Thomas W. Kreher | Applied Pneumatic Controls, Inc.
www.applied-pneumatic.com

Air Flow Formulas

Ernie said something about Cv being devised from a water test. Sonic Conductance was more scientific and a better method to teach ME students. My reply by e-mail only convinced him that I was clinging to the archaic, unscientific, inaccurate Cv practices. If that is not exact, it makes a good preface to the topic of universal air flow.

Cv and Sonic Conductance are but two of the many techniques to quantify air flow. None of the techniques, formulas, or labels actually changes the amount of air that will flow through a valve or orifice. Geometry, earth science, and mother nature are in control.

Franklin D. Yeaple tested 10 or more common formulas used to determine air flow by comparing them to actual flow back in the 1960s. I selected the formula that he reported to be closest to actual flow as Equation 1.

Both "The Compressed Air and Gas Handbook" and Ingersol Rand's compressed air reference book show the S.A. Moss formula for critical air flow. This formula with constants crunched is shown in Equation 2.

Equation 3 is the formula proposed as the ANSI/NFPA standard and used by large domestic valve manufacturers, Norgren, Numatics, etc. The constants are crunched for convenience using the square root of 530 degrees Rankin for temperature and 14.7 PSIA for atmosphere.

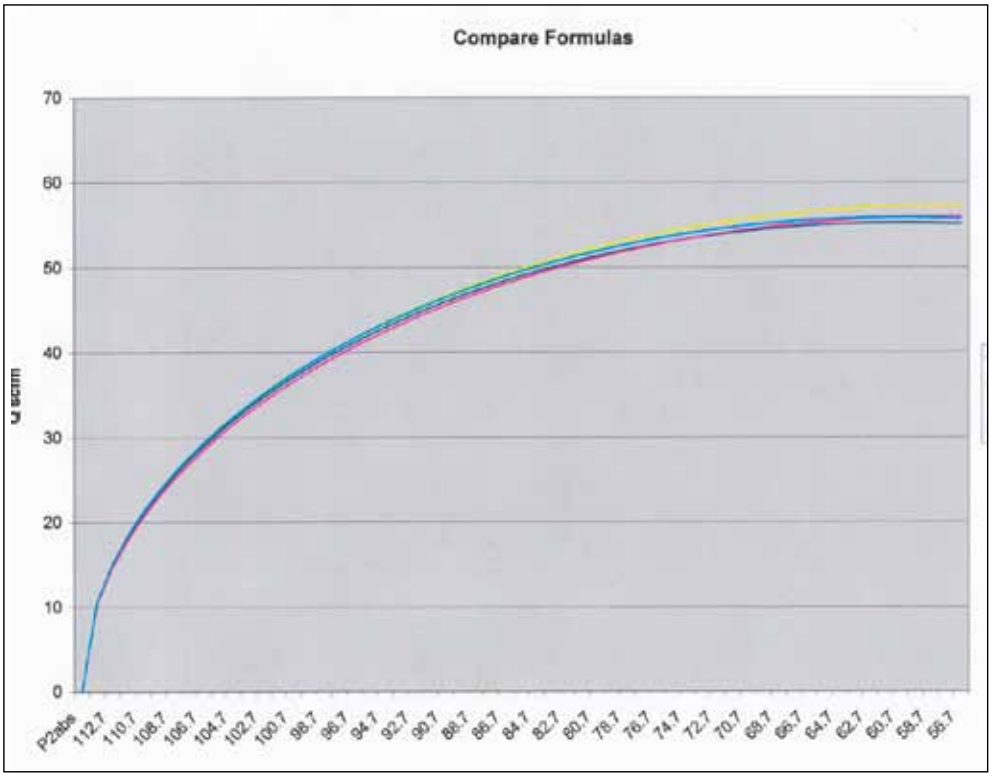
Finally, Equation 4 was reported by Franklin Yeaple to be the Sonic Conductance formula in an aged Design News supplement. Surprisingly, only the pressure ratio "r," critical pressure ratio "rc" and critical flow Qc define this equation without pressure or temperature given.

With 114.7 psia for absolute upstream pressure, Pu and a spreadsheet, four diverse formulas were calculated for Q scfm at the critical ratio of Pd/Pu = .53.

For Sonic Conductance, the critical flow 55.9 scfm from Equation 3 was selected for Qc. With the spreadsheet, the air flow, Q scfm, of these four formulas was calculated at 2 psig intervals from 0 to 100 psig. By the magic of Microsoft Excel, the four flow curves were graphed. (See Graph.)

At the same pressure, the four graphed lines are almost identical from 0 to 100 psig in sub-critical flow. At critical, choked (sonic) flow, the quantities are almost identical. The easy formula (Equation 4) selected from those tested in that era by Frank Yeaple shows a slight variance at high flow. Equations 2 and 3 are identical, and Equation 4 was assigned an identical critical flow to establish the parameters.

It is time to stop choosing sides and realize that Mother Nature is in control. Air flow is universal.



$$Q = Cv\ Pu\sqrt{r - r^2} \qquad Q = 1 \times 114.7 \sqrt{.53 - .53^2} = 57.25_{\ SCFM}$$

EQUATION #1, YEAPLE, HYDRAULIC & PNEUMATIC POWER AND CONTROL

$$Q = Cv \times Pu_{ABS} \times .4872 \qquad Q = 1 \times 114.7 \times .4872 = 55.88_{\ SCFM}$$

EQUATION #2, MOSS, INGERSOL RAND

$$Q = Cv \times .9766\sqrt{(Pu - Pd) \times Pd_{ABS}} \qquad Q = 1 \times .9766\sqrt{53.\ 91 \times 60.79} = 55.9_{\ SCFM}$$

EQUATION #3, ANSI/ NFPA, NORGREN, NUMATICS ETC.

$$Q = Qc\sqrt{1 - \left(\frac{r - rc}{1 - rc}\right)^2} \qquad Q = Qc\sqrt{1 - \left(\frac{r - .53}{.47}\right)^2} = 55.9_{\ SCFM}$$

EQUATION #4, SONIC CONDUCTANCE, YEAPLE, DESIGN NEWS SUP.