# Design Guide 4

## Improving Commercial Kitchen Ventilation System Performance By

# Optimizing Appliance Position and Hood Configuration

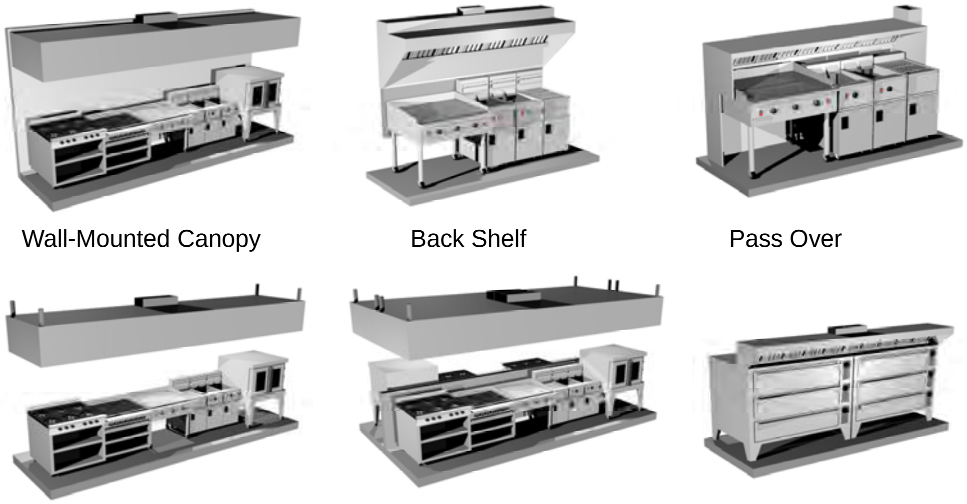
This design guide provides information that will help achieve optimum performance and energy efficiency in commercial kitchen ventilation systems by properly positioning the cooking equipment beneath a hood that has been configured to maximize its capture and containment (C&C) performance. The information presented is applicable to new construction and, in many instances, retrofit construction. The audience for this guideline is kitchen designers, mechanical engineers, code officials, food service operators, property managers, and maintenance technicians. This guide is intended to augment comprehensive design information published in the Kitchen Ventilation Chapter in the ASHRAE Handbook on HVAC Applications, as well as *Design Guides 1, 2 and 3.*

This guide focuses on the impact that equipment layout, with respect to hood position, can have on the ability of the hood to capture and contain. It describes the importance of subtle details including overhang, gap behind appliances, hood mounting height, and side panels.

"Hot air rises!" This introductory sentence to Design Guide 1 states the obvious. But why does it sometimes rise and stay within the hood envelope and other times fill the kitchen with smoke, grease, and heat? Recent research sponsored by the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) provided intriguing insights into this question. In addition to the more obvious "it depends on the amount of exhaust air" factor, this ASHRAE research demonstrated that hood style and construction features, as well as the positioning of appliances beneath the hood, had a dramatic influence on the ability of the hood to capture and contain. By making what might appear to be subtle changes to the design engineer, installing contractor or kitchen manager, a surprisingly wide range in the exhaust rates required for complete capture and containment (C&C) can occur due to appliance position and/or hood configuration. Within the real world of commercial food service, this explains why a similar hood installed over virtually the same appliance line performs successfully in one kitchen while the same design may fail in another. The key to performance is in the design details!

## Background

The design exhaust rate depends on the hood style and construction features. 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 same thermal plume challenge from a cooking appliance, 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.



Wall-Mounted Canopy

Back Shelf

Pass Over

Single-Island Canopy

Double-Island Canopy

Eyebrow

*Figure 1. Styles of Exhaust Hoods.*

Although a well-engineered proximity hood can be applied with success at very low exhaust rates (e.g., 150 cfm per linear foot over medium-duty equipment), this same style of hood (if specified without performance data and/or in accordance with maximum height and setback permitted by code) may fail to effectively capture and contain the cooking effluent at exhaust rates of 300 cfm/ft or more. Figure 2 illustrates relatively effective and ineffective applications of proximity hoods.

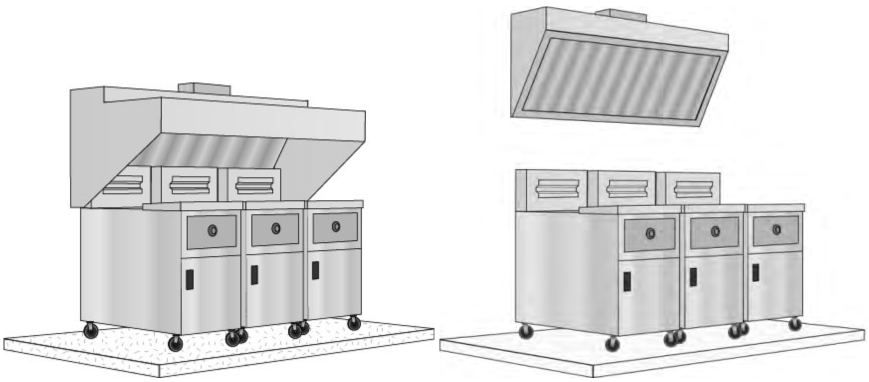


*Figure 2. Proximity Hood.*

*Effective Design*

*Ineffective Design*

Building and health codes typically provide basic construction and materials requirements for exhaust hoods, as well as prescriptive exhaust rates based on appliance duty and length of the hood (cfm per linear ft) or open face area of the hood (cfm per $ft^2$). Codes usually recognize exceptions for hoods that have been tested against a recognized standard, such as Underwriters Laboratories (UL) Standard 710. Part of the UL 710 standard is a “cooking smoke and flare up” test. This test is essentially a cooking effluent capture and containment (C&C) test where "no evidence of smoke or flame escaping outside the exhaust hood" must be observed.

Hoods bearing a recognized laboratory mark are called *listed* hoods, while those constructed to the prescriptive requirements of the building code are called *unlisted* hoods. Generally, an off-the-shelf *listed* hood can be operated at a lower exhaust rate than an *unlisted* hood of comparable style and size over the same cook line. Lower exhaust rates may be proven by laboratory testing with specific hood(s) and appliance lineup using the test protocol described in ASTM Standard F-1704, *Test Method for Performance of Commercial Kitchen Exhaust Systems*. This process is sometimes referred to as "custom-engineering" a hood. Figure 3 illustrates the dramatic reduction in ventilation rate that can be achieved by custom-engineering a hood and using a larger front overhang (discussed below).

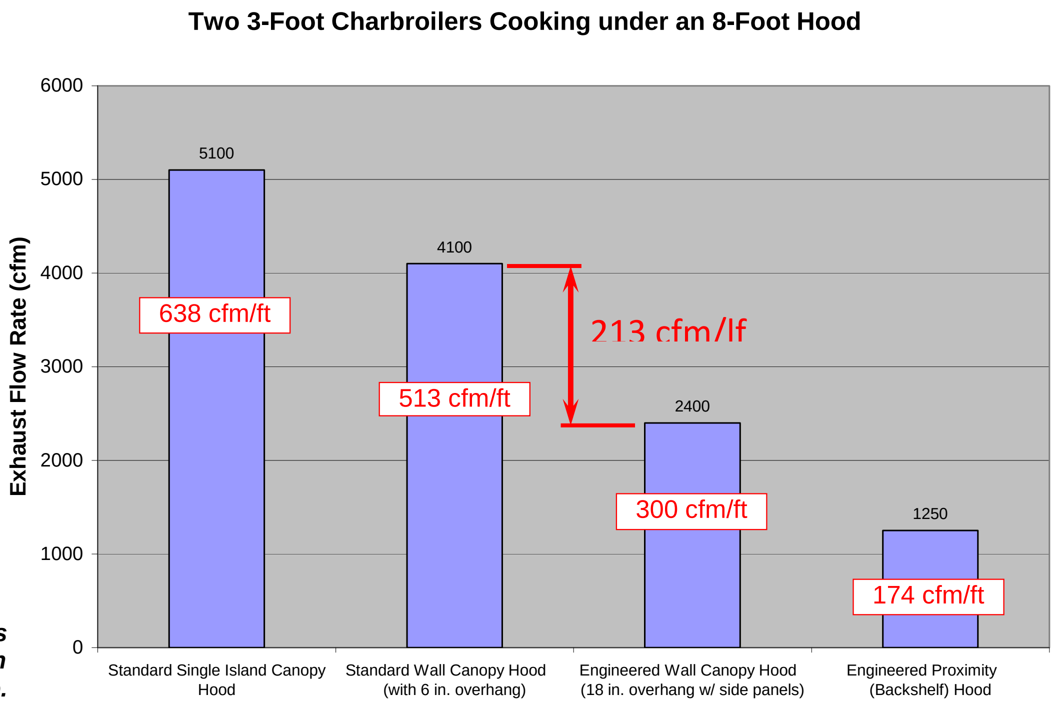


***Figure 3. Custom-engineering Achieves Significant Reduction in Exhaust Flow Rate.***

In addition to hood type, testing different combinations of these appliances demonstrated that minimum capture and containment (C&C) rates vary significantly due to appliance type and position under the hood.

## *Test Setup*

The ASHRAE research testing used a 10-ft wall-mounted canopy hood with sets of three cooking appliances (combinations of ovens, fryers, and broilers, as illustrated in Figures 4 and 5). Note that a clear plastic wall was used for the tests to allow the optical system to detect spillage at the sides of the hood.

***Figure 4. Appliances and Exhaust Hood Used in ASHRAE Research with Broiler at End.***

***Figure 5. Appliances and Exhaust Hood Used in ASHRAE Research with Broiler in Middle.***

The testing included the effect of side-to-side appliance position (at the ends and in the middle), as well as front-to-back under the canopy hood. The test matrix always had three appliances under the hood, including pairs of like appliances and one of the other appliances, as well as sets of three like appliances.

ASHRAE Standard 154, Ventilation for Commercial Cooking Operations provides the following definitions for appliance duty level:

The duty level is categorized based upon the exhaust airflow required to capture, contain and remove the cooking effluent and products of combustion under typical operating conditions with a non-engineered wall-mounted canopy hood (RP-1362, 2009). Historically duty levels were based upon the temperature of the cooking surface. The following appliance duty classifications are used in this standard:

- ***Light***: a cooking process that generally required an exhaust airflow rate of less than 200 cfm/ft (310 L/s/m).
- ***Medium***: a cooking process that generally required an exhaust airflow rate of 200 to 300 cfm/ft (310 to 460 L/s/m).
- ***Heavy***: a cooking process that generally required an exhaust airflow rate of 300 to 400 cfm/ft (460 to 620 L/s/m).
- ***Extra-heavy***: a cooking process that generally required an exhaust airflow rate greater than 400 cfm/ft (620 L/s/m).

Examples of appliances within each level:

- ***Light***: convection ovens, steamers, kettles, combi-ovens,
- ***Medium***: conveyor ovens, fryers, griddles, open-burner ranges,
- ***Heavy***: under-fired broilers, wok ranges,
- ***Extra-heavy:*** solid fuel (wood, charcoal, briquettes, and mesquite) appliances.

## Effect of Appliance Position

The position of an appliance under a hood can dramatically impact the ability of the hood to capture and contain the appliance's effluent plume. Lower exhaust rates can be used by locating a heavy-duty appliance, such as an underfired broiler, in the center of the hood rather than placing it at one end of the hood or the other. The dynamics around this concept seem to be common-sense. But, it is common to encounter kitchen designs where the underfired broiler is located at the end of the hood, challenging the ability of that hood to capture and contain the heat and smoke. Furthermore, the interaction of the broiler with other appliances in the cook line can influence hood performance.

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%. The factors underlying this variability in exhaust rate are explained below.

### *Appliance Position (side–to–side)*

Appliance position testing confirmed that the duty of the end appliances had the greatest influence on the exhaust rate of an appliance line. The end appliances drove the exhaust rate more than additional volume from the other two appliances, as they changed from off to cooking conditions or were varied in duty class. In most cases, locating the lowest duty appliance at the end of the appliance line achieved the lowest exhaust requirements for particular appliance lines. In other words, positioning the heaviest duty appliance in the middle of the appliance line optimized the hood performance.

Figure 6 shows results for combinations of these appliances in different positions. Note that the general trend, for tests with all appliances cooking, is that combinations with higher duty ratings require greater exhaust rates. Two interesting exceptions (red bars in Figure 6) are for a set of like-appliance tests of broilers and fryers where two of the appliances are off, and one on the end is cooking. These exceptions require significantly higher exhaust rates, in part due to the lack of thermal plume from the "off" appliances and the end position of the "on" appliance.

Location of appliances under the hood is often driven by menu preparation considerations. However, changes in layout can often be made without impacting kitchen operations. Be prepared to negotiate with operations and the food service consultant with respect to the performance benefit of including appliance position in planning equipment layout.

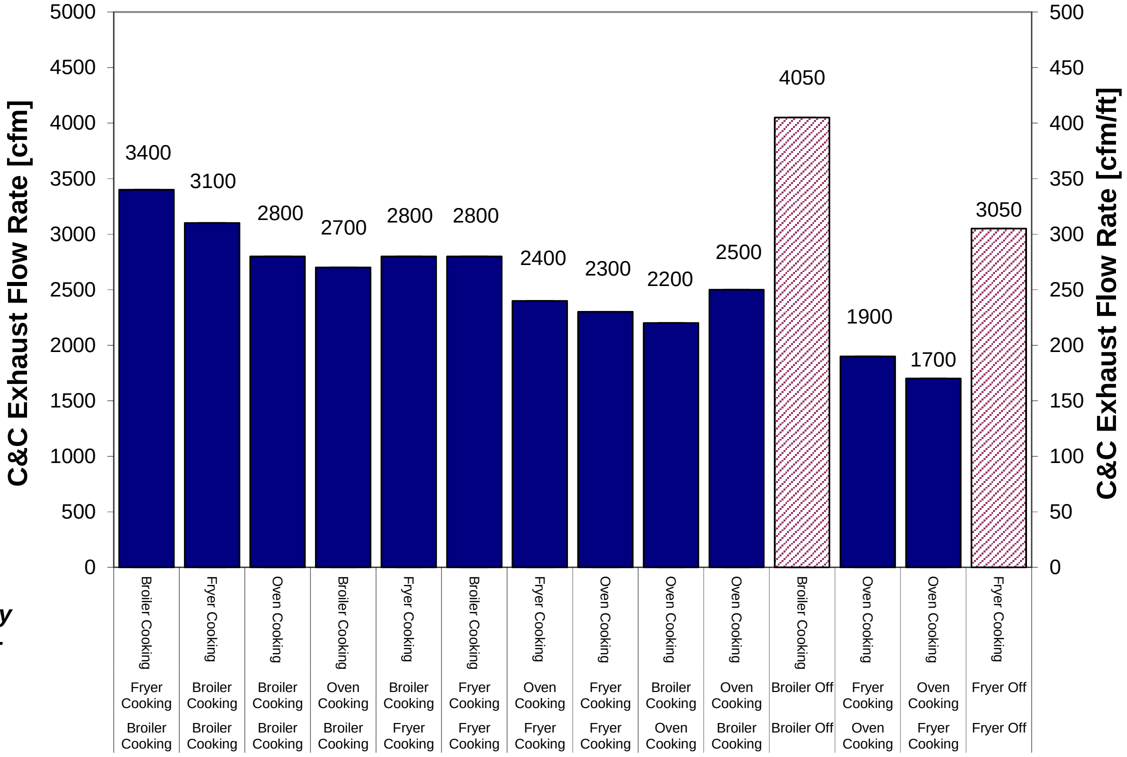


*Figure 6. Multi-Duty Appliance Line, Results for Dominant Duty Class.*

**Sizing Nomenclature for Canopy Hoods**

**Hood Length** refers to the linear dimension at the edge of the front face, or primary operating area, of the hood. Volumetric flow rates are normalized using the length of the front of the hood.

**Hood Depth** refers to the side dimension of the hood. The cross-section view in Figure 7 shows this dimension.

**Hood Height** refers to the vertical dimension of the hood. Figure 7 also shows this dimension, which is typically between 2 and 2.5 feet.

### *Appliance Position (front–to–back)*

Figure 7 illustrates front overhang and rear gap relative to an appliance position under a wall-mounted canopy hood. The increase in front overhang associated with pushing appliances toward the back wall significantly decreased the required exhaust rates. The ASHRAE research demonstrated that by maximizing the front overhang dimension, C&C exhaust rate reductions from 9 to 27% were achieved for three appliances of any duty class or combination under the 10-foot wall-canopy hood.

This exhaust rate reduction was not only due to the increased horizontal distance from the hood edge to the front of the appliance, but also because of the decreased distance between the back of the appliance and the wall. To separately evaluate the effect of reducing the gap between the wall and the rear of the appliance, a sheet metal panel was installed as a rear seal while keeping the front overhang constant. With a rear seal in place, a portion of the replacement air, which would have otherwise been drawn up from behind the appliances, was instead drawn in along the perimeter of the hood (helping guide the plume into the hood). When used on a heavy-duty broiler line, the rear seal reduced the exhaust rate between 1200 cfm and 1700 cfm depending on the initial overhang and associated depth of the rear seal. For all three conditions tested, this was approximately a 30% reduction in the exhaust rate.

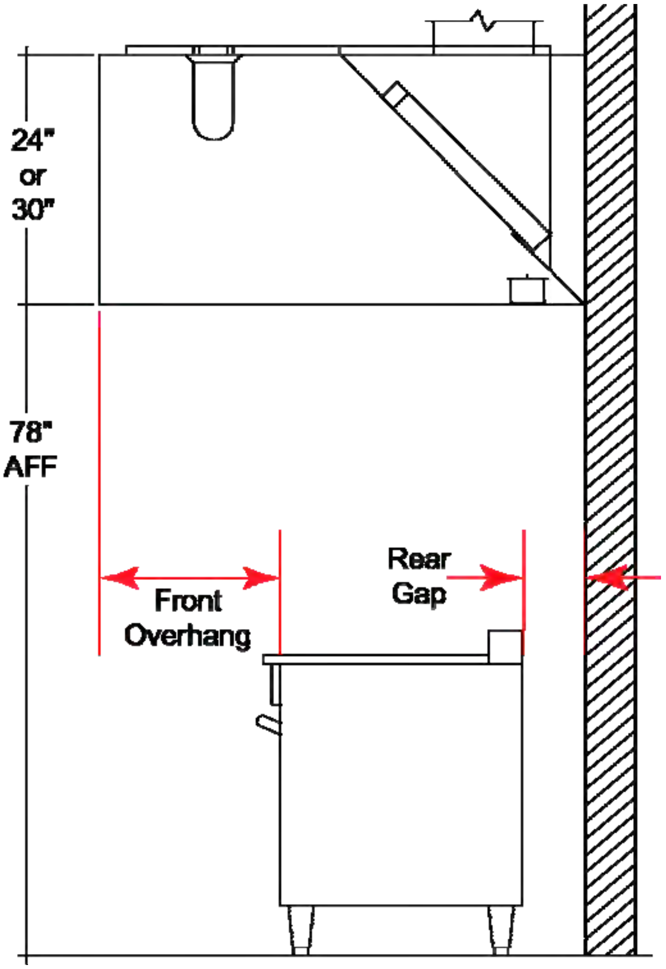


*Figure 7. Front Overhang and Rear Gap.*

A common practice in kitchens is to line up the fryers and broilers with the front of the largest appliance, which is typically a combination or convection oven. This practice results in the least amount of overhang and the greatest amount of rear gap. Appliances should be pushed as far back as practical or seal the rear gap to assure better C&C.

Figure 8 shows the results for a set of fryers with overhang distance at 6 inches, 12 inches, and 18 inches. As the overhang increases, the greater the reduction in the C&C exhaust rate. Figure 9 shows an example of a rear seal used during the research, which can be custom fabricated to fit the appliance geometries for a particular line up.

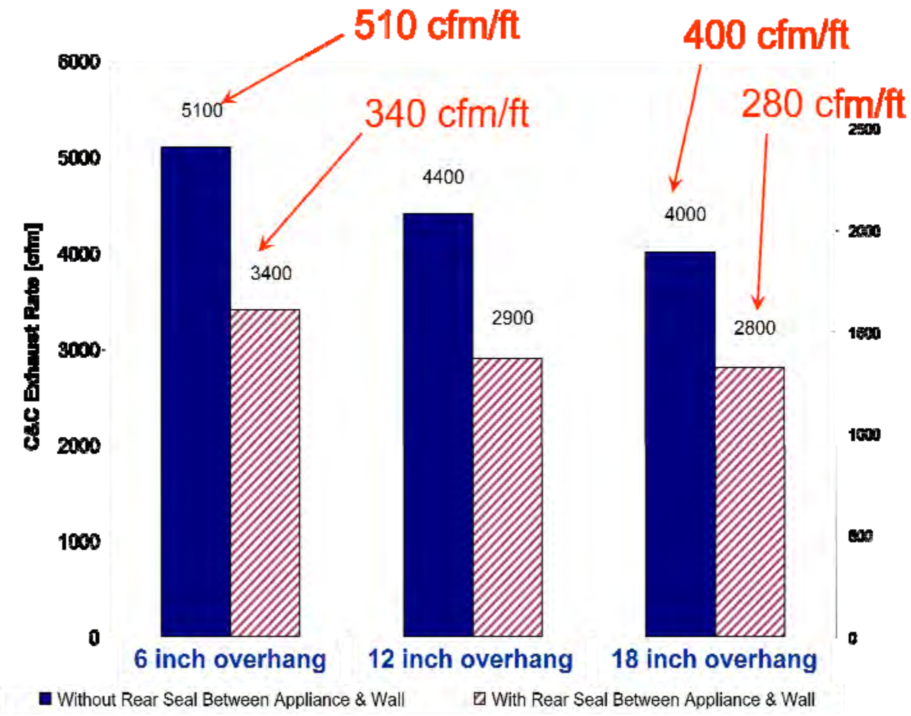


***Figure 8. Test Results With and Without Rear Seal.***

***Figure 9. Rear Seal Example.***

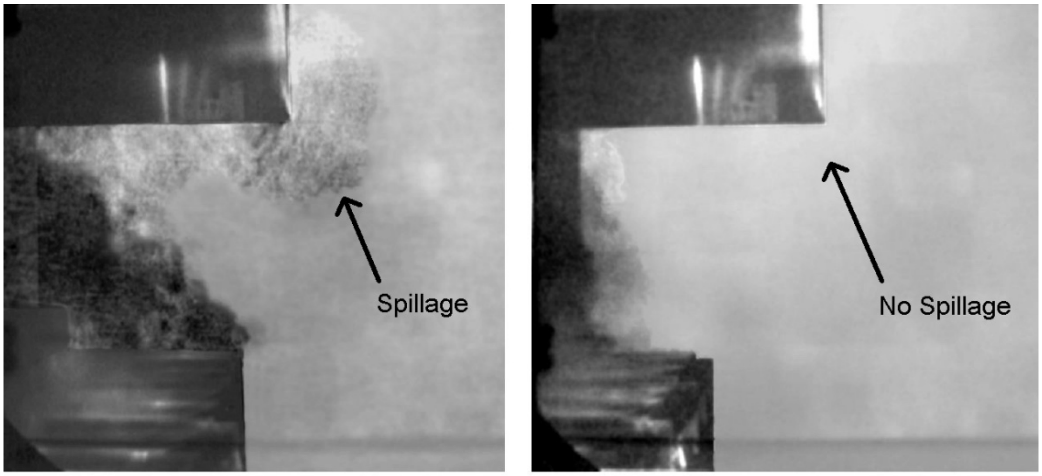
## Deeper Hoods (Maximizing Overhang)

An increase in overhang can improve the ability of a canopy hood to capture effluent because of the increased distance between the plume and hood edges. For new construction or retrofit, adding an extra foot (front-to-back, or side-to-side) for a canopy hood is an inexpensive means of assuring C&C. For an existing kitchen not undergoing renovation, this may be accomplished by pushing the appliances as far back under a canopy hood as practical (not something that is practical with a single-island canopy hood). This also decreases the gap between the rear of the appliance and the back wall, further improving the capture performance of the hood.

Larger overhangs are recommended 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. Larger overhangs are recommended for appliances that have larger (deeper) footprints. Specifying a deeper hood (e.g. 5 ft vs. 4 ft) will directly increase overhang, provided appliances remain as far back as possible under the hood, and is an effective solution for the oven or combination oven and its “door-opening” challenge. Remember that code-required overhangs are minimums, not best practice.

Although increasing the size of the hood improves C&C performance, for unlisted hoods under a local jurisdiction referencing the Uniform Mechanical Code (UMC), this would require an increase in the code-required exhaust rate because the UMC exhaust rates are based on cfm/ft$^2$ of hood aperture. Installation of shallow hoods (3-ft deep) was driven by this method of specifying the exhaust rate. Under the current edition of the International Mechanical Code (IMC) exhaust rates for unlisted hoods are specified on a “cfm/linear ft.” basis. Note that there is no cfm penalty for deeper unlisted hoods under the IMC, as well as for UL listed hoods under the IMC or the UMC.

Figure 9 illustrates the impact of overhang on three fryers cooking. At 2400 cfm (240 cfm/lf) exhaust rate, effluent is spilled with a 6-in overhang and is fully captured and contained with an 18-in overhang. Note that the plume is pulled forward with the 6-in overhang, in part due to the replacement air rising behind the appliances. The plume is pulled back toward the wall with the 18-in overhang and the reduced rear gap.



6 Inches of Front Overhang

18 Inches of Front Overhang

***Figure 9. The Importance of Front Overhang.***

The research also demonstrated that clearance from the back of the appliance to the hood back wall impacts the required exhaust flow rates. Figure 10 shows different combinations of front overhang and rear clearance to the back wall for three gas broilers under a wall canopy hood. Note that when the front overhang was only 6 in., the 5 ft. deep hood required a higher exhaust rate than the 4 ft. deep hood at this minimum overhang. But when the overhang was maximized to 24 in. for the 5 ft. hood, the exhaust rate was cut in half.

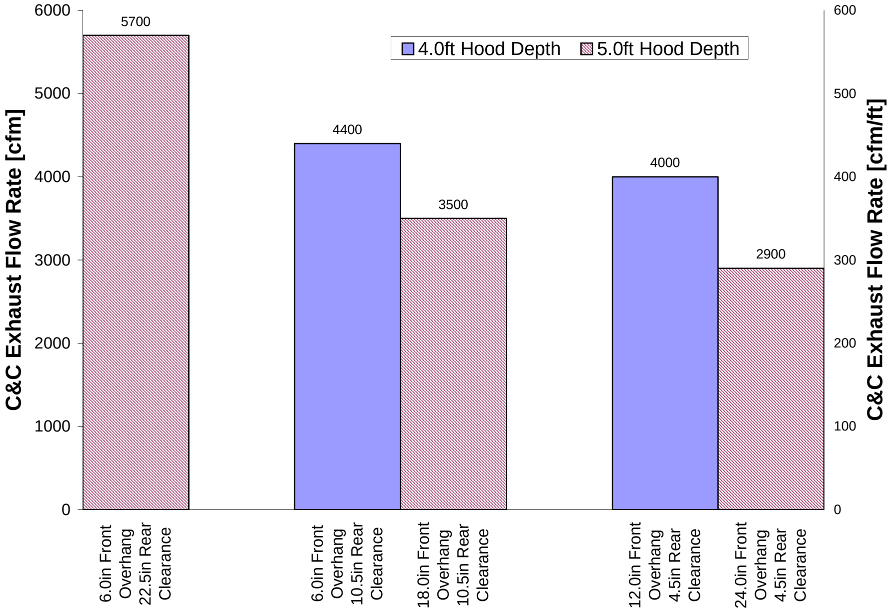


***Figure 9. Maximize Front Overhang and Minimize Rear Clearance for Best Performance.***

## Diversity in Appliance Duty

Estimating the total exhaust flow rate required for a line of multi-duty appliances using a rate from the like-duty appliance testing for the heaviest duty appliance in the line would over-estimate the exhaust requirement. A more accurate estimate is possible using the exhaust rates required for each appliance in its particular location. When these rates are applied proportionately to the length of the hood, a better estimate can be calculated for the total exhaust rate required by the appliance line assuming all appliances are turned on or are cooking. However, this general observation breaks down in cases with like-duty appliances under the hood where two of the three appliances are turned off (discussed under "Effect of Appliance Position" section above). Simply stated, turning off equipment may have a negative and counterintuitive impact on the overall exhaust requirement.

The research showed that range tops, which are often classified as heavy duty appliances, are actually medium duty to heavy duty appliances. Some combinations of burners result in thermal plume behavior that is similar to other medium duty appliances. Figure 11 illustrates the test results.

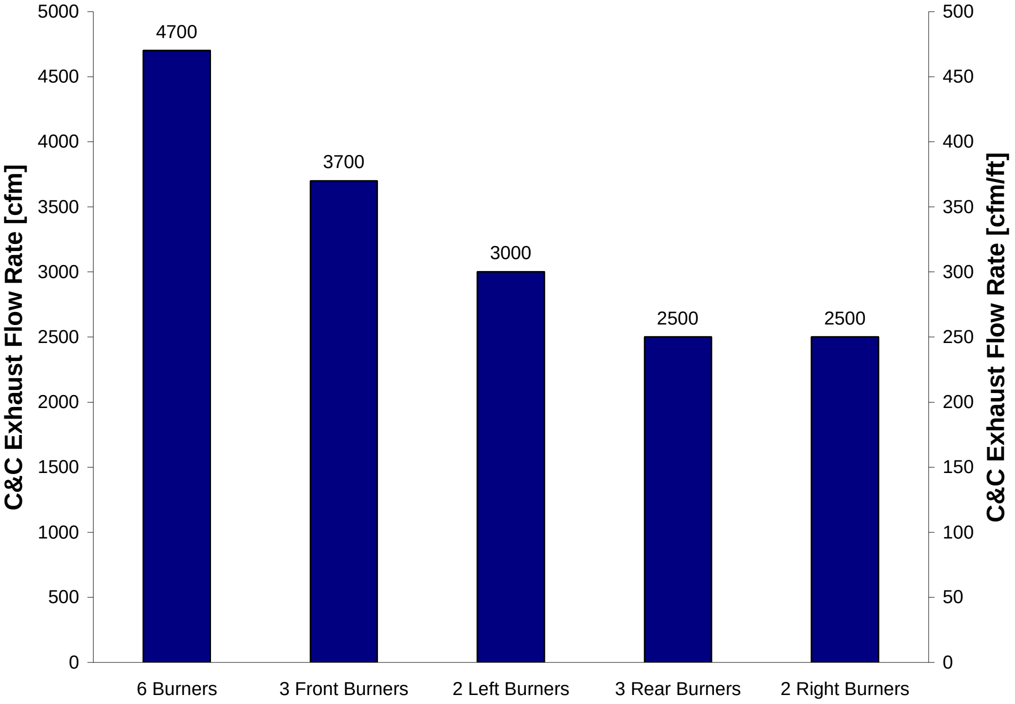


***Figure 11. Range Burner C&C Sensitivity Tests.***

## Side Panels

Side (or end) panels or skirts (both partial or full as represented in Figure 12) permit a reduced exhaust rate in most cases, 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. Side panels are a relatively inexpensive way to improve hood performance. Another benefit of end panels is to mitigate the negative effect that cross drafts can have on hood performance. It is important to know that partial side panels can provide almost the same benefit as full panels. The ASHRAE sponsored laboratory testing demonstrated reductions in capture and containment airflow rates up to 100 cfm/ft of hood by the application of partial side panels on 10-ft wall-canopy hoods. Although defying its definition as an "island" canopy, end panels may improve the performance of a double-island or single-island canopy hood.

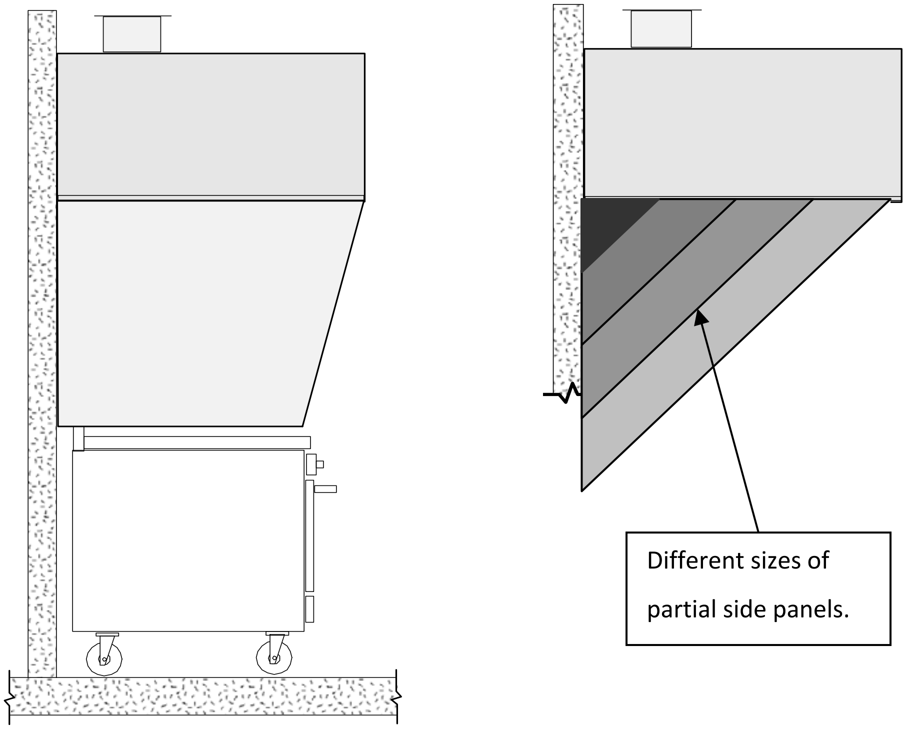


*Figure 12. Full and Partial Side Panels.*

Figure 13 shows a summary of results from tests using different sizes of side panels and different front overhang distances with a 6-vat fryer line.

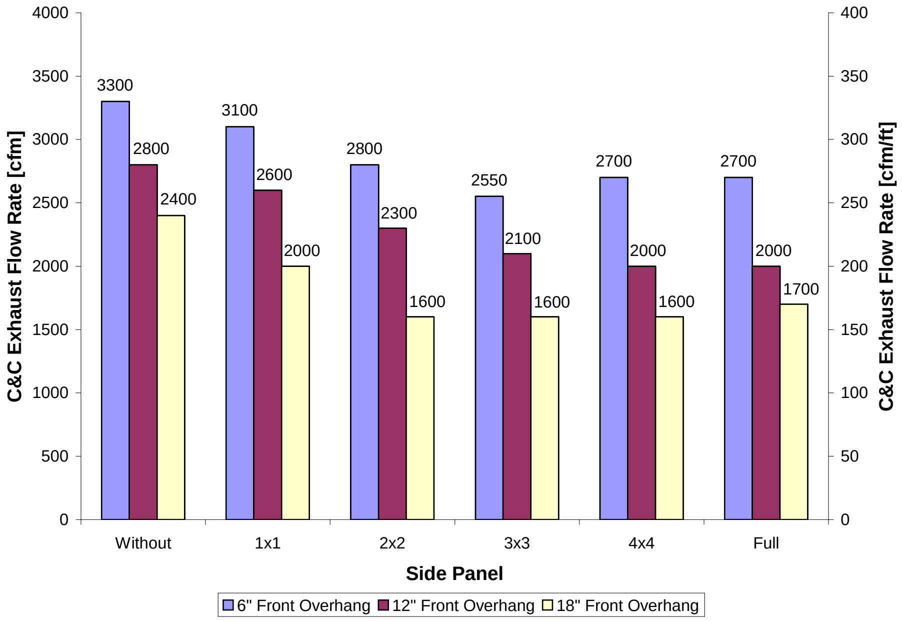


***Figure 13. C&C Changes Due to Front Overhang and Side Panels Over a 6-vat Fryer Line.***

## Hood Features

The ability of a hood to capture and contain cooking effluent can often be enhanced by adding passive features (e.g., angles, flanges, or geometric flow deflectors) or active features (e.g., low-flow, high-velocity jets) along the edges of the hood or within the hood reservoir. Such design features can improve hood performance dramatically over a basic box-style hood with the same nominal dimensions.

Filter shelf stand-offs are often built into hoods and recent research has demonstrated how they can cause spillage at the back corners of the hood. Very small side panels, e.g. 1-ft by 1-ft, can be used to correct spillage due to the adverse influence of a 3-in filter stand-off at the back of a wall-mounted canopy hood.

## Shelving

The installation of shelving above an appliance has anecdotally been thought to hinder hood performance (see Figure 14). Furthermore, it was generally thought that when shelving was installed, tubular construction would impact hood performance less than solid construction. However, no data had ever been published to qualify this hypothesis. Contrary to the expectations of the research team, C&C performance improved slightly with the installation of most shelf configurations over the six-burner range because the plume could either travel upward with minimal interference or could tightly wrap around the shelf and be directed toward the filters. The only exception was the installation of a solid shelf with only the rear three burners in operation. With six burners in operation, an 11%, or 500 cfm, reduction (from 4700 cfm to 4200 cfm) was observed with the wall-mounted tubular shelving. The shelf may have helped by reducing the volume of air coming up from behind the range and increasing the volume of air coming from the perimeter of the hood.

***Figure 14. Tubular and Solid Shelving.***

## Salamanders and Cheese Melters

Similar to shelving installed above cooking equipment, the installation of ancillary equipment such as a salamander or cheese melter was thought to hinder the ability of a hood to capture and contain the thermal plume generated by the appliance underneath.

Figure 15 shows side views of a salamander mounted on the appliance and mounted on the wall. It was best to mount the salamander on the wall rather than on the appliance. With the salamander mounted on the wall, its plume was closer to the hood filters and farther away from the front edge of the hood, which aided C&C performance. The plume from the six-burner range was also easier to capture and contain since the wall-mounted salamander did not disrupt its flow. In some cases, the wall-mounted salamander acted as a rear seal, which helped draw air from the front and sides of the cooking equipment rather than from the gap behind the appliances.

***Figure 15. Appliance-mounted and Wall-mounted Salamander.***

## *Hood Mounting Height*

Island and wall-mounted canopy hoods were traditionally mounted so that the front edge was 6-ft 6-in above the finished floor. In some jurisdictions, code officials have started to require mounting at 6-ft 8-in to assure compliance with requirements in the Americans with Disabilities Act (ADA). A series of tests in which the mounting height was increased incrementally over 1-ft showed a generally linear relationship in which threshold C&C rates increased.

Increasing hood mounting height by 2 inches resulted in a negligible change in exhaust rates. However, when the mounting height was increased by 1-ft (to 7-ft 6-in), C&C rates increased significantly. This is primarily due to the increased distance from the cooking surface to the exhaust hood edge, which allows the thermal plume to expand more. To capture the expanded plume, greater exhaust rates are required. With hoods mounted higher, it is more important to locate heavy duty appliances in the middle of the appliance lineup. Figure 16 illustrates results for broiler testing.

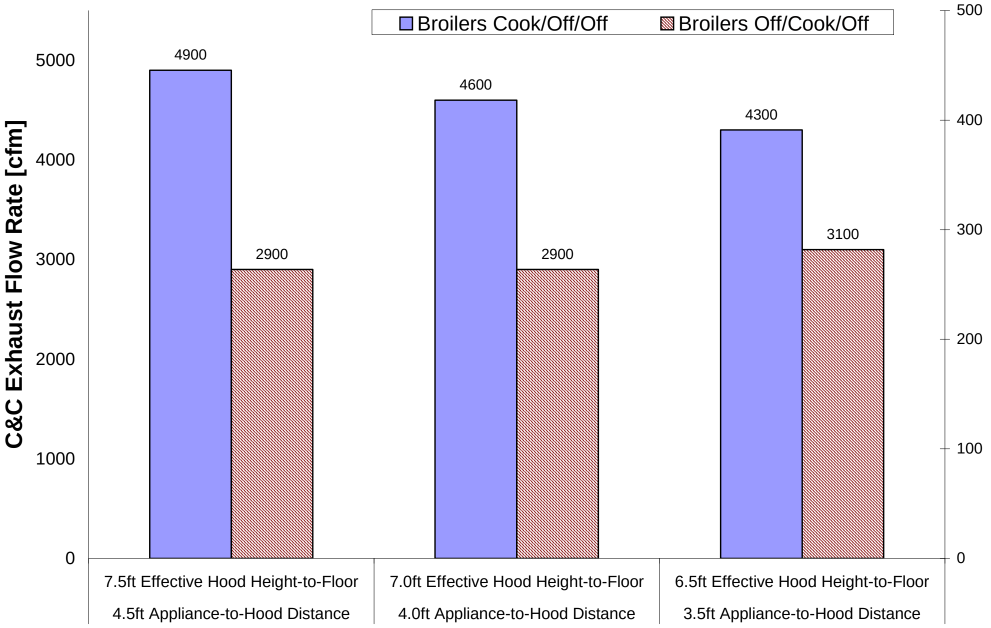


***Figure 16. Hood Mounting Height and C&C Rates.***

## Summary

The most important concept confirmed by the testing was that heavy duty equipment should be positioned in middle of the cook line. If a heavy duty appliance is on the end, 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 of the cook line. Ranges can be located at the end of 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 plume control effect that tends to assist capture and containment that is similar to but not as effective as a side panel. Partial side panels can provide most of the benefit of full side panels. Even very small side panels (e.g., 1-ft by 1-ft) can eliminate or reduce spillage.

Multiple, different appliances tend not to be used at the same time due to the sequences of menu preparation and consequently total plume strength is less than a group of like appliances that may be used at the same time for batch preparation.

The debate over interference with C&C from shelving and accessories mounted above the cooking surfaces has been answered. The testing found that wall-mounted shelving may improve hood performance in many cases. Wall-

### The Bottom Line

**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%.**

mounting for cheese melters or salamanders is preferred over appliance mounting, but in either case, capture and containment is not impaired.

Finally, mounting wall-canopy hoods at 6-ft 8-in AFF to comply with ADA requirements, rather than at the traditional height of 6-ft 6-in, has a negligible impact on exhaust C&C rates.

## References

1. The Commercial Kitchen Ventilation Design Guide series, available at http://www.fishnick.com/ includes:
   *Design Guide 1:* Selecting and Sizing Exhaust Hoods
   *Design Guide 2:* Optimizing Makeup Air
   *Design Guide 3:* Integrating Kitchen Exhaust Systems with Building HVAC
2. ASHRAE Research Project 1362, *Revised Heat Gain and Capture and Containment Exhaust Rates from Typical Commercial Cooking Appliances*. American Society of Heating, Refrigeration, and Air-conditioning Engineers. Atlanta, GA.
3. ASHRAE Research Project 1202, *Effect of Appliance Diversity and Position on Commercial Kitchen Hood Performance*. 2005. American Society of Heating, Refrigeration, and Air-conditioning Engineers. Atlanta, GA.
4. ASHRAE Applications Handbook. 2007. American Society of Heating, Refrigeration, and Air-conditioning Engineers. Atlanta, GA.
5. ASHRAE Standard 154, *Ventilation for Commercial Cooking Operations*. American Society of Heating, Refrigeration, and Air-conditioning Engineers. Atlanta, GA.

# Notes and Acknowledgments

### Funding

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