Section Va: Valve Actuators

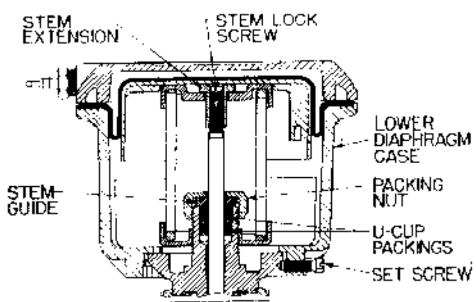
Code No. LIT-347Va

Valve Actuators

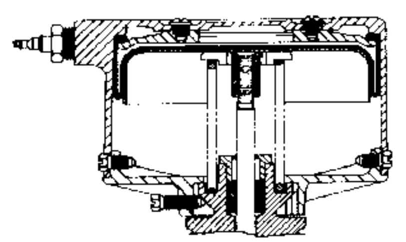
An actuator is a controlled device that provides the force required to move the plug in a valve, which regulates the flow of fluid in the system. Different size valves require different size actuators, depending on the characteristics of the system. An important characteristic to be considered is pump head, also known as dynamic pressure. This is the pressure the actuator must overcome to close a valve. The force generated by an actuator is directly proportional to the effective area of the actuator diaphragm.
There are six types of Johnson Controls actuators presently in use.

Pneumatic Actuators

The V-3000 is a pneumatic valve actuator that can be mounted on any of the V-3000, V-4000, and 1/2 inch VT series valve bodies. These valves range in size from 1/2 inch up to 1 1/2 inches. The second actuator, a
V-3802 is similar to the V-3000 except it is designed for use in confined areas. It is used on the 1/2 inch V-3854 valve and the VT series valves. Figures 1 and 2 show the different components of the V-3000 and
V-3802 actuators. The third type of actuator is called the SPA actuator. This enclosed actuator is constructed entirely out of plastic with the exception of the metal collar used to tighten down and hold the actuator to the valve. This compact actuator has an effective diaphragm area of
4 square inch and is designed to meet or exceed the specifications for the larger V-3802 actuator. The SPA actuator can be used on valves with 5/16 or 1/2 inch strokes.

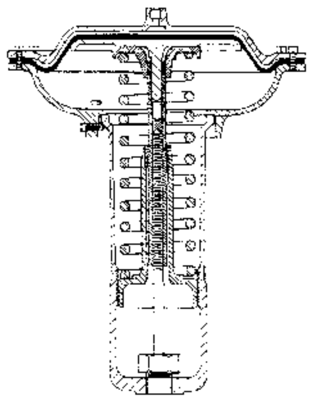


V-3000 VALVE ACTUATOR
FIGURE 1

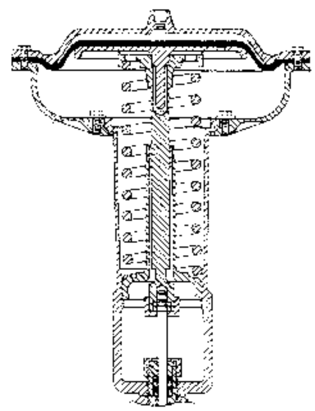


V-3802 VALVE ACTUATOR
FIGURE 2

The fourth type of actuator is the rubber diaphragm actuator with an encapsulated spring. These actuators are used on valves ranging from
2-1/2 inch through 6 inch in size. The actuator comes in three sizes 4R, 5R, and 8R tops. The size 4R denotes an effective top plate radius of
4 inches. **Johnson Controls previously manufactured a rubber diaphragm style actuator with a spring that was non-encapsulated. These actuators were used on valves ranging from 1/2 inch through**
10 inch in size. The actuator came in four sizes 3R, 4R, 5R, and, 8R. Repair parts for these actuators, except the diaphragm, are no longer available and repair is not recommended. Figures 3 and 4 show both types of actuators.

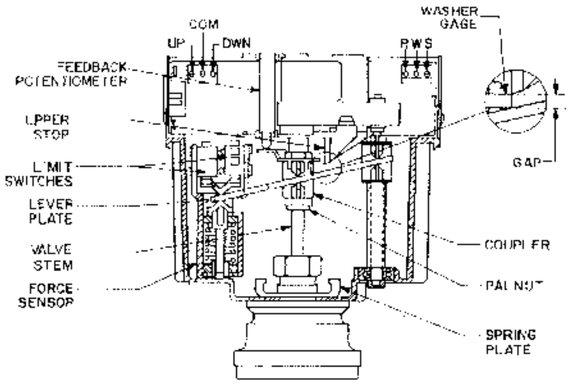


OLD DIAPHRAGM ACTUATOR (LEFT)
FIGURE 3

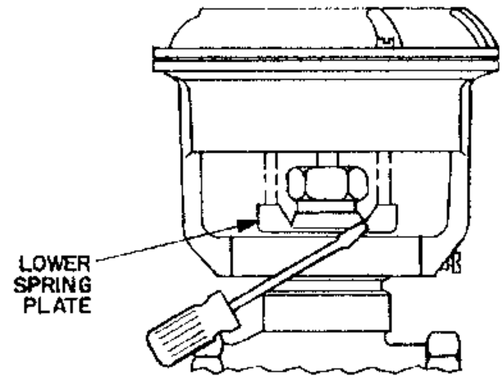


DIAPHRAGM ACTUATOR WITH ENCAPSULATED SPRING (RIGHT)
FIGURE 4

When a single pneumatic output is utilized to modulate both the heating and chilled water valves, the valves should be sequenced to prevent the possibility of both valves being open at the same time. Failure to sequence the valves will waste both energy and money. The spring ranges listed in the product bulletins are **nominal** and are valid only if there is no water pressure in the system. It is possible to select heating and chilled water valves with nominal spring ranges which do no overlap but once they are installed in a hydronic system the installed spring ranges may overlap. Generally the hydronic system pressure will shift the closeoff pressure of a normally open valve to a higher pressure and shift the opening pressure of a normally closed valve to a lower pressure.
In some cases the adverse effect of these pressure shifts can be compensated for by making an adjustment on the normally closed valve. It is possible to shift the entire spring range of a normally closed valve higher by manually turning the lower spring plate (as viewed from the top) counterclockwise (see Figure 6).
Do not use your finger to make this adjustment. The lower spring plate can be easily rotated by pushing it with a screw driver. Refer to
Table 6Va to determine the limits of this adjustment. In some cases this adjustment may be adequate to eliminate the overlap of the installed spring ranges of the heating and cooling valves. Thus, the cost of a pilot positioner or sequencing cumulator may be avoided.



INTERNAL VIEW
FIGURE 5



V-3000 VALVE ACTUATOR
SHOWING LOWER SPRING
PLATE ADJUSTMENT (TURN CCW)
FIGURE 6

Electric Actuators

The fifth type of actuator is a motor driven actuator with incremental (floating) or proportional control. Depending on the signal the motor will rotate the lead screw and lever clockwise or counterclockwise, which will, in turn, move the valve stem up or down. For floating control when the controller stops sending a signal, the actuator remains in place. For proportional control when the control signal halts, the actuator returns to the zero voltage input position. When the valve stem reaches either end of travel, the shut-off force builds up until it reaches its limit. When the limit is reached, the lever activates a force sensor which stops the motor. The shut-off limit is 50 pounds for the VA-805X series and 22 pounds for the VA802X series electric actuators. Figure 5 shows the internal view of the VA-8050 or VA-8020 actuators.

Maximum Seating Pressure

Graphs 1Va through 33Va can be used to determine the maximum fluid differential pressure against which the valve will close (valve pressure drop) for a given valve actuator size. The graph also provides a means for determining the actual (installed) spring range of the valve.

Examples

Normally Open Valves

Given:

1/2 inch, V-5252 N.O. Steam Valve, 2 to 5 psig nominal spring range, 15 psig maximum control pressure and 20 psig inlet steam pressure.

Find:

Most suitable valve actuator, actual (installed) spring range with actuator chosen, and maximum pressure the valve can close-off against.

Solution:

Figure 7 shows that the control pressure or diaphragm pressure must be great enough to overcome the combined spring force and the valve differential pressure. Since a 2 to 5 psig nominal spring range is given, the diaphragm pressure must be at least 5 psig to overcome the spring force.

Referring to Graph 13Va, follow the valve pressure drop scale to 20 psig. Read horizontally to intersect with the 2-1/2 inch valve line. Reading vertically to the diaphragm pressure scale, approximately 7.75 psig diaphragm pressure will be required to close this valve using a 5R actuator. The actual spring range will be 2 to 7.75 psig. The valve cannot exceed 35 psig steam due to the temperature limitations of the valve packings. The valve will remain closed against the 35 psig steam with a diaphragm pressure of 9.3 psig.

Normally Closed Valves

Given:

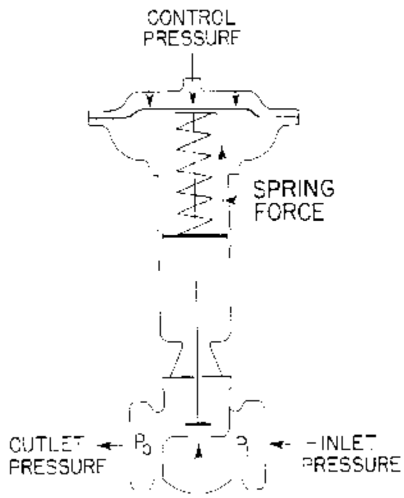
1 inch, V-3974, N.C. Water Valve, 9-13 psig spring, 15 psig maximum control pressure, and 30 psig pump differential pressure.

Find:

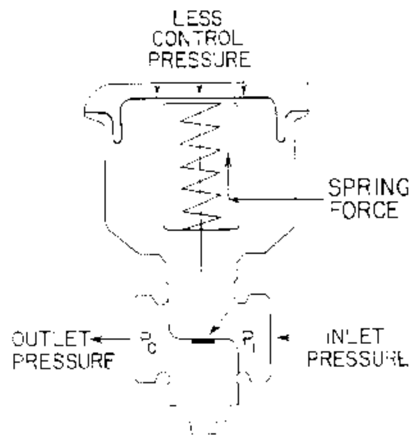
Actual (installed) spring range and maximum differential pressure that the valve can close-off against.

Solution:

Figure 8 shows that the spring must be able to overcome the force of the differential pressure across the valve. The control pressure or diaphragm pressure will be used only for opening the N.C. valve. Referring to Graph 5Va, follow the valve pressure drop scale to 30 psig. Read horizontally to intersect with the 1 inch valve line. Reading vertically to the diaphragm pressure scale, approximately 4.75 psig diaphragm pressure will generate sufficient force to close the valve with the V-3000 actuator. The actual spring range will be 4.75 to 13 psig. The maximum pressure against which the valve will close, with 0 psig on the diaphragm is 61 psig.



NORMALLY OPEN VALVE
FIGURE 7



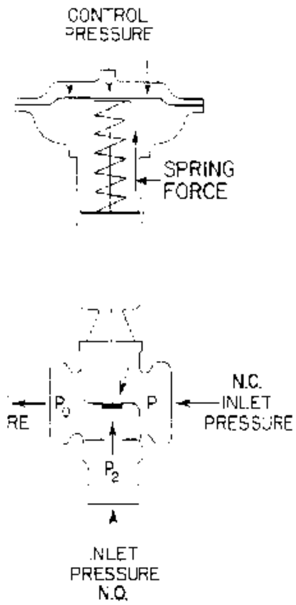
NORMALLY CLOSED VALVE
FIGURE 8

Three-Way Mixing Valves

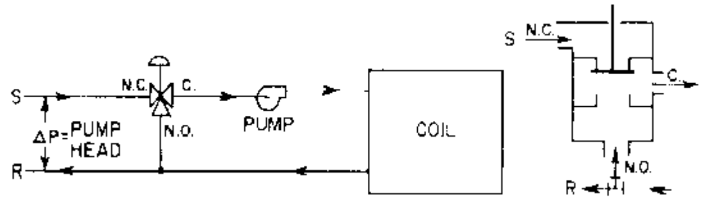
Figure 9 shows the internal configuration of a three-way mixing valve. The valve is constructed with two inlet ports and one outlet port. Valves given in the charts are the shutoff pressures for either the normally open or normally closed valve disc. Because of system characteristics and the valve configuration, certain considerations must be given to three-way mixing valves.

Mixing Application

When using a three way mixing valve in a mixing application piped N.C. to the coil as shown in Figure 9a, the actuator must be sized to seat the upper disc against the total pressure developed by the pump. If the valve was piped N.O. to the coil the actuator would be sized to hold the lower disc closed against the total pressure developed by the pump.



IEE-WAY MIXING VALVE
FIGURE 9



MIXING APPLICATION PIPING
NORMALLY CLOSED TO THE COIL
FIGURE 9a

Given:

2-1/2 inch, V-5842, three-way mixing valve (mixing application),
20 psig maximum control pressure, 9 to 13 psig spring range, and a pump head of 34.65 feet (1 psig = 2.31 ft H_2O)

Find:

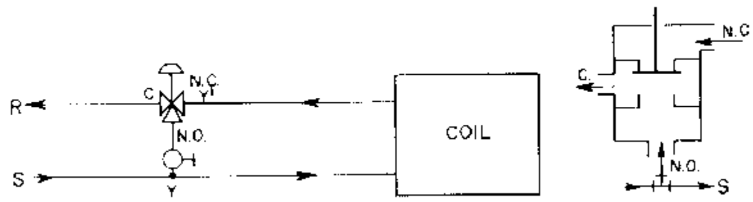
Actuator size, actual (installed) spring range, and maximum differential pressure that the valve can close against.

Solution:

Referring to Graph 21Va, 5R, and since this application is N.C. to flow through the coil, read vertically the maximum valve pressure drop (34.65/2.31 = 15 psig). Read horizontally to intersect with the
2-1/2 inch valve line. Reading vertically to the diaphragm pressure scale will show that the N.C. upper disc will remain closed with
7 psig applied to the diaphragm. Because of system characteristics, the pressure against which the lower seat must be held closed will be small and will not appreciably change the upper limit of the spring range. The actual (installed) spring range of the valve would be 7 to 13 psig and the spring would hold the upper N.C. disc against a fluid pressure of 97 psig with no air pressure on the diaphragm.

Bypass Application

When using a mixing valve in a bypass application as shown in
Figure 9b, it is recommended to size the spring and actuator to close off against twice the pressure drop across the valve plus the pressure drop through the coil. The same force is applied to the N.O. disc as well.



BYPASS APPLICATION
FIGURE 9b

Given:

A 3 inch V-5842 three-way mixing valve, 3 psig pressure drop through the valve and 20 psig maximum control pressure. Valve piped according to Fig. 9b with 9 to 13 psig spring range. Head loss through the coil is 10 feet WG or 4.34 psig. Use the previously recommended equation of (2 x ΔPv) + ΔPc to determine the maximum differential pressure.

Find:

Actual (installed) spring range, required actuator size, and maximum differential pressure the valve will close against.

Solution:

The maximum fluid pressure against which the actuator must hold the N.O. disc closed and the spring must hold the N.C. disc against is:

(2 x ΔPv) + ΔPc or

(2 x 3) + 4.34 = 10.34 psig

ΔPv = Pressure drop, through valve, psig

ΔPc = Pressure drop, through the coil, psig

Per Graph 21Va a 5R actuator would be required. Reading the valve pressure drop scale vertically to 10.34 psig, horizontally to the 3 inch valve line, N.C. port, and vertically to the diaphragm pressure scale, will show a diaphragm pressure of 6.75 psig for the spring to hold the N.C. port closed. Continuing horizontally at 10.34 psig to cross the 3 inch valve line and then vertically to the diaphragm pressure scale will show a diaphragm pressure of 15.75 psig to close the N.O. port. The actual spring range will be approximately 6.75 to 15.75 psig. The maximum differential pressure can be read directly from the valve size reference line extended to the valve pressure drop line at 0 psig and 20 psig diaphragm pressures.

Note that it is necessary to calculate the closing pressures, actual spring ranges, etc., for the N.O. and N.C. ports of the valve on this application.

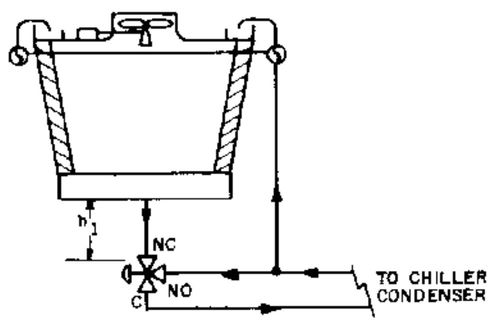
Butterfly Valves

The butterfly valve is the most commonly used valve in the HVAC industry next to the globe valve. When compared to the globe valve it has the advantage of being more compact and less expensive while having fewer parts. The design allows for bubble-tight shut-off, and it is available through JCI in sizes up to 20 in. with Cv ratings as large as 22,339. The sizing procedure of butterfly valves is based on the application. If sizing is being done for the two position application the shape of the flow characteristic is not important and a line size valve is normally installed. This is because modulating control is not needed and the pressure drop of the system will be lower. If the valve is used in a throttling application then a smaller than line size valve is installed and the Cv is calculated at
70 degree rotation. This allows for better controllability. The pressure drop for a butterfly valve is not as relevant as for a globe valve. This is because there is flow on both sides of the disc. The butterfly valve is also more likely to cavitate. Refer to the Engineering Data book section Vb:2 for further discussion.

Bypass Application - Open Circuit (Cooling Tower)

Three-Way Mixing Valve Configuration

In this open circuit a three way mixing valve is installed as shown in Figure 10. This is an extremely risky installation. For the valve to function properly, the value of h1 (in feet) multiplied by 0.433 must be greater than the pressure drop (in psig) across the valve at full flow. Otherwise, the pump suction can become restricted. The condenser water flow rate would then be reduced, and depending on the installation, the pump would be damaged by cavitation. for these reasons this arrangement is not recommended.



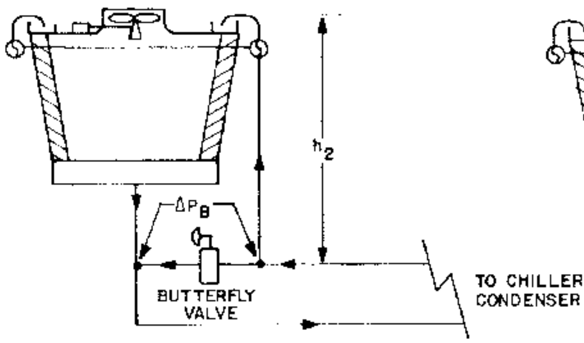
THREE-WAY MIXING VALVE
(NOT RECOMMENDED)
FIGURE 10

Single Butterfly Valve Configuration

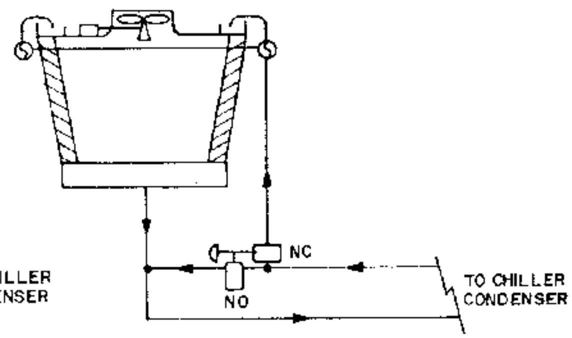
In a cooling tower arrangement a single butterfly valve is installed as shown in Figure 11. In this case the value of h2 (in feet) multiplied by 0.433 must be greater than the pressure drop (in psig) across the bypass piping and butterfly valve, ΔP_B at full flow. Otherwise, it will not be possible to stop the water flow to the hot water distribution basin. Remember a butterfly valve can pass a given amount with a much lower pressure drop than a three way valve. Also it is not unusual for cooling towers to be quite tall. The piping to the hot deck must be insulated for cold climates to prevent water freezing.

Dual Butterfly Valve Configuration

The two butterfly valves are installed as shown in Figure 12. In this case both valves are modulated in unison from the same control signal. Because one of the valves is installed



SINGLE BUTTERFLY VALVE
FIGURE 11



DUAL BUTTERFLY APPLICATION
FIGURE 12

in the piping to the hot water distribution basin, the height of the cooling tower is no longer of concern. This installation is the most trouble free installation. Unfortunately it is more costly than the single butterfly valve arrangement previously discussed.
Table 1Va and 2Va list the stroke lengths for the valves used with pneumatic actuators. Table 3Va and 4Va show the nominal shut-off pressures for the valves with electric actuator and linkage combination. Table 5Va contains the closeoff pressures for the VT valves with pneumatic and electric actuators.

Tables

TABLE 1Va
STROKES FOR ALL VALVES EXCEPT THOSE SHOWN IN TABLE 2Va

VALVE SIZE	CODE NUMBER	STROKE
1/2	V-4332,V-4440, VTM	5/16
1/2	V-3766,V-3854,V-3966	1/2
5/8	V-4334,V-4440	5/16
3/4	V-3754,V-3974,V-4324	1/2
1	V-3754,V-3974,V-4324	3/4
1 1/2	V-3754,V-3974,V-4324	3/4
1 1/2	V-5254,V-5464,V-5844	3/4
2	V-5254,V-5464,V-5844	3/4
2 1/2	V-5210,V-5252,V-5410,V-5462,V-5842	3/4
3	V-5252 (4R),V-5462 (4R)	3/4
3	V-5210,V-5252 (5R),V-5410,V-5462 (5R) ,V-5842	1 1/8
4	V-5210,V-5252,V-5410,V-5462,V-5842	1 1/8
5	V-5252,V-5462,V-5842	1 3/8
6	V-5252,V-5462,V-5842	1 1/2

TABLE 2Va
STROKES FOR V-7216 & V-7416

VALVE SIZE	STROKE
1/2	5/16
3/4 & 1	3/8
1 1/4, 1 1/2, 2	1/2

The metal-metal seating and high temperature teflon packing of the valves in Table 2Va allow for use in high temperature (338°F.) and pressure applications.

TABLE 3Va
NOMINAL SHUT-OFF PRESSURES
VA-8050 AND M100 SERIES ACTUATORS
(2-WAY VALVES)

VALVE BODY	VA-8050	M110 Y20EBD-5	M120/130 Y20EBD-1	M120/130 Y20EBD-6	M140 Y20EBD-2	M150 Y20EBD-3	M150 Y20EBD-4
VB-3752-19			5	11	21	46	26
VB-3752-22				7	13	30	18
VB-3752-25					5	15	7
VB-3754-4	80	60	124	150	150	150	150
VB-3754-5	45	35	72	97	150	150	150
VB-3754-6	20	15	32	44	70	130	80
VB-3754-7		7	17	25	40	75	45
VB-3970-11			5	11	22	47	27
VB-3970-14				7	14	31	18
VB-3970-17					6	15	7
VB-3974-4	85	62	132	150	150	150	150
VB-3974-5	45	35	74	102	150	150	150

* Shut-off values do not exceed 150 psig because of the potential for cavitation.

TABLE 4Va
NOMINAL SHUT-OFF PRESSURES
VA-8050 AND M100 ACTUATORS
(3-WAY VALVES)

VALVE BODY							
	VA-8050	M110 Y20EBD-5	M120/130 Y20EBD-1	M120/130 Y20EBD-6	M140 Y20EBD-2	M150 Y20EBD-3	M150 Y20EBD-4
VB-4322-9			5	11	21	46	26
VB-4322-11				7	13	30	18
VB-4322-13					5	15	7
VB-4324-4	80	60	124	150	150	150	150
VB-4324-5	45	35	72	97	150	150	150
VB-4324-6	20	15	32	44	70	130	80
VB-4324-7		7	17	25	40	75	45

* Maximum shut-off pressure is determined by the piping configuration. Refer to previous discussion.

TABLE 5Va
CLOSEOFF PRESSURES FOR VT VALVES WITH PNEUMATIC AND ELECTRIC ACTUATORS

ACTUATOR TYPE	EFFECTIVE AREA/OUTPUT FORCE	NOMINAL SPRING RANGE PSIG kPa	SUPPLY PRESS. PSIG kPa	N.O. TWO-WAY AND N.O. PORT THREE WAY PSIG kPa		N.C. TWO-WAY AND N.C. PORT THREE-WAY PSIG kPa	
				cv= 0.7	cv= 1.9 or 4.7	cv= 0.7	cv= 1.9 or 4.7
PNEUMATIC V-3000	8 sq. in. 5,160 sq mm	3 to 6 21 to 42	15 105	345 2415	212 1484	250 1750	71 497
			20 140	345 2415	338 2366		
		4 to 8 28 to 56	15 105	345 2415	161 1127	345 2415	101 707
			20 140	345 2415	287 2009		
		9 to 13 63 to 91	15 105	88 616	35 245	345 2415	250 1750
			20 140	345 2415	161 1127		
PNEUMATIC V-3802	4 sq. in. 2,580 sq mm	3 to 6 21 to 42	15 105	248 1736	98 686	-----	------
			20 140	345 2415	161 1127		
		4 to 8 28 to 56	15 105	184 1288	73 511	-----	-------
			20 140	344 2408	136 952		
		9 to 13 63 to 91	15 105	-----	-----	345 2415	116 812
			20 140	184 1288	73 511		
ELECTRIC VA-8020 & VA-8022	22 lb 98 N	--------	------	136 952	54 378	224 1568	64 448
ELECTRIC VA-8050, VA-8051 & VA-8052	50 lb 222 N	-------	------	345 2415	142 994	345 2415	168 1176
M110 with Y20EBD-5 LINKAGE	40 lb 178 N	--------	------	280 1960	111 777	345 2415	131 917

TABLE 6Va
NOMINAL SPRING RANGE SHIFT DUE TO LOWER SPRING PLATE ADJUSTMENTS ON VALVES WITH V-3000 ACTUATORS

CODE NUMBER	VALVE SIZE	SPRING RANGE	ADJUSTED SPRING RANGE			ADJUST RATIO
			1 TURN	2 TURNS	3 TURNS	
V-3966	1/2	9-13	9.44-13.44	9.88-13.88	10.32-14.32	0.44
V-3974	1/2	9-13	9.44-13.44	9.88-13.88	10.32-14.32	0.44
	3/4	9-13	9.44-13.44	9.88-13.88	10.32-14.32	0.44
	1	9-13	9.30-13.30	9.60-13.60	9.90-13.90	0.30
	1-1/2	9-13	9.30-13.30	9.60-13.60	9.90-13.90	0.30
V-4324	1/2	3-6	3.44-6.44	3.88-6.88	4.32-7.32	0.44
		9-13	9.44-13.44	9.88-13.88	10.32-14.32	0.44
	3/4	3-6	3.44-6.44	3.88-6.88	4.32-7.32	0.44
		9-13	9.44-13.44	9.88-13.88	10.32-14.32	0.44
V-4332	1/2	3-6	3.71-6.71	4.42-7.42	5.13-8.13	0.71
		9-13	9.71-13.71	10.42-14.42	11.13-15.13	0.71
V-4334	5/8	4-8	4.71-8.71	5.42-9.42	6.13-10.13	0.71
		9-13	9.71-13.71	10.42-14.42	11.13-15.13	0.71
VTM	1/2	3-6	3.53-6.53	4.06-7.06	4.59-7.59	0.53
		4-8	4.71-8.71	5.42-9.42	6.13-10.13	0.71
		9-13	9.71-13.71	10.42-14.42	11.13-15.13	0.71

Adjust Ratio Units - psi per revolution of lower spring plate
The spring ranges given are **Nominal Values**. The actual values will depend on the valve style and piping configuration of the system. If the valve is normally open (N.O.), then the nominal spring range will be shifted up **(e.g., 3-6# = 3-7#)**. If the valve is normally closed **(N.C.)**, then the nominal spring range will be shifted down **(e.g., 9-13# = 8-13#)**. If the valve is a mixing valve **(MIX)**, the spring shift will depend on the piping configuration. For systems piped N.C. to the coil, the system pressure will shift the spring down. For systems piped N.O. to the coil, the system will shift the spring up.
These spring ranges can be shifted without having to buy additional equipment such as a sequencer or positioner. By rotating the lower spring plate counterclockwise the spring range can be shifted up. The exact amount depends on the valve size and spring range. Table 5Va shows the adjusted **nominal** spring ranges for one, two or three counterclockwise turns of the lower spring plate. The Adjust Ratio was used to calculate each of the Adjusted Spring Ranges.

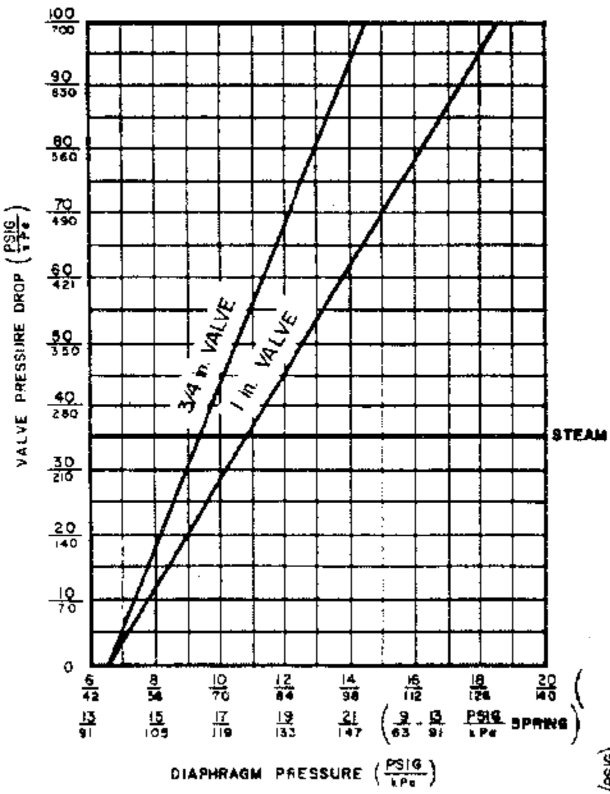
Example

If the lower spring plate on the 3/4 inch V-3974 was rotated counterclockwise two full turns the spring range would be shifted up
.88 psi (2 revs x .44 psi/rev = .88 psi) or (9.88-13.88).

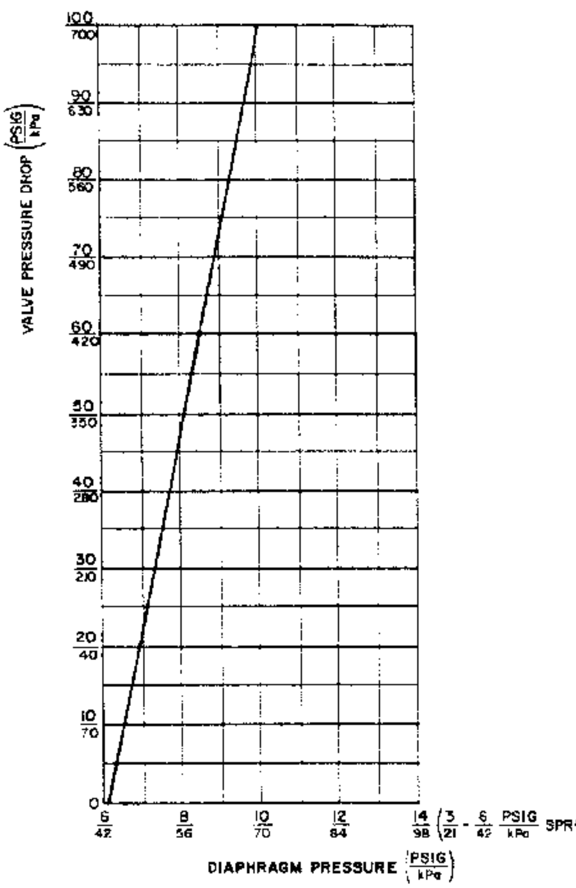
TABLE 7Va
SHUT-OFF PRESSURE GRAPHS PER VALVE, ACTUATOR SIZE AND SPRING RANGE

Valve	Actuator	Spring	Graph
V-3754	V-3000	3-6	1Va
V-3766	V-3000	9-13	2Va
V-3854	V-3000 V-3000	3-6 9-13	3Va
V-3966	V-3000	9-13	4Va
V-3974	V-3000	9-13	5Va
V-4324	V-3000 V-3000	4-8 9-13	6Va
V-4332	V-3000 V-3000	4-8 9-13	7Va
V-4334	V-3000 V-3000	4-8 9-13	8Va
V-4440	V-3000 V-3000	4-12 6-9	9Va 10Va
V-5210	8R	3-7	11Va
V-5252	4R 4R 5R 8R	2-5 9-13 2-5 2-5	12Va 13Va 14Va
V-5410	8R	9-14	15Va
V-5462	4R 5R 8R	9-13	16Va 17Va 18Va
V-5464	4R	9-13	19Va
V-5842	4R 4R 5R 8R	4-8 9-13 9-13 9-13	20Va 21Va 22Va
V-5844	4R 4R	4-8 9-13	23Va
V-7216	V-3000 4R 5R	3-7	24Va 25Va 26Va
V-7416	V-3000 4R 5R	9-14	27Va 28Va 29Va
VTM (N.O.)	V-3000 V-3802	3-6 4-8 9-13	30Va
VTM (N.C.)	V-3000 V-3802	3-6 4-8 9-13 9-13	31Va 32Va 32Va 33Va

NOMINAL SHUTOFF PRESSURES

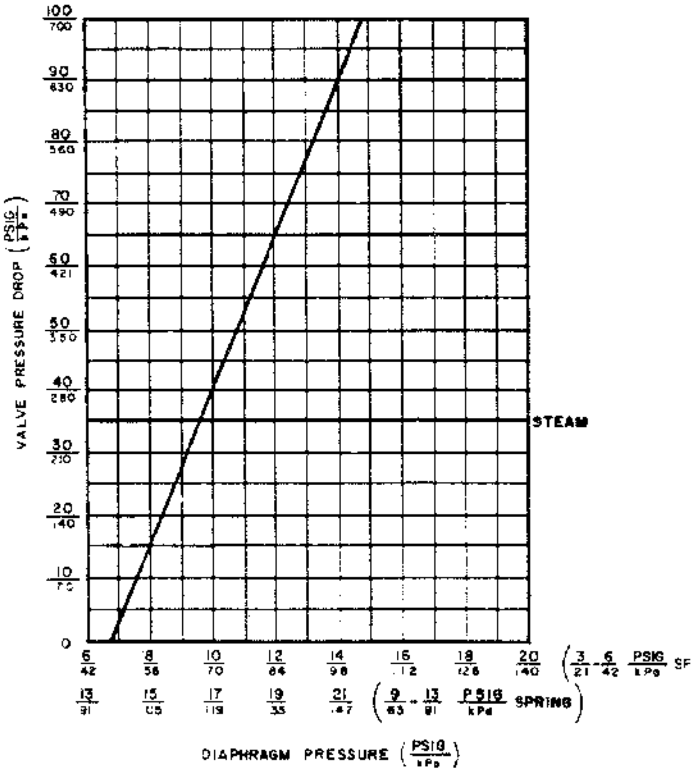


Graph 1Va:
V-3754 with V-3000 Actuator

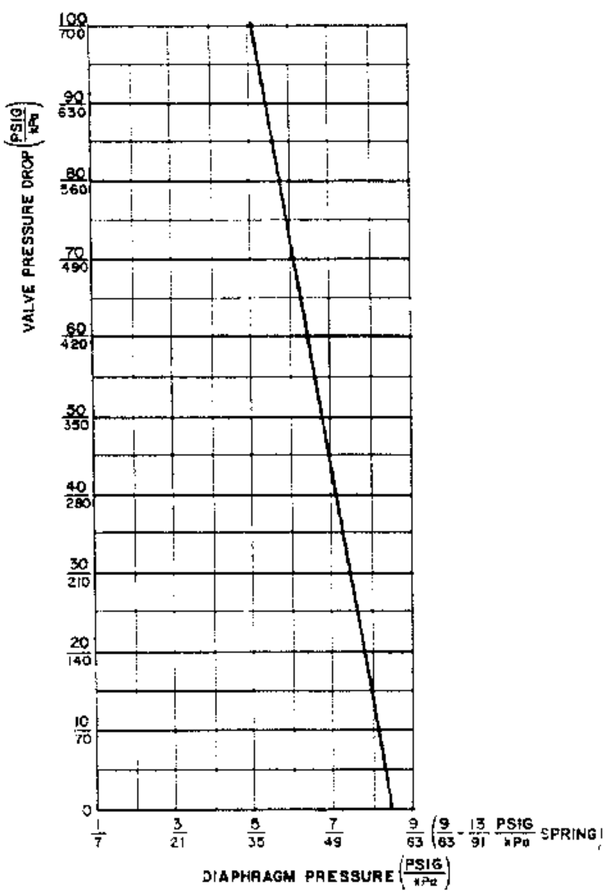


Graph 2Va:
V-3766 with V-3000 Actuator

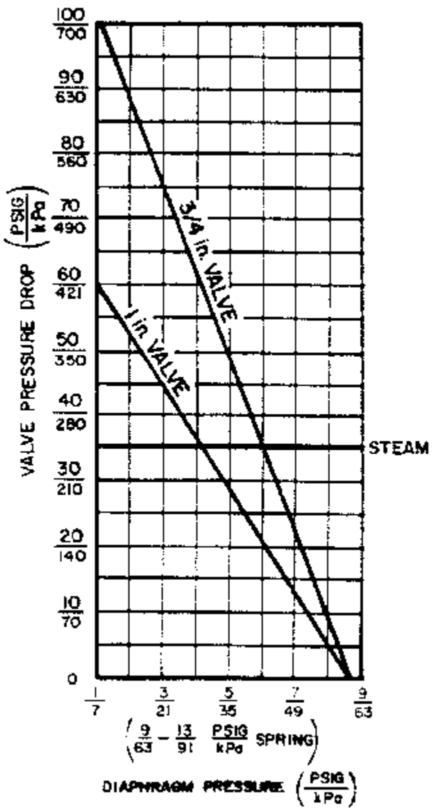
NOMINAL SHUTOFF PRESSURES



Graph 3Va:
V-3854 with V-3000 Actuator

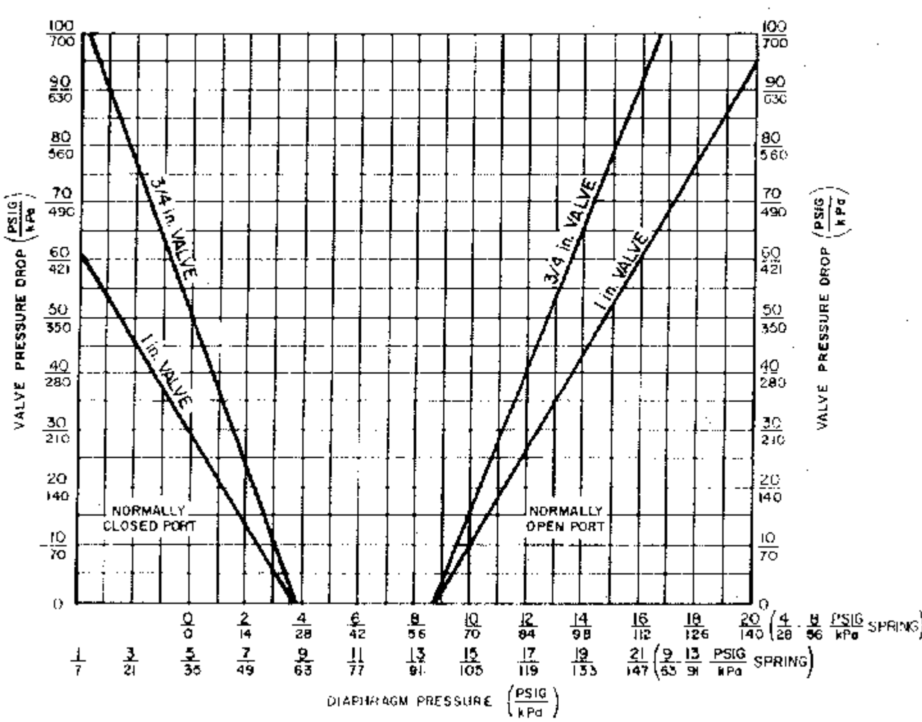


Graph 4Va:
V-3966 with V-3000 Actuator

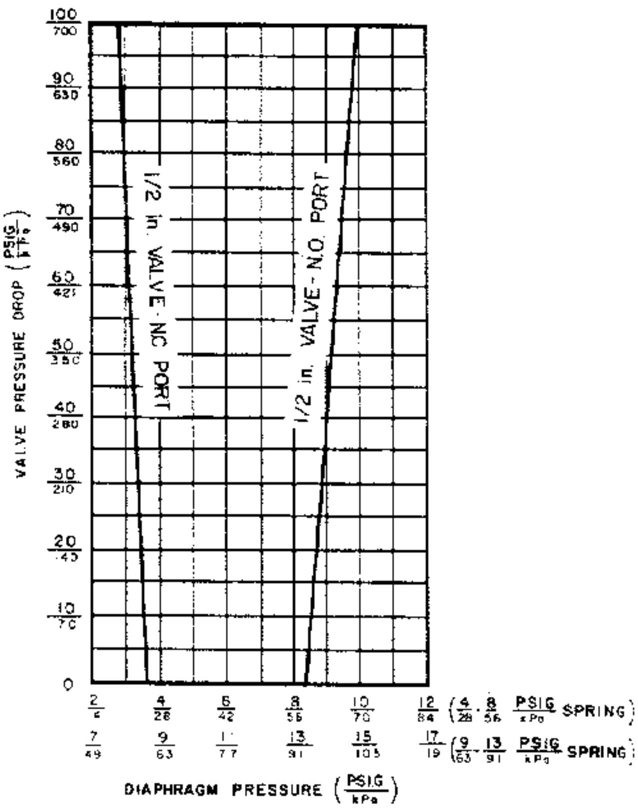


Graph 5Va:

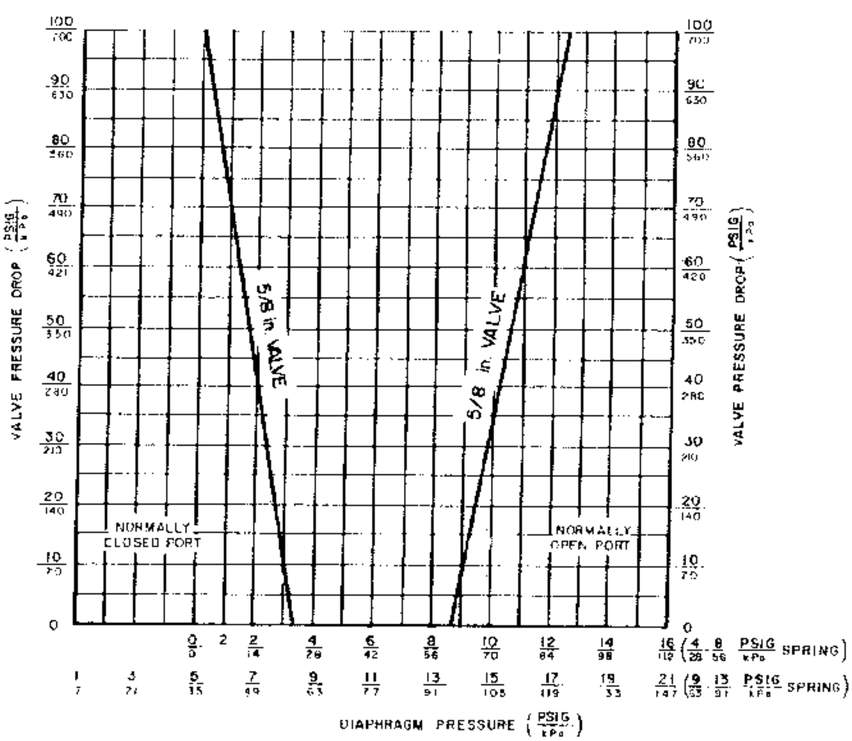
V-3974 with V-3000 Actuator



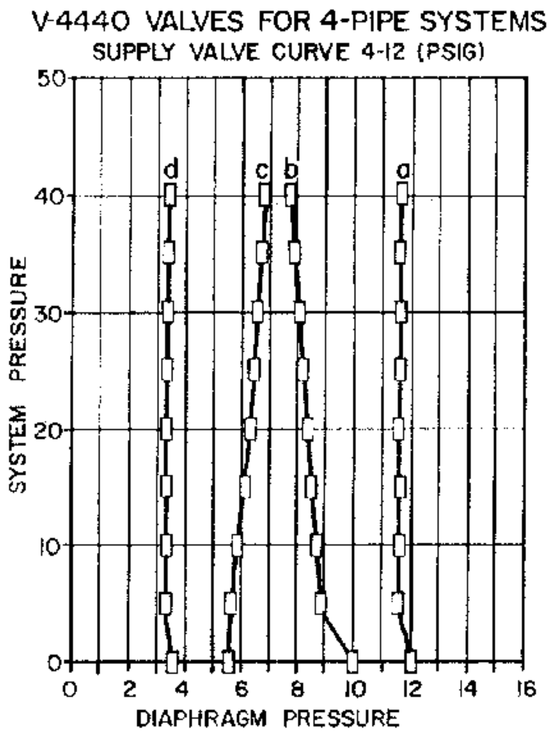
Graph 6Va: V-4324 with V-3000 Actuator



Graph 7Va: V-4332 with V-3000 Actuator



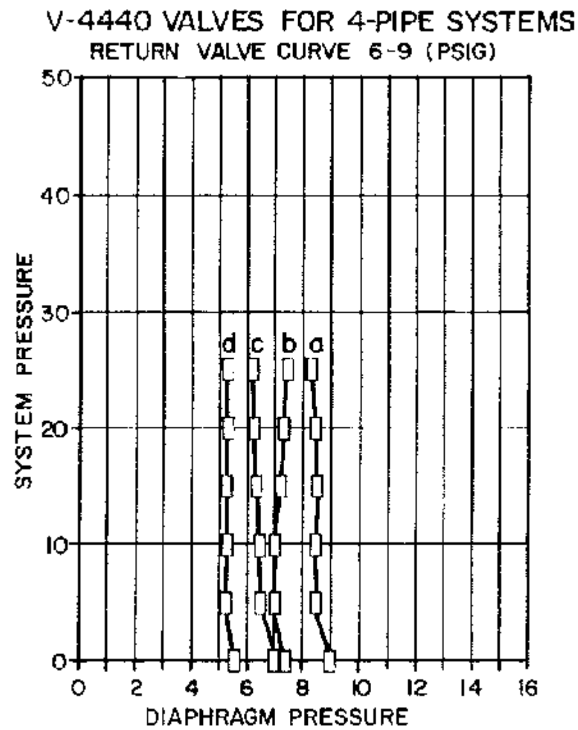
Graph 8Va: V-4334 with V-3000 Actuator



KEY

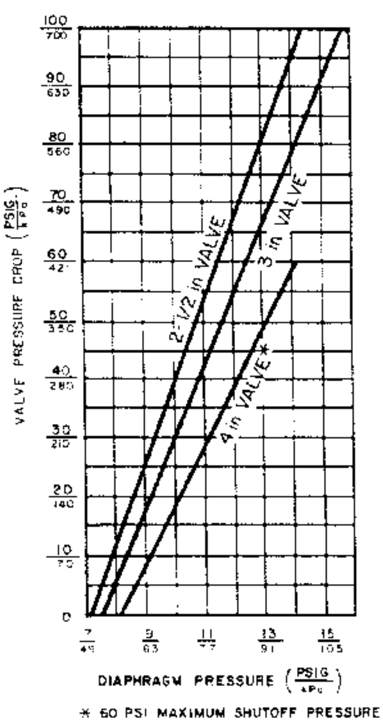
a. N.C. PLUG OPEN
b. N.C. PLUG CLOSED
c. N.O. PLUG CLOSED
d. N.O. PLUG OPEN

Graph 9Va:

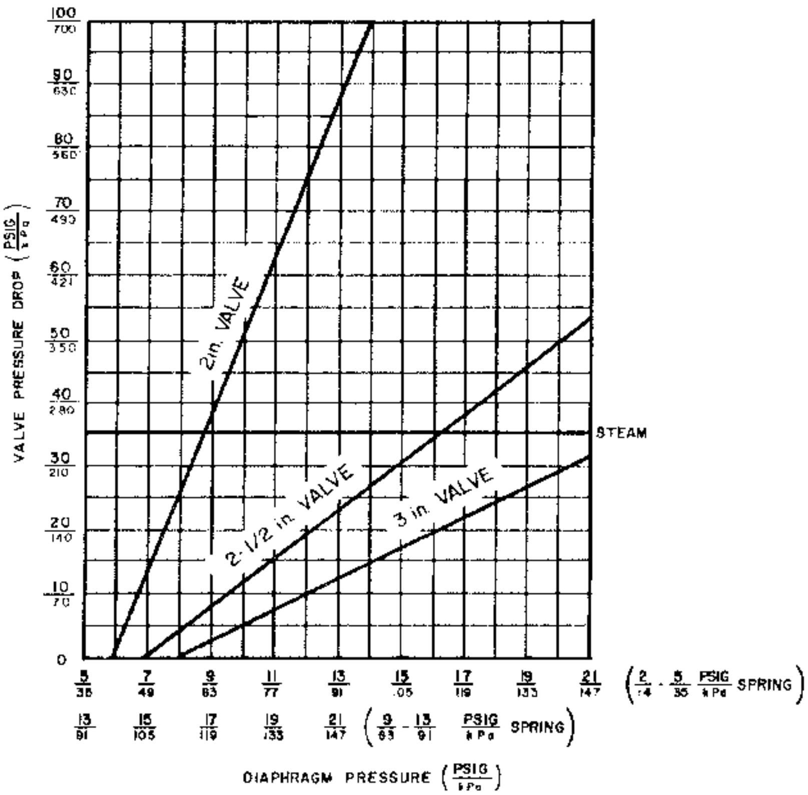


a. N.C. PLUG OPEN
b. N.C. PLUG CLOSED
c. N.O. PLUG CLOSED
d. N.O. PLUG OPEN

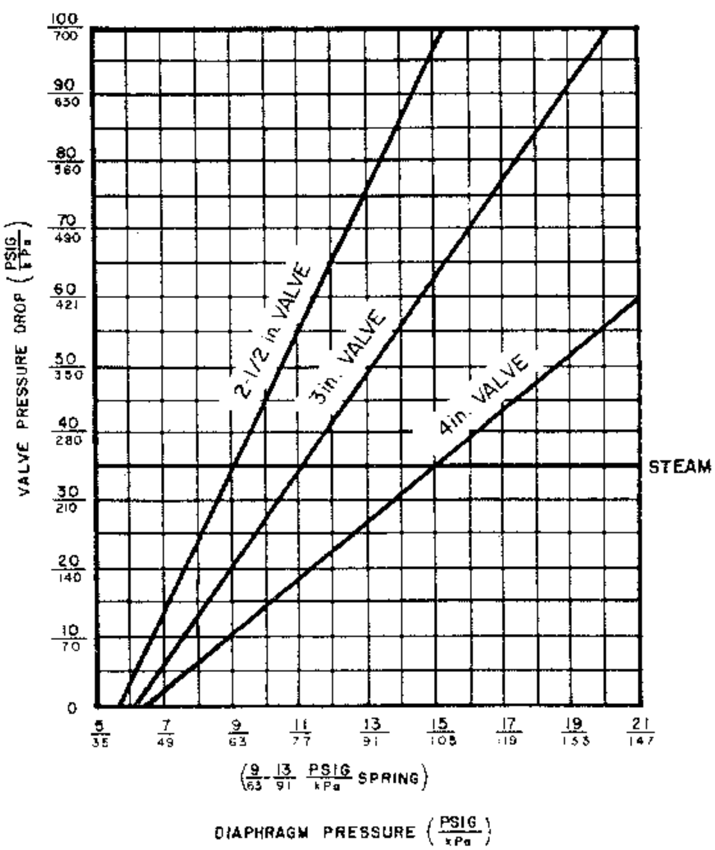
Graph 10Va:



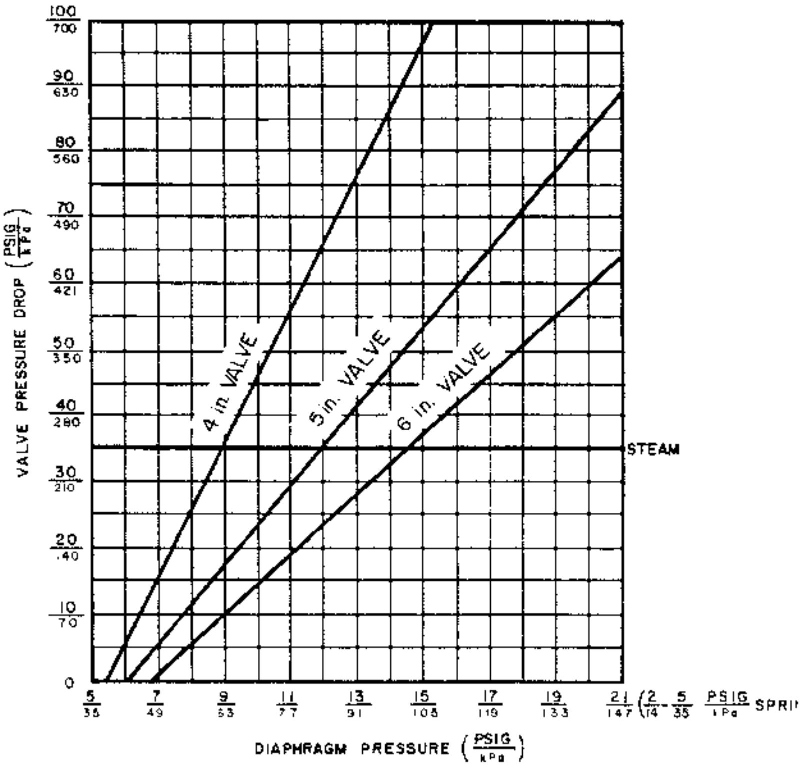
Graph 11Va:
V-5210 with 8R Actuator



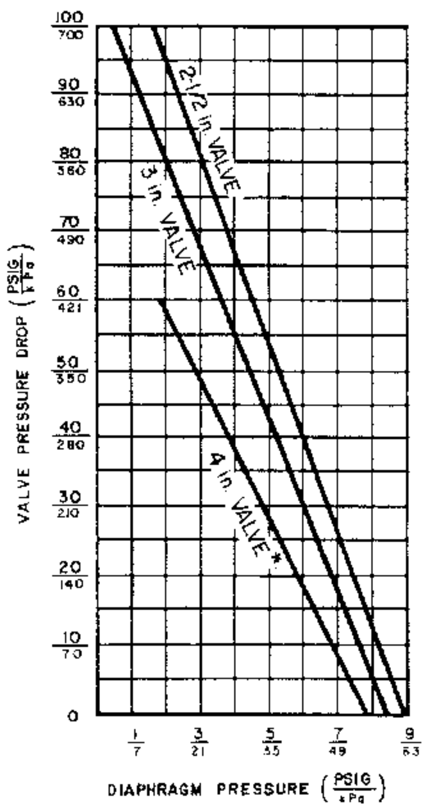
Graph 12Va: V-5252 with 4R Actuator



Graph 13Va: V-5252 with 5R Actuator

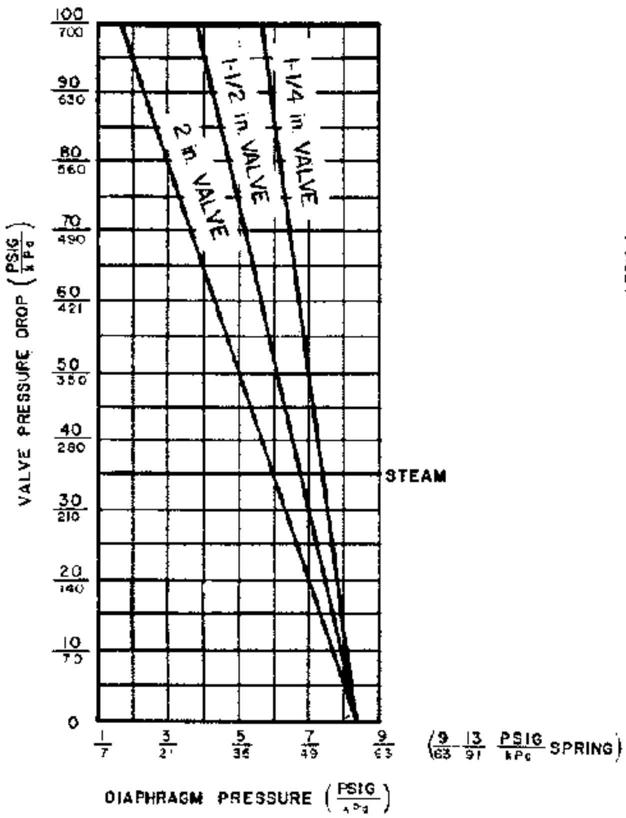


Graph 14Va: V-5252 with 8R Actuator

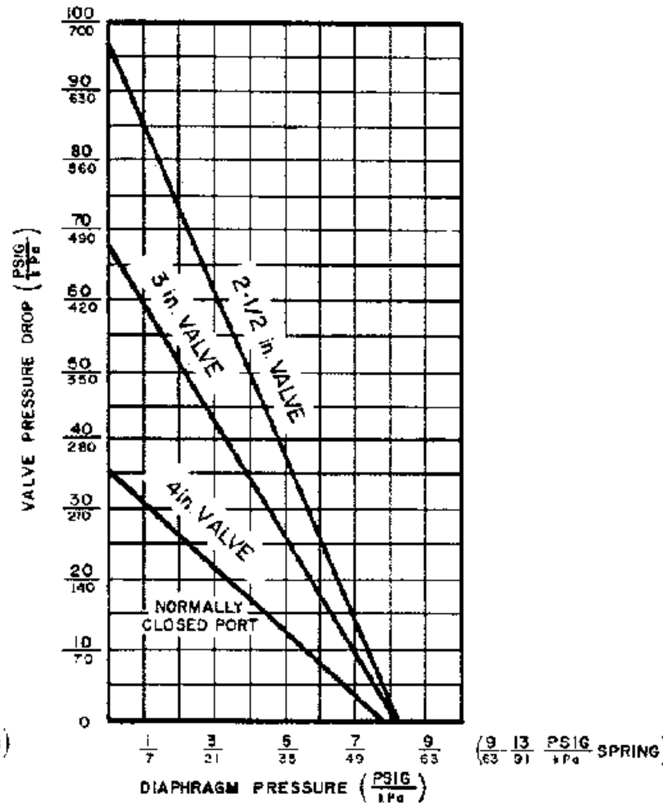


* 60 PSI MAXIMUM SHUTOFF PRESSURE

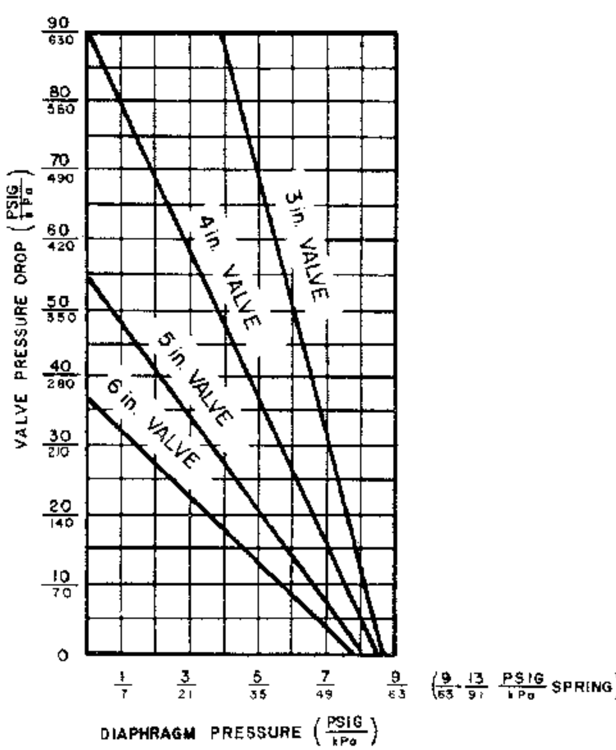
Graph 15Va:
V-5410 with 8R Actuator



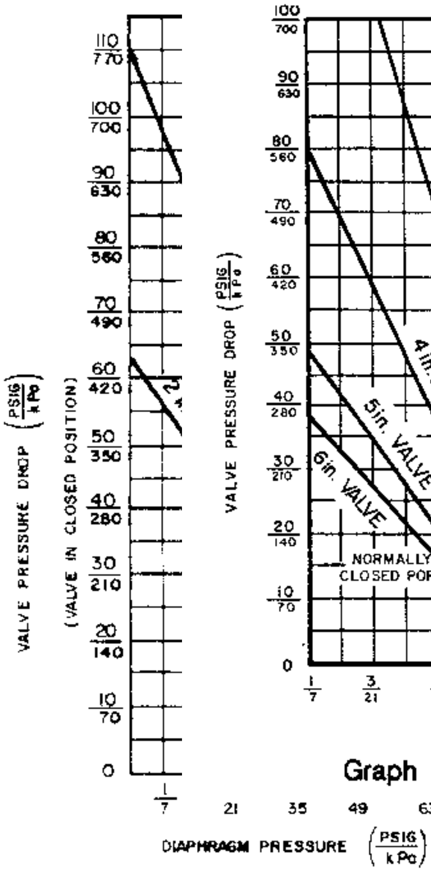
Graph 16Va:
V-5462 with 4R Actuator

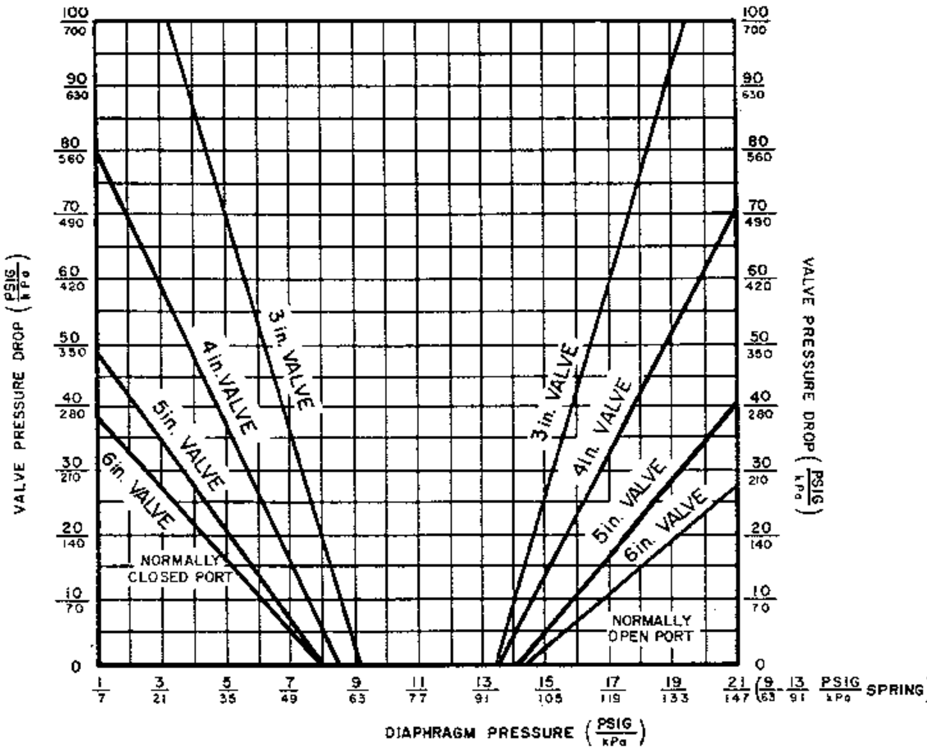


Graph 17Va:
V-5462 with 5R Actuator

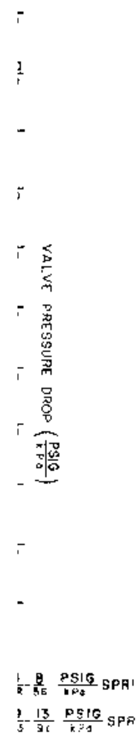


Graph 18Va:
V-5462 with 8R Actuator





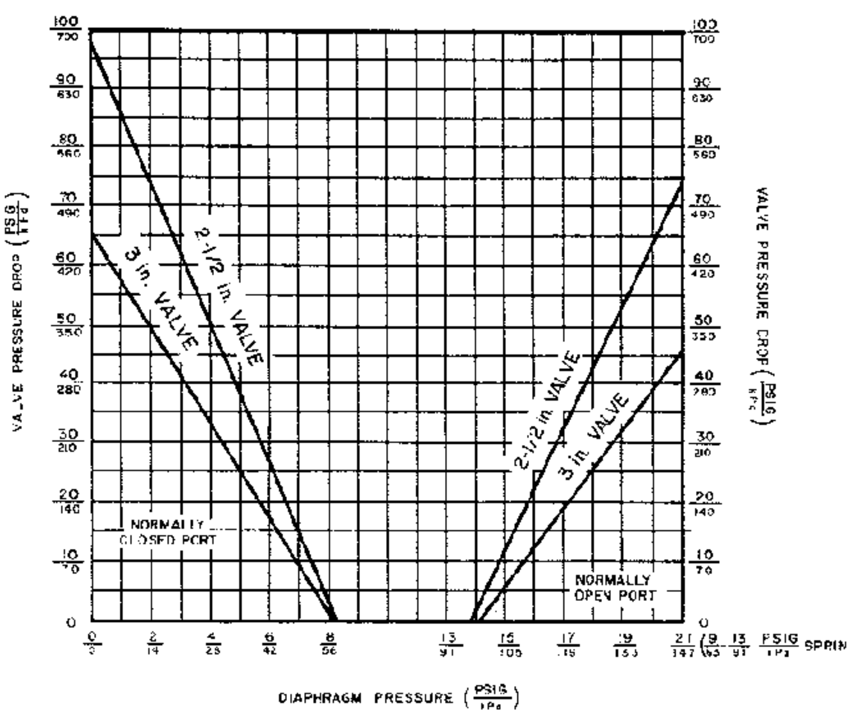
Graph 22Va: V-5842 with 8R Actuator



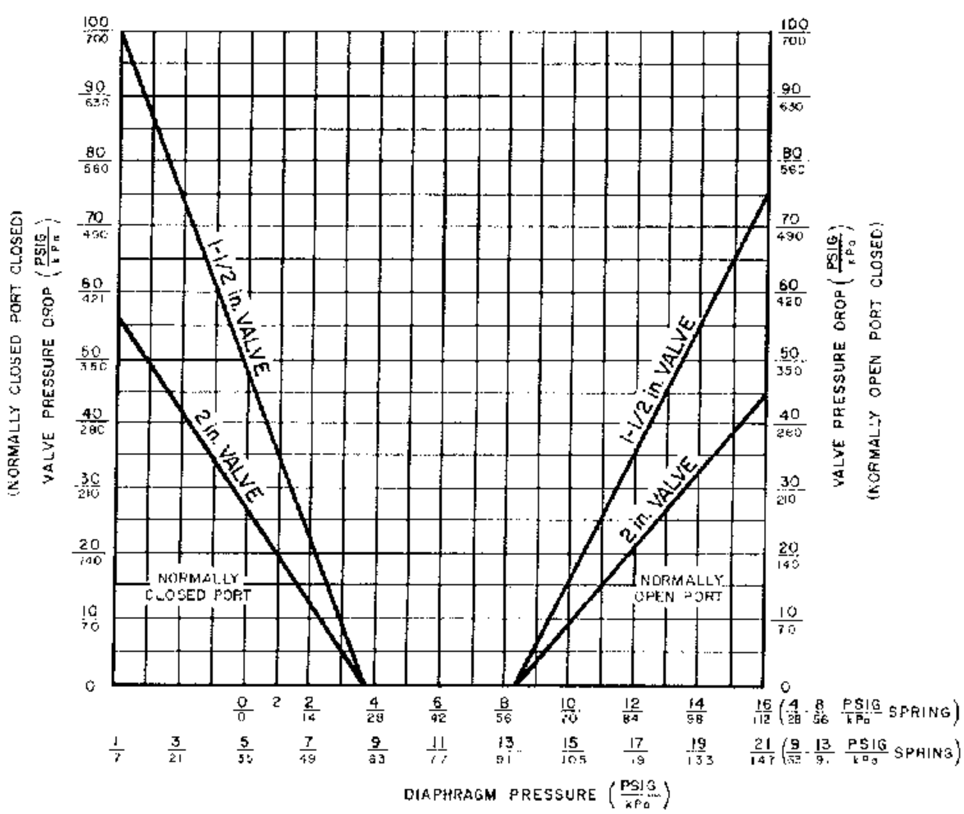
Graph 20Va: V-5842 with 4R Actuator

Graph 19Va:

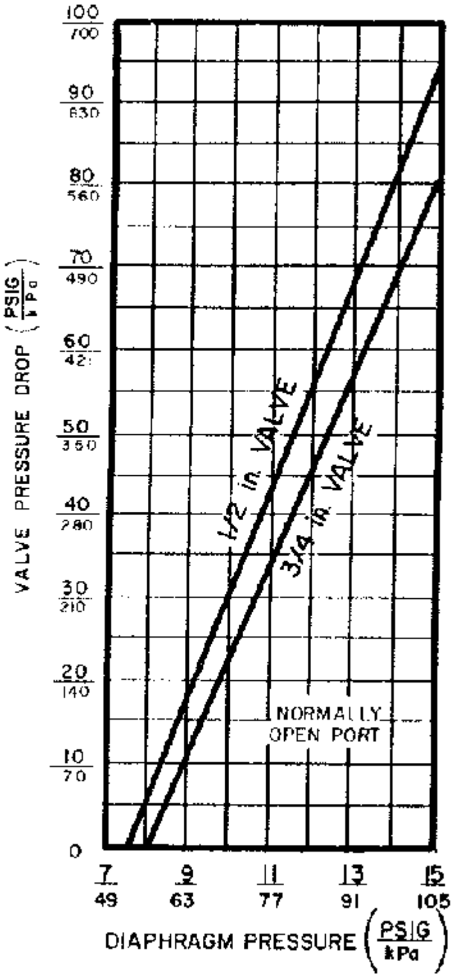
V-5464 Nominal Shutoff Pressures



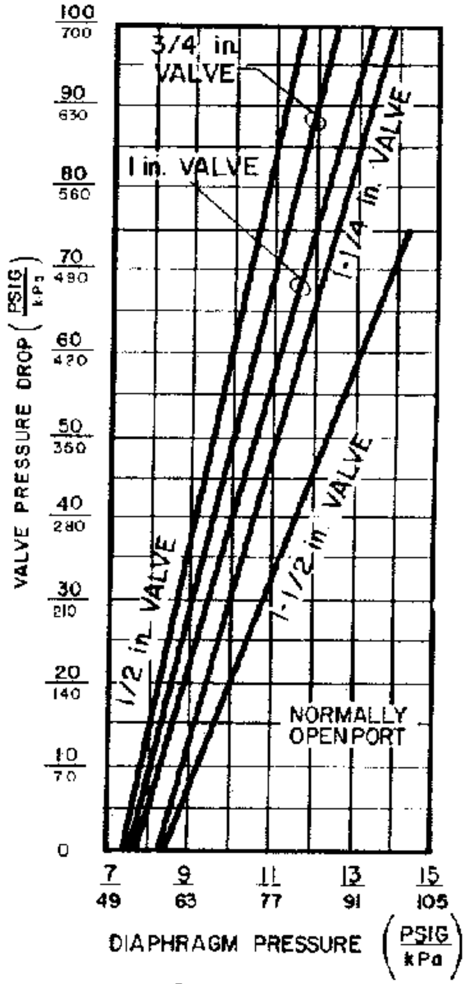
Graph 21Va: V-5842 with 5R Actuator



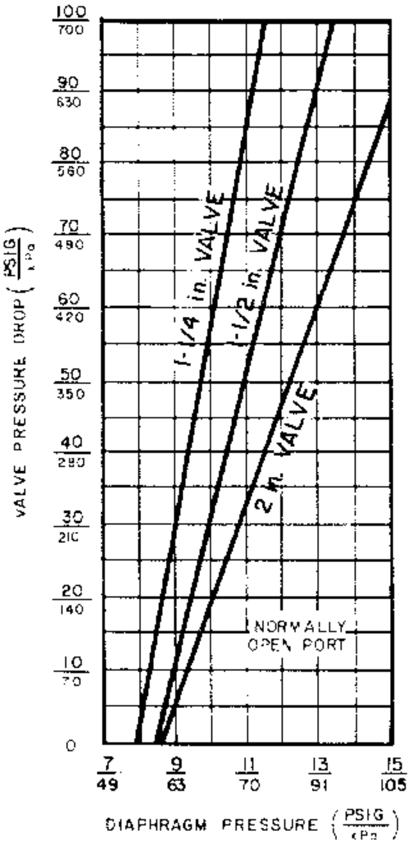
Graph 23Va: V-5844 Nominal Shutoff Pressures



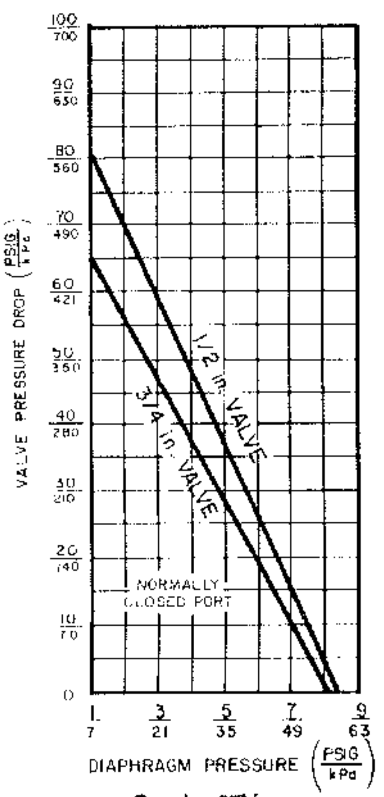
Graph 24Va:
V-7216 with V-3000 Actuator



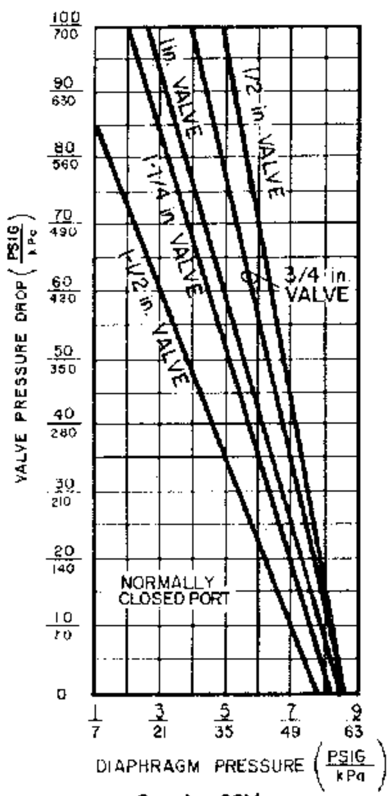
Graph 25Va:
V-7216 with 4R Actuator



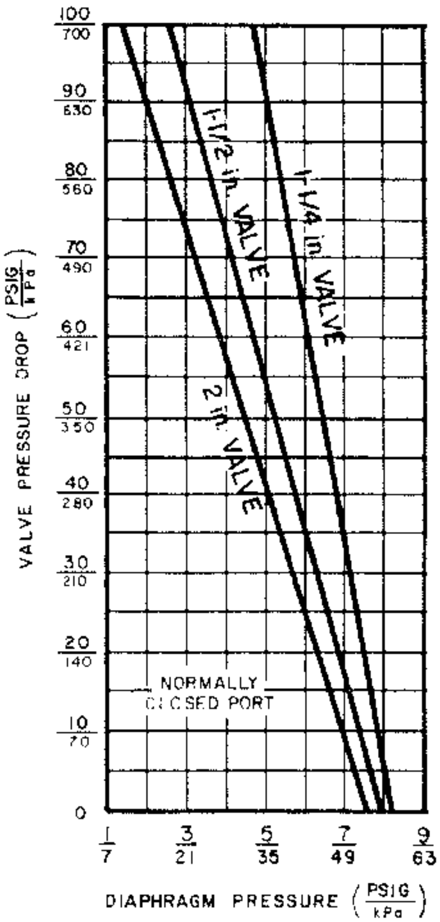
Graph 26Va:
V-7216 with 5R Actuator



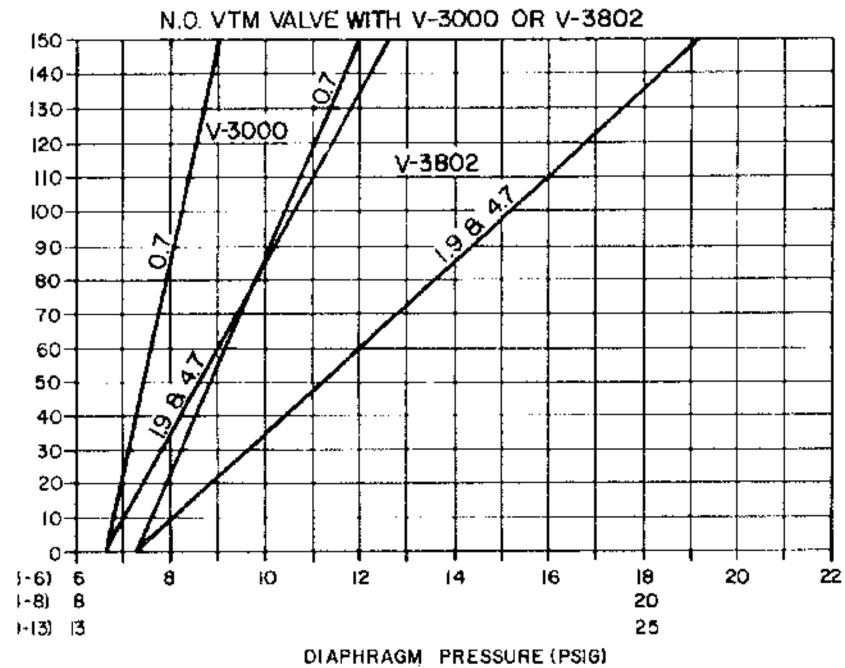
Graph 27Va:
V-7416 with V-3000 Actuator



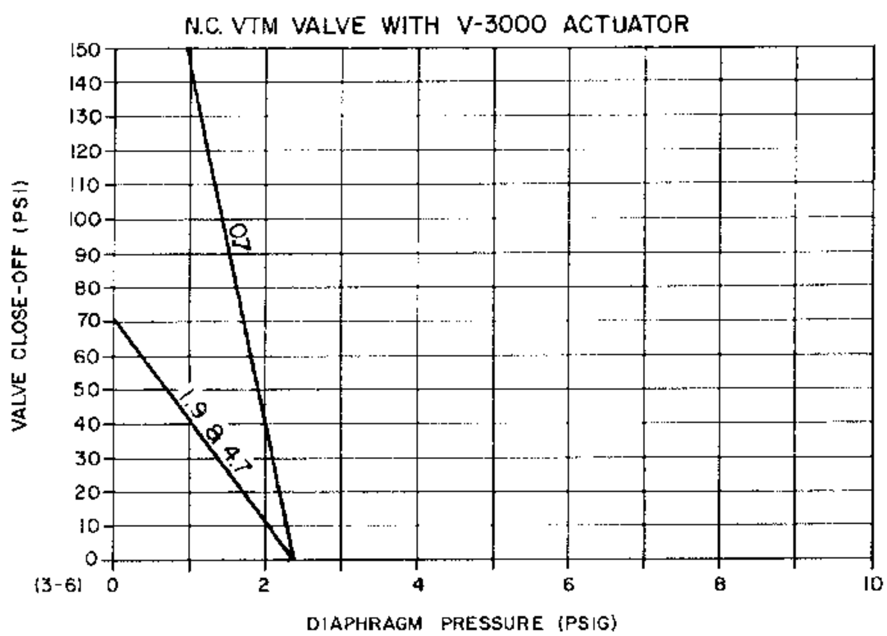
Graph 28Va:
V-7416 with 4R Actuator



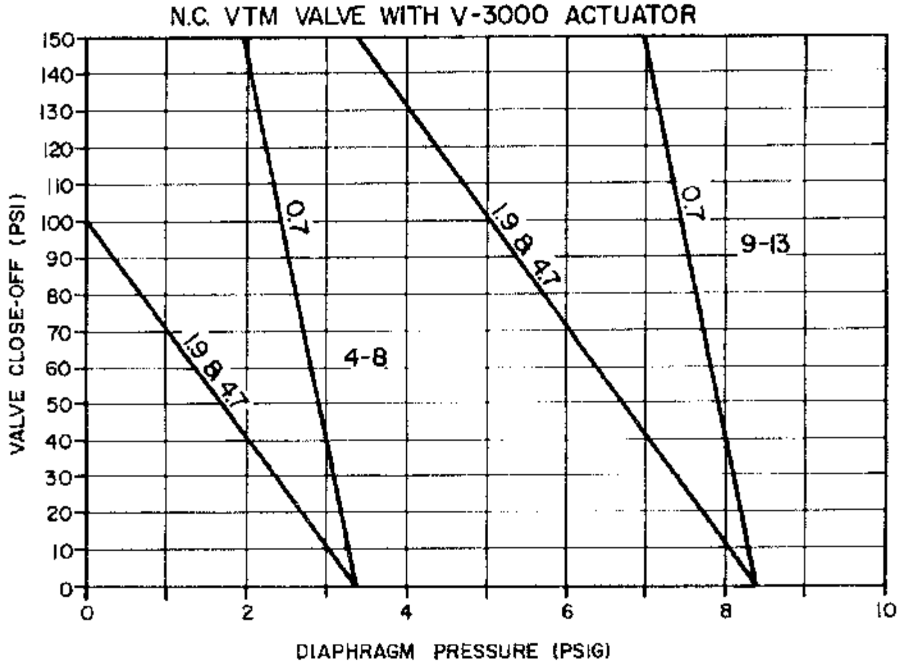
Graph 29Va:
V-7416 with 5R Actuator



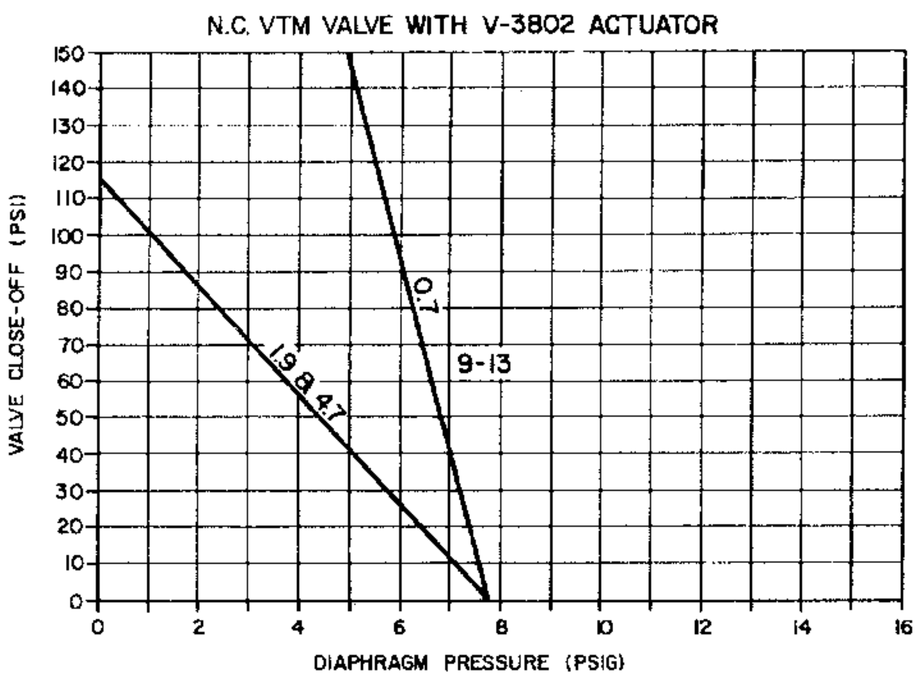
Graph 30Va:



Graph 31Va:



Graph 32Va:



Graph 33Va:

Notes

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