Butterfly Valves: Torque, Head Loss, and Cavitation Analysis

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American Water Works Association

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Butterfly Valves: Torque, Head Loss, and Cavitation Analysis

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Contents

Figures

Tables

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Preface

The purpose of this manual is to present a recommended method for calculating operating torque, head loss, and cavitation for butterfly valves typically used in water works service. It is a discussion of recommended practice, not an American Water Works Association (AWWA) standard. The text provides guidance on generally available methods for using butterfly valves as well as their cavitation, flow, and torque characteristics. Questions about specific situations or applicability of specific valves and values should be directed to the manufacturers or suppliers. Information in this manual is useful for technicians and engineers who want a basic understanding of the calculations associated with the use and specification of butterfly valves. The valve torque, flow, and cavitation coefficients given are typical but generic values covering a variety of products. Actual flow, cavitation, or torque coefficients for a particular manufacturer's valve should be used in calculations for a specific valve and application to obtain the highest calculation accuracy.

The history of this manual is related to that of American National Standards Institute ANSI/AWWA C504, Standard for Rubber-Seated Butterfly Valves. Until the 1994 edition, ANSI/AWWA C504 included Appendix A, which described a recommended method of calculating torques for butterfly valves. This appendix was deleted from the 1994 and subsequent editions of the standard for several reasons. The AWWA Standards Council directed that standards documents should not contain appendixes; appendix text should either be moved to the main body of the standard or be made into a separate, stand-alone document. Members of the committee for ANSI/AWWA C504 at the time were concerned that the existing text of Appendix A no longer represented the current state of knowledge concerning methods for calculating torques for butterfly valves. In 1993, a subcommittee was established to rewrite Appendix A as a separate manual incorporating the state-of-the-art theory for calculating torque and head-loss values for butterfly valves. This second edition of the manual expanded the introduction and some equations, added torque sign conventions, added double offset disc design variables and calculations, added equations for eccentricity torque, added metric units and equivalents, consolidated the nomenclature, and corrected some errors.

Manual M49 refers to AWWA standards available for purchase from the AWWA Bookstore. 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.

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Acknowledgments

The AWWA Standards Council Committee for Butterfly Valves developed this manual. The members listed below served on the committee at the time the manual was approved.

B.E. Bosserman, Chair, Mission Viejo, Calif.

User Members

A. Ali, ADA Consulting Ltd., Surrey, B.C.
S. Carpenter, San Diego County Water Authority, Escondido, Calif.
D.W. Coppes, Massachusetts Water Resources Authority, Southborough, Mass.
I.M. Schuraytz, Southfield, Mich.
D.C. Stone, Denver Water, Denver, Colo.
S.Y. Tung, City of Houston, Houston, Texas

General Interest Members

M.D. Bennett, MWH, Cleveland, Ohio
B.E. Bosserman, Mission Viejo, Calif.
M.L. Damoth, CH2M Hill, Redding, Calif.
F.L. Hinker, Santa Rosa, N.M.
M.C. Johnson, Utah State University, Water Research Lab, Logan, Utah
T. Jordan, HDR Inc., Denver, Colo.
T.J. McCandless,† American Water Works Association, Denver, Colo.
*W. Rahmeyer,** Utah State University, Water Research Lab, Logan, Utah
R.A. Ward, Dufresne Group, Windsor, Vt.
H.H. Wasserman, Wilton, Conn.
G.E. Laverick, Underwriters Laboratories Inc., Northbrook, Ill.

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L.W. Fleury,* Mueller Co., Cranston, R.I.
Steven Flora, M&H Valve, Cedar Bluff, Ala.
T.A. Hartman, Hartman Valve Corp., St. Louis, Mo.
J.R. Holstrom,* Sub-committee chair, Val-Matic Valve & Manufacturing Corp., Elmhurst, Ill.
A.W. Libke, DeZURIK, Sartell, Minn.
T.J. McAndrew, Rodney Hunt Company, Orange, Mass.

* Alternate
† Liaison

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Chapter 1

Introduction

Torque, head loss, and cavitation are important considerations in the selection and sizing of butterfly valves in water systems. Butterfly valve components must be able to withstand the forces and torques generated during use, and the actuator must operate and seat the valve. The head loss developed across any valve adds to the energy costs of a pumping system. Cavitation can damage a valve or adjacent piping if not controlled.

The topics in this introductory chapter include an explanation of basic butterfly valve design elements and their role in predicting torque, head loss, and cavitation.

Valve torque is calculated to allow proper actuator sizing and to provide assurance that the valve components can withstand the internal forces produced by flowing water and fluid pressure. Head loss characteristics must be known to predict torque, and system designers also use these data to calculate pump head requirements and to evaluate the energy costs associated with the head loss across the valve in pumping applications. Cavitation is analyzed to prevent undesirable sound and vibration and to prevent damage to the valve and adjacent piping.

Torque, head loss, and cavitation vary with a valve's angle of opening. These characteristics also depend on the geometry of the valve body and disc and on the characteristics of the system in which the valve is installed. Flow testing of a valve assumes a smooth, undisturbed flow upstream and downstream of the valve such as that produced by a long run of straight, constant-diameter pipe. Variation from this ideal condition can have an effect on valve torque and head loss. Flow disturbances caused by piping configuration—such as elbows, reducers, or other valves within a distance equal to eight times the diameter upstream of the valve—require further review by applying the recommendations given in chapter 6.

Coefficients provided by the butterfly valve manufacturer may be used to calculate the torque and head loss as described in this manual, provided that the values are determined based on testing methods described in chapter 5. The coefficients provided in this manual are presented only for illustrative purposes. Information from the valve manufacturer is needed before calculations can be performed for a specific use. However, generalized information may assist in determining the applicability or sensitivity of some characteristics.

Cavitation data can also be determined by flow testing. Values for a range of valve angles are helpful in predicting whether cavitation will occur in a given application.

SCOPE

This manual covers round or circular butterfly valves within the scopes of American Water Works Association (AWWA) and American National Standards Institute (ANSI) standards ANSI/AWWA C504-10 (2010) and ANSI/AWWA C516-10 (2010) with essentially full-ported designs where the port diameter and disc diameter are close to the nominal pipe size (NPS) or nominal diameter (in inches [in.] or millimeters [mm]). This includes sizes 3 in. (75 mm) and larger.

DISCUSSION OF TORQUE CALCULATIONS

The torque calculations are broken into 10 separate torque components and each is derived from a first-principles approach. The 10 separate torque components are classified into 2 categories: (1) passive or friction based or (2) active or dynamically generated. These 10 components are listed in Table 1-1.

Each of these components is evaluated mathematically from a first-principles approach and their equations are presented, except for the buoyancy torque (item 7) and the thrust bearing torque (item 5). These two are generally considered as negligible for this scope of the valves. The components of hub seal friction torque (item 3), weight and center of gravity torque (item 6), lateral offset or eccentricity torque (item 8), and hydrostatic unbalance torque (item 10) may not be applicable depending on the valve design and installation variables. Seating (and/or unseating) friction torque (item 1), packing friction torque (item 2), bearing friction torque (item 4), and dynamic or fluid dynamic torque (item 9) should always be included in operating torque calculations.

The passive torque components are friction related and in general either are constant for a given valve or are directly dependent on the differential pressure. These components always oppose actuator motion and are generally considered to be essentially the same magnitude in either direction of operation (opening or closing), except for seating and unseating. Seating and unseating torque may be evaluated separately or considered the same when differences are small.

The active or dynamic torque components are generated in the valve by the effects of the internal fluid media (water) or gravity acting on the valve. These components may oppose or assist the actuator's operation. Since dynamic torque generally tends to close the valve, the actuator may act as a brake to control the speed of the closing stroke but must also overcome this torque in the opening stroke.

Table 1-1 Torque component category

Item Number	Torque Component	Torque Category
1	Seating (and/or unseating) friction torque	Passive or friction based components
2	Packing friction torque	
3	Hub seal friction torque	
4	Bearing friction torque	
5	Thrust bearing friction torque	
6	Weight and center of gravity torque	Active or dynamically generated components
7	Buoyancy torque	
8	Lateral offset or eccentricity torque	
9	Dynamic or fluid dynamic torque	
10	Hydrostatic unbalance torque	