UNIT SIX
FLUID FLOW

Special Terms

Fluid Dynamics: The science concerned with the flow of fluids – materials that flow, either liquids or gases.

Compressor: A machine used for pressurizing gases.

Centrifugal Pump: The most common type of pump. The rotating parts impart energy to the liquid, thereby increasing its pressure and velocity.

Impeller: The rotating part of a centrifugal pump. It consists of a disk (or pair of disks) with vanes.

Reciprocating Pump: A pump that consists of a piston moving back and forth (reciprocating) in cylinder.

Duct: A tubular passage through which a fluid – usually a gas – is conducted. Ducts for gases are usually rectangular in cross section.

Density: The weight of a given volume of material. It is usually measured in terms of pounds per cubic foot or grams per cubic centimeter.

Viscosity: The resistance to flow of a fluid. It is usually measured in terms of the centipoises (cP) or the centistokes (cSt).

Throttling: The regulation of fluid flow by changing the size of the passage through which the material must flow.

Gate Valve: A common type a valve designed to be either fully open or fully closed.

Valve Trim: The moving parts of a valve that are made wet by the liquid flowing past.

Globe Valve: A common variety of valve designed for throttling fluid flow.

Vocabulary Practice

1. Define *fluid dynamics*. What are fluids?
2. What does a *compressor* do?
3. How does a *centrifugal pump* work?
4. What is the *impeller* of a centrifugal pump?
5. What is a *reciprocating pump*?
6. What is a *duct*? What is the usual shape of ducts used for gases?
7. What is meant by *density*?
8. What is the definition of *viscosity*? What units are used to express viscosity?
9. What is *throttling*?
10. What is a *gate valve*?
11. What parts of a valve are called the *trim*?
12. What is a *globe valve* used for?

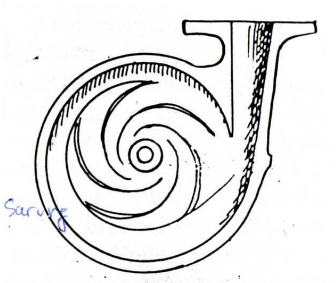
Fluid Flow

In the chemical process industries, plants most often handle materials in a fluid state – that is, as a liquid or a gas. In general,

fluids are much easier to transport from one place to another than are solids. Fluids can be transported in pipes in a continuous fashion, whereas solids-handling frequently requires rather complicated mechanical conveyors.

Since piping makes up so large a part of most process plants, the chemical engineer has to be thoroughly familiar with its design. The sizing of pipes is part of the subject of ***fluid dynamics***, the science concerned with the flow of fluids. Fluid dynamics is also involved in the choice of pumps and ***compressors***, both of which impart pressure energy to the fluid; it is this energy that causes flow. Pumps are used for pressurizing liquids and compressors for gases.

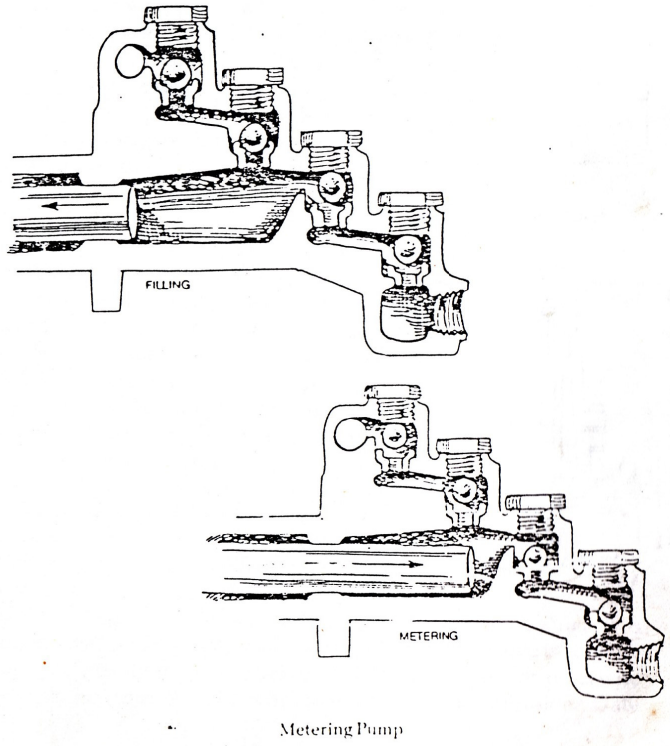
The most common type of pump used in the process industries is the ***centrifugal pump.*** In such a pump, a rotating wheel (or disk) with vanes on it, called an ***impeller,*** is used to impart energy to the liquid. The liquid enters the pump near the center of the impeller, where it is caught by the impeller's vanes. These impart a velocity to the liquid and centrifugal force carries it to the wall of the pump, where it exits. (The wall, or outer part of the pump, is called the casing). Although the basic principle of the centrifugal pump is simple, there are many variations of pump design, depending on the kind of liquid to be handled. For example, centrifugal pumps may be designed for liquids containing large pieces of solid material (such as sewage), liquids at high temperatures, very abrasive materials (such as suspensions of sand in water), or very corrosive liquids (such as acids and alkalis). Centrifugal pumps are available in dozens of different materials, although the most common is carbon steel. They are supplied in all of the materials of construction described in Unit Three, as well as others. One of the most desirable characteristics of centrifugal pumps is that they provide a steady flow, without pulsation of pressure.



Cross-section of a Centrifugal Pump

The second largest class of pumps used in process plants is the reciprocating type. All such pumps consist of pistons moving back and forth in cylinders. ***Reciprocating pumps*** can easily be designed to reach pressures far higher than those achieved by centrifugal pumps, and this is the area of their most common use. Unlike the centrifugal pump, the reciprocating pump imparts pressure in pulses – one at each stroke of the piston. One way of getting around this problem is by using a number of pistons in the pump, each of which reaches the end of its stroke (and, consequently, its highest pressure) at a different time. The pulsations of such a multiple-piston pump tend to average out so that the pulses are not severe enough to affect most processes.

Another use of reciprocating pumps is for metering liquids. Each stroke of the piston displaces the same volume of liquid, so that the output of the pump can be easily calculated. Although any



Metering Pump

reciprocating pump can be used in this way, some are especially designed for metering liquids. They are built so that the speed of the pump and stroke (distance traveled) of the piston are both adjustable. When constructed with several individually adjustable pistons, they are called proportioning pumps. (The use of proportioning pumps was described in Unit Two).

Gases move in a pipe or ***duct*** whenever the inlet pressure is higher than the outlet pressure. Pressurization can be accomplished by means of either fans or compressors. Fans are used for low pressures.

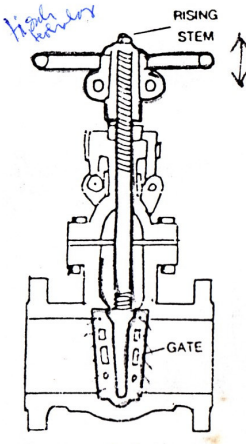
Like pumps, compressors may be either of the centrifugal or reciprocating variety. The reciprocating compressor is very similar in principle to the reciprocating pump. (The common bicycle pump is actually a very simple variety of hand-powered reciprocating compressor). Centrifugal compressors are generally of the turbine variety, and are similar in principle to the centrifugal pump, although far more complicated in actual design.

In the design and selection of both pumps and compressors, the ***density*** and ***viscosity*** of the fluid to be moved are of particular importance. The density of any material is the mass of a sample divided by its volume. It is usually expressed as grams per cubic centimeter or pounds per cubic foot. Viscosity is somewhat more difficult to define without using mathematical expressions, but it can generally be considered as resistance to flow. When poured from a jar, honey flows much more slowly than water. Thus honey has a higher viscosity (or is more viscous) than water. Both density and viscosity normally decrease with increasing temperature, although the changes in viscosity are more pronounced than the density changes. Some heavy fuel oils are so viscous at normal temperatures that they cannot be pumped. Consequently it is necessary to heat them so that the viscosity is reduced sufficiently to allow them to flow. Storage tanks for such fuel oils are equipped with steam coils for heating purposes.

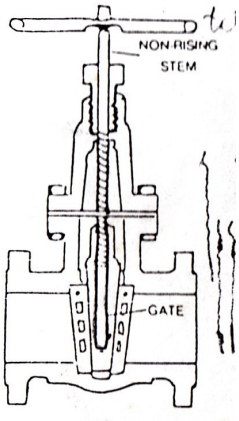
Controlling the flow of liquids in pipes is done by means of valves. There are two basic classes of valves: on/off and ***throttling***. An on/off valve, as the name implies, is either fully open (on) or fully closed (off). A throttling valve may be fully open, partially

open (or, looking at it another way, partially closed), or fully closed. A partially open valve presents a resistance that slows down flow, so throttling valves are used to change the rate of flow of liquids. On/off valves are sometimes called stop or block valves because they either permit flow or stop it entirely.

The most common variety of valve used in process plants is called a ***gate valve***. Its "gate" is a disk of metal that either closes off the pipe or is raised up into the body of the valve so that the opening in the pipe is unobstructed. When the gate is in the raised (or open) position, the body of the valve acts like a part of the pipe and the fluid flows almost as if the valve were not there. It is possible to use a gate valve for throttling by closing the gate only part of the way, but the valve is not designed for such service and will often be damaged if it is used in this way. The liquid flow tends to wear away the sharp edges of the gate so that it will not close tightly and will leak. When used properly, the gate in the open position is withdrawn into the body of the valve so there is no wear on it from liquid flow.



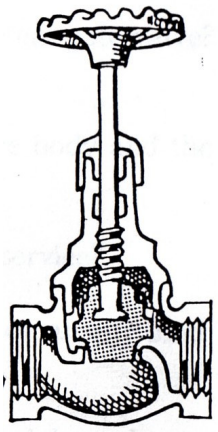
Gate Valves



A gate valve is usually opened or closed by turning a handwheel. In the more common pattern of gate valve, a threaded rod (or stem) is attached to the gate and is moved by the handwheel. When the gate is open, the stem projects above the handwheel and is therefore called a rising-stem valve. Rising-stem valves are preferred because, by looking at the stem, it is easy to see whether the valve is open or closed. When designing a piping system, space must be provided above the valve so the stem will not hit anything when it rises. If this space cannot be provided, the engineer can

specify a nonrising-stem valve. These can sometimes lead to dangerous situations because an operator may forget that it is a nonrising-stem valve and assume it is closed – because he cannot see the stem – when the valve is actually open. Nonrising-stem gate valves should be painted, or otherwise marked in some distinctive manner, to prevent confusion. Gate valves are available for every size of pipe and in a wide variety of construction materials. The ***valve trim*** (those moving parts that are made wet by the fluid in the pipe) is frequently made of material that is harder and more corrosion-resistant than the remainder of the valve.

When it is necessary to control the quantity of liquid flowing in a pipe (that is, to throttle it), the most common valve used is the globe valve. To pass through a ***globe valve***, liquid must turn through two right angles. This causes swirls and eddies in the liquid stream, which wastes energy. This is in contrast to the "straight-through" flow pattern in a gate valve. This waste of energy in globe valves shows up as a pressure drop in the pipeline and in increased pumping costs. Although a globe valve can be used for on/off service without damage to the valve, it is normally restricted to throttling service because of its energy losses.



Globe Valve

Globe valves are usually installed so that the flow is upward around the shut-off disk. This is to prevent the accumulation of solids that might prevent full closure above the disk. It also permits maintenance to be performed on the upper part of the valve when it is closed but still in the pipeline, because this part is isolated from the high pressure (input) side of the line. To facilitate proper installation, globe valves usually have an arrow cast, or otherwise marked, on the body of the valve. The valve should be installed so that the arrow points in the direction of liquid flow. Globe valves are available in a wide size range, although very large globe valves are less common than very large gate valves. They are also available in

most construction materials, both for the body of the valve and for the trim.

As described in the preceding unit on instrumentation, some valves are automatically opened and closed by an instrument rather than by hand. These control valves are generally a variety of globe valve, since their most common use is for throttling. A special and rather complex mechanism is needed to accomplish automatic control so these valves are much larger and far more expensive than the common hand-operated varieties.

Discussion

1. Why must a chemical engineer have a good knowledge of fluid dynamics?
2. Describe the way a centrifugal pump operates.
3. What are some of the special services for which centrifugal pumps are designed?
4. What kinds of materials are used for making centrifugal pumps?
5. What is one desirable characteristic of a centrifugal pump?
6. How does a reciprocating pump operate?
7. What is the most common use for reciprocating pumps?
8. What is an advantage of reciprocating pumps with a number of pistons?
9. Why are reciprocating pumps used for metering liquids?
10. Under what conditions will a gas move in a duct?
11. What are the two varieties of compressors?
12. How would you determine the density of a fluid?
13. Which is more viscous, honey or water?
14. How does the viscosity of a fluid change as the temperature rises?
15. What are the two main classes of valves?

16. What is the difference between an on/off valve and a throttling valve?
17. What is another name for an on/off valve?
18. Is a gate valve designed for use in throttling? Explain why.
19. What is a rising-stem gate valve?
20. When would an engineer specify a nonrising-stem gate valve? What kind of problems might this cause?
21. Are the same materials always used for a valve body and the valve trim?
22. What kind of valve is usually used for throttling service?
23. Can globe valves be used as stop valves? Are they usually used this way? Why?
24. How might an engineer check to see that a globe valve is installed in the right direction?

Review

A. So far in this book, a number of things related to plant safety have been mentioned. They include pressure vessel codes, dikes in tank farms, the use of rising-stem gate valves, and emergency shutdown procedures. Discuss how all of the factors mentioned in the text – and any others that you may also know of – contribute to the good safety record of the chemical process industries.

B. Indicate which of the following statements are <u>true</u> and which are <u>false</u>.

1. An impeller is an important part of a reciprocating pump.
2. A gate valve is a common type of on/off valve.
3. The density of a liquid changes as the temperature changes.

4. The viscosity of a liquid changes as the temperature changes.
5. Density is another name for viscosity.
6. Globe valves may be used for throttling, but this is not recommended because parts of the valve may be damaged.
7. Fans are used when only low pressures must be imparted to gases.
8. All centrifugal pumps are made of carbon steel.
9. A bicycle pump is really a kind of compressor.
10. Liquid enters a centrifugal pump near the outer wall, or casing.
11. Fluid dynamics is the science concerned with the flow of heat.
12. Compressors are made in both rotary and reciprocating types.
13. Reciprocating pumps are generally used when high pressures must be achieved.
14. Centrifugal pumps are commonly used for metering liquids.
15. Valve bodies and valve trim are often made of different materials.
16. A globe valve usually has an arrow on its body.
17. The impeller of a centrifugal pump rotates while the pump is operating.
18. Gate valves are available for use only with small sizes of pipe.

19. Some centrifugal pumps are designed to pump corrosive liquids.
20. A chemical engineer needs to understand fluid dynamics.
21. A proportioning pump is a kind of metering pump.
22. Some fuel oils are very viscous.
23. A problem of centrifugal pumps is that the flow from them pulsates badly.
24. Liquids and gases are both fluids.
25. Gate valves cause greater energy losses in a pipeline than do globe valves.