Design Guide 3

Optimizing Makeup Air

Improving Commercial Kitchen Ventilation (CKV) System Performance

Optimizing Makeup Air is the third 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 is intended to augment comprehensive design information published in the Kitchen Ventilation Chapter in the ASHRAE Applications Handbook on HVAC as well as the other Design Guides in this series.

Takeaways from Design Guide 1: *Selecting & Sizing Exhaust Hoods* & Design Guide 2: *Optimizing Appliance Position & Hood Configuration*

- *Properly size hood exhaust rates based on the menu items being cooked, duty classifications of appliances under the hood, and the style and geometry of the hood itself .*
- *Specify listed hoods over unlisted hoods. Listed hoods of comparable style and size can be operated at a lower exhaust rate over the same cookline.*
- *Group appliances according to cooking plume production and their associated ventilation requirements.*
- *Specify different ventilation rates for hoods or hood sections based on the different appliance duty classifications under the hood(s) (e.g. light, medium heavy, etc.)*
- *Where practical, place heavy-duty appliances such as charbroilers in the center of the hood section rather than the end.*
- *Increase hood overhang by pushing appliances as far back and inward under the hood as practical. Specify deeper hoods (e.g. 5-foot) to further maximize hood overhang when using appliances with plume surges or large footprints.*
- *Install side and/or back panels on canopy hoods to increase effectiveness and reduce heat gain.*
- *Specify hoods with features such as interior angles or low-flow, high-velocity jets (<7 cfm) along the edges of the hood or within the hood reservoir.*
- *Install a demand-controlled kitchen ventilation (DCKV) system on the exhaust hood to modulate the exhaust fan rate in proportion to cooking load.*

Introduction

An effective commercial kitchen ventilation system requires balance — air balance. As the designer, installer, or operator of the kitchen ventilation system, you may be the first person called upon to perform your own "balancing act" when the exhaust hood doesn't work. Unlike a cooking appliance, which can be isolated for troubleshooting, the exhaust hood is only one component of the kitchen ventilation system. To further complicate things, the CKV system is a subsystem of the overall building heating, ventilating, and air conditioning (HVAC) system. Fortunately, there is no "magic" to the relationship between an exhaust hood and its requirement for replacement or makeup air. The physics are simple: air that exits the building (through exhaust hoods and fans) must be replaced with outside air that enters the building (intentionally or otherwise). The essence of air balance is "air in" = "air out".

Background

If air doesn't come in to replace air exhausted through the hood, problems can arise. Not only will the building pressure become too "negative", the hood may not capture and contain the cooking plume due to reduced exhaust flow. We have all experienced the "can't-open-the-door" syndrome because the exhaust fan is sucking too forcefully on the inside of the restaurant. The mechanical design may call for 8,000 cubic feet per minute (cfm) of air to be exhausted through the hood. But if only 6,000 cfm of outdoor air can squeeze in through closed dampers on rooftop units and cracks and crevices in the building envelope, then only 6,000 cfm is available to be exhausted through the hood. The exhaust fan creates more suction (negative pressure) in an unsuccessful attempt to pull more air through the hood.

There is no piece of equipment that generates more controversy in the foodservice equipment supply and design community than the exhaust hood in all its styles and makeup air combinations. The idea that not installing a dedicated makeup air supply will save the operator money both in first cost and operating costs is shortsighted. This approach may be satisfactory if, by design, all the makeup air can be provided through the rooftop HVAC units (this strategy has been adopted successfully by several leading quick-service restaurant chains). However, in full-service and institutional kitchens with larger exhaust requirements, it may not be practical (or energy efficient) to supply 100% of the makeup air through the building HVAC system.

The solution is to specify an independent makeup air supply. However, once a dedicated makeup air supply has been added to your system, the challenge becomes introducing the makeup air into the kitchen without disrupting exhaust hood capture or causing discomfort for kitchen staff. Kitchens are not large areas; dumping a large amount of high-velocity makeup air, for example, in front of a cookline does not go as smoothly in practice as it does on paper! Not only can makeup air velocities impact the ability of a hood to capture and contain the cookling plume, locally supplied makeup air that is too cold or too hot can create an uncomfortable working environment. This guide presents strategies that can help minimize the impact makeup air introduction will have on hood performance, energy consumption, and kitchen comfort.

Makeup Air Distribution

Air that is removed from the kitchen through an exhaust hood must be replaced with an equal volume of makeup air through one or more of the following pathways:

- **Transfer Air** (e.g. from the dining room)
- **Displacement Diffusers** (floor- or wall-mounted)
- **Ceiling Diffusers with Louvers** (2-way, 3-way, 4-way)
- **Slot Diffusers** (ceiling)
- **Ceiling Diffusers** with Perforation
- **Integrated Hood Plenum** (see Figure 1) including:

    1. Short Circuit (internal supply)
    2. Air Curtain Supply
    3. Front Face Supply
    4. Perforated Perimeter Supply
    5. Combinations of the above

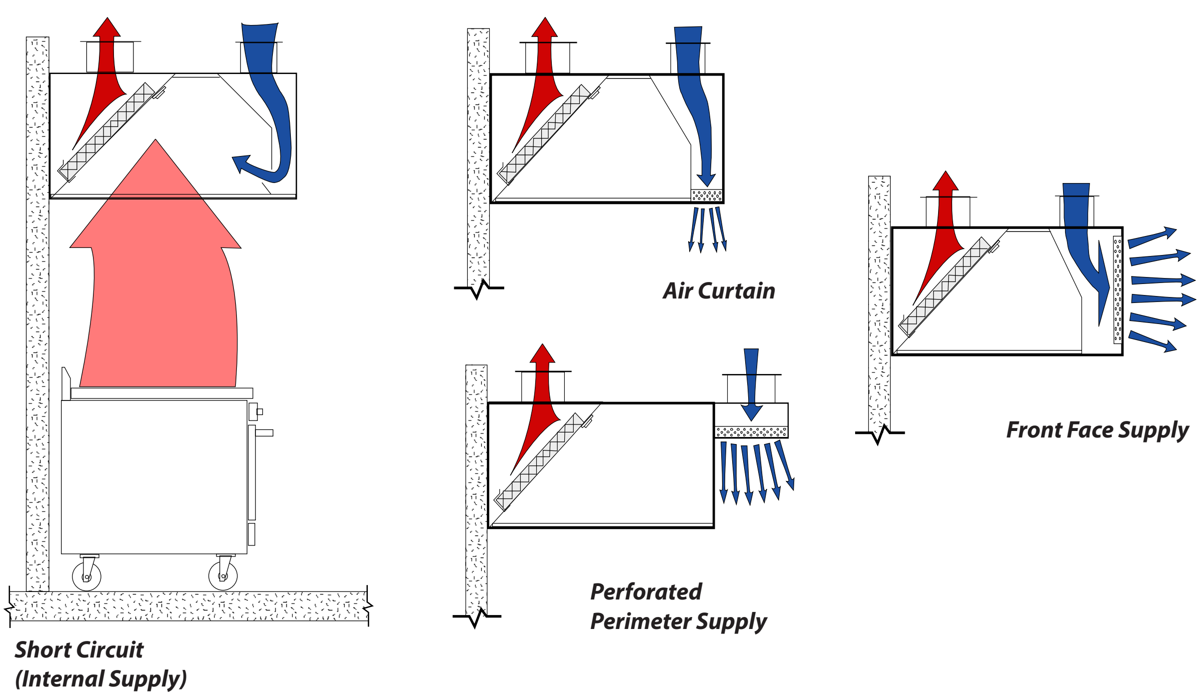

Figure 1. Types of Makeup Air Supply Integrated with the Hood.

Influence of Makeup Air on Exhaust Hood Performance

Makeup air supplied through displacement ventilation diffusers remote from the hood, perforated diffusers located in the ceiling as far as possible from the hood, or as transfer air from the dining room generally work well if air velocities approaching the hood are less than 75 feet per minute (fpm). However, makeup air introduced in close proximity to an exhaust hood has the potential to interfere with the hood's ability to capture and contain the cooking plume. The chances of makeup air affecting hood performance increases as the percentage of the locally supplied makeup air (relative to the total exhaust) is increased. In fact, the 80% rule-of-thumb for sizing airflow through a makeup air unit can be troublesome particularly if the exhaust flow rate has been over-specified.

The temperature of the locally supplied makeup air can also affect hood performance as air density (buoyancy) impacts the dynamics of air movement around the hood. Generally, hotter makeup air temperatures (e.g. 90°F) will affect hood performance more adversely than cooler air (e.g. 75°F). In most temperate climates, like many areas in California, evaporative cooling is an effective method of maintaining makeup air temperatures within a range that is comfortable for kitchen staff and does not hinder hood performance. But operators must also factor in the maintenance requirements of evaporative coolers.

The primary recommendation for mitigating the impact locally supplied makeup air will have on hood performance is to minimize air velocity (fpm) as it is introduced near the hood. This can be acheived by minimizing the volume (cfm) of makeup air through any one pathway, maximining the area of the grilles or diffusers through which makeup air is supplied, or using a combination of pathways.

The first step in reducing the makeup air requirement is to minimize the design exhaust rate. For a thorough discussion of exhaust hood rates, please refer to Design Guide 1: ***Selecting & Sizing Exhaust Hoods***.

The second step in reducing makeup air flow is to take credit for outside air that must be supplied by the HVAC system to meet code requirements for ventilating the dining room. Depending on the arhitectural layout between the kitchen and dining room, it may be practical to transfer most air from the dining room to the kitchen. For example, if 1,600 cfm of outdoor air supplied to a 160-seat dining room can be transferred to the kitchen, the local makeup air requirement can be reduced accordingly.

Rather than supplying 80-90% of the exhaust rate through one local makeup air strategy, designers should attempt to keep this ratio below 60% (the other 40% of the replacement air must be derived from another source such as transfer air, another local strategy, or the HVAC supply). Not only will hood performance be superior, the kitchen environment will benefit from the cooling contribution of the "recycled" dining room air. It's important to note that the outdoor air is usually conditioned before it is introduced in the dining room. So... why not use this conditioned outdoor air as makeup air? The advantages and challenges of integrating the building HVAC system with the CKV system in this manner are explored further in Design Guide 4: *Integrating Kitchen Exhaust with Building HVAC*.

The third step in reducing makeup air flow is to select a configuration for introducing local makeup air into the kitchen that compliments the style and size of the hood. If transfer air is not an option, consider a combination of makeup air strategies (e.g. face discharge and perforated ceiling diffusers). This approach reduces the velocity of air being supplied through each local pathway, mitigating potential problems with hood capture. Effective options (at 60% or less) include front face supply and perforated perimeter supply. Short-circuit supply is not recommended and air curtains should be used with extreme caution. The pros and cons of the different configurations are discussed below. Note a recurring theme — minimizing makeup air discharge velocity is key to avoiding detrimental impacts on hood capture and containment.

Short-Circuit Supply (Internal Makeup Air)

Internal makeup air hoods were developed as a strategy to reduce the amount of conditioned air required by an exhaust system. By introducing a portion of the required makeup air in an untempered condition directly into the exhaust hood reservoir, the net amount of conditioned air exhausted from the kitchen is reduced.

However, research has shown that internal makeup air cannot be introduced at a rate that is more than 15% of the threshold capture and containment exhaust rate without causing spillage. When short circuit hoods are operated at higher percentages of internal makeup air, they fail to capture and contain the cooking plume often spilling at the back of the hood (although front spillage can occur as well; see Figure 2 with red arrows indicating makeup air flow). Dilution of the cooking plume with the internal makeup air makes it hard to visualize spillage, but a degraded kitchen environment (e.g. hot, humid, smokey, etc.) is confirmation that hood performance has been compromised. If the design exhaust rate is significantly higher than the threshold for capture and containment (i.e. includes a large safety factor), the percentage of short-circuit air can be increased accordingly, creating a condition of apparent benefit.

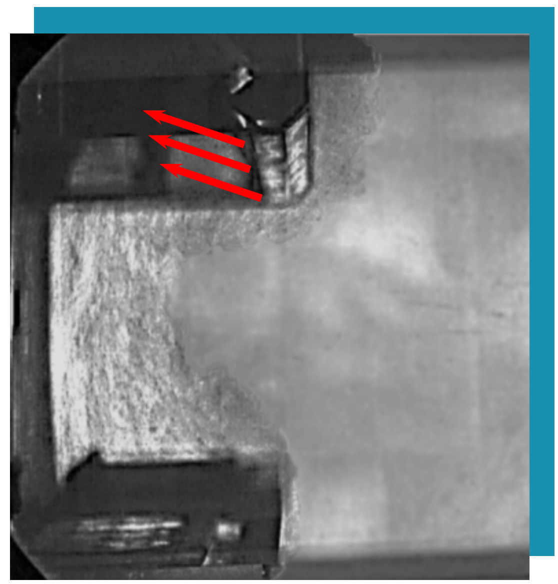

Figure 2. Cooking Plume Displaced by Short Circuit Supply Causing Hood to Spill.

Short circuit hoods are simply **not** recommended. This recommendation is endorsed by leading hood manufacturers even though they may still include short-circuit hoods in their catalogs.

Air Curtain Supply

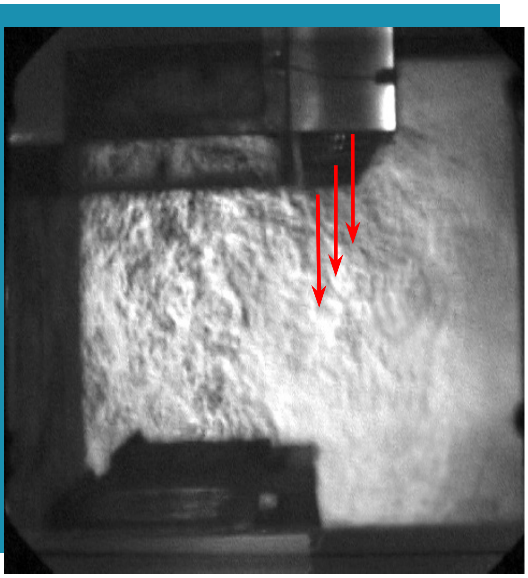

Figure 3. Cooking Plume Being Pulled Outside the Hood by the Air Curtain.

Introducing makeup air through an air curtain is a risky design option. Most hood manufacturers recommend limiting the precentage of makeup air supplied through an air curtain to less than 20% of the hood's exhaust flow. The negative impact of an air curtain is clearly illustrated in Figure 3 during a test of a wall-mounted canopy hood operating over two underfired broilers.

An air curtain, by itself or in combination with another pathway, is not recommended unless velocities are kept to a minimum and the designer has access to performance data on the air curtain configuration being specified. It is too easy for the as-installed system to oversupply, creating higher discharge velocities that cause the cooking plume to spill into the kitchen.

Front Face Supply

Supplying air through the front face of the hood is a configuration that has been recommended by many hood manufacturers. But a front face discharge with louvers or a perforated face can perform poorly if its design does not consider discharge air velocity and direction. Not all face discharge systems share the same design; internal baffling and/or a double layer of perforated plates can improve the uniformity of flow. Face discharge velocities should not exceed 150 fpm and should exit the front face in a horizontal direction. Greater distance between the lower capture edge of the hood and the bottom of the front face area may decrease the tendency of the makeup air supply interfering with hood capture and containment. Figure 4 represents a poorly designed face supply, which can negatively affect hood capture in the same fashion as an air curtain or four-way diffuser.

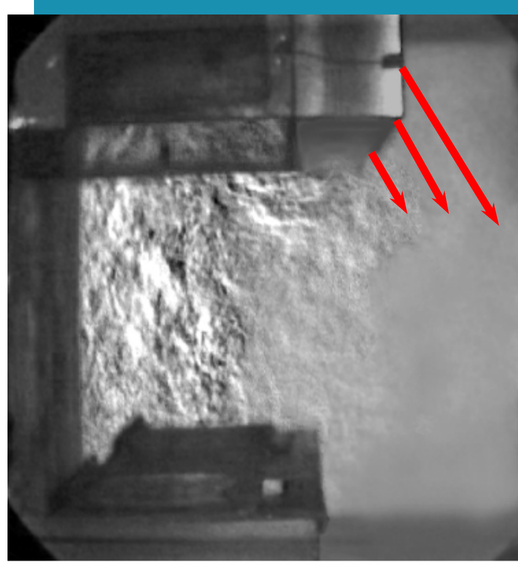

Figure 4. Cooking Plume Pulled Outside the Hood by a Poorly Engineered Front Face Supply.

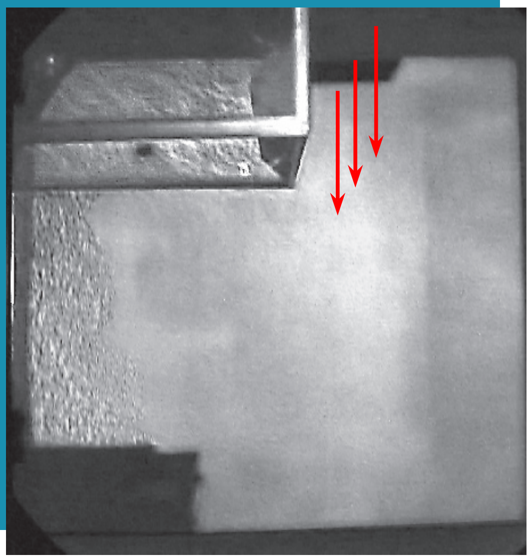

Figure 5. Effective Plume Capture with Makeup Air Supplied Through a 16-in wide Perforated Perimeter Supply.

Perforated Perimeter Supply

Perforated supply plenums (with perforated face diffuser) are similar to a front face supply, but the air is directed downward (Figure 5) toward the hood capture area. This may be advantageous under certain conditions. Face discharge velocities should not exceed 150 fpm from any section of the diffuser and the distance to lower edge of the hood should be no less than 18-inches (or else the system begins to act like an air curtain). Widening the plenum will lower the discharge velocity for a given flow of makeup air and reduce the chance of the supply air affecting capture and containment. If the perforated supply plenum is extended along the sides of the hood as well as the front, the increased area will permit proportionally more makeup air to be supplied.

Four-Way Ceiling Diffusers

Four-way diffusers located close to the kitchen exhaust hoods (see Figure 6) can have an adverse effect on hood performance, particularly when the flow through the diffuser approaches its design limit. Air from a diffuser within the vicinity of the hood should not be directed toward the hood. Airflow at the diffuser neck or discharge velocity at the diffuser face should be set at a value such that the terminal velocity does not exceed 50 fpm at the edge of the hood capture area. It is recommended that only perforated plate ceiling diffusers be used in the vicinity of the hood. To reduce air velocities from the diffusers at a given supply rate, the more diffusers the better!

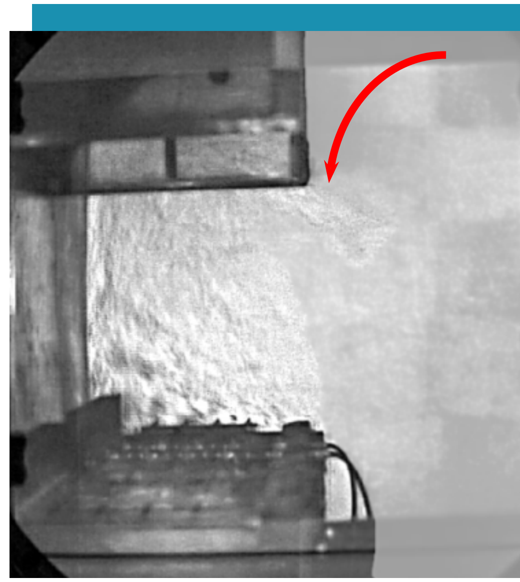

Figure 6. Thermal Plume Pulled Outside Hood by the Air Discharged from a 4-Way Diffuser.

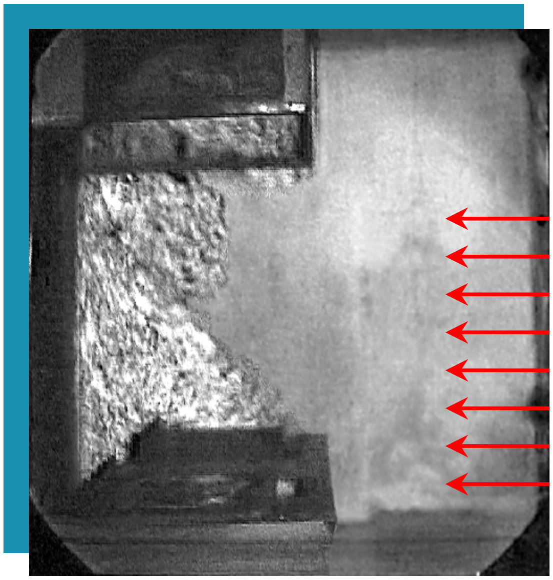

Figure 5. Effective Plume Capture When Makeup Air is Supplied at Low Velocity from Displacement Diffusers.

Displacement Diffusers

Supplying makeup air through displacement diffusers at a good distance away from the hood (illustrated in Figure 7) is an effective strategy for introducing makeup air. It is analogous to low-velocity "transfer air" from the dining room. However, the diffusers require floor or wall space that is usually at a premium in the commercial kitchen. A couple of remote displacement diffusers (built into a corner) could help diversify the introduction of makeup air into the kitchen when transfer air is not viable.

Influence of Other Factors on Hood Performance

Cross Drafts

Cross drafts can have detrimental effects on all combination of hoods and appliance lines. Cross drafts affect island canopy hoods more than wall-mounted canopy hoods due to their open areas allowing drafts to push or pull cooking plumes out from under the hood. A pedestal fan used by staff for addtional cooling, for example, can severely degrade hood performance, making hood capture impossible and spilling the cooking plume into the kitchen space. Delivery and service doors, pass-through openings, and drive-through windows may be sources of cross drafts due to external and internal air pressure differences. Cross drafts can also develop when the makeup air system is not functioning properly, causing air to be pulled from open drive-through windows or doors.

Safety Factor in Exhaust Rates

Diversity in appliance use, hood reservoir size as well as the fact that maximum plume generation from cooking only occurs at random during normal kitchen operations, may mask the unfavorable influence of local makeup air sources on hood performance. Consequently, spillage may be infrequent or simply unobserved. However, better makeup air designs allow reduced exhaust rates and minimized energy costs while maintaining a margin of safety with respect to capture and containment.

Design Considerations

Air Balance with DCKV Systems

If the kitchen exhaust hood employs a demand-controlled ventilation system (see Design Guide 2: *Optimizing Appliance Position & Hood Configuration* for more on DCKV systems), the system must be interlocked with a variable flow makeup air system to maintain air balance in the kitchen. There are two methods of supplying variable flow makeup air with a DCKV system:

1. Use variable speed fans in dedicated makeup air units. In this configuration, variable frequency drives (VFDs) control the fan speed of both the exhaust fan ***and*** supply fan in tandem, resulting in a direct energy reduction on both fans.

2. Operations without dedicated makeup air units link the DCKV to the roof top unit (RTU) outside air damper to draw in a proportional amount of outdoor air to the air exhausted from the kitchen. When the exhaust fan rate increases, the damper will open to allow more outside air in to maintain air balance (and vice versa).

DCKV systems can exhaust less air and bring in less makeup air on average than traditional single-speed systems. For further discussion of DCKV systems in relation to HVAC, please refer to Design Guide 4: *Integrating Kitchen Exhaust with Building HVAC*.

Energy Perspective

As a critical part of a kitchen ventilation system, supplying and conditioning makeup air comes with energy considerations. Combined heating and cooling costs for makeup air range from **$1.72** to **$2.05** per cfm in California climates, assuming a 16-hour operating day and 360 operating days per year, which can add up to substantial energy costs if heating and/or cooling are required. Therefore, an unbalanced kitchen ventilation system can result in unnecessary costs. With proper makeup air design focusing on minimizing direct makeup air, diversifying makeup pathways and emphasizing system air balance, operators can optimize their ventilation system to save energy, while keeping kitchen staff comfortable.

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.

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Southern California Edison P.O. Box 6400 Rancho Cucamonga, CA 91729 1-800-990-7788 www.sce.com

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Southern California Gas Company 9240 Firestone Blvd Downey, CA 90241 (562) 803-7323 www.socalgas.com

Research Team

Frontier Energy, Inc. 12949 Alcosta Boulevard, Suite 101 San Ramon, CA 94583 (925) 866-2844 www.frontierenergy.com	Noresco (formerly Architectural Energy Corporation) 9750 E Easter Ave #100 Centennial, CO 80112 (303) 481-0073 www.noresco.com

Research Labs

Food Service Technology Center 12949 Alcosta Boulevard, Suite 101 San Ramon, CA 94583 (925) 866-2844 www.fishnick.com