

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

AWWA MANUAL M44

Second Edition



**American Water Works
Association**

Science and Technology

AWWA unites the entire water community by developing and distributing authoritative scientific and technological knowledge. Through its members, AWWA develops industry standards for products and processes that advance public health and safety. AWWA also provides quality improvement programs for water and wastewater utilities.

MANUAL OF WATER SUPPLY PRACTICES—M44, Second Edition

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

Copyright © 1996, 2006 American Water Works Association

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information or retrieval system, except in the form of brief excerpts or quotations for review purposes, without the written permission of the publisher.

Disclaimer

The authors, contributors, editors, and publisher do not assume responsibility for the validity of the content or any consequences of their use. In no event will AWWA be liable for direct, indirect, special, incidental, or consequential damages arising out of the use of information presented in this book. In particular, AWWA will not be responsible for any costs, including, but not limited to, those incurred as a result of lost revenue. In no event shall AWWA's liability exceed the amount paid for the purchase of this book.

Project Manager/Technical Editor: Melissa Valentine

Production: Claro Systems

Manuals Coordinator: Beth Behner

Library of Congress Cataloging-in-Publication Data

Distribution valves :b selection, installation, field testing, and maintenance.--2nd ed.

p. cm. -- (AWWA manual M44)

Includes bibliographical references and index.

ISBN 1-58321-430-5

1. Water-pipes--Valves. 2. Water--Distribution. I. American Water Works Association.

TD491.D576 2006

628.1'44--dc22

2006042942

Printed in the United States of America

American Water Works Association

6666 West Quincy Avenue

Denver, CO 80235

ISBN 1-58321-430-5



Printed on recycled paper



Documents

Document Sharing Hub

Contents

List of Figures, v

Preface, vii

Acknowledgments, ix

Chapter 1 History and Design Considerations 1

History, 1

Design Considerations, 3

Chapter 2 Types and Selection of Valves 9

Valves Used for On–Off Operation
and Flow Control, 10

Valves Used Primarily For On–Off Control, 16

Special-Purpose Valves, 19

Actuators, 23

Valve End Connections, 24

Chapter 3 Valve Tests, Unloading, Inspection, and Storage 27

Manufacturing Plant Valve Tests, 27

Manufacturer’s Documents, 28

Unloading at the Utility, 32

Inspection After Unloading, 32

Storage, 33

Bolts, 33

Chapter 4 Installation 35

Inspection Before Installation, 35

Installation, 36

Testing After Installation, 37

Chapter 5 Operation and Maintenance 45

Planning a Maintenance Schedule, 46

Reactive Versus Preventative Maintenance, 46

Valve Maintenance Procedures, 47

Record Keeping, 47

Chapter 6 Distribution Valves Emergency Response Planning 53

Planning a Response, 54

During an Emergency or Event, 54

After the Event, 54

Post-Incident Review, 55

Bibliography, 57

Index, 59

List of AWWA Manuals, 61

This page intentionally blank

Figures

- 1-1 A historical timeline for valve development, 2
- 1-2 Valve elements (rectangular butterfly valve), 4
- 1-3 Eccentric plug valve with handwheel actuator, 5
- 1-4 Eccentric plug valve with hydraulic actuator, 6
- 2-1 Globe valve, 11
- 2-2 Butterfly valve, 12
- 2-3 Plug valve, 13
- 2-4 Cone valve, 14
- 2-5 Ball valve, 15
- 2-6 Pinch valve, 16
- 2-7 Diaphragm valve, 17
- 2-8 Control valve, 17
- 2-9 Gate valve, 18
- 2-10 Resilient-seated gate valve, 18
- 2-11 Swing-type check valve, 20
- 2-12 Pressure relief valve, 21
- 2-13 Inserting valve, 23
- 2-14 Pneumatic actuator, 24
- 2-15 Valve end connections, 25
- 3-1 Sample shop drawing, 29
- 3-2 Information from a maintenance manual, 31
- 4-1 Crossover tighten method, 36
- 4-2 Drawing of a typical valve casing, 38
- 4-3 Drawing of a typical valve casing extension and plug, 39
- 4-4 Drawing of a typical valve casing top section, 40
- 4-5 Drawing of a typical valve casing bottom section, 41
- 4-6 Drawing of a typical valve bonnet, 42
- 4-7 Valve vault cross section, 43
- 5-1 Sample valve report, 49

This page intentionally blank

Preface

This manual is a guide to the selection, installation, field testing, and maintenance of water distribution valves. Although the manual focuses on distribution valves, other valves, primarily used in plant operations, are also discussed. The manual provides a history of valves and a brief overview of the theory and flow characteristics of valves. It is a discussion of recommended practice, not an AWWA standard calling for compliance with certain specifications. It provides guidance on generally available valve alternatives. Questions about specific situations or applicability of specific valves should be directed to the manufacturer or supplier.

Information contained in this manual is useful for operators, technicians, and engineers for all size utilities, but it is particularly useful for small- and medium-sized organizations. The manual deals only with the more commonly used valves, including the following:

- globe
- butterfly
- plug
- ball
- cone
- gate
- check

Special-use valves are also discussed, but the intent here is only to introduce their availability and applications. Over the years, a wide variety of valves have been developed for specialized purposes. Fire hydrants, though 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 refers to AWWA standards for various types of valves. Copies of those 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. Kanwal Oberoi, Charleston Commissioners of Public Works, Charleston, SC, has provided the drawings for Figures 4-2 through 4-6 and 5-1.

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.

This page intentionally blank

www.sepana.ir

Acknowledgments

This manual was developed by the AWWA Distribution Operations and Maintenance Committee. AWWA staff providing publication assistance: Beth Behner, Manuals Coordinator and William C. Lauer, Technical Advisor. The membership of the committee at the time it approved this manual was as follows:

Greg Ramon, *Chair*
Frank J. Moritz Jr., *Vice Chair*

Larry L. Bittle Jr., Bexar Metropolitan Water District, San Antonio, Texas	(AWWA)
James M. Brady, Philadelphia Water Department, Philadelphia, Pa.	(AWWA)
Michael E. Grahek, Los Angeles Department of Water, Los Angeles, Calif.	(AWWA)
Ken S. Hall, Petaluma, Calif.	(AWWA)
George C. Mallakis, Simi Valley, Calif.	(AWWA)
Kenneth C. Morgan, Charlotte-Mecklenburg Utilities, Charlotte, N.C.	(AWWA)
Frank J. Moritz Jr., Ridgewood Water Department, Ridgewood, N.J.	(AWWA)
William G. Mowell, Ridgewood Water Department, Ridgewood, N.J.	(AWWA)
Michael J. O'Connell, Burns & McDonnell Engineering Inc., Kansas City, Mo.	(AWWA)
Greg Ramon, City of Phoenix Water Services Department, Phoenix, Ariz.	(AWWA)
Patrick J. Staskiewicz, Ottawa County Road Commission, Grand Haven, Mich.	(AWWA)
Henry Young Jr., Denver Water, Denver, Colo.	(AWWA)

This edition was reviewed and approved by the AWWA Distribution and Plant Operations Division Board of Trustees and the AWWA Technical Educational Council. The Distribution and Plant Operations Division had the following personnel at the time of approval:

Kanwal Oberoi, *Chair*
Kenneth C. Morgan, *Vice Chair*

Jerry L. Anderson, CH2M Hill, Louisville, Ky.	(AWWA)
Robert L. Gardner, Wannacomet Water Company, Nantucket, Mass.	(AWWA)
Rhonda E. Harris, Pro-Ops Inc., Dallas, Texas	(AWWA)
George A. Kunkel Jr., Philadelphia Water Department, Philadelphia, Pa.	(AWWA)
Bill C. Lauer, American Water Works Association, Denver, Colo.	(AWWA)
Kenneth C. Morgan, Charlotte-Mecklenburg Utilities, Charlotte, N.C.	(AWWA)
Kanwal Oberoi, Charleston Commissioners of Public Works, Charleston, S.C.	(AWWA)
Nicholas G. Pizzi, Environmental Engineering & Technology, Twinsburg, Ohio	(AWWA)
Melinda L. Raimann, Cleveland Division of Water, Cleveland, Ohio	(AWWA)
Lois M. Sherry, American Water Works Association, Denver, Colo.	(AWWA)

This page intentionally blank



Chapter 1

History and Design Considerations

A distribution system is a piping system that delivers water at service pressure from the pressure 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 in the system 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

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 the most modern distribution systems used today, valves have been a vital component of every system. 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 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 regulation 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, there are hundreds of new designs and refinements of old designs available to system planners. Figure 1-1 shows a historical timeline for valve development.

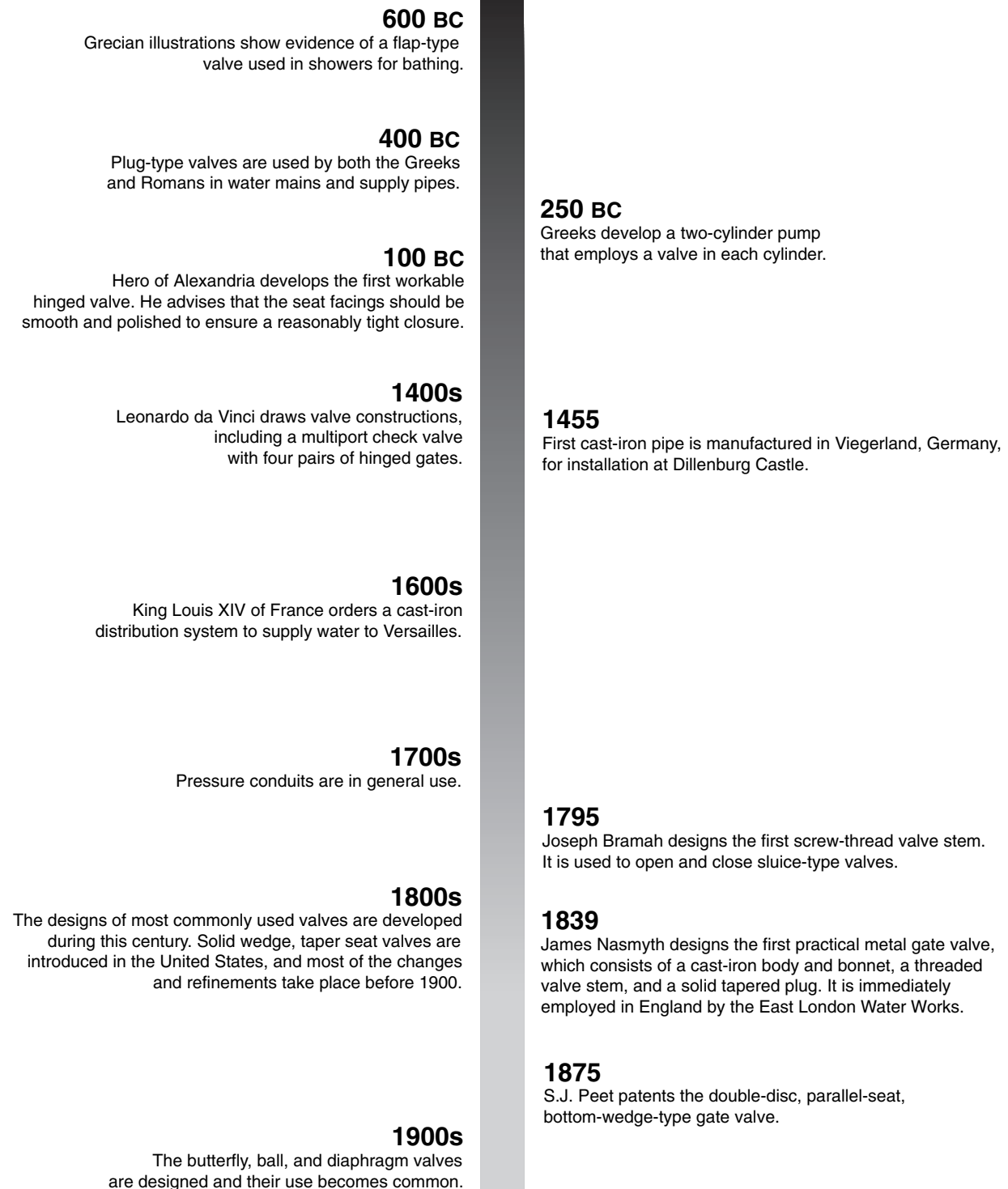


Figure 1–1 A historical timeline for valve development

System designers have many choices when they select valves for use in the 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 the valve is made from, the material it will come in contact with, what it will be used for and costs. 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 other factors discussed are general valve elements involved in flow control, such as the mechanism for adjusting the flow and the sealing mechanism.

Flow Resistance

The term flow resistance refers to a fluid's resistance to moving through the piping system. Flow resistance plays an important role in decisions about flow pressure, pumping requirements, and pipe size, as well as in the selection of an appropriate valve for a specific application. A pressure drop caused by friction always accompanies the flow of liquid in a pipe and through 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; 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 it 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.

There are many equations that allow planners to calculate the pressure drop in a given system. System planners 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. Therefore, the equivalent length of PVC would be double that of steel.

The considerable complexity of the flow resistance of valves is beyond the scope of this manual. For more information, consult the references listed in the bibliography 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 (generally 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 but does not rotate. Some stems both rotate

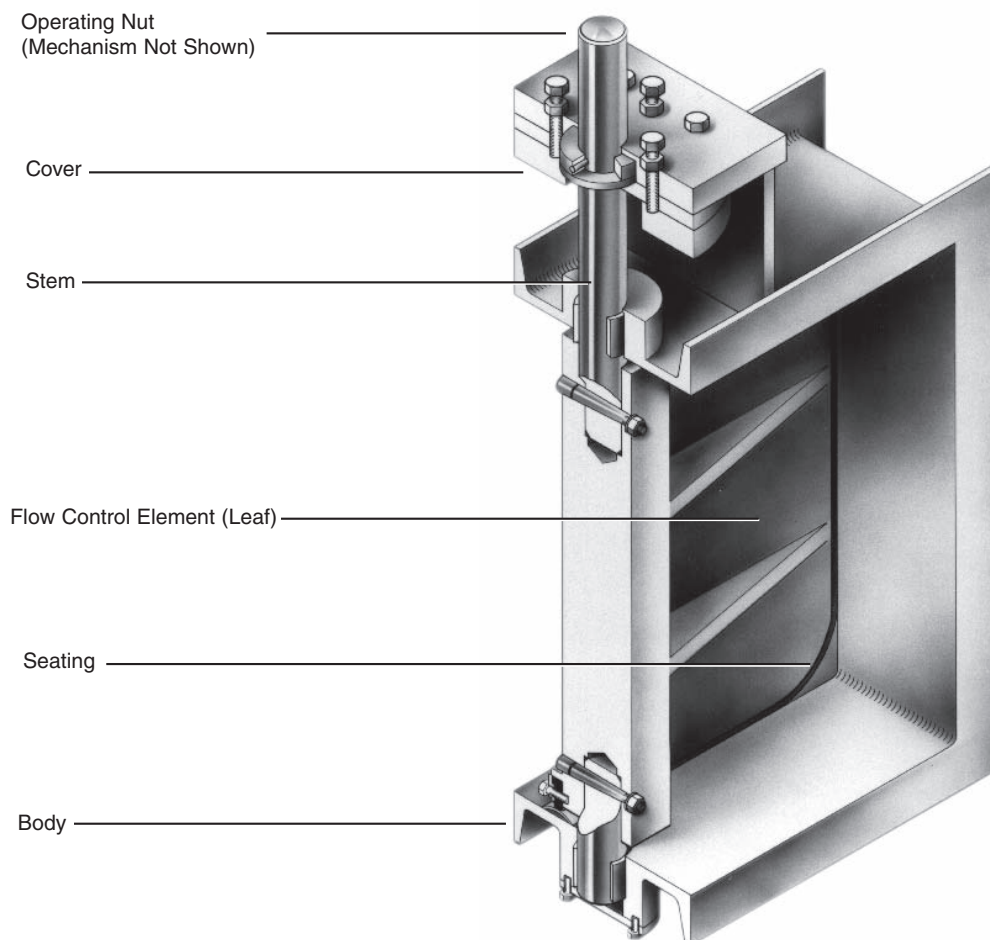


Figure 1–2 Valve elements (rectangular butterfly valve)

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, and valve size.

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:

- The valve must be operated remotely.
- 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.

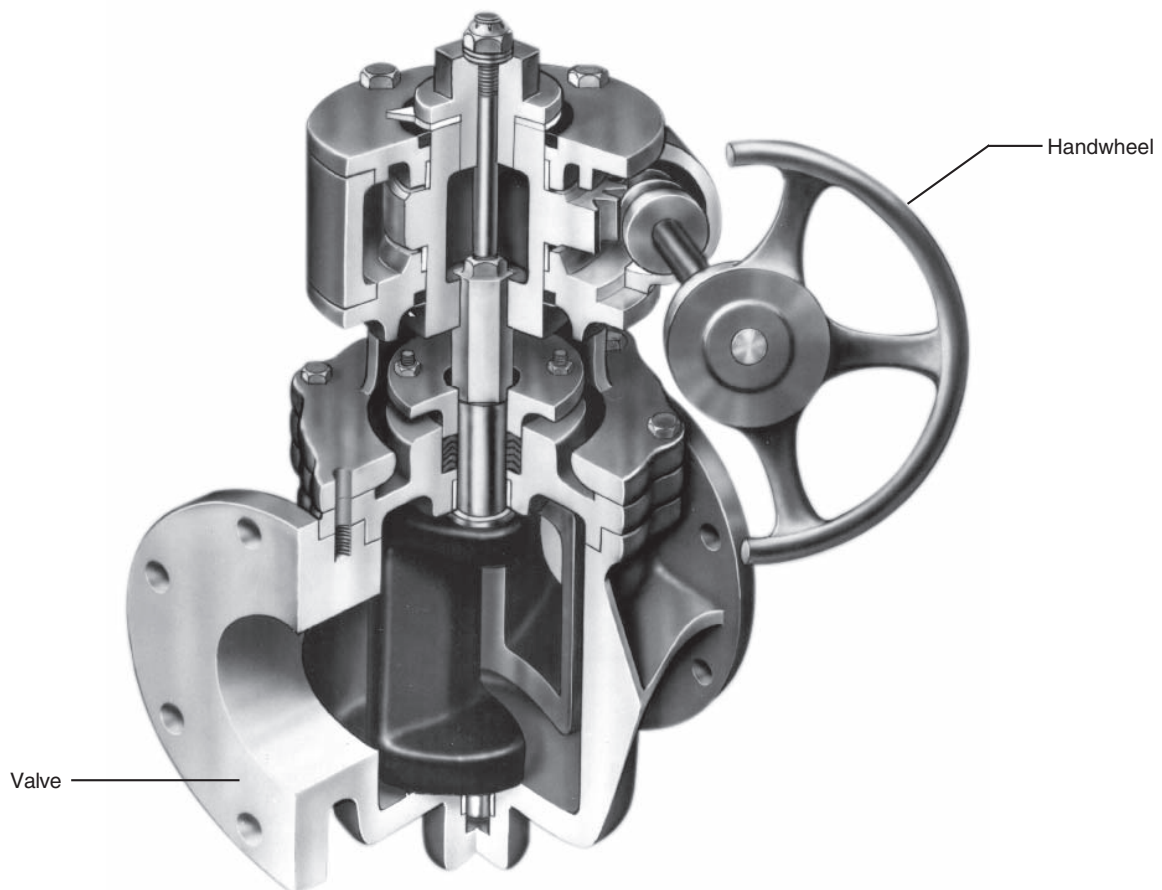


Figure 1–3 Eccentric plug valve with handwheel actuator

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 the valve is open.

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 operators, 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. Electric motors are also used to operate valves. A typical hydraulic operator installation is shown in Figure 1-4.

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 and tear 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.

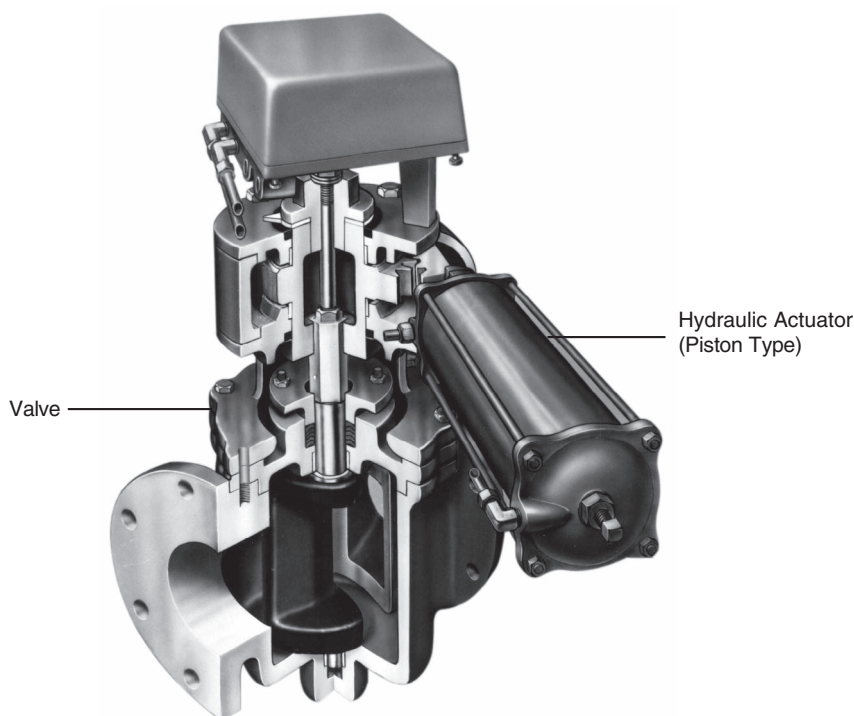


Figure 1-4 Eccentric plug valve with hydraulic actuator

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 it will come in contact with, 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.

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.

This page intentionally blank



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 joint type.

Although certain valve types can be used for many different applications, operators should choose a valve that carefully balances efficiency and cost for the specific application. For example, butterfly valves in sizes 12 in. and larger are less costly than gate valves but have more flow resistance. 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;
- 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;
- the need for an unobstructed waterway to maximize flow or accommodate cleaning operations such as “pigging”;
- ability of the valve to resist attack by corrosion and erosion;
- actuator requirements (if any);
- installation requirements such as weight and accessibility.

This chapter will cover only the most common types of valves and their functions as previously listed.

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:

- closing down
 - globe
 - piston
- sliding
 - gate
- rotating
 - plug
 - ball
 - butterfly
 - cone
- flexing
 - diaphragm
 - pinch

Valves may also be grouped based on the uses for which they are most adaptable. The most common uses are for opening and closing a flow (on–off operation), and for flow control (throttling or controlling the amount of liquid and the direction entering a system or diverting the flow). Valves are used for special purposes as well, such as pressure relief, air release, and pressure control.

VALVES USED FOR ON–OFF OPERATION AND FLOW CONTROL

Some valves can be used for both on–off operation and flow control. Other valves are more efficient for throttling operations (butterfly, ball, cone, and globe valves). Still others, such as plug valves, are more effective for on–off operations but can also be used in some throttling operations. The following paragraphs 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:

- high flow resistance
- possibility of sediment being trapped by seating

Description. Globe valves are closing-down valves where 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 there is little friction encountered in opening and closing the seats, it is resistant to friction wear. However, globe valves tend to trap particulates in the seat, and the flow resistance is high in these valves. See Figure 2-1.

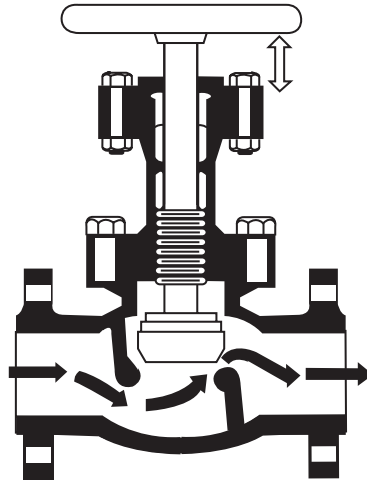


Figure 2–1 Globe valve

Piston Valves

Advantages:

- suitability for on–off operation
- suitability for some flow regulation

Disadvantage:

- high flow resistance

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 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.

Butterfly Valves

Advantages:

- suitability for both on–off and flow control
- ease of operation
- short face-to-face dimension
- light weight as compared to same size gate valves

Disadvantages:

- some flow resistance
- incompatibility with “pigging” (described in this section)
- high-velocity limitations

Description. A popular type of valve for 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 a flow-through disc design, the flow is also directed through openings in 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.

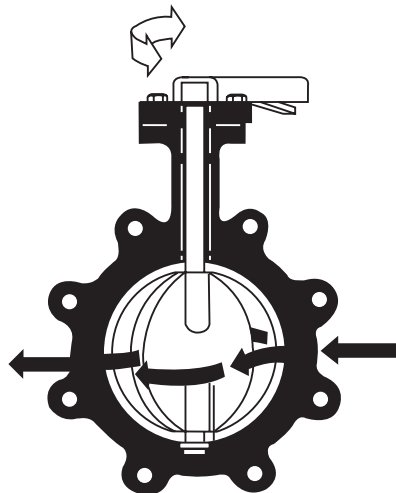


Figure 2–2 Butterfly valve

The rubber seat may be attached to either the disc or the valve body. Butterfly valves are covered by ANSI/AWWA C504 *Standard for Rubber-Seated Butterfly Valves*.

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 operator should consult the manufacturer before such applications.

Advantages to butterfly valves are that they provide shutoff capabilities, some throttling capabilities, and ease of operation, particularly in sizes 16 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 are generally more economical than gate valves.

However, butterfly valves do not provide a clear waterway. Restriction of flow in a fully open butterfly valve is greater than in a fully open gate valve 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