Distribution Valves: Selection, Installation, Field Testing, and Maintenance

Third Edition
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History and Design Considerations

A water distribution system is a piping network that delivers water at service pressure from the source to the end-user connection. Generally, the system originates at a treatment plant or pumping station and ends at a residential, industrial, or commercial service connection. The system may also terminate at a fire hydrant or connect to a subordinate system. Valves are a significant component of any water distribution system and are most commonly used for isolating a section of a flow line, controlling the flow, releasing air, and preventing backflow.

The topics in this introductory chapter include a brief historical review of valves and major design considerations, such as flow resistance, flow-control elements, and sealing mechanisms.

**HISTORY**

Valves have been a vital component of every water system from the water systems of Greece in 600 BC, which used flap valves to control water for showers, to the London Water Works and the first practical gate valve in the 1800s, to most modern water distribution systems used today. What is believed to be the earliest form of the mechanical valve, the bellows, is shown in hieroglyphs on the wall of an Egyptian tomb built more than 3,500 years ago. These wall paintings depict a bellows with bamboo piping used to smelt ore. Ever since, people have been refining and designing valves to fit different applications.

As water distribution systems became larger and more complex, particularly after the development of cast-iron pipe, designers met the challenges of water flow requirements with improved valve designs. However, many of the valve types currently used in water utility systems were developed in the 1800s and are still used with little change in their basic features. Nonetheless, hundreds of new designs and refinements are available to system designers. Figure 1-1 shows a historical timeline for valve development.
Grecian illustrations show evidence of a flap-type valve used in showers for bathing.

Plug-type valves are used by both the Greeks and Romans in water mains and supply pipes.

Greeks develop a two-cylinder pump that employs a valve in each cylinder.

Hero of Alexandria develops the first workable hinged valve. He advises that the seat facings should be smooth and polished to ensure a reasonably tight closure.

Leonardo da Vinci draws valve constructions, including a multiport check valve with four pairs of hinged gates.

King Louis XIV of France orders a cast-iron distribution system to supply water to Versailles.

Pressure conduits are in general use.

The designs of most commonly used valves are developed during this century. Solid wedge, taper seat valves are introduced in the United States, and most of the changes and refinements take place before 1900.

The butterfly, ball, and diaphragm valves are designed and their use becomes common.

First cast-iron pipe is manufactured in Viergerland, Germany, for installation at Dillenburg Castle.

Joseph Bramah designs the first screw-thread valve stem. It is used to open and close sluice-type valves.

James Nasmyth designs the first practical metal gate valve, which consists of a cast-iron body and bonnet, a threaded valve stem, and a solid tapered plug. It is immediately employed in England by the East London Water Works.

S.J. Peet patents the double-disc, parallel-seat, bottom-wedge-type gate valve.

Figure 1-1  A historical timeline for valve development
System designers have many choices when they select valves for use in the water distribution system. Making the right valve choice depends on many factors, including the size of the pipeline, the hydraulic pressures the valve will control, the material from which the valve is made, the material with which it will come in contact, what it will be used for, and cost. The following section describes basic design considerations when selecting a valve.

**DESIGN CONSIDERATIONS**

This section discusses important factors to consider when selecting valves. The first factor discussed is flow resistance, or friction, which causes head loss (loss of pressure) as the water flows through the system. The consideration of the loss of pressure through the system can directly impact the type and size of valve selected for a portion of a design project or for the entire design project. The other factors discussed are general valve elements involved in flow control, such as adjusting the flow and the sealing mechanism.

**Flow Resistance**

The term flow resistance refers to a fluid’s resistance when moving through the piping system. Flow resistance plays an important role when designing a water distribution system. Flow resistance impacts flow pressure, pumping requirements, pipe size, and water volume, as well as the selection or type of valve needed for the specific application. A pressure drop caused by friction impacts the amount of water that can move through the pipe and valves. This drop is caused by fluid particles rubbing against each other and against the pipe. One can observe the effect of friction by connecting pressure gauges to a pipe system at both the beginning (upstream) and the end (downstream) of the system or to an isolated portion of the system; with gauges at the same elevation, the upstream gauge will show higher pressure than the downstream gauge.

Different pipe materials experience different levels of friction and so are said to have different friction factors. For example, a copper pipe is smoother than an iron pipe, and water flowing through the copper pipe will encounter less friction. In addition, for a given nominal diameter, the inside actual diameter may vary depending on pipe material. Flow is affected not only by the roughness of the pipe but also by the pipe diameter; friction increases as the diameter of the pipe decreases. The pressure drop associated with flow through a valve, i.e., the friction loss in the valve, depends on the type of valve.

Many equations allow distribution designers to calculate the pressure drop in a given system. System designers can calculate average flow resistance based on the turbulence of the flow, the roughness of the pipe, pipe diameter, valve and bend types, and other factors. Generally, the flow resistance of a valve is expressed in terms of the length of straight steel pipe that would have an equivalent resistance. For example, a 12-in. gate valve is rated at about a 13.2-ft (4-m) equivalent length of clean schedule 40 steel pipe, and a 12-in. globe valve is rated at about 340 ft (100 m). The relative resistance of PVC is about half that of steel.

The considerable complexity of the flow resistance of valves is beyond the scope of this manual. For more information, consult the sources listed in the additional readings at the end of the manual and manufacturers’ technical data.
Flow-Control Elements

The many different types of valves have basic functions and elements that are similar. This section will discuss those basics. Figure 1-2 shows the basic valve elements.

Flow control. A valve controls flow through one of four basic closure methods:

- A disc or plug moves against or into an opening
- A flat, cylindrical, or spherical surface slides across an opening
- A disc or ellipse rotates across the diameter of a pipe or circular element
- A flexible material moves into a flow passage

The valve parts that control the flow element, or closure member, are the stem and the operating mechanism—a handwheel, lever, or key that attaches to the operating nut.

Stems. Most valves employ a threaded stem to move the flow element. Although there are exceptions, such as safety valves and check valves, most valves have stems that extend to the outside of the valve. A rotating stem provides movement for nonrising-stem gate valves, ball valves, rotating-disc gate valves, butterfly valves, and most plug valves. Quick-opening gate valves, rising-stem gate valves, globe and diaphragm valves, and outside-spring safety and relief valves operate with a stem that moves axially.

Figure 1-2 Valve elements (rectangular butterfly valve)
Some stems both rotate and move axially, such as globe and needle valves, lift-type cone or plug valves, and most pinch valves. The factors that influence stem design and selection include torque, thrust, valve size, and physical parameters.

**Valve operation mechanisms.** Most valves are operated with a handwheel (Figure 1-3), operating nut, or lever. Not every application lends itself to such a simple solution, so designers have devised a variety of methods for both manual and automatic valve operation. Special methods are usually needed when special conditions exist, such as:

- The valve must be operated remotely.
- The secure operation of the valve is critical.
- The valve is inoperable using normal methods.
- The size of the valve makes it impossible for one person to operate the valve.

The bury depth of valves may vary. Stem extensions or adjustable valve keys have been designed to operate most valves. Stem extensions usually consist of a steel rod and a coupling that attaches to the valve stem. If the extension must be very long to reach a valve, extra support is provided to keep the extension rigid and to prevent bending or breaking. Operators can use adjustable shafts or steel rods and universal joints to reach valves in difficult locations.

![Figure 1-3 Eccentric plug valve with handwheel actuator](image)
Floor stands, gear operators, and wheel operators give personnel a mechanical advantage in opening or closing valves that are inconvenient to reach or are large and difficult to operate. Position indicators may be installed on nonrising-stem valves to show how far open the valve is.

Accessories for automatic operation are also available. They can be used simply to open or close a valve or to throttle flows. Hydraulic or pneumatic actuators, which operate with a diaphragm or piston construction, are common. In a piston type, two chambers in a cylinder are isolated from each other by a piston. The valve stem is connected to the piston. As hydraulic fluid or air is pumped to one side or the other of the piston, the piston is forced back and forth inside the cylinder, which operates the valve. A typical hydraulic operator installation is shown in Figure 1-4. Electric motors are also used to operate valves.

**Sealing Mechanisms**

Valves are employed to control the flow of fluid through a piping system. Valve seatings are the portions of the valve that contact the valve body to form a seal that stops or diminishes the flow of liquid. Because they undergo wear during the sealing process, they will become less effective over time. Valve-sealing mechanisms used in water distribution systems are usually metal seatings or soft seatings. Another sealing mechanism involves using a sealant such as that used in a lubricated plug valve.

Figure 1-4  Eccentric plug valve with hydraulic actuator
**Metal seatings.** The material for metal seatings should be carefully chosen because the seatings are prone to damage by corrosion, erosion, abrasion, and deformation. The type of metal chosen for an application should be considered in relation to the types of fluids with which it will come in contact, replacement capabilities, how often it will be operated, and other factors that may cause damage or wear to the sealing mechanism. Different metals offer various sealing abilities and resistance to damage. System designers should choose a valve that has seatings offering the best compromise between sealing ability and wearability based on the environment for which it is designed.

**Soft seatings.** Soft seatings are sealing mechanisms generally made from various natural or synthetic rubbers or plastics. The soft material readily conforms to the mating surface, creating an effective seal. This type of seating should be designed to prevent the seating material from being moved or deformed by fluid pressure. Presently there are limitations on the use of soft seatings on large valves.

**Sealant.** Valve passageways can be sealed by a substance (the sealant) injected into the space between the seatings after the valve is closed. The sealant fills any spaces that might be left open by the seatings and thus prevents leakage. Sealant is also used in emergencies to provide a seal when the original seal has failed.

Based on advancements in material and product development, new ways of sealing valves are being implemented and evaluated to enhance the reliability of valves and all their components. Two examples of the newer approaches for coating valves are the fusion-bonded epoxy process as well as the use of the powder coating technology.