

M44

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

Third Edition



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Distribution Valves:

Selection, Installation, Field Testing, and Maintenance

Third Edition



**American Water Works
Association**

Manual of Water Supply Practices—M44, Third Edition

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

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Library of Congress Cataloging-in-Publication Data

Names: Morgan, Kenneth C. | Oberoi, Kanwal. | American Water Works Association.

Title: M44--distribution valves : selection, installation, field testing, and maintenance / by Kenneth C. Morgan, Kanwal Oberoi.

Other titles: Distribution valves

Description: Second edition. | Denver, CO : American Water Works Association, 2016.

Identifiers: LCCN 2015050635 | ISBN 9781625760821 | ISBN 9781613003343 (eISBN)

Subjects: LCSH: Water-pipes--Valves. | Water--Distribution.

Classification: LCC TD491 .M6164 2016 | DDC 628.1/5--dc23 LC record available at <http://lcn.loc.gov/2015050635>

Printed in the United States of America

ISBN: 978-1-62576-082-1

eISBN: 978-1-61300-334-3



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Preface

The importance of valves in the water distribution system cannot be overstated. Their effective selection, installation, operation, maintenance, repair, and replacement are vital to appropriately conveying an essential product to the customer. The primary focus of M44 is distribution valves; however, other valves essential to plant operations are also discussed. Specific to distribution systems, M44 is a guide for the selection, installation, field testing, and maintenance of water distribution valves.

This manual offers a brief history of valves and an overview of their theory and flow characteristics. It is a discussion of recommended practice rather than an AWWA standard calling for compliance with certain specifications. It provides guidance on generally available valve alternatives. Questions about specific situations or the applicability of a particular valve should be directed to the manufacturer or supplier.

Information contained in M44 is useful for operators, technicians, and engineers for all sizes of utilities, but it is particularly useful for small- and medium-sized organizations. The manual primarily discusses the more commonly used valves, but some of the “specialty” or “special use” valves are covered as well. The extent of the presentation of the specialty valves is only to introduce their availability and applications.

This manual provides general information to utilities and contractors on the proper installation and field testing of valves. Essential procedures related to operation and maintenance are also covered within this document. Additionally, procedures for determining valve criticality to assist an agency to establish, implement, and maintain an effective utilization of valves during their response to emergencies is provided as well.

Fire hydrants, although technically considered valves, are not covered in this manual. The reader is referred to AWWA Manual M17, *Installation, Field Testing, and Maintenance of Fire Hydrants*. This manual (M44) refers to AWWA standards for various types of valves. Copies of these standards may be purchased from the AWWA Bookstore.

Several manufacturers graciously provided valve illustrations and other documentation. AWWA does not endorse any manufacturer’s products, and the names of the manufacturers have been removed from the material provided.

Metrication note: Valve sizes are listed in their current US designation; i.e., nominal pipe sizes in inches. To obtain an exact metric equivalent, use a conversion factor of 25.4 mm/in.

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Acknowledgments

The AWWA Technical and Educational Council and the AWWA Distribution and Plant Operations Division gratefully acknowledge the contributions made by those volunteers who drafted, edited, and provided the significant and critical commentary essential to updating this manual. The Technical Review Board members dedicated many hours in the final stages of preparation of this edition to ensure the overall technical quality, consistency, and accuracy of the manual.

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Chapter **1**

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.

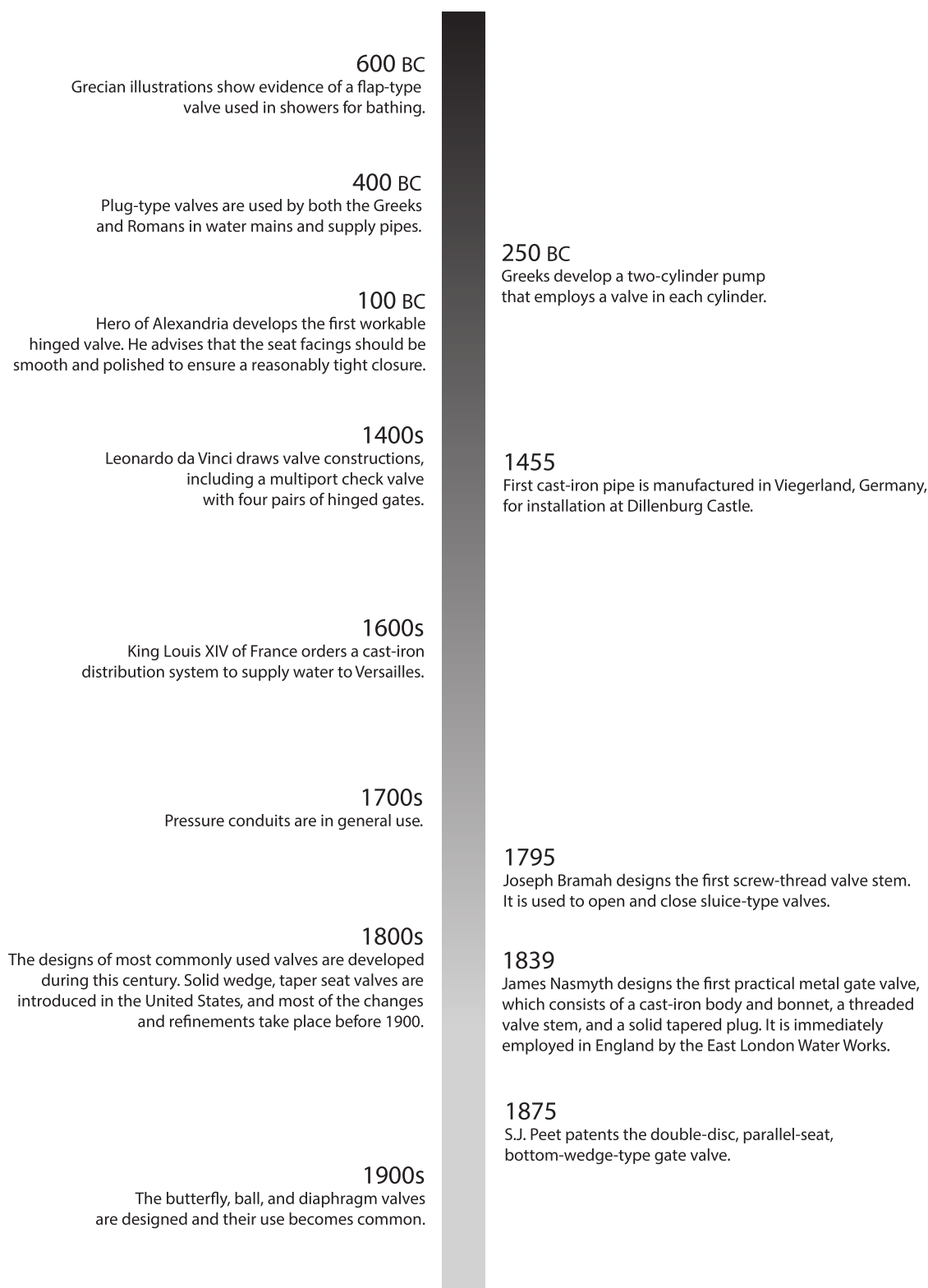


Figure 1-1 A historical timeline for valve development

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.

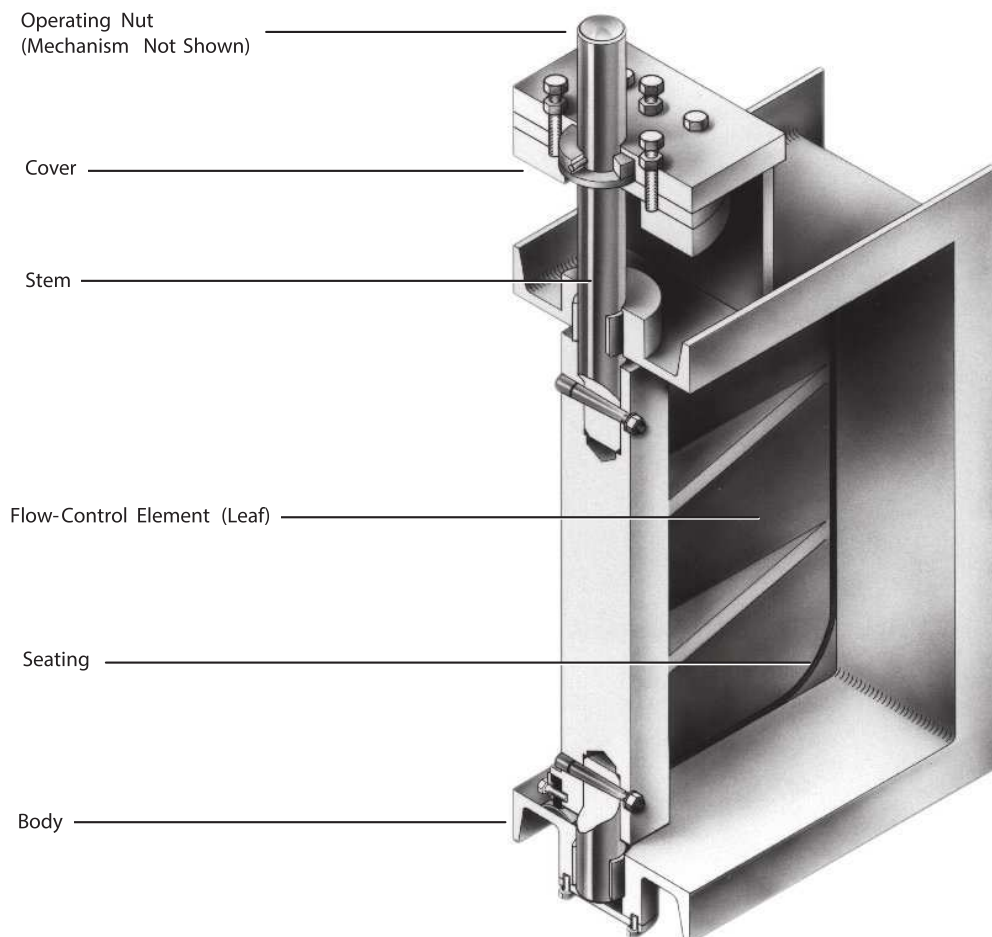


Figure 1-2 Valve elements (rectangular butterfly valve)

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.

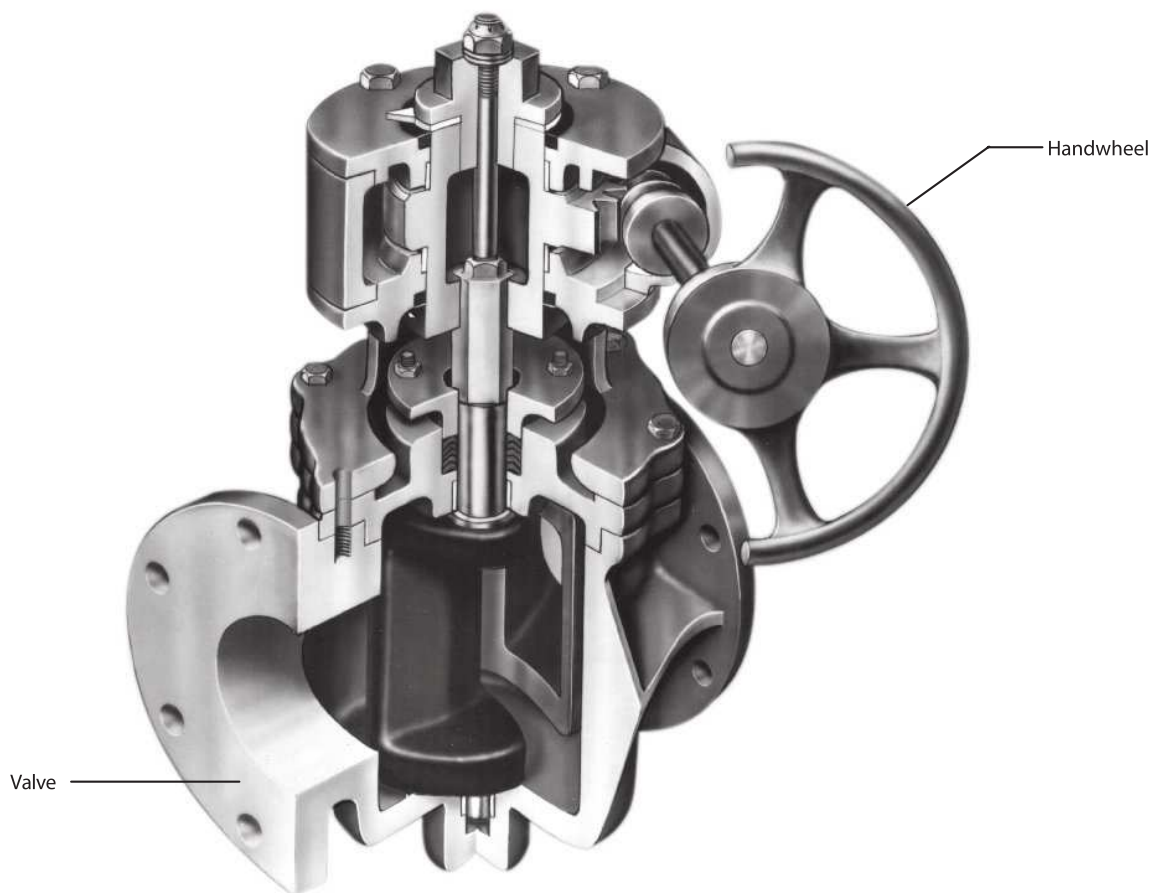


Figure 1-3 Eccentric plug valve with handwheel actuator

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.

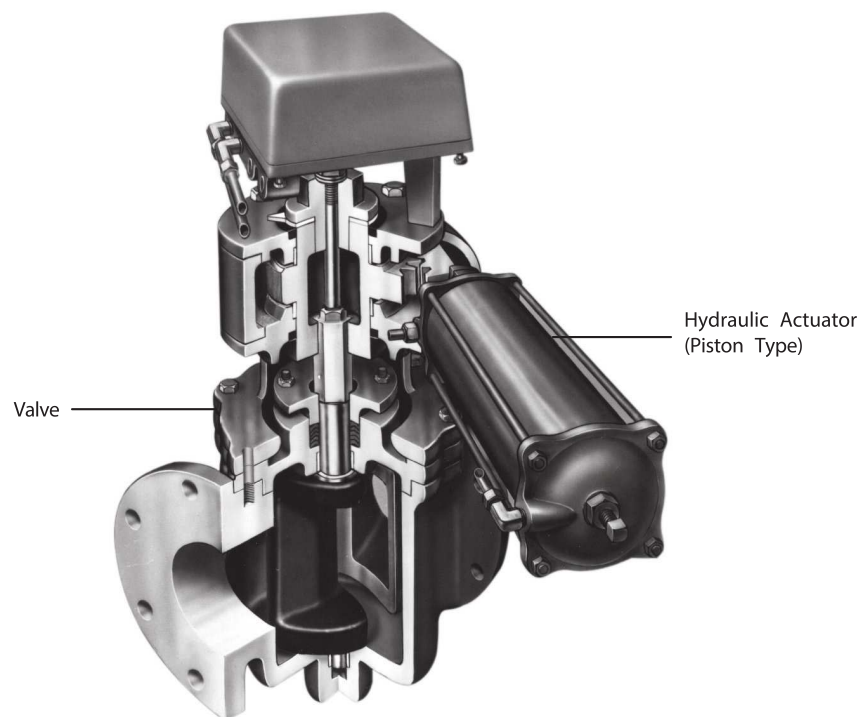


Figure 1-4 Eccentric plug valve with hydraulic actuator

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.

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Chapter **2**

Types and Selection of Valves

This chapter introduces the major types of valves and the parameters that should be considered when selecting a valve. These parameters include the purpose of the valve, size, operation, and application.

Although certain valve types can be used for many different applications, designers should choose a valve that carefully balances the number of times the valve is operated, maintenance requirements, efficiency, and cost for the specific application. Factors to be considered in the valve selection and specifying process include:

- The requirement that the valve either control or shut off the flow in the manner demanded by service conditions
- The frequency of the valve's operation
- Conformance to appropriate American Water Works Association (AWWA), American Society of Mechanical Engineers (ASME), American National Standards Institute (ANSI), and other product standards
- Ability of the valve to withstand maximum working or test pressures, as set forth in the AWWWA standards
- The need for an unobstructed waterway to maximize flow or accommodate cleaning operations such as "pigging"
- Design and material selection to resist attack by corrosion and/or erosion
- Adaptation requirements for actuator mounting (if any)
- Installation considerations such as weight, accessibility, and dimensional clearances
- Maintenance needs and costs

This chapter will cover only the most common types of valves and their functions. Valves can be grouped based on their method of flow regulation. The general types of flow regulation and the common valves for those types are as follows:

- Flow-control or regulating valves—designed to withstand the demands of usage in the partially open position
 - Globe
 - Piston
 - Diaphragm
 - Butterfly
 - Pinch
- Isolation or shutoff valves—designed to be used primarily in the fully open or fully closed positions
 - Multiturn—gate
 - Quarter turn
 - Plug
 - Ball
 - Cone
 - Duckbill

VALVES USED FOR ON-OFF OPERATION AND FLOW CONTROL

Some valves can be used for both on-off operation and flow control. Most valves are more efficient for either throttling (ball, cone, and globe valves) or on-off (gate valves) applications. The following sections describe the major types of valves and list their best applications. The advantages and disadvantages are somewhat subjective and may not strictly apply in all situations; the information should be used together with engineering data and operational judgment.

Globe Valves

Advantages:

- Suitability for flow regulation
- High sealing capacity
- Resistance to wear

Disadvantages:

- Have a greater ability to allow material to get trapped in the seat
- Produce a higher resistance to flow through the valve
- More prone to reducing the ability to fully close the valve when material is trapped in the seat

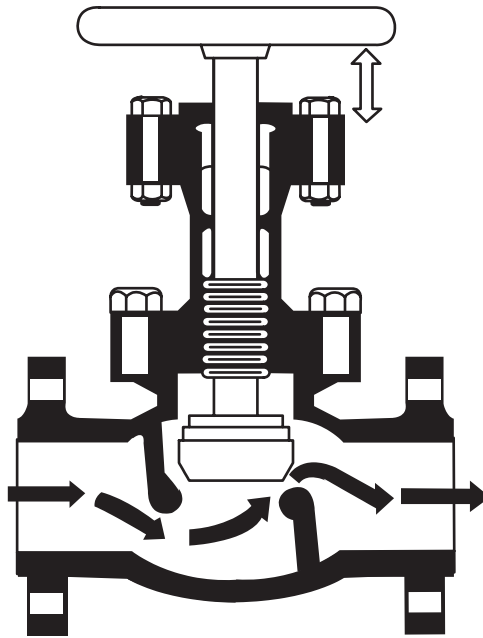


Figure 2-1 Globe valve

Description. Globe valves are regulating valves in which the closure member is moved directly on or off the seat, generally by a rotating threaded stem. The closure member is commonly referred to as a disc. This valve is well suited for flow regulation because of the short distance between the open and closed positions. It also has a high sealing capacity. Because little friction is encountered in opening and closing the seats, the valve is resistant to friction wear. However, globe valves tend to trap particulates in the seat, and the flow resistance is high in these valves. This flow resistance, in turn, usually reduces the flow (see Figure 2-1).

Piston Valves

Advantages:

- Suitability for on-off operation
- Suitability for some flow regulation

Disadvantages:

- High head loss
- Sediment entrapment causing wear

Description. Piston valves use a piston-shaped closure member that intrudes into the seat bore. Sealing is achieved between the sides of the piston and the seat bore. Therefore, flow cannot start until the piston is completely withdrawn. This type of valve is most effective for on-off operation and is somewhat useful for flow regulation. Solids that might be deposited on the seat tend to be wiped away during closing. A primary advantage is that the sealing surface of the piston is protected from flow when the valve is in the fully open position.

Butterfly Valves

Advantages:

- Suitability for both on-off and flow control, 90° operation
- Ease of operation
- Short face-to-face dimension
- Relatively light weight as compared other valve types
- Accept multiple types of actuation
- Lower initial cost
- Can be used for larger-diameter pipes
- More cost-effective in larger diameters

Disadvantages:

- Some head loss
- Partially blocked waterway when valve is fully open
- Incompatibility with pigging (described in this section)
- High-velocity limitations

Description. A common valve in the distribution system, especially in larger sizes, the rubber-seated (sometimes called *resilient-seated*) butterfly valve (see Figure 2-2) has been used in distribution systems since the 1950s. In the butterfly valve, a circular disc or vane that has a diameter less than or equal to that of the pipe is fastened to a shaft running through the valve body and extending outside to an actuator. The disc or vane rotates 90° in the waterway. In the full-open position, the disc is parallel to the flow. The flow, split by the disc, continues on either side of the disc. In the closed position, the disc is perpendicular to the flow and stops the flow. The clearance between the disc and the valve body is sealed by a rubber seat. For additional information on butterfly valves consider AWWA Manual M49, *Butterfly Valves: Torque, Head Loss, and Cavitation Analysis*.



Figure 2-2 Butterfly valve

The rubber seat may be attached to either the disc or the valve body. Butterfly valves are covered by ANSI/AWWA C504, Rubber-Seated Butterfly Valves 3 In. (75 mm) Through 72 In. (1,800 mm); C516, Large-Diameter Rubber-Seated Butterfly Valves, Sizes 78 In. (1,800 mm) and Larger, and AWWA Manual M49, *Butterfly Valves: Torque, Head Loss, and Cavitation Analysis*.

A butterfly valve shuts off pressure as though it were a gasket. The seat holds until the pressure exceeds the seal compression, after which the seal leaks. The valve is set at the factory to hold the rated working pressure (the pressure at which the valve is designed to operate) and should not be expected to seal at higher pressures. The reduction in flow of the butterfly valve is a function of the angle of the disc opening in the pipe. The valve is generally effective for flow control in the range of 20° to 70° open, depending on the difference in pressure across the valve and other characteristics of the valve. Butterfly valves may be used for throttling in some situations; however, they are not intended for long-term throttling. The designer should consult the manufacturer before specifying a butterfly valve for throttling applications.

Advantages of butterfly valves are that they provide shutoff capabilities, some throttling capabilities, and ease of operation, particularly in sizes 12 in. and larger. The actuators required by larger valves increase the mechanical advantage to allow for ease of operation. Additionally, butterfly valves that are 12 in. and larger generally have a lower initial cost than other valve types.

However, butterfly valves do not provide a clear waterway. Restriction of flow in a fully open butterfly valve is greater than in some other types of valves because the disc remains in the waterway. As the valve size increases, the proportion of the open flow area to the cross-sectional area of the disc increases. If a large number of butterfly valves are used, pressure loss in a distribution system can be significant. When flow resistance is critical, other types of valves may be required.

Another disadvantage is that butterfly valves prevent the use of pigging, which involves using line pressure to force a bullet-shaped plug through a water line to locate and clean flow restrictions.

Plug Valves

Advantage:

- Suitability for both throttling and flow regulation

Disadvantage:

- Cause some flow resistance

Description. Plug valves (Figure 2-3) are primarily used in systems where slurries, grit, or solids will flow through the valve. The eccentric plug valve is a quarter-turn valve allowing a cost-effective low-torque actuation for shutoff and throttling applications. These valves can be adapted to operate with various types of manual or automated actuation. Plug valves are available in flanged, mechanical joints, or threaded-end configurations in standard or 100 percent ported design per ANSI/AWWA C517.

Flow restriction in a plug valve depends on the size and shape of the plug opening. For example, some plug valves have tapered openings where the opening is smaller at the bottom than at the top. Tapered plugs cause more flow restriction than a rectangular design of the same size because there is more plug area blocking the flow. Flow resistance can range from that which is slightly more than a gate valve to more than that of a butterfly valve. Advantages of the plug valve include that it can be installed in any position without special consideration and, when utilizing a rectangular port design, change in flow is consistent throughout travel of the plug.



Figure 2-3 Eccentric nonlubricated plug valve

Larger plug valves require an actuator for 90° rotation. Smaller plug valves may be operated with either a 90° rotating lever handle or actuator.

Conically tapered metal (often *brass*) plug valves are often used as simple shutoff valves in household *natural gas* lines.

Cone Valves

Advantages:

- Full waterway opening with low flow resistance
- Good flow-control characteristics
- Suitability for throttling or flow modulation

Disadvantages:

- Large physical size and weight require facility to be preplanned to accommodate the valves
- More costly when compared to other types of valves, such as ball, gate, or butterfly valves
- Maintenance of this valve is more difficult and costly than maintenance of some of the other valves

Description. The cone valve (Figure 2-4) is a quarter-turn (90°) rotary valve for which the flow-control device is a cone seating in a conically shaped body. The seating surfaces are commonly metal to metal. Cone valves have a tolerance for high velocities. Cone valves are typically used to control flow and in pump discharge where high head and high velocities occur; this can require single or multiple configurations. These valves can work well in areas where controlling the variations of flow or where higher velocities within the system are experienced. These valves are often used in dam structures, hydroelectric facilities, and water treatment plants and systems, as well as in spillways.