Design Guide 2

Optimizing Appliance Position & Hood Configuration

Improving Commercial Kitchen Ventilation (CKV) System Performance

Optimizing Appliance Position and Hood Configuration is the second 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 guide is intended to augment comprehensive design information published in the Kitchen Ventilation Chapter in the ASHRAE handbook on HVAC as well as the other design guides in this series.

Introduction

Hood style, construction features, and control options, as well as the positioning of appliances beneath the hood, have a dramatic effect on the ability of the hood to capture and contain. If the design engineer, installing contractor, or kitchen manager make even subtle changes to appliance positioning or hood configuration, a surprisingly wide range of exhaust rates required for proper capture and containment can occur. This explains why a similar hood installed over virtually the same appliance line may perform successfully in one kitchen, while failing in another. To further realize reduced exhaust rates and optimize system performance with regard to energy savings, employing the "smart" controls of a demand-controlled kitchen ventilation (DCKV) system can automate exhaust rates based on cooking need. This guide will explore the effects of appliance position, hood configuration, and demand controls on commercial kitchen ventilation systems.

Effect of Appliance Position

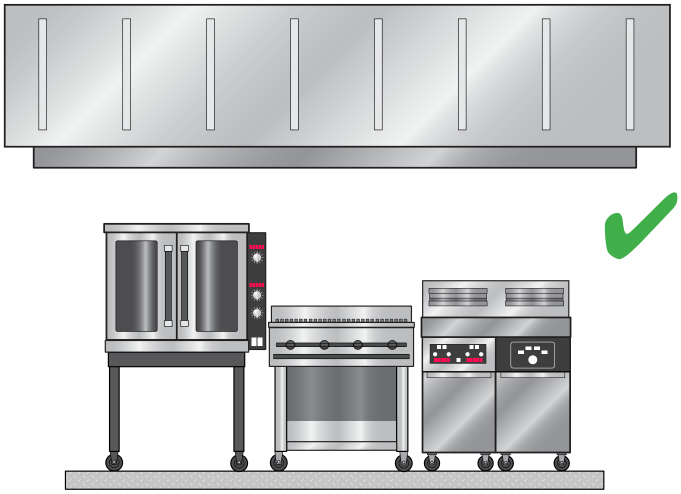
The position of an appliance under a hood can significantly impact the ability of the hood to capture and contain the appliances' cooking plume. Appliance location from side-to-side and front-to-back can increase or decrease the threshold of capture and containment by as much as 30%. The factors underlying this variability in exhaust rate are explained below.

Side-to-Side Positioning

Research has confirmed that the appliance located at the end of the hood can have the greatest impact on the effective exhaust rate of the entire hood. The end appliances drive the exhaust rate more than additional volume from the other appliances as they change from "off" to a cooking state or as they vary in duty class. In most cases, locating the lowest duty appliance at the end of the cookline can acheive the lowest exhaust requirements for those cooklines. Center positioning provides greater reservoir capacity to capture and contain the cooking plume produced by heavy-duty appliances, whereas end positioning reduces the effective reservoir to only one side of the appliance. Therefore, positioning the heaviest duty appliance in the middle of the appliance line is recommended to optimize hood performance. See Figure 1 for proper location of a heavy-duty underfired broiler under a hood.

The general trend gathered in research analyzing cooklines of diverse appliance duty was that with all appliances cooking, the combinations with higher duty ratings require greater exhaust rates. However, there are exceptions for cooklines where one appliance located on the end is cooking while the others are turned off. This scenario requires significantly higher exhaust rates in part due to the lack of cooking plume from the "off" appliances and the end positioning of the "on" appliance.

Appliance location 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 foodservice consultant with respect to the performance benefit of including appliance positioning in planning equipment layout.



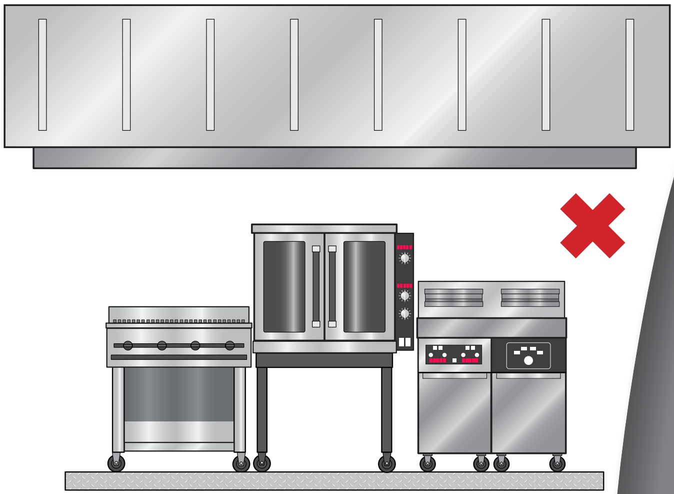


Figure 1. Underfired Broiler Positioning Under the Hood.
Hood performance improves when the broiler is located in the center rather than the end of the hood.

Front-to-Back Positioning

Figure 2 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 decreases required exhaust rates for effective capture and containment. By maximizing the front overhang dimension, research demonstrated that capture and containment exhaust rates were reduced by 9 to 27% for three appliances of any duty class under a 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 the decreased distance between the back of the appliance and the wall. With a sheet metal panel installed as a rear seal, a portion of the air, which otherwise would have 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 1,200 cfm and 1,700 cfm depending on the overhang and associated depth of the rear seal. This resulted in approximately a 30% exhaust rate reduction. Figure 3 shows an example of a rear gap seal that can be custom fabricated to fit the appliance geometries for a particular cookline.

A common practice in many commercial kitchens is to align the front of 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 the rear gap should be sealed to assure better capture and containment.

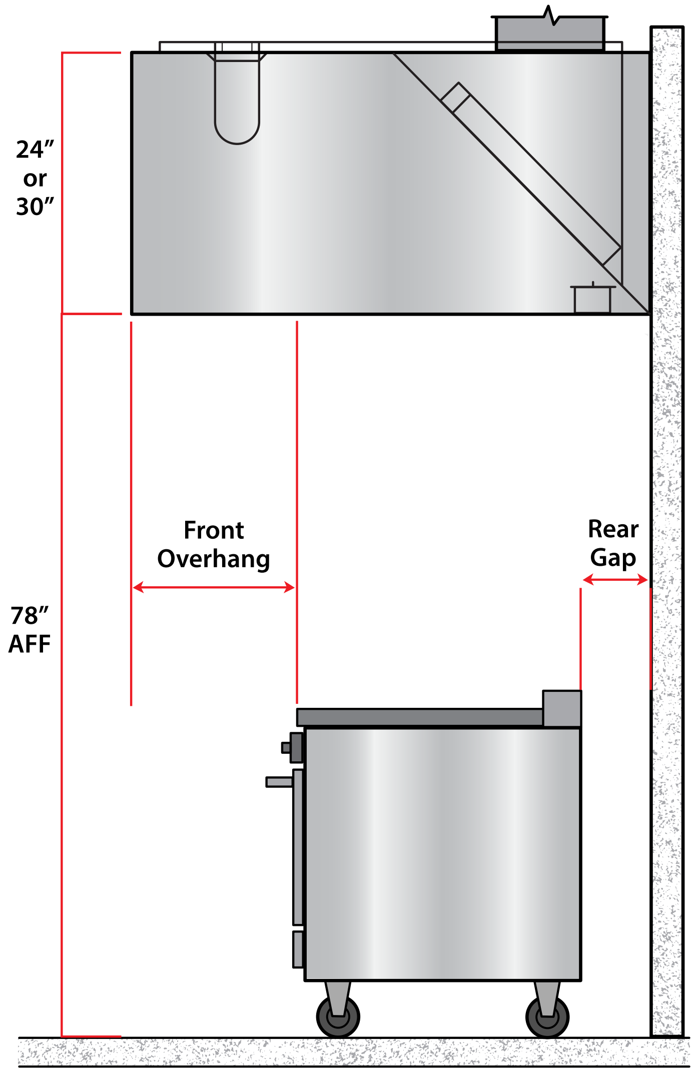


Figure 2. Front Overhang and Rear Gap.

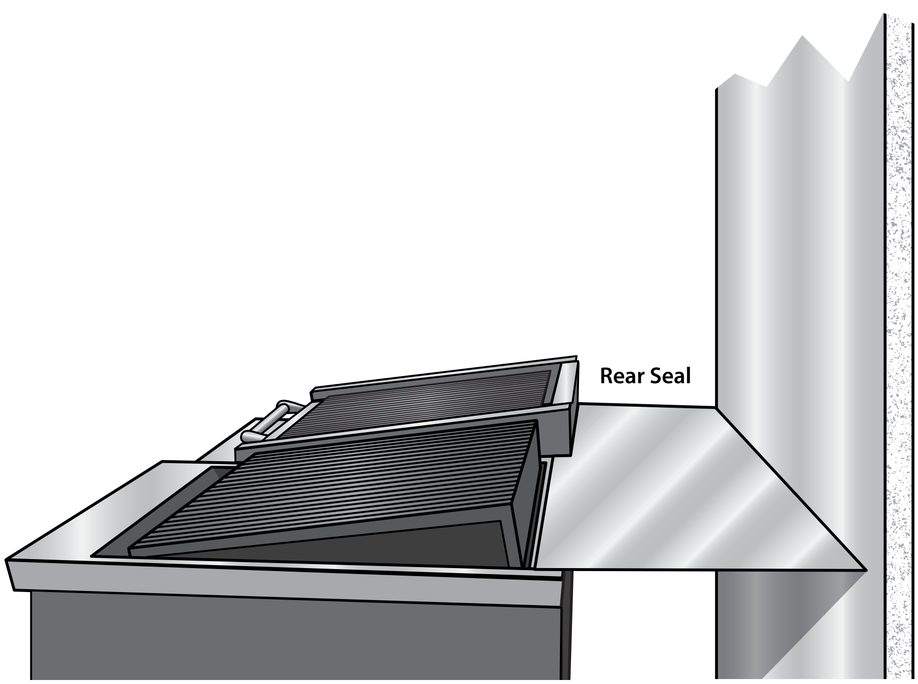


Figure 3. Rear Seal Example.

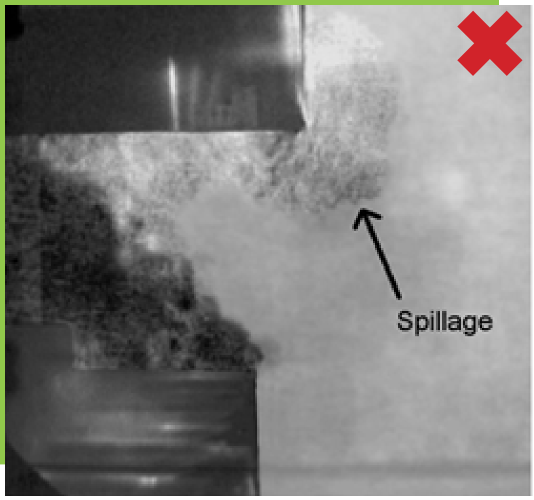
Hood Configuration & Ancillary Equipment

Deeper Hoods & Maximizing Overhang

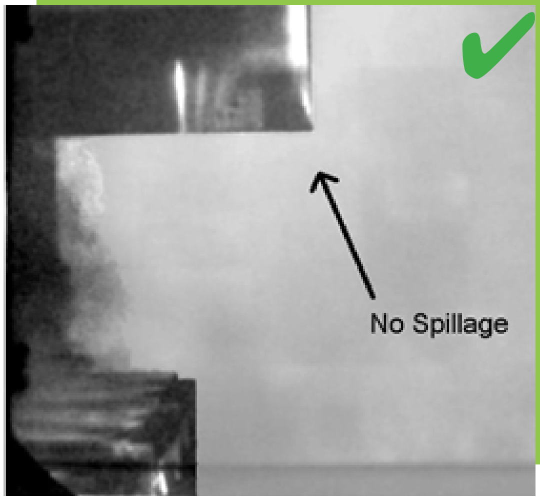
For new construction or retrofit, adding an extra foot of overhang (front-to-back or side-to-side) for a canopy hood is an inexpensive means of assuring capture and containment. For an existing kitchen not undergoing renovation, this may be accomplished by pushing appliances as far back under the canopy hood as practical as discussed above in the 'Front-to-Back Positioning' section (note: this would not be practical with a single-island canopy 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 (i.e. deeper) footprints. Specifying a deeper hood (e.g. 5-foot vs. 4-foot) will directly increase overhang, provided appliances remain as far back under the hood as possible. A deeper hood is an effective solution for combination and convection ovens during "door-opening" plume surges.

Figure 4 illustrates the impact of overhang on three fryers in a cooking state. At a 2,400 cfm (240 cfm/lf) exhaust rate, cooking plume is spilled with a 6-inch overhang and is fully captured and contained with an 18-inch overhang. Note that the plume is pulled forward with the 6-inch overhang, in part due to the air rising behind the appliances. The plume is pulled back toward the wall with the 18-inch overhang and the reduced rear gap.



6-Inch Front Overhang.



18-Inch Front Overhang.

Figure 4. Two Front Overhang Scenarios with Three Fryers.

Hood Features

Passive hood features such as interior angles close to, or at, the capture edge of the hood can improve capture and containment performance, allowing reduced exhaust by directing cooking plume back toward the filters. Hoods designed with these geometric features require as much as 20% less air compared to hoods identical in size and shape without these features. The ability of a hood to capture and contain can also be enhanced by active features such as low-flow, high-velocity jets (< 7 cfm). Jets along the edges of the hood or within the hood reservoir can act like additional angles or lips directing plume back into the hood.

Filter shelf stand-offs are often built into hoods. Research has shown that these shelves can cause spillage at the back corners of the hood by reducing the usable reservoir. Very small side panels, e.g. 1-foot by 1-foot, can be used to correct spillage due to the adverse influence of a 3-inch filter stand-off at the back of a wall-mounted canopy hood.

Side Panels

Side (or end) panels (both full and partial as represented in Figure 5) permit a reduced exhaust rate in most cases, as more of the air is drawn across the front of the equipment, improving capture of the cooking plume generated by the hot equipment. Side panels are a relatively inexpensive way to improve hood performance. Another benefit of side panels is to mitigate the negative effect that cross drafts can have on hood capture and containment. Note that partial side panels can provide the same benefit as full panels. Research has demonstrated reductions in capture and containment airflow rates up to 100 cfm/lf of hood by the application of partial side panels on a 10-foot wall-canopy hood.

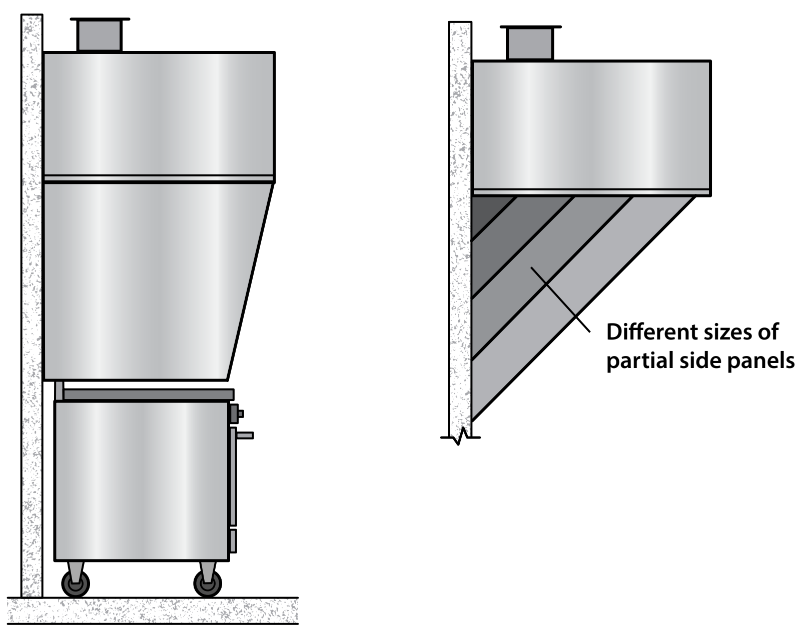


Figure 5. Full and Partial Side Panels.

Hood-Mounting Height

Island and wall-mounted canopy hoods were traditionally mounted so that the front edge was 6-foot 6-inches above the finished floor. In some jurisdictions, code officials started to require mounting at 6-foot 8-inches to assure compliance with the Americans with Disabilities Act (ADA). Tests in which the mounting height increased incrementally over 1-foot showed a generally linear relationship where threshold capture and containment rates increased with the increased height of the hood above the appliances (or floor).

Increasing hood mounting height by 2-inches results in a negligible change in exhaust rates. However, when the mounting height increases by 1-foot (to 7-foot 6-inches), capture and containment rates increase significantly. This is primarily due to the increased distance from the cooking surface to the exhaust hood edge, which allows the cooking plume more area to expand. To capture the expanded plume, greater exhaust rates are required. With higher-mounted hoods, it is even more critical to locate heavy-duty appliances in the middle of the cooking lineup.

Shelving

Installation of shelving above an appliance (see Figure 6) has anecdotally been thought to hinder hood performance. Furthermore, it was generally thought that when shelving was installed, tubular construction would impact hood performance less than solid construction. Contrary to this perception, capture and containment performance slightly improves with the installation of most shelf configurations over a six-burner range because the plume can either travel upward with minimal interference ***or*** tightly wrap around the shelf and be directed toward the filters. The only exception with a six-burner range was the installation of a solid shelf with only the three rear burners in operation. With all six burners in operation, an 11%, or 500 cfm, reduction (from 4,700 cfm to 4,200 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.

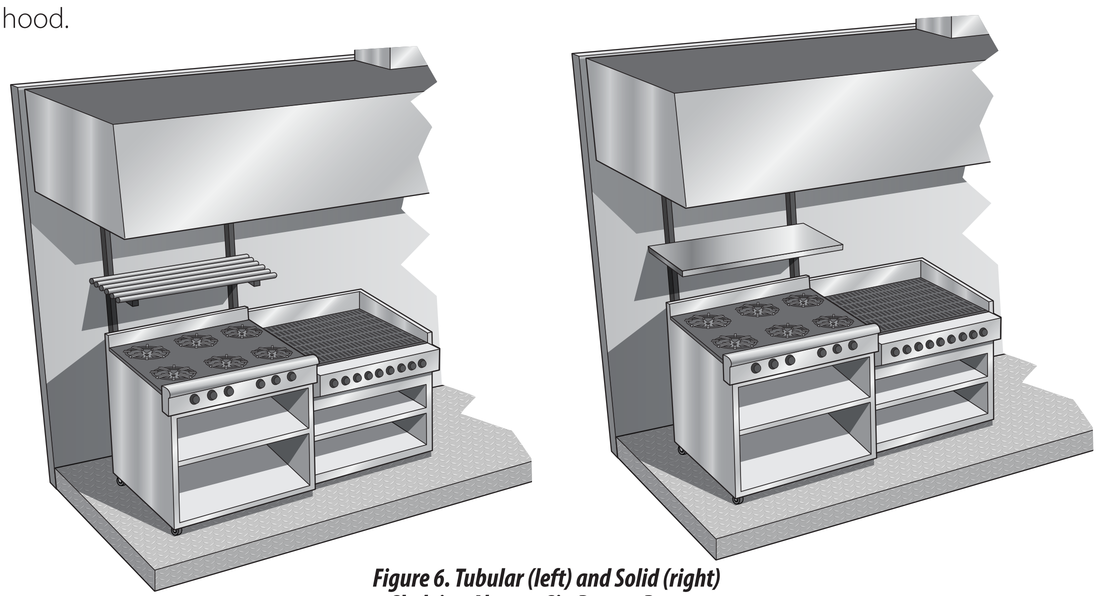


Figure 6. Tubular (left) and Solid (right) Shelving Above a Six-Burner Range.

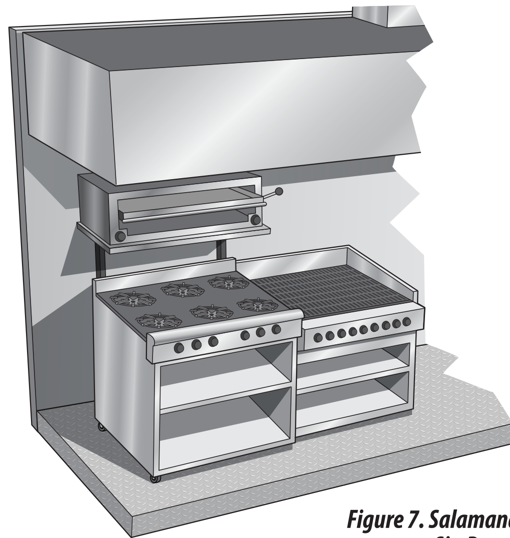
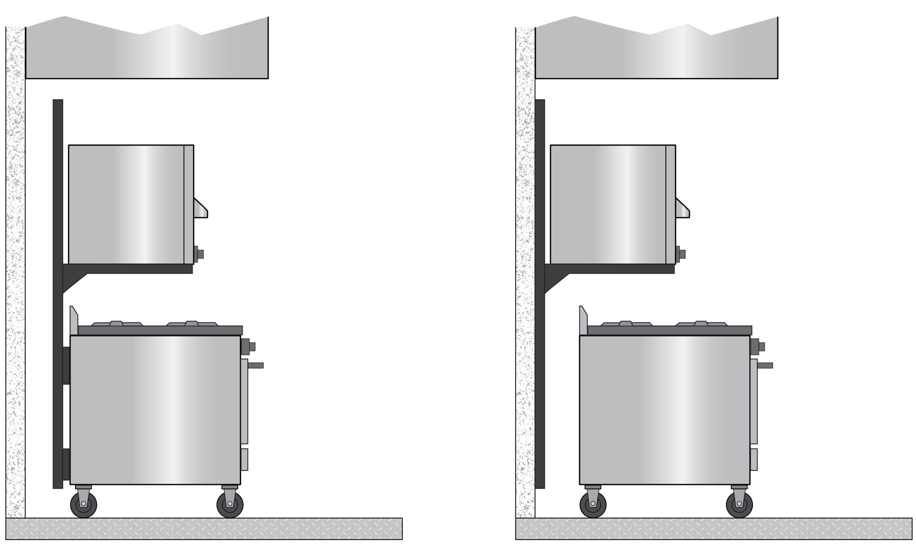


Figure 7. Salamander Mounted Above Six-Burner Range.

Salamanders & Cheese Melters

Similar to shelving installed above cooking equipment, the installation of ancillary equipment such as a salamander (Figure 7) or cheese melter was originally thought to hinder the ability of the hood to capture and contain the cooking plume.

Figure 8 shows side views of a salamander mounted directly onto an appliance and a salamander mounted to the wall. It is best to mount the salamander to the wall instead of to the appliance. Mounted to the wall, the plume from the salamander is closer to the hood filters and farther away from the front edge of the hood, aiding in capture and containment performance. The plume from the appliance underneath the salamander is also easier to capture since the wall-mounted salamander does not disrupt its flow. In some cases, the wall-mounted salamander can act as a rear seal, helping to draw air from the front and sides of the cooking equipment rather than from the gap behind the appliances.



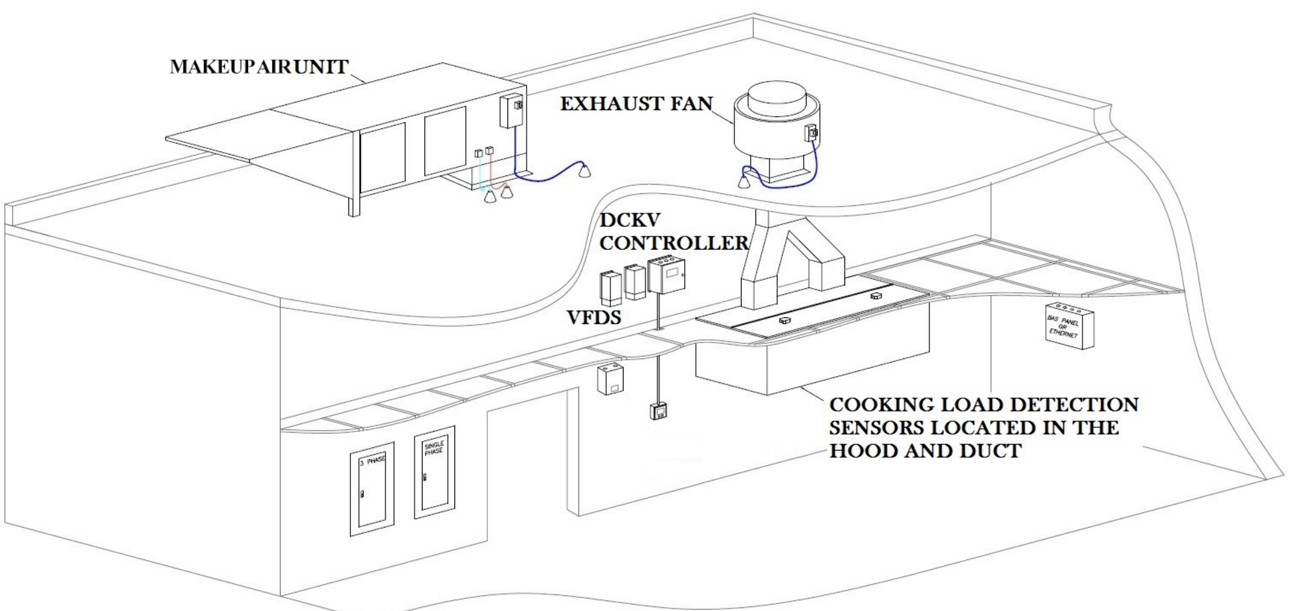
Appliance-Mounted Salamander. *Wall-Mounted Salamander.*

Figure 8. Salamander Positioning.

DCKV Systems

Along with properly positioning appliances under the hood and weighing certain hood features, designers and operators should consider installing a DCKV system. DCKV systems are capable of varying the hood exhaust rate based on temperature sensors that measure heat load, or optical/infrared sensors that detect the presence of a cooking plume generated by the appliances, or a combination thereof. Instead of running the exhaust fan at 100% speed at all times regardless of cooking load, DCKV systems modulate the amount of air exhausted in response to a full-load, partial-load, or no-load cooking condition. Figure 9 lays out a typical configuration for a DCKV system.

Nearly all DCKV systems will feature direct air temperature measurements at several points within the hood and the exhaust duct. Systems can utilize optical or infrared sensors to detect heat rising from the cooking equipment or the temperature of the cooking surfaces. If the system detects high heat load, steam, and/or smoke, ***variable frequency drives (VFDs)*** ramp up the exhaust fan speed high enough to remove the cooking plume. Conversely, when there is little or no cooking activity under the hood and full fan capacity is not needed, the VFDs reduce the exhaust fan speed to minimize the fan motor energy used to exhaust the kitchen space (as well as the energy required to condition the makeup air).



Source: Melink Corporation.

Figure 9. Typical DCKV Equipment & Configuration.

By applying DCKV to a foodservice ventilation system, a fan energy reduction is immediately realized. For example, a 20% fan speed reduction results in nearly a 50% reduction in fan power. The DCKV system reduces the average exhaust rate, and as a result, the makeup air rate is reduced. Considerations related to DCKV systems and makeup air are covered in Design Guide 3: *Optimizing Makeup Air*.

DCKV also affords a more precise and flexible method of commissioning or further tuning of the exhaust system that would otherwise involve a belt and pulley adjustment. Sometimes exhaust rates can be set excessively high for the cooking process even at full load; in these situations, the maximum fan speed setting can be readily decreased through the DCKV controller and/or the VFD itself.

While there is currently no ENERGY STAR® category for DCKV systems, the Environmental Protection Agency (EPA) identified DCKV for an Emerging Technology Award in 2015. As a result, some utilities offer rebates on purchase of a DCKV system; check with your local utility to see if any rebates might be available in your area.

Many ventilation manufacturers offer DCKV systems with a variety of options. Table 1 below lists some of the DCKV products available.

Using DCKV systems can dramatically reduce the overall kitchen ventilation system energy use over a traditional single-speed system. For this reason, DCKV systems come highly recommended for all retrofit or new construction commercial kitchen design projects.

Table 1. Various DCKV System Products.

Manufacturer	Product Name
Accurex	Vari-Flow
CaptiveAire	SC-EMS
Franke	VariVent
Gaylord	DCV-F
Gaylord	DCV-R
Greenheck	Vari-Flow
Halton	M.A.R.V.E.L.
Intellinox	ecoAZUR
Melink	Intelli-Hood
Spring Air	TruFlow
Streivor	DemandAire

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 northeast 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.

Notes and Acknowledgments

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