# MACHINE DESIGN

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Penton

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EDITED BY KENNETH KORANE

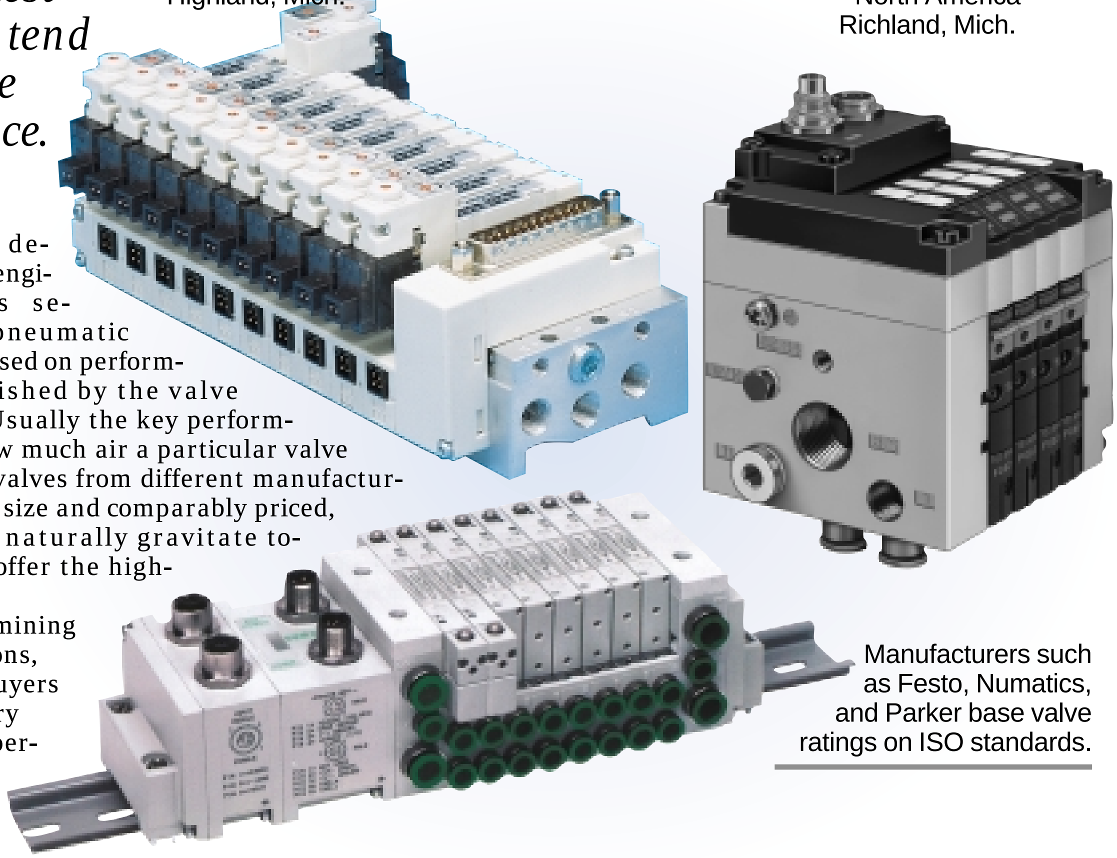
# Clearing the air on pneumatic valve ratings

*Flow specifications based on Japanese test standards tend to overstate performance.*

Henry Fleischer
Vice President for Research & Development
Numatics Inc.
Highland, Mich.

Karl Forster
Vice President of Engineering
Festo Corp.
Hauppauge, N.Y.

David C. Franson
Technical Service Manager
Parker Hannifin Corp.
Pneumatic Div. North America
Richland, Mich.



Manufacturers such as Festo, Numatics, and Parker base valve ratings on ISO standards.

Most design engineers select pneumatic control valves based on performance data published by the valve manufacturer. Usually the key performance factor is how much air a particular valve can flow. When valves from different manufacturers are the same size and comparably priced, most designers naturally gravitate toward ones that offer the highest flow.

But when examining valve specifications, most potential buyers assume that every manufacturer's performance numbers are based on the same test method. In fact, this is not the case. Manufacturers in the Americas and Europe typically determine valve performance based on international test standards. Manufacturers in the Far East tend to use a different method and then apply conversion factors to present the data in a more widely accepted format.

Unfortunately, the lack of a universal test standard means users do not always get the performance they expect. Product catalog information on flow capacity can be inconsistent from one manufacturer to another and, if the difference is not recognized, it can create serious design difficulties.

Problems can arise, especially in close-tolerance applications that operate near a system's capacity limits. Cycle times can be slower than expected, since a valve's maximum flow may actually be lower than published figures would indicate. The result is an underperforming machine that may require costly redesign.

## MEASURING FLOW

Pneumatic-valve flow represents a critical performance characteristic. To be meaningful, it must be determined by a standard, repeatable test method. Since 1989, this measurement has been defined by the international standard ISO 6358. National or branch standards — such as ANSI/NFPA T3.21.3-1990 in the U.S. and VDI 2173 in Germany — are based on this ISO standard.

The ISO 6358 test measures standard nominal flow $q_{nN}$, which is converted to imperial flow coefficient $C_V$ or metric equivalent $K_V$. Higher $C_V$s indicate greater flow and faster actuation.

The ANSI/NFPA standard rates flow in terms of $C_V$ and most American and European companies express pneumatic-valve flow capability in terms of either $C_V$ or $K_V$. Users in the American market have come to expect that all manufacturers test their valves in the same manner to produce $C_V$ values that hold the same meaning — in essence comparing "apples to apples." Unfortunately this is not always the case. Some manufacturers do not use ANSI/NFPA or ISO 6358 to calculate $C_V$, and seriously overstate a valve's capabilities. Thus, it is critical to know the underlying method used to determine flow measurements.

## JAPANESE STANDARDS

Some valve manufacturers publish $C_V$s that are calculated from the results of a completely different test — Japanese Industrial Standard (JIS) B 8375-1981. The JIS standard tests for effective sectional area $S$, calculated in mm$^2$, not $C_V$ (a dimensionless number).

Some manufacturers multiply the effective area by a constant to produce a supposedly equivalent $C_V$. The most common conversion is $S \approx 18.45C_V$.

This is a critical flaw. Converting JIS test data into $C_V$ results in flow ratings that exceed ANSI/NFPA or ISO values by 25 to 50%. As a result, manufacturers that use the JIS method publish flow ratings that substantially overstate actual perform-

## SORTING OUT TEST METHODS

Substantial differences separate the American flow-testing standard (ANSI/NFPA T3.21.3-1990) and the Japanese standard (JIS B 8375-1981) which manufacturers use to determine the $C_V$s of pneumatic valves. ANSI/NFPA notes $C_V$ is a dimensionless coefficient of flow based on the hydraulic definition that a device with $C_V = 1$ will have flow of 1 gpm for a pressure drop $\Delta p = 1$ psi. The JIS standard does not list its basis for measurement.

The ANSI/NFPA standard measures $C_V$ at low pressure drops. The standard limits pressure drop across the measured valve, 1.0 psi $\leq \Delta p \leq$ 2.0 psi or 0.07 bar $\leq \Delta p \leq$ 0.14 bar. This ensures a realistic downstream pressure $p_2 = p_1 - \Delta p$, where $p_1$ and $p_2$ are upstream and downstream pressure, respectively.

In contrast, JIS testing is always at critical flow — the point where airflow reaches the speed of sound. Beyond this point, any increase in pressure drop will not increase flow. This point is reached with an ideal nozzle when the downstream pressure (absolute) reaches about 53% of upstream pressure (absolute). Most flow calculations for pneumatic systems assume the fluid is incompressible, but these assumptions are only valid at low pressure drops (such as in the ANSI/NFPA test). Testing far away from incompressible flow (for example, at high pressure drops in the JIS test) makes it more difficult to accurately estimate flow.

Another major difference is that the JIS test is conducted with an unrealistic downstream pressure $p_2$ = 14.7 psia, or atmospheric pressure. In practical applications, the outlet port of a valve does not vent to atmosphere but, rather, connects to an actuator. Pressure must exceed atmospheric for the actuator to move. If the pressure on both sides of the actuator were atmospheric, no net force would be generated and it would not move. Thus, the measured flow data is of limited value. Downstream pressure in the ANSI/NFPA test exceeds atmospheric.

Engineers typically size pneumatic components using upstream and downstream pressures and flow. The ANSI/NFPA test method measures the flow at standard conditions as well as upstream and downstream pressures. The JIS test only measures upstream pressure and time; other values are calculated.

The ANSI/NFPA test standard is quite specific about the test setup and operating conditions. This includes defining pipe lengths up and downstream, and where and how to locate pressure taps. Pneumatic flow depends largely on the flow conditions defined by the pressure drop between the pressure taps. The ANSI/NFPA testing also considers the effect of pressure drop caused by piping. The JIS standard does not completely define the test setup and does not specify if pressure drop caused by piping is part of the final test result. Without completely defining the test setup, there is a probability that different manufacturers test products differently. Therefore, results from one manufacturer to another will differ even if they test the exact same component.

Practical applications will have virtually constant upstream pressure like the ANSI/NFPA test — very unlike the JIS test which has constantly varying upstream pressure. Force of the actuator will be determined by the secondary pressure, a measured value in the ANSI/NFPA test but an assumed value in the JIS test.

Tests on various orifice sizes using the ANSI/NFPA test show the actual $C_V$ values and predicted results to be very close. Similar data using the values from the JIS test is not readily available.

Calculations for $C_V$ per the ANSI/NFPA test include expansion factors based on diameter ratios. A comparison of the conversion values for effective areas using $C_V$ corrected for expansion factors show that if the JIS conversions were similarly corrected the predicted values would be 75 to 80% of those obtained without using the correction factors. It appears, although without seeing the actual computations for the JIS test, that these expansion factors have been neglected.

## Comparing flow measurements

| VALVE | NOMINAL FLOW, lpm ISO 6358 | NOMINAL FLOW, lpm ANSI/NFPA T3.21.3 | NOMINAL FLOW, lpm JIS 8375-1983 |
|---|---|---|---|
| A | 2,402 | 2,224 | 3,462 |
| B | 486 | 446 | 635 |
| C | 212 | 190 | 282 |
| D | 83 | 79 | 87 |
| E | 18 | 16 | 27 |

In one comparison of flow ratings, Festo tested five different valves to ISO, ANSI/NFPA, and JIS flow standards. The results, shown in the table, highlight substantial differences between the test methods.

ance. It is a bit like filling up at the gas station from a pump that reads 10 gallons but delivers only seven.

ANSI/NFPA methods also permit users to extract the actual data used to calculate $C_V$, such as flow, pressure drop, and time. This is not possible with the JIS conversion because it is not based on the original raw testing data.

Tests conducted in Parker's labs compared JIS-based performance data from several manufacturers' catalogs versus ratings on the same valves subjected to the ANSI/NFPA flow test. The actual results ranged from 20 to 35% less than the published $C_V$s.

Festo tested identical valves to ISO, ANSI/NFPA and JIS flow standards. The results, shown in the table, highlight substantial differences between the test methods. Unfortunately, a general error rate cannot be derived from this data, so a standard correction factor cannot be applied to JIS data to compensate for the overstated ratings.

Engineers aware of the potential discrepancies in $C_V$ measurements usually try to compensate for the testing variance. But uninformed users who rely on published ratings will expect higher performance than the valve can actually deliver.

### WORLD STANDARDIZATION

Until all manufacturers adhere to a global standard for flow testing, manufacturers of pneumatic equipment should make their customers aware of potential problems created by differences in flow measurement. System designers should require proper data from companies not following international standards.

Parker Hannifin, Festo, and Numatics are all firmly committed to international standards for rating pneumatic performance. Parker's position is that companies should publish $C_V$ figures based on ANSI/NFPA or ISO standards, and not attempt to convert from other test methods.

Festo fully supports ISO 6358 as the proper basis for international standardization. The company also feels the standard should be expanded to encompass other valve data, switching time for example, where ISO and Japanese test methods also differ.

Numatics urges users who have test facilities to set up an ANSI/NFPA test rig to compare valve performance and determine true $C_V$ ratings. While this entails time and expense, it is a prudent course to follow, particularly when purchasing large quantities of valves for applications that require precise timing and operate at maximum flow.

In the best interest of all valve customers, catalog data must be comparable. Therefore all important data needs to be based on commonly agreed international standards defining the test conditions. Otherwise users of pneumatic equipment may be misled and could draw inconsistent conclusions that lead to equipment malfunctions. ■