RB-007

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RB-007: Failure Modes of Outdoor BBQ Hoods

P2 — Applied

EXECUTIVE SUMMARY

This paper synthesizes the plume physics (RB-001/RB-003), indoor-versus-outdoor gap analysis (RB-004), hood geometry analysis (RB-005), and wind interaction analysis (RB-006) into a comprehensive failure mode taxonomy for outdoor barbecue ventilation hoods. Six primary failure modes are identified: momentum-limited capture, geometry-induced spillage, wind-deflected plume escape, insufficient exhaust rate, excessive mounting height, and inadequate overhang. Each mode is characterized by its root physical mechanism, triggering conditions, observable smoke escape pattern, Froude number regime, and corrective action classification (correctable post-installation versus design-locked). The paper delivers diagnostic criteria enabling field identification of failure modes from visible symptoms, and a corrective action matrix ranking interventions by effectiveness and feasibility.

THE CHALLENGE

The central practical problem is this: a homeowner or installer observes smoke escaping from around the hood during cooking. The smoke escape may be continuous, intermittent, directional, or diffuse. The question is: why is the hood failing, and what can be done about it?

Outdoor Ventilation Standard

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Key Quantitative Findings

Centerline velocity u_0 = 1.03 * Q_c^(1/3) * (z - z_0)^(-1/3), ranging from 1.0 to 2.8 m/s (200 to 560 ft/min) at standard mounting heights. This velocity decays as z^(-1/3) — slowly relative to other plume parameters.

Plume capture diameter d_capture = 0.48 * (z - z_0) + D_eff, ranging from 31 to 61 inches at standard mounting heights for common cooking sources. This grows linearly with height.

Gaussian velocity profile. Velocity falls from u_0 at the centerline to 37% of u_0 at the velocity half-width (b_u = 0.144 * (z - z_0)) and to only 6% at the capture boundary (2 * b_T). The plume edge is effectively stagnant.

Plume appearance: The plume is barely visible as a coherent thermal column at the hood face. In warm ambient conditions (above approximately 25 degrees C), the temperature excess at 48 inches is so low (8 to 36 degrees C above ambient per RB-001 Table 3.4) that the plume may not produce visible condensation or shimmer. Smoke particulates are present but dispersed over a wide area.

Comparison across heights: If the grill can be temporarily raised (using blocks or a temporary surface), moving it 6 inches closer to the hood produces a visible, immediate improvement in capture. This height sensitivity is the signature of FM-2.

Indoor-rated blower applied outdoors. A 400 CFM blower (adequate for a medium gas grill indoors per ASHRAE 154) is installed outdoors where 609 CFM is required (RB-003 Table 3.8a at 30 inches, K_CFM = 3.0). The blower provides only 66% of the required capacity.

Blower operating against excessive static pressure. A blower rated at 900 CFM at 0 inches of water column may deliver only 500 to 600 CFM against the static pressure of a long or restrictive duct run (0.5 to 1.5 inches WG). The effective CFM at operating conditions is below the requirement.

25% escape at 6.7 mph

Centerline exit at 9.7 mph

50% escape at 12.6 mph

Why This Research Matters

This research provides the first physics-based, quantitative methodology for outdoor cooking ventilation design. These findings enable proper hood sizing, CFM specification, and mounting height selection — preventing the common failures that occur when indoor assumptions are applied outdoors.

📄 The Full Research Paper Includes:

✓ Complete derivations and governing equations

✓ Quantitative design tables and correction factors

✓ Engineering methodology with worked examples

✓ Interactive calculation tools and diagrams

✓ Full reference bibliography and validation data