TECHNICAL FEATURE

Capture and Containment

Commercial Kitchen Ventilation Exhaust Hoods

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The science of commercial kitchen ventilation (CKV) continues to evolve at a rapid pace, driven by ASHRAE research projects,[1–4] an expanding line of high-performance and innovative products, and ongoing testing by various organizations and research facilities.[5] All of this information, along with the results of a California Energy Commission-funded makeup air research project,[6] is leading to updates of the national codes (ASHRAE Standard 154, NFPA 96, UMC, ASHRAE/IES Standard 90.1 and California Title 24)[7–11] and fundamentally changing the way CKV systems are designed and operated (e.g., application of demand-controlled kitchen ventilation).[12]

ASHRAE's comprehensive 39-page *Handbook—HVAC Applications* chapter on kitchen ventilation[13] is a dramatic improvement over the two paragraphs in the *Handbook* that existed when the authors began their careers in kitchen ventilation. However, there are still many details associated with the installation of exhaust hoods, makeup air systems, and appliance layout that are overlooked (or not recognized for their importance) within the design and specifications for CKV systems.[14] This article focuses on CKV system attributes and installation best practices that have been identified and/or quantified through public-domain research (as referenced above).

"Hot air rises!" This introductory sentence to a design guide series[14] coordinated by the authors states the obvious. So why then does the thermal plume off cooking equipment sometimes rise and stay within the hood reservoir, while at other times it fills the kitchen with smoke, grease, and heat? Research sponsored by ASHRAE has provided intriguing insights into this question.

In addition to the more obvious "it depends on the amount of exhaust air" factor, research has demonstrated that hood style, construction features and installation configurations, makeup air introduction, as well as the positioning of appliances beneath the hood had a

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dramatic influence on the ability of the hood to capture and contain.

By making what might appear to the design engineer, installing contractor or kitchen manager to be subtle changes, a surprisingly wide range in the exhaust rates required for complete capture and containment (C&C) of cooking effluent can result due to appliance position and/or hood installation details and configuration. Within the real world of commercial food service, this explains why an identical exhaust hood installed over virtually the same appliance line performs successfully in one kitchen and fails in another.

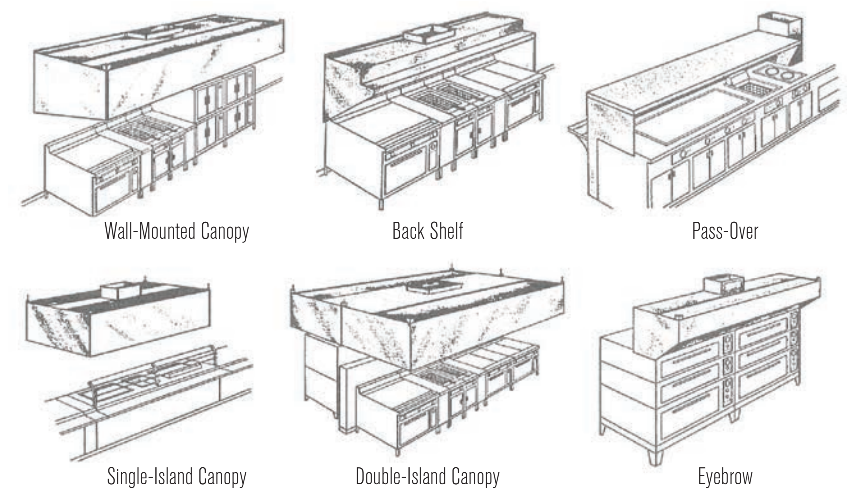


FIGURE 1 Styles of exhaust hoods. Source: 2015 *ASHRAE Handbook—Applications,* Chapter 33, Kitchen Ventilation.

However, as stated, such attributes (often outside the direct responsibility of the hood manufacturer) are often neglected within the CKV design specifications (e.g., end panels, appliance placement, overhang, space behind appliances, size of hood, etc.). The key to optimizing CKV performance is in the design details.

Hood Factor: Capture and Containment

First, the design exhaust rate that is the foundation for capture and containment (C&C) depends on the hood style and construction features. Driven in part by standardized test methods and their application by third-party laboratories, many aerodynamic features have been integrated into the design of leading brands of listed hoods (e.g., flanges or lips along the hood's lower edge, air jets, filter position and size, elimination of filter shelf, etc.). 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 (*Figure 1*).

Generally, for the identical cooking appliance (thermal plume) challenge, 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 susceptible to cross drafts. Single-island canopy hoods present the "ultimate" capture and containment challenge in hood applications and are often the foundation of C&C problems in display cooking kitchens.

ASTM Standard F1704

Threshold exhaust rates for a specific hood and appliance configuration may be determined by laboratory testing under the specifications of ASTM F1704-12, *Standard Test Method for Capture and Containment Performance of Commercial Kitchen Exhaust Ventilation Systems.*[15] This standard test method was developed to provide a reliable measure of a hood's ability to capture and contain the effluent produced by a defined cooking challenge.

The phrase "hood capture and containment" is defined in ASTM F1704-12 as "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 the products getting into the hood reservoir, while containment refers to these products staying in the hood reservoir and not spilling out into the adjacent space.

The phrase "minimum capture and containment" is defined as "the conditions of hood operation at which the exhaust flow rate is just sufficient to capture and contain the products generated by the appliance in idle or heavy-load cooking conditions, or at any intermediate prescribed load condition." During a C&C test with the cooking appliances in a full production, part loading or idle condition, the exhaust rate is reduced until spillage of the plume is observed.

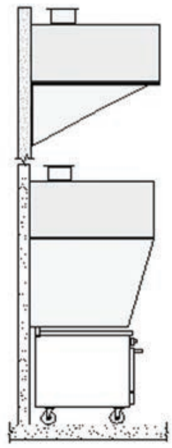


FIGURE 2 Illustration of a full and partial side panel on a wall-canopy hood.

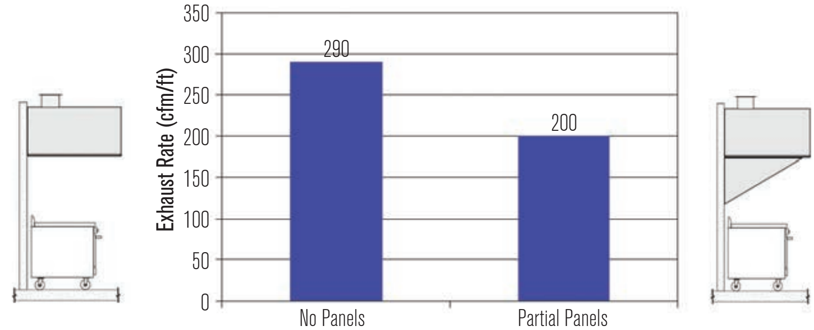
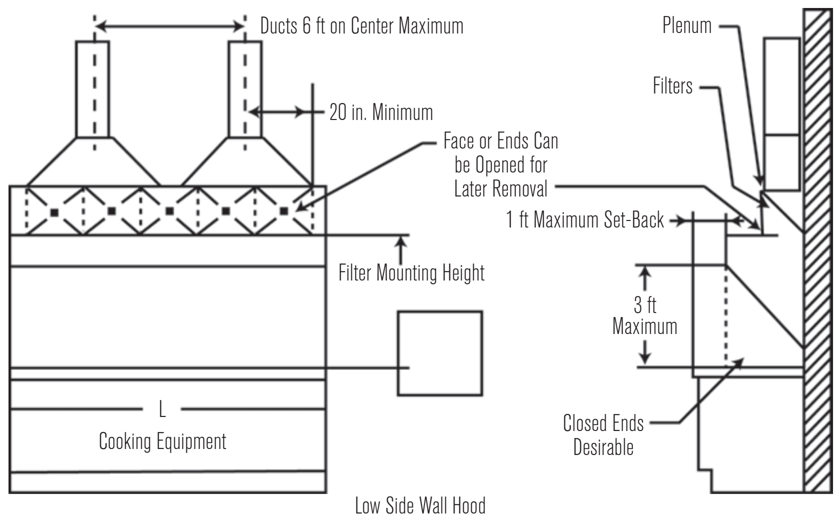


FIGURE 3 Reduction in C&C exhaust rates with and without side panels (Ninety tests of different hood and appliance setups.)



Q = 200 cfm/lineal ft of cooking surface (200 L)
Minimum duct velocity = 1,000 to 4,000 fpm, to suit conditions
h_e = (filter resistance + 0.1 in.) + 0.50 VP_4 (straight take off)
h_e = (filter resistance + 0.1 in.) + 0.25 VP_4 (tapered take off)

FIGURE 4 Recommended hood design from Industrial Ventilation Manual in 1980.[17]

The exhaust rate is then increased in fine increments until a condition of C&C is established. Similar in concept to the listed "cfm" derived from UL 710, *Exhaust Hoods for Commercial Cooking Equipment,*[16] the threshold of C&C for an ASTM F1704-12 test is established under ideal laboratory conditions and is only a reference point for selecting the exhaust airflow for a real-world project.

Side Panels, End Panels and End Walls

Side (or end) panels or skirts (both partial or full as represented in *Figure 2*) permit a reduced exhaust rate, as more of the replacement air is drawn across the front of the equipment, improving capture of the effluent plume generated by the hot equipment. Although defying its definition as an "island" canopy, end panels can dramatically improve the performance of a double-island or single-island canopy hood. Another benefit of end panels is to mitigate the negative effect that cross drafts or airflow from diffusers can have on hood performance.

Laboratory testing[1,2,3,5] has demonstrated reductions in capture and containment airflow rates up to 100 cfm/ft (155 L/s·m) of hood by the application of partial side panels on 10 ft (3 m) wall-canopy hoods. On average, a reduction of 30% was determined for more than 90 tests of different hoods and appliance loading (heavy, medium, light-duty) with and without some configuration of a side panel (*Figure 3*).

The lead author's first professional-development exercise was attending a class on industrial ventilation in the early 1980s. What became apparent was the dramatic difference between the design of a fume hood and a kitchen exhaust hood.[17] Of specific interest was the fact that the design drawing illustrating best practices for a low side-wall kitchen hood recommended closed ends (*Figure 4*). This recommendation was replicated in other design guides published by leading kitchen hood manufacturers at that time. However, no suggested

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reduction in exhaust rates associated with addition of the side panels was provided.

In general, the attributes incorporated within the fume hood design to ensure 100% capture efficiency were lacking in the commercial kitchens that the authors surveyed. It's been a long, slow battle to gain market adoption of something so simple.

PHOTO 1 Demonstrating the performance benefit of side panels retrofit to a proximity hood—35 years ago.[18]

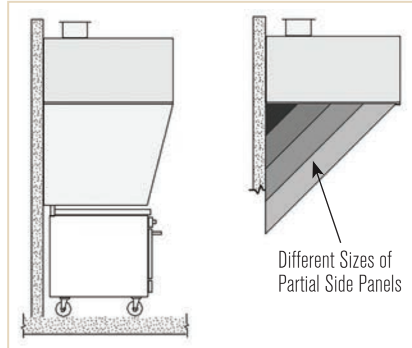

FIGURE 5 Illustration of full and partial end panels used for testing in *Figure 6*.

At the beginning of a "kitchen ventilation-centric" career, the lead author headed up a Canadian government-sponsored restaurant energy-efficiency program.[18] Testing kitchen ventilation with a smoke generator at a university cafeteria revealed, both quickly and dramatically, the value of adding side walls to an exhaust hood (*Photo 1*).

Thirty-five years later, we are still trying to encourage, as standard practice rather than best practice, the specification of side panels on kitchen exhaust hoods. It's time for the engineers and designers of CKV systems to understand the benefit and defend the inclusion of side panels within the CKV system specification.

Of particular importance to this best practice recommendation is the fact that partial side panels can provide much of the benefit offered by full side panels (*Figure 5*). Even very small side panels (e.g., 1 ft × 1 ft × 45 degrees [0.3 m × 0.3 m × 45 degrees]) can improve C&C performance.

The impact on C&C airflow for different side panel configurations on six fryers cooking under a 10 ft (3 m) wall-canopy hood for three overhangs (6, 12 and 18 in. [152, 305 and 457 mm]) is shown in *Figure 6*. The range in airflow is dramatic, from 3,300 cfm (1557 L/s) for no side panel with a 6 in. (152 mm) overhang down to 1,600 cfm (755 L/s) for a 4 ft (1.2 m) partial panel and an 18 in. (457 mm) overhang. The data speaks for itself.

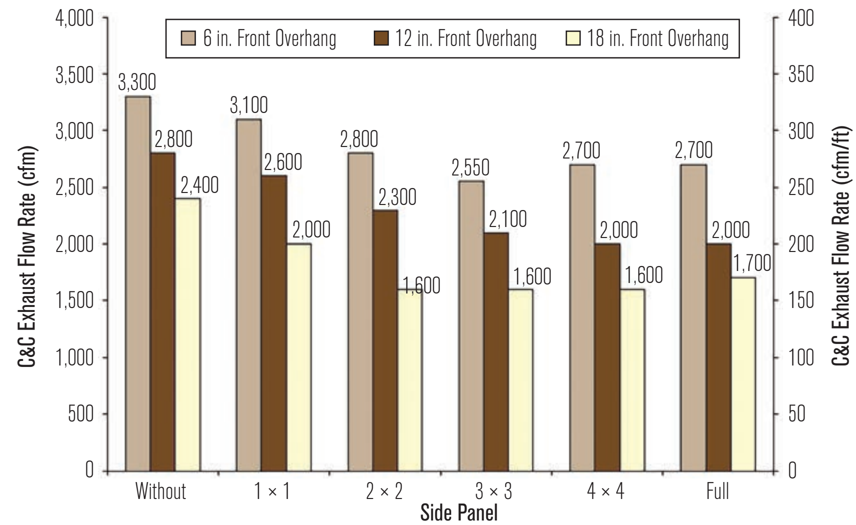

FIGURE 6 C&C airflow rates for six fryers cooking under a 10 ft × 4 ft wall-canopy hood.

The authors recognize that side panels or skirts may not always be appropriate or physically practical. Under these situations (albeit limited in our opinion), the specification of a "listed" hood that has its own design features (flanges, lips, air jets, elimination of filter shelf) to minimize spill from the end of the hood is important.

Third party laboratories have published hood performance data derived from the ASTM F1704-12 Test Method, illustrating differences in C&C airflow for the leading hood brands.[5] However, we are not conceding to the sales pitch that "our hoods work so well that side panels

PHOTO 2 Retrofitted end panels pass the test in a real-world kitchen.

PHOTO 3 (LEFT) AND PHOTO 4 (RIGHT) Real-world illustrations of excessive gap behind cooking equipment and wall.

are not necessary." They are! In our experience, the C&C performance along the end of the hood is always improved by adding a panel or skirt. Alternatively stated, a high-performance hood with end panels becomes an even higher performing hood than it is in its naked configuration.

Think about the design of a fume hood or fireplace. No engineer would ever consider using a canopy hood without back, sides and partial front. The fact that the effluent from cooking processes is not considered dangerous to one's health (at least on the short term) may explain why the design community bends to the desire of the client for a wide-open kitchen.

For those who know the authors professionally, we sound like a broken record. But, bar none, the most significant and cost-effective technique for improving hood performance is the addition of a side panel, side skirt, or end wall. We have never tested an exhaust hood in the laboratory that didn't benefit from the addition of a side panel of some configuration, regardless of how well the hood performed without this attribute. And, with 30 years of troubleshooting in the field, we have retrofit side panels onto dozens of CKV systems as a fix to hood performance issues (*Photo 2*). But, the resistance to specifying even partial end panels remains ingrained in the industry as the perception of "reduced" view within the kitchen endures.

Ironically, the end panels that are used to fix hood "capture" problems in the field elicit no disdain for loss of vision or communication in the kitchen, as making the "problem" go away trumps any imposition by the panels. In hindsight, this article could have simply been titled "The Benefit of Specifying Side Panels on Kitchen Exhaust Hoods."

Overhang and Rear Gap

Somewhat less controversial, but still not embraced to the extent warranted, is that an increase in overhang will significantly improve the ability of a wall-canopy hood to capture and contain cooking effluent. This may be accomplished by pushing the appliances as far back to the wall as practical and/or by specifying a deeper hood. This also decreases the gap between the rear of the appliance and the back wall, further improving the capture performance of the hood.

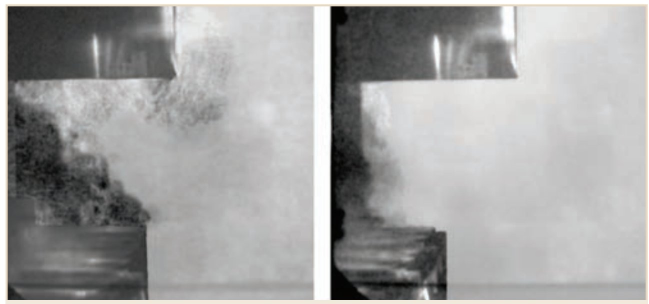

PHOTO 5 C&C performance with different overhangs.

Sometimes, more space than necessary exists between the rear of cooking equipment and the back wall (*Photos 3* and *4*), often to accommodate sloppy piping. This can also occur when appliances such as a range, fryer or griddle are positioned to line up with the front of deeper appliances such as combination ovens.

A large overhang also is beneficial for appliances that create plume surges when doors or lids are opened, such as convection and combination ovens, steam kettles, compartment steamers and pressure fryers. Specifying a deeper hood (e.g., 5 ft vs. 4 ft [1.5 m vs. 1.2 m]) will directly increase overhang, provided appliances are situated as far back as possible in the hood. This is an effective solution for the oven or combination oven and its "door-opening" challenge.

Be aware that code-required overhangs are minimums, not best practice. The cost to punch out the hood an extra foot is minimal in context with the total cost of the CKV system. *Photo 5* illustrates the impact of overhang on six fryers cooking under a 10 ft (3 m)

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wall-canopy hood. At 2,400 cfm (1133 L/s) or 240 cfm/ft (372 L/s·m) exhaust rate, effluent was spilled with a 6 in. (152 mm) overhang, while it was fully captured and contained with an 18 in. (457 mm) overhang.

Finally, something that works in concert: increased overhang and reduced rear gap (*Figure 7*). And, if one inserts a rear seal (solid shelf) behind the appliance to fill in the rear gap (*Photo 6*), the hood performance gets even better. This performance advantage is quantified in *Figure 8*, where the C&C exhaust rate ranged from a high of 5,100 cfm (2407 L/s) with 6 in. (152 mm) overhang and no rear seal to a low of 2,800 cfm (1321 L/s) with an 18 in. (457 mm) overhang and a 4.5 in. rear seal. Even with a 6 in. (152 mm) overhang, a 16.5 in. (419 mm) rear seal reduced the exhaust flow to 3,400 cfm (1605 L/s). And, that does not include the added benefit of side panels that brought the lowest C&C value down to 2,500 cfm (1180 L/s). Amazing! 250 cfm/ft (387 L/s·m) for charbroilers cooking a full load of burgers at a 600°F (316°C) surface temperature.

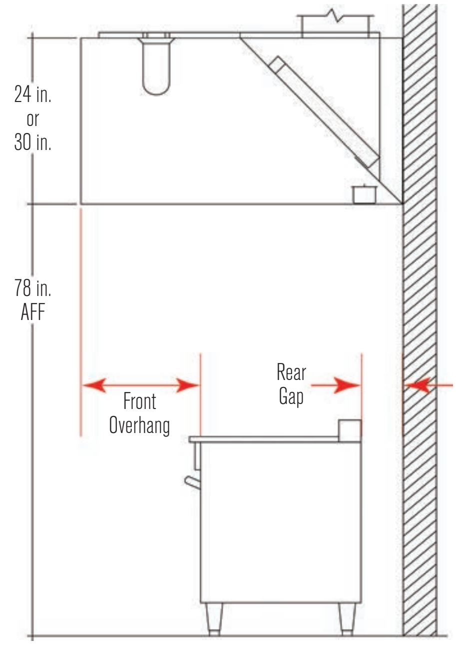
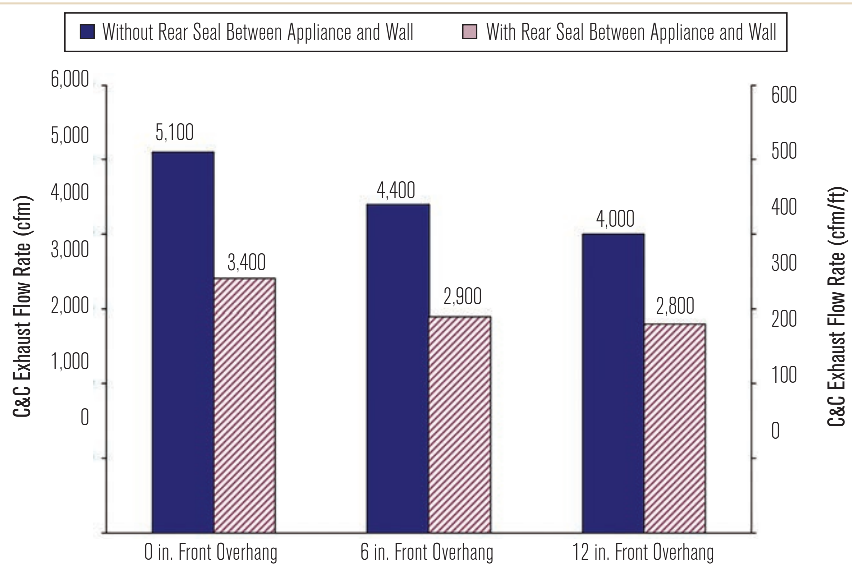


FIGURE 7 Front overhang relationship to rear gap. PHOTO 6 Sealed gap behind appliances.



Front Overhang to Appliance (in.)	Front Overhang to Cooking Surface (in.)	Distance Between the Rear of The Appliance and Backwall (in.)
0	6.0	16.5
6.0	12.0	10.5
12.0	18.0	4.5

FIGURE 8 C&C exhaust rates for broiler operation under a 10 ft wall-mounted canopy hood at different overhangs with and without rear seal.

Internal Height of Hood (Volume of Hood Reservoir)

The volume of hood reservoir (or capture tank in front of the filter bank) is determined by the hood depth and height. As discussed, a deeper hood facilitates a larger overhang and associated reduction in exhaust airflow for C&C. This reduction in exhaust rate is also attributed to the increased hood reservoir. But, another way to increase capture tank volume is to increase the internal hood height. While this is not always practical given the ceiling height of kitchens, there are high-ceiling kitchens that can accommodate increasing the hood height (*Figure 9*). Again, the cost of the additional stainless steel could be considered minor compared to the total cost of the hood or CKV system.

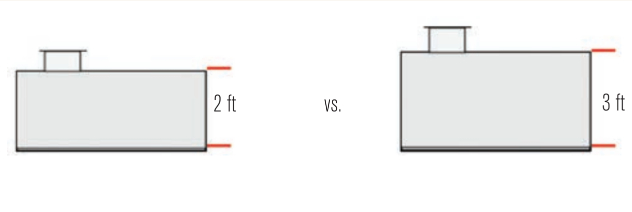


FIGURE 9 Illustration of 2 ft high hood vs. 3 ft high hood.

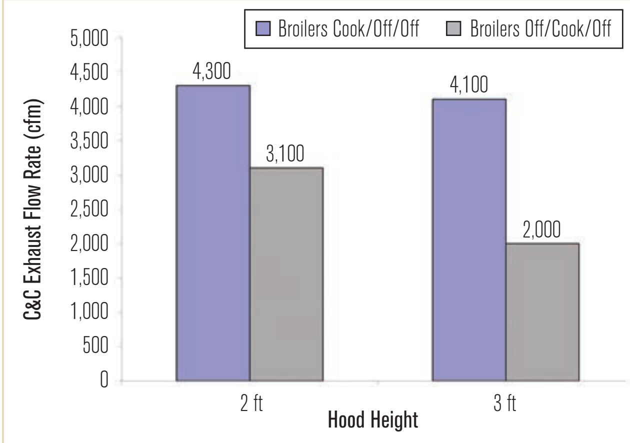


FIGURE 10 Three underfired broilers installed under 10 ft long × 4 ft deep wall-mounted canopy hood.

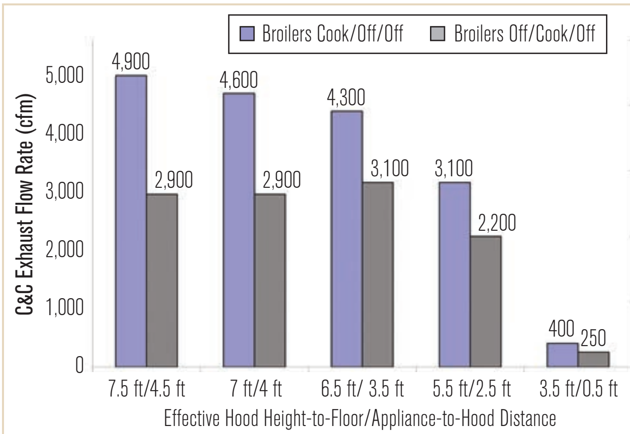


FIGURE 11 Effect of hood mounting height on C&C exhaust airflow for a 10 ft wall-mounted canopy hood operating over three 3 ft underfired broilers.

The first question asked: How much difference does it make? And the answer: It depends. The graph in *Figure 10* shows threshold C&C exhaust rates for three 3 ft (0.9 m) under-fired broilers placed under a 10 ft (3 m) wall-canopy hood without side panels. During the C&C testing, only one of the three broilers was used for full-load cooking.

The blue column shows the exhaust rate when the broiler on the left end of the hood was in operation, while the gray column shows when the broiler in the middle was in operation. Both broiler-use conditions were tested with the 2 ft (0.6 m) high and 3 ft (0.9 m) high hood.

For the broiler-on-the-end condition, the extra hood height made little difference. But, when the broiler in the middle was operated, a dramatic reduction in exhaust air needed for C&C was demonstrated. In fact, the threshold 2,000 cfm (944 L/s) for C&C with the broiler in the middle of the higher hood was more than a 50% reduction over the 4,300 cfm (2029 L/s) for the broiler on the end of the shallower hood. And, if an end wall was installed on the hood with the broiler cooking on the end, the C&C exhaust rates approach the values measured for the broiler in the middle of the hood. Who would have guessed such a dramatic difference?

Hood Mounting Height

The effect that mounting height of a wall-canopy hood has on hood performance is often debated within the design community. While building codes universally require a minimum 6.5 ft (2 m) distance between the lower edge of the hood and the finished floor, it is often desirable to increase the hood height spec to ensure that this minimum is always attained. It is not unheard of for the hood to be hung at 6.5 ft (2 m) before the floor tiles are installed. Red tag! So the question is often: What is the impact of hood height on C&C?

In response, the authors set out to obtain data for a 10 ft (3 m) hood operating over three 3 ft (0.9 m) under-fired broilers installed at different floor-to-front-edge-of-hood heights. In *Figure 11*, the blue columns reflect C&C performance when only the left end broiler is cooking, while the gray bars are C&C values with the middle broiler cooking. Overall, increasing hood-mounting height to 7.5 ft (2.3 m) has a minimal impact. Remember, the negative impact for the broiler on the end of the hood could be eliminated with a side panel.

While the hood height of 5.5 ft (1.7 m) is not realistic for a wall-mounted canopy hood, it illustrated why a proximity hood can outperform a canopy hood. And, while a mounting height of 3.5 ft (1.1 m) is ridiculous for a canopy hood, the low exhaust rate shows how little exhaust is really needed to contain the cooking effluent, illustrating the potential benefit of a totally integrated hood/appliance system.

Appliance Position Under the Hood

An important (albeit intuitive) concept confirmed by the testing was that heavy-duty equipment should be positioned in the middle of the cook line. If a heavy-duty appliance is on the end, incorporating a side panel or end wall is imperative. In particular, broilers should not be placed at the end of a cook line. Fryers, which are classified as medium duty, also have an adverse effect on C&C when located at the end the cook line.

PHOTO 7 (LEFT) AND PHOTO 8 (RIGHT) Illustration of heavy-duty appliance position under a wall-canopy hood.

Gas-fired ranges (typically six burner) can be located at the end of a cook line because under typical operating conditions the plume strength is not as high as that of broilers. Locating double-stacked ovens or steamers at the end of the hood is beneficial due to a plume-control effect that tends to assist capture and containment that is similar to but not as effective as a side panel. Again, both are desired.

Appliance location from side-to-side and from front-to-back can increase or decrease the threshold of capture and containment by as much as 30%. Multiple, different appliances tend not to be used at the same time due to the sequences of menu preparation. Consequently total plume strength is less than a group of like appliances that may be used at the same time for batch preparation (*Photos 7* and *8*). The variation in exhaust rate for a six-burner range located at the left side of the hood with different burners operating is illustrated in *Figure 12*. The variation is significant, confirming that the design flow rate becomes a judgment call (through experience) by the CKV designer.

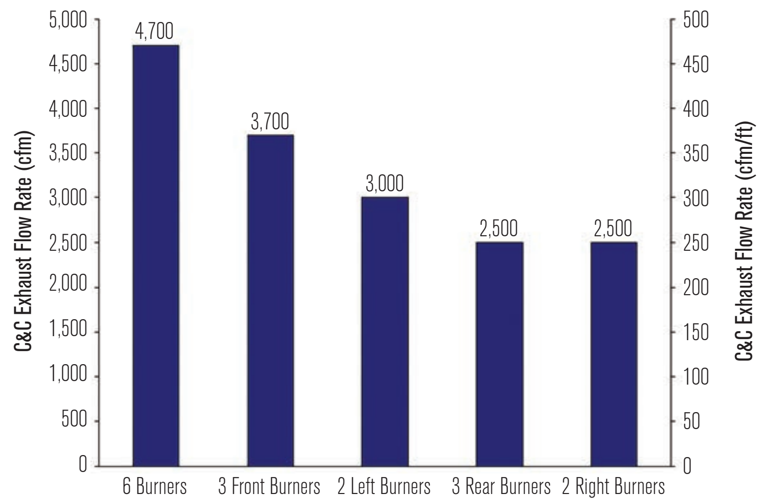


FIGURE 12 Threshold C&C flow rates for different range burner usage configurations.

Minimize Dedicated Makeup Air Volume and Velocity

Historically, this concept has been counter to general practice, as locally supplied makeup air is often the easiest design solution where the makeup airflow is 80% (or more) of the exhaust flow. Often, locally supplied makeup introduces air quantities and velocities that interfere with the ability of the exhaust hood to capture and contain cooking effluent. Once the transfer airflow has been established, the quantity of dedicated makeup air is determined by subtracting the amount of transfer air from the total exhaust air volume.

Introduce this reduced amount of makeup air at the lowest velocity possible by maximizing the area of the supply grilles. And, as a side note, do not specify four-way diffusers anywhere near exhaust hoods (or, for that matter, anywhere in the kitchen). CKV research[6] demonstrated that supplying more than 60% of the replacement air requirement within the vicinity of the hood could challenge the hood's ability to capture and contain, requiring the exhaust airflow to be increased to attain C&C.

Bottom Line

This article has focused on the subtle aspects of hood installation and appliance placement that can significantly impact hood performance but are often neglected within the design. It is the authors' hope that by presenting parametric comparisons of various configurations for a given hood installation and appliance layout, the benefits of what often appear to be minor attributes will encourage engineers to embrace a more detailed specification. And, while the introduction of makeup air is a major factor that affects hood performance and is discussed briefly, it could be the subject of a dedicated article. In summary, tools for the Design Toolbox include:

- Bigger hoods (including deeper or taller hoods);
- Lower hoods (or proximity style where practical);
- Side panels, end panels, end walls;
- Push back equipment (minimize rear gap)—consider rear seal or shelf;
- Heavy-duty equipment (e.g., broiler) in middle;
- Light-duty equipment (e.g., ovens) on the end;
- Don't waste hood space over non-cooking equipment;
- Introduce makeup air at low velocity; and
- Ensure an air balance of the kitchen CKV-HVAC system.

Who would believe that 35 years from the authors' introduction to kitchen ventilation that the industry is still innovating at a rapid pace? And thanks to ASHRAE research, standards and *Handbook—HVAC Applications*, we can confidently say that North America now leads the world with respect to design practices and high-performance products for CKV systems—a paradigm shift from when we started our careers in the commercial kitchen.

Acknowledgments

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