Quarter-Turn Valves: Head Loss, Torque, and Cavitation Analysis

Third Edition

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Quarter-Turn Valves: Torque, Head Loss, and Cavitation Analysis


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The purpose of this manual is to present a recommended method for calculating operating torque, head loss, and cavitation for quarter-turn 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 quarter-turn 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 quarter-turn 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 appendices; 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. The 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. This third edition manual broadens the application of these methods to include other quarter-turn valves such as ball, plug, and rotary cone valves.

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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Introduction

Head loss, torque, and cavitation are important considerations in the selection and sizing of quarter-turn valves in water systems. Quarter-turn valve components must be able to withstand the forces and torques generated during use, and the actuator must drive 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 quarter-turn valve design elements and their role in predicting operating head loss, torque, and cavitation. Prior editions limited this manual of standard practice to butterfly valves (BFV). This edition has been expanded to include information on other quarter-turn valves, including ball (BV), rotary cone (RCV), and eccentric plug valves (PV). Many of the included illustrations are targeted toward BFVs but are generally applicable to all the valves of this scope.

Head loss characteristics must be known to predict valve operating torque, and system designers also use these data to size a control valve, calculate pump head requirements, and evaluate the energy costs associated with the head loss across the valve in pumping applications. Valve torque is calculated to allow proper actuator sizing and to provide assurance that the valve components can withstand the internal forces produced by the fluid flow and pressure.

Cavitation is analyzed to avoid undesirable sound and vibration and to prevent damage to the valve and adjacent piping. Cavitation data are determined by flow testing. Values for the range of valve angles are helpful in predicting if cavitation will occur in a given application.

Head loss, torque, and cavitation vary with a valve’s position (angle of opening). These characteristics also depend on the geometry of the valve body and closure member as well as the characteristics of the system in which the valve is installed. Flow testing procedures of a valve require a smooth, undisturbed flow upstream and downstream of the valve, such as that produced by a run of straight, constant-diameter pipe. Although variation from this ideal condition has an effect on valve head loss and torque, these conditions are the benchmark and basis for analysis. Flow disturbances caused by piping configuration, such as elbows, reducers, or other valves within a distance less than eight times the diameter upstream of the valve, may require further review by applying the recommendations given in chapter 6.
Coefficients provided by the quarter-turn valve manufacturer may be used to calculate the head loss and torque as described in this manual of standard practice, provided that the data are determined on the basis of testing methods described in chapter 5. The typical coefficients provided in this manual are presented only for illustrative and approximation purposes. Information from the valve test data or the manufacturer is needed before calculations can be performed for a specific valve in a specific use with high accuracy. However, generalized or typical information will assist in determining the applicability or sensitivity of some characteristics for valve type selection and for most system design considerations.

The closure members of this manual of standard practice are typically referred to as the ball, disc (BFV), cone, or plug. This manual of standard practice may refer to a general closure member or to one specific design. International and European standards will also use the term obturator for the closure member.

SCOPE

The fluid flow and torque calculations are based on water or wastewater flow and do not specifically relate to other liquids or gases. The adjustments for application to other fluids can be found in other texts on fluid mechanics. This manual of standard practice covers round or circular BVs and BFVs within the scopes of AWWA and American National Standards Institute (ANSI) standards ANSI/AWWA C504-15, ANSI/AWWA C507-15, and ANSI/AWWA C516-14 with essentially full-ported designs in which the port diameter and closure member diameter are close to the nominal pipe size (NPS) or nominal diameter (in inches or millimeters). This includes BFVs in sizes 3 in. (75 mm) and larger and BVs in sizes 6 in. (150 mm) through 60 in. (1,500 mm).

This manual of standard practice also covers PVs that have round or oblong ports and are available with either full or reduced port areas within the scope of ANSI/AWWA C517-09. Reduced port areas are generally greater than 75 percent of full pipe area.

Rotary cone valves in sizes 6 in. thru 84 in. and pressure ratings of 125 cold working pressure (CWP) or 275 CWP in cast- or ductile-iron construction or ANSI Classes 150 and 300 in steel construction are often used in this industry and referenced in other AWWA manuals of standard practices, such as M44. This valve type does not have an AWWA standard devoted to design and construction. This type of valve is also included in this manual of standard practice.

Some manufacturers produce valves that are configured as three-way and/or four-way valves, which have three or four connection ports and require special considerations not included in this manual of standard practice. The valves covered are of the two-way (two end connections, on-off or throttling) configuration. For all of these valves, it is important to use the matching data for the valve design of interest.

NEW DEFINITIONS, MRST AND AST

For purposes of clarity and understanding, many of the AWWA quarter-turn valve standards are now referring to the operating torque requirements of the valves as two different terms. These are actuator sizing torque (AST) and minimum required shaft torque (MRST), and their definitions appear later in this chapter. These are not to be considered as single values but a series of values (or curves) that vary with valve position. In some cases, one or two (break and/or break and run) conservative or bounding values may be used throughout the entire valve stroke, but in many cases, values at 10°, 5°, or fewer degree increments of valve travel are necessary. The torque predictions of this manual of standard practice provide the most probable operating torque requirements for a valve when