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Applied Fluid Mechanics

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APPLIED FLUID MECHANICS

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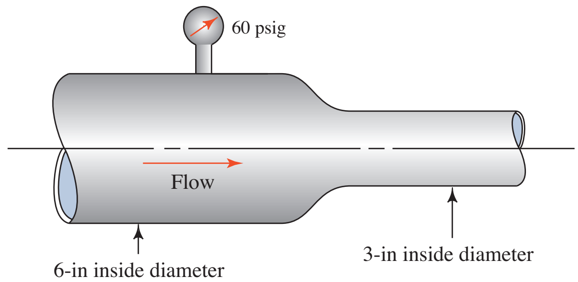


FIGURE 6.34 Problem 6.81.

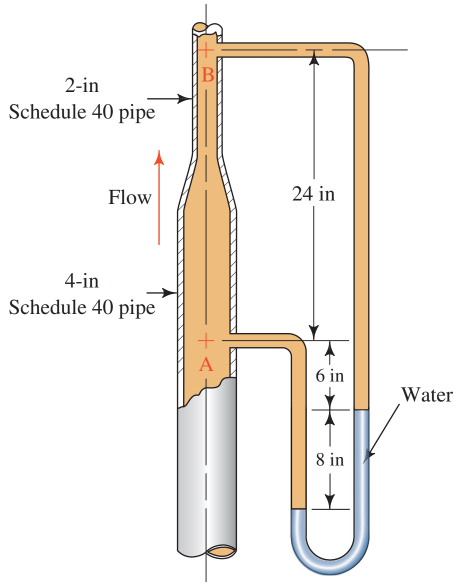


FIGURE 6.35 Problem 6.82.

6.83 Draw a plot of elevation head, pressure head, velocity head, and total head for the siphon system shown in Fig. 6.27 and analyzed in Problem 6.72.

6.84 Draw a plot of elevation head, pressure head, velocity head, and total head for the fabricated reducer shown in Fig. 6.28 and analyzed in Problem 6.73.

6.85 Figure 6.36 shows a system in which water flows from a tank through a pipe system having several sizes and elevations. For points A–G, compute the elevation head, the pressure head, the velocity head, and the total head. Plot these values on a sketch similar to that shown in Fig. 6.7.

6.86 Figure 6.37 shows a venturi meter with a U-tube manometer to measure the velocity of flow. When no flow occurs, the mercury column is balanced and its top is 300 mm below the throat. Compute the volume flow rate through the meter that will cause the mercury to flow into the throat. Note that for a given manometer deflection h, the left side will move down $h/2$ and the right side would rise $h/2$.

6.87 For the tank shown in Fig. 6.38, compute the velocity of flow from the outlet nozzle at varying depths from 10.0 ft to 2.0 ft in 2.0-ft increments. Then, use increments of 0.5 ft to zero. Plot the velocity versus depth.

6.88 What depth of fluid above the outlet nozzle is required to deliver 200 gal/min of water from the tank shown in Fig. 6.37? The nozzle has a 3-in diameter.

Torricelli's Theorem

6.89 Derive Torricelli's theorem for the velocity of flow from a tank through an orifice opening into the atmosphere under a given depth of fluid.

6.90 Solve Problem 6.88 using the direct application of Torricelli's theorem.

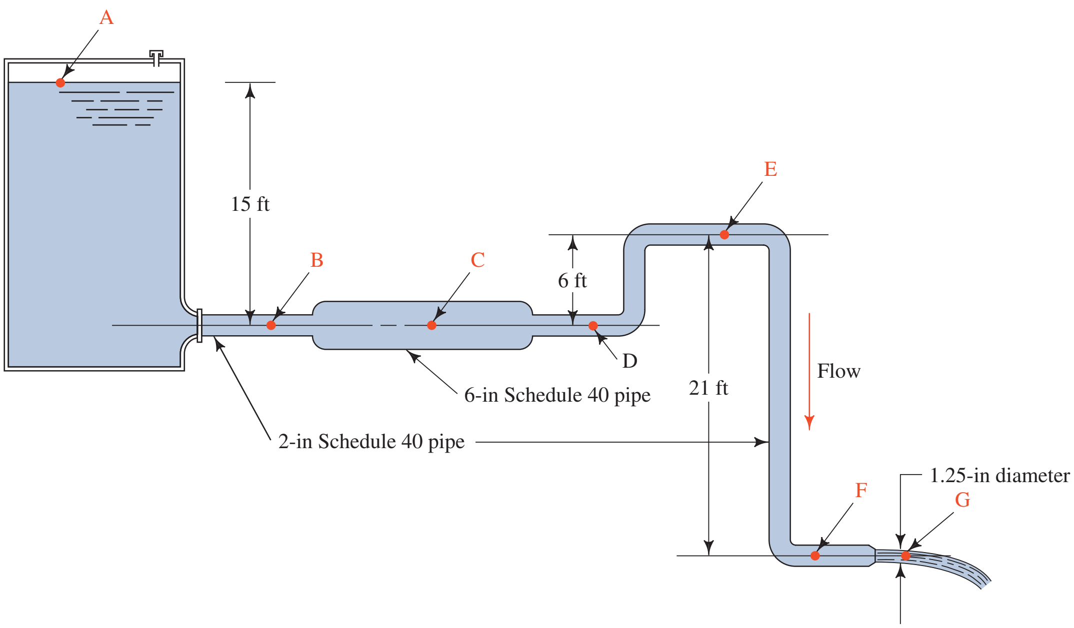


FIGURE 6.36 Flow system for Problem 6.85.

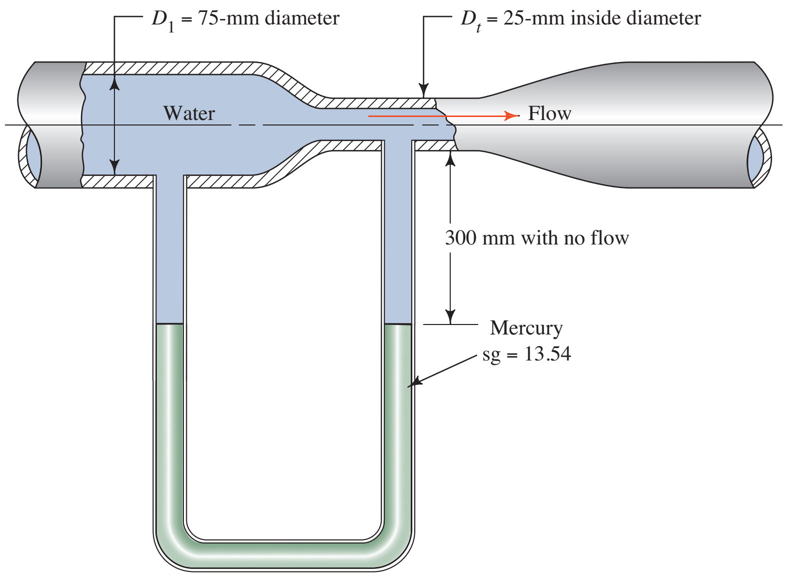


FIGURE 6.37 Venturi meter for Problem 6.86.

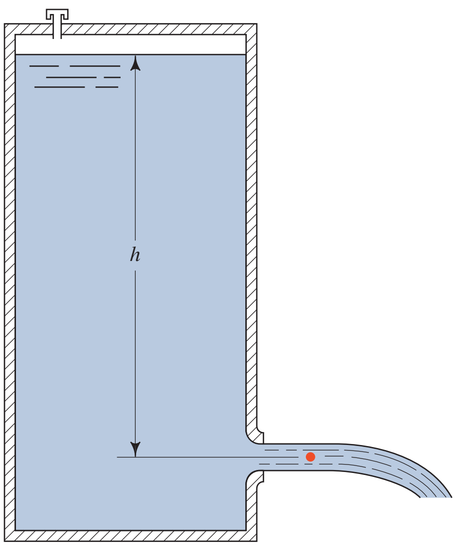


FIGURE 6.38 Tank for Problems 6.87–6.88.

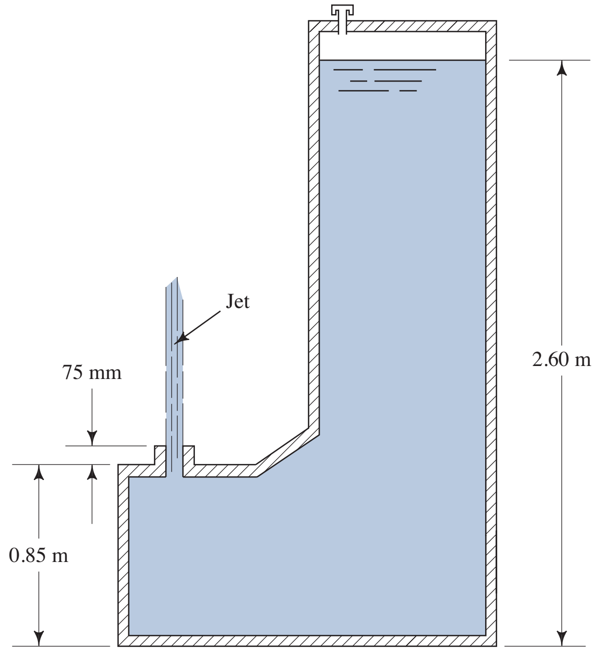


FIGURE 6.39 Problem 6.91.

6.91 To what height will the jet of fluid rise for the conditions shown in Fig. 6.39?

6.92 To what height will the jet of water rise for the conditions shown in Fig. 6.40?

6.93 What pressure is required above the water in Fig. 6.12 to cause the jet to rise to 28.0 ft? The water depth is 4.50 ft.

6.94 What pressure is required above the water in Fig. 6.13 to cause the jet to rise to 9.50 m? The water depth is 1.50 m.

Flow Due to Falling Head

6.95 Compute the time required to empty the tank shown in Fig. 6.14 if the original depth is 2.68 m. The tank diameter is 3.00 m and the orifice diameter is 150 mm.

6.96 Compute the time required to empty the tank shown in Fig. 6.14 if the original depth is 55 mm. The tank diameter is 300 mm and the orifice diameter is 20 mm.

6.97 Compute the time required to empty the tank shown in Fig. 6.14 if the original depth is 15 ft. The tank diameter is 12 ft and the orifice diameter is 6 in.

6.98 Compute the time required to empty the tank shown in Fig. 6.14 if the original depth is 18.5 in. The tank diameter is 22.0 in and the orifice diameter is 0.50 in.

6.99 Compute the time required to reduce the depth in the tank shown in Fig. 6.14 by 1.50 m if the original depth is 2.68 m. The tank diameter is 2.25 m and the orifice diameter is 50 mm.

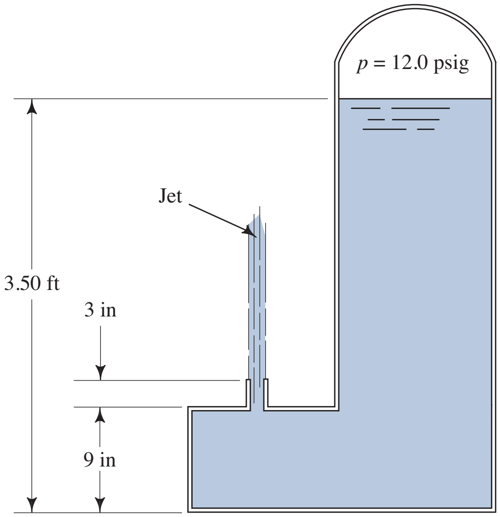


FIGURE 6.40 Problem 6.92.

6.100 Compute the time required to reduce the depth in the tank shown in Fig. 6.14 by 225 mm if the original depth is 1.38 m. The tank diameter is 1.25 m and the orifice diameter is 25 mm.

6.101 Compute the time required to reduce the depth in the tank shown in Fig. 6.14 by 12.5 in if the original depth is 38 in. The tank diameter is 6.25 ft and the orifice diameter is 0.625 in.

6.102 Compute the time required to reduce the depth in the tank shown in Fig. 6.14 by 21.0 ft if the original depth is 23.0 ft. The tank diameter is 46.5 ft and the orifice diameter is 8.75 in.

6.103 Repeat Problem 6.97 if the tank is sealed and a pressure of 5.0 psig is above the water in the tank.

6.104 Repeat Problem 6.101 if the tank is sealed and a pressure of 2.8 psig is above the water in the tank.

6.105 Repeat Problem 6.96 if the tank is sealed and a pressure of 20 kPa(gage) is above the water in the tank.

6.106 Repeat Problem 6.100 if the tank is sealed and a pressure of 35 kPa(gage) is above the water in the tank.

Supplemental Problems

6.107 A village currently carries water by hand from a lake that is 1200 m from the village center. It is later determined that the surface of the lake is 3 m above the elevation of the village, so someone began to wonder if a simple plumbing line could deliver the water. If a flexible plastic line with a 20-mm inside diameter could be installed from the lake to the village, what theoretical flow rate is possible, ignoring all losses?

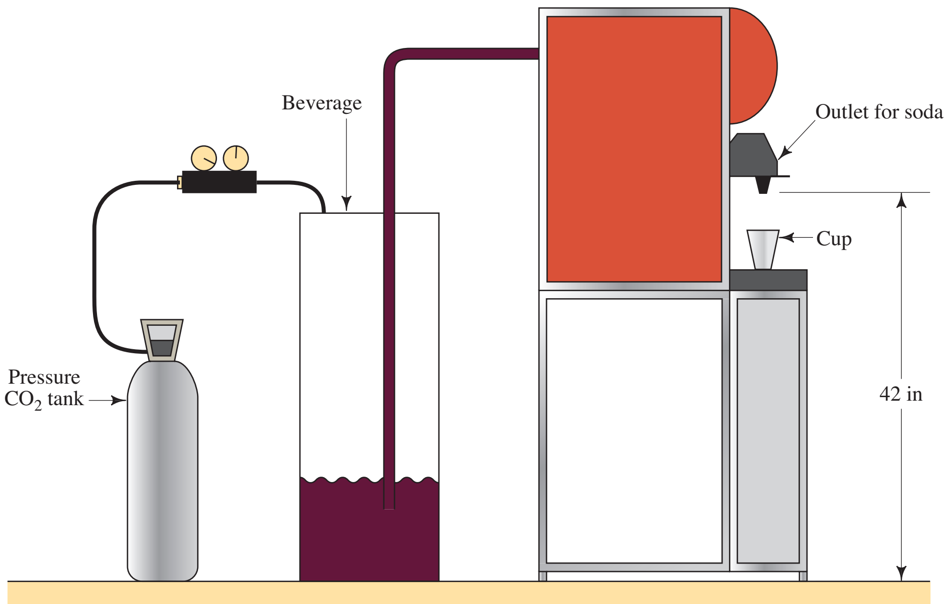
6.108 A "spa tub" is to be designed to replace bath tubs in renovations. There are to be 6 outlet nozzles, each with a diameter of 12 mm, and each should have an outlet velocity of 12 m/s. What is the required flow rate from the single pump that supplies all of these nozzles? If there is one suction line leading to the pump, what is the minimum diameter to limit the velocity at the inlet of the pump to 2.5 m/s?

6.109 A simple soft drink system relies on pressurized CO_2 to force the soft drink (sg = 1.08) from its tank sitting on the floor up to the outlet where cups are filled. Determine the required CO_2 pressure to allow a 16 oz cup to be filled in 6 s, when the beverage tank is nearly empty, given Fig. 6.41.

6.110 A concept team for a toy company is considering a new squirt gun. They have an idea for one that could shoot a vertical stream to a height 7 m from a 5-mm-diameter nozzle. People like squirt guns that shoot for a long time, but also do not like water tanks that are too big or heavy. If the tank of this squirt gun can hold 3 L, how long can the squirt gun shoot?

6.111 Bernoulli's principle applies to Venturi tubes that are used in many practical devices such as "air brush" painters, vacuum systems, carburetors, water bed drains and many other devices. One such system used to spray fertilizer is

FIGURE 6.41 Problem 6.109.



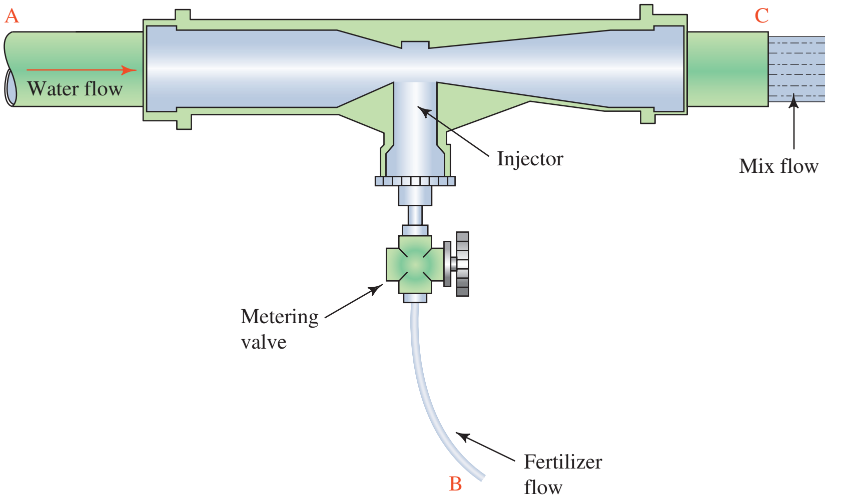


FIGURE 6.42 Problem 6.111.

shown in Fig. 6.42. Port A is connected to a water supply that is directed through the venturi. At the throat of the Venturi, Port B is connected to the supply of fertilizer concentrate from a container below. Port C is the spray nozzle that directs the diluted fertilizer solution out to the plants. Port A, 10 mm in diameter, is connected to a water supply that reads 180 kPa while flowing at 12 L/min. Determine the vacuum pressure in the 3.5-mm-diameter throat if the metering valve is completely closed. Explain what will happen to the fertilizer concentrate in the container below as the metering valve is opened.

6.112 A decorative fountain for a corporate world headquarters is to be designed to shoot a stream of water straight up in the air. If the designers would like the fountain to reach at least 50 ft into the air, what pressure must exist at the nozzle inlet? The nozzle has an inlet diameter of 5.0 in and an outlet diameter of 2.0 in.

6.113 You are to develop a mixing valve for use in a dairy processing facility. The rated output of the valve is to be 10 gal/min of chocolate milk. There will be two separate input lines, one for milk and the other for chocolate syrup. Your valve is to ensure that the proper ratio of milk to chocolate syrup is 16:1. As a start for your design, determine the minimum diameters of the milk, syrup, and chocolate milk fittings if they are to limit the velocity in each line to a maximum of 8.0 ft/s.

6.114 While maneuvering at the scene of a fire, a truck accidently backs over a fire hydrant and breaks it. The diameter of the water line to the hydrant is 6 in, but due to internal plumbing, the effective diameter at the water outlet is 4 in. If the flow rate of the water leaving the hydrant is 1000 gal/min, what height will the water reach?

6.115 You would like to empty the in-ground pool in the back yard but the drain at the bottom of the pool is no longer functional. Given the dimensions in Fig. 6.43, determine the flow rate from the pool at the instant shown if the hose has an inside diameter of 0.5 in. What had to happen to initiate flow from the drain hose? What will happen to the flow rate as the level of the pool drops?

6.116 A pressure washer available to home owners lists 1300 psi and 2 gpm among its specifications. We know, however, that the actual pressure of the water is atmospheric (0 gage) once it exits the nozzle. The key feature of the so-called pressure washer then is actually the velocity with which it exits the nozzle. Neglecting any losses, what would be the velocity of the stream from this machine if it achieves the specified flow rate through an outlet nozzle having a diameter of 0.062 in?

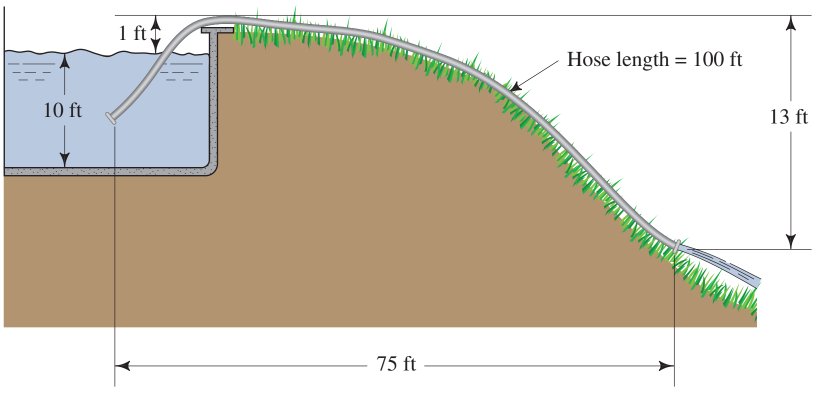


FIGURE 6.43 Problem 6.115.

ANALYSIS PROJECTS USING BERNOULLI'S EQUATION AND TORRICELLI'S THEOREM

1. Create a spreadsheet for computing the values of the pressure head, the velocity head, the elevation head, and the total head for given values of pressure, velocity, and elevation.
2. Enhance the spreadsheet in Project 1 by causing it to list side by side in several combinations the various head components in order to compare one with another as done when using Bernoulli's equation.
3. In the spreadsheet in Project 1, include the ability to compute the velocity of flow from given data for volume flow rate and pipe size.
4. Create a spreadsheet for computing, using Eq. (6–26), the time required to decrease the fluid level in a tank between two values for any combination of tank size and nozzle diameter. Apply it to Problems 6.95–6.102.
5. Add the ability to pressurize the system to the spreadsheet in Project 4. Apply it to Problems 6.103–6.106.
6. Create a spreadsheet for computing the velocity of flow from an orifice, using Torricelli's theorem for any depth of fluid and any amount of pressure above the fluid. Apply it to Problems 6.90–6.94.

CHAPTER SEVEN

GENERAL ENERGY EQUATION

THE BIG PICTURE

You will now expand your ability to analyze the energy in fluid flow systems by adding terms to Bernoulli's equation which was introduced in Chapter 6. You will account for a variety of forms of energy that were neglected before, such as:

- Energy lost from a system through friction as the fluid flows through pipes
- Energy lost as the fluid flows through valves, or fittings where the fluid must travel in complex paths, accelerate or decelerate, or change direction
- Energy added to the system by a pump as it provides the impetus for the fluid to move and increases the fluid pressure
- Energy removed from the system by fluid motors or turbines that use the energy to drive other mechanical systems.

Adding these terms to Bernoulli's equation eliminates many of the restrictions that were identified in Section 6.7 and transforms it into the *general energy equation* that you will apply as you study Chapters 7–13.

As an example of a system where energy losses and additions occur, refer now to Fig. 7.1 showing a portion of an industrial fluid distribution system. The fluid enters from the left, where the suction line draws fluid from a storage tank. The inline pump adds energy to the fluid and causes it to flow into the discharge line and then through the rest of the piping system. Note that the suction pipe is larger than the discharge pipe. If the sizes of the pump suction inlet and the discharge ports provided by the pump manufacturer are different from the pipe sizes, a gradual reducer or a gradual enlargement may be needed. This is a common occurrence. The fluid then passes straight through the run of a tee, where a valve in the branch line can be opened to draw some fluid off to another destination point. After leaving the tee, the fluid passes through a valve that can be used to shut off the discharge line. Just downstream from the valve is another tee where now the fluid takes the branch path, passes around a 90° elbow, and passes through another valve. The discharge pipe beyond the valve is insulated and the fluid travels through the long, straight pipe line to its ultimate destination.

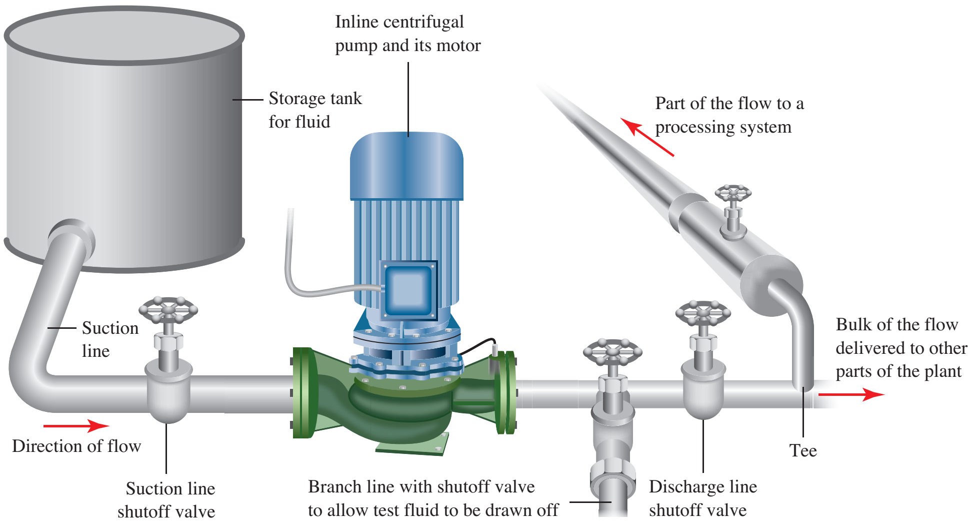


FIGURE 7.1 In systems like this typical industrial pipeline installation, showing a pump, valves, tees, and other fittings, you must use the general energy equation to analyze its performance.