Linear Actuator Sizing, Unbalanced Trim

Introduction

An important part of selecting the correct control valve is the proper sizing of its actuator. In throttling services, three questions must be answered:

1. Will the actuator handle the throttling differential pressure?
2. Will the actuator provide sufficient thrust to overcome application pressures to open or close the valve, and generate enough seat loading for tight shutoff?
3. Will the spring fail the valve in the proper direction?

With on/off services, only questions 2 and 3 must be answered.

The equations in this section use the following variables:

A_L = Lower cylinder area, in^2
A_U = Upper cylinder area, in^2
A_S = Area of the seat, in^2 (see Table 16-IV or equation 16.1)
A_{Stem}* = Plug stem cross-sectional area, in^2 (see Table 16-IV or equation 16.3)
A_R = Area of the seat retainer bore, in^2 (see equation 16.2)
P_1 = Pressure on upstream side of the valve, psig
P_2 = Pressure on downstream side of the valve, psig
P_S = Air supply pressure, psig
S_E = Spring force with the spring extended to full stroke, lbs (see Table 16-VI)
S_R = Spring force with the spring fully retracted, lbs (see Table 16-VI)
S_{FC30} = Spring force at 30 percent of stroke in fail-closed actuators, lbs (see Table 16-VI or equation 16.4)
S_{FO30} = Spring force at 30 percent of stroke in fail-open actuators, lbs (see Table 16-VI or equation 16.5)
F_P = Packing friction, lbs (see Table 16-V)
R_{SL} = Required seat load to achieve desired shutoff, lbs (see equation 16.6)

Table 16-I: Guardian Metal Bellows Effective Area

Model Number	Body Size (inches)	Bellows psi Rating	Effective Bellows Area
1-LP	½, ¾, 1	160	.886
1-HP	½, ¾, 1	310	.886
2-LP	1½, 2	160	1.916
2-HP	1½, 2	310	1.916
3-LP	3	160	2.835
3-HP	3	310	2.835
4-LP	4	160	3.343
4-HP	4	310	3.343

* Use effective bellows area for Guardian valves, see Table 16-I. For Guardian II valves, see page 16-15.

When an actuator's stroke length exceeds the longest stroke length shown for that size actuator on Table 16-VI, the actuator will not have a spring. For actuators without a spring, $S_E = S_R = 0$.

The areas of the seat, A_S, and the seat retainer bore, A_R, are calculated using the following equations. Note that the area of the seat retainer bore is not used when sizing actuators for valves with standard trim or when sizing actuators for Class 150 through 600 MegaStream valves.

$$A_S = \frac{\pi d_S^2}{4} \tag{16.1}$$

$$A_R = \frac{\pi(d_S+0.125)^2}{4} \tag{16.2}$$

Where:

d_S = The seat orifice diameter, inches (Trim Number)

The plug stem cross-sectional area, A_{stem}, is calculated using the following equation:

$$A_{stem} = \frac{\pi d_{stem}^2}{4} \tag{16.3}$$

Where:

d_{stem} =The plug stem diameter, inches (see Table 16-IV)

The spring forces at 30 percent of stroke in fail-closed and fail-open actuators, S_{FC30} and S_{FO30}, are calculated using the following formulas:

$$S_{FC30} = S_E + R_S (0.30)\, S \tag{16.4}$$

$$S_{FO30} = S_R - R_S (0.30)\, S \tag{16.5}$$

Where:

R_S = Spring rate, lb/in (from Table 16-VI)

S = Stroke length, inches

The required seat load, R_{SL}, is calculated using the following equation:

$$R_{SL} = \pi d_C L_S \tag{16.6}$$

Where:

L_S = Seat load per circumferential inch to achieve
desired shutoff, lbs/in (from Table 8-II)

d_C = The diameter of the seating contact surface, in (from the following table)

Trim Type	d_C=
Standard MegaStream Tiger-Tooth	Trim Number
CavControl ChannelStream	Trim Number + 0.125 inch

Step 1: Determine Actuator's Maximum Allowable Throttling Pressure Drop

(Not required for on/off service)

Refer to Table 16-IV to find the standard actuator for the given body size.

Determine the maximum allowable throttling pressure drop (ΔP_a) that the selected actuator can handle by using equations (16.7) and (16.8):

Air-to-open, flow-over: or air-to-close, flow-over:

$$\Delta P_a = \frac{A_C J_O}{A_S} \tag{16.7}$$

Air-to-close, flow-under; or air-to-open, flow-under:

$$\Delta P_a = \frac{A_C J_C}{A_S} \tag{16.8}$$

Where:

ΔP_a = Maximum allowable throttling pressure drop, psi

A_C = Area of cylinder actuator, square inches (see Table 16-III; for air-to-open flow, use the lower cylinder area; for air-to-close flow, use upper cylinder area)

A_S = Area of the seat, square inches

J_O = Air supply adjustment factor for flow-over (see Table 16-II)

J_C = Air supply adjustment factor for flow-under (see Table 16-II)

Table 16-II: Air Supply Stiffness Factors

Supply Pressure	J_C	J_O
30	14.1	14.1
45	28.2	20.7
60	37.6	28.2
80	56.4	35.8
100	75.2	42.4
150	118.0	61.2

Compare the maximum allowable throttling pressure drop to the actual pressure drop. If the actual throttling drop is less than ΔP_a, the selected actuator is sufficient. However, if the actual throttling drop is greater than ΔP_a, the next larger actuator size should be chosen and the above calculation should be repeated.

The maximum allowable throttling pressure drop may also be selected by referring to the appendix at the end of this section. To use these tables, follow the procedure below:

A) Select the correct table based on the trim size used on the valve.

B) Find the correct air supply pressure in the left column.

C) Looking to the right, find the allowable throttling drop (ΔP_a) for the various actuator sizes and air actions (air-to-open or air-to-close).

Table 16-III: Actuator Data

Cylinder Size	Cylinder Bore Dia.(in.)	Upper Cylinder Area (sq. in.)	Lower Cylinder Area (sq. in.)	Stem Dia. (in.)	Stem Area (sq. in.)	Max. Vol. Over Piston (cu.in.)
25	5.50	23.76	22.97	1.00	0.79	100
50+	7.75	47.17	46.39	1.00	0.79	331
50	7.75	47.17	45.67	1.38	1.50	331
100+	11.00	95.03	93.26	1.50	1.77	1031
100	11.00	95.03	91.06	2.25	3.98	1031
200	15.50	188.7	184.7	2.25	3.98	2087
300	19.50	298.6	292.7	2.75	5.94	3733
400*	15.50	371.5	365.5	2.75	5.94	3033
500	25.25	500.7	494.8	2.75	5.94	5519
600*	19.50	590.2	583.1	3.00	7.07	5661

* Tandem, double piston configuration   + Used as oversized actuators in place of the next smaller actuator

Table 16-IV: Standard Unbalanced Valve/Actuator Data

Valve Size (inches)	Rating Class	Full Area Trim Size	Seat Area (sq. in.)	Stem Dia.	Stem Area (sq. in.)	Std. Act. Size*	Stroke (inches)
1/2	150-600	.50	.196	.562	.248	25	.75
3/4	150-2500	.72	.405	.562	.248	25	.75
1	150-600	.81	.518	.562	.248	25	.75
1	900-1500	.81	.518	.562	.248	25	.75
1	2500	.72	.405	.562	.248	25	.75
1 1/2	150-600	1.25	1.23	.875	.601	25	1.00
1 1/2	900-1500	1.25	1.23	.875	.601	50	1.00
1 1/2	2500	1.00	.785	.875	.601	50	.75
2	150-600	1.62	2.07	.875	.601	25	1.50
2	900-1500	1.62	2.07	.875	.601	50	1.50
2	2500	1.25	1.23	.875	.601	50	1.00
3	150-600	2.62	5.41	1.125	.99	50	2.00
3	900-1500	2.62	5.41	1.5	1.77	100	2.00
3	2500	2.00	3.14	1.125	.99	100	1.50
4	150-600	3.50	9.62	1.125	.99	50	2.50
4	900-1500	3.50	9.62	1.5	1.77	100	2.50
4	2500	2.62	5.41	1.5	1.77	100	2.00
6	150	5.00	19.63	1.125	.99	50	3.00
6	300-1500	5.00	19.63	2.0	3.14	100	3.00
6	2500	4.00	12.57	2.0	3.14	100	3.00
8	150	6.25	30.68	1.5	1.77	100	4.00
8	300-600	6.25	30.68	2.0	3.14	100	4.00
8	900-1500	6.25	30.68	2.5	4.91	100	4.00
8	2500	5.00	19.63	2.5	4.91	100	3.00
10	150	8.75	60.13	2.0	3.14	100	4.00
10	300-600	8.75	60.13	2.5	4.91	100	4.00
10	900-1500	8.00	50.27	3.0	7.07	100	4.00
10	2500	6.25	30.68	3.0	7.07	100	4.00
12	150	9.50	70.88	2.0	3.14	100	4.00
12	300-600	9.50	70.88	3.0	7.07	100	4.00
12	900-2500	8.00	50.27	3.0	7.07	100	4.00
14	150	11.00	95.03	3.0	7.07	100	4.00
14	300-600	11.00	95.03	3.0	7.07	100	4.00

* Minimum standard actuator size. Oversized actuators may be required for large pressure drops.

TABLE 16-V: Typical Stem Packing Friction Forces

Note: All numbers in pounds-force

Plug Stem Diameter* (inches)	Teflon Single V	Teflon Twin V	Glass and Carbon-filled Teflon	Standard Grafoil	Twin Grafoil	Braided PTFE	Braided AFPI	SafeGuard SureGuard Single V	SafeGuard SureGuard Twin V
0.56	44	49	45	356	642	44	271	52	68
0.88	49	54	63	560	842	49	344	70	89
1.13	54	50	78	712	1001	54	399	85	106
1.50	64	60	103	954	1239	64	486	111	135
2.00	82	75	141	1272	1557	82	600	149	177
2.50	105	90	184	1590	1875	105	714	192	225
3.00	133	105	232	1908	2193	133	829	239	279

TABLE 16-VI: Cylinder Actuator Spring Data

Cylinder	Stroke (inches)	Spring Design	Rate (lb/in)	Air-to-open (Air-to-retract)			Air-to-close (Air-to-extend)		
				S_E: Spring Extended (lbs)	S_{FC30} (lbs)	S_R: Spring Retracted (lbs)	S_R: Spring Retracted (lbs)	S_{FO30} (lbs)	S_E: Spring Extended (lbs)
25	¾	STD	180	281	322	416	450	410	315
	1	STD	180	236	290	416	450	396	270
	1½	STD	180	146	227	416	450	369	180
	¾	DUAL	447	629	728	964			
	1	DUAL	447	629	762	1075			
	1½	DUAL	447	405	606	1075			
50	1½	STD	164	369	443	615	656	582	410
	2	STD	164	287	385	615	656	558	328
	2½	STD	164	205	328	615	656	533	246
	3	STD	164	123	271	615	656	508	164
	1½	DUAL	447	1194	1395	1864			
	2	DUAL	447	970	1238	1864			
	2½	DUAL	447	747	1082	1864			
	3	DUAL	447	523	925	1864			
100 thru 600	2	STD	300	1125	1305	1725	1725	1545	1125
	2½	STD	300	975	1200	1725	1725	1500	975
	3	STD	300	825	1095	1725	1725	1455	825
	4	STD	300	525	885	1725	1725	1365	525
	2	HEAVY	535	2098	2419	3168			
	2½	HEAVY	535	1831	2232	3168			
	3	HEAVY	535	1563	2045	3168			
	4	HEAVY	535	1028	1670	3168			
	2	DUAL	885	3471	4002	5241			
	2½	DUAL	885	3029	3693	5241			
	3	DUAL	885	2586	3383	5241			
	4	DUAL	885	1701	2763	5241			

Step 2: Determine Actuator Size For Actuation Thrust

Calculate the actuator cylinder areas required by using the applicable group of equations in the following tables. Compare the calculated areas to the corresponding areas for the actuator size selected in Step 1. Actuator areas are listed in Table 16-III. If the calculated areas are less than or equal to the corresponding areas for the selected actuator, the actuator size is adequate. If the calculated areas are larger, an actuator with cylinder areas larger than the calculated areas must be selected.

When determining the required actuator size, various service conditions should be considered. For each sizing equation, the conditions to be considered for that equation are listed with the equation. Each equation should be evaluated for each listed condition that will actually occur. The condition numbers refer to the following list.

Service Conditions to be considered:

1. P_1 and P_2 for flow conditions. If more than one flow condition will occur, each should be evaluated.
2. P_1 and P_2 at shutoff. If more than one set of pressures will occur during shutoff, each set of pressures should be evaluated. The possibility of P_2 dropping to atmospheric pressure (0 psig) should be considered. Pressures used to bench test the valve should also be considered.
3. P_1 and P_2 equal to the maximum value of P_1. This condition may occur if the pipeline is pressurized and the pipe downstream from the valve is blocked. For this condition, set $R_{SL} = 0$ in the sizing equations.
4. P_1 and P_2 equal to 0. This condition will occur if the pipeline is depressurized. This condition will also occur during bench testing of the valve. For this condition, set $R_{SL} = 0$ in the sizing equations.

NOTES:

1. On valves larger than 24-inch, the weight of the plug may need to be accounted for; contact factory.
2. A negative number calculated for A_L or A_U indicates that the smallest available actuator will work for the condition being evaluated.
3. For valves with a trim number smaller than the plug stem diameter, A_S-A_{Stem} will be a negative number. In this case, the negative sign must be retained during the sizing calculations.

Table 16-VII: Actuator Sizing - Standard Globe valves with Unbalanced Trim

Valve Orientation	Fail Action	Actuator to . . . Service Condition	Equation
Flow-over	Fail-closed (air-to-open)	stroke valve from full open to 30 percent open 1, 3, 4	$A_U \geq \frac{P_1 A_{stem} - S_{FC30} + F_P}{P_S}$ (16.9)
		stroke valve closed from 30 percent open and provide tight shutoff 1 (with $R_{SL} = 0$), 2, 3, 4	$A_U \geq \frac{P_2 A_S - P_1(A_S - A_{stem}) - S_E + F_P + R_{SL}}{P_S}$ (16.10)
		lift plug off seat and stroke valve from closed to 30 percent open 1, 2, 3, 4	$A_L \geq \frac{P_1 (A_S - A_{stem}) - P_2 A_S + S_{FC30} + F_P}{P_S}$ (16.11)
		stroke valve from 30 percent open to full open 1, 3, 4	$A_L \geq z \frac{- P_1 A_{stem} + S_R + F_P}{P_S}$ (16.12)
	Fail-open (air-to-close)	stroke valve from full open to 30 percent open 1, 3, 4	$A_U \geq \frac{P_1 A_{stem} + S_{F030} + F_P}{P_S}$ (16.13)
		stroke valve closed from 30 percent open and provide tight shutoff 1 (with $R_{SL} = 0$), 2, 3, 4	$A_U \geq \frac{P_2 A_S - P_1 (A_S - A_{stem}) + S_R + F_P + R_{SL}}{P_S}$ (16.14)
		lift plug off seat 2, 3, 4	$A_L \geq \frac{P_1(A_S - A_{stem}) - P_2 A_S - S_R + F_P}{P_S}$ (16.15)
		stroke valve from closed to 30 percent open 1, 3, 4	$A_L \geq \frac{P_1(A_S - A_{stem}) - P_2 A_S - S_{F030} + F_P}{P_S}$ (16.16)

Table 16-VIII: Actuator Sizing - Standard Globe Valves with Unbalanced Trim (and Class 150 to 600 MegaStream)

Valve Orientation	Fail Action	Actuator to . . . Service Condition	Equation
Flow-under	Fail-closed (air-to-open)	stroke valve closed and provide tight shutoff 1 (with $R_{SL} = 0$), 2, 3, 4	$A_U \geq \dfrac{P_1A_S - P_2(A_S - A_{stem}) - S_E + F_P + R_{SL}}{P_S}$ (16.17)
		lift plug off seat and stroke valve from closed to 30 percent open 1, 2, 3, 4	$A_L \geq \dfrac{P_2\,(A_S - A_{stem}) - P_1A_S + S_{FC30} + F_P}{P_S}$ (16.18)
		stroke valve full open 1, 3, 4	$A_L \geq \dfrac{-\,P_2A_{stem} + S_R + F_P}{P_S}$ (16.19)
	Fail-open (air-to-close)	stroke valve closed and provide tight shutoff 1 (with $R_{SL} = 0$), 2, 3, 4	$A_U \geq \dfrac{P_1A_S - P_2(A_S - A_{stem}) + S_R + F_P + R_{SL}}{P_S}$ (16.20)

Table 16-IX: Actuator Sizing - ChannelStream and CavControl Valves with Unbalanced Trim

Valve Orientation	Fail Action	Actuator to . . . Service Condition	Equation
Flow-over	Fail-closed (air-to-open)	stroke valve closed and provide tight shutoff 1 (with $R_{SL} = 0$), 2, 3, 4	$A_U \geq \dfrac{P_2A_R - P_1(A_R - A_{stem}) - S_E + F_P + R_{SL}}{P_S}$ (16.21)
		lift plug off seat and stroke valve full open 1, 2, 3, 4	$A_L \geq \dfrac{P_1\,(A_R - A_{stem}) - P_2A_R + S_R + F_P}{P_S}$ (16.22)
	Fail-open (air-to-close)	stroke valve closed and provide tight shutoff 1 (with $R_{SL} = 0$), 2, 3, 4	$A_U \geq \dfrac{P_2A_R - P_1(A_R - A_{stem}) + S_R + F_P + R_{SL}}{P_S}$ (16.23)
		lift plug off seat and stroke valve full open 1, 2, 3, 4	$A_L \geq \dfrac{P_1\,(A_R - A_{stem}) - P_2A_R - S_E + F_P}{P_S}$ (16.24)

Table 16-X: Actuator Sizing - Tiger-Tooth and High Pressure MegaStream Valves with Unbalanced Trim

Valve Orientation	Fail Action	Actuator to . . . Service Condition	Equation
Flow-under	Fail-closed (air-to-open)	stroke valve closed 1, 3, 4	$A_U \geq \dfrac{P_1A_R - P_2\,(A_R - A_{stem}) - S_E + F_P}{P_S}$ (16.25)
		provide tight shutoff 2, 3, 4	$A_U \geq \dfrac{P_1A_S - P_2(A_S - A_{stem}) - S_E + F_P + R_{SL}}{P_S}$ (16.26)
		lift plug off seat 2, 3, 4	$A_L \geq \dfrac{P_2\,(A_S - A_{stem}) - P_1A_S + S_E + F_P}{P_S}$ (16.27)
		stroke valve full open 1, 3, 4	$A_L \geq \dfrac{P_2\,(A_R - A_{stem}) - P_1A_R + S_R + F_P}{P_S}$ (16.28)
	Fail-open (air-to-close)	stroke valve closed 1, 3, 4	$A_U \geq \dfrac{P_1A_R - P_2\,(A_R - A_{stem}) + S_R + F_P}{P_S}$ (16.29)
		provide tight shutoff 2, 3, 4	$A_U \geq \dfrac{P_1A_S - P_2\,(A_S - A_{stem}) + S_R + F_P + R_{SL}}{P_S}$ (16.30)

Step 3: Determine Spring Size

If it will be necessary for the valve to stroke open or closed upon loss of air supply pressure, the fail-safe spring must be sized. The required spring force is calculated by using the applicable equations in the following tables. Each sizing equation should be evaluated for the listed conditions that will actually occur. The condition numbers refer to the service conditions listed in step 2.

After the required spring force is calculated, it must be compared to the standard spring force for the actuator selected in steps 1 and 2. This spring force is listed in Table 16-VI. If the required spring force is less than the standard spring force of the selected actuator, a standard spring will be sufficient. If the required spring force is greater than that of a standard spring force, compare the required spring with the dual (or heavy-duty) spring force for the same size actuator (see Table 16-VI). If the dual spring force is larger than the required spring force, the dual spring should be used. If the dual spring force is not large enough, a volume tank or larger actuator will be required. Section 19 contains volume tank sizing information.

If the spring or actuator size selected to provide sufficient spring force is different from that used during step 2, the calculations of step 2 must be verified using the new spring or actuator information.

Table 16-XI: Spring Sizing - Standard Globe valves with Unbalanced Trim (and Class 150 to 600 MegaStream)

Valve Orientation	Fail Action	Spring to . . .	Service Condition	Equation	
Flow-over	Fail-closed (air-to-open)	stroke valve from full open to 30 percent open	1, 3, 4	$S_{FC30} \geq P_1 A_{stem} + F_P$	(16.31)
		stroke valve closed from 30 percent open and provide tight shutoff	1 (with $R_{SL} = 0$), 2, 3, 4	$S_E \geq P_2 A_S - P_1 (A_S - A_{stem}) + F_P + R_{SL}$	(16.32)
	Fail-open (air-to-close)	lift plug off seat	2, 3, 4	$S_R \geq P_1 (A_S - A_{stem}) - P_2 A_S + F_P$	(16.33)
		stroke valve from closed to 30 percent open	1, 3, 4	$S_{FO30} \geq P_1 (A_S - A_{stem}) - P_2 A_S + F_P$	(16.34)
		stroke valve from 30 percent open to full open	1, 3, 4	$S_E \geq - P_1 A_{stem} + F_P$	(16.35)
Flow-under	Fail-closed (air-to-open)	stroke valve from full open to 30 percent open	1, 3, 4	$S_{FC30} \geq P_2 A_{stem} + F_P$	(16.36)
		stroke valve closed and provide tight shutoff	1 (with $R_{SL} = 0$), 2, 3, 4	$S_E \geq P_1 A_S - P_2 (A_S - A_{stem}) + F_P + R_{SL}$	(16.37)
	Fail-open (air-to-close)	lift plug off seat and stroke valve from closed to 30 percent open	1, 2, 3, 4	$S_{FO30} \geq P_2 (A_S - A_{stem}) - P_1 A_S + F_P$	(16.38)
		stroke valve full open	1, 3, 4	$S_E \geq - P_2 A_{stem} + F_P$	(16.39)

Table 16-XII: Spring Sizing - ChannelStream and CavControl with Unbalanced Trim

Valve Orientation	Fail Action	Spring to . . . / Service Condition	Equation	
Flow-over	Fail-closed (air-to-open)	stroke valve closed and provide tight shutoff 1 (with R_{SL} = 0), 2, 3, 4	$S_E \geq P_2A_R - P_1(A_R - A_{stem}) + F_P + R_{SL}$	(16.40)
	Fail-open (air-to-close)	lift plug off seat 2, 3, 4	$S_R \geq P_1(A_R - A_{stem}) - P_2A_R + F_P$	(16.41)
		stroke valve full open 1, 3, 4	$S_E \geq P_1(A_R - A_{stem}) - P_2A_R + F_P$	(16.42)

Table 16-XIII: Spring Sizing - Tiger-Tooth and High Pressure MegaStream Valves with Unbalanced Trim

Valve Orientation	Fail Action	Spring to . . . / Service Condition	Equation	
Flow-under	Fail-closed (air-to-open)	stroke valve closed 1, 3, 4	$S_E \geq P_1A_R - P_2(A_R - A_{stem}) + F_P$	(16.43)
		provide tight shutoff 2, 3, 4	$S_E \geq P_1A_S - P_2(A_S - A_{stem}) + F_P + R_{SL}$	(16.44)
	Fail-open (air-to-close)	lift plug off seat 2, 3, 4	$S_R \geq P_2(A_S - A_{stem}) - P_1A_S + F_P$	(16.45)
		stroke valve full open 1, 3, 4	$S_E \geq P_2(A_R - A_{stem}) - P_1A_R + F_P$	(16.46)

Linear Actuator Sizing, Pressure-balanced Trim

Introduction

As noted in the procedure for unbalanced trim, in throttling services three questions must be answered:

1. Will the actuator handle the throttling differential pressure?
2. Will the actuator provide sufficient thrust to overcome application pressures to open or close the valve, and generate enough seat loading for tight shutoff with the given air supply pressure?
3. Will the spring fail the valve in the proper direction?

With on/off services, only questions 2 and 3 must be answered.

The equations in this section use the following variables:

A_L = Lower cylinder area, in^2
A_U = Upper cylinder area, in^2
A_S = Area of the seat, in^2 (see Table 16-XIV or equation 16.47)
A_{stem} = Plug stem cross-sectional area, in^2 (see Table 16-XIV or equation 16.49)
A_R = Area of the seat retainer bore, in^2 (see equation 16.48)
ob_O = Off-balance area tending to open the valve, in^2; $ob_O = A_{SI} - A_S$ (see Table 16-XIV)
ob_C = Off-balance area tending to close the valve, in^2; $ob_C = A_{SI} - A_{stem} - A_S$ (see Table 16-XIV)
P_1 = Pressure on upstream side of the valve, psig
P_2 = Pressure on downstream side of the valve, psig
P_S = Air supply pressure, psig
S_E = Spring force with the spring extended to full stroke, lbs (see Table 16-VI)
S_R = Spring force with the spring fully retracted, lbs (see Table 16-VI)
S_{FC30} = Spring force at 30% of stroke in fail-closed actuators, lbs (see equation 16.50)
S_{FO30} = Spring force at 30% of stroke in fail-open actuators, lbs (see equation 16.51)
F_P = Packing friction, lbs (see Table 16-V)
F_S = Pressure balance seal friction, lbs (see Table 16-XVI)
R_{SL} = Required seat load to achieve desired shutoff, lbs (see equation 16.52)
A_{SI} = Sleeve area, in^2 (see Table 16-XIV or 16-XV)

When an actuator's stroke length exceeds the longest stroke length shown for that size actuator in Table 16-VI, the actuator will not have a spring. For actuators without a spring, $S_E = S_R = 0$.

The areas of the seat, A_S, and the seat retainer bore, A_R, are calculated using the following equations. Note that the area of the seat retainer bore is not used when sizing actuators for valves with standard trim or when sizing actuators for Class 150 through 600 MegaStream valves.

$$A_S = \frac{\pi d_S^2}{4} \qquad (16.47)$$

$$A_R = \frac{\pi (d_S + 0.125)^2}{4} \qquad (16.48)$$

Where:

d_S = The seat orifice diameter, in (Trim Number)
d_S = T N + 0.125 for ChannelStream and CavControl

The plug stem cross-sectional area, A_{stem}, is calculated using the following equation:

$$A_{stem} = \frac{\pi d_{stem}^2}{4} \qquad (16.49)$$

Where:

d_{stem} = The plug stem diameter, in (see Table 16-XIV)

The spring forces at 30 percent of stroke in fail-closed and fail-open actuators, S_{FC30} and S_{FO30}, are calculated using the following equations:

$$S_{FC30} = S_E + R_S(0.30)\, S \qquad (16.50)$$

$$S_{FO30} = S_R - R_S(0.30)\, S \qquad (16.51)$$

Where:

R_S = Spring rate, lb/in (see Table 16-VI)
S = Stroke length, inches

The required seat load, R_{SL}, is calculated using the following equation:

$$R_{SL} = \pi d_C L_S \qquad (16.52)$$

Where:

L_S = Seat load per circumferential inch to achieve

TABLE 16-XIV: Standard Pressure-balanced Valve/Actuator Data (inches)

Valve Size (inches)	Rating Class	Full Area Trim Size	Seat Area (sq. in.)	Stem Dia. (sq. in.)	Stem Area (sq. in.)	Sleeve Area (sq. in.)	Off-balance Area sq.in. Flow Under To Close	Off-balance Area sq.in. Flow Over To Open	Standard Actuator Size	Stroke (inches)
2	600	1.62	2.07	.562	.248	2.58	.26	.51	25	1
2	1500	1.62	2.07	.562	.248	2.41	.09	.34	25	1
2	2500	1.25	1.23	.562	.248	1.55	.07	.32	25	1
3	600	2.62	5.41	.875	.601	6.77	.76	1.36	50	1.5
3	1500	2.62	5.41	.875	.601	6.49	.48	1.08	100	2
3	2500	2.0	3.14	.875	.601	3.86	.12	.72	100	1.5
4	600	3.5	9.62	.875	.601	11.41	1.19	1.79	50	2
4	1500	3.5	9.62	1.125	.994	11.41	.80	1.79	100	2
4	2500	2.62	5.41	1.125	.994	6.77	.37	1.36	100	2
6	150	5.0	19.63	1.125	.994	22.69	2.06	3.06	50	2.5
6	600	5.0	19.63	1.5	1.77	23.76	2.36	4.13	100	2.5
6	1500	5.0	19.63	1.5	1.77	22.69	1.29	3.06	100	2.5
6	2500	4.0	12.57	1.5	1.77	15.03	.69	2.46	100	2.5
8	600	6.25	30.68	1.5	1.77	35.78	3.33	5.10	100	3
8	1500	6.25	30.68	2.0	3.14	35.78	1.96	5.10	100	4
8	2500	5.0	19.63	2.0	3.14	23.76	.99	4.13	100	4
10	600	8.0	50.27	2.0	3.14	58.36	4.95	8.09	100	3
10	1500	8.0	50.27	2.5	4.91	58.36	3.18	8.09	100	4
10	2500	6.25	30.68	2.5	4.91	37.12	1.53	6.44	100	4
12	600	9.5	70.88	2.5	4.91	78.54	2.75	7.66	100	4
12	1500	9.5	70.88	2.5	4.91	78.54	2.75	7.66	100	4
12	2500	8.0	50.27	2.5	4.91	56.75	1.57	6.48	100	4
14	150	11.0	95.03	2.5	4.91	108.43	8.49	13.40	100	4
14	600	11.0	95.03	3.0	7.07	108.43	6.33	13.40	100	4
14	1500	11.0	95.03	3.0	7.07	103.87	1.77	8.84	100	4
16	600	12.75	127.68	3.0	7.07	140.50	5.75	12.82	100	4
16	1500	12.75	127.68	3.0	7.07	137.89	3.14	10.21	100	4

Trim Type	d_C=
Standard MegaStream Tiger-Tooth	Trim Number
CavControl ChannelStream	Trim Number + 0.125 inch

desired shutoff, lbs/in (see Table 8-II)

d_C = The diameter of the seating contact surface, in (see the following table)

Step 1: Determine Actuator's Maximum Allowable Throttling Pressure Drop

Refer to Table 16-XIV to find the standard actuator for the given body size.

Determine the maximum allowable throttling pressure drop (ΔP_a) that the selected actuator can handle by using equations (16.53) and (16.54):

Air-to-open, flow-over or air-to-close, flow-over:

$$\Delta P_a = \frac{A_C J_O}{ob_O} \tag{16.53}$$

Air-to-open, flow-under or air-to-close, flow-under:

$$\Delta P_a = \frac{A_C J_C}{ob_C} \tag{16.54}$$

Where:

ΔP_a = Maximum allowable throttling pressure drop, psi

A_C = Area of cylinder actuator, square inches (see Table 16-III; for air-to-open flow use lower cylinder area; for air-to-close flow use upper cylinder area))

ob_C = Off-balance area tending to close the valve, in^2; $ob_C = A_{SI} - A_{stem} - A_S$ (see Table 16-XIV)

ob_O = Off-balance area (sq.in.) tending to open the valve $ob_o = A_{SI} - A_S$ (see Table 16-XIV)

J_O = Air supply adjustment factor for flow-over

(see Table 16-II)

J_C = Air supply adjustment factor for flow-under (see Table 16-II)

Compare the maximum allowable throttling pressure drop to the actual pressure drop. If the ΔP_{actual} is less than ΔP_a, the selected actuator is sufficient. However, if the ΔP_{actual} is greater than ΔP_a, the next larger actuator size should be chosen and the above calculation should be repeated.

Step 2: Determine Actuator Size For Actuation Thrust

Calculate the actuator cylinder areas required by using the applicable equations in the following tables. Compare the calculated areas to the corresponding areas for the actuator size selected for the throttling drop. These areas are listed in Table 16-III. If the calculated areas are less than or equal to the corresponding areas for the selected actuator, the actuator size is adequate. If the calculated areas are larger, an actuator with lower and upper cylinder areas larger than the calculated areas must be selected.

When determining the required actuator size, various service conditions should be considered. For each sizing equation, the conditions to be considered for that equation are listed with the equation. Each equation should be evaluated for each listed condition that will actually occur. The condition numbers refer to the following list.

Service Conditions to be considered:

1. P_1 and P_2 for flow conditions. If more than one flow condition will occur, each should be evaluated.
2. P_1 and P_2 at shutoff. If more than one set of pressures will occur during shutoff, each set of pressures should be evaluated. The possibility of P_2 dropping to atmospheric pressure (0 psig) should be considered.
3. P_1 and P_2 equal to the maximum value of P_1. This condition may occur if the pipeline is pressurized and the pipe downstream from the valve is blocked.
4. P_1 and P_2 equal to 0. This condition will occur if the pipeline is depressurized. This condition will also occur during bench testing of the valve.

NOTES:

1. On valves larger than 24-inch, the weight of the plug may need to be accounted for; contact factory.
2. A negative number calculated for A_L or A_U indicates that the smallest available actuator will work for the condition being evaluated.

Table 16-XV: Pressure-balanced Sleeve Area

ChannelStream and CavControl	Valves other than ChannelStream and CavControl not listed in Table 16-XIV	
$A_{SI} = A_R = A_S$	**Pressure Class**	$\mathbf{A_{SI}}$
	150 - 600	$(1.10)\ A_S + A_{stem}$
	900 - 1500	$(1.05)\ A_S + A_{stem}$
	2500	$(1.03)\ A_S + A_{stem}$

Table 16-XVI: Seal Friction Forces

Type of Seal	Seal Friction, F_S, (lbs)
Teflon	$F_S = 58(TN) + 12$
O-Ring and Spring Energized Elastomer	$F_S = 14(TN) + 0.029(P_1 - P_2)$
Muskegon Piston Rings	$F_S = 0.00613(TN)(P_1 - P_2)$
NiResist Piston Rings	$F_S = 0.0613(TN)(P_1 - P_2)H_S$

Where:

TN = Trim Number

H_S = Seal height
= 0.13 for TN = 1.00 to TN = 2.25
= 0.19 for TN = 2.62 to TN = 5.00
= 0.25 for TN = 5.50 to TN = 9.50
= 0.38 for TN = 11.00 to TN = 22.00

Table 16-XVII: Actuator Sizing - Standard Globe Valves with Pressure-balanced Trim

Valve Orientation	Fail Action	Actuator to . . . / Service Condition	Equation
Flow-over	Fail-closed (air-to-open)	stroke valve from full open to 30 percent open 1, 3, 4	$A_U \geq \dfrac{P_1 A_{stem} - S_{FC30} + F_P + F_S}{P_S}$ (16.55)
		stroke valve closed from 30 percent open and provide tight shutoff 1 (with $R_{SL} = 0$), 2, 3, 4	$A_U \geq \dfrac{P_1(ob_O) - P_2(ob_C) - S_E + F_P + F_S + R_{SL}}{P_S}$ (16.56)
		lift plug off seat and stroke valve from closed to 30 percent open 1, 2, 3, 4	$A_L \geq \dfrac{P_2(ob_C) - P_1(ob_O) + S_{FC30} + F_P + F_S}{P_S}$ (16.57)
		stroke valve from 30 percent open to full open 1, 3, 4	$A_L \geq \dfrac{- P_1 A_{stem} + S_R + F_P + F_S}{P_S}$ (16.58)
	Fail-open (air-to-close)	stroke valve from full open to 30 percent open 1, 3, 4	$A_U \geq \dfrac{P_1 A_{stem} + S_{FO30} + F_P + F_S}{P_S}$ (16.59)
		stroke valve closed from 30 percent open and provide tight shutoff 1 (with $R_{SL} = 0$), 2, 3, 4	$A_U \geq \dfrac{P_1(ob_O) - P_2(ob_C) + S_R + F_P + F_S + R_{SL}}{P_S}$ (16.60)
		lift plug off seat and open valve from closed to 30 percent open 1, 2, 3, 4	$A_L \geq \dfrac{P_2(ob_C) - P_1(ob_O) - S_{FO30} + F_P + F_S}{P_S}$ (16.61)
		stroke valve from 30 percent open to full open 1, 3, 4	$A_L \geq \dfrac{- P_1 A_{stem} - S_E + F_P + F_S}{P_S}$ (16.62)

Table 16-XVIII: Actuator Sizing - Standard Globe Valves (and Class 150 to 600 MegaStream)

Valve Orientation	Fail Action	Actuator to . . . / Service Condition	Equation
Flow-under	Fail-closed (air-to-open)	stroke valve from full open to 30 percent open 1, 3, 4	$A_U \geq \dfrac{P_2 A_{stem} - S_{FC30} + F_P + F_S}{P_S}$ (16.63)
		stroke valve closed from 30 percent open and provide tight shutoff 1 (with $R_{SL} = 0$), 2, 3, 4	$A_U \geq \dfrac{P_2(ob_O) - P_1(ob_C) - S_E + F_P + F_S + R_{SL}}{P_S}$ (16.64)
		lift plug off seat and stroke valve from closed to 30 percent open 1, 2, 3, 4	$A_L \geq \dfrac{P_1(ob_C) - P_2(ob_O) + S_{FC30} + F_P + F_S}{P_S}$ (16.65)
		stroke valve from 30 percent open to full open 1, 3, 4	$A_L \geq \dfrac{- P_2 A_{stem} + S_R + F_P + F_S}{P_S}$ (16.66)
	Fail-open (air-to-close)	stroke valve from full open to 30 percent open 1, 3, 4	$A_U \geq \dfrac{P_2 A_{stem} + S_{FO30} + F_P + F_S}{P_S}$ (16.67)
		stroke valve closed from 30 percent open and provide tight shutoff 1 (with $R_{SL} = 0$), 2, 3, 4	$A_U \geq \dfrac{P_2(ob_O) - P_1(ob_C) + S_R + F_P + F_S + R_{SL}}{P_S}$ (16.68)
		lift plug off seat and open valve from closed to 30 percent open 1, 2, 3, 4	$A_L \geq \dfrac{P_1(ob_C) - P_2(ob_O) - S_{FO30} + F_P + F_S}{P_S}$ (16.69)
		stroke valve from 30 percent open to full open 1, 3, 4	$A_L \geq \dfrac{- P_2 A_{stem} - S_E + F_P + F_S}{P_S}$ (16.70)

Table 16-XIX: Actuator Sizing - ChannelStream and CavControl Valves with Pressure-balanced Trim

Valve Orientation	Fail Action	Actuator to . . .	Service Condition	Equation	
Flow-over	Fail-closed (air-to-open)	stroke valve closed and provide tight shutoff	1 (with R_{SL} = 0), 2, 3, 4	$A_U \geq \frac{P_2A_{stem} - S_E + F_P + F_S + R_{SL}}{P_S}$	(16.71)
		lift plug off seat and stroke valve full open	1, 2, 3, 4	$A_L \geq \frac{- P_2A_{stem} + S_R + F_P + F_S}{P_S}$	(16.72)
	Fail-open (air-to-close)	stroke valve closed and provide tight shutoff	1 (with R_{SL} = 0), 2, 3, 4	$A_U \geq \frac{P_2A_{stem} + S_R + F_P + F_S + R_{SL}}{P_S}$	(16.73)
		lift plug off seat and stroke valve full open	1, 2, 3, 4	$A_L \geq \frac{- P_2A_{stem} - S_E + F_P + F_S}{P_S}$	(16.74)

Table 16-XX: Actuator Sizing - Tiger-Tooth and High Pressure MegaStream Valves with Pressure-balanced Trim

Valve Orientation	Fail Action	Actuator to . . .	Service Condition	Equation	
Flow-under	Fail-closed (air-to-open)	stroke valve closed	1, 3, 4	$A_U \geq \frac{P_2(A_{SI} - A_R) - P_1(A_{SI} - A_R - A_{stem}) - S_E + F_P + F_S}{P_S}$	(16.75)
		provide tight shutoff	2, 3, 4	$A_U \geq \frac{P_2(A_{SI} - A_S) - P_1(A_{SI} - A_S - A_{stem}) - S_E + F_P + F_S + R_{SL}}{P_S}$	(16.76)
		lift plug off seat	2, 3, 4	$A_L \geq \frac{P_1(A_{SI} - A_S - A_{stem}) - P_2(A_{SI} - A_S) + S_E + F_P + F_S}{P_S}$	(16.77)
		stroke valve full open	1, 3, 4	$A_L \geq \frac{P_1(A_{SI} - A_R - A_{stem}) - P_2(A_{SI} - A_R) + S_R + F_P + F_S}{P_S}$	(16.78)
	Fail-open (air-to-close)	stroke valve closed	1, 3, 4	$A_U \geq \frac{P_2(A_{SI} - A_R) - P_1(A_{SI} - A_R - A_{stem}) + S_R + F_P + F_S}{P_S}$	(16.79)
		provide tight shutoff	2, 3, 4	$A_U \geq \frac{P_2(A_{SI} - A_S) - P_1(A_{SI} - A_S - A_{stem}) + S_R + F_P + F_S + R_{SL}}{P_S}$	(16.80)
		lift plug off seat	2, 3, 4	$A_L \geq \frac{P_1(A_{SI} - A_S - A_{stem}) - P_2(A_{SI} - A_S) - S_R + F_P + F_S}{P_S}$	(16.81)
		stroke valve full open	1, 3, 4	$A_L \geq \frac{P_1(A_{SI} - A_R - A_{stem}) - P_2(A_{SI} - A_R) - S_E + F_P + F_S}{P_S}$	(16.82)

Step 3: Determine Spring Size

If the valve is required to stroke open or closed upon loss of air supply pressure, the actuator fail-safe spring must be sized. The required spring force is calculated by using the applicable equations in the following tables. For each sizing equation, the conditions to be considered for that equation are listed. Each equation should be evaluated for the listed conditions that will actually occur. The condition numbers refer to the service conditions listed in Step 2.

After the required spring force is calculated, it must be compared to the standard spring force for the actuator selected in steps 1 and 2. This spring force is listed in Table 16-VI. If the required spring force is less than the standard spring force for the selected actuator, a standard spring will be sufficient. If the required spring force is greater than that of a standard spring, compare the required spring force with the dual (or heavy-duty) spring force for the same size actuator (see Table 16-VI). If the dual spring force is larger than the required spring force, the dual spring should be used. If the dual spring force is not large enough, a volume tank or larger actuator will be required. Section 19 contains volume tank sizing information.

If the spring or actuator size selected to provide sufficient spring force is different from that used during step 2, the calculations of step 2 must be verified using the new spring or actuator information.

Table 16-XXI: Spring Sizing - Standard Globe valves with Pressure-balanced Trim (and Class 150 to 600 MegaStream)

Valve Orientation	Fail Action	Spring to . . . / Service Condition	Equation	
Flow-under	Fail-closed (air-to-open)	stroke valve from full open to 30 percent open 1, 3, 4	$S_{FC30} \geq P_2 A_{stem} + F_P + F_S$	(16.83)
		stroke valve closed from 30 percent open and provide tight shutoff 1 (with R_{SL} = 0), 2, 3, 4	$S_E \geq P_2(ob_O) - P_1(ob_C) + F_P + F_S + R_{SL}$	(16.84)
	Fail-open (air-to-close)	lift plug off seat and stroke valve from closed to 30 percent open 1, 2, 3, 4	$S_{FO30} \geq P_1(ob_C) - P_2(ob_O) + F_P + F_S$	(16.85)
		stroke valve from 30 percent open to full open 1, 3, 4	$S_E \geq - P_2 A_{stem} + F_P + F_S$	(16.86)
Flow-over	Fail-closed (air-to-open)	stroke valve from full open to 30 percent open 1, 3, 4	$S_{FC30} \geq P_1 A_{stem} + F_P + F_S$	(16.87)
		stroke valve closed and provide tight shutoff 1 (with R_{SL} = 0), 2, 3, 4	$S_E \geq P_1(ob_O) - P_2(ob_C) + F_P + F_S + R_{SL}$	(16.88)
	Fail-open (air-to-close)	lift plug off seat and stroke valve from closed to 30 percent open 1, 2, 3, 4	$S_{FO30} \geq P_2(ob_C) - P_1(ob_O) + F_P + F_S$	(16.89)
		stroke valve full open 1, 2, 3, 4	$S_E \geq - P_1 A_{stem} + F_P + F_S$	(16.90)

Table 16-XXII: Spring Sizing - ChannelStream and CavControl with Pressure-balanced Trim

Valve Orientation	Fail Action	Spring to . . . / Service Condition	Equation	
Flow-over	Fail-closed (air-to-open)	stroke valve closed and provide tight shutoff 1 (with R_{SL} = 0), 2, 3, 4	$S_E \geq P_2 A_{stem} + F_P + F_S + R_{SL}$	(16.91)
	Fail-open (air-to-close)	lift plug off seat and stroke valve full open 1, 2, 3, 4	$S_E \geq - P_2 A_{stem} + F_P + F_S$	(16.92)

Table 16-XXIII: Spring Sizing - Tiger-Tooth and High Pressure MegaStream Valves with Pressure-balanced Trim

Valve Orientation	Fail Action	Actuator to . . . Service Condition	Equation
Flow-under	Fail-closed (air-to-open)	stroke valve closed 1, 3, 4	$S_E \geq P_2(A_{SI} - A_R) - P_1(A_{SI} - A_R - A_{stem}) + F_P + F_S$ (16.93)
		provide tight shutoff 2, 3, 4	$S_E \geq P_2(A_{SI} - A_S) - P_1(A_{SI} - A_S - A_{stem}) + F_P + F_S + R_{SL}$ (16.94)
	Fail-open (air-to-close)	lift plug off seat 2, 3, 4	$S_R \geq P_1(A_{SI} - A_S - A_{stem}) - P_2(A_{SI} - A_S) + F_P + F_S$ (16.95)
		stroke valve full open 1, 3, 4	$S_E \geq P_1(A_{SI} - A_R - A_{stem}) - P_2(A_{SI} - A_R) + F_P + F_S$ (16.96)

Linear Actuator Sizing, Guardian II Metal Bellows Seal

Introduction

The following data must be used when sizing actuators for Guardian II metal bellows valves. This information along with the previous equations listed in Sizing and Selection section 16 will be combined for accurate sizing. See Table XXIV for the initial sizing information needed. While sizing, the actuator pressure limits in Table XXV must not be exceeded. For valve and actuator combinations not listed, the actuator pressure limit is 150 psig.

Table 16-XXIV: Guardian II Bellows Valve Actuator Sizing Information

Valve Size (inches)	ANSI Pressure Class	Max. Stroke Length (inches)	Effective Bellows Area (sq. in.)	Relaxed Position (in. from seat)	Bellows Spring Rate (lb/in)
½, ¾, 1	150, 300	0.5	0.75	0	36
1½, 2	150, 300	1.0	1.35	0	26
3	150, 300	1.5	1.35	0.25	26
4, 6	150	2.5	2.38	0	15
4, 6	300	2.5	2.18	0	42
8	150	3.0	4.53	0	20
8	300	3.0	4.75	0	112

To determine actuator spring forces, the stroke length of a valve must be known. Many Guardian II stroke lengths are given in Table XXVI. For the trims not listed in Table

Table 16-XXV
Guardian II Actuator Pressure Limits

Valve Size (inches)	ANSI Pressure Class	Actuator Size (sq. in.)	Max. Actuator Pressure (psig)
6	300	200	100
6	300	300	60
8	150	200	100
8	150	300	60
8	300	200	100
8	300	300	60

XXVI, the stroke length is determined by comparing the maximum stroke length listed in Table XXIV to the stroke length of a standard Mark One valve that is the same size and has the same trim. The actual stroke length of the valve with a Guardian II bellows seal will be the shorter of these two stroke lengths.

Fluid pressure inside the valve acts on the effective bellows area. This area is listed in Table XXIV and should be substituted for the actuator stem area in the actuator sizing equations.

The relaxed position of the bellows is the distance from the seat where the bellows is not in tension or compression. The metal bellows acts as a spring that is compressed or stretched as the plug is moved from the relaxed position. To account for the spring force of the bellows, it is necessary to add a term to the sizing equations of Section 16 of the Sizing & Selection manual. The term is added to the numerator on the right side of the equations for actuator area and is added to the right side of equations for spring force. This additional term is designated S_B. For equations used to determine the actuator or spring size required **to close the valve**, S_B is calculated by using Equation 1.

$$S_B = R_B(P_R - P_A) \qquad \text{(Equation 1)}$$

For equations used to determine the actuator or spring size required **to open the valve**, S_B is calculated by using Equation 2.

$$S_B = R_B(P_A - P_R) \qquad \text{(Equation 2)}$$

Where:

S_B = Spring force of the metal bellows, lbs.

P_A = Actual position of the plug, in. (If the equation from Sizing & Selection section 16 determines the force required to move the plug through a range of stroke values, use the position that gives the largest value for S_B).

P_R = Relaxed position of the plug, in. (See Table XXIV).

R_B = Spring rate of the metal bellows, lb/in. (See Table XXIV).

Table 16-XXVI: C_v Data (=% Trim, Flow Over)

Valve Size (inches)	Trim Number	Stroke (inches)	Full C_v
½	.50	.50	4.2
	.31	.50	2.3
¾	.72	.50	7.5
	.50	.50	5.4
	.31	.50	2.6
1	.81	.50	11.0
	.50	.50	5.7
	.31	.50	2.6
1½	1.25	1.00	30
	1.00	.75	22
	.81	.75	18
2	1.62	1.00	44
	1.25	1.00	33
	1.00	.75	23
	.81	.75	19
3	2.62	1.50	107
	1.62	1.50	49
4	3.50	2.50	206
	2.25	2.00	113
6	5.00	2.50	405
	3.50	2.50	236
8	6.25	3.00	698
	5.00	3.00	474

Table 16-XXVII: Examples of Modifications to Actuator Sizing Equations

Equation	Modified Equation	S_B Equation	S_B Evaluation Position (P_A)
16.9	$A_U \geq \dfrac{P_1 A_{bellows} - S_{FC30} + F_P + S_B}{P_S}$	1	30 percent open (0.3 X Stroke Length)
16.10	$A_U \geq \dfrac{P_2 A_S - P_1(A_S - A_{bellows}) - S_E + F_P + R_{SL} + S_B}{P_S}$	1	On seat (0.0 inches)
16.11	$A_L \geq \dfrac{P_1 (A_S - A_{bellows}) - P_2 A_S + S_{FC30} + F_P + S_B}{P_S}$	2	30 percent open (0.3 X Stroke Length)
16.12	$A_L \geq \dfrac{- P_1 A_{bellows} + S_R + F_P + S_B}{P_S}$	2	Full open (Stroke Length)
16.31	$S_{FC30} \geq P_1 A_{bellows} + F_P + S_B$	1	30 percent open (0.3 X Stroke Length)
16.32	$S_E \geq P_2 A_S - P_1 (A_S - A_{bellows}) + F_P + R_{SL} + S_B$	1	On seat (0.0 inches)

Rotary Actuator Sizing, Valdisk and Valdisk 150

Introduction

To select an actuator for a Valdisk or Valdisk 150 high performance butterfly valve, five sequential steps are necessary:

1. Determine the shaft orientation and actuator stiffness requirements.
2. Calculate the seating and breakout torque.
3. Calculate the dynamic torque.
4. Select an actuator capable of providing sufficient torque to overcome the seating/breakout torque and dynamic torque based on available air supply.
5. If a fail-open or fail-close action is required, select an actuator capable of providing sufficient torque to overcome the seating/breakout torque and dynamic torque based on available spring torque.

Step 1: Determine the Shaft Orientation

Because the disc in a Valdisk or Valdisk 150 is double offset, when the shaft is oriented upstream the dynamic torque created by the process fluid will force the disc into the seat. A disc with the shaft oriented downstream will move toward the open position when near the seat. As a general rule, a valve that is required to fail-close on loss of instrument air supply usually has the shaft upstream. A valve which is required to fail open has the shaft downstream.

The above rule applies to all applications where the flowing fluid is a gas. On liquid applications with the shaft upstream, the actuator must be adequately stiff to prevent the disc from closing too rapidly, thus eliminating any potential pressure surge condition which would result in water hammer. To determine if the actuator has sufficient stiffness, calculate the following:

$$\text{Actuator Stiffness (required)} = \frac{\Delta P\ (\text{max})}{\text{Sup. Press.}} \qquad (16.97)$$

Compare the required actuator stiffness with the maximum actuator stiffness values found in Table 16-XXVIII (according to valve size). Shaft upstream on a fail-closed liquid service can be used, provided the required stiffness does not exceed the actuator stiffness (max) for the actuator size selected. Note that in all cases the standard actuator size for a given valve size is indicated first in the chart. A larger actuator size may be required to ensure adequate stiffness. If the required stiffness exceeds all those indicated for the actuator sizes available for a given valve size, shaft downstream orientation is required.

Step 2: Find the Seating and Breakout Torque

Using table 16-XXX and the following equations, calculate the seating and breakout torque.

Table 16-XXVIII: Actuator Stiffness (max.) for Shaft Upstream, Liquid Applications

Valve Size (inches)	Actuator Size					
	Standard 25	Standard 50	Standard 100	Standard 200	Toggle-link 100	Toggle-link 200
2	3.1					
3	3.1					
4	1.7	8.8				
6	0.81	4.3	6.9	15.9		
8		2.4	6.0	13.8	13.2	30.4
10		1.3	3.4	7.8	7.5	17.2
12			2.4	5.5	5.3	12.1
14			1.4	3.2	3.1	7.0
16			0.98	2.2	2.16	4.8
18			0.84	1.9	1.85	4.2
20			0.53	1.2	1.17	2.6
24			0.39	0.87	.86	1.9

Table 16-XXIX: Dynamic Torque Factors vs. Disc Position

Valve Size (in.)	Dynamic Torque Factor vs. Disc Position (Degrees Open)																	
	10°		20°		30°		40°		50°		60°		70°		80°		90°	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0		0	1	0	2	0	2						
4	0	0	0	0	0	0	0	0	0	1	1	2	1	4	0	6	-4	4
6	0	0	0	1	1	1	1	3	2	4	4	9	6	17	0	23	-19	19
8	0	0	0	1	1	2	2	4	3	7	4	12	1	19	-8	28	-23	23
10	0	1	1	2	2	6	5	9	7	17	8	28	4	46	-18	65	-55	55
12	1	2	2	7	5	13	10	20	16	38	18	61	8	101	-40	144	-121	121
14	1	3	3	10	6	18	15	28	22	54	25	85	12	142	-56	201	-168	168
16	2	4	4	12	8	23	19	36	27	67	32	106	15	177	-69	250	-211	211
18	5	10	10	29	19	54	44	83	64	156	73	247	34	411	-161	582	-489	489
20	5	10	10	31	21	58	47	89	68	168	78	264	6	440	-173	623	-524	524
24	7	14	14	42	28	78	64	121	92	227	106	358	50	596	-234	845	-710	710
30	24	49	49	146	97	268	219	414	316	779	365	1230	170	2046	-804	2899	-2436	2436

A = Shaft Downstream
B = Shaft Upstream

NOTE: *When degrees of opening are not known, use highest value of C_d for valve size.*

Shaft downstream: (Torque required to close valve)

$$T_{st} = - T_P - T_S - \Delta P_{MAX}(C_{BT} + C_{OT}) - T_H \qquad (16.98)$$

Shaft downstream: (Torque required to open valve)

$$T_{bo} = T_P + T_S + \Delta P_{MAX}(C_{BT} - C_{OT}) + T_H \qquad (16.99)$$

Shaft upstream: (Torque required to close valve)

$$T_{st} = - T_P - T_S - \Delta P_{MAX}(C_{BT} - C_{OT}) - T_H \qquad (16.100)$$

Shaft upstream: (Torque required to open valve)

$$T_{bo} = T_P + T_S + \Delta P_{MAX}(C_{BT} + C_{OT}) + T_H \qquad (16.101)$$

Where:
- T_{st} = Seating torque
- T_{bo} = Breakout required
- T_P = Packing torque
- T_S = Seat torque
- ΔP_{MAX} = Maximum pressure drop at shutoff
- C_{BT} = Bearing torque factor
- C_{OT} = Off-balance torque factor
- T_H = Handwheel torque. T_H = O without handwheel (See Table 16 - XXXII)

NOTE: *Negative values calculated for T_c, T_{bo}, T_{st}, indicate the disc will tend to resist closing. Positive values indicate the disc will tend to resist opening.*

Step 3: Calculate the Dynamic Torque

Since the net torque output of rotary actuators varies as disc position changes, it may be necessary to find the dynamic torque on the shaft at various degrees of opening. This is generally required only when a relatively high actual pressure drop is expected through part or all of the disc rotation. With the shaft oriented downstream a torque reversal occurs at approximately 70 to 80 degrees open, which could result in some controllability problems. To avoid this, change the shaft orientation to shaft upstream or limit the disc rotation to 70 degrees.

For gas applications use Table 16-XXX and the following equations to find the required dynamic torque:

To close the disc:

$$T_D = - T_P - \Delta P_{eff}(C_{BT}) \qquad (16.102)$$

To open the disc:

$$T_D = T_P + \Delta P_{eff}(C_{BT}) \qquad (16.103)$$

For liquid applications use Tables 16-XXIX, 16-XXX and the following equations to find the required dynamic torque:

To close the disc

$$T_D = -T_P - \Delta P_{eff}(C_{BT} - C_d) \qquad (16.104)$$

To open the disc

$$T_D = T_P + \Delta P_{eff}(C_{BT} - C_d) \qquad (16.105)$$

Where:
- T_D = Dynamic torque: (-)values indicate the disc will resist closing. (+) values indicate the disc will resist opening.
- C_d = Dynamic torque factor from Table 16-XXIX for appropriate shaft orientation and degrees of opening. Use highest C_d value if degrees of opening are unknown.
- ΔP_{eff} = ΔP(actual) at the flowing condition at the operating degrees of opening limited to ΔP (choked)
- T_P = Packing torque factor, from Table 16-XXX

Table 16-XXX: Static Breakout Torque = Sizing

Valve Size (inches)	ANSI Pressure Class	T_P = Packing Torque (in-lb)					T_S = Seat Torque (in-lb)	C_{BT} = Bearing Torque Factor		C_{OT} = Off Balance Torque Factor
		(1)	(2)	(3)	(4)	(5)		(6)	(7)	
2	150,300,600	50	280	477	350	63	74	0.09	0.13	0.20
3		50	280	477	350	63	154	0.20	0.30	0.40
4		57	333	533	399	71	270	0.48	0.72	0.71
6		64	385	590	448	81	596	1.27	1.90	1.66
8		79	490	702	543	104	980	2.73	4.10	2.58
10	150,300*	79	490	702	543	104	1612	4.46	6.69	4.25
12		104	648	870	691	151	2102	8.60	12.90	5.55
14	150*	104	648	870	691	151	4338	11.98	17.97	25.65
16		122	753	983	789	190	5853	16.61	24.92	34.62
18		122	753	983	789	190	6639	21.99	32.99	39.27
20		141	858	1095	886	234	9378	35.50	53.25	55.42
24		141	858	1095	886	234	11829	44.78	67.17	65.40
30		182	1068	1319	1081	342	19521	110.83	166.25	38.49

(1) TFE or filled TFE V-ring packing
(2) Grafoil packing
(3) Twin Grafoil Packing
(4) Asbestos free packing
(5) Braided PTFE packing
(6) Filament wound glass/TFE bearing
(7) 316 stainless steel/solid film lubricant coated bearing and stellite bearings
* For higher pressure class data, consult factory

Table 16-XXXI: Valve/Actuator Compatibility - Valdisk/Valdisk 150

Actuator Size (sq.in.)	Spring Size	Valves Size (inches)												
		2	3	4	6	8	10	12	14	16	18	20	24	30
STD. 25	STD.													
STD. 25	H.D.													
STD. 50	STD.													
STD. 50	H.D.													
STD. 100	STD.													
STD. 100	H.D.													
STD. 200	STD.													
STD. 200	H.D.													

NOTE: For Valdisk valve compatibility with Toggle-link actuators, contact factory.

Table 16-XXXII: Declutchable Handwheel Torque (T_H)

Actuator Size (sq.in.)	Handwheel Torque (in-lbs)
25	150
50	250
100 - 200	375

C_{BT} = Bearing torque factor, from Table 16-XXX

ΔP(choked) is shown as:

$$\Delta P(\text{choked}) = F_L^2 (P_1 - F_f P_V) \quad (16.106)$$

Where:

F_L = Valves recovery coefficient

P_1 = Upstream pressure, psia

F_f = Liquid critical pressure ratio

P_V = Vapor pressure of the liquid, psia

Step 4: Determine Actuator Size Based on Air Supply

Select an actuator from Table 16-XXXIII with sufficient net torque to overcome the calculated seating/breakout and dynamic torque through the full stroke rotation of the valve based on the available air supply.

After the actuator size has been selected, all gas and liquid applications with shaft downstream should be checked for sufficient actuator stiffness. Using the following equation, calculate corrected air supply:

$$S_C = 0.867S_a - 12.3 \quad (16.107)$$

Where: S_C = Corrected supply pressure

S_a = Actual supply pressure

Using S_C, consult Table 16-XXXIII and confirm that the actuator size selected has sufficient torque to overcome the dynamic torque values (calculated from step 3). Choose a larger actuator size if the torque available throughout the full stroke rotation is less than the dynamic torque calculated.

Finally, check the valve/actuator interface compatibility in Table 16-XXXI for the actuator chosen.

Step 5: Select Actuator Based on Available Spring Torque

If the spring must move the disc to a desired failure position upon air supply loss, select an actuator from table 16-XXXIII according to the following criteria. (Available actuator sizes are indicated in Table 16-XXXI.)

For fail-closed valves, which do not require tight shutoff on air failure, the spring must provide sufficient torque to overcome the calculated dynamic torque through the full stroke rotation of the valve. For valves requiring tight shutoff, the spring must also provide sufficient torque at the 0 degree (closed) position to overcome the required seating torque.

For fail-open valves, the spring must deliver sufficient torque at the 90 degrees (closed) position to overcome the calculated breakout torque. It must also have sufficient torque to overcome the dynamic torque throughout the full stroke rotation of the valve.

Should the required torque be greater than the available springs can provide, a volume tank can be used to ensure failure on loss of air supply.

For liquid applications with the shaft oriented upstream, the selected actuator should have adequate stiffness. It should also provide sufficient torque to overcome the seating/breakout torque and dynamic torque through the fall stroke rotation of the valve with the available air supply and available spring torque, if a failure mode is required.

Table 16-XXXIII: Net Torque Output of Standard Actuators at Various Supply Pressures (in-lb)

NOTE: *For air-to-open/fail-closed actuators the 0 degree position shown corresponds to the disc or ball being seated.*
For air-to-close/fail-open actuators the 90 degree position shown corresponds to the disc or ball being seated.

Actuaor Size	Supply Pressure	Degrees from Fail Position on Air Supply Loss									
		0	10	20	30	40	50	60	70	80	90
STD 25 with STD Spring	150	3013	3399	3700	3907	4000	3970	3811	3514	3084	2532
	140	2755	3165	3444	3631	3714	3685	3531	3253	2854	2339
	120	2397	2695	2928	3080	3145	3110	2972	2731	2390	1962
	100	1986	2228	2412	2530	2573	2535	2414	2211	1928	1577
	80	1574	1759	1896	1979	2002	1961	1856	1688	1463	1191
	60	1163	1290	1381	1428	1430	1386	1298	1167	1001	806
	40	751	821	864	876	858	811	738	645	537	420
	Spring Torque	54	86	125	169	213	254	284	299	293	262
STD 25 with HD Spring	150	2647	2973	3223	3386	3448	3403	3246	2976	2600	2124
	140	2441	2738	2964	3110	3162	3115	2966	2716	2368	1931
	120	2030	2270	2450	2558	2590	2542	2409	2195	1905	1552
	100	1618	1802	1934	2009	2020	1967	1850	1673	1441	1167
	80	1206	1333	1418	1457	1448	1392	1292	1151	978	781
	60	795	865	902	907	877	818	733	630	515	396
	Spring Torque	440	542	647	749	839	908	945	937	878	758
STD 50 with STD Spring	150	10701	11981	13015	13751	14134	14089	13575	12568	11043	9035
	140	9970	11157	12114	12798	13136	13083	12596	11653	10232	8365
	120	8516	9513	10318	10874	11141	11075	10649	9826	8615	7053
	100	7059	7873	8515	8953	9153	9073	8693	7999	6995	5712
	80	5602	6227	6716	7033	7156	7062	6736	6174	5372	4373
	60	4147	4586	4913	5114	5166	5058	4784	4347	3755	3034
	40	2690	2942	3111	3192	3171	3049	2829	2519	2134	1693
	Spring Torque	222	343	489	651	816	966	1081	1134	1107	983
STD 50 with HD Spring	150	9774	10898	11781	12380	12651	12533	12000	11036	9648	7850
	140	9044	10074	10880	11425	11652	11527	11021	10122	8837	7183
	120	7591	8430	9083	9502	9657	9519	9073	8300	7216	5865
	100	6133	6790	7281	7585	7668	7516	7117	6473	5597	4527
	80	4678	5148	5481	5660	5671	5508	5163	4646	3974	3186
	60	3223	3505	3681	3741	3680	3501	3209	2821	2356	1846
	Spring Torque	1148	1428	1726	2026	2304	2529	2662	2667	2511	2167
STD 100 with STD Spring	150	26194	29415	32022	33847	34730	34559	33234	30711	26943	22035
	140	24385	27397	29784	31459	32253	32069	30831	28446	26936	20378
	120	20805	23329	25330	26685	27303	27104	25983	23921	20932	17119
	100	17226	19271	20859	21914	22368	22119	21134	19394	16920	13808
	80	13640	15200	16399	17153	17413	17133	16296	14878	12915	10485
	60	10055	11139	11929	12391	12472	12159	11447	10350	8901	7167
	40	6469	7077	7472	7624	7526	7181	6605	5829	4893	3851
	Spring Torque	704	1049	1461	1913	2370	2783	3088	3225	3135	2775
STD 100 with HD Spring	150	24678	27231	29008	29925	29917	28969	27058	24266	20699	16483
	140	22881	25195	26771	27539	27459	26475	24632	22001	18691	14832
	120	19304	21127	22317	22784	22507	21490	19782	17472	14680	11563
	100	15713	17070	17847	18012	17567	16518	14946	12956	10674	8245
	80	12130	12999	13385	13248	12612	11538	10101	8432	6662	4927
	60	8545	8939	8921	8483	7673	6558	5257	3910	2662	1611
	Spring Torque	2217	3256	4485	5831	7185	8405	9299	9691	9407	8316
STD 200 with STD Spring	80	27695	31132	33903	35838	36820	36663	35280	32620	28633	23416
	70	24156	27119	29480	31134	31916	31730	30501	28139	25670	20206
	60	20595	23091	25069	26406	27014	26813	25699	24656	20697	16926
	50	17051	19072	20643	21696	22126	21876	20897	19173	16724	13646
	40	13501	15043	16227	16969	17223	16952	16109	14703	12760	10357
	30	9951	11022	11808	12253	12328	12015	11307	10219	8785	7071
	Spring Torque	704	1049	1461	1913	2370	2783	3088	3225	3135	2775
STD 200 with HD Spring	80	26192	28930	30894	31940	32005	31052	29104	26177	22393	17887
	70	22636	24918	26467	27214	27122	26136	24302	21693	18420	14650
	60	19094	20889	22056	22505	22217	21198	19499	17208	14445	11370
	50	15538	16872	17629	17779	17326	16275	14709	12735	10478	8083
	40	11991	12842	13212	13064	12421	11346	9914	8257	6507	4799
	30	8441	8821	8792	8345	7530	6414	5116	3778	2536	1514
	Spring Torque	2217	3256	4485	5831	7185	8405	9299	9691	9407	8316

(continued)

Table 16-XXXIII: (continued)
Net Torque Output of Toggle-link Actuators at Various Supply Press. (in-lb)

NOTE: *For air-to-open/fail-closed actuators the 0 degree position shown corresponds to the disc or ball being seated. For air-to-close/fail-open actuators the 90 degree position shown corresponds to the disc or ball being seated.*

Actuaor Size	Supply Pressure	Degrees from Fail Position on Air Supply Loss									
		0	10	20	30	40	50	60	70	80	90
STD 100 with No Spring	150	55253	50511	48414	47688	47565	47596	47231	46243	44044	40216
	140	51566	47141	45183	44506	44390	44417	44077	43155	41094	37629
	120	44200	40407	38730	38149	38050	38072	37781	36991	35224	32255
	100	36835	33674	32276	31792	31709	31728	31486	30827	29357	26891
	80	29465	26937	25818	25431	25365	25380	25185	24659	23482	21504
	70	25783	23570	22591	22252	22195	22208	22038	21577	20548	18821
	60	22100	20203	19364	19074	19024	19035	18889	18494	17611	16126
STD 100 with STD 20" Spring	150	46475	41517	39053	37762	37004	36347	35492	34086	31885	28585
	140	42763	38174	35847	34581	33832	33173	32336	30996	28927	25968
	120	35341	31457	29418	28256	27519	26856	26033	24847	23070	20597
	100	27996	24741	22967	21923	21185	20532	19745	18676	17192	15219
	80	20640	18023	16531	15583	14860	14190	13447	12513	11320	9842
	70	16973	14671	13318	12409	11702	11029	10295	9427	8381	7156
	60	13303	11309	10103	9244	8536	7866	7149	6348	5447	4469
	Spring Torque	8764	8854	9234	9802	10469	11161	11775	12185	12209	11625
STD 100 with HD 28" Spring	150	42482	37897	35540	34250	33432	32745	31840	30466	28395	25370
	140	38800	34552	32330	31070	30261	29572	28686	27398	25457	22747
	120	31452	27836	25881	24741	23946	23233	22399	21227	19580	17376
	100	24099	21123	19447	18393	17627	16909	16095	15068	13712	11997
	80	16745	14404	13009	12063	11299	10577	9798	8900	7836	6620
	70	13077	11049	9794	8889	8139	7414	6652	5815	4900	3930
	60	9405	7687	6576	5722	4976	4249	3506	2735	1962	1242
	Spring Torque	12677	12491	12773	13330	14038	14783	15436	15804	15699	14847
STD 200 with No Spring	120	90138	82403	78982	77799	77597	77646	77052	75440	71847	65573
	100	75117	68671	65820	64834	64666	64705	64210	62867	59870	54840
	80	60092	54935	52655	51865	51731	51761	51365	50291	47891	43857
	70	52580	48067	46072	45381	45263	45291	44944	44004	41906	38384
	60	45067	41199	39489	38897	38796	38819	38521	37716	35915	32887
	50	37558	34335	32910	32416	32332	32352	32104	31433	29934	27419
	40	30046	27467	26327	25932	25864	25880	25682	25144	23944	21928
STD 200 with STD 20" Spring	120	81372	73545	69667	67776	66960	66341	65317	63265	59683	53947
	100	66376	59778	56415	54835	54063	53409	52467	50725	47718	43167
	80	51346	45950	43301	41931	41139	40508	39606	38139	35730	32194
	70	43764	39076	36736	35455	34705	34045	33203	31846	29737	26720
	60	36215	32250	30176	29000	28245	27602	26775	25573	23761	21229
	50	28722	25402	23601	22546	21806	21140	20364	19282	17770	15758
	40	21221	18554	17039	16083	15359	14689	13944	12999	11784	10272
	Spring Torque	8764	8854	9234	9802	10469	11161	11775	12185	12209	11625
STD 200 with HD 28" Spring	120	77455	69905	66066	64242	63370	62710	61663	59644	56196	50755
	100	62436	56083	52894	51326	50491	49816	48813	47105	44228	39946
	80	47376	42304	39777	38398	37592	36886	35982	34519	32240	28972
	70	39792	35474	33196	31945	31133	30444	29554	28247	26266	23481
	60	32321	28628	26640	25488	24692	23979	23141	21953	20271	18007
	50	24823	21783	20081	19016	18249	17532	16714	15675	14290	12525
	40	17326	14934	13517	12555	11798	11077	10294	9380	8299	7043
	Spring Torque	12677	12491	12773	13330	14038	14783	15436	15804	15699	14847
STD 200 with HD 34" Spring	120	74734	67370	63658	61889	60983	60326	59298	57364	53986	48740
	100	59697	53551	50490	48931	46106	47431	46441	44783	42018	37928
	80	44588	39793	37353	36033	35208	34501	33610	32197	30030	26953
	70	37026	32944	30791	29558	28770	28059	27182	25926	24055	21462
	60	29543	26095	24212	23099	22310	21609	20769	19632	18059	15977
	50	22050	19252	17655	16641	15866	15148	14353	13353	12078	10505
	40	14567	12404	11099	10175	9416	8698	7929	7065	6087	5019
	Spring Torque	15446	15021	15198	15718	16422	17180	17808	18127	17921	16866

Rotary Actuator Sizing, ShearStream

Introduction

To select an actuator for a ShearStream high performance ball valve, three steps are necessary:

1. Determine seating/breakout torques. (Also determine the dynamic torque in liquid applications.)
2. Select an actuator capable of providing sufficient torque to overcome the seating/breakout torque and dynamic torque based on available air supply.
3. If a failure action is required, select an actuator capable of providing sufficient torque to overcome the seating/breakout torque and dynamic torque based on available spring torque.

Step 1: Determine Seating/Breakout Torques.

Normally, ShearStream valves are installed with the shaft downstream. However, in an erosive service the valve should be installed with the shaft upstream. With the shaft upstream, erosive action will occur in the retainer and not the ball surface or the valve body. To determine the seating/breakout torque, use equation (16.108) or (16.109), according to the application.

For shaft downstream, seating/breakout torque is shown as:

$$T_{bo} = T_P + T_S + \Delta P_{max}(C_B + C_s) + T_H \qquad (16.108)$$

For shaft upstream, seating/breakout torque is shown as:

$$T_{bo} = T_P + T_S + \Delta P_{max}(C_B) + A + T_H \qquad (16.109)$$

NOTE: *$A = (T_S - \Delta P(C_S)$. If A is less than zero, enter zero for A.*

In liquid service applications, the dynamic torque must also be determined. Actuator sizing is based on the seating/breakout torque and dynamic torque. To determine dynamic torque, use the following equation:

$$T_D = T_P + \Delta P_{eff}(C_D + C_B) \qquad (16.110)$$

Where:

T_{bo} = Seating/breakout torque (in-lb) is the torque required to close and open the valve.

T_P = Packing torque (in-lb) is the torque required to overcome the friction of the packing on the shaft. Packing torque varies with packing material. (See Table 16-XXXVI)

T_S = Seat torque (in-lb) is the torque required to overcome the friction of the seat on the ball. (See Table 16-XXXVI)

ΔP_{max} = Pressure drop (lb/in^2) across the valve when valve is in the closed position.

T_D = Dynamic torque (in-lb) is the torque required to overcome the torque on the closure member caused by the fluid-dynamic forces on the ball.

ΔP_{eff} = Actual pressure drop (lb/in^2) across the valve at the flowing condition which occurs when the valve is in an open position. ΔP_{eff} is less than or equal to ΔP(choked).

$$\Delta P_{choked} = F_L^2(P_1 - F_f P_V) \qquad (16.111)$$

Where: F_L = Valve recovery coefficient (See Table 16-XXXIV)

P_1 = Upstream pressure, psia

F_f = Liquid critical pressure ratio

P_v = Vapor pressure of liquid, psia

C_B = Bearing torque factor (in^3). As the pressure across the valve increases, the force on the bearings increases proportionally.

$C_B(\Delta P)$ = bearing torque (in-lb).

(See Table 16-XXXVI)

C_S = Seat torque factor (in^3). As the pressure across the valve increases, the force at which the seat pushes into the ball increases (shaft downstream) or decreases (shaft upstream). (See Table 16-XXXVI)

C_D = Dynamic torque factor. (See Table 16-XXXVI)

T_H = Handwheel torque. $T_H = 0$ without handwheel (See Table 16-XXXII)

Table 16-XXXIV: Approximate F_L

Percent of Rated C_V	Approximate F_L
10	.90
20	.85
30	.82
40	.78
50	.73
60	.68
70	.65
80	.63
90	.62
100	.60

Table 16 - XXXV: Valve/Actuator Compatibility - ShearStream

Actuator Size (in^2)	Spring Size	Valve/Actuator Compatibility Valve Size (inches)								
		1	1.5	2	3	4	6	8	10	12
STD. 25	STD.									
STD. 25	H.D.									
STD. 50	STD.									
STD. 50	H.D.									
STD. 100	STD.									
STD. 100	H.D.									
STD. 200	STD.									
STD. 200	H.D.									

Table 16-XXXVI: ShearStream Static Torques - Sizing

Valve Size	T_P=Packing Torque (in-lb)					T_S=Seat Torque	C_B=Bearing Torque Factor		C_S=Seat Torque Factor	C_D = Dynamic Torque Factor	
(in.)	(1)	(2)	(3)	(4)	(5)	(in-lb)	(6)	(7)		60°	90°
1	43	228	421	301	57	20	0.06	0.09	0.1	0.25	0.6
$1^1/_2$	50	280	477	350	63	40	0.06	0.09	0.1	0.5	1.0
2	50	280	477	350	63	60	0.06	0.09	0.15	1.0	2.1
3	57	333	533	399	71	150	0.19	0.28	0.42	4.5	8.0
4	57	333	533	399	71	360	0.38	0.58	0.82	10.0	17.0
6	71	438	646	496	92	540	0.97	1.45	1.64	19.5	30.5
8	71	438	646	496	92	670	1.58	2.37	2.62	52.0	75.5
10	104	648	870	691	151	1100	4.38	6.57	4.55	108.0	165.5
12	104	648	870	691	151	1300	5.61	8.41	6.05	191.0	218.5

(1) TFE or filled TFE V-ring packing
(2) Grafoil
(3) Twin Grafoil
(4) Asbestos-free packing (AFP)
(5) Braided PTFE
(6) TFE lined bearings
(7) Metal bearings