RB-001

P0 — Foundation • Version 1.0 • 2025-08-14

RB-001: Buoyant Plume Behavior from Barbecue and High-Heat Cooking Sources

P0 — Foundation

EXECUTIVE SUMMARY

This paper establishes the quantitative plume physics foundation for all subsequent research in the Outdoor Ventilation Standard. It characterizes buoyant cooking plume behavior across four outdoor cooking source types using Heskestad plume correlations, Morton-Taylor-Turner entrainment theory, and McCaffrey plume zone classification.

THE CHALLENGE

Outdoor cooking appliances release thermal energy through combustion of fuel and radiative/convective heating of food, cookware, and surrounding air. The heated gas mixture rises as a turbulent buoyant plume, entraining ambient air and expanding laterally with height. The plume carries combustion byproducts, aerosolized grease particulates, and gaseous cooking effluent. The purpose of a ventilation hood is to intercept this plume at the **Plume Interception Plane** before it disperses into the ambient atmosphere via **Open-Boundary Dilution**.

Outdoor Ventilation Standard

Scan for full research paper

Key Quantitative Findings

Charcoal heat release is calculated from fuel consumption rate and specific energy content: briquettes at approximately 29 MJ/kg (12,500 BTU/lb); lump hardwood charcoal at approximately 33 MJ/kg (14,200 BTU/lb).

Wood-fired values assume hardwood fuel at approximately 19 MJ/kg (8,200 BTU/lb) with active flaming combustion.

Pellet smoker values are based on pellet consumption rates at various temperature settings; wood pellets contain approximately 18-20 MJ/kg (8,000-8,600 BTU/lb).

During normal cooking, burners may operate at 50-75% of rated capacity, and not all burners may be active simultaneously

u_0 = 1.03 * (12.3)^(1/3) * (1.17)^(-1/3) = 1.03 * 2.31 * 0.95 = 2.25 m/s.

A medium gas grill produces a plume with centerline velocity of 2.30 m/s at 18 inches, decaying to 1.71 m/s at 48 inches — a reduction of only 26%.

Even at 48 inches above the source, a medium gas grill plume has a centerline velocity of 337 ft/min (1.71 m/s)

Centerline velocity drops as (z - z_0)^(-1/3) — reducing by approximately 26% when height doubles

Plume diameter grows linearly with height — adding approximately 3 inches of capture diameter per 6 inches of height

A charcoal grill rated at 30,000 BTU/hr produces a plume comparable to a gas grill of only approximately 12,000-15,000 BTU/hr in convective terms

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