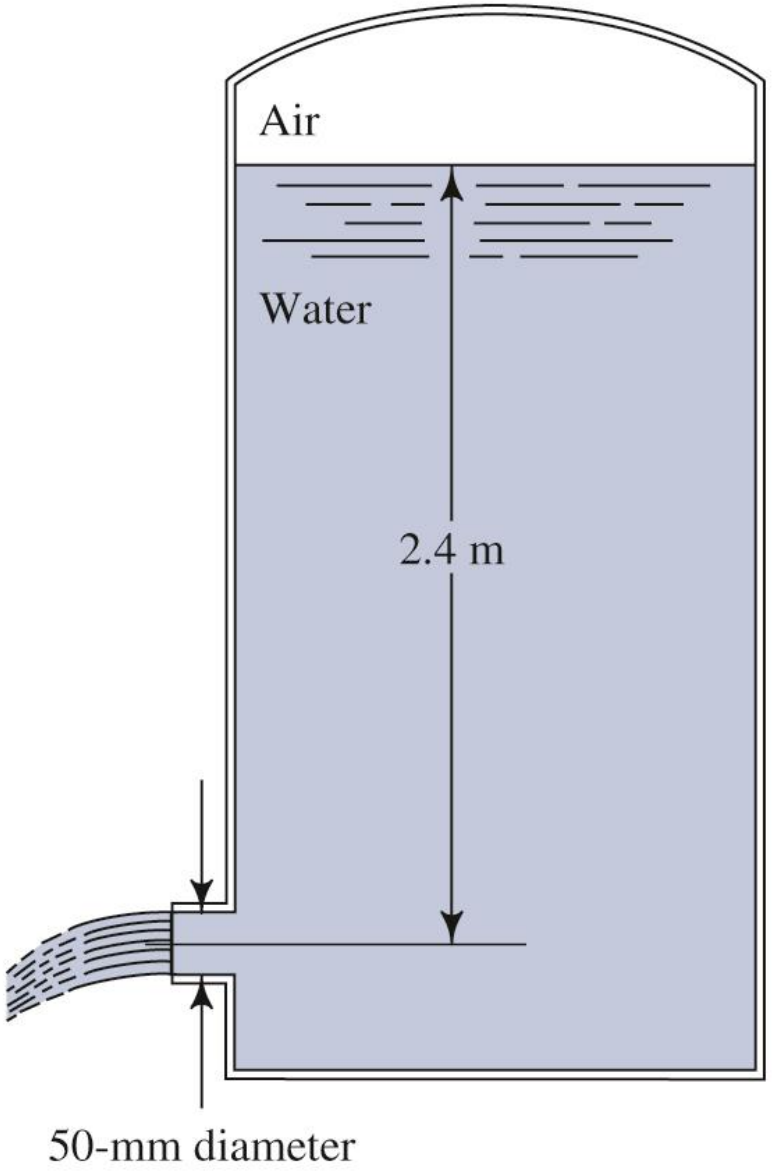
For the pump test arrangement shown in the Figure below, determine the mechanical efficiency of the pump if the power input is measured to be 3.85 hp when pumping 500 gal/min of oil (γ= 56.0 lb/ft^3).



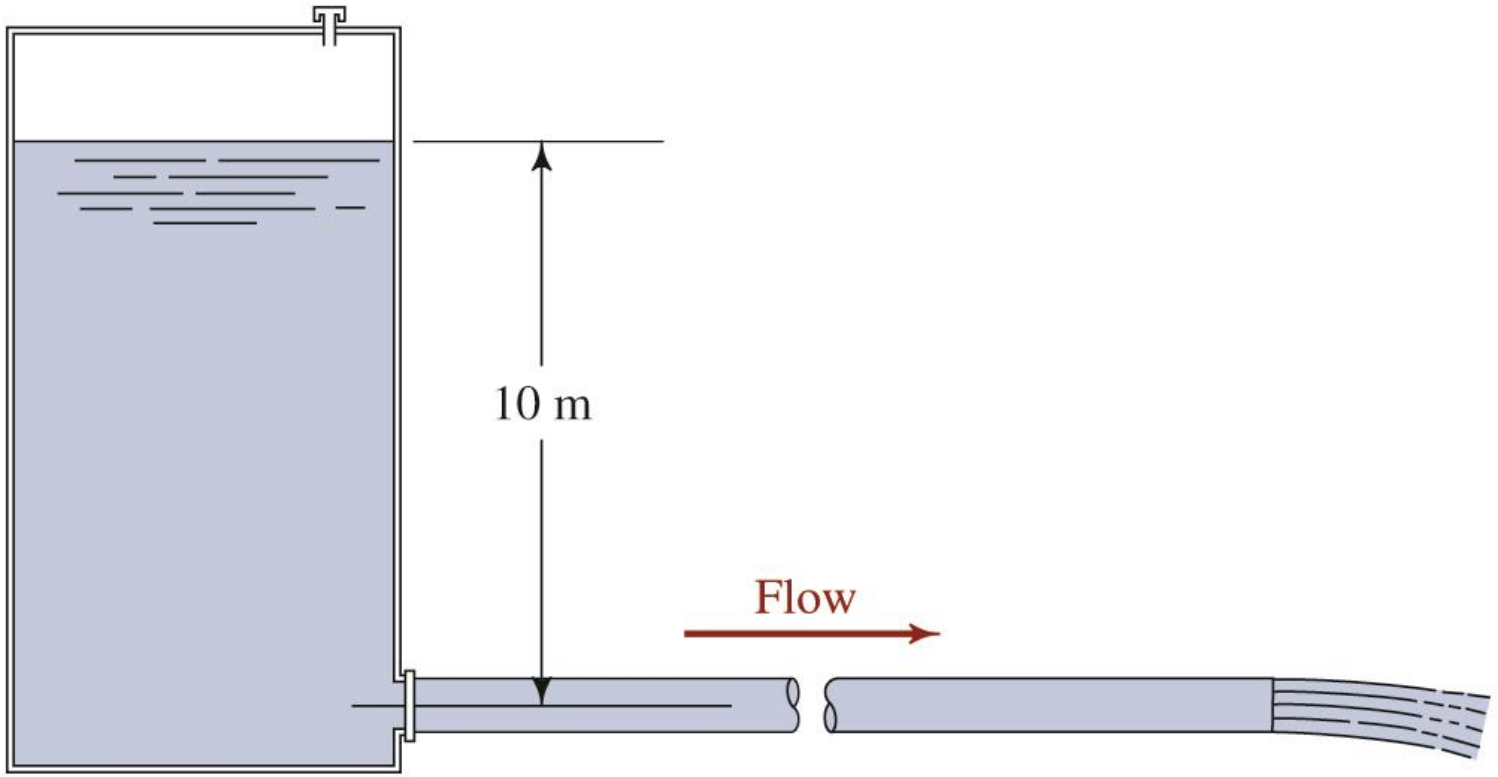
Fabricated reducer for Problem 7.2



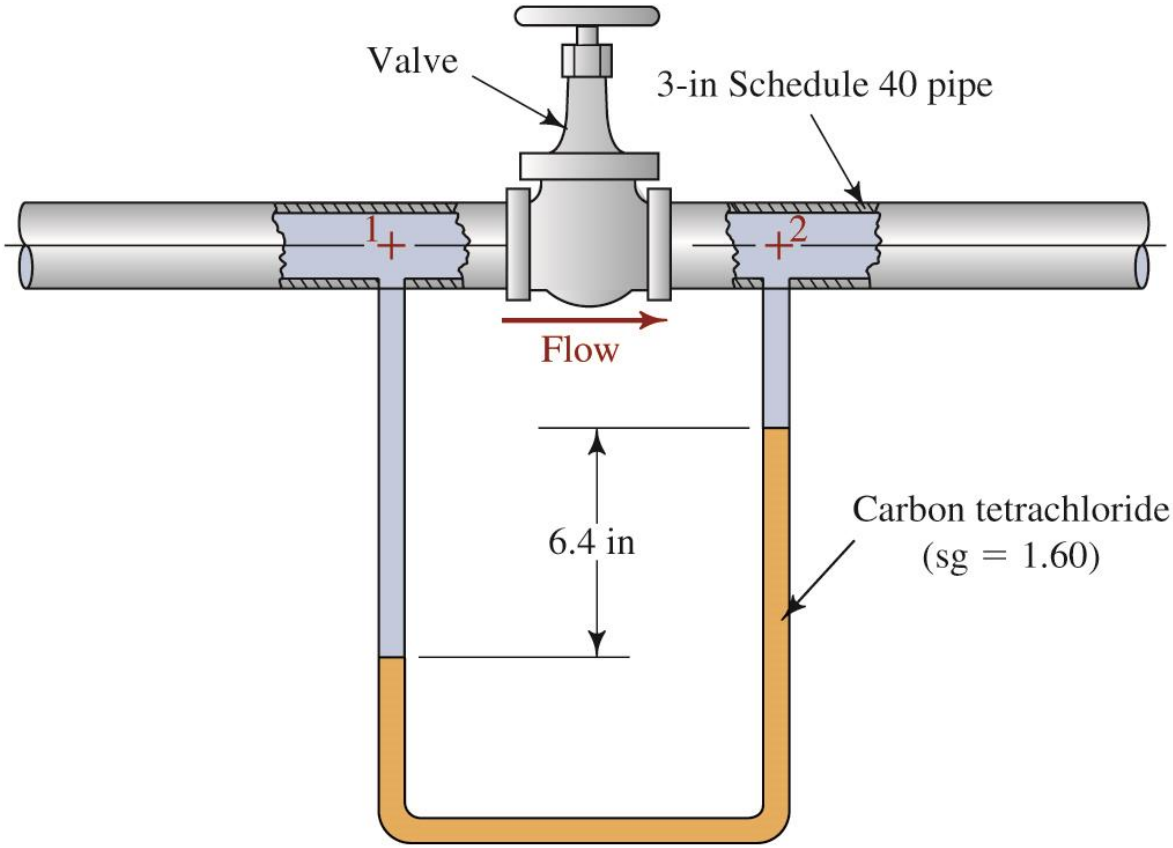
Pressurized tank for Problem 7.3



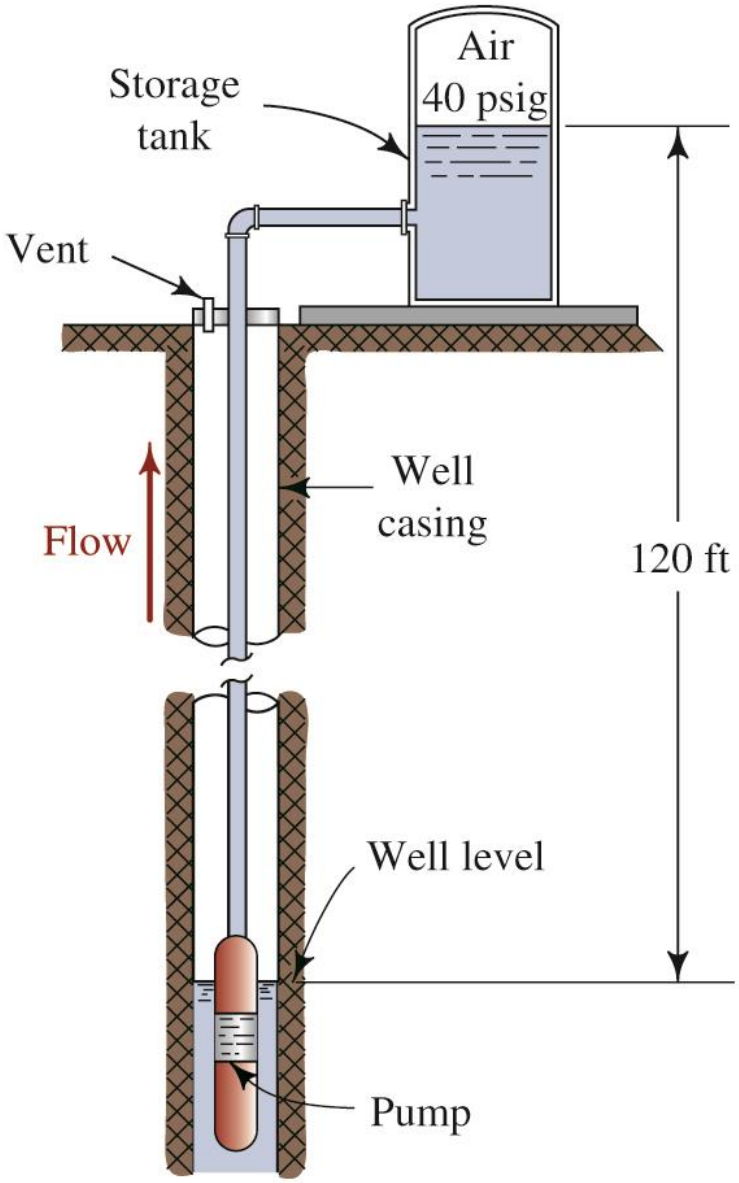
Large reservoir for Problem 7.4



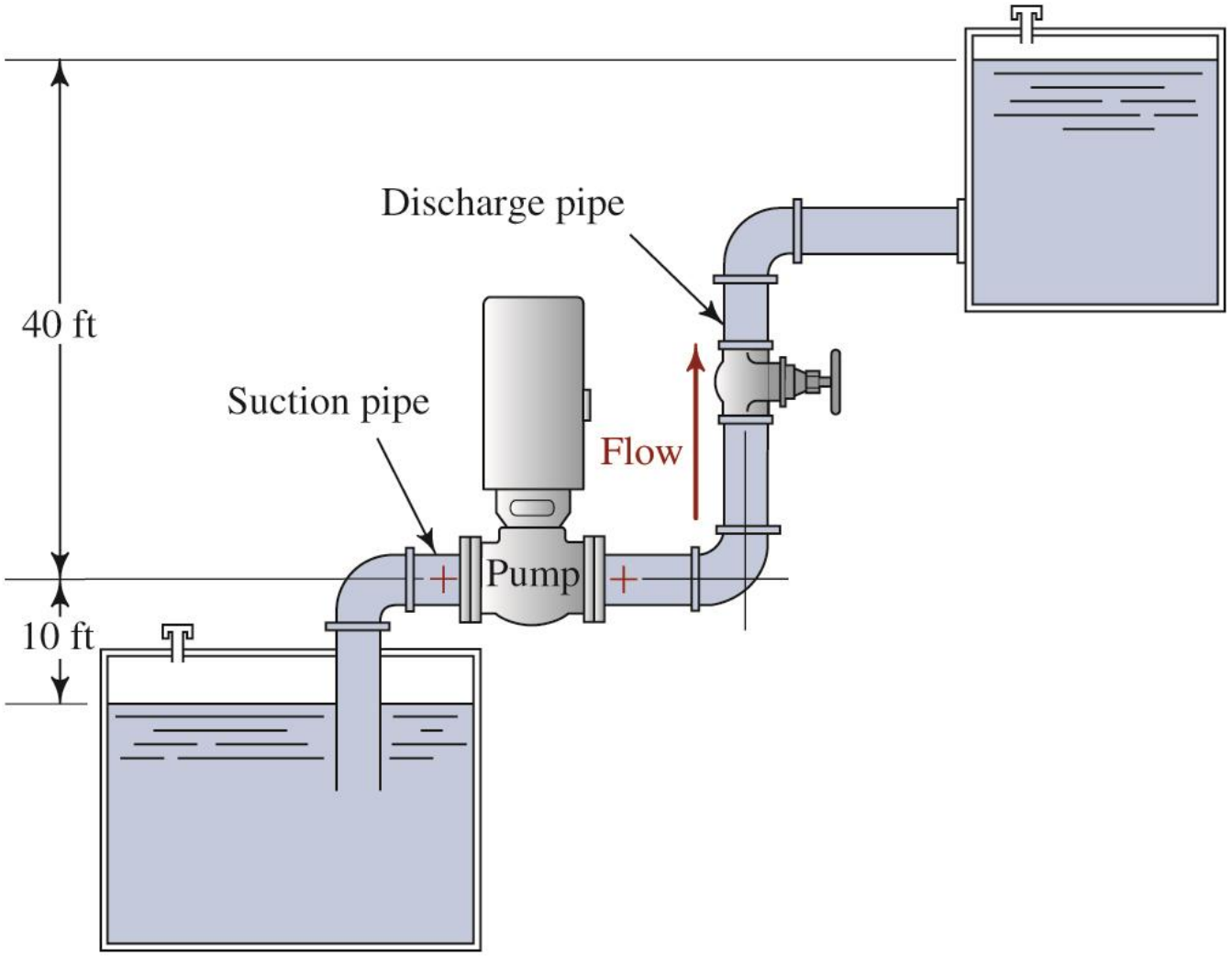
Manometer to measure energy loss in valve for Problem 7.6



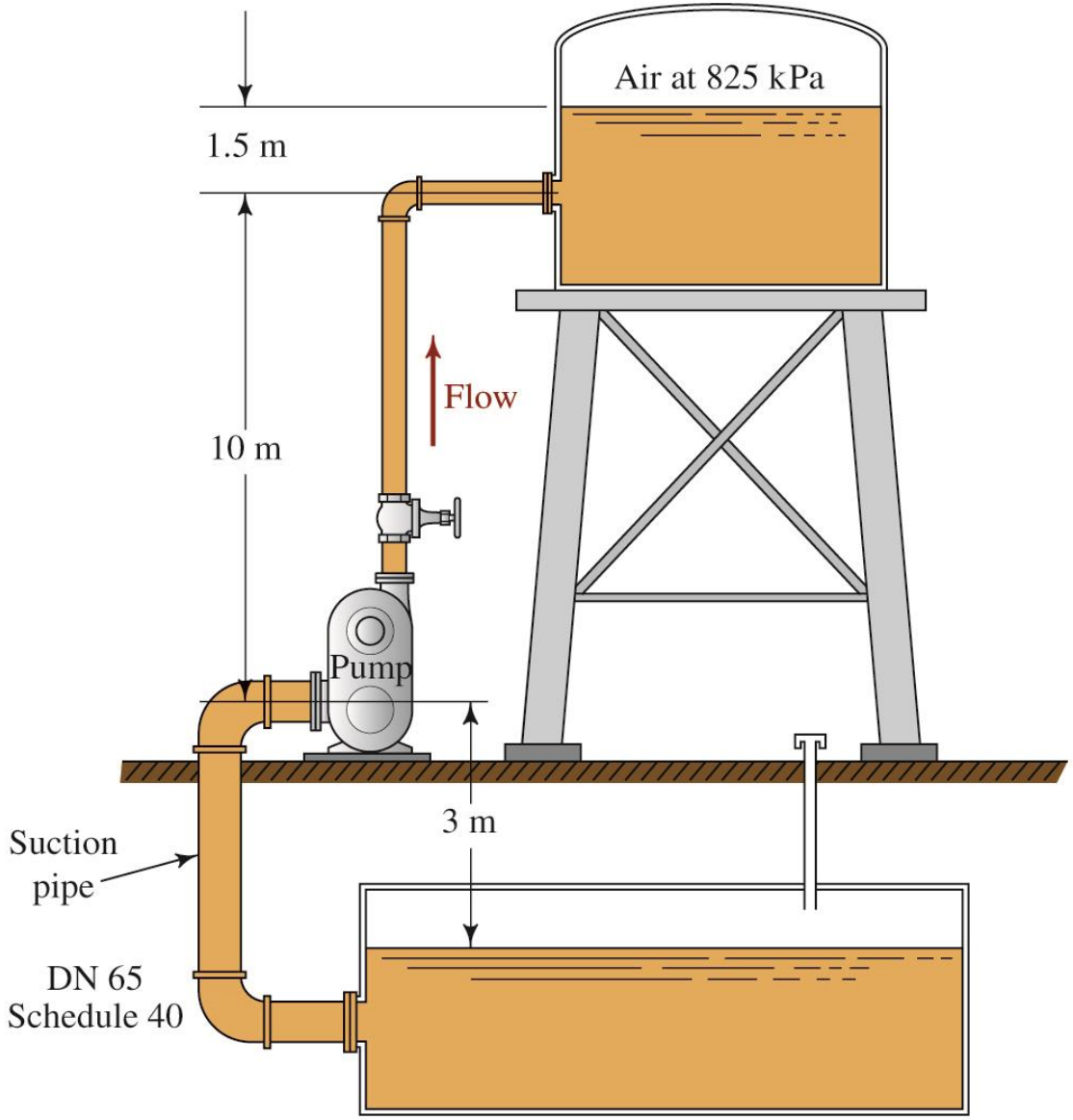
Well pump for Problem 7.11



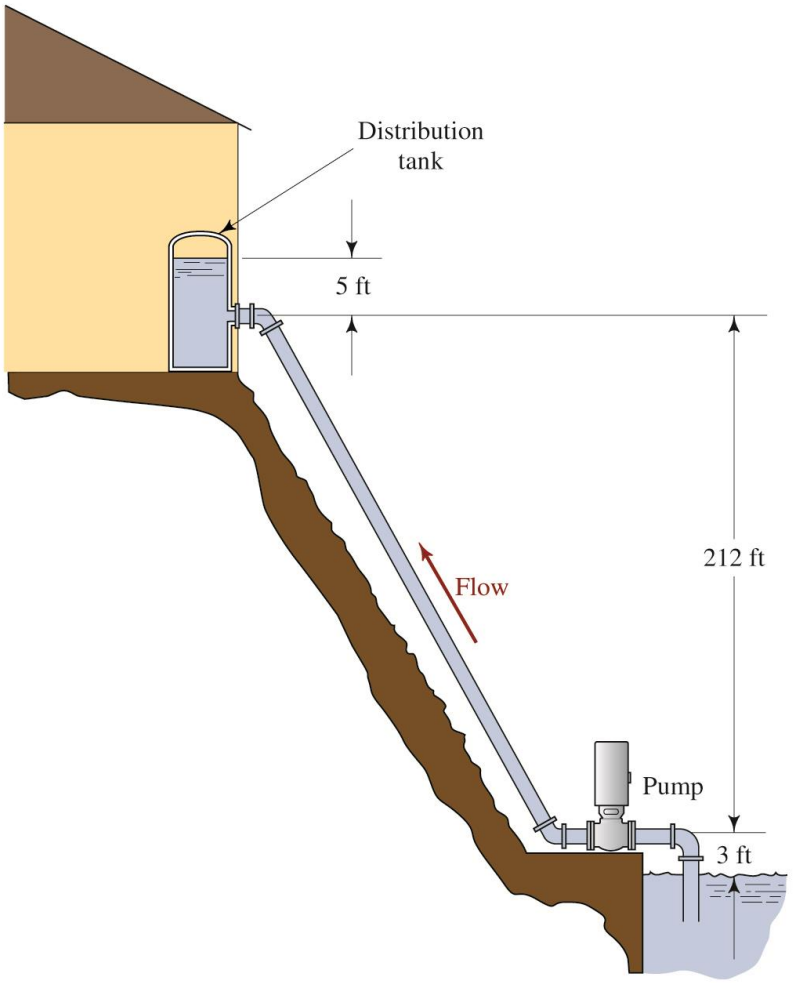
Problems 7.14 and 7.15



Oil pump and tanks for Problem 7.16



Cabin water system for Problems 7.42 and 7.43



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