FLOWSERVE®

Flowserve - Edward Valves

Flow Performance, Stability and Sealability of Piston Lift and Tilting Disc Check Valves

Flow Performance, Stability and Sealability of Piston-Lift and Tilting Disc Check Valves

Problem

Check valve sizing and selection based on outdated methods that result in unstable and self-destructing operation.

Solution

Flowserve-Edward has years of check valve research to help customers select the valve best suited for their application.

Introduction

Of the various types of valves, check valves generally receive the least attention. So long as a check valve performs its basic functions of allowing forward flow and limiting reverse flow, it is considered to be a passive component requiring no further concern.

A check valve must open and close in response to flow direction, but it relies on a relatively primitive balance between hydrodynamic forces and gravity for control of its operation. In spite of these limitations and neglected maintenance, check valves produce relatively few problems. However, when problems do occur, they may be serious.

The objectives of the program were twofold: first, to analyze the performance of Flowserve-Edward check valves; second, to gather the empirical data needed for a mathematical model to be used in sizing these valves for particular applications. The test program considered three primary questions, the first two pertaining to forward flow and the third pertaining to flow in the reverse direction:

1. Will the valve open fully at normal flow, or will it assume a partial opening in balance with the disk weight?

2. If the valve is partially open, will it be stable or will it flutter and eventually fail?

3. When a flow reversal occurs, will the valve close and seal well at low differential pressure, or will it require a high differential in order to seal?

These questions are reflected in the three major phases of the tests, as described below.

Basic Flow Performance Tests

Flowserve-Edward subjected all of the valves to basic flow performance tests in straight pipe runs in circulating-water test loops. The main emphasis of this testing was to collect data with valves partially open and to identify the flow rate required to open valves fully. Measurements included flow rate, upstream pressure and temperature, valve opening (lift), and valve pressure drop. In addition, the test included noise observations to identify the onset of cavitation.

Results of these tests established the relationships between the following sets of attributes:

- Flow coefficient (C_V) and lift
- Lift and flow rate
- Pressure drop and flow rate

These tests also established incipient cavitation and liquid pressure recovery coefficients for most valves. An interesting observation from these water tests was that the check elements in most valves were relatively stable at all lifts and flow rates, even when cavitation occurred. Most valves displayed inherent stability, even at very small openings. However, the flow rates in the test loops (equipped with centrifugal pumps) were very steady; unsteady liquid flow might produce different results.

In contrast to the relative stability in liquid tests, limited testing with air flow demonstrated a trend toward disk instability at lifts under approximately 10 percent and at pressures below 30 psi, even with the check valve mounted in straight pipe. Since instability at small openings can produce repetitive disk-seat impact, such operation can be damaging and should be avoided.

Flow Disturbance Tests

Following the flow performance tests, Edward retested some of the valves with upstream flow disturbances.

Table 1 summarizes the results of the flow disturbance tests. Elbows immediately upstream affected the stability of some check valves, but had no discernible effect on others. While the observed effects appeared minor, long-term effects of even minor disk flutter could include damage to seating or guiding surfaces. Table 1 also shows that the throttled butterfly valve had a more distinct effect on check valve performance and stability than elbows did. Effects included increased disk flutter and reduced valve opening at a given flow; in some cases, full check valve opening could not be achieved at any attainable flow. With the butterfly valve moved five diameters upstream of the check valve, adverse effects decreased but were not eliminated. Normal performance was restored with the butterfly 11 diameters upstream.

Special Seat Tightness Tests

Standard seat tightness tests only consider sealing performance under high differential pressures. However, some applications — e.g., various nuclear services — require tight sealing under very low differential pressures, and various types of metal-seated check valves have encountered problems. Edward designed its special tests to evaluate sealing under all these conditions and performed this test on most of the valves included in the overall test program.

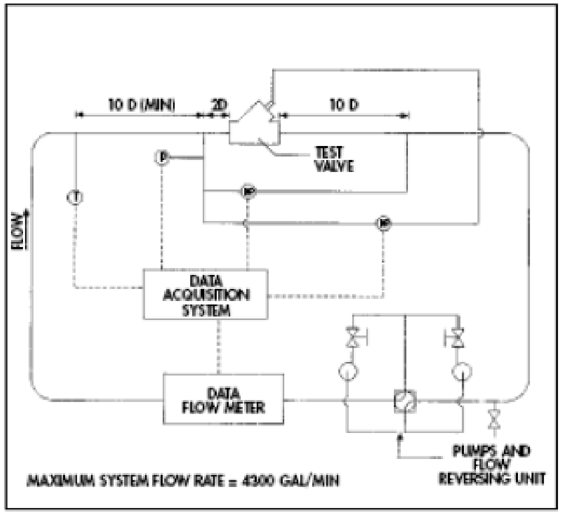

Figure 1: NPS 10 test loop and straight pipe flow test arrangement

In this test, Edward gradually increased the differential pressure from 0 to 110 percent of the cold working pressure of the valve, then reduced it back to 0. Generally, with increasing pressure, relatively high leakage was observed up to a threshold pressure at which the leakage rate suddenly decreased. Edward engineers have concluded that that this threshold represents the point where forces due to pressure are sufficient to shift the closure element into good metal-to-metal contact with the body seat. In tests of size 4 and larger piston-lift and tilting-disk check valves, the threshold pressure was less than 50 psi. Small forged-steel ball and piston-lift check valves were less consistent, sometimes seating at less than 50 psi and sometimes requiring 250 psi or more.

Seat tightness data, both from these tests and past research, have allowed Edward to produce tightness guidelines for the company's standard check valves. Generally, metal-seated check valves should not be expected to seal well at reversed differential pressures less than 50 psi. Some larger valves show sealing differential thresholds as low as 5 psi, but some small valves require much more than 50 psi to establish full metal-to-metal seating contact. Below the threshold, leakage rates may be relatively large and could lead to rapid leak-down from a tank with just a gravity or elevation head to seat the valve.

As a general rule, metal seat check valves should not be relied upon for isolation at low differential pressures. Leakage rates are difficult to predict. Once seated by high pressure, most check valves remain seated to lower pressures than would be required for initial seating as pressure increases. However, this is also difficult to predict.

Where tight shutoff is required, a stop-check valve is often a good compromise, because it can be seated with a handwheel or actuator to establish a seal when flow is not required. Obviously, the stem must be moved to the open position to restore normal check valve flow capability.

"Soft seats" are sometimes considered for low pressure sealing in check valves, and they can provide a solution for some applications. However, the selection of a proper plastic or elastomeric soft-seating material requires careful consideration of pressure, temperature, and line fluid effects. Some materials will perform well at high temperatures in air but not in water. Others are quickly destroyed by hydrocarbons. Thus, there are no "general purpose" soft-seated check valves.

The primary coefficient describing each check (or stop-check) valve is a sizing parameter for full lift. In general, the sizing parameter is defined as follows:

$SP = w/\sqrt{\rho}$

Where SP = valve sizing parameter
w = weight flow rate (lb/hr)
ρ = weight density of fluid at valve inlet (lb/ft^3)

Using this method, systems design engineers and valve users need only calculate the sizing parameter (SP) for their particular applications, since, in the typical problem statement, weight flow rate and fluid density are known quantities. Engineers and users can then compare this parameter with the sizing parameter required for full lift (SP_{FL}) for a specific check valve, as listed in the Flowserve-Edward product catalogs.

Flowserve-Edward full-lift sizing parameters were calculated assuming that the line fluid is room temperature water, but the values are sufficiently accurate for common liquids, including water at typical feedwater temperatures. The Flowserve-Edward catalogs also provide correction factors that allow application of the data to lighter fluids, such as gases or steam.

Typical ways the sizing parameter method are applied are:

• Selecting a check valve size for a new application: Choose a valve with $SP_{FL}<SP$ to assure full check valve opening at the flow rate of interest. If the valve size selected is less than the line size desired for other reasons (e.g., velocity limitation), the Edward catalog includes procedures for estimating the effects of upstream and downstream pipe reducers.

• **Evaluating an existing, installed valve:** Compare the SP for the application with the published SP_{FL} for the valve in question. If $SP<SP_{FL}$, the valve is not fully open. Since this may lead to problems, Flowserve-Edward provides other procedures for predicting actual valve opening and determining the acceptability of valve performance. These procedures are described briefly below, and are covered at length in the Edward catalog. For evaluating check valves operating at less than full opening, Edward employs the following ratios:

Figure 2: Flow disturbance test installation: A size 4, Class 600, 901 bonnet piston-lift check valve with two upstream elbows (out of plane).

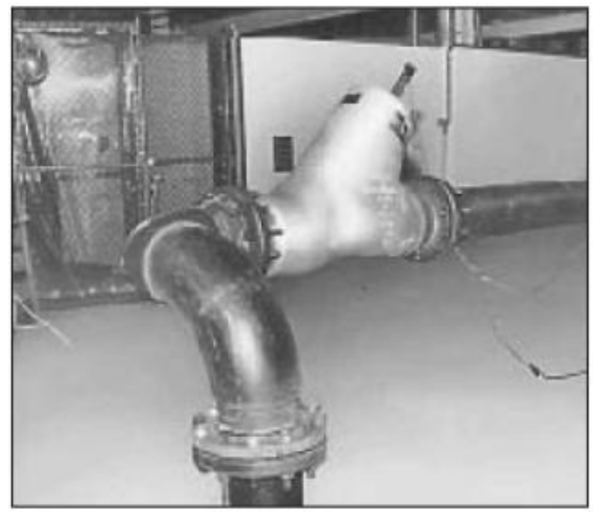

Figure 3: Another example flow disturbance test installation with two upstream elbows, this time employed with a size 10, Class 1500, Flite-Flow®" inclined-bonnet piston-lift check valve.

$R_F = SP/SP_{FL}$ $R_P = \Delta P/\Delta P_{FL}$

Where
R_F = the normalized sizing parameter
R_P = the normalized pressure drop
$\Delta\rho$ = actual pressure drop
ΔP_{FL} = pressure drop at full opening

Graphs provide “percent open” predictions as a function of the normalized sizing parameter. Normalized pressure drop is also presented in graphs as another function of normalized sizing parameter. Figure 4, pg. 6, shows just one set of graphs illustrating these functions. The index numbers on these graphs represent specific groups of valves, and tables in the Flowserve-Edward product catalogs indicate which curves apply to which specific valves. Other data presented in the catalog include coefficients for incipient cavitation and other coefficients for describing choked liquid and gas flows. While these conditions do not arise often in check valves, they may be important in some cases. For example, if an existing valve is replaced with one of a smaller size to assure full opening at a low flow condition, cavitation might occur at another high flow condition in a hot feed-water line.

Application To Specific Problems

The two examples that follow serve to illustrate how one can use Flowserve-Edward procedures to size check valves and resolve problems that arise in specific check valve applications.

Example 1

Problem: Size, a cast-steel, globe, piston-lift check valve for the following boiler feedwater conditions and determine the pressure drop:

Design Conditions: 1715 psig at 275°F

Operating Conditions: 1500 psig at 275°F

Flow Rate: 635,400 lb/hr (water)

Solution:

1. Based on the design conditions, a Class 900 valve is required (per ASME/ANSI B16.34).

2. Determine fluid density at the operating conditions (Table 2)

$\rho = 58.1$ lb/ft^3

3. Calculate sizing parameter for the application:

$SP = w/\sqrt{\rho} = 635{,}400/\sqrt{58.1} = 83{,}360$

4. From Table 10 of the catalog (the relevant section is provided here in Table 3), select the largest Class 900 check valve with a sizing parameter for full lift (SP_{FL}) less than 83,360 to assure full valve opening. This is size 8 valve (SP_{FL} = 69,500). Note that the valve flow coefficient (C_V) is 910.

5. Calculate the pressure drop from equation 1C of the Flowserve-Edward product catalog:

$\Delta P = 1/\rho(w/63.3F_PC_V)^2$

Where F_P = piping geometry correction factor

Assume separate calculations show that NPS 8 pipe is satisfactory, so F_P = 1.0.

$\Delta P = 1/58.1(635{,}400/63.3 \times 1.0 \times 910)^2 = 2.1$ psi

Note: *Usually the largest valve that will be fully open is the most desirable, to minimize both pressure drop and pumping costs in applications involving normally open flowing conditions. If this application involves infrequent operation, a size 6 valve might be used to minimize investment cost. Similar calculations would show that the size 6 valve would also be fully open and could be used if its pressure drop is acceptable.*

Example 2 Problem:

Due to a change in feedwater system design and plant operating schedules, the valve selected in Example 1 must operate at a higher flow and temperature during full power operation, and it must also operate at a reduced flow during limited hot-standby operating conditions. Evaluate valve operation at the following conditions:

Full power: 833,000 lb/hr at 1750 psig and 455°F

Hot standby: 400,000 lb/hr at 1750 psig and 455°F

Solution:

1. From the preceding example and Table 10 of the catalog (Table 3):
$C_V = 910$
$SP_{FL} = 69{,}500$
$DP_{FL} = 1.5$ psi

2. Determine fluid density, using Table 2:
$\rho = 51.2\ lb/ft^3$

3. Calculate sizing parameter at the full power condition:

$SP = w/\sqrt{\rho} = 833{,}000/\sqrt{51.2} = 116{,}400$

Since $SP > SP_{FL}$, the check valve will be fully open.

4. Calculate pressure drop at the full power condition:

$\Delta P = 1/\rho(w/63.3F_PC_V)^2$

$1/52.1(833{,}000/63.3x1.0x910)^2 = 4.1$ psi

5. Calculate sizing parameter at the hot standby condition:

$SP = w/\sqrt{\rho} = 400{,}000/\sqrt{51.2} = 55{,}900$

Since $SP<SP_{FL}$, the check valve will not be fully open.

6. In order to predict the valve opening and pressure drop at the hot-standby condition first calculate the normalized sizing parameter:

$R_F= SP/SP_F = 55{,}900\text{-}69{,}500 = 0.80$

Then, using the curves labeled “2” on Figure 4, find that $R_P = 1.0$ and “Percent Open” = 40. Finally, to determine the actual pressure drop, you use the following equation:

$\Delta P = (R_P)(\Delta P_{FL}) = (1.0)(1.5) = 1.5$ psi

Thus, the methods presented in the catalog predict that the valve would be about 40 percent open under the hot standby condition, with a pressure drop of approximately 1.5 psi. Other sections of the Flowserve-Edward product catalog may be reviewed for guidelines regarding the acceptability of this operating condition. Since this valve would be more than 25 percent open and this would be a limited part-time operating mode, the catalog suggests that this condition should be satisfactory. However, this valve should be monitored or inspected periodically for signs of flutter or wear.

Table 1
Effects of Upstream Flow Disturbances on Check Valve Performance
(Compared to Performance in Straight Pipes)

Valve Size and Type	Single* Elbow at Valve Inlet	Double Elbows (out of plane) at Valve Inlet	Throttled Butterfly Valve		
			At Valve Inlet	5 Diam. Upstream	11 Diam. Upstream
Size 2 inclined bonnet, piston-lift	Higher lift for some flow; disk flutter at lower lifts**	Higher lift for some flow	–	–	–
Size 4 angle piston-lift	No effect	No effect	-	-	-
Size 4 90^{o} bonnet piston-lift	Some, lower or higher lift for some flow	No effect	Disk flutter and chatter; failure to achieve full opening	–	–
Size 8 angle piston-lift	No effect	-	-	-	-
Size 8 90^{o} bonnet piston-lift	Disc flutter or partial lift	-	-	-	-
Size 10 inclined bonnet piston-lift	Some or lower lift for same flow; slight disc wobble	No effect	Failure to acheiv full opening; disk flutter & chatter	Failure to achieve full opening	No effect
Size 10 Tilting Disc	No effect	Minor flutter	Same, lower or higher lift for same flow; disc flutter & chatter	Minor flutter	No effect

*Test were conducted with 90^{o} elbows in the horizontal plane and in the vertical plane (with flow both from above and below).
**One size 2 valve exhibited flutter at lower lifts; another was stable

Table 2
Saturated Water – Temperature, Pressure and Density (U.S. Units)

Water Temp. ^{o}F	32	70	100	200	300	400	500	600	700
Vapor Pressure, P_V	0.09	0.36	0.95	22.5	67	247	681	1543	3206
Water Density, ρ	62.4	62.3	62.0	60.1	57.3	53.7	49.0	42.3	19.9

Pressure is psia, density is lb/ft^3

Table 3 **Flowserve-Edward Cast Steel Globe Valve Flow Coefficients** **Class 900**										
NPS	**All Stop and Check Valves**				**Check Valve Coefficients**					**Perf Curves Fig. 4**
	C_V	F_L	X_T	K_i	d	ΔP_{co}	ΔP_{FL}	SP_{FL}	C	
3	110	0.96	0.60	.10	2.87	0.92	1.5	8510	53	4
4	200	0.97	0.60		3.87	1.3	2.3	19,500	66	5
5	305	0.97	.61		4.75	1.3	2.5	30,600	69	4
6	530	0.81	0.42	0.07	5.75	1.2	1.5	41,500	64	3
8	910	0.81	0.42		7.50	1.3	1.5	69,500	63	2
	1400	0.81	0.42		9.37	1.6	1.8	119,000	69	1
	2000	0.81	0.42		11.12	1.8	2.1	182,000	75	2
	2400	0.81	0.42		12.25	1.6	1.9	211,000	72	2

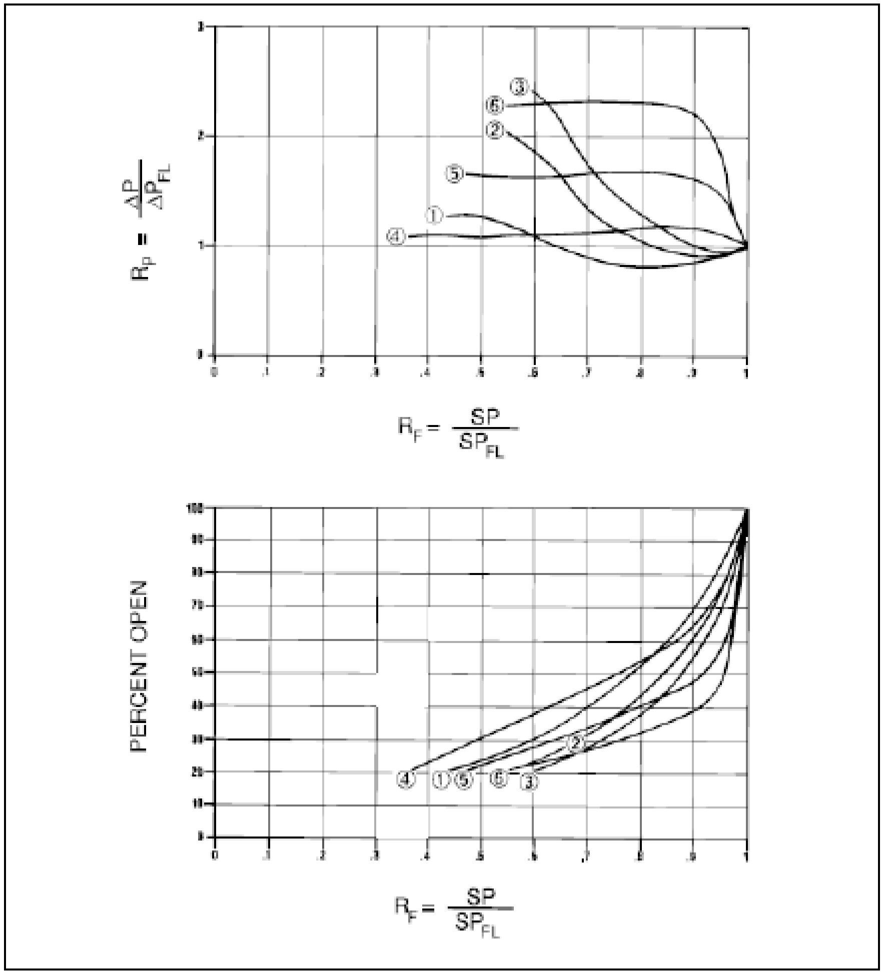

Figure 4: Edward cast steel globe and piston-lift check valve performance curves

Flowserve Corporation has established industry leadership in the design and manufacture of its products. When properly selected, this Flowserve product is designed to perform its intended function safely during its useful life. However, the purchaser or user of Flowserve products should be aware that Flowserve products might be used in numerous applications under a wide variety of industrial service conditions. Although Flowserve can (and often does) provide general guidelines, it cannot provide specific data and warnings for all possible applications. The purchaser/user must therefore assume the ultimate responsibility for the proper sizing, selection, installation, operation and maintenance of Flowserve products. The purchaser/user should read and understand the Installation Operation Maintenance (IOM) instructions included with the product and train its employees and contractors in the safe use of Flowserve products in connection with the specific application.

While the information and specifications contained in this literature are believed to be accurate, they are supplied for informative purposes only and should not be considered certified or as a guarantee of satisfactory results by reliance thereon. Nothing contained herein is to be construed as a warranty or guarantee, express or implied, regarding any matter with respect to this product. Because Flowserve is continually improving and upgrading its product design, the specifications, dimensions and information contained herein are subject to change without notice. Should any question arise concerning these provisions, the purchaser/user should contact Flowserve Corporation at any one of its world-wide operations or offices.

For more information about Flowserve Corporation, contact www.Flowserve.com or call USA 1-800-225-6989

Flowserve Corporation
Flow Control Division
Edward & Anchor/Darling Valves
1900 South Saunders St
Raleigh, NC 27603 USA

Toll – Free Telephone Service
(U.S. and Canada)
Day: 1-800-225-6989

After Hours Customer Service
1-800-543-3927

U.S. Sales Office
Phone: 919-832-0525
Fax: 919-831-3369

Website:
www.Flowserve.com