A Design Guide offering ideas and resources to focus on sustainable design for the modern CKV System. Optimize CKV applications, manage energy with ventilation systems and focus on a fully integrated system.
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Foundations of Modern CKV

The design of the modern commercial kitchen, including the ventilation system, can be a challenging endeavor. The idea seems simple - air being exhausted from the building must be replaced in order to maintain balance. However, the CKV system is only one component of the overall restaurant HVAC system and all of these, when designed, must work well together to maintain comfort level for both the restaurant patrons and restaurant staff.

The information contained in this Design Handbook will focus on the design of sustainable, fully integrated ventilation systems. Lower energy costs, improved indoor air quality, decreased building damage and reduced environmental impact are all goals of a sustainable design.

Information on the following topics will be included:

- Exhaust Hoods
- Grease Filtration
- Use of Pollution Control Unit
- Exhaust Solutions and Demand Ventilation
- Ductwork to Exhaust Effluent
- Dedicated Makeup Air

Optimize CKV applications, manage energy with ventilation systems and focus on a fully integrated system.
The focal point of the Kitchen Ventilation System - the exhaust hood - is used to remove heat, smoke, grease, steam and combustion products from the kitchen. The Hood Application Guide will give design ideas to choose the correct type and exhaust rate for your specific application, kitchen layout and cooking load for the equipment located under the hood.

Exhaust hoods are classified as either a *Type I* or *Type II* hood. Type I hoods are designed for removing grease and smoke, also called effluents. Effluent includes gaseous, liquid and solid contaminants produced by the cooking process and can also include products of combustion. Type I hoods must include grease filters or extractors listed to UL Standard 1046, “Grease Filters for Exhaust Ducts,” and a fire suppression system listed to UL Standard 300. Type II hoods are used for heat and condensate applications.

Type I hoods are further broken out into *Unlisted and Listed* classifications. Listed hoods are tested to UL Standard 710, “Standard For Safety Exhaust Hoods for Commercial Kitchen Cooking Equipment.” Listed hoods are constructed in accordance with the terms of the manufacturer’s listing and are required to be installed in accordance with NFPA 96 or the model codes. International and Uniform Mechanical codes allow Type I hoods to be exempt from code-specified exhaust rates if listed to UL 710.
Below is a table showing the minimum exhaust flow rates required per International Mechanical Code (IMC) for unlisted hoods. Backshelf and wall canopy style hoods are shown below.

<table>
<thead>
<tr>
<th>Type of Hood</th>
<th>CFM per Linear Foot of Hood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Light Duty Equip</td>
</tr>
<tr>
<td><strong>Unlisted</strong></td>
<td></td>
</tr>
<tr>
<td>Wall-Mounted Canopy</td>
<td>200</td>
</tr>
<tr>
<td><strong>Unlisted</strong> Backshelf</td>
<td>250</td>
</tr>
</tbody>
</table>

Listed hoods are recommended to be used in all applications because of the lower exhaust rates per foot. Typical minimum exhaust rates for listed wall canopy and backshelf hoods are shown in the table below.

*Specific manufacturer Listed Minimum exhaust rates could vary.

<table>
<thead>
<tr>
<th>Type of Hood</th>
<th>CFM per Linear Foot of Hood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Light Duty Equip</td>
</tr>
<tr>
<td><strong>Listed</strong></td>
<td></td>
</tr>
<tr>
<td>Wall-Mounted Canopy</td>
<td>150-200</td>
</tr>
<tr>
<td><strong>Listed</strong> Backshelf</td>
<td>100-200</td>
</tr>
</tbody>
</table>

**Styles of Hoods**

- **Wall Canopy** - cover cooking equipment located against a wall
- **Single Island Canopy** - cover cooking equipment in a single island configuration
- **Double Island Canopy** - cover cooking equipment that is in a back to back configuration
- **Backshelf, Proximity or Low Profile** - cover counter height equipment
- **Eyebrow** - mounts directly to oven

**How Hoods Work**

Effluent generated by a cooking process will form a buoyant thermal plume that will rise and expand. The hood capturing and containing this effluent should be sized and at a proper height to contain the plume as it rises. If a a wall is present, then the ‘Coanda Effect’ will enhance capture and containment by helping draw the effluent toward the wall and up into the hood. Hoods must accommodate the natural recirculation
of the effluent within the hood, and should be sized to hold surges of effluent as well occurring from door openings, lid openings, turning food, lowering baskets of food, passthrough windows, etc. Makeup air can aid in capture and containment of the hood by effectively “pushing” effluent into the hood.

**Schlieren Flow Visualization**

Schlieren flow visualization is the latest thermal imaging technology that allows observation of heat and effluents generated by the cooking process, otherwise ‘invisible’ to the naked eye. Smoke and sometimes steam may be visible. Other effluents including convective heat, water vapor, grease vapor and combustion by-products are all invisible.

The Schlieren System features a light source, imaging lens and refractive surface, which can visualize the refraction of light due to changes in air temperature and density. The result is a well defined, real-time image illustrating the heat and effluent generated and associated flow patterns.

Schlieren technology is used to determine the threshold of capture and containment performance; the ability of the hood to capture and contain grease laden vapors, convective heat and other products of cooking processes.

The Schlieren images seen to the right show different exhaust rates for a hood directly above a range top. On the image on the top, the thermal plume is escaping the hood at 165 CFM per linear foot. The same hood, now shown at an exhaust rate of 220 CFM per linear foot, is shown on the bottom. The hood at the higher CFM rate is now completely capturing and containing the buoyant thermal plume.
Hood Application Guide

Step One: Determining the Appropriate Hood Style
When determining the appropriate hood model, the following must be considered:

• Local Code Requirements
• Location of the Job Site
• Equipment Size, Type and Location under the hood
• Equipment Operation and usage
• Menu and Food Products cooked
• Air Volume - Building and HVAC design
• Kitchen Layout - Walls, doors, pass through windows and drive through windows

Refer to page four for the different styles of hoods available to meet your specific application including wall canopy, backshelf and island hoods.

Step Two: Determining the Proper Hood Size
When determining the appropriate hood length, the following must be considered:

\[
\text{Hood Length} = \text{Overall Equipment Length}^* + (\text{Side Overhang}^{**} \times 2)
\]

*Overall equipment length should include any space between the cooking equipment, usually one to two inches.
**Side overhang is defined as the required distance from the end of the hood to the outside edge of the cooking equipment.

For example:

Equipment Layout Length is 9’0” and Side Overhang is 6”

Hood Length = 9’0" + (6” x 2) = 10’0” minimum length required

When determining the appropriate front and side overhang, the following must be considered:

\text{Side overhang} is determined by the listing of the hood model, or if the hood is not Listed, then by the prevailing code set.

When determining the width of the hood, the following must be considered:

\[
\text{Hood Width} = \text{Space between wall & equipment} + \text{Depth of Cooking Equipment} + \text{Front Overhang}^*
\]

*Distance from the front edge of the hood to the front edge of the appliance.

The front overhang is determined by the listing of the hood model.

For example:

Distance between Wall and Equipment = 6”
Equipment Depth = 24”
Front Overhang = 12”

Hood Width = 6” + 24” + 12” = 42” minimum width required
The formulas listed on the previous page for front and side overhang are for minimum overhang requirements. Research and testing has shown that increased side and front overhang can improve system performance. Recommended side and front overhang are shown in the table below:

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>OVERHANG***</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FRONT</td>
</tr>
<tr>
<td>Charbroiler*</td>
<td>18” - 24”</td>
</tr>
<tr>
<td>Fryer or Griddle</td>
<td>12”</td>
</tr>
<tr>
<td>Conveyor Oven</td>
<td>12”</td>
</tr>
<tr>
<td>Convection Oven**</td>
<td>24”</td>
</tr>
</tbody>
</table>

* For upright broilers, mesquite broilers and open flame grills with heavy cooking loads, we recommend a 18” minimum front and side overhang if possible. The additional overhang will ensure that the rapidly expanding effluents are captured and contained by the hood.

** Exceptions to overhang must be considered on long hoods with convection ovens underneath.

***From current testing, 12” minimum overhang on all sides is recommended for single island cooking operation.

Most hoods on the market today are available in one piece up to 16 feet long. If the total length of the hood needed is greater than 16 feet, then the hoods are supplied in two pieces. Two exhaust risers are recommended on hoods greater than 12 feet, especially those with heavy cooking loads.

**Step Three: Cooking Surface Temperature Determination**

Exhaust hoods that are tested and listed to UL Standard 710 cover appliances with equipment temperatures: 400, 600 and 700 degrees F. General practice is to group appliances by their duty rating. If multiple duties are under the hood, then the exhaust rate will be based on the highest duty rating for the entire hood length. Exhaust rates are determined by the group of equipment under the hood. The following chart will help determine the cooking temperature of some common types of equipment.

<table>
<thead>
<tr>
<th>400/450°F Surfaces (Light Duty)</th>
<th>600°F Surfaces (Medium Duty)</th>
<th>700°F Surfaces (Heavy Duty)</th>
<th>700+°F Surfaces (Extra Heavy Duty)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ovens</td>
<td>Open-Burner Ranges</td>
<td>Gas Charcoal Charbroilers</td>
<td>Mesquite Grills Solid Fuel</td>
</tr>
<tr>
<td>Steamers</td>
<td>Gas Charbroilers</td>
<td>Gas Conveyer Charbroiler</td>
<td></td>
</tr>
<tr>
<td>Kettles</td>
<td>Electric Charbroilers</td>
<td>Woks</td>
<td></td>
</tr>
<tr>
<td>Griddles</td>
<td></td>
<td>Chain Broilers</td>
<td></td>
</tr>
<tr>
<td>Fryers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Braising Pans</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Step Four: Determination of Exhaust Rate**

Being able to determine the appropriate exhaust rate to capture, contain and remove effluent generated varies based on the style of hood, equipment under the hood and the cooking process. The exhaust rate for the hood should factor a base number and then adjust for actual cooking experiences and options on the hood, such as end panels and overhang. The recommendation is to use ASTM F 1704-05 values as the base, versus the minimum listed exhaust rate values seen determined by the UL 710 testing. The testing for UL 710 is done in a draft-free laboratory; thus, the recommended design values given by the manufacturer may be higher than the listed values.
ASTM F 1704-05, “Standard Test Method for Capture and Containment Performance of Commercial Kitchen Exhaust Ventilation Systems,” uses Schlieren flow visualization to determine the threshold of capture and containment of a hood and appliance combination under cooking and idle conditions. The flow visualization is used to determine whether the heat, generated by the cooking equipment and process, is being captured by the kitchen exhaust hood. From this, a value for exhaust flow rate of the hood can be determined to fully capture both the effluent and the heat generated.

Below are typical exhaust rates suggested for a Listed, wall canopy style hood that has been tested to ASTM F 1704-05:

<table>
<thead>
<tr>
<th>Suggested 175 CFM/ft</th>
<th>Suggested 200 CFM/Ft</th>
<th>Suggested 300 CFM/ft</th>
<th>Suggested 375 CFM/Ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ovens Steamers Kettles Griddles Fryers</td>
<td>Open Burner Ranges Gas Charbroilers Gas Charcoal Charbroilers Woks</td>
<td>Gas Charcoal Charbroilers Woks Mesquite Grills Solid Fuel Conveyor Charbroilers Charcoal Charbroilers</td>
<td></td>
</tr>
</tbody>
</table>

Once the base exhaust rate is established, other items need to be considered such as the style of hood, options on the hood, dynamic effects and a safety factor.

The amount of exhaust required by a ventilator is proportional to the cooking surface temperatures and contaminant level produced by the equipment. This calculation is significant for proper integration with the entire ventilation system (HVAC, makeup air, etc).

**Exhaust CFM = Length of hood * ASTM Exhaust Flow Rate per Linear Foot**

For example:

- **Hood Length = 10’0”**
- **Conditions = 450 degree F rated appliances, light cooking**
- **ASTM Listed Flow Rate = 175 CFM/Ft**
- **Exhaust = 10’ * 175 CFM/Ft = 1750 CFM/Ft**

Dynamic conditions in the kitchen can interfere with the ability of the hood to capture and contain the generated effluent. Verify in the design that there are no four-way diffusers within ten feet of the hood in any direction. Non-directional perforated diffusers are recommended for use around the hood. It is also critical to evaluate the mechanical layout of the building including walls, walkways, pass-through and positioning of lights and poles.

The addition of **end panels**, as shown in the pictures to the right, is a simple and proven technology to achieve full capture and containment at lower exhaust rates. The top image shows a hood not capturing the effluent; the same hood, shown in the bottom, is now capturing fully with the addition of the end panels.
Other design guidelines to keep in mind, based on testing done by the industry, to help determine the CFM value used:

- Heavy-duty appliances should be placed in the middle of the lineup under the hood or under an exhaust riser
- Place Light-duty appliances, including ovens, on the end of the line
- Push back appliances as close to the wall as possible extending the front overhang
- Use side panels and end panels
- Seal the gap between the appliances and the rear wall
- Use larger hoods - both deeper and taller. Recommendations are 54” deep hoods as standard for depth. 30” tall hoods with 20” filters are recommended to be used on 700 degree rated surfaces.
- Do not locate four-way diffusers or HVAC returns near the hood
- Minimize the distance from the cooking surface to the hood by hanging the hood at a practical and minimum height allowed by code
- Introduce dedicated makeup air at low velocity, using perforated perimeter supply, and avoid use of an internal compensating hood, front face discharge or air curtain

Sales engineers for the hood manufacturers are also available to assist you in determining the proper hood style and exhaust rate based on the needs of your application. Determine the lowest, sustainable exhaust rate that will ensure full capture and containment of effluents. Comfort, safety and additional load on the HVAC system can be compromised if proper capture and containment of the effluent is not achieved. Key required elements under IMC Section 507 are the hood system shall be designed to capture and contain all effluent, exhaust and supply flow rates shall be measured and verified, and a visual performance test (smoke puffer, smoke candles, etc.) shall be conducted.

**Type II Hoods**

Type II hoods are typically used for two different application usages: condensate hood or as a heat and fume hood. Condensate hoods are used in applications with high-moisture exhaust, and an example of this application would be over a dishwasher. Hoods for these applications are designed to direct the condensate, which forms on the interior surfaces of the hood, toward a gutter located on the perimeter of the hood. The gutter allows for collection and drainage of the condensate instead of dripping down onto the appliances. Exhaust rates are in the ranges of 100-150 CFM per foot based on the hood length. Hoods for dishwashers are usually undersized in many applications and allow for moisture to escape the hood; below are recommendations for front and side overhang for a conveyor dishwasher.

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>OVERHANG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FRONT</td>
</tr>
<tr>
<td>Conveyor Dishwasher</td>
<td>12”</td>
</tr>
</tbody>
</table>

The second use of Type II hoods is to cover equipment producing only heat and vapor. Typically exhaust rates for these applications are in the range of 100-300 CFM per foot depending on the application. Some jurisdictions allow the use of a Type II hood for use over ovens; please verify with the authority having jurisdiction in your area if a Type II hood is acceptable.
Grease Filtration

Type I hoods are required to have grease filters, baffles or extractors listed to UL Standard 1046, “Grease Filters for Exhaust Ducts.” The filter, under Standard 1046, tests filters to ensure their ability to remove grease, drain off the collected grease and limit the projection of flames downstream after exposure to grease-laden air. This standard is a safety oriented test for filters and is not intended to evaluate the grease extraction performance of the filter. Grease extraction performance can be evaluated by ASTM F 2519 described below.

Devices used in Type I hoods for the removal of grease can comprise the following types: baffle filters, cartridge filters, extractors used in water wash hoods and multi-stage filtration. Filters work on the same basic principle - air being exhausted passes through a series of baffles or stages, and centrifugal force forces the grease particles out of the airstream to be drained out. The amount of grease removed varies based on the design of the filter, type of cooking and equipment used and air velocity through the filters.

Removing grease at the source, the hood, is a very important part of the commercial kitchen operation. Not capturing grease can lead to the following issues:

- Collection on the fan - lead to an unbalanced load and failure of the fan over time
- Accumulation in the plenum and duct - increased fire hazard
- Increased duct cleanings
- Collection on the rooftop itself and other rooftop equipment including HVAC units
- Potential of odor problems with the accumulation of grease

**Grease Particle Capture Efficiency**

The UL Standard 1046 for grease filters is a safety-based standard, which does not measure filter grease removal performance. ASTM F 2519, “Standard Test Method for Grease Particle Capture Efficiency of Commercial Kitchen Filters and Extractors,” provides a realistic, reliable and repeatable way to measure and determine the grease removal performance of kitchen hood filters.

Research has documented the grease emissions characteristic generated in commercial cooking operations to contain both grease vapor and small particles. Typically, higher temperature appliances, such as charbroilers and woks, will generate smaller sized grease particles and more grease vapor than those produced by lower temperature appliances, such as ovens and fryers.

The ASTM F 2519 Standard generates a challenge aerosol using oleic acid to create emissions having similar particle size and distribution characteristics of real-world cooking between 0.3 and 10 microns in diameter. An optical particle counter is used to measure the particulate, by size, passing through the filter. The result is a capture efficiency percentage graph across a particle size range up to 10 microns.

Manufacturers can now test their filters by an independent third party under the ASTM F 2519 Standard, to document accurate grease particle removal efficiency at a given particle size, or a graph of results across a particle size range from 0.3 to 10 microns. The following graph compares grease collection efficiencies of four grease filter options.
The standard baffle filter, available in aluminum and stainless steel, is represented by the black line in the previous graph. Between eight and ten microns, the standard baffle filter will capture approximately 20 to 30 percent and at five microns will capture only 6 percent. In comparison, the multi-stage filter, between eight and ten microns, is capturing nearly 100 percent. At five microns, the multi-stage filter is capturing in the 95 percent range. More efficient filters have a greater static pressure or resistance to flow, which must be considered for proper fan selection.
Pollution Control Unit

Concerns about air quality and increasingly stringent standards about where air is exhausted or exhausting into a public area are some concerns when talking about grease extraction. In many cities today and with the rise of multi-use projects, where a restaurant space is located below or near housing, further filtration of the exhaust air is required. Technology, called a pollution control unit, that includes a multi-stage grease filtration system is used to remove smoke and grease particles further downstream of the grease hood. Many variations of the pollution control unit, including electrostatic precipitators and water mist or scrubbers, are on the marketplace today.

With the growing cost of utilities and water, a simple and low maintenance unit, such as a multi-stage pollution control unit should be considered. This technology uses a series of mechanical filters to remove grease and smoke from the exhaust airstream. Typically these units include a high efficiency filter for the removal of smaller grease particles, a HEPA filter for the removal of smoke and an odor control filtration module.

Pollution control unit is tested to UL Standard 710 and must include a fire suppression system listed to UL Standard 300. The picture below shows the filter stages of a pollution control unit by one manufacturer.

Maintenance of these systems is an important aspect to ensure the proper removal of effluent and odor from the airstream. The high efficiency, HEPA and odor control filters used in the triple pass unit are ordinarily disposable. Maintenance cycle and changeout of the filters is dependent on the cooking application, type of cooking and filtration at the hood itself. When using these systems downstream, the greater the filtration at the hood source, the less periodic maintenance for the pollution control unit.

After choosing the correct hood model, correct exhaust CFM and grease filtration options, the next step in design is choosing the equipment that is exhausting the effluent and bringing back in the replacement air.
Exhaust fans should meet the following specifications: be capable of handling heated grease-laden air, designed to keep the motor out of the airstream and effectively cooled to help prevent early failure. Common fans used in the industry today include power roof ventilators (also called centrifugal), utility sets and inline fans.

**Types of Fans**

**Centrifugal upblast fans** are listed in compliance with UL Standard 762, “Power Roof Ventilators for Restaurant Exhaust Appliances.” To meet the requirements of UL 762 and NFPA 96, the fan must include an integral hinge kit to provide access for cleaning, a grease drain and a collection device for grease. Options available for an upblast fan include the choice of a belt or direct drive. Belt drive fans can handle higher static pressure and exhaust CFMs than a direct drive and are a better choice when using with a variable speed system. Belt drive fans usually have more maintenance associated with belts, pulleys and bearings.

Direct drive fans have less friction while operating, because they do not require the belts and pulleys; instead, speed is controlled by a rheostat. The reduction is friction increases operating efficiency and lowers operating costs by eliminating belt and bearing replacement. Direct drive fans are generally less expensive but are limited to lower CFM and static pressure applications.

**Utility sets** are usually constructed of steel, mounted outdoors and used for high pressure/high CFM applications. Typically, the utility set will include a motor cover for weather protection, blower housing, and a blower wheel with motors. When used for grease applications and to meet UL Standard 762 the following must be included: a grease drain, grease collection device and access panel to allow for cleaning of the blower. When selecting a utility set, it is recommended to keep the discharge velocity at less than 1800 fpm.

**Inline fans** are used in applications where an exterior installation or rooftop installation is not possible. These fans are located in the duct run inside of a building and are constructed of steel. When listed under UL 762, the fan must include a grease drain, grease collection device and blower housing access panel for cleaning.

Consult a sales engineer of the manufacturer with help on correct fan type and size for your design application.
Exhaust Terminations

**Rooftop terminations** are preferred because discharge can be directed away from the building and the fan is more accessible for cleaning. According to NFPA 96 7.8.2.1, rooftop terminations are required to meet certain parameters including some of the ones listed below:

- Minimum of 10 feet of horizontal clearance from the outlet to adjacent buildings, property lines and air intakes
- A minimum of 5 feet of horizontal clearance from the outlet (fan housing) to any combustible structure
- A vertical separation of 3 feet below any exhaust outlets for air intakes within 10 feet of the exhaust outlet
- A hinged upblast fan with the following conditions: Ductwork shall be a minimum of 18 inches from any roof surface and the fan shall discharge a minimum of 40 inches away from any roof surface

**Wall terminations** are another option seen in installation today. According to NFPA 96 7.8.3, wall terminations are required to meet certain parameters including some of the ones listed below:

- Through a non-combustible wall with a minimum of 10 feet of clearance from the outlet to adjacent buildings, property lines, grade level, combustible construction electrical equipment or lines, and the closest point of any air intake or operable door or window at or below the plane of the exhaust termination
- The closest point of any air intake or operable door or window above the plane of the exhaust termination shall be a minimum of 10 feet in distance, plus 3 inches for each degree from horizontal
- Exhaust flow directed perpendicularly outward from the wall face or upward

**Fan Actions**

Exhaust systems must be designed and installed to prevent a fire starting in the grease exhaust system from damaging the building and to prevent the spread of the fire through the grease exhaust system. Exhaust fans, in fire conditions, typically are required by codes to remain on while the supply fan turns off. The exhaust fan remains on to carry the fire suppressant liquid through the duct and the supply turns off to avoid feeding the fire. NFPA 96 calls for the exhaust fan to continue to run in a fire condition, unless required to remain on by a listed component of the ventilating system or of the fire-extinguishing system.

**IMC 2006 Code Requirement**

A recent change adopted in the 2006 edition of International Mechanical Code (IMC) is 507.2.1.1, which states that Type I hood systems shall be designed and installed to automatically activate the exhaust fan whenever cooking operations occur. Several methods are indicated in the code to achieve this operation, including the use of heat sensors.

Manufacturers are using temperature sensors in the ductwork/hood riser to activate the exhaust system. When a preset temperature on the sensor is exceeded, then the exhaust fan will begin to operate. Forms of variable-speed exhaust systems are also used to meet this code.
Variable frequency drives modulate the exhaust and supply levels based on the temperature readings of the sensor in the riser. Instead of the exhaust system running at 100 percent all hours of operation, the exhaust level is modulated in relation to the cooking load. Low periods where there is little to no cooking can see the fan run at lower CFMs, which equates to savings for utility costs and fan operating costs.

**Fan Laws and Energy Savings**

Most commonly used fan laws in simplified terms are seen below.

1. Flow Rate (CFM) varies linearly with RPM:
   \[
   \text{CFM 1} / \text{CFM 2} = \text{RPM 1} / \text{RPM 2}
   \]
2. Static Pressure varies as the square of the RPM:
   \[
   \text{SP 1} / \text{SP 2} = (\text{RPM 1} / \text{RPM 2})^2
   \]
3. Horsepower varies as the cube of RPM:
   \[
   \text{HP 1} / \text{HP 2} = (\text{RPM 1} / \text{RPM 2})^3
   \]

The Demand Ventilation system or Variable Speed system, as mentioned above, can modulate the airflow rate based on cooking load and demand. Because of the cubic relationship between fan flow and energy, the energy savings of reducing exhaust are proportionately greater than the flow reduction. Below is a table of the fan energy savings associated with reducing exhaust CFM rates by varying percentages.

<table>
<thead>
<tr>
<th>Percentage of Exhaust Reduction</th>
<th>Percentage of Fan Energy Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>27%</td>
</tr>
<tr>
<td>20%</td>
<td>47%</td>
</tr>
<tr>
<td>30%</td>
<td>66%</td>
</tr>
<tr>
<td>40%</td>
<td>78%</td>
</tr>
<tr>
<td>50%</td>
<td>87%</td>
</tr>
</tbody>
</table>

Because of the same cubic relationship, if the exhaust CFM is increased then the fan energy costs rise dramatically. The importance of choosing the correct exhaust flow rate for the application and cooking load is of great importance.

<table>
<thead>
<tr>
<th>Percentage of Exhaust Increased</th>
<th>Percentage Increase of Fan Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>33%</td>
</tr>
<tr>
<td>20%</td>
<td>73%</td>
</tr>
<tr>
<td>30%</td>
<td>120%</td>
</tr>
<tr>
<td>40%</td>
<td>174%</td>
</tr>
<tr>
<td>50%</td>
<td>237%</td>
</tr>
</tbody>
</table>

Designing the correct CFM initially and the use of the Demand Ventilation system can help the end user save on fan energy costs. With the reduction of the airflow rates, the potential savings on makeup air heating and cooling will also be a factor. An analysis of applications for payback and energy savings can be evaluated with information provided by the Outdoor Airload Calculator (please see Reference sheet for link to this application online).
As part of the exhaust system, the grease duct conveys effluent from the exhaust hood to the outside. Effective ductwork must be greasetight, clear of combustibles and sized properly to convey the exhaust airstream. Ducts used in Type I applications must also contain products of combustion and fire to prevent the spreading of fire via the ductwork.

Ducts used in commercial kitchen ventilation systems can be either round or rectangular. Rectangular duct is typically fabricated in the shop and welded onsite. Round ductwork is usually ductwork that is factory built and listed to UL Standard 1978, “Grease Ducts.” The requirements seen in the standard cover modular grease duct assemblies, unwelded connections between adjoining duct parts, fittings, access doors, and the like intended for use with grease ducts installed in accordance with NFPA 96 and the International Mechanical Code.

**Duct Materials and Clearance to Combustibles**

IMC and other codes call for minimum specifications for materials and thickness of the metals used to construct ductwork. Joints, seams and penetrations of grease ducts must be made with a continuous liquid-tight weld or braze made of the external surface of the duct system. Duct-to-hood joints are also called to be made with continuous internal or external liquid-tight welded or brazed joints; joints should be smooth, accessible for inspection and without grease traps.

Grease duct exhaust fires can generate very high temperatures, which without proper clearance, can ignite combustible materials near the duct. Because of this, ductwork is required in most codes to be 18 inches from combustible construction. NFPA Standard 96 also requires clearance to limited combustible materials: 3 inches from noncombustible materials (such as gypsum wallboard) attached to noncombustible structures (such as metal studs).

Factory built grease duct systems are an alternative to code-prescribed welded systems. Listed and labeled factory-built grease ducts are allowed because of the exceptions in the codes for this product. Listed ductwork can be installed with reduced clearance to combustibles in accordance with the manufacturer’s instructions.

Available materials, such as duct wrap, can also be applied directly to the ductwork for clearance reduction to combustibles. These materials are tested to ASTM Standard E2336, “Standard Test Methods for Fire Resistive Grease Duct Enclosure Systems.” The test standard is now written into IMC 2006 Edition and the 2008 Edition of NFPA Standard 96. These materials are tested to five separate and distinct tests to verify the effectiveness of the enclosure. The flexible wrap type enclosure systems available on the market today that meet all five criteria of ASTM E2336 are all applied in a minimum of two insulation layers. It is important to find materials that have met all the requirements of ASTM E2336; moreover are thinner, lighter, flexible, and offer installation advantages.
Duct enclosures are used when grease ducts penetrate a fire-resistance-rated wall or floor-ceiling assembly; the duct must be continuously enclosed from the point the duct penetrates the first fire barrier until the duct leaves the building. Both listed and welded ductwork are subject to the enclosure requirements laid forth by codes. Clearance must be maintained between the duct and the shaft when the duct is in the rated enclosure; NFPA Standard 96 and IMC require minimum of 6 inch clearance. The enclosure can also only contain one ductwork assembly. Some listed ductwork, which is tested to UL Standard 2221, is manufactured to be used without the shaft enclosure. Usually this ductwork is a double wall construction and has fire-resistant insulation material between the two walls. This product must be installed in compliance with the terms of the manufacturer’s listing.

**Air Velocity**

IMC and NFPA Standard 96 have set the minimum velocity for exhaust ductwork to be at 500 fpm. This is a recent change from 1500 fpm and allows for greater flexibility in design and the use of variable-speed exhaust systems. Helping the change was ASHRAE sponsored research which revealed that velocities below 1500 fpm caused less grease deposit on horizontal duct runs.

**Recommendations for Design and Install**

When designing duct system for an application, the most ideal installation would be a straight duct run from the hood upwards to the exhaust fan above. If the situation described above is unavailable, then any change of direction, offset or elbows will lead to increased static pressure for the fan to overcome. Change of directions, if accounted for when determining static pressure for a system, can be used if designed properly; if not designed properly then system effect can occur. System Effect occurs in an air system when two or more elements such as fittings, a hood and a fitting, or a fan and a fitting occur within close-proximity to one another. The effect is to increase the energy or pressure in a system as air flows through the elements. To avoid increased system effect and added static pressure for the fan to overcome, please use the following recommendations:

- Exhaust ductwork straight up to the inlet of the fan
- First elbow at least 18” above the hood
- Allow for minimum of 4 feet between the use of two elbows
- Use radius back elbows
- Avoid an elbow directly into the inlet of the fan

**Replacement Air**

A correctly designed ventilation system requires air balance. Air being exhausted out of the building, through the exhaust hoods and fans, must be replaced with outside air that enters the building. If the replacement air requirements are not met then two consequences can occur: the proper building pressurization and the capture and containment of the hood is compromised. Proper building pressurization needs to be maintained to aid in the safe operation of equipment such as hot water heaters, preventing the escape of odors to adjacent spaces, preventing unfiltered air from being suctioned into the space and maintaining a comfortable environment for the whole building. IMC requires the electrical interlock between the exhaust fan and replacement air sources to help ensure correct pressure control.
Replacement air may be introduced into the building in a variety of methods through HVAC units, dedicated makeup air, which provides heated and/or cooled outside air. Indoor Air Quality (IAQ) engineers must design outside air systems to meet total ventilation requirements, and thus, replacement air for the hood must be integrated into this design.

Replacement air can be classified into three subcategories: makeup air, supply air and transfer air. **Makeup air** is typically the language used to describe a system that is providing replacement air specifically for the hood. Dedicated makeup air, depending on local requirements and area of the country, may be tempered or untempered. **Supply air** is outside air introduced through the HVAC and is dedicated to the comfort conditioning of the space in which the hood is located. **Transfer air** is introduced through the HVAC and used for comfort conditioning and ventilation requirements of a space adjacent to the hood. Air can be transferred through wall openings, door louvers and/or ceiling grilles.

**Design Recommendations**

In most applications, especially full-service restaurants and institutional kitchens, the recommendation for proper replacement air strategy is provide a dedicated makeup air system which can provide around 70-80% and then have the remainder be from transfer air. The goal of dedicated makeup air is to introduce the maximum amount of air close to the hood and not hinder the capture ability of the hood. Many designs have been tried in the industry throughout the years to bring in makeup air including short-circuit hoods, front face discharge and air curtain designs. Research has shown that the amount of makeup air and the distribution methods for each of these designs can lead to hood failure and an increased load on the HVAC system. Another method in use today is the backwall supply, also called a rear discharge or back return. This application can be used to bring in a maximum of fifty percent of the exhaust air and the discharge area should be at least 12 inches below the cooking surface of the appliances.

When designed properly, the use of a **perforated perimeter supply** is the recommended method to bring in makeup air close to the hood. The perforated perimeter supply, based on lab testing and field experience, confirm this method has the least effect on hood operation, minimal load on the HVAC system and around 70-80 percent of the exhaust rate can be brought in through this method.

**Perforated Perimeter Supply**

Perforated Perimeter Supply directs the air downward toward the capture area of the hood. Velocity and temperature of the air delivered by this means is an important part to consider. For proper hood performance, discharge velocities should be in the range of 140-160 fpm for a wall mounted canopy hood, unless in tropical climates where the recommendation would then be 180-200 fpm. The perimeter supply should be mounted 18 inches up from the front lip of the hood for best results. It is recommended to deliver the makeup air between 45-55 degrees F and 85 degrees F - below the balance point of the restaurant.
Tempered Dedicated Makeup Air

IMC requires makeup air to be conditioned to within 10 degrees F of the kitchen space, except where the replacement air does not decrease the comfort of the kitchen. This requirement can be met by having all replacement air come directly from the HVAC units; the air is then cooled and heated to the thermostat setting usually between 68 and 75 degrees F. The majority of the air that is provided, especially near the hood, will be exhausted back out of the space by the hood. Unlike this scenario, a dedicated makeup air unit employs moderate tempering, heating to 55 degrees F and cooling to 85 degrees F.

Tempering methods of makeup air can include indirect and direct fired gas heat, evaporative coolers, direct expansion cooling and water coils for heating and cooling. Heating is recommended for locations where the winter design temperature is below 23 degrees F; many jurisdictions around the country require heating of the makeup air. Direct-fired heating is the most efficient and economical means of make-up air tempering. Direct-fired heating refers to heating equipment that burns gas directly in the fresh air stream resulting in the most efficient method of heat transfer. Direct-fired heaters generate the lowest cost per BTU of heating when compared to indirect-fired and electric strip heaters. Below are some of the benefits to the using direct fired units:

- Direct fired heating is a more thermally efficient process than indirect fired units. Typically direct fired heaters are over 90% efficient, while indirect heaters are around 70% efficient.
- Direct fired heating is environmentally clean and equipment is listed to the ANSI Z83.4a-2001 and CSA 3.7a-2001 safety standard. These safety standards allow for a maximum of CO and NO₂ generated by the heater.
- Direct fired heaters can operate on either natural or LP gas and achieve high temperature rises.

Depending on where area of the country, different equipment is used for cooling the makeup air to 85 degrees or chosen setpoint. For areas of high humidity, direct expansion cooling (DX cooling) is recommended, as well as in areas where the summer design temperature is above 95 degrees F. DX cooling modules will also need to include a condenser and thermal expansion valve. In areas with a hot and dry climate, an evaporative cooler is the recommended equipment for cooling.

Balance Point

The balance point for a space should be considered and understood when having tempered makeup air and a rooftop HVAC unit supplying transfer air. When the outdoor temperature is below the balance point, supplemental heat must be added to make up the difference. Also, for each zone and its respective thermostat, the outdoor temperature which that zone is in cooling mode and below the zone which is in heating mode. Commercial kitchens have a relatively low balance point, typically between 55 and 60 degrees. Heating and cooling in a commercial kitchen can occur simultaneously when the package unit and dedicated makeup air controls are not coordinated.
Balance point is also dependent on the equipment selected and the density of the appliances. The temperature of the kitchen is sensed by the package unit thermostat. The dedicated makeup air unit is in heat mode due to low outdoor temperatures relative to the balance point. In return, the package unit could be cooling because it senses the hotter temperatures in the kitchen. Simultaneous cooling and heating can be avoided with an interlock relay kit; the relay kit locks out the heating of the makeup air if the kitchen package unit is cooling.

Modern Kitchens

The concept of sustainability is quite profound and is the driver for a design for a fully integrated system. Restaurants consume more energy than all other commercial spaces. If you look more closely at the energy use in the restaurants, a significant portion is directly attributed to the HVAC system. Operators of modern commercial kitchens expect the following: efficient buildings with improved operating costs, improved occupant and public health, efficient equipment that saves energy, equipment that supports the food and cuisine for the application, equipment that is easy to use and self adjusting based on requirements and reduced environmental impact.

In order to achieve the benefits of a sustainable system, the following design principles should be considered:

- Aerodynamic hoods, tested and listed to UL Standard 710, are the centerpiece of the ventilation system. Lower CFM rates can be achieved with listed hoods versus hoods that have to meet code specified CFM values; consider manufacturers who have tested their hoods to ASTM 1704 for real-world capture and containment performance.
- Determine the appropriate exhaust CFM by using the following methods: grouping equipment by duty cycle, use of end panels, ensure correct placement of equipment particularly charbroilers and using correct overhang for both the side and front of the hoods.
- Use of advanced grease filters to remove more grease at the hood and use a pollution control unit if necessary for final grease, smoke and odor control is the concern.
- The use of direct drive fans, where applicable, is more energy efficient and can offer savings on operating costs.
- To maximize energy savings during low cooking or no cooking periods, a variable speed system can be used. Exhaust and supply airflow is based on the cooking load and not operating at full capacity all hours the application is in operation.
- Use of dedicated makeup, in addition to fresh air in the form of transfer air, for applications. Tempering dedicated makeup air to temperatures respectively lower and higher than HVAC thermostat settings helps to save on energy and operating costs.
- Direct fired heating is the most thermally efficient choice because the combustion process and heat remain in the airstream. Indirect fired gas heating employs a heat exchanger where the combustion process is not directly in the airstream.

Optimize CKV applications, manage energy with ventilation systems and focus on a fully integrated system.
Ventilation Definitions

**Advection:** The process of transport of an atmospheric property solely by the mass motion of the atmosphere.

**Air Handler:** Air moving device. Typically utilized in conjunction with supply air ducts, and can contain heating or cooling elements.

**Ambient:** Surroundings; especially, of or pertaining to the environment about a body but undisturbed or unaffected by it, as in ambient air or ambient temperature.

**Balance Point:** The outdoor temperature at which the building heat load (created by equipment, lights, solar load, people, etc.) satisfies the building heating thermostat. When the outdoor temperature is below the balance point, supplemental heat must be added to the building to maintain desired space temperatures. When the outdoor temperature is above the balance point, heat introduced into the space, through makeup air and other sources, competes directly with the building air conditioning. The building thermostat can call for air conditioning down to the balance point.

**Belt:** A device, typically made of rubber, used to transfer energy from a power source to a driven source. Usually used in conjunction with pulleys.

**BHP (Brake Horsepower):** The actual power developed by a motor as measured by the force applied to a shaft or flywheel.

**Capture Area:** The area on the bottom plane of an exhaust hood free for air to enter.

**Capture & Containment:** The complete evacuation of 100% of smoke and heat from a cooking appliance.

**CFM (Cubic Feet per Minute):** A unit of volume flow rate, equal to a uniform flow of 1 cubic foot in 1 minute.

**Cogged Belt:** A device, typically made of a grooved rubber material, used to transfer energy from a power source to a driven source. Usually used in conjunction with pulleys.

**Conduction:** Transmission of energy by a medium which does not involve movement of the medium itself.

**Contactor:** An electrical device used to make or break the connection of wires. Elements are usually made of metal and are energized by an electric coil.

**Convection:** Diffusion in which the fluid as a whole is moving in the direction of diffusion. Transmission of energy or mass by a medium involving movement of the medium itself.

**Effluent:** Liquid which flows outward or away from a containing space.

**EDB (Entering Dry Bulb):** The dry bulb temperature of air entering an air handler.

**EWB (Entering Wet Bulb):** The wet bulb temperature of air entering an air handler.

**Evacuate:** To remove something, especially gases and vapors, from an enclosure. Also known as exhaust.

**FPM (Foot per Minute):** A unit of speed equal to the speed of a body which travels uniformly 1 foot in 1 minute.

**Heat:** Energy in transit due to a temperature difference between the source from which the energy is coming and a sink toward which the energy is going; other types of energy in transit are called work.
Ventilation Definitions

**Heat Capacity:** The quantity of heat required to raise a system 1 degree in temperature in a specified way, usually at constant pressure or constant volume.

**Heat Resistant Belt:** A device, typically made of a high temperature rated rubber material that resists excessive heat, used to transfer energy from a power source to a driven source. Usually used in conjunction with pulleys.

**Hood (Type I):** Exhaust hood used for collection and removal of grease and smoke. It includes listed grease filters, baffles, or extractors for removal of grease, and fire suppression equipment. Typically used to cover equipment such as ranges, fryers, griddles, broilers, ovens, steam kettles, or other equipment producing smoke or grease laden air.

**Hood (Type II):** Exhaust hood used for collection and removal of steam, vapor, heat, and odors where grease is not present. It may or may not have grease filters or baffles and typically does not have a fire suppression system. Typically used to cover equipment such as dishwashers, steam tables, ovens, steamers, and kettles if they do not produce smoke or grease laden vapor and if the authority having jurisdiction allows it.

**HP (Horsepower):** The unit of power equal to 550 foot-pounds per second, and approximately 745.7 watts.

**Inch of Water:** The pressure exerted by a 1-inch-high column of water when the acceleration of gravity has the standard value of 32.17 ft/sec2.

**Indigenous:** Existing and having originated naturally in a particular region or environment.

**Latent Heat:** The amount of heat absorbed or evolved by a unit mass of a substance during a change of state (such as fusion, sublimation, or vaporization) at constant temperature and pressure.

**LDB (Leaving Dry Bulb):** The dry bulb temperature of air exiting an air handler.

**LWB (Leaving Wet Bulb):** The wet bulb temperature of air exiting an air handler.

**Oil Resistant Belt:** A device, typically made of a rubber material that resists excessive slippage due to the presence of oil, used to transfer energy from a power source to a driven source. Usually used in conjunction with pulleys.

**Overload:** An electrical device, used in conjunction with a contractor that provides electrical protection to a motor. Prevents the motor from using more power than for which it is designed.

**Radiant Energy:** The emission and propagation of waves transmitting energy through space or through some medium, for example a surface that emits heat to the surroundings by radiation rather than by conduction or convection.

**RPM (Revolution Per Minute):** A unit of angular velocity equal to the uniform angular velocity of a body which rotates through an angle of 360°, so that every point in the body returns to its original position, in 1 minute.

**Sensible Heat:** The sum of the internal energy of a substance plus the product of the system’s volume multiplied by the pressure exerted on the system by its surroundings.
Sone: A unit of loudness, equal to the loudness of a simple 1000-hertz tone with a sound pressure level 40 decibels above 0.0002 microbar; a sound that is judged by listeners to be n times as loud as this tone has a loudness of n sones.

Starter: An electrical device typically used to energize an electric motor. Consists of a contactor and motor overload protection.

Static Pressure: The normal (perpendicular) component of stress, the force per unit area, exerted across a surface moving with a fluid, especially across a surface which lies in the direction of fluid flow.

System Curve: A parabolic fan curve traveling through the coordinates (0, 0) and (CFM, SP). Defined by a system constant (k) and the formula: SP = k * CFM²

Therm: A unit of heat energy, equal to 100,000 BTUs.

References & Resources

ASHRAE

HVAC Applications Handbook 2007, Chapter 31: Kitchen Ventilation
ASHRAE Standard 154 - Kitchen Ventilation

PG&E Food Service Technology Center: www.fishnick.com

CKV Design Guides, Improving Commercial Kitchen Ventilation System Performance, by FSTC and Southern California Edison:
http://www.fishnick.com/equipment/ckv/designguides/

Design Guide 1 - Selecting and Sizing Exhaust Hoods
Design Guide 2 - Optimizing Makeup Air

http://www.energy.ca.gov/reports/2003-04-10_500-03-007F.PDF

Kitchen Hood Performance Reports
http://www.fishnick.com/publications/appliancereports/hoods/
CKV Test Facility: www.archenergy.com/services/food/ckvfacility

Sample Schlieren videos can be seen here

Outdoor Airload Calculator: http://www.archenergy.com/oac/

ASTM F 1704-05:


ASTM F2519-05:


http://www.fishnick.com/equipment/ckv/greasegroup

UL Standard 710:


UL Standard 1046:


NPFA 96, 2008 Edition:


International Mechanical Code, 2006 Edition:


Shortridge Velgrid: http://www.shortridge.com/velgrid.htm

Smoke Puffers: http://www.evhill.com

ThermoTek

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