SIZING PNEUMATIC CYLINDERS and ISO VALVES

Look at flow coefficient, cylinder bore, and rod speed to best match pneumatic actuators and valves.

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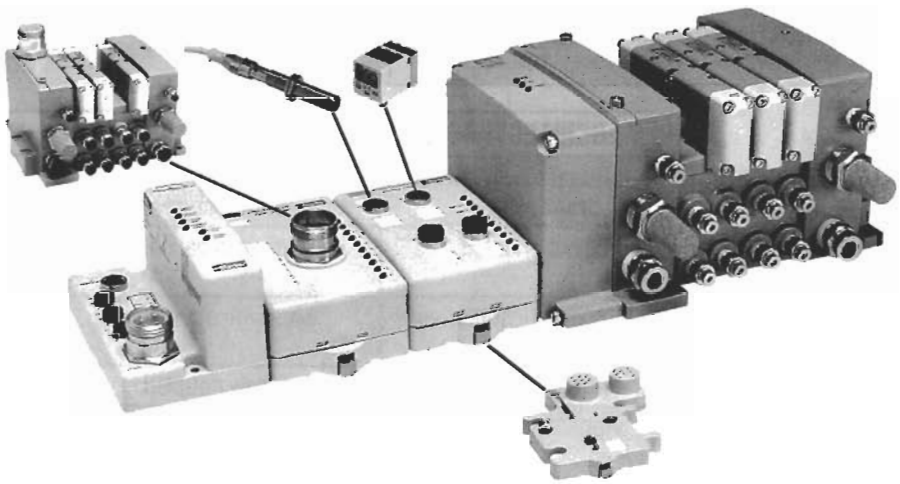

Parker's Isysnet Field Bus System includes a valve drive module that controls up to 32 solenoids; I/O modules with up to 256 inputs and 256 outputs; and communications modules using EtherNet/IP, ControlNet, DeviceNet, and Profibus DP. The plug-in pneumatic valves meet ISO 15407 and 5599 dimensional and electrical standards.

In recent years, much discussion has centered on C_v ratings (also known as capacity coefficients or flow factors) and whether or not American, European, and Japanese pneumatic-valve manufacturers rate valves the same way. With ANSI/NFPA, ISO, and JIS organizations all specifying slightly different test methods and rating criteria, the confusion is understandable.

Leaving that ongoing discussion to the respective standards organizations, here's a look at the practical aspects of designing the most efficient and economical system without under or oversizing components. First, we'll calculate C_vs for standard pneumatic cylinders and examine C_v values for standard ISO valves, including 18 and 26 mm and ISO Sizes 1, 2, and 3. We'll also chart average rod speed relative to cylinder bore size to pinpoint ISO valves that best match flow demands.

Edited by Kenneth Korane

The approach is based on standard C_v calculations:

$$C_v = \frac{Q}{22.48\sqrt{\frac{GT}{(P_1 - P_2)P_2}}}$$

where Q = volumetric flow rate in standard cubic feet per minute (scfm), based on 14.7-psi atmospheric pressure and 60°F air temperature.

To simplify the equation, experts typically assume a conservative pressure change between inlet and outlet ports ($P_1 - P_2$) of 5 psi. For time or process-critical applications, reduce this to 2 psi. And, in many cases, a pressure drop of 10 psi is not detrimental to the application. A 10-psi pressure drop permits smaller valves that lower costs and require less mounting space.

To simplify calculations, let's tabulate values for a portion of

C_v VALUES FOR TWO-POSITION ISO VALVES

Average rod speed, mm/sec	Cylinder diameter, mm														
	8	10	12	16	20	25	32	40	50	63	80	100	125	160	200
25	0.001	0.001	0.002	0.003	0.005	0.008	0.013	0.021	0.032	0.051	0.063	0.129	0.202	0.331	0.517
50	0.002	0.003	0.004	0.007	0.010	0.016	0.026	0.041	0.065	0.103	0.166	0.259	0.404	0.662	1.035
75	0.002	0.004	0.006	0.010	0.016	0.024	0.040	0.062	0.097	0.154	0.248	0.388	0.606	0.994	1.552
100	0.003	0.005	0.007	0.013	0.021	0.032	0.053	0.083	0.129	0.205	0.331	0.517	0.809	1.325	2.070
125	0.004	0.006	0.009	0.017	0.026	0.040	0.066	0.103	0.162	0.257	0.414	0.647	1.011	1.656	2.587
150	0.005	0.008	0.011	0.020	0.031	0.049	0.079	0.124	0.194	0.308	0.497	0.776	1.213	1.987	3.105
175	0.006	0.009	0.013	0.023	0.036	0.057	0.093	0.145	0.226	0.359	0.580	0.906	1.415	2.318	3.622
200	0.007	0.010	0.015	0.026	0.041	0.065	0.106	0.166	0.259	0.411	0.662	1.035	1.617	2.649	4.140
225	0.007	0.012	0.017	0.030	0.047	0.073	0.119	0.186	0.291	0.462	0.745	1.164	1.819	2.981	4.657
250	0.008	0.013	0.019	0.033	0.052	0.081	0.132	0.207	0.323	0.513	0.828	1.294	2.021	3.312	5.174
275	0.009	0.014	0.020	0.036	0.057	0.089	0.146	0.228	0.356	0.565	0.911	1.423	2.223	3.643	5.692
300	0.010	0.016	0.022	0.040	0.062	0.097	0.159	0.248	0.388	0.616	0.994	1.552	2.426	3.974	6.209
325	0.011	0.017	0.024	0.043	0.067	0.105	0.172	0.269	0.420	0.667	1.076	1.682	2.628	4.305	6.727
350	0.012	0.018	0.026	0.046	0.072	0.113	0.185	0.290	0.453	0.719	1.159	1.811	2.830	4.636	7.244
375	0.012	0.019	0.028	0.050	0.078	0.121	0.199	0.310	0.485	0.770	1.242	1.940	3.032	4.968	7.762
400	0.013	0.021	0.030	0.053	0.083	0.129	0.212	0.331	0.517	0.822	1.325	2.070	3.234	5.299	8.279
425	0.014	0.022	0.032	0.056	0.088	0.137	0.225	0.352	0.550	0.873	1.407	2.199	3.436	5.630	8.797
450	0.015	0.023	0.034	0.060	0.093	0.146	0.238	0.373	0.582	0.924	1.490	2.329	3.638	5.961	9.314
475	0.016	0.025	0.035	0.063	0.098	0.154	0.252	0.393	0.614	0.976	1.573	2.458	3.840	6.292	9.832
500	0.017	0.026	0.037	0.066	0.103	0.162	0.265	0.414	0.647	1.027	1.656	2.587	4.043	6.623	10.349

VALVE RATINGS

		C_v values	
ISO valve size	PH designation	Two position	Three position
18 mm	HB	0.55	0.5
26 mm	HA	1.1	1.0
Size 1	H1	1.5	1.2
Size 2	H2	3.0	2.8
Size 3	H3	6.0	5.0

These tables chart flow requirements based on cylinder size and average rod speed. The large table highlights two-position ISO valves that meet the needed C_v.

the equation for 2, 5, and 10-psi pressure changes. Here, we create a constant A, defined as

$$A = \frac{1}{22.48}\sqrt{\frac{GT}{(P_1 - P_2)P_2}}$$

and list values for varying inlet gage pressures in the accompanying Basic Data table.

This reduces the flow-coefficient equation to $C_v = QA$. In terms of cylinder volume and time,

$$Q = \frac{VP_1}{28.8tP_a}$$

where atmospheric pressure, P_a, is assumed to be 14.7 psi.

Next, calculate values for compression ratio, $C_r = P_1/P_a$, for various inlet pressures and also list values in the Basic Data table.

Restating the volumetric flow-rate equation in terms of compression ratio results in

$$Q = \frac{VC_r}{28.8t}$$

Now examine the impact of cylinder volume and stroke time for known C_v values of ISO valves. Given that $C_v = QA$; and $V = (\pi/4)d^2l$, we can restate the equation as:

$$C_v = \left(\frac{(\pi/4)C_rA}{28.8}\right)\left(\frac{l}{t}\right)\left(d^2\right)$$

Here, l/t is a simplified representation of average rod velocity in inches per second.

This equation works well for NFPA cylinders. But because designers usually specify ISO cylinders in metric units, apply the conversion factor 1 in. = 25.4 mm and revise the equation:

$$C_v = \left(\frac{(\pi/4)C_rA}{28.8(25.4)^3}\right)\left(\frac{l}{t}\right)\left(d^2\right)$$

Assuming 80 psig for inlet pressure — based on a typical plant operating at 100 psig with line losses — and using a conservative 5-psi pressure drop for the constant A, chart average cylinder rod speed versus cylinder diameter in terms of required C_v. The accompanying tables for two and three-position valves highlight areas where each ISO valve meets C_v requirements. **MD**

MAKE CONTACT

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Circle 621

BASIC DATA

Inlet pressure, psig	Compression ratio	*A* constants		
		2-psi ΔP	5-psi ΔP	10-psi ΔP
10	1.7	0.152	0.103	—
20	2.4	0.126	0.084	0.065
30	3.0	0.111	0.073	0.055
40	3.7	0.100	0.065	0.048
50	4.4	0.091	0.059	0.044
60	5.1	0.085	0.055	0.040
70	5.8	0.079	0.051	0.037
80	6.4	0.075	0.048	0.035
90	7.1	0.071	0.046	0.033
100	7.8	0.068	0.044	0.032
110	8.5	0.065	0.042	0.030
120	9.2	0.063	0.040	0.029
130	9.8	0.061	0.039	0.028
140	10.5	0.058	0.037	0.027
150	11.2	0.057	0.036	0.026
160	11.9	0.055	0.035	0.025
170	12.6	0.053	0.034	0.024
180	13.2	0.052	0.033	0.024
190	13.9	0.051	0.032	0.023
200	14.6	0.050	0.032	0.023

The tables lists compression ratios, P_1/P_a, as well values for the constant *A*, for a range of inlet pressures and pressure drops.

Nomenclature

- d = Cylinder diameter, in.
- G = Specific gravity of the fluid (G = 1 for air)
- l = Cylinder length, in.
- P_1 = Absolute pressure at inlet port (gage pressure + 14.7), psi
- P_2 = Absolute pressure at outlet port, psi
- P_a = Atmospheric pressure, psi
- Q = Volumetric flow rate, scfm
- T = Absolute temperature of air, °R
- t = Time to fill cylinder, sec
- V = Cylinder volume, in.^{3}