Flow Rate Through Valves

A Practical Guide for Engineers

Abstract

This paper documents the development of a web-based **Cv Flow Rate Calculator**, which determines gas flow rates through control valves based on the valve flow coefficient (Cv), upstream and downstream pressures, gas properties, and temperature. The tool implements the standard ISA/ANSI equations for subsonic (non-choked) and choked flow conditions. Results include volumetric flow rates in SCFM and ACFM, mass flow rates in multiple units, and identification of choked vs. non-choked flow regimes. Assumptions, calculation procedures, and practical applications are presented.

1. Introduction

Valve sizing and system design often require the calculation of expected flow rates through valves. The flow coefficient **Cv** is a measure of valve capacity, defined as the flow rate of 60°F water in gallons per minute (GPM) that produces a 1 psi pressure drop across the valve. For gases, ISA/ANSI equations are used to relate Cv to standard volumetric flow rate under given pressure and temperature conditions. This calculator provides a streamlined way to evaluate flow under both normal and critical (choked) conditions.

2. Governing Equations

2.1 Non-Choked Flow ($P_2 > ½P_1$)

When downstream pressure is greater than half the upstream absolute pressure, flow is subsonic and depends on both upstream and downstream pressures:

$$q = N_2 C_v P_1 \left(1 - \frac{2\Delta P}{3P_1}\right) \sqrt{\frac{\Delta P}{P_1 G_g T_1}}$$

where:

- q: standard volumetric flow rate (SCFM)
- N2: numerical constant (1360 for SCFM, psig, and °R)
- Cv: valve flow coefficient
- P1P_1: upstream absolute pressure (psia)
- ΔP=P1−P2\Delta P = P_1 - P_2: pressure drop
- Gg: specific gravity relative to air
- T1: upstream absolute temperature (°R)

2.2 Choked Flow ($P_2 \leq ½P_1$)

When downstream pressure is less than or equal to half the upstream pressure, the flow reaches sonic velocity at the valve throat. In this regime, flow becomes independent of P_2:

$$q = 0.471 N_2 C_v P_1 \sqrt{\frac{1}{G_g T_1}}$$

3. Assumptions

- Ideal gas behavior (no real gas compressibility corrections).
- Single-phase gas, constant molecular weight.
- Temperature uniform across the valve.
- Cv value accurately represents the valve at given travel/position.
- Standard ISA/ANSI correlations apply; accuracy typically ±5%.

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4. Usage of the Tool

Inputs required:

- Upstream pressure (P_1) in psia or psig.
- Downstream pressure (P_2) in psia or psig.
- Temperature in °F, °C, K, or °R.
- Gas type (from database with molecular weight, γ, specific gravity).
- Cv value of the valve.

Outputs provided:

- Volumetric flow rate in SCFM and ACFM.
- Mass flow rate (lb/min, lb/hr, kg/hr, g/s).
- Pressure ratio (P_2/P_1) and determination of choked vs. non-choked flow.
- Display of which governing equation was applied.

5. Applications

- **Control Valve Sizing:** Ensure proper valve capacity for process requirements.
- **System Design:** Predict flow rates under normal and upset conditions.
- **Process Control:** Anticipate valve performance at varying loads.
- **Safety Analysis:** Assess emergency relief or blowdown scenarios.

6. Critical Flow and Sonic Limitation

When $P2 \leq \frac{1}{2} P1_1$, the flow is limited by sonic velocity. This represents the maximum flow rate attainable regardless of further reduction in downstream pressure. Engineers must recognize this "sound barrier" in valve sizing and relief system design.

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7. References

1. ISA/ANSI Standard S75.01 – Flow Equations for Sizing Control Valves.