

Plenum / Fan Matching Module — User Guide

1. Purpose & Scope

The Plenum/Fan Matching module evaluates airflow through a rectangular plenum feeding a finned heat sink. The tool determines the fan–system operating point, computes plenum and channel velocities, estimates airflow distribution among three flow paths (channels, top gap, side gaps), and provides a velocity-based 3D visualization. All user inputs and displayed results are in English units (inches, ft/s, cfm, inH₂O). Internally, the solver uses SI units.

2. User Workflow

- Enter air properties (density and viscosity).
- Enter plenum and inlet geometry (inches).
- Enter heat-sink fin geometry.
- Enter or edit the fan curve (Q in cfm, Δp in inH₂O).
- Press Solve to compute the operating point.
- View: key results, fan/system curves, Vch(x) distribution, and 3D flow visualization.

3. Solution Method Overview

3.1 Fan Curve Interpolation

Fan data from the table are sorted by flow rate. Piecewise-linear interpolation gives $\Delta p_{fan}(Q)$. Linear extrapolation is used at the curve ends. The fan curve is treated as a continuous function.

3.2 System Pressure Drop Model

The system curve includes:

- Inlet minor loss at the blower aperture.
- Parallel-branch network losses (channels, top gap, side gaps).
- Exit minor loss at the plenum outlet.

3.2.1 Inlet Loss

$$\Delta p_{in} = K_{in} \cdot \frac{1}{2} \rho V^2, \text{ with } K_{in} \approx 1.0$$

3.2.2 3-Branch Parallel Network

The plenum-over-HS region is approximated by three ducts in parallel: fin channels, the top gap, and side gaps. Each branch uses hydraulic diameter D_h , flow area A , length L , and a minor loss term.

Each branch is reduced to a quadratic resistance: $\Delta p_i = k_i Q_i^2$, where k_i is determined by evaluating friction + minor losses at a reference velocity of 1 m/s.

Flow split is then:

$$Q_i \propto 1 / \sqrt{k_i}$$

3.2.3 Exit Loss

$$\Delta p_{\text{exit}} = K_{\text{exit}} \cdot \frac{1}{2} \rho V^2, \text{ with } K_{\text{exit}} \approx 1.0$$

3.3 Operating Point Search

The solver scans from $Q = 0$ to the maximum fan curve flow. For each Q :

- Compute $\Delta p_{\text{fan}}(Q)$.
- Compute $\Delta p_{\text{sys}}(Q)$.
- Compute $|\Delta p_{\text{fan}} - \Delta p_{\text{sys}}|$.

The Q with minimum difference defines the operating point (Q^* , Δp^*).

3.4 V_2 Velocity Distribution Along Fins

The fin length L_f is divided into slices. A manifold model predicts how plenum pressure decays as flow is removed into the channels. A guessed plenum inlet pressure P_0 is iteratively adjusted using bisection until the total channel flow equals the operating flow Q^* . This produces $V_{\text{ch}}(x)$.

3.5 3D Visualization

The 3D view uses Three.js to show the plenum, inlet, heat sink base/fins, and three translucent velocity blocks (channels, top gap, sides). Colors reflect relative velocity magnitude. This view is illustrative and not CFD.

4. Limitations

- Simplified Darcy–Weisbach friction model.
- Generic minor-loss coefficients.
- 1D V_2 model neglects spanwise non-uniformity.
- 3D geometry is schematic, not scale-accurate.
- Not a replacement for CFD or hardware testing.

5. References

- Crane TP-410 — Flow of Fluids Through Valves, Fittings, and Pipe.
- Idelchik — Handbook of Hydraulic Resistance.
- Munson, Young & Okiishi — Fundamentals of Fluid Mechanics.
- Shah & London — Laminar Flow Forced Convection in Ducts.
- Fan manufacturer data for interpreting fan curves.