Design Guide 1

Selecting & Sizing Exhaust Hoods

Improving Commercial Kitchen Ventilation (CKV) System Performance

Selecting & Sizing Exhaust Hoods is the first design guide in a series that will help you achieve optimum performance and energy efficiency in your commercial kitchen ventilation system. The information presented is applicable to new construction and, in many instances, retrofit construction.

This design guide reviews the fundamentals of kitchen exhaust systems and describes the design process from the perspective of exhaust hood application.

Fundamentals of Kitchen Exhaust

Hot air rises! In a kitchen, an exhaust fan may remove much of the heat produced by cooking appliances, but mix in smoke, volatile organic compounds, grease, and vapor from the cooking process and it becomes necessary to remove these products to avoid health and fire risk. While an exhaust hood serves this purpose, a key question remains: "What is the appropriate exhaust rate for my kitchen operation?" The answer depends on several factors — the types of food products being cooked, the cooking equipment under the hood, the style and geometry of the hood itself, and how the makeup air (conditioned or otherwise) is introduced into the kitchen.

The Cooking Factor

Cooking appliances are categorized as either light-, medium-, heavy-, or extra heavy-duty depending on the intensity of their thermal plume and the quantity of grease, smoke, heat, water vapor, and combustion products they produce. The intensity of the thermal plume is a major factor in determining the exhaust rate. Thermal plumes rise, but are also turbulent and their "surge" characteristics can differ depending on the cooking method. For example, the plume from cooking hamburgers is strongest when flipping patties. Ovens and pressure fryers may generate little plume until opened to remove food product. Open-flame, non-thermostatically controlled appliances such as underfired broilers and open-top ranges produce strong, steady plumes. Thermostatically-controlled appliances such as griddles and fryers have weaker plumes that fluctuate in sequence with thermostat cycling (particularly in gas-fired equipment with flues). As the plume rises, it should be captured inside the hood and removed by exhaust fan suction. Air in proximity of the appliances and the hood moves in to replace the exhausted plume. This replacement air, which must ultimately originate as outside air, is referred to as "makeup air". Design issues related to makeup air and its impact on hood performance are the subject of Design Guide 3: *Optimizing Makeup Air.*

Building codes distinguish between cooking processes that create smoke and grease (e.g., frying, griddling, or charbroiling) and those that produce only heat and moisture (e.g., dishwashing and some baking and steaming operations). Cooking that produces smoke and grease requires liquid-tight construction with a built-in fire suppression system (Type I hood), while operations that produce only heat and moisture do not require liquid-tight construction or a fire suppression system (Type II hood).

Menu items can produce varying levels of smoke and grease depending on their fat content and mode of cooking. A hamburger cooked on a charbroiler releases finer smoke particles and more grease than a hamburger cooked on a griddle for instance. However, higher fat content foods tend to release more smoke and grease regardless of cooking process. The high fat content of hamburger patties contributes to the significant amount of grease and smoke released during cooking. Conversely, chicken breasts have much less fat and as a result release less grease particulate whether cooked on a charbroiler or a griddle.

The Hood Factor

The design exhaust rate also depends on hood style and construction. Wall-mounted canopy hoods, island (single or double) canopy hoods, and proximity (backshelf, pass-over, or eyebrow) hoods all have different capture areas and are mounted at different heights and horizontal positions relative to the cooking equipment (see Figures 1 and 2). Generally, for an identical cooking load, a single-island canopy hood requires more exhaust than a wall-mounted canopy hood, and a wall-mounted canopy hood requires more exhaust than a proximity (backshelf) hood. The performance of a double-island canopy tends to emulate the performance of two back-to-back wall-canopy hoods, although the lack of a physical barrier between the two hood sections makes the configuration more susceptible to cross drafts.

Although a well-designed proximity hood can be applied with success at very low exhaust rates (e.g., 150 cfm per linear foot over medium-duty equipment), proximity hoods (if specified without performance data and/or in accordance with maximum height and setback permitted by code) may also fail to effectively capture and contain the cooking plume at exhaust rates of 300 cfm/ft or more. Figure 3 illustrates relatively effective and ineffective applications of proximity hoods.

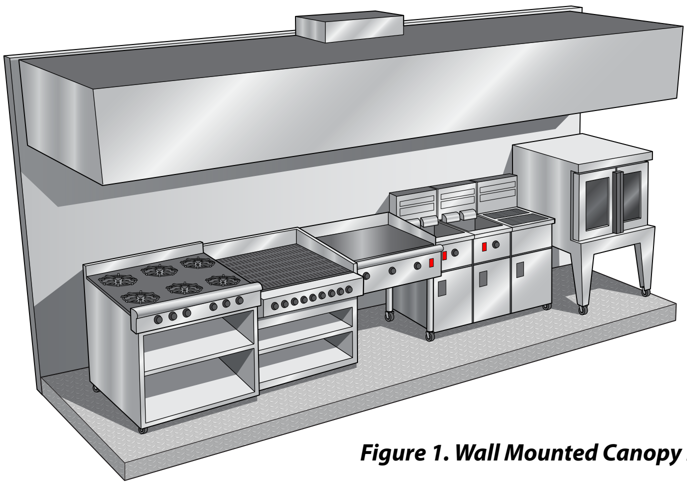


Figure 1. Wall Mounted Canopy Hood.

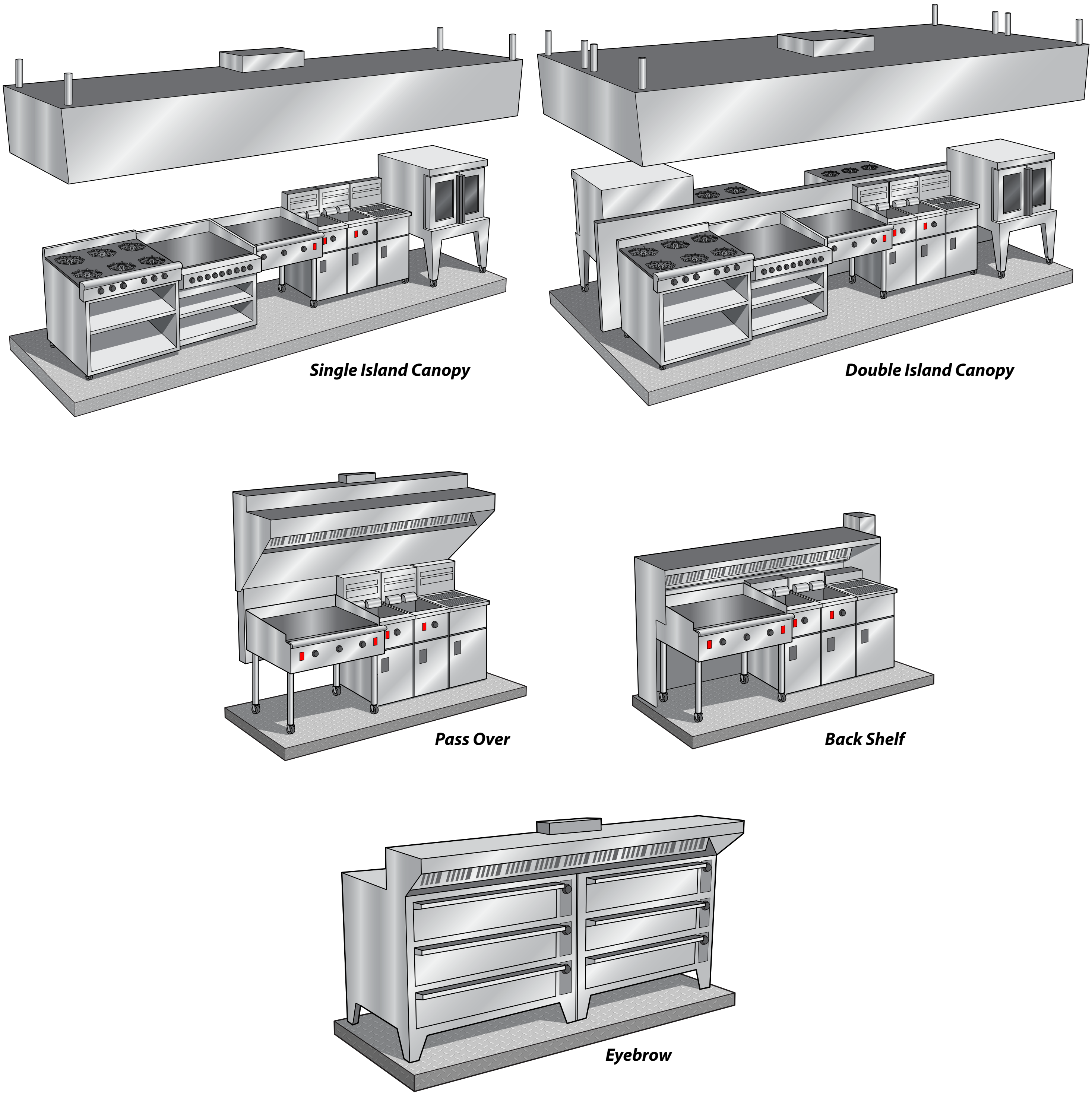
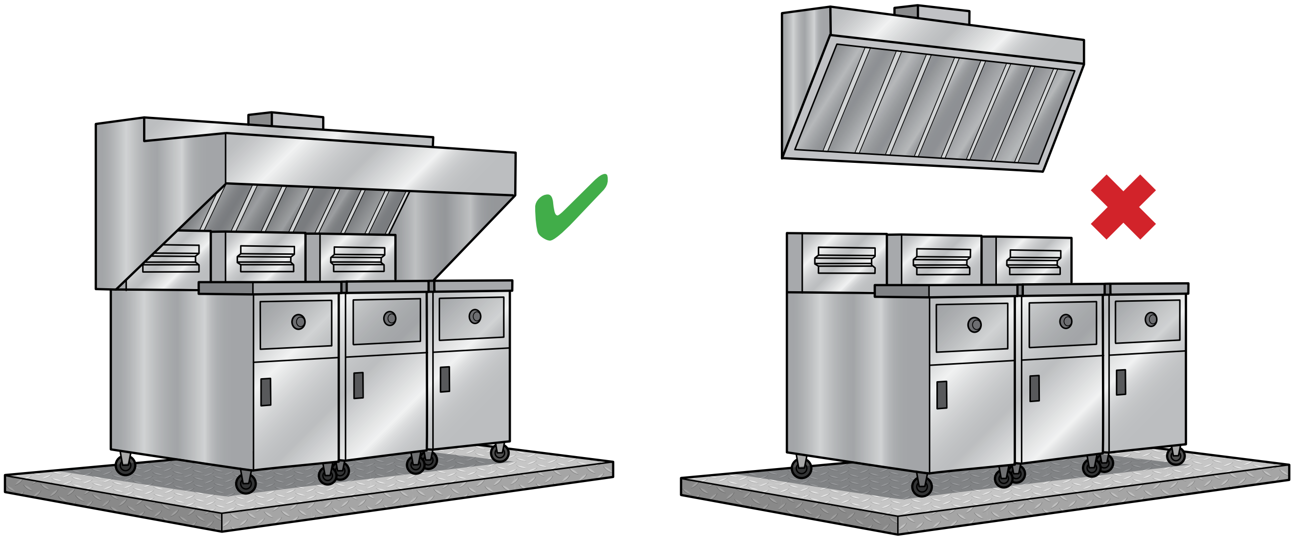


Figure 2. Other Styles of Exhaust Hoods.



Effective Design with Side Panels ***Ineffective Design***

Figure 3. Proximity Hood.

Building and/or health codes typically provide basic construction and material requirements for exhaust hoods as well as prescriptive exhaust rates based on appliance duty and hood length (cfm per linear ft.). Codes recognize exceptions for hoods that have been tested against a recognized standard such as Underwriters Laboratories (UL) Standard 710. Part of the UL standard is a "cooking smoke and flare up" test, which is essentially a cooking plume capture and containment test where "***no evidence of smoke or flame escaping outside the exhaust hood"*** must be observed. Hoods bearing a recognized laboratory mark are called ***labeled*** or ***listed*** hoods, while those constructed to the prescriptive requirements of the building code are called ***code*** or ***unlisted*** hoods. Code hoods are becoming increasingly scarce in new installations and retrofit applications. The additional testing required of a listed hood is more attractive and less risky for the local code official. Generally, a ***listed*** hood can be operated at a lower exhaust rate than an ***unlisted*** hood of comparable style and size over the same cookline. Lower exhaust rates may be substantiated by laboratory testing with specific hood(s) and appliance lineups using the test protocol described in the American Society for Testing & Materials (ASTM) F1704 ***Test Method for Performance of Commercial Kitchen Ventilation Systems.*** This process is sometimes referred to as "custom-engineering" a hood.

Laboratory hood testing with different combinations of appliances has demonstrated that minimum capture and containment rates vary significantly with appliance type and position underneath the hood. For example, a heavy-duty appliance positioned at the end of a hood is more prone to plume spillage than that same appliance positioned in the middle of the hood.

Appliance Duty Classifications From CMC

Light Duty

- Gas and electric ovens (including standard, bake, roasting, revolving, retherm, convection, combination convection/steamer, rotisserie, countertop conveyorized baking/finishing, deck, and pastry)
- Discrete element ranges (with or without oven)
- Electric and gas steam-jacketed kettles less than 20 gallons (76 L)
- Electric and gas pasta cookers
- Electric and gas compartment steamers (both pressure and atmospheric)
- Electric and gas cheesemelters
- Electric and gas tilting skillets (braising pans)
- Electric and gas rotisseries
- Electric and gas salamanders

Medium Duty

- Electric and gas hot-top ranges
- Gas open-burner ranges (with or without oven)
- Electric and gas flat griddles
- Electric and gas double-sided griddles
- Electric and gas fryers (including open deep fat fryers, donut fryers, kettle fryers, and pressure fryers)
- Electric and gas conveyor pizza ovens

Heavy Duty

- Gas underfired broilers
- Gas chain (conveyor) broilers
- Electric and gas wok ranges
- Electric and gas over-fired (upright) broilers

Extra Heavy Duty

- Appliances using solid fuel for cooking such as charcoal, briquette, and mesquite to provide the heat source for cooking.

The Design Process

Successful application of the fundamentals of commercial kitchen ventilation during the design process requires a good grasp of your local building code requirements, menu and appliance preferences, and project budget. Information about kitchen equipment and ventilation requirements may evolve over the course of the design phase. Data needed by other members of the design team may require early estimates of certain parameters (e.g., the amount of exhaust and makeup air, motor horsepower, water supply and wastewater flow rates). As more decisions are made, new information may allow (or require) refinements to the design that affect exhaust and makeup air requirements.

The fundamental steps in the design of a CKV system are:

1. Establish location and "duty" classifications of appliances including menu effects. Determine (or coordinate with a foodservice consultant) preferred appliance layout for optimum exhaust ventilation.
2. Select hood type, style, and features.
3. Size exhaust airflow rate.
4. Select makeup air strategy; Size airflow and layout diffusers.

Steps 1 through 3 are discussed in this guide and augmented in Design Guide 2: ***Optimizing Appliance Position & Hood Configuration***; Step 4 is the subject of Design Guide 3: ***Optimizing Makeup Air***.

A good understanding of how building code requirements apply to kitchen design is essential. Local or state building codes are usually based on one of the "model" building codes promulgated by national code organizations. Our discussion of the building codes will be limited to requirements that affect design exhaust and makeup air rates, which are usually found in the mechanical code. The mechanical code establishes the minimum requirements for design and installation of mechanical (HVAC) systems, appliances, appliance venting, duct and ventilation systems, combustion air provisions, hydronic systems, and solar systems. The mechanical code is incorporated by reference in the building code.

Historically, codes and test standards used "temperature" ratings for classifying cooking equipment. Although these temperature ratings roughly correlated with the ventilation requirement of the appliances, there were many gray areas. During development of the ASHRAE Standard 154, ***Ventilation for Commercial Cooking Appliances,*** it was recognized that plume strength (which considers plume volume and surge characteristics) as well as plume temperature would be a better measure for rating appliances for application in building codes. "Duty" ratings were created for most commercial cooking appliances under Standard 154. These ratings have been adopted by the International Mechanical Code (IMC), Uniform Mechanical Code, and the California Mechanical Code (CMC). The kitchen ventilation chapter of the ASHRAE Applications Handbook (2019 edition) applied the same concept to establish ranges of exhaust rates for listed hoods[1]. The duty classifications listed on page 7 are culled from the CMC.

The IMC, UMC, and CMC dictate exhaust rates based on hood type and appliance duty. Table 1 states these exhaust rates in "cfm per linear foot of hood" ("linear foot" in this case applies to the distance from edge-to-edge along the front face of the hood) for the UMC and CMC. Table 2 presents the exhaust rates for the IMC. The code requires that the exhaust rate for the highest duty-rated appliance be applied to the entire hood. The IMC, UMC, and CMC all require a minimum 6-inch hood overhang (front and sides) for canopy style hoods.

Table 1. CMC and UMC Hood Exhaust Flow Rates.

	Minimum Exhaust Flow Rates for Unlisted Hoods (cfm per linear foot of hood length)			
Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra-Heavy Duty Equipment
Wall-mounted Canopy	200	300	550	550
Single Island Canopy	400	500	700	700
Double Island Canopy	250	300	550	550
Eye Brow	250	250	not permitted	not permitted
Backshelf	250	300	not permitted	not permitted
Passover	250	300	not permitted	not permitted

Table 2. IMC Hood Exhaust Flow Rates.

	Minimum Exhaust Flow Rates for Unlisted Hoods (cfm per linear foot of hood length)			
Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra-Heavy Duty Equipment
Wall-mounted Canopy	200	300	400	550
Single Island Canopy	400	500	600	700
Double Island Canopy	250	300	400	550
Eye Brow	250	250	not permitted	not permitted
Backshelf	250	300	400	not permitted
Passover	250	300	400	not permitted

The prescriptive mechanical code exhaust rate requirements must be conservative because the AHJ (authority having jurisdiction) has no control over the design of an exhaust hood or the positioning and diversity of appliances placed beneath the hood. However, in cases where the CKV system design and appliance configuration has been optimized, the code-specified exhaust rate may be significantly greater than what is required for effective capture and containment of the cooking plume. The code-based safety factor[5] (which may be necessary for unlisted systems) can place an energy cost burden on the CKV system through its demand for more heated and cooled makeup air.

[1]The rule for unlisted hoods is to apply the duty rating for the highest duty appliance to the length of the entire hood (or separate section of hood served by an individual exhaust fan). For listed hoods, the same rule may be applied if little is known about the expected cooking operations. If details of the cooking operation are known, rates for each appliance may be applied and added up to determine the total exhaust rate.

While the exhaust rates shown in Table 1 and Table 2 are the minimum mandatory rates for unlisted hoods, the rates in Table 3 reflect the typical range in design exhaust rates for UL listed hoods. The values in this table may be useful for estimating the "cfm" advantage offered by listed hoods over unlisted hoods for a given project. But in the final stage of design, exhaust rates may be adjusted to account for:

1. **Diversity of Operations** — How many appliances will be on at the same time?
2. **Position Under the Hood** — Appliances with strong thermal plumes located at the end of a hood tend to spill effluent more easily than the same appliance located in the middle of the hood.
3. **Hood Overhang** (in combination with appliance push-back) — Positioning a wall-mounted canopy hood over an appliance line with an 18-inch overhang can dramatically reduce the required ventilation rate when compared to the minimum overhang requirement of 6-inches. Some manufacturers "list" their hoods for a minimum 12-inch overhang, providing an immediate advantage over unlisted hoods.
4. **Appliance Operating Temperature or Other Appliance Design Features** — For example, a griddle used exclusively by a multi-unit restaurant at 325ºF versus 400ºF surface temperature. Or an 18-inch versus a 24-inch deep griddle surface.
5. **Differences in Plume Strength from Menu Selections** — For example, cooking hamburgers on a griddle versus a charbroiler or using a charbroiler to cook chicken versus hamburgers.
6. **Operating Experience of a Multi-Unit Restaurant** — The CKV system design exhaust rate (for the next new restaurant) may be increased or decreased based on real-world assessments of the CKV system in recently constructed facilities.

Table 3. Typical Exhaust Rates for Listed Hoods	**Minimum Exhaust Flow Rate (cfm per linear foot of hood length)**			
Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra-Heavy Duty Equipment
Wall-mounted Canopy	150-200	200-300	200-400	350+
Single Island Canopy	250-300	300-400	300-600	550+
Double Island Canopy	150-200	200-300	250-400	500+
Eye Brow	150-250	150-250	not recommended	not recommended
Backshelf/Passover	100-200	200-300	300-400	not recommended

High-Performing Hoods

High-performing hoods are recognized in the industry as hoods with energy-saving attributes integrated within their design. The energy savings are derived from the fact that the hoods can exhaust a particular appliance line at comparatively low exhaust airflow rates. Energy standards such as California Title 24 and ASHRAE 90.1 set maximum exhaust airflow rates for specific appliance line applications. The maximum airflow rates ensure the minimum amount of energy to move and temper the exhaust air and makeup air. Table 4 addresses the maximum airflow rates culled from ASHRAE 90.1. For a further discussion of the prescriptive requirements for high performance hoods, please refer to Design Guide 4: *Integrating Kitchen Exhaust with Building HVAC*.

Table 4. Maximum Exhaust Rates for Listed Hoods under Title 24.	**Maximum Net Exhaust Flow Rate (cfm per linear foot of hood length)**			
Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra-Heavy Duty Equipment
Wall-mounted Canopy	140	210	280	385
Single Island Canopy	280	350	420	490
Double Island Canopy	175	210	280	385
Eye Brow	175	175	not allowed	not allowed
Backshelf / Passover	210	210	280	not allowed

Glossary

ASHRAE — American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ASTM — American Society for Testing and Materials.

Building Codes — Historically, the United States had three organizations that drafted model building codes that were adopted by local jurisdictions as law. These organizations sponsored development of standardized building codes, usually called "model building codes", to assure better code uniformity within the three regions in which they evolved. In the north-east US, the Building Officials Council Association sponsored the National Building Code. In the southeast US, the Southern Building Code Council International sponsored the Standard Building Code. In western US, the International Council of Building Code Officials sponsored the Uniform Building Code. California jurisdictions adopted the UBC, including the Uniform Mechanical Code (UMC), which is adopted statewide as the California Mechanical Code (CMC). Also, local Health officials may follow the California Health and Safety Code for ventilation requirements.

Capture & Containment (C&C) — The ability of the hood to capture and contain grease-laden cooking vapors, convective heat, and other products of cooking processes. Hood capture refers to these products entering the hood reservoir from the area under the hood, while containment refers to these products staying in the hood reservoir and not spilling out into the adjacent space. "Minimum capture and containment" is defined as the conditions of hood operation in which minimum exhaust flow rates are just sufficient to capture and contain the products being generated by the appliance(s) in idle or heavy-load cooking conditions, and at any intermediate prescribed load condition (ASTM F1704-12).

CKV — Commercial Kitchen Ventilation.

Demand Ventilation Control (DVC) — Controls that automatically adjust roof top ventilation equipment according to occupancy need. For the purpose of these design guides, DVC refers to controls as applied to dining room ventilation. DVC is <u>not</u> the same as Demand-Controlled Kitchen Ventilation controls on the kitchen exhaust hood.

Demand-Controlled Kitchen Ventilation (DCKV) — Control systems that are capable of varying the kitchen hood exhaust rate based on temperature sensors located in the exhaust duct that measure heat load, or optical/infrared sensors located in the hood reservoir that detect the presence of a cooking plume generated by the appliances, or a combination thereof. DCKV systems modulate the amount of air exhausted in response to a full-load, partial-load, or no-load cooking condition.

HVAC — Heating, Ventilation and Air Conditioning.

Makeup Air (MUA) — Outside air that replaces exhausted air. Replacement air may be introduced through the general building HVAC system, through dedicated mechanical units serving the kitchen or through infiltration.

Roof Top Unit (RTU) — A air handling unit located on the roof top that provides heating, ventilation, and air conditioning to the area below. RTUs for restaurants are typically constant-volume, packaged, single-zone units. Also referred to as an Air-Handling Unit (AHU).

Safety Factors — Designers should apply a safety factor to their exhaust rate to address dynamic conditions encountered in real kitchens. Although manufacturers do not publish safety factors to be applied to their minimum listed "cfm", they will typically recommend increasing the exhaust rate by 5% to 25% over the minimum listing.

Variable Frequency Drives (VFD) — Used in DCKV systems, a type of motor controller that drives an electric motor (in this case, the exhaust fan motor) by varying the frequency and voltage supplied to the electric motor. Other names for VFD are variable speed drive, adjustable speed drive, adjustable-frequency drive (AFD), AC drive, microdrive, and inverter.

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