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(Revision of ANSI/AWWA C504-00)

American Water Works Association

The Authoritative Resource on Safe Water℠

AWWA Standard

Rubber-Seated Butterfly Valves

American National Standards Institute

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AWWA Standard

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Committee Personnel

The AWWA Standards Committee on Butterfly Valves, which reviewed and approved this standard, had the following personnel at the time of approval:

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Contents

All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

Foreword

This Foreword is for information only and is not a part of ANSI/AWWA C504.

I. Introduction.

I.A. *Background.* Butterfly valves are generally used for pipelines carrying liquids and gases. Manufacturers of butterfly valves developed tight-closing, rubber-seated types for cooling water systems and power stations. Since 1940, most new valves installed for this type of service have been rubber-seated butterfly valves.

Since the late 1940s, rubber-seated butterfly valves have gained increased acceptance for use in water treatment plants and water supply and distribution lines because (1) they provide tight shutoff; (2) are relatively easy to operate, even with large pressure differentials across the valves; and (3) require relatively little space for installation.

I.B. *History.* The need for standardization of butterfly valves was recognized by the American Water Works Association (AWWA) in June 1953.

The committee appointed for the task of standardization developed AWWA C504, which was approved as tentative and published in September 1954. Four years later, in 1958, the tentative standard was accepted as a standard.

The 1954 tentative standard was written to describe the then-available types of standard rubber-seated butterfly valves that had been in successful operation for at least five years prior to 1954. The standard established three pressure and two velocity classifications, standards for materials, laying lengths, minimum body and disc designs, and actuator sizes for valves having rubber seats in the valve body.

Since the publication of AWWA C504 in 1954, butterfly-valve designs have been improved and refined. In September 1962, a new committee was charged with the task of reviewing AWWA C504 and recommending revisions to the standard in order to make it compatible with then-current valve designs.

Generally, modern butterfly-valve designs for water service include cast-body construction in 25-psi (172-kPa), 75-psi (517-kPa), 150-psi (1,034-kPa), and 250-psi (1,723-kPa) pressure classes; flanged, mechanical-joint, and wafer bodies; rubber seats in valve bodies or on the valve discs; and operating conditions (limited by the design shutoff pressure and velocities of water flow) that produce torques considered maximum for the shaft size used.

Revisions in the 1970 edition were initiated to minimize the corrosion of seating surfaces, to provide more adequate requirements for stainless steel, and to provide for painting of valve interiors with asphalt varnish.

Revisions in 1974 and 1980 provided fine-tuning of the provisions of the standard. Major changes included addition of provisions concerning the connection between shaft and disc and the use of carbon-steel shafts with stainless-steel journals.

Revisions to the 1987 edition included using the word "actuator" rather than "operator" and provided definitions of valve classifications. Major changes included the addition of certain sprayed-metal seat surfaces and nonmetallic cylinder components as acceptable materials. Appendix B (now Appendix A), Installation, Operation, and Maintenance of Rubber-Seated Butterfly Valves, was added.

Revisions to the 1994 edition included the deletion of Appendix A for calculating torques, the addition of soft metrication, reference to actuator requirements given in ANSI/AWWA C540, Power-Actuating Devices for Valves and Hydrants, introduction of class 250 valves, and adoption of additional materials and material requirements.

This eighth edition of ANSI/AWWA C504 was approved by the AWWA Board of Directors on Feb. 12, 2006.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.
2. Specific policies of the state or local agency.

*Persons outside the United States should contact the appropriate authority having jurisdiction.

3. Two standards developed under the direction of NSF, NSF*/ANSI† 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.

4. Other references, including AWWA standards, *Food Chemicals Codex, Water Chemicals Codex,*‡ and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA C504 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.

2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.

3. Determine current information on product certification.

II. Special Issues.

II.A. *General.* Conditions under which a valve is to be operated must be evaluated carefully by the purchaser. The evaluations must include the determination of the hydraulic characteristics of the system in which the valve will be installed and the operation of the valve (on–off or throttling), including (1) the maximum transient and static differential pressure across the valve disc and (2) flow through the valve under the most adverse operating conditions.

* NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

† American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

‡ Both publications available from National Academy of Sciences, 550 Fifth Street NW, Washington, DC 20418.

Torque requirements for valve operation vary considerably with differential pressure across the valve, fluid velocity, fluid temperature, and upstream piping conditions.

Flow direction is important in the installation and use of a butterfly valve. Some valves' performance and sealing characteristics vary with direction of flow. Flow direction can affect the torque requirements and throttling characteristics of valves with offset discs or discs that do not have identical surface configurations on each side. Many butterfly valves have different sealing characteristics on one side vs. the other. A manufacturer may have a recommended high-pressure sealing side for long-term reliability.

Hydraulic testing, flow capacities, and valve torques are based on the flow, upstream of a valve, being uniform and undisturbed, like the flow produced by a long length of constant-diameter, straight pipe. Piping configurations that produce a non-uniform or turbulent flow pattern upstream of the valve can increase torque requirements, create damaging vibrations, increase head loss, and increase stresses in valve components.

Some hydraulic systems can produce flow velocities much higher than the maximum of 16 ft/sec (4.9 m/sec) described in this standard. Typically high velocities can result from line breaks, during fire fighting or in surge relief applications. The effects of high velocities and asymmetrical turbulent flow conditions can result in high loads and torque requirements, which are unaccounted for in this standard. These design conditions should be clearly specified by the purchaser.

II.B. *Buried Valves Larger Than 48 In.* When valves are provided with flanged ends in buried applications, the purchaser is advised to consider providing means to accommodate issues such as differential settlement, capability to remove the valve or actuator for maintenance access to the valve interior for inspection, support of the valve, and controlling the shear loading on the adjacent pipe flanges. Where practical, flanged valves in buried installations should be located in vaults. Many types of large buried pipes are designed to deflect 2–5 percent of pipe diameter, which is harmful to the valve integrity. Adjacent pipe must be supported or stiffened to provide a round mating connection for the valve in service.

II.C. *Advisory Information on Product Application.* This standard does not describe all possible applications or manufacturing technologies. The purchaser should identify special requirements and required deviations from this standard and include appropriate language in purchase documents. Refer to Sec. III.A in this Foreword. Other advisory information is provided below.

1. The maximum anticipated fluid velocity through the valve, maximum non-shock shutoff pressure, water temperature range, and valve classification are used by manufacturers to calculate torque requirements, which then may determine valve operating-component design and actuator sizing. This information should be provided according to items 5, 6, 7, and 24 of Sec. III.A in this Foreword. Note: If this information is not provided, class B valve classifications will be provided and actuators will be sized for the most severe conditions listed in this standard. This may result in a significant unwarranted expense.

Turbulence is also a factor that may affect torque requirements. Turbulence will be considered only if information on piping conditions is provided according to item 27 of Sec. III.A in this Foreword.

2. This standard limits handwheel rim pull, but not handwheel diameter. A smaller handwheel may require a more expensive actuator requiring more turns. If a large-diameter handwheel is of concern because of clearance or other limitations, the diameter should be limited to an acceptable dimension according to item 14 of Sec. III.A in this Foreword.

3. This standard refers to ANSI/AWWA C540, which permits the use of some plated components in metallic water-hydraulic cylinder actuators. The purchaser should be aware of the possibility of plating failure, particularly when the operating water is aggressive. The purchaser may limit acceptability to cylinders having components that do not depend on platings to resist corrosion according to item 16 of Sec. III.A in this Foreword.

4. This standard permits several metallic seating-surface materials. This standard recommends seating surfaces of stainless steel or nickel-copper alloy in cases where valves are to be operated more frequently than once a month. The purchaser may require these alloys for specific applications according to item 11 of Sec. III.A in this Foreword.

5. This standard also accepts sprayed mating-seat surfaces when the surfaces are applied under certain conditions. The suitability of this type of surface depends, to a large extent, on the quality of the manufactured product. The purchaser should be aware of the manufacturer's previous experience with similar applications. The purchaser may limit acceptability to a specific product or application according to item 11 of Sec. III.A in this Foreword.

6. The material references for metals in Sec. 4.3 and 4.4 of this standard are based on successful experience. There may be instances where the water is very aggressive, and the listed materials, particularly the bronzes, may not be suitable for surfaces in both the valve and, if applicable, the hydraulic cylinder actuators wet. The

requirements for elastomers are included in Sec. 4.4 of this standard. This standard does not require rubber parts to be specifically tested or to be specifically suitable for service with line content containing chlorine or chloramines. Standardized tests measuring resistance to chlorine- or chloramine-bearing waters were not available at the date of revision of this standard. If these or other chemical constituents are of concern, special requirements may be included in the purchase documents. Refer to item 28 of Sec. III.A in the Foreword.

7. This standard does not require a minimum waterway area nor does it limit head loss across the valve. If this is of concern, limitations should be provided. Refer to item 26 of Sec. III.A of this Foreword.

8. This standard allows a party other than the valve manufacturer to mount an actuator to a valve. Sec. 5.1.1 and 5.1.2.1 require that the valve and actuator assembly be performance and leak tested as an assembly. The purchaser is cautioned that the valve manufacturer cannot assume responsibility for the valve's sealing and operating performance if the actuator is mounted by a party other than the valve manufacturer. If this is a concern, requirements on actuator mounting should be included in the purchase documents.

9. Electric actuators meeting the requirements of ANSI/AWWA C540 can be supplied with or without an intermediate quarter-turn mechanism. If desired, the purchaser should specify a multi-turn actuator coupled to an intermediate mechanism according to ANSI/AWWA C504.

III. Use of This Standard. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. *Purchaser Options and Alternatives.* The following items should be provided by the purchaser:

1. Standard to be used—that is, ANSI/AWWA C504, Rubber-Seated Butterfly Valves, of latest edition.

2. Whether compliance with NSF/ANSI 61 Drinking Water System Components—Health Effects, is required, in addition to the requirements of the Safe Drinking Water Act.

3. Size of valve.

4. Quantity required.

5. Type of body: flanged (short body or long body), wafer, or mechanical-joint ends.

6. Minimum acceptable valve classification.

7. Maximum nonshock shutoff pressure and maximum nonshock line pressure.

8. Required flow rate through valve.

   a. Under normal conditions.

   b. Under maximum-flow conditions.

      — When opening (consider factors such as fire flow).

      — When closing (consider factors such as line break).

9. Description of connecting piping: material, outside diameter (OD) and inside diameter (ID), and flanged or plain end.

10. Information or data required from the valve manufacturer or supplier. This information can include the following:

   a. Valve port diameter

   b. Clearances required for the actuator, and clearances required to remove the actuator

   c. The number of turns to open and close for manual actuators

   d. Assembled weight

   e. Valve-torque data

   f. Cavitation coefficients

   g. Preferred-flow direction, if applicable (Foreword Sec. II., Special Issues)

   h. Valve component materials (Sec. 4.3)

   i. Principal dimensions, including laying length (Table 1)

   j. Actuator manufacturer, model, and torque capability (Sec. 4.3.8)

   k. Interior and exterior coating materials (Sec. 4.4.2)

   l. Clearance beyond the valve body required for the valve disc to open fully (Sec. A.5.7)

11. Materials.

   a. If the purchaser specifies a wetted component that was not part of the tested and certified valve, the certification may not be valid.

   b. If one or more of the materials included in this standard are unacceptable, specify the acceptable materials that are included in this standard.

   c. If materials included in the standard are not suitable for exposure to line content or are otherwise unacceptable, specify materials that are suitable and acceptable. (Refer to item 6, Sec. II.C of this Foreword.)

d. Metallic mating seats: Specify any limitations on acceptability of seat materials or sprayed seats for specific applications or specific products. Refer to items 4 and 5, Sec. II.C of this Foreword.

12. Type of installation: buried, submerged, or in-plant.

13. Actuator type and service conditions.

   a. Type—manual, electric, cylinder, or other.

   b. Service—open–close or modulating.

14. Manual actuator.

   a. Type—handwheel, chainwheel, or wrench nut.

   b. Direction to turn the handwheel, chainwheel, or wrench nut to open valves. (Unless otherwise specified, the valve will open by turning counterclockwise.)

   c. Position indicator:

   — If required.

   — Configuration for buried, submerged, or in-plant service.

   d. Special devices or features if required: extension shaft, floor stand, handwheel diameter, or position transmitter.

15. Cylinder actuator.

   a. Operating medium: air, water, or oil.

   b. Medium pressure: maximum and minimum.

   c. Characteristics: control scheme, opening and closing speed ranges, if different from the 30 to 60 sec required by ANSI/AWWA C540.

   d. Position indicator:

   — If required.

   — Configuration.

   e. Special requirements:

   — Specify any limitations on acceptability or any special construction required.

16. Other actuators: actuators other than those described in this standard or ANSI/AWWA C540 shall be specified by the purchaser in detail.

17. Valve and actuator arrangement and position.

18. If an affidavit of compliance is required with the provisions of ANSI/AWWA C540 signed by the actuator manufacturer.

19. If the flow resistance coefficient for a fully open valve calculated in accordance with AWWA Manual M49, *Butterfly Valves: Torque, Head Loss, and Cavitation Analysis*, is required.

20. If valve position vs. flow resistance curves are required, they should be referenced to procedures described in AWWA Manual M49.

21. If shop inspection by the purchaser is required.

22. Maximum transient pressure and characteristics, if known.

23. Water temperature range.

24. If a leakage test in both directions is required.

25. If a leakage test with the actuator attached is required. NOTE: This may not be a standard practice for some manufacturers and, therefore, may result in increased cost and delivery time.

26. If a maximum head loss is required. This information should be provided for each size and class of valve. NOTE: Not all manufacturers may use the same test methods for measuring head loss. This should be discussed by the purchaser and the manufacturer. It is recommended that the purchaser reference AWWA Manual M49 if a maximum headloss is specified.

27. A drawing or description of the piping arrangement sufficient to describe significant turbulent line flow conditions to which the valve disc may be subjected.

28. Considerations relating to anticipated problems with rubber components exposed to line content containing chlorine, chloramines, or other chemicals. If these problems are anticipated, the purchaser should identify the maximum expected concentrations of these chemicals and other factors, such as pH and temperature ranges, which may affect the corrosivity of these chemicals. The purchaser should consult with the manufacturers and, if appropriate, specify special requirements for these components.

29. This standard requires flat-faced flanges. If other facings are desired, they must be specified by the purchaser.

30. If purchase documents require shop inspection or test observations to be performed by the purchaser, the extent of such inspections and observations should be defined.

31. Maximum seating and operating torque requirements of the conditions defined in the scope.

32. Details of other federal, state, local, and provincial requirements (Sec. 4.2.1).

33. The provision of test records that are specified according to Sec. 4.2.3, 4.3.8.5.8, 4.3.8.5.9, 5.1.1, 5.1.2, 5.1.3, and 5.1.4 of this standard. Test records required for power actuators under ANSI/AWWA C540 may also be requested. The purchaser may require all records or may stipulate a breakdown of production test records or proof-of-design test records.

34. Detailed description of nonstandard end connections (Sec. 4.3.1 and 4.3.2).

35. Type of shaft seal (Sec. 4.3.7). This standard does not require that seal materials be resistant to permeation by organic compounds such as organic solvents or petroleum-based products. If the purchaser's application involves such source conditions (usually in buried applications), then the purchaser should consult with valve manufacturers to specify the proper shaft seals.

36. Electric actuator (Sec. 4.3.8.6).

a. Type: multi-turn actuator coupled to an intermediate mechanism or integral quarter-turn unit.

b. Characteristics: operating voltage, control scheme, and time of operation (unless otherwise specified, fully open to fully closed, or the reverse, will be approximately 60 sec).

c. Position indicator: configuration.

d. Special considerations: type of service environment should be stated and appurtenances required.

37. Protective coatings, if other than specified in Sec. 4.4.2 of this standard.

38. If an affidavit of compliance is required with the provisions of this standard signed by the valve manufacturer (Sec. 6.3).

III.B. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard must be provided by the purchaser.

IV. Major Revisions. The major revisions made to the standard in this edition include the following:

1. Revised material references to use Unified Numbering System (UNS) designations.

2. Added ductile iron as an acceptable material for actuator worm gears in buried service.

3. Allowed the use of the valves from the proof-of-design tests to be rebuilt and used as production valves.

4. Added advisory text on valve and adjacent pipe installation in Appendix A.

V. Comments. If you have any comments or questions about this standard, please call the AWWA Volunteer & Technical Support Group at 303.794.7711, FAX at 303.795.7603, write to the group at 6666 West Quincy Avenue, Denver, CO 80235-3098, or e-mail at standards@awwa.org.

ANSI/AWWA C504-06
(Revision of ANSI/AWWA C504-00)

American Water Works Association

AWWA Standard

Rubber-Seated Butterfly Valves

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard establishes minimum requirements for rubber-seated butterfly valves, 3 in. (75 mm) through 72 in. (1,800 mm) in diameter, with various body and end types, for fresh water having a pH range from 6–12 and a temperature range from 33°–125°F (0.6°–52°C). This standard covers rubber-seated butterfly valves suitable for a maximum steady-state fluid working pressure of 250 psig (1,723 kPa, a maximum steady-state differential pressure of 250 psi (1,723 kPa), and a maximum full open velocity of 16 ft/sec (4.9 m/sec).

1.1.1 *Body types, classes, and sizes.* Valves described in this standard are provided in four body types and in classes as follows:

1.1.1.1 Wafer valves. Class 150B, in sizes 3–20 in. (75–500 mm).

1.1.1.2 Short-body and long-body flanged valves. Class 25A, class 25B, class 75A, class 75B, class 150A, and class 150B, in sizes 3–72 in. (75–1,800 mm), and class 250B in sizes 3–48 in. (75–1,200 mm).

1.1.1.3 Mechanical-joint-end valves. Class 150B and class 250B, in sizes 3–24 in. (75–600 mm), and class 25A, class 25B, class 75A, class 75B, class 150A, class 150B, and class 250B, in sizes 30–48 in. (750–1,200 mm).

1.1.2 *Definition of classification.* In each case, the numeric designation represents the pressure rating (the maximum steady-state fluid working pressure, in pounds per square inch gauge) and also the maximum steady-state differential pressure, in pounds per square inch, for which the valve is designed. The designations *A* and *B* define the flow-rate capabilities with the valve in the fully open position. *A* valves are rated for a maximum velocity of 8 ft/sec (2.4 m/sec), and *B* valves are rated for a maximum velocity of 16 ft/sec (4.9 m/sec) in the piping section upstream of the valve.

Sec. 1.2 Purpose

The purpose of this standard is to provide the minimum requirements for rubber-seated butterfly valves, suitable for freshwater service.

Sec. 1.3 Application

This standard can be referenced in purchase documents for rubber-seated butterfly valves, which are described by the scope as defined above.

SECTION 2: REFERENCES

This standard references the following documents in their current editions. These documents form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

ANSI*/AWWA C111/A21.11—American National Standard for Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.

ANSI/AWWA C540—Power-Actuating Devices for Valves and Slide Gates.

ANSI/AWWA C550—Protective Interior Coatings for Valves and Hydrants.

ASME† B16.1—Cast-Iron Pipe Flanges and Flanged Fittings.

ASME Boiler and Pressure Vessel Codes.

ASTM‡ A36—Standard Specification for Carbon Structural Steel.

ASTM A48—Standard Specification for Gray Iron Castings.

ASTM A108—Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished.

*American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

†ASME International, Three Park Ave., New York, NY 10016.

‡ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

ASTM A126—Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings.

ASTM A216—Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service.

ASTM A240—Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.

ASTM A276—Standard Specification for Stainless Steel Bars and Shapes.

ASTM A395—Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures.

ASTM A436—Standard Specification for Austenitic Gray Iron Castings.

ASTM A439—Standard Specification for Austenitic Ductile Iron Castings.

ASTM A516—Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service.

ASTM A536—Standard Specification for Ductile Iron Castings.

ASTM A564—Standard Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes.

ASTM A743/A743M—Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Applications.

ASTM B127—Standard Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip.

ASTM B154—Standard Test Method for Mercurous Nitrate Test for Copper and Copper Alloys.

ASTM B160—Standard Specification for Nickel Rod and Bar.

ASTM C633—Standard Test Method for Adhesion or Cohesion Strength of Thermal Spray Coatings.

ASTM D429—Standard Test Methods for Rubber Property—Adhesion to Rigid Substrates.

ASTM D471—Standard Test Methods for Rubber Property—Effect of Liquids.

ASTM D1141—Standard Practice for the Preparation of Substitute Ocean Water.

ASTM D1149—Standard Test Method for Rubber Deterioration—Surface Ozone Cracking in a Chamber.

AWWA Manual M49, *Butterfly Valves: Torque, Head Loss, and Cavitation Analysis*.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Actuator:* A device attached to the valve for the purpose of rotating the valve disc to an open, closed, or intermediate position; preventing disc overtravel; and maintaining the disc in any position.

2. *Bearing:* The cylindrical journal located in the body hubs that is used to support the valve shaft(s) and transmit disc forces to the valve body while minimizing friction and wear.

3. *Body:* The primary pressure-retaining structure of the valve that forms a portion of the pipeline and that has ends adapted for connection to the piping.

4. *Butterfly valve:* A valve that uses a disc rotatable through an angle of approximately 90° as a closure member. The valve is closed when the edge of the disc is perpendicular to the flow way, open when parallel to the flow way, or used for throttling when positioned between open and closed.

5. *Chainwheel:* A chain-driven wheel with a closed loop of chain draped over it to facilitate actuation of an overhead-mounted valve.

6. *Cylinder actuator:* An actuator that employs fluid power and mechanically converts hydraulic or pneumatic pressure acting on a piston within a cylinder.

7. *Disc:* The closure member that is positioned in the flow stream to permit flow or to obstruct flow (depending on closure position) and that rotates through an angle of 90° from full open to full shutoff.

8. *Electric actuator:* An electromechanical actuator that employs the power of an electric motor converted through a gear-reduction unit.

9. *Fluid working pressure:* The internal hydrostatic pressure for which the valve body is designed without regard to disc position or actuator capacity.

10. *Handwheel:* A circular-rimmed component connected to the input shaft of an actuator to facilitate manual actuation of a valve.

11. *Hub:* A structural, raised-area (boss) member cast integrally on the valve body and used to support the valve-shaft bearing and valve shaft.

12. *Long-body flanged valve:* A flanged valve designed to be installed between, and attached to, pipe flanges.

13. *Manual actuator:* An actuator that can be operated by a person without the need for an external energy source, such as electrical power or fluid pressure.

14. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

15. *Mating surface:* The metal ring around the inside of the valve body or the outside edge of the valve disc that seals with the rubber seat when the disc is closed.

16. *Mechanical-joint end valve:* A valve with mechanical-joint-type ends conforming to ANSI/AWWA C111/A21.11.

17. *O-ring seal:* A type of seal consisting of an elastomer in the shape of a torus, i.e., a circular shape with a circular cross section.

18. *Outboard thrust bearing:* A bearing that is provided on the shaft outboard of the shaft seal or in the actuator housing to protect the shaft seal from side-thrust forces induced by the actuator.

19. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

20. *Rated differential pressure:* Pressure classes as defined in Sec. 1.1.2.

21. *Rubber seat:* A rubber ring around the outside edge of the valve disc or the inside of the valve body to effect a seal against the metal seating surface when the disc is closed.

22. *Shaft:* A bar extending through the body hubs and into the disc to support the disc and transmit operating torque to the disc-closure member.

23. *Shaft seal:* A circular seal between the valve shaft and the inside cylindrical surface of the body hub that prevents the pressurized water from exiting and outside contaminants from entering the valve body in the area where the shaft protrudes through the body.

24. *Short-body flanged valve:* A flanged valve designed to be installed between, and attached to, pipe flanges.

25. *Supplier:* The party that supplies material or services. A supplier may or may not be the manufacturer.

26. *Thrust bearing:* A device that supports the axial forces of the shaft and is used to center the disc in the valve body.

27. *Wafer valve:* A flangeless body valve having a minimal face-to-face laying length designed to be installed between pipe flanges.

SECTION 4: REQUIREMENTS

Sec. 4.1 Permeation

The selection of materials is critical for water service and distribution piping in locations where there is likelihood the pipe will be exposed to significant concentrations of pollutants that are comprised of low molecular weight petroleum products or organic solvents or their vapors. Research has documented that pipe materials such as polyethylene, polybutylene, polyvinyl chloride, and asbestos cement; and elastomers, such as used in jointing gaskets and packing glands, may be subject to permeation by lower molecular weight organic solvents or petroleum products. If a water pipe must pass through such a contaminated area or an area subject to contamination, consult with the manufacturer regarding permeation of pipe walls, jointing materials, etc., *before* selecting materials for use in that area.

Sec. 4.2 Materials

4.2.1 *General.* Materials shall comply with the requirements of the Safe Drinking Water Act and other federal requirements. Refer to ANSI/AWWA C540 and ANSI/AWWA C550 for materials required for power actuators and interior coatings.

4.2.2 *Physical and chemical properties.* Materials shall be in conformance with the physical and chemical requirements of this subsection.

4.2.2.1 Gray iron. ASTM A126, Class B or ASTM A48, Class 40.

4.2.2.2 Ductile iron. ASTM A536, Grade 65-45-12, 70-50-05, or 80-55-06 or ASTM A395, Grade 60-40-18.

4.2.2.3 Alloy gray iron. ASTM A436, Type 1 or 2, or ASTM A439, Type D2.

4.2.2.4 Stainless steel. ASTM A240, UNS Designation S30400 or S31600, ASTM A276, UNS Designation S30400 or S31600, ASTM A743, grade CF8 or CF-8M, or ASTM A564, UNS Designation S17400.

4.2.2.5 Nickel-copper alloy. ASTM B127.

4.2.2.6 Carbon steel. ASTM A108.

4.2.2.7 Cast steel. ASTM A216, Grade WCB.

4.2.2.8 Fabricated steel. ASTM A36, ASTM A516, or better.

4.2.2.9 Nickel rod. ASTM B160.

4.2.2.10 Rubber seats. See Sec. 4.3.5.2.

4.2.2.11 Brass or bronze. Components made of brass or bronze shall be to ASTM or Unified Numbering System (UNS) standards.

4.2.2.11.1 Any bronze alloy used in the cold-worked condition shall be capable of passing the mercurous nitrate test, in accordance with ASTM B154 to minimize susceptibility to stress corrosion.

4.2.2.11.2 Bronze shall not contain more than 7 percent zinc. If aluminum-bronze is used, the alloy shall be inhibited against dealuminization by receiving a temper anneal at 1,200°F ±50°F (650°C ±28°C) for 1 hr per in. of section thickness, followed by cooling in moving air or by water quenching.

4.2.2.12 Corrosion-resistant metals. Corrosion-resistant metals used for clamping and retaining rubber seats, shaft and disc connection hardware, glands or gland assemblies, thrust bearings, and O-ring removable recesses that are wetted by line content shall be made of stainless steel, nickel-copper alloy, or bronze, conforming to the aforementioned requirements.

4.2.3 *Tests*. Whenever valve components are to be made in conformance with ASTM or other standards that include test requirements or testing procedures, the valve manufacturer shall meet these requirements or procedures. The records of these tests shall be made available to the purchaser if agreed on by the purchaser and manufacturer.

Sec. 4.3 General Design

4.3.1 *Valve bodies*.

4.3.1.1 Laying length. Laying lengths for class 25, 75, and 150 flanged-end and wafer valves shall be as specified in Table 1. There is no standard laying length for class 250 flanged-end bodies or mechanical-joint end bodies, except as footnoted in Table 2.

4.3.1.2 Shaft-bearing hubs. The bodies of valves shall have two shaft-bearing hubs cast integrally with the valve bodies.

4.3.1.3 Wafer-valve bodies. Wafer-valve bodies shall be designed for installation between ASME B16.1, class 125 cast-iron flanges. No part of the valve internals shall extend beyond the body ends when the disc is in the closed position.

4.3.1.4 Mechanical joints. Mechanical-joint bell dimensions shall conform to ANSI/AWWA C111/A21.11. Slots with the same width as the diameter of the

Table 1 Laying lengths for flanged and wafer valves and minimum body shell thicknesses for all body types

Valve Size		Laying Length*						Minimum Body Shell Thickness							
		Short Body		Long Body		Wafer		Class 25A Class 25B		Class 75A Class 75B		Class 150A Class 150B Class 250B (Ductile Iron)		Class 250B (Gray or Alloy Gray Iron)	
in.	*(mm)*	*in.*	*(mm)*	*in.*	*(mm)*	*in.*	*(mm)*	*in.*	*(mm)*	*in.*	*(mm)*	*in.*	*(mm)*	*in.*	*(mm)*
3	(75)	5	(127)	5	(127)	2	(50.8)	0.370	(9.4)	0.37	(9.4)	0.370	(9.4)	3/8	(9.5)
4	(100)	5	(127)	7	(178)	2 1/4	(57.2)	0.400	(10.2)	0.40	(10.2)	0.400	(10.2)	15/32	(11.9)
6	(150)	5	(127)	8	(203)	2 13/16	(71.4)	0.430	(10.9)	0.43	(10.9)	0.430	(10.9)	5/8	(15.9)
8	(200)	6	(152)	8 1/2	(216)	2 15/16	(74.6)	0.460	(11.7)	0.46	(11.7)	0.460	(11.7)	5/8	(15.9)
10	(250)	8	(203)	15	(381)	3 1/8	(79.4)	0.500	(12.7)	0.50	(12.7)	0.540	(13.7)	11/16	(17.5)
12	(300)	8	(203)	15	(381)	3 3/8	(85.7)	0.540	(13.7)	0.54	(13.7)	0.580	(14.7)	3/4	(19.1)
14	(350)	8	(203)	16	(406)	3 3/4	(96.3)	0.540	(13.7)	0.58	(14.7)	0.630	(16.0)	7/8	(22.2)
16	(400)	8	(203)	16	(406)	4 1/8	(105.0)	0.580	(14.7)	0.63	(16.0)	0.680	(17.3)	1	(25.4)
18	(450)	8	(203)	16	(406)	4 5/8	(117.0)	0.630	(16.0)	0.68	(17.3)	0.790	(20.1)	1 1/8	(28.6)
20	(500)	8	(203)	18	(457)	5 1/8	(130.0)	0.660	(16.8)	0.71	(18.0)	0.830	(21.1)	1 1/8	(28.6)
24	(600)	8	(203)	18	(457)			0.740	(18.8)	0.80	(20.3)	0.930	(23.6)	1 1/4	(31.8)
30	(750)	12	(305)	22	(559)			0.870	(22.1)	0.94	(23.9)	1.100	(27.9)	1 3/4	(44.5)
36	(900)	12	(305)	22	(559)			0.970	(24.6)	1.13	(28.7)	1.220	(31.0)	1 7/8	(47.6)
42	(1,050)	12	(305)	24	(610)			1.070	(27.2)	1.16	(29.5)	1.350	(34.3)	2 1/4	(57.2)
48	(1,200)	15	(381)	26	(660)			1.180	(29.9)	1.37	(34.8)	1.480	(37.6)	2 1/2	(63.5)
54	(1,350)	15	(381)	28	(711)			1.300	(33.0)	1.51	(38.4)	1.630	(41.4)		
60	(1,500)	15	(381)	30	(762)			1.390	(35.3)	1.62	(41.1)	1.890	(48.0)		
66	(1,650)	18	(457)	34	(864)			1.625	(41.3)	1.80	(45.7)	2.000	(50.8)		
72	(1,800)	18	(457)	36	(914)			1.750	(44.5)	2.00	(50.8)	2.375	(60.3)		

*Includes rubber if rubber extends over the flange face. Tolerance for valves 10 in. (250 mm) and smaller is ±1/8 in. (3.17 mm). Tolerance for valves 12 in. (300 mm) and larger is ±3/16 in. (4.76 mm). Laying lengths do not apply to class 250B flanged-end or mechanical-joint end valves.

Table 2 Available flange dimensions and drilling

Availability*	Valve Class	Sizes	Allowable Body Materials	ASME B16.1 Class for Flange Dimensions	ASME B16.1 Class for Flange Drilling
Standard	25A	All	All	Class 125	Class 125
Standard	25B	All	All	Class 125	Class 125
Standard	75A	All	All	Class 125	Class 125
Standard	75B	All	All	Class 125	Class 125
Standard	150A	All	All	Class 125	Class 125
Standard	150B	All	All	Class 125	Class 125
Standard	250B	48 in. (1,200 mm)	All	Class 250	Class 250
Optional†	250B	48 in. (1,200 mm)	All	Class 250	Class 125
Optional‡	250B	All	Ductile Iron	Class 125	Class 125

*Unless otherwise specified, the dimensions and drilling of end flanges shall conform to the "standard" valve class configuration.

†When selecting this option, all flange holes shall be tapped.

‡When selecting this option, body-laying length shall comply with the short-body configuration of Table 1.

bolt holes may be provided instead of holes in the bell flange only at those places where the valve body interferes with the insertion of bolts.

4.3.1.5 Shell thickness. Minimum body shell thicknesses shall conform to the requirements listed in Table 1. Shell thickness measurements taken at points diametrically opposite to each other shall, when added together and divided by two, equal or exceed the minimum body shell thickness given in Table 1. At no point shall the shell thickness be more than 12.5 percent below the metal thickness shown in this table.

4.3.1.6 Materials. Unless otherwise specifically requested by the purchaser, bodies of valves shall be of gray iron, ductile iron, or alloy-gray iron.

4.3.2 *End flanges.*

4.3.2.1 Dimensions. Flanges shall be flat faced. Unless otherwise specified, the dimensions and drilling of valve flanges shall conform to Table 2 for flanged-end valves or ANSI/AWWA C111/A21.11 for mechanical-joint end valves.

4.3.2.2 Bolt holes. Flanges shall have full-sized bolt holes through the body flanges, except that drilled and tapped holes in wafer valves and in flanges of short-body valves will be acceptable in locations in which the valve body will not permit a through-hole.

4.3.3 *Valve shafts.*

4.3.3.1 Shafts. Each valve shall have a one-piece shaft extending completely through the valve disc or have a stub-shaft arrangement, as described below.

4.3.3.1.1 A stub shaft comprises two separate shafts inserted into the valve-disc hubs. Each stub shaft shall be inserted into the valve-disc hubs a distance of at least 1 1/2 shaft diameters.

4.3.3.1.2 Valve shafts shall have a minimum diameter extending through the valve bearings and into the valve disc, as specified in Table 3.

4.3.3.2 Connection. The connection between the shaft and the disc shall be designed to transmit shaft torque equivalent to at least 75 percent of the torsional strength of the minimum required shaft diameters. Rigid shaft restraint shall be provided. Hardware used in connecting the shaft to the disc shall be of corrosion-resistant metals. The disc shall be mechanically secured to the shaft by a process such as bolting, riveting, threading, upsetting, or cross-pinning, and shall not rely solely on chemical bonding, adhesives, or welding. The shaft shall be capable of nondestructive separation from the disc.

4.3.3.3 Size. The portion of the shaft that extends through the valve bearings shall be full size. If the valve-shaft diameter is reduced to fit connections to the valve operating mechanism, the smaller portion shall have fillets with radii equal to the offset to minimize the possibility of stress concentration at the junction of the two different shaft diameters. The smallest diameter of the shaft shall be capable of transmitting the maximum calculated valve-operating torque without the torsional shear stress exceeding 40 percent of the yield strength of the shaft material. In addition, maximum valve shaft stresses in the full-size portion of the shaft shall not exceed the lesser of 1/5 of the tensile strength or 1/3 of the yield strength of the material used. Tensile and yield strengths shall be based on the minimum strength stated in Sec. 4.2.2.

4.3.3.4 Valve-shaft material. Valve shafts shall be wrought stainless steel or nickel-copper alloy.

4.3.4 *Valve discs.*

4.3.4.1 Disc material. Valve discs shall be made of gray iron; cast steel; fabricated steel; bronze, as referenced in Sec. 4.2.2.11; alloy gray iron; ductile iron; or

Table 3 Minimum shaft diameters*

Valve Diameter		Shaft Diameter—*in. (mm)*													
in.	*(mm)*	Class 25A*		Class 25B*		Class 75A*		Class 75B*		Class 150A*		Class 150B*		Class 250B*	
3	(75)	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)
4	(100)	5/8	(15.9)	5/8	(15.9)	5/8	(15.9)	5/8	(15.9)	5/8	(15.9)	5/8	(15.9)	5/8	(15.9)
6	(150)	3/4	(19.1)	3/4	(19.1)	3/4	(19.1)	3/4	(19.1)	1	(25.4)	1	(25.4)	1	(25.4)
8	(200)	7/8	(22.2)	7/8	(22.2)	7/8	(22.2)	7/8	(22.2)	1 1/8	(28.6)	1 1/8	(28.6)	1 1/8	(28.6)
10	(250)	1	(25.4)	1	(25.4)	1 1/8	(28.6)	1 1/8	(28.6)	1 3/8	(34.9)	1 3/8	(34.9)	1 3/8	(34.9)
12	(300)	1 1/8	(28.6)	1 1/8	(28.6)	1 1/4	(31.8)	1 1/4	(31.8)	1 1/2	(38.1)	1 1/2	(38.1)	1 1/2	(38.1)
14	(350)	1 1/4	(31.8)	1 3/8	(34.9)	1 3/8	(34.9)	1 1/2	(38.1)	1 3/4	(44.5)	1 3/4	(44.5)	1 3/4	(44.5)
16	(400)	1 3/8	(34.9)	1 1/2	(38.1)	1 1/2	(38.1)	1 5/8	(41.3)	2	(50.8)	2	(50.8)	2	(50.8)
18	(450)	1 1/2	(38.1)	1 5/8	(41.3)	1 5/8	(41.3)	1 7/8	(47.6)	2 1/8	(54.0)	2 1/4	(57.2)	2 1/4	(57.2)
20	(500)	1 1/2	(38.1)	1 7/8	(47.6)	1 3/4	(44.5)	2 1/8	(54.0)	2 3/8	(60.3)	2 1/2	(63.5)	2 1/2	(63.5)
24	(600)	1 3/4	(44.5)	2 1/4	(57.2)	2	(50.8)	2 1/2	(63.5)	2 3/4	(69.9)	3	(76.2)	3	(76.2)
30	(750)	2	(50.8)	2 3/4	(69.9)	2 1/2	(63.5)	3	(76.2)	3 1/2	(88.9)	3 5/8	(92.1)	3 5/8	(92.1)
36	(900)	2 1/2	(63.5)	3 1/2	(88.9)	3	(76.2)	3 5/8	(92.1)	4	(102.0)	4 3/8	(111.0)	4 3/8	(111.0)
42	(1,050)	2 7/8	(73.0)	3 3/4	(95.3)	3 3/8	(85.7)	4 1/4	(108.0)	4 1/2	(114.0)	5	(12.07)	5	(127.0)
48	(1,200)	3 1/4	(82.6)	4 1/4	(108.0)	3 7/8	(98.4)	4 7/8	(124.0)	5 1/8	(130.0)	5 5/8	(143.0)	5 5/8	(143.0)
54	(1,350)	3 5/8	(92.1)	4 7/8	(124.0)	4 1/4	(108.0)	5 1/2	(140.0)	5 3/4	(146.0)	6 3/4	(171.0)	—	—
60	(1,500)	4	(102.0)	5 1/2	(140.0)	4 3/4	(121.0)	6	(152.0)	6 1/4	(159.0)	7 1/4	(184.0)	—	—
66	(1,650)	4 1/2	(114.0)	6	(152.0)	5	(127.0)	6 3/4	(171.0)	7	(178.0)	7 3/4	(197.0)	—	—
72	(1,800)	4 7/8	(124.0)	6 1/2	(165.0)	5 3/4	(146.0)	7 1/2	(191.0)	7 1/2	(191.0)	8 1/2	(216.0)	—	—

*For an explanation of classification, see Sec. 1.1.2. Diameters for all classes of valves except for class 250B are based on use of any allowable material. Diameters for class 250B valves are based on use of ASTM A564, UNS Designation S17400, condition H1150 shaft material.

stainless steel. Class 250B discs shall be ductile iron, fabricated steel, cast steel, or stainless steel.

4.3.4.2 Disc design. The disc shall be designed to withstand full differential pressures across the closed valve disc without exceeding a stress level equivalent to one fifth of the tensile strength of the material.

4.3.4.3 Disc thickness. The thickness of the valve disc shall not be more than 2 1/4 times the shaft diameter listed in Table 3.

4.3.4.4 External ribs. Valve discs shall be of a cast or fabricated design with no external ribs transverse to the flow.

4.3.5 *Valve seats.*

4.3.5.1 Pressure classes. Valve seats shall be designed to be leak-tight in both directions at differential pressures up to, and including, the rated pressure of the valve class.

4.3.5.2 Rubber seats. Rubber seats of valves 30 in. (750 mm) and larger shall be of a design that permits removal and replacement at the site of the installation.

4.3.5.2.1 Rubber seats shall be applied to either the body or the disc, shall be of new natural or synthetic rubber, and may be reinforced.

4.3.5.2.2 Rubber seats shall be clamped, mechanically secured, or bonded to the body or disc. The method used for bonding shall be tested in accordance with ASTM D429, Method A or B. For Method A, the minimum strength shall be not less than 250 psi (1,725 kPa). When Method B is used, the peel strength shall not be less than 75 lb/in. (1.33 kg/mm). Rubber seats applied to the valve body and penetrated by the valve shaft shall be adequately reinforced to prevent the seat from becoming inflated by pressure behind the seat. Circumferential joints of rubber seats shall be bonded together. The design of the seat shall provide tight shutoff with flow in either direction, according to the tests required by Sec. 5 of this standard.

4.3.5.2.3 Rubber compounds shall contain no more than 8 ppm of copper ion and shall include copper inhibitors to prevent copper degradation of the rubber material.

4.3.5.2.4 Rubber compounds shall be capable of withstanding an ozone resistance test when tested in accordance with ASTM D1149, using 50 parts per 100 million minimum ozone concentration. The tests shall be conducted on unstressed samples for 70 hr at 104°F (40°C) without visible cracking in the surfaces of the test samples after tests.

4.3.5.2.5 Rubber compounds shall be free of vegetable oils, vegetable-oil derivatives, animal fats, and animal oils. Reclaimed rubber shall not be used. Rubber compounds shall contain no more than 1.5 parts of wax per 100 parts of rubber hydrocarbon.

4.3.5.2.6 Rubber compounds shall have less than 2 percent volume increase when tested in accordance with ASTM D471 after being immersed in distilled water at 73.4°F ±2°F (23°C ±1°C) for 70 hr.

4.3.5.3 Mating surfaces.

4.3.5.3.1 Rubber seats shall mate with the following acceptable seat surfaces: stainless steel; nickel-copper alloy; bronze; alloy gray iron; nickel-chromium alloy (72 percent minimum nickel and 14 percent minimum chromium); or nickel alloy (85 percent minimum nickel). The width of the seat surface shall, at a minimum, cover the entire surface wiped by, or in contact with, the rubber seat.

4.3.5.3.2 In cases where valves are to be operated frequently (more than once a month), seating surfaces of stainless steel or nickel-copper alloy are recommended.

4.3.5.3.3 Plated mating surfaces are not acceptable. Sprayed mating-seat surfaces are acceptable only when applied by the plasma nontransferred arc, or sprayed-and-fused process. A welding process may be used to attach the mating surface to the disc or body. Both processes shall be in accordance with the following:

a. If the mating seat is applied by the plasma nontransferred arc, sprayed-and-fused, or weld overlay process, the final surface shall have a minimum thickness of 7 mil (0.18 mm) and meet the chemical requirements of Sec. 4.3.5.3.1.

b. The wear resistance of the seating-surface material shall be demonstrated as capable of 100,000 opening and closing cycles under full-rated pressure in water without damage.

c. After the cycle test above, the corrosion resistance and bond integrity of the mating-seat-surface material and base metal combination shall be demonstrated as capable of withstanding immersion in 150°F (65.6°C) ASTM D1141 substitute ocean water for 12 months.

d. The application procedure shall be qualified in accordance with the ASME Boiler and Pressure Vessel Code, Sec. IX, QW-216. The liquid-penetrant examination of the test sample shall show no linear indications or porosity on, or adjacent to, the seating surface.

e. For any overlay, the following performance items are required: diffusion of the overlay into the base metal to a minimum depth of 50 μm; a visually pore-free surface with no cracking in the adjacent base metal; absence of bubbling through of the molten base metal into the surface of the overlay; and bond strength of 1,500 psi (10.4 MPa) minimum, as determined by ASTM C633.

f. The manufacturer shall establish and maintain a written quality-assurance program to control the qualified procedure and quality of finished parts.

g. Leak tightness shall be demonstrated by mating-seat performance during a 20-min, 150-psig (1,034-kPa) proof-of-design gas leakage test. The production seat test shall be in accordance with Sec. 5.1.2.1, except that valves larger than 20 in. (500 mm) in diameter shall be tested for a minimum duration of 10 min. The alternative hydrostatic leakage test, per Sec. 5.1.2.2, shall not be applicable. Impregnation of mating-seat surfaces is not permitted.

4.3.5.4 Clamps and retaining rings. Clamps and retaining rings for rubber seats shall be made of corrosion-resistant metallic material, as referenced in Sec. 4.2.2.12. Nuts, screws, and hardware used with clamps and retaining rings shall be of stainless steel or nickel-copper alloy.

4.3.6 *Valve bearings.*

4.3.6.1 Sleeve bearings. Valves shall be fitted with sleeve-type bearings contained in the hubs of the valve body. The maximum distance from the inside metal surface of the valve body to the inside end of the sleeve bearings shall not exceed 1/8 in. (3.17 mm). Bearings shall be designed for a pressure not to exceed the published design load for the bearing material or one-fifth the compressive strength of the bearing or shaft material. Valve shafts or extensions of the valve shaft shall be designed for connection to actuators, as described in Sec. 4.3.8.

4.3.6.2 Outboard thrust bearing. A bearing of corrosion-resistant material shall be provided on the shaft outboard of the shaft seal or in the actuator housing to protect the shaft seal from side-thrust forces developed in the operating mechanism.

4.3.6.3 Thrust bearings. Each valve shall be equipped with either one or two thrust bearings, which shall hold the valve disc securely in the center of the valve seat. Valves 20 in. (500 mm) and smaller without hydraulic or external axial shaft loads are excepted from this requirement.

4.3.6.4 Self-lubricating materials. Sleeve and other bearings fitted into the valve body or actuator gear case shall be of self-lubricated materials that do not have a harmful effect on water or rubber and do not have a coefficient of friction in excess of 0.25 when run at the maximum bearing pressure.

4.3.7 *Shaft seals.* A shaft seal shall be provided where shafts project through the valve bodies for actuator connection.

4.3.7.1 Seal design. Shaft seals shall be designed for the use of standard V-type packing; O-ring seals; O-ring loaded U-cup seals; or a pull-down packing.

4.3.7.2 O-rings. If O-rings are used, they shall be contained in a removable cartridge constructed of corrosion-resistant metallic materials referenced in Sec. 4.2.2.12 or suitable nonmetallic materials.

4.3.7.3 Seal replacement. Shaft seals shall be of a design allowing replacement of seals without removing the valve shaft.

4.3.7.4 Stuffing box and pull-down packing gland. When the purchaser specifically requests that the shaft seals use a stuffing box and pull-down gland, the design of the valve and stuffing box assembly shall permit adjustment or complete replacement of packing without disturbing any part of the valve or actuator assembly except the packing-gland follower.

4.3.7.4.1 Stuffing-box depth shall be sufficient to accept at least four rings of packing.

4.3.7.4.2 Gland or gland assemblies shall be of corrosion-resistant metallic materials referenced in Sec. 4.2.2.12 or engineered plastic materials recommended by their manufacturers for this service and proven successful by experience in this or similar applications.

4.3.7.4.3 Packing shall be made of resilient, nonmetallic material suitable for this service.

4.3.7.4.4 Packing shall not contain asbestos.

4.3.8 *Valve actuators*. The actuator is essentially an integral part of a butterfly valve. Intermediate mechanisms used between actuating devices and the valve stem to produce the quarter-turn motion of a butterfly valve shall meet the requirements of this section.

4.3.8.1 Torque capability. The rated torque capability of each actuator shall be sufficient to seat, unseat, and rigidly hold, in any intermediate position, the valve disc it controls, according to the operating conditions specified by the purchaser. If the purchaser fails to specify a temperature range, differential pressure, flow, or classification, actuator sizing shall be based on the most severe conditions listed in this standard. If the purchaser specifies a valve classification and fails to specify differential pressure or flow, actuator sizing shall be based on the pressure or flow requirement of the specified class rather than the most severe pressure and flow conditions listed in this standard.

4.3.8.2 Stop-limiting devices. Valve actuators shall be equipped with adjustable, mechanical, stop-limiting devices to prevent overtravel of the valve disc in the open and closed positions.

4.3.8.3 Safety factor. Actuator housings, supports, and connections to the valve shall be designed with a minimum safety factor of 5, based on the ultimate tensile strength, or a minimum safety factor of 3, based on the yield strength of materials used.

4.3.8.4 Actuator's position-control capability. The actuator shall be designed to control the valve in all positions, from fully open to fully closed and from fully closed to fully open, with control in any intermediate position.

4.3.8.5 Manual actuators.

4.3.8.5.1 Each manual actuator shall have gearing totally enclosed.

4.3.8.5.2 Actuators shall be designed to produce the required operating torque with a maximum rim pull of 80 lb (356 N) on the handwheel or chainwheel and a maximum input of 150 ft-lb (203 N•m) on wrench nuts. Adjustable stop-limiting devices shall be provided in the actuators for the open and closed positions. Actuator components between the input and these stops shall be designed to withstand, without damage, a rim pull of 200 lb (890 N) for handwheel or chainwheel and an input torque of 300 ft-lb (406 N•m) for wrench nuts.

4.3.8.5.3 Actuators for buried service valves shall be not less than 90 percent grease packed and totally sealed using gaskets, O-rings, or similar means. The valve shaft shall be fully enclosed with a housing, including where it connects to the actuator or bonnet extension.

4.3.8.5.4 The manufacturer shall select a representative actuator within each of the torque ranges for proof-of-design testing purposes.

4.3.8.5.5 Gear actuators or traveling-nut actuators shall be self-locking and designed to transmit twice the actuator rated output torque without damage to the faces of the gear teeth or the contact faces of the screw or nut.

4.3.8.5.6 Traveling-nut actuators shall have steel drive screws and an internally threaded bronze or ductile-iron nut. Actuators shall be enclosed.

4.3.8.5.7 Actuators that include worm gearing shall be totally enclosed in a gear case and shall have bronze or ductile-iron worm gears and hardened-steel worms that operate in a lubricant. Ductile-iron worm gears for buried service shall be supported in the housing and cover with self-lubricated sleeve bearings.

4.3.8.5.8 The design shall be verified by subjecting one prototype actuator of each model and torque rating to a shop torque test equal to or greater than twice the rated torque. In addition, manual actuators shall be tested while the actuator components are against the open and the closed stop-limiting devices referred to in Sec. 4.3.8.2 by applying a 200-lb (890-N) pull to a handwheel or chainwheel actuator and an input torque of 300 ft-lb (406-N•m) to an actuator nut. After testing, the actuator shall be completely disassembled and carefully examined for evidence of damage. On the purchaser's request, the manufacturer shall provide the purchaser with certified copies of reports describing the procedures and results of the

Table 4 Prototype actuator test cycles required

Torque Range		
ft-lb	*(N•m)*	Number of Cycles
Up to 3,750	(5,080)	10,000
3,751–6,250	(5,080–8,470)	5,000
6,251 and greater	(8,470 or greater)	1,000

tests for each model and torque rating of actuator to be provided. Sec. 4.2.2 does not apply to materials specified in Sec. 4.3.8.5 because actuator materials are not in contact with the line contents.

4.3.8.5.9 The design shall also be verified by cycle testing of one prototype actuator of each model through a full 90° cycle with full-rated actuator torque at the point of unseating. The number of cycles shall be in accordance with Table 4. After the cycle testing, the actuator shall be completely disassembled and inspected to determine whether or not excessive wear or permanent deformation affecting its function has occurred. Successful completion of the test will identify the design methods used in a series of actuators within the torque ranges listed as suitable.

4.3.8.6 Electric actuators.

4.3.8.6.1 Electric actuators shall meet the requirements of ANSI/AWWA C540 and be rated to produce not less than the required valve-seating and dynamic torques. Actuators used for modulating service shall be rated to produce not less than twice the required valve dynamic torque. Motors shall be sized for 1.5 times the actuator-torque requirement.

4.3.8.6.2 Unless otherwise specified, electric-motor-actuated valves shall operate from fully open to fully closed positions, or the reverse, in 60 sec ±10 sec.

4.3.8.6.3 The manufacturer shall apply a label in the area of the auxiliary handwheel, listing the maximum number of turns from full open to full close and full close to full open (90°).

4.3.8.6.4 The intermediate mechanism (nonintegral to actuator) between the electric actuator and the valve stem shall meet the requirements of Sec. 4.3.8.5, except the input testing requirements of Sec. 4.3.8.5.2 and 4.3.8.5.8 do not apply.

4.3.8.7 Cylinder actuators. Cylinder actuators shall be water-hydraulic, oil-hydraulic, or pneumatic cylinders meeting the requirements of ANSI/AWWA C540.

Table 5 Safety factors for cylinder torques

Type of Service	Operating Fluid	Safety Factor
Open-shut	Water or oil	1.25
Throttling	Water or oil	1.25
Open-shut	Air	1.25
Throttling with positioner	Air	1.5 for cylinders greater than 80 in.^{3} (1.3 liters) 2.0 for smaller cylinders
Throttling without positioner	Air	10.0

Minimum safety factors for cylinder torques shall not be less than those shown in Table 5. Safety factors are the ratio of cylinder torque to required valve operating torque (T_R). Cylinder torque (T_o) is equal to

$$T_o = (A - a)LPE \qquad \text{(Eq 1)}$$

The safety factor (SF) is equal to

$$SF = \frac{T_o}{T_R}$$

Where:

A = area of the cylinder based on the inside diameter (ID)

a = area of piston rod in one direction and zero in other direction

L = moment arm (shortest distance between piston-rod axis and valve-disc axis for given disc position)

P = cylinder operation pressure

E = efficiency factor, taking into account friction losses in the actuator and the linkages, including the increase in piston and piston-rod seal friction with pressure, and friction of the valve shaft in the outboard bearing caused by cylinder thrust.

4.3.8.7.1 Cylinders shall be equipped with adjustable flow-control devices to control the operating media exhausted from the cylinder. For air service, the flow-control devices shall be mounted directly on the cylinder or connected within 6 in. (152 mm) of the cylinder by rigid metal pipe or rigid metal tubing. Opening and closing times shall be field adjustable. Minimum operating time shall be 30 sec.

4.3.8.7.2 Intermediate quarter-turn mechanism. The intermediate mechanism (nonintegral to actuator) used between the cylinder actuator and the valve stem shall meet the requirements of ANSI/AWWA C540, including proof-of-design test requirements.

4.3.8.7.3 Cylinders shall be equipped with adjustable flow-control devices to control the operating media exhausted from the cylinder. For air service, the flow-control devices shall be mounted directly on the cylinder or connected within 6 in. (152 mm) of the cylinder by rigid metal pipe or rigid metal tubing. Opening and closing times shall be field adjustable. Minimum operating time shall be 30 sec.

4.3.8.7.4 Intermediate quarter-turn mechanism. The intermediate mechanism (nonintegral to actuator) used between the cylinder actuator and the valve stem shall meet the requirements of ANSI/AWWA C540, including proof-of-design test requirements.

Sec. 4.4 Workmanship and Coating

4.4.1 *Workmanship.* Valve parts shall be designed and manufacturing tolerances set to provide interchangeability of parts between units of the same size and type produced by any one manufacturer. When assembled, valves manufactured in accordance with this standard shall be well-fitted and shall operate smoothly. The body and shaft seal shall be watertight.

4.4.2 *Coating.* Interior and exterior surfaces, except finished or bearing surfaces, shall be carefully prepared by removing dirt, grease, and rust and shall be cleaned to the extent that the coating will bond to surfaces.

4.4.2.1 Interior surfaces. Unless otherwise specified by the purchaser, ferrous surfaces, except finished or bearing surfaces, shall be shop coated with an asphalt or epoxy coating. Whenever the purchase documents require a special interior coating, such as an epoxy, and unless otherwise specified, this special coating system shall conform to the requirements of ANSI/AWWA C550.*

4.4.2.2 External surfaces.

4.4.2.2.1 External surfaces of buried valves shall be shop coated with an asphalt or epoxy coating.

*Asphalt coatings may not be holiday free. Epoxy coatings are more likely to result in a holiday-free surface. If severe service conditions exist, the purchaser should consider an epoxy coating. Special holiday testing, as specified in ANSI/AWWA C550 can also be required if conditions justify the added expense.

4.4.2.2.2 When the valves will be installed in an aboveground location to be subsequently field coated, the exterior of each valve, except flange faces, shall be shop coated with a suitable metal primer to a dry-film thickness of not less than 3 mil. The primer shall be compatible with the anticipated field coatings when the field coatings are identified by the purchaser. Flange faces shall be protected from atmospheric corrosion.

4.4.2.2.3 The coating required in Sec. 4.4.2.1 and 4.4.2.2 is for usual conditions. The purchaser should specify other coating, or special protection systems if required for severe conditions such as exposure to corrosive soils, corrosive water, fumes, or abrasion.

SECTION 5: VERIFICATION

Sec. 5.1 Testing

5.1.1 *Performance tests.* To demonstrate that the valve and actuator are workable, valves having direct-mounted actuators, except those provided with extension shafts of more than 36 in. (900 mm), shall be shop operated three times from the fully closed to the fully opened position and the reverse under no-flow conditions.

5.1.2 *Leakage tests.*

5.1.2.1 For valves without direct-mounted actuators (i.e., those furnished with torque tubes or floor stands) or for valves with actuators mounted on extension shafts of more than 36 in. (900 mm), each valve shall be shop tested for leaks in the closed position. For valves having direct-mounted actuators, except those with extension shafts of more than 36 in. (90 mm), the valve and actuator assembly shall be shop tested for leaks with the actuator stops adjusted and the actuator in the closed position. The test shall be conducted with the disc in the horizontal plane. With the disc in the closed position, air pressure equal to the valve class shall be supplied to the lower face of the disc for the full test duration.

The upper surface of the valve disc shall be visible and shall be covered with a pool of water at 0 psig (0 kPa) pressure. The duration of the test shall be at least 5 min. There shall be no indication of leakage past the valve disc (visible in the form of bubbles in the water pool on top of the disc) during the test period.

5.1.2.2 As an alternative to the test procedure and disc orientation listed in Sec. 5.1.2.1, valves may be given a hydrostatic test at the pressures stated in Sec. 5.1.2.1. During the test, the valves shall be drop-tight. The minimum duration of the test shall be 5 min for valves 20 in. (500 mm) and smaller and 10 min for valves 24 in. (600 mm) and larger.

5.1.2.3 Unless the purchaser specifies testing in both directions, the valves are required to be tested only in the direction most likely to leak.

5.1.3 *Hydrostatic test.* Valve bodies shall be subjected to an internal hydrostatic pressure equivalent to twice the rated pressure. During the hydrostatic test, there shall be no leakage through the metal, the end joints, or shaft seal, nor shall any part have permanent visible deformation. The duration of the hydrostatic test shall be sufficient to allow visual examination for leakage. Test duration shall be at least 1 min for valves 8 in. (200 mm) and smaller, 3 min for valves 10 in. (250 mm) through 20 in. (500 mm), and 10 min for valves 24 in. (600 mm) and larger.

5.1.4 *Proof-of-design tests.*

5.1.4.1 On request by the purchaser, the manufacturer shall provide a certified statement that proof-of-design tests were performed as described in this standard, and all requirements were successfully met.

5.1.4.2 One valve of each size and class shall be hydrostatically tested with twice the rated pressure applied to one side of the disc and zero pressure on the other side. The test is to be performed in each direction across the disc, and, in the case of flanged valves, the valve body shall be bolted to a flanged test head. Under the hydrostatic test, the manufacturer may make special provisions to prevent leakage past the seats, and no part of the valve or disc shall have permanent visible deformation resulting from this test.

5.1.4.3 It is the purpose of this section to demonstrate the adequacy of each basic type offered by a manufacturer to perform, under design pressures, within the applicable rating of the valve for a sufficient number of operations to simulate a full service life. The adequacy is to be demonstrated by testing valves selected to represent each basic type of seat design in each applicable size group in Table 6 and in a pressure class or classes equal to or greater than the valves being purchased. The required number of cycles appears in Table 6. Every cycle shall consist of applying the rated differential pressure to the disc in the closed position, then opening the valve (which will relieve the pressure) to the wide-open position, and then closing the disc.

Table 6 Valve test cycles required

Size Group		
in.	*(mm)*	Number of Cycles
3–20	(75–500)	10,000
24–42	(600–1,050)	5,000
48–72	(1,200–1,800)	1,000

On completion of the cycle test, the valve shall be drop-tight in both directions under the rated differential pressure.

5.1.4.4 Actuator proof-of-design test is discussed in Sec. 4.3.8.

5.1.4.5 The tested valve can be rebuilt and used for production provided that it is fully disassembled and there are no worn areas (body, disc, shaft, or pins) that may affect the performance of the valve. Additionally, the seat, seat hardware, bearings, body gaskets, and shaft seals shall be replaced. Following reassembly, the rebuilt valve shall be retested in accordance with Sec. 5.1.1, 5.1.2, and 5.1.3.

Sec. 5.2 Notice of Nonconformance

Any butterfly valve or part not conforming to the requirements of this standard shall be made satisfactory or replaced.

SECTION 6: DELIVERY

Sec. 6.1 Marking

Markings shall be cast on the body with raised letters or provided on a corrosion-resistant plate. The markings shall show the valve size, manufacturer, class, and year of manufacture. The minimum size of cast letters shall be 1/4 in. (6.35 mm) for 3-in. (75-mm) through 12-in. (300-mm) valves and 1/2 in. (12.7 mm) for larger valves. Corrosion-resistant plates shall have minimum 1/8-in. (3.18-mm) etched or engraved letters.

Sec. 6.2 Shipping

The manufacturer shall carefully prepare valves for shipment. Cavities shall be drained of water. Valves larger than 36 in. (900 mm) shall be bolted or otherwise fastened to skids. Uncoated steel and iron-machined surfaces shall be coated with a corrosion inhibitor. Full-face flange protectors of waterproof plywood or weather-resistant pressboard, of at least the outside diameter of the flange, shall be fastened to each flange to protect both the flange and the valve interior. Small valves may be fully packaged at the manufacturer's option. Components shipped unattached shall be adequately protected and identified for correct field assembly.

Sec. 6.3 Affidavit of Compliance

Whether the purchaser has an agent at the plant or not, the purchaser may require an affidavit attesting that the valves provided comply with applicable provisions of this standard.

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APPENDIX A

Installation, Operation, and Maintenance of Rubber-Seated Butterfly Valves

This appendix is for information only and is not a part of ANSI/AWWA C504.

SECTION A.1: GENERAL

Butterfly valves are a significant component of any water distribution system or treatment plant operation. Valve failure caused by faulty installation, improper operation, or maintenance in these systems could result in damage, downtime, and costly repairs. In buried or underground installations, problems or malfunctions can result in extensive and costly excavation to correct or eliminate the problem. Many problems with butterfly valves can be traced to improper installation, operation, or maintenance procedures.

SECTION A.2: UNLOADING

Inspect valves on receipt for damage in shipment and conformance with quantity and description on the shipping notice and order. Unload valves carefully to the ground without dropping. On valves larger than 36 in. (900 mm), use forklifts or slings under the skids. On smaller valves, do not lift valves with slings or chain around the operating shaft, actuator, or through the waterway. Lift these valves with eye bolts or rods through the flange holes or chain hooks at ends of the valve parts.

SECTION A.3: STORAGE

If it is not practical to store the valve indoors, protect the valve and actuators from weather and the accumulation of dirt, rocks, and debris. When valves fitted with power actuators and controls are stored, energize electric actuators or otherwise protect electrical-control equipment to prevent corrosion of electrical contacts caused by condensation resulting from temperature variation. Do not expose rubber seats to sunlight or ozone for any extended period. Also, see the manufacturer's specific storage instructions.

SECTION A.4: INSPECTION PRIOR TO INSTALLATION

Make sure flange faces, joint-sealing surfaces, body seats, and disc seats are clean. Check the bolting attaching the actuator to the valve for loosening in transit and handling. If loose, tighten firmly. Open and close the valve to make sure it operates properly and that stops or limit switches are correctly set so that the valve seats fully. Close the valve before installing.

SECTION A.5: INSTALLATION

It is strongly recommended that instruction manuals supplied by the valve manufacturer be reviewed in detail before installing butterfly valves. Be sure that inspection, as described in Sec. A.4, is carried out at the jobsite prior to installation.

A.5.1 Handle valves carefully when positioning, avoiding contact or impact with other equipment, vault walls, or trench walls.

A.5.2 Valves are to be installed in accordance with the manufacturer's instructions. To maintain the integrity of valves greater than 48 in., it is important to avoid subjecting the valve to pipe loads that could drive the valve out of round, such as the use of valve foundations or supports without proper pipe supports. The valve should be supported independently of the adjacent piping, and the adjacent piping should be supported independently of the valve. Piping to and from the valve should be adequately supported and controlled. Valve inlet and outlet piping should be supported as near to the valve as practical. This removes most of the static load and allows identification of piping fit problems during installation and easier removal of the valve for maintenance. Piping considerations should include allowable flange loadings, thermal expansion and contraction, and differential settlement.

A.5.3 When valves have adjustable seating, install the seat-adjustment side of the valve for access and adjustment in service.

A.5.4 Foreign material in a butterfly valve can damage the rubber seat when valves are operated. Be sure valve interiors and adjacent piping are cleaned of foreign material prior to mating up valve-to-pipe-joint connection.

A.5.5 Prepare pipe ends and install valves in accordance with the pipe manufacturer's instructions for the joint used. Do not deflect the pipe-valve joint. Do not use a valve as a jack to pull pipe into alignment. The installation procedure should minimize the bending of the valve/pipe connection with pipe loading.

A.5.6 In the case of wafer-type butterfly valves, concentrically center the valve disc between the mating flanges.

A.5.7 Make sure the valve disc, when opened, will not contact the pipe port. This is especially necessary on pipe with linings and when wafer valves are used. Check manufacturer's recommendations for minimum pipe inside diameter required for clearance.

A.5.8 Buried valves installed with valve boxes shall be installed so that the valve box does not transmit shock or stress to the valve actuator as a result of shifting soil or traffic load.

A.5.9 When valves are installed in vaults, the vault design shall provide space for removal of the valve-actuator assembly for purposes of repair. The possibility of groundwater or surface water entering the valve and the disposal of the water should be considered. The valve operating nut should be accessible from the top opening of the vault with a tee wrench.

SECTION A.6: TESTING

When rubber-seated butterfly valves are used to isolate sections of a line for testing, it is important to realize that these valves are designed or factory adjusted to hold rated pressure only. Test pressures above valve rated pressure may cause leakage past the rubber seat and damage to the valve.

A.6.1 In order to prevent time lost searching for leaks, where feasible, it is recommended that excavations for buried valves not be backfilled until after pressure tests have been made.

A.6.2 Seat leakage can occur from foreign material in the line. If this occurs, open the valve 5°–10° to obtain high-velocity flushing action, then close. Repeat several times to clear the seats for tight shutoff.

A.6.3 Seat leakage can result from a rotational shift in position of the disc with relation to the body seat. Readjust closing the stop in accordance with the manufacturer's instructions.

SECTION A.7: OPERATION

A.7.1 Do not permit the use or operation of any valve at pressures above the rated pressure of the valve.

A.7.2 Do not exceed 300 ft-lb (406 N•m) input torque on actuators with wrench nuts and do not exceed 200-lb (890-N) rim pull for handwheels or chainwheels. If portable auxiliary actuators are used, size the actuator or use a torque-limiting device to prevent application of torque exceeding 300 ft-lb (406 N•m). If an oversize actuator with no means of limiting torque is used, stop the actuator before the valve is fully opened or closed against stops and complete the operation manually. Be sure to check the actuator directional switch against the direction indicated on wrench nut, handwheel, or records before applying opening or closing torque.

A.7.3 If a valve is stuck in some intermediate position between open and closed, check first for jamming in the actuator. If nothing is found, the interference is inside the valve. In this case, do not attempt to force the disc open or closed, because excessive torque in this position can severely damage internal parts.

SECTION A.8: MAINTENANCE

Maintenance of rubber-seated butterfly valves by the owner is generally limited to actuators and shaft seals. In some instances, valve design permits field adjustment or replacement of rubber seats when leakage occurs past the disc. Unless the owner has skilled personnel and proper equipment, any major internal problem will probably require removal of the valve from the line and return to the manufacturer for repair.

A.8.1 Normal maintenance is in the area of shaft seals and actuators. Seal leakage, broken parts, hard operation, and, in some cases, seat leakage should be corrected by a repair crew as soon as possible after a defect is reported.

A.8.2 If repairs are to be made in the field, repair crews should take a full complement of spare parts to the jobsite. Be sure to review the valve manufacturer's maintenance instructions prior to any repair work.

A.8.3 Provision should be made to stop line flow and isolate the valve from line pressure prior to performing any corrective maintenance.

A.8.4 After completing repairs, cycle the valve through one complete operating cycle and, after line pressure has been restored, inspect for leakage.

A.8.5 If major repairs require the removal of the valve for repair, be sure to notify interested parties in the water department and fire department that the valve and line are out of service. On completion of repair and reinstallation, notify the same personnel of the return of the valve and line to service.

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ADOPTION NOTICE

ANSI/AWWA-C504, "American Water Works Association Standard for Rubber-Seated Buterfly Valves," was adopted on 06-JUN-89 for use by the Department of Defense (DoD). Proposed changes by DoD activities must be submitted to the DoD Adopting Activity: Defense Supply Center Columbus, P.O. Box 3990, Attn: DCSC-VAT, Columbus, OH 43216-5000. DoD activities may obtain copies of this standard from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094. The private sector and other Government agencies may purchase copies from the American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235.

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