Integrating Kitchen Exhaust with Building HVAC

Improving Commercial Kitchen Ventilation (CKV) System Performance

Integrating Kitchen Exhaust Systems with Building HVAC is the fourth 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 3: *Optimizing Makeup Air*

- *Minimize direct makeup air.*
- *Do <u>not</u> use short-circuit hoods. Use caution with air curtain designs.*
- *Avoid 4-way or slot ceiling diffusers in the kitchen, especially near hoods.*
- *Diversify makeup air pathways (use combinations of perforated perimeter supply, face supply, displacement diffusers, etc.).*
- *Minimize makeup air velocity near the hood; it should be less than 75 fpm.*
- *Consider evaporative makeup air cooling in warmer, drier climates in California.*
- *Install an interlocked demand-controlled ventilation system (DCKV) with variable frequency drives to modulate both exhaust and supply fan rates based on cooking load.*

Introduction

When designing for air balance requirements in a commercial kitchen, there is an opportunity to use code-required outdoor air supply to the dining room as makeup air in the kitchen, reducing or eliminating the fraction of makeup air needed from the independent makeup air unit (MAU). Since occupancy ventilation air is conditioned in most cases, transferring to the kitchen as a contribution to the makeup air requirement can improve comfort conditions for kitchen staff. Figure 1 shows an optimized kitchen ventilation design with maximized transfer air from the dining room.

This guide explains the advantages and challenges of integrating makeup air with the building HVAC system to maximize the use of occupancy ventilation air as makeup air. The *Outdoor Air Ventilation* section describes how outside air requirements are calculated based on occupancy or conditioned floor area. The *Foodservice HVAC* section discusses design issues related to selection and control of rooftop HVAC units including building energy and control system maintenance issues. The *Design Considerations* section describes methods to assure proper air transfer to the kitchen space. The *High-Performing Hoods & DCKV* section explores code requirements for these energy-efficient measures in relation to a transfer air strategy.

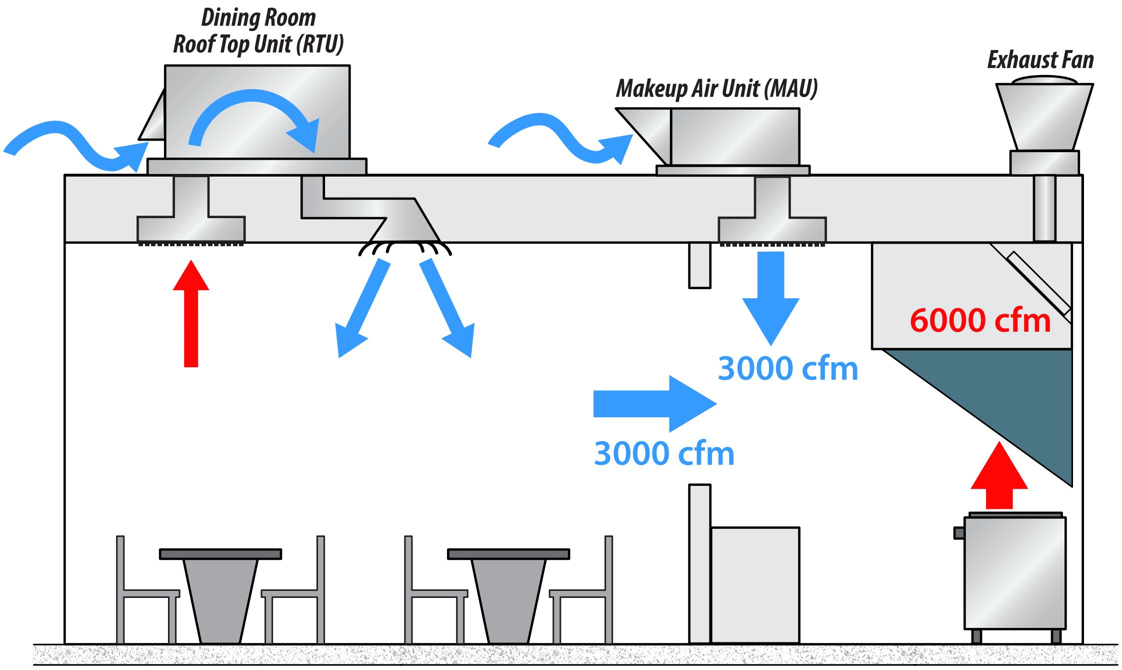


Figure 1. Optimized CKV Design with Maximized Transfer Air from Dining Room.

Outdoor Air Ventilation

"How much occupancy ventilation air is available for use as transfer air?" State and local building codes prescribe the ventilation rates for occupancy and kitchen exhaust. The California 2019 ***Building Energy Efficiency Standards for Residential and Nonresidential Buildings*** are commonly referred to as Title 24 (which is part of the California Code of Regulations). The energy efficiency standards are only Part 6 of Title 24, which contains the entire statewide building code. Part 6 provides that the design outdoor ventilation rate shall be the greater of two methods for determining outside air rates. The first method (Method A)[1] is based on the net occupiable floor area in square feet times a factor listed in Table 120.1-A, Minimum Ventilation Rates. A portion of Table 120.1-A is reproduced in Table 1. Restaurants, cafeterias, and bars have an outside air ventilation rate of 0.50 cfm/ft^2, while kitchens have 0.15 cfm/ft^2.

Table 1. Minimum Outdoor Air Ventilation Rates.

	[Title 24, Table 120.1-A]
Occupancy Category - Food & Beverage Service	Area Outdoor Air Rate (cfm/ft^2)
Restaurant dining rooms	0.50
Cafeteria/fast-food dining	0.50
Bars, cocktail lounges	0.50
Kitchen (cooking)	0.15

The second method (Method B)[2] requires 15 cfm per person times the expected number of occupants. The expected number of occupants is the expected number specified by the building designer. For spaces with fixed seating, the expected number of occupants is determined in accordance with the Title 24 code. For dining rooms, Title 24 sets egress occupancy by the number of fixed seats.

Title 24 recognizes exceptions to the design minimum outside airflow rate if the space is designed with demand ventilation controls (DVC) using carbon dioxide as a proxy for the current occupancy level. If the building employs DVC, the total ventilation flow may be reduced during periods of low occupancy.

Title 24 requires demand ventilation controls on HVAC systems that serve a space with design occupancy density, or a maximum occupancy load factor for egress that is equal to or greater than 25 people per 1,000 ft^2 (or 40 ft^2 per person or less) if the system has one or more of the following: (1) an air economizer, or (2) modulating outside air control, or (3) a design outdoor airflow rate >3,000 cfm.[3] Most restaurants have higher occupancy loads, so demand ventilation must be considered in restaurant design per Title 24. There is an exception to this requirement if the exhaust from the space is greater than the design ventilation rate specified in Method B (i.e., 15 cfm per person) minus 0.2 cfm per ft^2 of conditioned area.[4] This is an important exception that permits maximizing the use of occupancy ventilation air as transfer air and avoiding the need for demand ventilation in the dining room.

The application of these requirements to restaurants also depends on the size of the HVAC units (and whether they have an outdoor air economizer) and whether the dining room and kitchen are considered separate zones. These issues are discussed in the *Design Considerations* section of this guide.

Foodservice HVAC

"How will selecting and sizing of HVAC equipment affect the availability of transfer air?"

Restaurant HVAC is typically provided by constant-volume, packaged, single-zone air conditioning and heating units, commonly called roof top units or RTUs as that is where they are usually located. The cooling/heating capacity and the number of RTUs selected for a restaurant depend on the estimated thermal loads, thermal zoning, the first costs, and building code requirements.

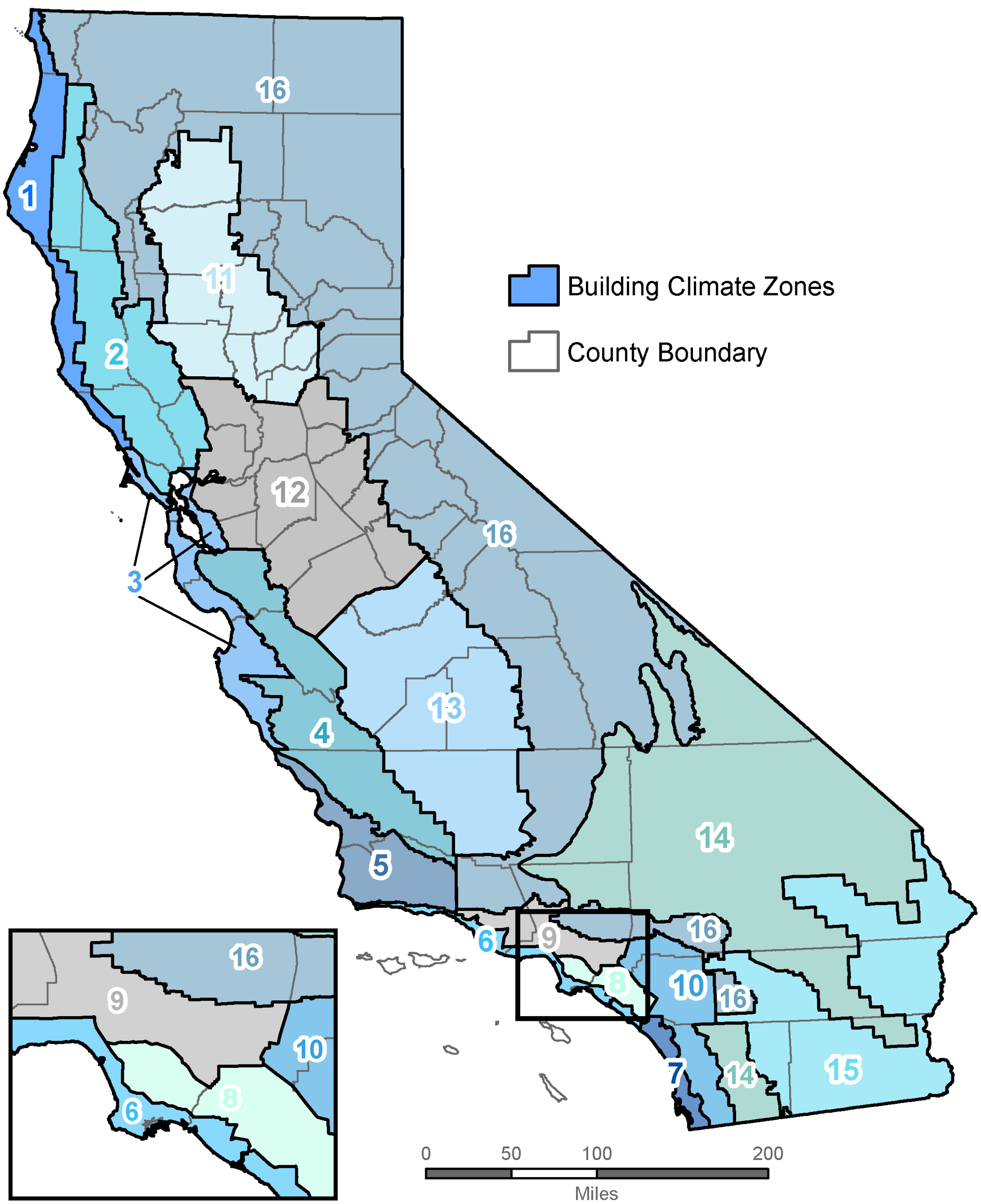
The cooling and heating capacities of RTUs are selected based on the hottest and coldest days expected during a year. In addition, the cooling capacities of dining room RTUs are sized assuming that peak design occupancy also occurs on peak cooling days. Likewise, kitchen RTUs are sized assuming that a peak business day (corresponding to a peak occupancy day in the dining room) with heavy cooking loads occurs on peak cooling days.

The number of RTUs used in a design depends on the number of thermal zones, the amount of required occupancy ventilation air, the design latent load, differences in the amount of ductwork required, and the impact of RTU weight on the roof structure. Thermal zoning divides the restaurant into areas that have similar thermal conditions during the day. For example, a small dining room with east and west windows may have two RTUs, one serving the east side and one serving the west side. The latent capacity of RTUs is usually no larger than 25% of total cooling capacity at design conditions due to coil sizing and design airflow rates. This may be a factor that increases the number of units depending on the amount of occupancy outside air and latent load. The amount of above-ceiling space for duct runs and the arrangement of structural members in the roof may also affect the number of RTUs. Larger RTUs usually require larger and longer duct runs that are often more difficult to install due to tight spaces above the ceiling and hence may be installed with field modifications that restrict airflow. Smaller RTUs will require shorter and smaller duct runs that may reduce restrictions introduced during construction. The placement of RTUs on the roof also plays a role in the design of the roof structure and hence the cost of the roof. Trade-offs can be made between the number and weight of RTUs to minimize the cost of the roof framing.

The first cost (purchase and install) of an RTU depends on cooling capacity, supply air capacity, the presence or absence of other features (such as air or water economizers), and the sophistication of the unit controls.

Building codes have increasingly demanded better energy efficiency and improved air quality from packaged air conditioning units. Examples include increases in required minimum energy efficiency ratios (EERs), duct sealing requirements, improved programmable thermostats and unit controls, and air or water economizers.

An air economizer is a damper section attached to the RTU that allows 100% of the design supply air to be outside air while shutting off the return air to the RTU. A water economizer is an RTU section that evaporates water directly (adding moisture to the supply air stream) or indirectly (no moisture added to supply air stream) to cool the supply air stream.



Source: California Energy Commission, 2017. https://www.energy.ca.gov/maps/renewable/building_climate_zones.html.

Figure 2. California Building Climate Zone Areas.

Title 24[5] requires that each RTU with a total mechanical cooling capacity of over 54,000 Btu/h have:

1. An air economizer capable of modulating outside-air and return-air dampers to supply 100% of the design supply air quantity as outside air; ***or***

2. A water economizer capable of providing 100% of the expected system cooling load at outside air temperatures of 50°F dry-bulb/45°F wet-bulb and below.

In air economizer mode, the supply fan for a typical small-to-medium size packaged RTU is not capable of providing enough power to supply outside air equal to 100% of design supply air without at least a passive vent in the return duct or in the building envelope. If some type of relief vent is not present, economizer operation of the RTUs will likely over-pressurize the building and the resulting backpressure will reduce the fan's ability to draw in 100% outside air. In some cases, a powered relief vent will be needed to assure that the economizer can draw in 100% of the design supply air.

Title 24[6] provides an exception to the mandatory economizer feature by selecting RTUs with cooling efficiencies that meet or exceed the cooling efficiency requirements listed in Table 2. California building climate zones are presented in Figure 2 on the previous page for reference.

Table 2. Economizer Trade-Off for Cooling Systems. **[Title 24, Table 140.4-D]**

Climate Zone	Efficiency Improvement[7]
1	70%
2	65%
3	65%
4	65%
5	70%
6	30%
7	30%
8	30%
9	30%
10	30%
11	30%
12	30%
13	30%
14	30%
15	30%
16	70%

Design Considerations

"Should transfer air from the dining room to the kitchen be maximized or minimized?" Deciding whether to use a traditional design with an independent makeup air unit with minimal transfer air from adjacent spaces ***or*** to use an integrated ventilation design that maximizes transfer air depends on several factors — physical layout, occupancy ventilation and controls/maintenance.

Physical Layout

In the case of a typical quick-service restaurant, separation of the dining and kitchen areas is often no more than a serving counter. In effect, the entire restaurant is a single zone from the perspective of air movement within the space. However, in many casual dining restaurants, the kitchen is separated from the dining room by a wall. In this case, the dining room and kitchen are considered two separate zones. With this layout, the designer/operator can either use the maximum amount of transfer air by integrating the HVAC with the kitchen ventilation system ***or*** keep the two systems separate and use demand ventilation controls in the dining room (and potentially DCKV in the exhaust hood and makeup air unit in the kitchen).

As discussed in Design Guide 3: *Optimizing Makeup Air*, air removed from the kitchen must be replaced with an equal volume of makeup air. The makeup air may come from an independent makeup air unit that discharges into the kitchen, outside air from the kitchen RTUs, and/or outside air from the dining room RTUs as transfer air.

The overall air balance in the restaurant is usually designed so that the air pressure in the entire building is slightly positive relative to the outside when the mechanical system is running. However, air pressure in kitchens is usually slightly negative relative to the dining room, adjacent spaces, and the outside due to the exhaust hood suction. This naturally assists in transferring air from the dining room to the kitchen and tends to keep cooking odors confined to the kitchen. But it may also allow unconditioned air into the kitchen when back doors or drive-through windows are open.

If transfer air is used, there must be enough open area between the dining and kitchen zones such that the transfer air velocity is relatively low (i.e., less than 75 feet per minute), or properly sized ducts or other openings must be placed between the two spaces (e.g., through transoms). There may or may not be door openings, open passages or pass-through openings in the wall between the dining room and the kitchen. The amount of available open area from doors, passages and pass-through openings may provide enough area to keep the transfer air velocity relatively low. Too much air moving through a pass-through opening can cool food quickly, possibily resulting in customer complaints. If the amount of open area is insufficient to allow air transfer at low velocity, transfer ducts must be included in the design. If the transfer air ducts are long, or due to structural space constraints, too small, an in-line duct fan should be used.

Occupancy Ventilation & Demand Ventilation Control

Dining room RTUs have a minimum outside air setting that is usually based on the design occupancy. During periods of low occupancy, the dining space is over-ventilated, and energy may be wasted by unnecessarily conditioning outside air. To minimize energy waste, Title 24 requires the use of DVC if certain HVAC and occupancy rules are met.

Demand ventilation controls in the dining room can be problematic if the outside air provided by the dining room RTUs is used as makeup air for the kitchen exhaust hood. If the kitchen exhaust hoods are traditional constant flow rate systems, a dining room DVC system can starve the kitchen exhaust system of makeup air if transfer air from the dining room is used.

On the other hand, if kitchen exhaust is controlled by a DCKV system, a dining room DVC may be acceptible under certain conditions. When peak menu production occurs close to peak occupancy, then it makes sense to utilize transfer air and combine the DVC and DCKV systems. In this case, as the kitchen exhaust rate is reduced, so is the outdoor air being introduced at the RTUs; otherwise, the interlock requirements of the DCKV system would utilize the kitchen makeup air unit. Typically, this would occur when menu preparation is not in sync with dining room occupancy and the ventilation of the kitchen and dining area are independent of one another.

Figure 2 lays out alternative paths for complying with Title 24's demand ventilation control requirement for high occupancy areas such as dining rooms. This is the first step in deciding whether to integrate the kitchen ventilation system with the dining room system. If demand ventilation control **is not** required, then analyzing an integrated ventilation approach is straightforward. If demand ventilation control **is** required in the dining room, the best practice in order to supply outside air to an interlocked DCKV system is through a modulating tempered air makeup unit in the kitchen. This simpler approach eliminates balance and pressure problems that can occur between the dining room and kitchen zones. Demand-controlled kitchen ventilation for the exhaust hoods should always be considered, but the designer must carefully evaluate when transfer air will be needed and when/if it will be available.

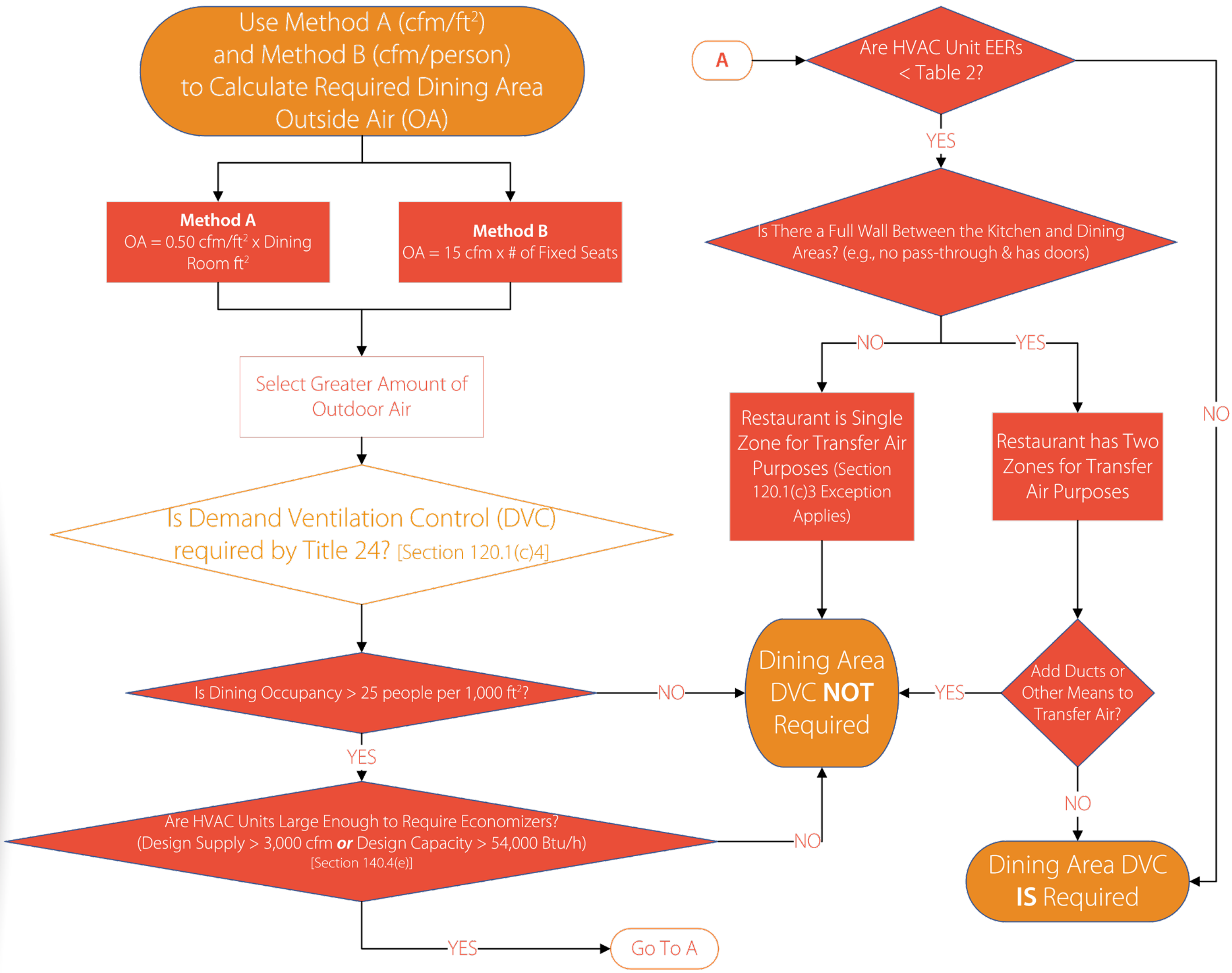


Figure 2. Flow Chart to Evaluate Whether DVC is Required for Dining Areas Under Title 24.

Controls and Maintenance

Other issues that can affect the decision to integrate the building and kitchen ventilation systems pertain to controls and maintenance. Keeping the systems separate provides some assurance that the hood will have the proper amount of makeup air. If the makeup air is supplied from multiple roof top units, there will be less impact on hood performance if one of the RTUs is not running or outdoor air dampers are closed. This is often not noticed by restaurant staff unless customers complain. However, if the independent makeup air unit is not running, the hood may have difficulty maintaining proper capture and containment and the exterior doors will be difficult to open due to the negative pressure in the building. Usually cooking plumes spilling from the hood will get the attention of kitchen staff and a maintenance action will be initiated. A design that includes DCKV on the hood system with tempered local makeup air supplied in the kitchen space may minimize air balance problems.

High-Performing Hoods, DCKV, & Transfer Air

As referenced in Design Guide 1, Title 24 addresses the use of high-performing hoods with well-engineered designs that can ventilate appliances at relatively low exhaust airflow rates. Title 24[8] contains certain prescriptive requirements for commercial kitchen exhaust and ventilation systems that are not part of an addition or alteration (i.e. new construction). The prescriptive requirements include:

1. Limiting the amount of makeup air introduced directly into the hood cavity to 10% of the hood exhaust airflow rate (i.e., through short-circuit hoods).

2. For foodservice operations having total Type I and Type II hood exhaust airflow rates greater than 5,000 cfm, each Type I hood shall have an exhaust rate that complies with Table 4[9] listed on page 9 of Design Guide 1: ***Selecting & Sizing Exhaust Hoods***.

The exception to requirements 1 and 2 above is where 75% of the total Type I and Type II exhaust makeup air is transfer air.[10]

Title 24 also addresses broader energy efficiency measures[11] where a kitchen/dining facility having a total Type I and Type II kitchen hood exhaust airflow rate greater than 5,000 cfm shall have at least one of the following:

1. At least 50% of all makeup air is transfer air;

2. A DCKV system installed on at least 75% of the exhaust air;

3. Listed energy recovery devices with a sensible heat recovery effectiveness of not less than 40% on at least 50% of the total exhaust airflow; ***or***

4. A minimum of 75% of makeup air volume that is unconditioned, or heated to no more than 60°F, or cooled without the use of mechanical cooling.

In some cases, mechanical cooling is required (making option 4 above difficult to acheive) to maintain thermostat setpoint in the kitchen due to the low supply air design temperatures required to balance the high heat gains from cooking equipment. However, for facilities that minimize the exhaust airflow rate (Design Guide 1) with well-designed, high-performing hoods along with optimum appliance placement (Design Guide 2) and care to limit local makeup air (Design Guide 3), 50% transfer air is feasible in option 1 above. DCKV is an energy-efficient option for most facilities (option 2), especially for the large commercial and hospitality market where payback can be as low as 2 to 5 years. Heat recovery (option 3) within commercial kitchens is becoming more prevalent due to new innovations in heat exchangers as they become part of appliance flues, hood filters, exhaust systems and pollution control devices. However, installing these devices on at least 50% of the total exhaust airflow can be costly and may have lengthy payback periods.

Endnotes

1. California Energy Commission, ***2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings,*** Title 24, Part 6, Section 120.1(c)3A. CEC-400-2018-020-CMF, December 2018.
2. Title 24, Part 6, Section 120.1(c)3B.
3. Title 24, Part 6, Section 120.1(d)3.
4. Title 24, Part 6, Section 120.1(d)3, Exception 1.
5. Title 24, Part 6, Section 140.4(e).
6. Title 24, Part 6, Section 140.4(e)1, Exception 4.
7. If a unit is rated with an IPLV, IEER, or SEER, then to eliminate the required air or water economizer, the applicable minimum cooling efficiency of the HVAC unit must be increased by the percentage shown. If the HVAC unit is only rated with a full load metric, such as EER or COP cooling, then that metric must be increased by the percentage shown.
8. Title 24, Part 6, Section 140.9(b).
9. Title 24, Part 6, Table 140.9-A - Maximum Net Exhaust Flow Rate.
10. Title 24, Part 6, Section 140.9(b)1B, Exception 1.
11. Title 24, Part 6. Section 140.9(b)2B.

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 not 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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