

# Kitchen Ventilation Systems

## Application & Design Guide



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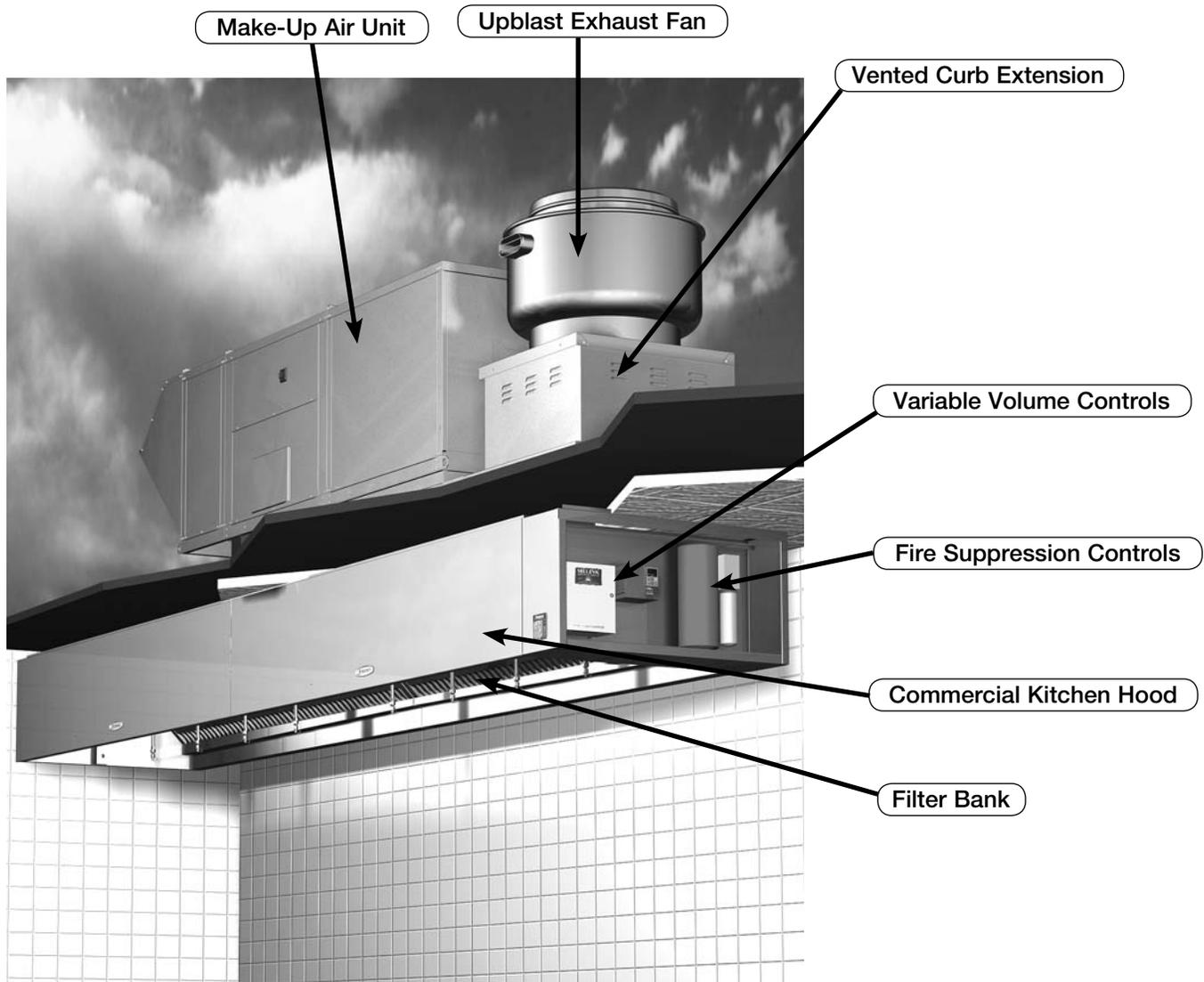
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## INTRODUCTION

A kitchen hood is not just a box. Every commercial kitchen requires ventilation, and in the past, the importance of a proper ventilating system has been overlooked. Today, designers, installers, and operators are recognizing the value in well-designed commercial kitchen ventilation (CKV) systems. Emphasizing “system” because it is not just a box, it is an engineered system of exhaust hoods, ventilators, make-up air ventilators, grease removal apparatuses and more. Taking time to properly design a CKV system will increase the health and safety of the kitchen operators and increase the efficiency and energy savings for the owner.

This guide discusses many of the factors that must be analyzed when designing an efficient kitchen ventilation system. It offers a background in the basic theories of CKV design, product types with their application, necessary calculations with examples, troubleshooting, and more. This guide will assist in the development of a well-balanced and functional system.

Although this guide will aid in a successful design, it is important to keep in mind the variation in standards and codes which have been adopted. Each county may have slightly different requirements for the designer to meet. The local authority having jurisdiction (AHJ) should be consulted to ensure the final design meets the requirements set forth. See the design and code reference section on *pages 52 and 53* of the guide for a listing of common codes. If you would like to discuss any of the topics to further detail please contact Greenheck.



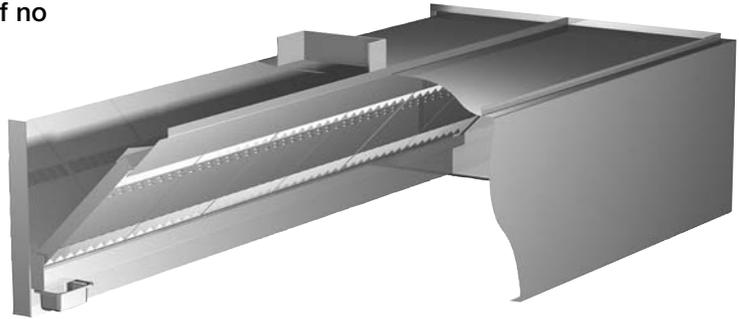
## TYPES OF COMMERCIAL KITCHEN VENTILATION HOODS

### Two Types of Hoods

Two different types of kitchen hoods are used in the commercial kitchen. These hoods are classified as a TYPE I or TYPE II ventilation hood. TYPE I hoods are used over cooking equipment producing heat and grease laden effluent. These hoods require a fully-welded ducting system. TYPE II hoods are used over non-grease producing cooking equipment exhausting heat and condensation. Various categories of TYPE I and TYPE II ventilation hoods exist for different applications and personal preferences.

### TYPE I Canopy Hood

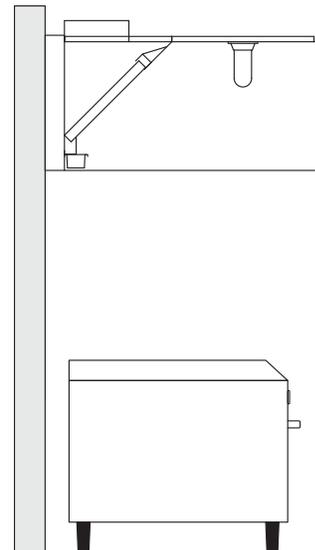
The canopy hood uses the updraft concept to capture and contain the contaminated air generated by the cooking process. Heated air is less dense than the surrounding air causing it to become buoyant. If no cross drafts are present, the contaminated air will rise up into the hood where it is captured and contained until it can be exhausted through the grease filters to the outside. Wall, single island, and double island represent the three configurations of canopy hoods. Although each configuration is mounted from the ceiling directly above the cooking equipment, each is used for a different application.



### Wall Canopy Hoods

The wall canopy hood is used when the cooking equipment is placed against a wall. Hoods that are used against a wall have a tendency to capture and contain the effluent using less airflow than in an island type application. Make-up air from the kitchen enters the area below the hood replacing the air being exhausted. The wall located on the backside of the hood will cause the make-up air to enter at the front and sides of the hood creating a front-to-rear airflow pattern. The plume will rise from the appliance and will be attracted to any surface parallel and near the cooking equipment, in this case, the wall. This phenomena is known as the *Coanda Effect*. The plume is then directed into the hood, enhancing capture and containment. Cross drafts still threaten spillage, but to a lesser degree than island style hoods. National Fire Protection Association (NFPA 96) and International Mechanical Code (IMC) should always be consulted when using a wall canopy hood. Wall canopy hoods may or may not be mounted directly against the wall depending on the type of wall. NFPA 96 defines three types of walls; *non-combustible, limited combustible, and combustible*. Most commercial kitchen applications have limited combustible walls which require a 3-inch air space between the back of the hood and the wall. Most hood manufacturers provide a 3-inch space with the hood enabling it to be placed against the wall.

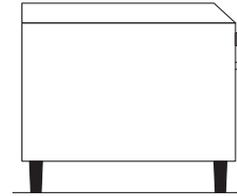
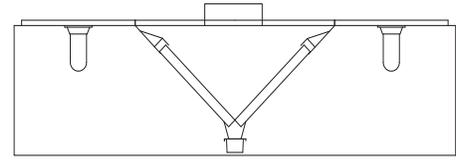
IMC requires a minimum hood overhang of 6 inches from the cooking equipment on each end of the hood, and it is recommended that there is a minimum overhang of 6-12 inches beyond the widest cooking appliance for the front. Greater overhangs will increase capture and containment.



Wall Canopy

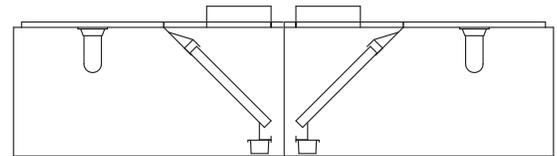
### Single Island Hoods

A single island hood is used over one row of cooking equipment placed where no walls exist. Single island hoods can be seen from all directions, therefore, have four finished sides. With four exposed sides, this type of hood is more susceptible to cross drafts, spillage, and is dependent only on the thermal updraft of heat from the cooking equipment and how quickly the exhaust fan can rid the hood of contaminated air. These hoods should be sized larger and use more airflow than a wall canopy hood with the same cooking battery. The single island hood must overhang the cooking equipment by a minimum of 6 inches on all four sides of the hood. However, it is recommended that the overhang be extended to 12 inches on all sides of the hood. Extending hood overhangs increases capture volume which aids capture and containment. To eliminate the front to back airflow on a single island, a V-bank of filters improves capture and containment by directing the contaminated air to the center of the hood.



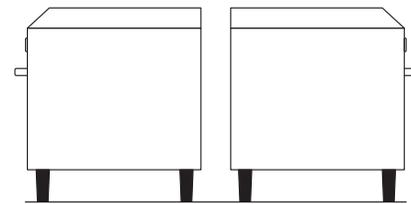
**Single Island Canopy**

A wall canopy can be installed as an island hood with a finished back enhancing its aesthetic appearance. However, it is not recommended because the front to back airflow pattern of a wall canopy will cause capture problems when being utilized as a single island canopy.



### Double Island Hoods

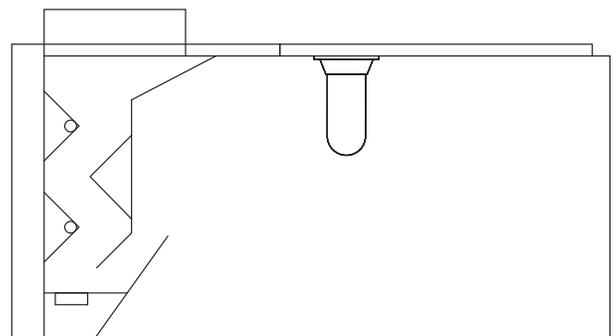
A double island hood is placed over two rows of cooking equipment placed back to back. This configuration is made up of two wall canopy hoods placed back to back, thus creating four finished sides. This category of hood performs similar to the wall canopy hood due to two thermal plumes rising against each other, but is still susceptible to cross drafts. A double island hood must overhang the equipment by a minimum of 6 inches on all four sides of the hood but would benefit from additional overhang.



**Double Island Canopy**

### Water Wash Hoods

Available in a wall canopy or double island configuration, water wash hoods are a cartridge type canopy hood, meaning the grease filtration device is built into the exhaust plenum. Water wash hoods utilize water spray nozzles in the exhaust plenum to clean the grease collected by the filtration system (see **Figure 35** on **page 24**) after a certain period of operation. These wash cycles can be programmed to run for a specified length of time and can be set to run automatically at the end of the day. Continuous water mist can be used to extinguish embers on a solid fuel cooking operation. The hood is controlled through a remote mounted control box including an adjustable flow detergent pump, a wash cycle timer in a solid state programmable controller, and a detergent reservoir. These hoods have a high up-front cost and have a higher operating cost than other types of hoods.



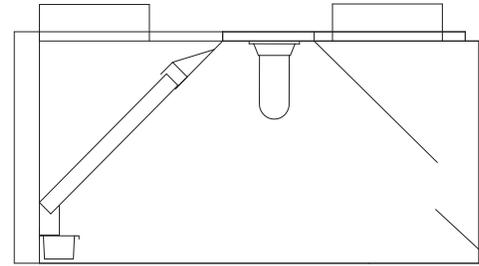
**Water Wash Hood - End View**

**Short Circuit Hoods** \*Warning: NOT RECOMMENDED\*

Short circuit canopy hoods were once thought of as an energy saving device. The theory, by introducing untempered make-up air inside the hood reservoir it would reduce the amount of tempered air being exhausted from the kitchen, minimizing heating and cooling loads. This was done to get around old codes which set a minimum exhaust rate that was much higher than needed to achieve capture and containment. Make-up air was short-circuited by as much as 80-90% of the exhaust rate resulting in spillage of the contaminated air.

\*Schlieren Imaging (see Schlieren Imaging on page 8) confirms that only 15% of the minimum capture and containment airflow can be brought through the hood without causing spillage.

Short circuit hoods are ineffective because they do not discharge the make-up air in the correct location. Think of the cooking equipment as a generator of contaminated air. The purpose of make-up air is to replace the air that is being generated at the cooking surface. Both the hood and exhaust system are designed to capture and contain the airflow generated by the cooking equipment. Short circuit hoods dump make-up air into the capture and containment area, thus overfilling the hood and releasing a mix of make-up and contaminated air into the room causing greasy surfaces and increased heat loads. For these reasons, short circuit hoods are not recommended.

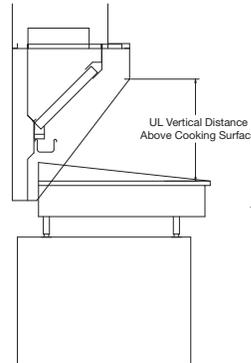


**Short-Circuit Hood - End View**

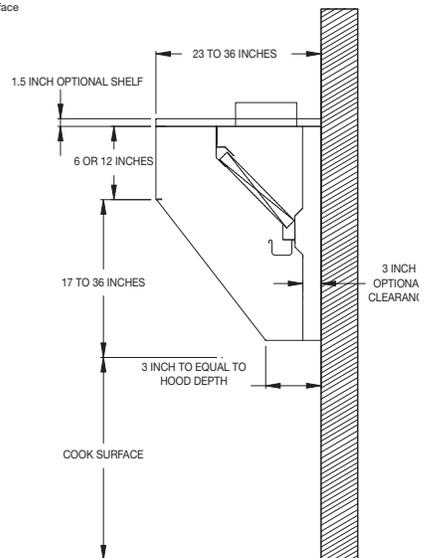
\*Data provided by Architectural Energy Corporation, and Fisher-Nickel, Inc.

**Proximity Hoods (Backshelf)**

Proximity hoods are TYPE I hoods that are shorter in height and depth than a typical canopy hood. The name "Proximity" or "Backshelf" refers to the close location of the hood with respect to the cooking equipment. Actual distance from the cooking equipment varies between manufacturers due to their UL listing; typically mounted at 10-36 inches above the appliance. Cooking equipment may extend past the face of the hood creating underhang, therefore cooking equipment such as large skillets and ovens may not be used. See the manufacturer's UL listing. Even with underhang, these hoods are still able to capture the contaminated air due to their close proximity. Large surges of contaminated air may escape from the hood, therefore proximity hoods are best suited for light and medium duty cooking applications such as griddles. The major benefit is reduced airflow required to obtain capture and containment compared to a canopy hood with the same cooking lineup. The savings are realized through reduced heating and cooling loads.



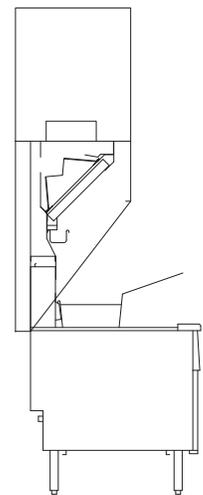
**Proximity Hood Hanging Height**



**Flue Bypass Proximity Hoods**

Proximity hoods are mounted closer to the cooking equipment subjecting the grease filters to abnormal heating loads from appliance flues. When gas-fired cooking equipment with flues are used, flue bypass proximity hoods offer another advantage. Instead of allowing the heat from the flues to pass-thru the face of the filters, the flues are ducted to discharge the hot air directly to the back of the exhaust plenum, bypassing the grease filters. Normally, this heat would hit the filters, causing them to radiate heat onto the cooking personnel. Radiant heat loads are greatly reduced with the absence of the hot flue gases and grease is less likely to bake to the filter face which enables the filters to be cleaned more easily. Airflow requirements are lowered because the hood does not have to capture the excess heat, only the heat and grease from the cooking surface must be contained.

The flues on the equipment must be sized correctly to the bypass chamber to ensure grease is not pulled into the flue. Dampers control the amount of hot flue gases that exit through the exhaust plenum. This airflow is critical to cooking equipment performance, therefore, the dampers must be set according to the cooking equipment beneath the particular hood. Greenheck should be consulted prior to ordering flue bypass proximity hoods to ensure a proper hood-to-equipment fit. Flue bypass is recommended for fryers and griddles.



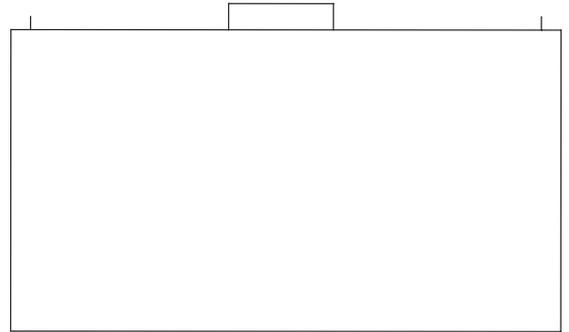
**Flue Bypass**

## TYPE II Hoods

TYPE II hoods are commonly referred to as oven or condensate hoods. In essence, these are stripped down exhaust only canopy hoods. The purpose of the TYPE II hood is to remove heat, moisture, and odor-ridden air from non-grease producing appliances. The hoods do not contain grease filter banks but rather a duct collar to exhaust the contaminated air. A TYPE II hood duct does not need to be fully-welded, instead it can be a standard galvanized duct because there is no grease loading. Flex-duct is not allowed for TYPE II hoods.

### Oven Hood

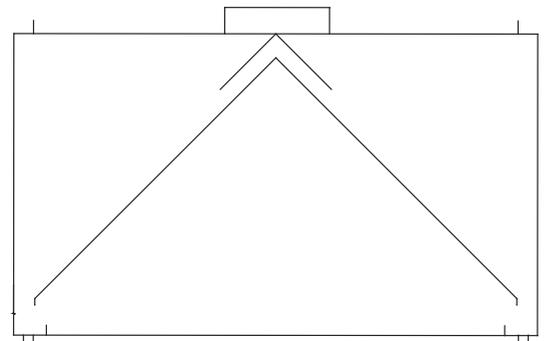
The oven hood is an exhaust only canopy hood with an exhaust duct collar for the removal of heat and vapor. These hoods are the simplest of all hoods and are usually placed over ovens or small appliances only producing heat and odor. For complete capture and containment, overhangs should be measured with the oven door open.



*Oven Hood - End View*

### Condensate Hood

The condensate hood is an exhaust only canopy hood with U-shaped gutters to capture and direct condensate to a drain. It also has an exhaust duct collar for heat, moisture, and odor-ridden air to exit. Many manufacturers have options for condensate baffles in the hood to help condense the moisture laden air, one or two baffle configurations are typical, depending on the moisture content of the contaminated airstream. Condensate hoods are usually found mounted over dishwashers. For complete capture and containment of large plumes of heat and steam, 18-36 inches of overhang are recommended.



*Condensate Hood - End View*

## HOOD CERTIFICATION

Most jurisdictions require TYPE I exhaust hoods to bear the Underwriters Laboratory (UL) label. UL 710 is the test criteria in which UL listed exhaust hoods are tested. Tests include temperature, cooking, flare-up, fan failure, fire, and burnout testing. In order to complete the analysis, these hoods have to be operating at a minimum exhaust airflow rate to obtain capture and containment determined under laboratory conditions.

This is where the misconception of the UL listing becomes apparent. The minimum airflow that UL uses to test hoods is obtained by first adjusting airflow to the manufacturer's recommendation, then fine tuning it to ensure complete capture and containment of the effluent generated by cooking hamburgers. This airflow is then assumed to be the minimum capture and containment value for the UL testing of a particular hood in a controlled laboratory environment. This airflow is then considered safe for the flare-up and burn tests that follow. The temperature of the hood shall remain in a range that does not compromise the structural integrity of the hood at the listed airflow. The airflow does not guarantee capture and containment.

UL minimum airflow ratings in the hoods exist only as a safety rating. It does not guarantee capture and containment and therefore, should rarely be used as design criteria. It is important to realize that UL established airflow rates are determined and utilized under laboratory conditions. More exhaust and/or lesser supply rates may be required in real environments. There are situations where extremely light cooking applications exist where the exhaust rate may be at or near the UL listings, but only in these light, low volume, and light cooking battery situations.

## DETERMINING EXHAUST RATE

2

Having the proper exhaust rate is one of the most crucial calculations in a kitchen ventilation system. Not only will it allow the system to capture as it is designed, but can save money each year through energy savings as well as initial start-up costs. Throughout the industry there are two common methods to determine exhaust airflow, which will be discussed in this section. It is important to establish how contaminated air is generated and how it behaves.

### Cold vs. Hot

Concepts used to determine airflow rates in the past were developed through testing on non-operating (cold) equipment. As shown in *Figure 1*, smoke bombs were commonly placed at the front edge of the cooking equipment. The exhaust rate would then be increased until all the smoke was captured, thus determining a minimum capture velocity. Additionally, it increases the amount of make-up air needed to balance the room which decreased overall system efficiency.

Fortunately, the majority of tests are required to be completed over operating (hot) equipment. Greenheck's approach utilizes the thermal updraft produced through the transfer of heat from the surface to air. The updrafts help to transfer the contaminated air (heat, grease vapor, smoke, steam, and gas combustion) to the kitchen hood as seen in *Figure 2*. Implementing this approach can significantly reduce the airflow required to obtain capture and containment. By realizing that hot air rises, a more efficient and less costly system can be achieved.

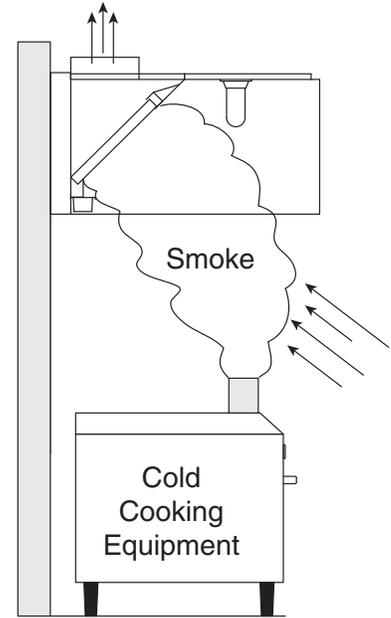


Figure 1

### The Cooking Equipment

When using the "Greenheck Method" the cooking equipment can be thought of as a generator of contaminated air. The quantity of such air generated by each appliance is ultimately dependent upon the temperature and size of the physical cooking surface. Gas flues on gas equipment are also considered generators. Heat from appliance surfaces cause a change in the density of surrounding air creating a thermal updraft. While hot air rises, it is replaced by air in the immediate vicinity as shown in *Figure 2*. The replacement air assists in establishing minimal capture velocity at the cooking surface and contains the contaminated air generated by the cooking equipment. There are many factors that can alter the direction and velocity of this air which are discussed in the design consideration (*pages 42-45*) section of this guide.

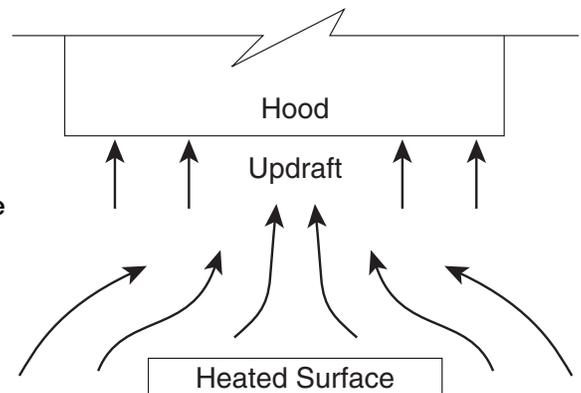


Figure 2

### Schlieren Imaging

Schlieren Imaging is a powerful tool now being used for research in the commercial kitchen ventilation industry. Schlieren Imaging enables people to see the heat given off by appliances and watch its flow pattern in the hood. It is an excellent way to test for capture and containment due to the ability to zoom in closely along edges of the hood and observe any escaping effluent. Schlieren images are made visible by taking advantage of the different air densities yielding a high contrast optical image.

*Figure 3A & 3B* are an example of the heat load seen in a common kitchen application. Both hoods use the same exhaust rate, however, the hood in *Figure 3A* is spilling heat into the space.

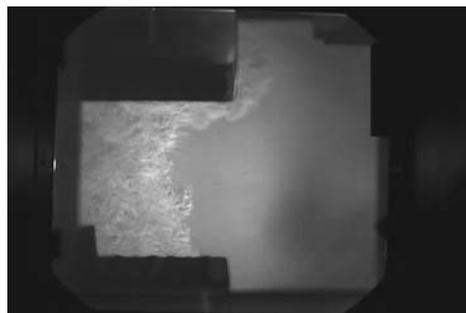


Figure 3A

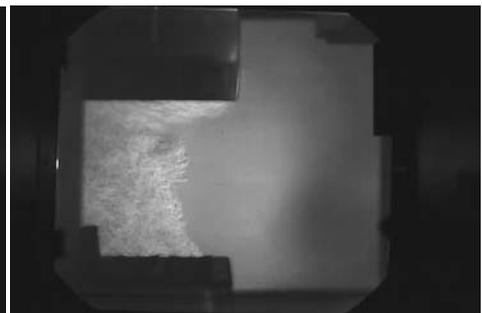


Figure 3B

Previously undetectable to the eye, it is apparent that the heat gain to the space can be quite significant. **Figure 3B** demonstrates Greenheck’s PEL lip technology, which is a 1.5 inch return lip along the bottom edge of the hood. This lip directs airflow back into the hood allowing cfm requirements to be reduced without spillage. A properly designed system should look like the image on the right.

**Utilizing Exhaust Flow Definitions**

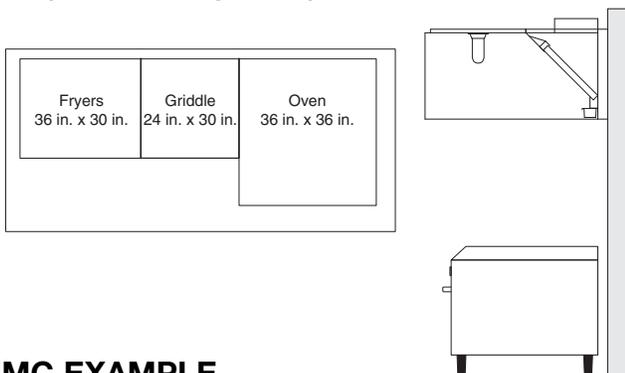
Using any of the concepts, every piece of cooking equipment can be placed into a category which assigns a value to the actual updraft velocity or airflow volume per foot. These values can be used for CFM hood calculations. **Figure 4** categorizes common kitchen appliances and provides the updraft velocity factors and International Mechanical Codes airflow volume per linear foot necessary to complete the calculations.

Recognize that the extra-heavy category contains nearly all solid fuel cooking appliances. Solid fuel is the most volatile and uncontrollable fuel source in a commercial cooking operation. There is no on/off switch like most appliances, but rather one can add fuel or let the fuel burn out. Thus, the load is extremely variable and may exceed projected exhaust requirements. In these situations it is important to have additional airflow up front and size exhaust and supply fans so their airflow can be increased if needed. Lastly, look into standards and code requirements such as: Local Codes, State Codes, NFPA 96, IMC, or any other required agencies in the area to ensure proper installation.

	LIGHT	MEDIUM	HEAVY	EXTRA-HEAVY
Equipment (Greenheck’s Appliance Classification)	Gas & Electric Ovens Gas & Electric Steamers Gas & Electric Ranges Food Warmers Pasta Cookers Pizza Ovens Non-Cooking Appliance Smoker Rotisserie	Combi-Ovens Gas & Electric Fryers Griddles Tilting Skillets Tilting Braising Pans Grill Hibachi Grill Salamander	Upright Broiler Electric Char-Broiler	Gas Char-Broiler Mesquite Infrared Broiler Lava Rock Char-Broiler Wok Chain Broiler
Greenheck Method (updraft velocity in feet per minute)	50	85	150	185
International Mechanical Code 2003 Edition (cfm per linear foot)	200	300	400	550

Figure 4

A typical cooking battery has been created and will be used to illustrate the IMC code method, Greenheck Method, Free Foot Consideration, and Greenheck’s Airflow Volume per linear foot method. **Figure 5** illustrates the typical cooking battery.



**ASSUMPTIONS**

- 3 inch spacing behind hood
- Typical 6 inch overhang required on sides and front
- Hood Dimensions: 9 ft. 0 in. long x 4 ft. 0 in. wide
- Greenheck Method uses actual containment area of 45 in. because of 3 in. integral air space

Figure 5

**IMC EXAMPLE**

IMC requires that when calculating the exhaust rate for a combination of appliances, the highest exhaust rate be applied over the entire length of the hood. Therefore, in the case of the hood above, IMC requires 300 cfm/ft. for the 9 feet of hood yielding a total of 2700 cfm. Furthermore, it is recommended by IMC and NFPA that any hood over a solid fuel cooking battery shall have a separate hood, duct, and exhaust system.

## Greenheck Method

### 1. The first step is to determine the appliance area (A)

2

$$\text{Appliance Area} = \left( \frac{(\text{Length (inches)} * \text{Depth (inches)})}{144 \text{ inches}^2} \right)$$

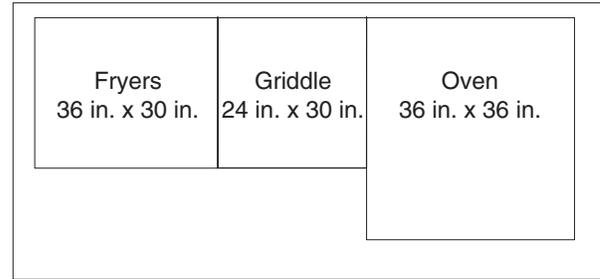
OR

$$\text{Appliance Area} = \text{Length (feet)} * \text{Depth (feet)}$$

$$\text{Fryer} \quad A = \left( \frac{(36 \text{ inches} * 30 \text{ inches})}{144 \text{ inches}^2} \right) = 7.5 \text{ feet}^2$$

$$\text{Griddle} \quad A = \left( \frac{(24 \text{ inches} * 30 \text{ inches})}{144 \text{ inches}^2} \right) = 5.0 \text{ feet}^2$$

$$\text{Oven} \quad A = \left( \frac{(36 \text{ inches} * 36 \text{ inches})}{144 \text{ inches}^2} \right) = 9.0 \text{ feet}^2$$



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$$\text{Total Area} = 21.5 \text{ feet}^2$$

### 2. The second step is to determine the quantity of contaminated air

$$Q_C = \text{Area (feet}^2) * \text{Thermal Updraft Velocity (feet per minute)}$$

$$\text{Fryer} \quad Q_C = 7.5 \text{ feet}^2 * 85 \text{ fpm} = 637 \text{ cfm}$$

$$\text{Griddle} \quad Q_C = 5.0 \text{ feet}^2 * 85 \text{ fpm} = 425 \text{ cfm}$$

$$\text{Oven} \quad Q_C = 9.0 \text{ feet}^2 * 50 \text{ fpm} = 450 \text{ cfm}$$

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$$\text{Total Airflow} = 1513 \text{ cfm}$$

$Q_C$  - Quantity of contaminated air generated by the cooking equipment. Using **Figure 4**, identify the appropriate updraft velocity and multiply it by the area of the appliance.

### 3. The third step is to determine the quantity of air to contain surges including the free foot area consideration

$$Q_F = (\text{Total Area of Hood} - \text{Total Area of Appliances}) * 50 \text{ fpm}$$

$$\text{Hood Area} = \left( \frac{(\text{Length (inches)} * \text{Width (inches)})}{144 \text{ inches}^2} \right)$$

OR

$$\text{Hood Area} = \text{Length (feet)} * \text{Width (feet)}$$

$$Q_F = \left[ \frac{(108 \text{ inches} * 45 \text{ inches})}{144 \text{ inches}^2} - 21.5 \text{ feet}^2 \right] * 50 \text{ fpm} = 612 \text{ cfm}$$

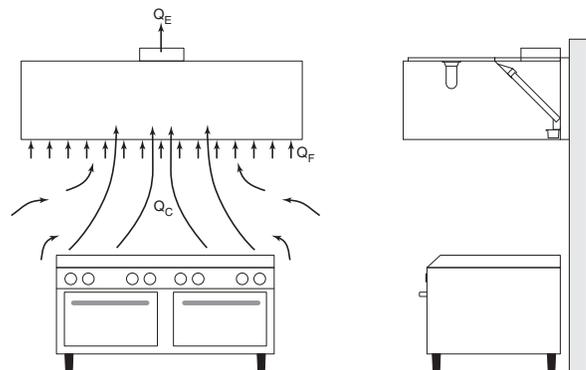
$Q_F$  - Quantity of air required to contain surges and drafts. Use the minimum updraft velocity of 50 fpm and multiply it by the difference in area between the hood containment area and the appliance area.

### 4. The fourth step is to determine the total airflow volume

$$Q_E = Q_C + Q_F$$

$$Q_E = 1513 \text{ cfm} + 612 \text{ cfm} = 2125 \text{ cfm}$$

$$Q_{E \text{ FINAL}} = 2125 \text{ cfm}$$



### Greenheck airflow volume per linear foot (cfm/linear foot) method

The commercial kitchen ventilation industry uses several different ways to calculate the exhaust airflow required to obtain capture and containment. A vast majority of companies, standards, and codes use airflow in cfm/lineal foot. To help do a comparison, Greenheck suggests the following cfm/lineal foot values shown in **Figure 6** below. The example calculation below uses the typical cooking battery from the Greenheck Method example on the previous page. Like the Greenheck Method, the linear foot method is appliance specific. Use the appropriate airflow volume rate across the length of each appliance. Use the light duty airflow for end overhangs and the sum of the individual rates is the total airflow. Lastly, note that hood factors should be applied after obtaining an exhaust value using cfm/lineal foot.

HOOD TYPE	LIGHT	MEDIUM	HEAVY	EXTRA - HEAVY
Wall Canopy	200	250	350	450
Backshelf	150	200	300	N/A

Note: 1. Double Island hoods are considered two wall canopy hoods  
 2. Single Island hoods need to be multiplied by the hood factor after using the wall mounted canopy value

Figure 6

### EXAMPLE CALCULATION

#### Limits and Assumptions (for cfm per lineal foot calculations)

- Used for hoods 54 in. or less in width
- Cannot be used for pizza ovens
- Cannot be used for cook chill
- 6 ft. 6 in. hanging height
- Vertical updrafts
- Proper room ventilation
- Proper overhangs

$$\text{Airflow (cfm)} = \text{Length (feet)} * \text{Airflow Volume} \left( \frac{\text{cfm}}{\text{linear foot}} \right)$$

Left Overhang      Airflow = 0.5 feet \* 200  $\left( \frac{\text{cfm}}{\text{linear foot}} \right)$  = 100 cfm

Fryer                      Airflow = 3 feet \* 250  $\left( \frac{\text{cfm}}{\text{linear foot}} \right)$  = 750 cfm

Griddle                    Airflow = 2 feet \* 250  $\left( \frac{\text{cfm}}{\text{linear foot}} \right)$  = 500 cfm

Oven                        Airflow = 3 feet \* 200  $\left( \frac{\text{cfm}}{\text{linear foot}} \right)$  = 600 cfm

Right Overhang      Airflow = 0.5 feet \* 200  $\left( \frac{\text{cfm}}{\text{linear foot}} \right)$  = 100 cfm

Total Airflow = 2050 cfm

### FREE FOOT AREA CONSIDERATION

The Greenheck Method assumes in most cases a 6 inch overhang on the front and ends of the hood under the typical cooking battery and open end conditions. Unfortunately, the method penalizes for additional square feet of empty hood. Additional overhang can help increase capture by utilizing a larger “holding tank” for the effluent before it’s exhausted, helping with large momentary surge. However, there are limits to how much overhang is effective. Therefore, Greenheck will allow a 1 foot extension beyond the built-in 6 inches of overhang creating a free foot area without increasing the required airflow. This can be used for both Greenheck Method and CFM per lineal foot. See **Figure 7** below.

### CORRECTING FOR FREE FOOT AREA

Extra Overhang = 0.25 feet  
 Length of Hood = 9.0 feet  
 Updraft Velocity = 50 feet per minute

$$\text{Free Area} = 0.25 \text{ feet} * 9.0 \text{ feet} = 2.25 \text{ feet}^2$$

$$\text{Excess Airflow (cfm)} = 2.25 \text{ feet}^2 * 50 \text{ fpm} = 112$$

$$\text{Corrected Exhaust Airflow (cfm)} = (2125 - 112)\text{cfm} = 2013 \text{ cfm}$$

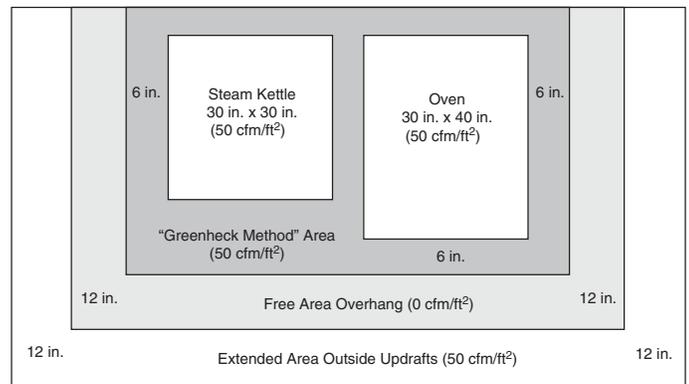


Figure 7

**2**

The table to the right illustrates the difference in exhaust CFM between the Greenheck Method and the IMC method. At a cost of approximately \$2.00/cfm each year, the Greenheck method offers significant savings. The Greenheck Method considers all the cooking equipment as a separate item to determine the best exhaust rate. It not only is the most accurate, but is the lowest airflow volume of the three methods. The Greenheck Method is appliance specific to determine the proper amount of exhaust required so that the system is not under-exhausting or over-exhausting, costing more money in either operation, cleaning, or upgrading costs.

Method	Exhaust CFM
International Mechanical Code	2700
Greenheck Method	2013
Greenheck cfm/lineal ft.	2050

## HOOD FACTORS

There are several design factors that can either hinder or enhance the performance of the kitchen ventilation system. For that reason, **Figure 8** has customized the exhaust airflow to the application. Notice there are some scenarios that will increase the airflow significantly and others that do not change or will decrease the airflow. Use this chart after you have already determined the airflow using the Greenheck Method, or Greenheck airflow volume per lineal foot. Simply multiply the cfm by the multiplication factors for each item that applies.

Condition	Multiplying Factor
Wall Canopy	1.0
Wall Canopy - Finished Back	1.3
Single Island - V-Bank	1.2
Double Island	1.0
Mini Skirts - 2x2	0.92
End Skirts - Full / Wall	0.90
Exhaust Only	1.0
Supply Plenums	1.1
Char-Broiler at end of Canopy or under a Single Island hood	1.2
Hanging Height 6 ft. 6 in.	1.0
Hanging Height 7 ft. 0 in.	1.1

*Figure 8*

## EXAMPLE HOOD FACTOR CALCULATION

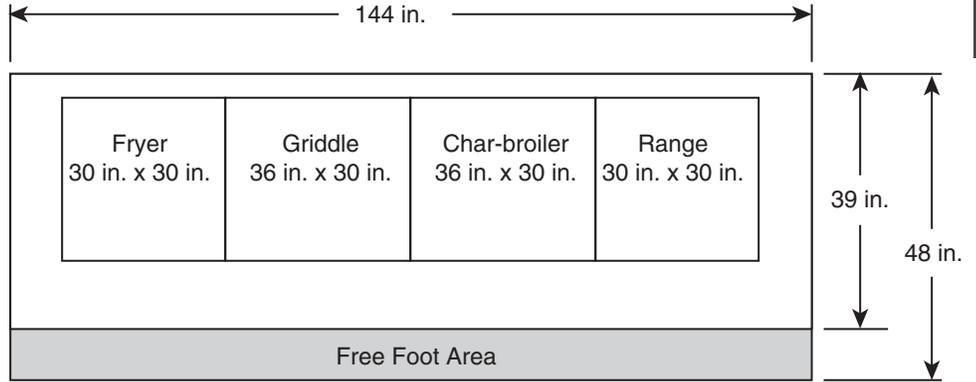
Given a determined exhaust rate of 3000 cfm, it has now been determined that the application will have the following conditions:

1. Char-Broiler at the end of the canopy (1.2)
2. Full End Skirts (0.9)

Therefore the new airflow will be:  $\text{Airflow (cfm)} = 1.2 * 0.9 * 3000 \text{ cfm} = 3240 \text{ cfm}$

**Putting it all together - complete example**

To put all of the information from this section together, the following is a full example from start to finish. Examine first the cooking battery and hood to the right and follow through the calculations illustrated below.



**1. The first step is to determine the appliance area (A)**

$$\text{Appliance Area} = \left( \frac{(\text{Length (inches)} * \text{Depth (inches)})}{144 \text{ inches}^2} \right)$$

OR

$$\text{Appliance Area} = \text{Length (feet)} * \text{Depth (feet)}$$

$$\text{Fryer} \quad A = \left( \frac{(30 \text{ inches} * 30 \text{ inches})}{144 \text{ inches}^2} \right) = 6.25 \text{ feet}^2$$

$$\text{Griddle} \quad A = \left( \frac{(36 \text{ inches} * 30 \text{ inches})}{144 \text{ inches}^2} \right) = 7.5 \text{ feet}^2$$

$$\text{Char-Broiler} \quad A = \left( \frac{(36 \text{ inches} * 30 \text{ inches})}{144 \text{ inches}^2} \right) = 7.5 \text{ feet}^2$$

$$\text{Range} \quad A = \left( \frac{(30 \text{ inches} * 30 \text{ inches})}{144 \text{ inches}^2} \right) = 6.25 \text{ feet}^2$$

---


$$\text{Total Area} = 27.5 \text{ feet}^2$$

**2. The second step is to determine the quantity of contaminated air**

$$Q_C = \text{Area (feet}^2) * \text{Thermal Updraft Velocity (feet per minute)}$$

$$\text{Fryer} \quad Q_C = 6.25 \text{ feet}^2 * 85 \text{ fpm} = 531 \text{ cfm}$$

$$\text{Griddle} \quad Q_C = 7.5 \text{ feet}^2 * 85 \text{ fpm} = 637 \text{ cfm}$$

$$\text{Char-Broiler} \quad Q_C = 7.5 \text{ feet}^2 * 185 \text{ fpm} = 1387 \text{ cfm}$$

$$\text{Range} \quad Q_C = 6.25 \text{ feet}^2 * 50 \text{ fpm} = 312 \text{ cfm}$$

---


$$\text{Total Airflow} = 2867 \text{ cfm}$$

$Q_C$  - Quantity of contaminated air generated by the cooking equipment. Using *Figure 4 on page 9*, identify the appropriate updraft velocity and multiply it by the area of the appliance.

### 3. The third step is to determine the quantity of air to contain surges including the free foot area consideration

$$Q_F = (\text{Total Area of Hood less free foot} - \text{Total Area of Appliances}) * 50 \text{ fpm}$$

$$\text{Hood Area} = \left( \frac{(\text{Length (inches)} * \text{Width (inches)})}{144 \text{ inches}^2} \right)$$

OR

$$\text{Hood Area} = \text{Length (feet)} * \text{Width (feet)}$$

$$Q_F = \left[ \frac{(144 \text{ inches} * 36 \text{ inches})}{144 \text{ inches}^2} - 27.5 \text{ feet}^2 \right] * 50 \text{ fpm} = 425 \text{ cfm}$$

$Q_F$  - Quantity of air required to contain surges and drafts. Use the minimum updraft velocity of 50 fpm and multiply it by the difference in area between the hood containment area and the appliance area.

### 4. The fourth step is to determine the total airflow volume

$$Q_E = Q_C + Q_F$$

$$Q_E = 2867 + 425 = 3292 \text{ cfm}$$

### 5. The fifth step (if applicable) is to account for hood conditions by multiplying by applicable hood factors

Mini Skirts Factor is 0.92

$$Q_{E \text{ FINAL}} = Q_E * 0.92$$

$$Q_{E \text{ FINAL}} = 3292 \text{ cfm} * 0.92 = 3028 \text{ cfm}$$

$$Q_{E \text{ FINAL}} = 3028 \text{ cfm}$$

All calculations shown in this example have been built into Greenheck's Computer Aided Product Selection (CAPS) program. These examples illustrate the logic used to properly determine exhaust rates. To obtain CAPS, request online at [www.greenheck.com](http://www.greenheck.com) or consult your local Greenheck representative.

## SUPPLY AND MAKE-UP AIR

The design of the make-up air system will have the single largest affect on hood performance. Supply air is defined as air that is brought into the space, but make-up air is dedicated to “making-up” the air being exhausted. Make-up air is brought into the kitchen at approximately an equal rate to the air being exhausted by the kitchen hood. This means that 100% of the air being exhausted must be made up. This can be accomplished through one supply type, transfer air, or multiple sources. A slight negative pressure is desirable in the kitchen with respect to the dining room to keep odors out of the dining area, but pressure levels should not exceed negative 0.02 in. wg. The key to designing a system is to introduce make-up air in the most economical way without affecting the capture and containment of the hood. Maximum hood performance can be obtained by distributing air at low velocities evenly throughout the room as seen in *Figure 9*. This section will layout which type of make-up air system is desirable for a restaurant’s particular needs.

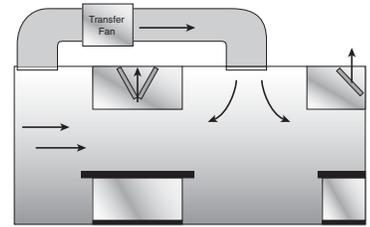


Figure 9

### Tempered or Untempered?

Air that is heated or conditioned before it is brought in from the outdoors is called tempered air. If the goal is to make the kitchen comfortable, then utilize tempered air. If the goal is low cost, then use untempered air. Both tempered and untempered can be introduced, however, selecting the proper supply types will affect comfort and economic efficiency. Once this decision has been made a type of make-up air system can be selected, but always keep two things in mind. When tempering the air, use a source that will distribute the air throughout the kitchen to increase employee comfort. When using untempered air, use a source that will keep the air near the hood so it can be exhausted quickly without mixing in the space causing discomfort and increased heating/cooling loads. Make-up air temperature should not vary more then 10° F from the air in the space. However, this limit can be exceeded if the make-up air does not decrease the comfort of the occupied space or is part of an air conditioning system.

Northern climates with cold winters and short mild summers will almost always require heated make-up air and no cooling. Southern climates with long hot and humid summers and short mild winters will want to minimize the amount of hot, humid air that has to be conditioned by keeping make-up air near the hood. In a hot and dry environment the air can be cooled in the make-up air unit using an evaporative cooler, which will greatly reduce air conditioning loads.

*Figure 10* has two columns. The left column ranks various ways of bringing tempered air into the kitchen. The best options all distribute the tempered air throughout the room. The right column ranks various ways of bringing untempered air into the kitchen. The best options keep make-up air near the hood to decrease heating/cooling loads seen in the rest of the building. The supply options listed at the top of each column are proven through testing and research to be the best ways of introducing make-up air. Choosing the supply options listed near the bottom will not work as well as options listed near the top.

Goal is Comfort		Goal is Low Cost
Tempered MUA	GOOD	No Air Conditioning
Perforated Ceiling		Back Supply Plenum
Perforated Face		Air Supply Plenum
Back Supply Plenum		Perforated Face
Air Supply Plenum		Perforated Ceiling
Variable Supply Plenum		Variable Supply Plenum
Register Face		Air Curtain
4-Way Diffuser		Short Circuit
Short Circuit		Register Face
Air Curtain		BAD

Figure 10

### Supply Options

Make-up air can be introduced through the hood with an integrated supply plenum or an external supply plenum. The advantages of using an external supply plenum verses an integrated supply plenum can be seen in *Figure 11*.

The shaded region represents the volume of the hood. Increasing the volume allows more smoke and heat to be held in the hood until it can be exhausted. This is important over cooking equipment that produces a great deal of heat and smoke, such as a char-broiler. External supply plenums are usually less expensive and can be retrofitted to most exhaust only hoods.

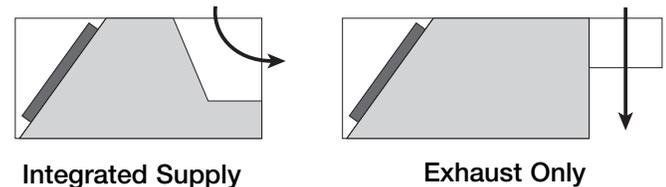


Figure 11

### Exhaust Only Hood with Non-Directional Ceiling Diffusers

This system will work best when bringing tempered air into the kitchen or can be used in climates where outside air closely matches desired indoor conditions. An exhaust only hood has no make-up air entering the room through the hood. This system is the least complex and in most cases works the best, however, may not be the most economical. The amount of exhausted air must be made up, therefore non-directional perforated ceiling diffusers and/or transfer air would be used to make-up 100% of the air. The most important thing to remember is to place many non-directional perforated diffusers throughout the room to keep air velocities low and uniform. Uneven air distribution will cause drafts in the kitchen causing capture and containment to suffer (*Figure 12*). Make sure the transfer air from another room, especially if supplied through a pass-thru window, is kept at a low velocity. This can be accomplished by increasing the amount of air through ceiling diffusers in the kitchen.

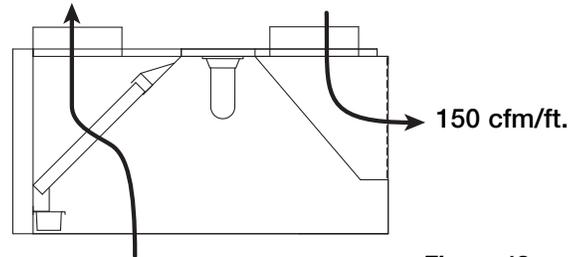


*Figure 12*

3 This system is the least complex and in most cases works the best, however, may not be the most economical. The amount of exhausted air must be made up, therefore non-directional perforated ceiling diffusers and/or transfer air would be used to make-up 100% of the air. The most important thing to remember is to place many non-directional perforated diffusers throughout the room to keep air velocities low and uniform. Uneven air distribution will cause drafts in the kitchen causing capture and containment to suffer (*Figure 12*). Make sure the transfer air from another room, especially if supplied through a pass-thru window, is kept at a low velocity. This can be accomplished by increasing the amount of air through ceiling diffusers in the kitchen.

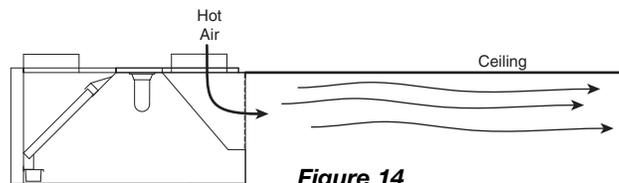
### Face Supply

Located on the front of the hood (*Figure 13*), face discharge is designed to throw make-up air across the room. Use face supply when tempered air is brought in through MUA into a tempered kitchen or when the MUA and kitchen are untempered because mixing will occur with the air in the space. Registers can be used for larger kitchens with longer throws, but perforated face panels are recommended for lower air velocities, which will minimize drafts in the kitchen. The maximum supply rate is 250 cfm/ft. through perforated panels under ideal conditions. For optimum performance design to recommended values of 150 cfm/ft. Face supply should not be used when a wall, another hood, menu board, or other object is less than 6 feet from the face.



*Integrated Face Supply Plenum*

*Figure 13*

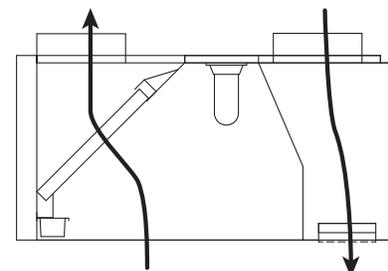


*Figure 14*

The problem with bringing hot untempered air into an air-conditioned room can be seen in *Figure 14*. Hot air will not fall into the room and cycle back out through the hood, rather the hot air will hug the ceiling because it is more buoyant. If humidity is present in the hot make-up air, it will condense on the metal ceiling diffuser when it mixes with the air-conditioned air brought through it. Most of the hot air along the ceiling will be taken in at a return grill by the roof top unit (RTU) and conditioned before it is introduced back into the room, thus totally defeating the purpose of bringing in untempered make-up air.

### Integrated Air Curtain

The hood integrated air curtain (*Figure 15*) discharges air at the bottom-front edge of the hood and directs air downward. If spot cooling for the cooking personnel is desired, use tempered air. This type of hood can also be used to keep untempered air near the hood, although employee comfort will suffer. Buoyant, hot, humid air will have a tendency to travel out into the room with this type of hood as *Figure 14* illustrates rather than back into the hood. The maximum supply rate is 125 cfm/ft. through perforated panels under ideal conditions. For optimum performance design to recommended values of 65 cfm/ft. Caution must be used with the design of air curtain hoods (*See Figure 17*).



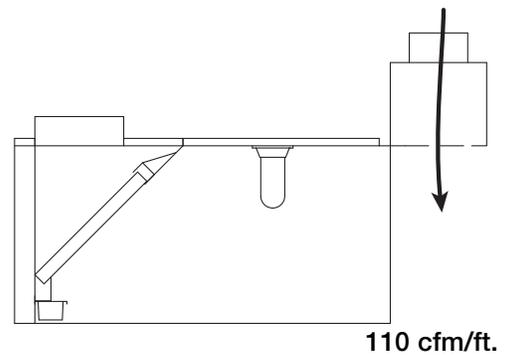
*Figure 15*

65 cfm/ft

*Integrated Air Curtain*

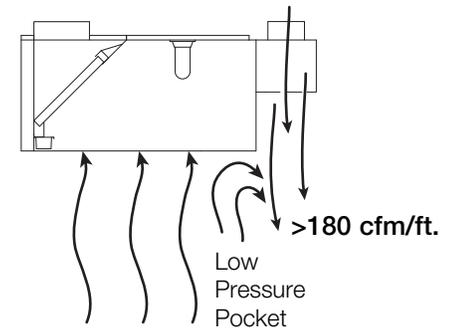
## External Air Supply Plenum

The external air supply plenums (**Figure 16**) provide spot cooling when using tempered air, but can also keep untempered air near the hood, which will save on heating/cooling loads. There are advantages over the integrated air curtain. Mounted 14-20 inches above the bottom edge of the hood or flush with drop ceiling, external air supply plenums can supply airflow at a maximum rate of 180 cfm/ft. For optimum performance, design to the recommended rate of 110 cfm/ft. In addition, external plenums can be attached to the face or ends of an exhaust only hood to create a curtain of air on all exposed sides of the hood, thus increasing the volume of air brought in at the hood.



**External Air Supply Plenum**  
**Figure 16**

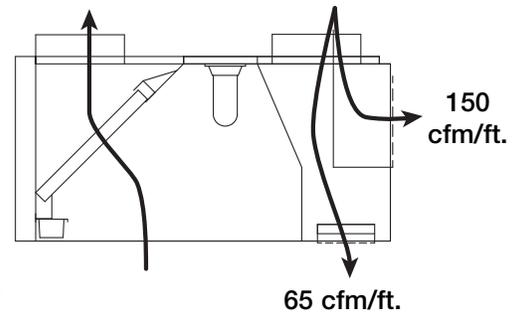
In **Figure 17** notice the pocket of low pressure caused by the air flowing from the external air supply plenum. When velocities are too great, there is enough pressure differential to cause the hood to spill heat and contaminate. This effect can be observed on external and integrated air curtains, however, integrated air curtains are more susceptible to it due to the location of discharge.



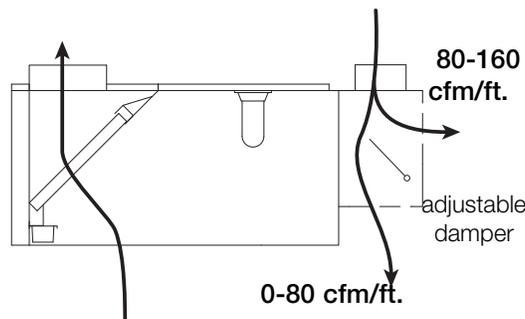
**Figure 17**

## Combination Hood

Combination hoods (**Figure 18**) are a combination of face supply and air curtain supply and are better suited for cooler climates where outside air can be used to cool the kitchen. See Face Supply (pg. 16) and Integrated Air Curtain (pg. 16) for design considerations for the different parts of the combination hood. More make-up air can be brought through a combination hood than a face or air curtain alone, but the same limits exist for each part of the plenum, maximum 250 cfm/ft. from the face and maximum 125 cfm/ft. from the air curtain. Perforated panels should always be used to reduce air velocities and eliminate spillage from the hood. Supply rates should be designed to recommended values of 150 cfm/ft. through the face and 65 cfm/ft. through the curtain for optimum performance. An exhaust only hood with a variable supply plenum (**Figure 19**) can be used instead of a combination hood which will increase maximum supply rates (see external air curtain, face supply) and not take up valuable capture and containment volume.



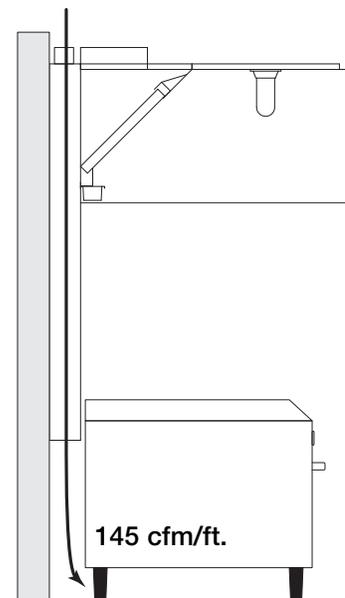
**Combination Hood** **Figure 18**



**External Variable Supply Plenum** **Figure 19**

## Back Supply Plenum

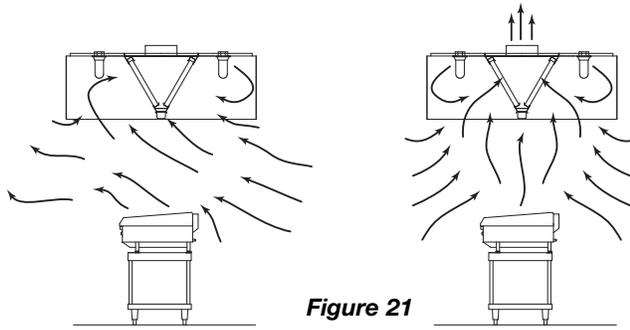
An effective way to introduce untempered make-up air into the kitchen is from the rear of the hood through a back supply plenum (**Figure 20**). These plenums are also ideal for heating air during the colder months since hot air will rise from its low discharge position. This plenum is mounted 31.25 inches above the finished floor and directs airflow through perforated panels behind and below the cooking equipment without affecting capture and containment, cooking surface temperature, or pilot lights. When using untempered air, utilizing low air velocities will keep the air near the hood. These plenums are 6 inches deep and stretch across the entire length of the hood, therefore they function as a backsplash panel and provide the 3-inch clearance to limited combustibles needed in most circumstances. Back supply plenums are able to supply a maximum of 250 cfm/ft. For optimum performance design to the recommended rate of 145 cfm/ft.



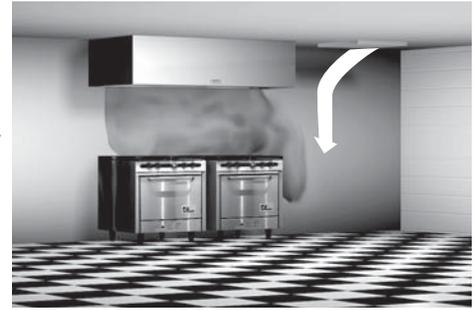
**Back Supply Plenum** **Figure 20**

### Multiple Sources

**Figure 21** depicts two scenarios. The picture on the left shows air brought in through one side of the room while the picture on the right shows air brought in evenly throughout the room.



**Figure 21**

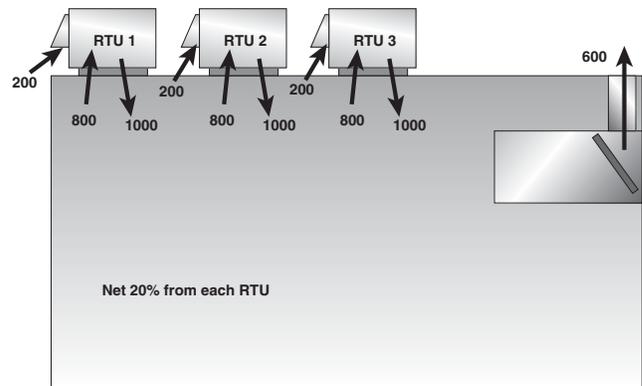


**Figure 22**

To accomplish even airflow, use any one of the hood supply types along with multiple non-directional ceiling diffusers, or transfer air from another room. The amount of air to each diffuser decreases with an increase in number of diffusers, thus lowering air velocities. Various types of diffusers can be used, but non-directional perforated panel diffusers work best. Transfer air can be brought into the kitchen through non-directional ceiling diffusers from the building HVAC as long as air velocities are kept below 50 ft./min at the hood. **Figure 22** illustrates the spillage of effluent when using a 4-way diffuser within 10 feet of the hood. See the room balance section of this guide for an example of multiple sources.

### Roof Top Units (RTU's)

In many places where comfort is the main goal, a roof top unit will be used to supply the make-up air (**Figure 23**). These units condition the space while only taking in some outside air. The example shows that each RTU is providing 1000 cfm, but removing 800 cfm for a net of 200 cfm per RTU. Thus, the three RTU's are providing a total of 600 cfm. RTU's that are set to run in this situation should be in the "ON" mode instead of the "AUTO" mode. The auto mode cycles the RTU's on and off depending on the cooling or heating load. When the units are not running, a huge negative pressure will occur. When in the "ON" position, the units will run constantly and only temper what is needed. RTU's are usually the most expensive to operate.



**Figure 23**

### Non-Directional Ceiling Diffusers

When distributing tempered air, non-directional perforated ceiling diffusers can dramatically improve hood performance and employee comfort. Using multiple non-directional diffusers, small amounts of air are distributed throughout the room introducing a large amount of make-up/supply air without high discharge velocities. As many diffusers as possible should be used to maximize kitchen hood performance. Non-directional perforated panels are recommended for use with ceiling diffusers to keep airflow even and at a low velocity. Perforation causes the air to gently enter the room without a fixed direction. For this reason, these diffusers can be used near the hood in smaller kitchens. The air velocity at the edge of the hood capture area should not exceed 50 ft./min. It is not recommended to use diffusers near the hood, and 3-way and 4-way diffusers should not be used in the kitchen. Ceiling diffusers are typically used in combination with another make-up air option.

	Supply Type	Dimensions (inches)	Recommended Supply Rate	
			cfm/linear ft.	fpm
External	Back Supply	6 wide	145	290
	Air Supply Plenum	12 wide	110	150
		24 wide	180	150
	Variable Supply Plenum	11 high 9 wide	160	150
	Face Supply Plenum	18 wide	150	150
Internal	Perforated Combination	16 high 8 wide	150	150
	Register Combination	12 high 8 wide	130	—
	Perforated Face	16 high	150	150
	Register Face	12 high	250	—
	Perforated Air Curtain	8 wide	75	—
	Register Air Curtain	8 wide	65	—
	Short Circuit	UL limits (not recommended)		

**Figure 24**

### Recommended Supply Rates

**Figure 24** is a summary of the recommended supply rates for each type of make-up air. These values should be used when designing the system to achieve maximum hood performance.

## ROOM BALANCE AND AIRFLOW TESTING

### Capture & Containment

Capture and containment (C & C) is the hood's ability to catch the contaminated airflow and hold it inside the hood until it can be pulled through the filters to the outside. A well-designed kitchen should have approximately equal amounts of air entering the system as leaving it. If this rule is not followed, capture & containment will suffer and there may be a noticeable amount of contaminated air spilling out of the hood, which will cause odor, excess heat, and a greasy film on the walls and ceiling of the kitchen.

### Cross Drafts

Another way to reduce spillage is to reduce cross drafts present in the kitchen. Cross drafts are created from an unbalanced room, unequal air distribution, too much airflow from one source, or a separate air movement source such as a fan. An unbalanced kitchen will become hot due to escaping heat. In an effort to cool the kitchen, employees will open doors and run fans to cool themselves, which is a mistake. These two things will create cross drafts and further disrupt capture & containment, making the situation worse. If cross drafts are unavoidable, end skirts on both sides of the hood are the easiest and most inexpensive aid in reducing cross draft effects. **Figure 25** illustrates the effects of an unbalanced room condition creating air currents. **Figure 26** shows the effects of having a fan in the space at or near the hood. Avoid both of the situations depicted in **Figures 25** and **26**.

4



Figure 25

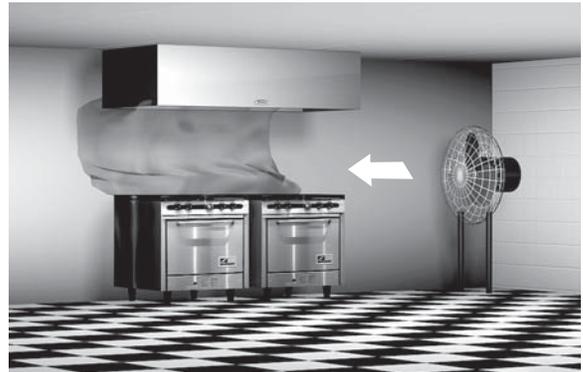


Figure 26

### Room Pressure

Kitchen room pressure should be kept at a slight positive to the outside at all times. This can be accomplished by providing slightly more air than what is being exhausted. The dining room should be kept at an even greater positive pressure, which will allow a slight airflow from the dining area to contain heat and odors to the kitchen. Even though both dining area and kitchen are positive, the kitchen is negative when compared to the dining area. (See **Figure 27**) Positive room pressure will also keep outdoor contaminants such as dust and insects from entering into the kitchen while building doors are open for deliveries, maintenance, or other patron traffic.

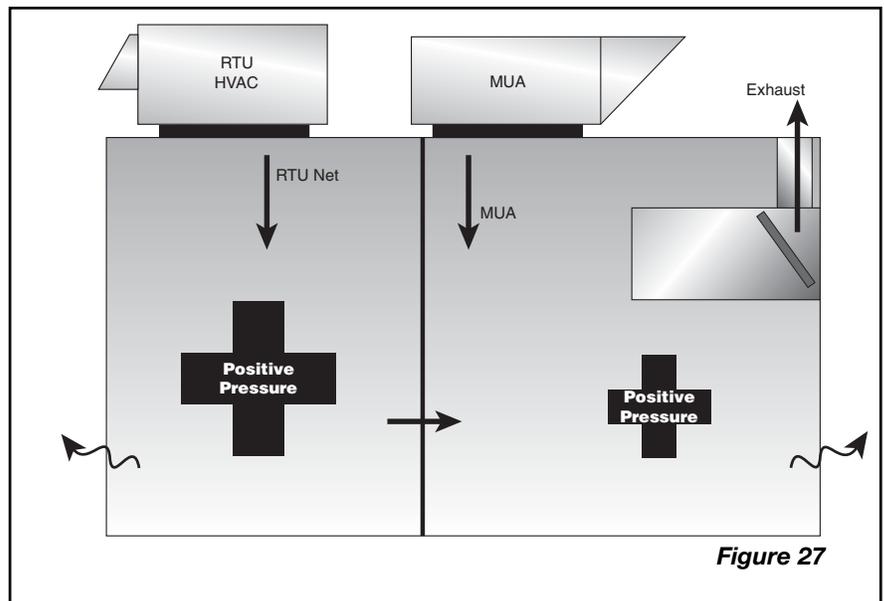


Figure 27

Illustrated below in **Figure 28** is a typical supply air diagram for a kitchen and dining room arrangement with the accompanying air balance tables. The hood has a dedicated exhaust fan and make-up air unit. The kitchen also has a dedicated HVAC supply (RTU) unit to help take some of the conditioning load. In the dining area another dedicated HVAC unit is used to supply the air and make up any losses from rest rooms or other small exhausted areas. Notice, there is transfer air going into the kitchen from the dining area, thus the kitchen is slightly negative to the dining area containing odors although the balance of the dining area of 200 cfm exfiltration (EXF) shows that the building as a whole is at a slight positive to the outdoors as desired.

4

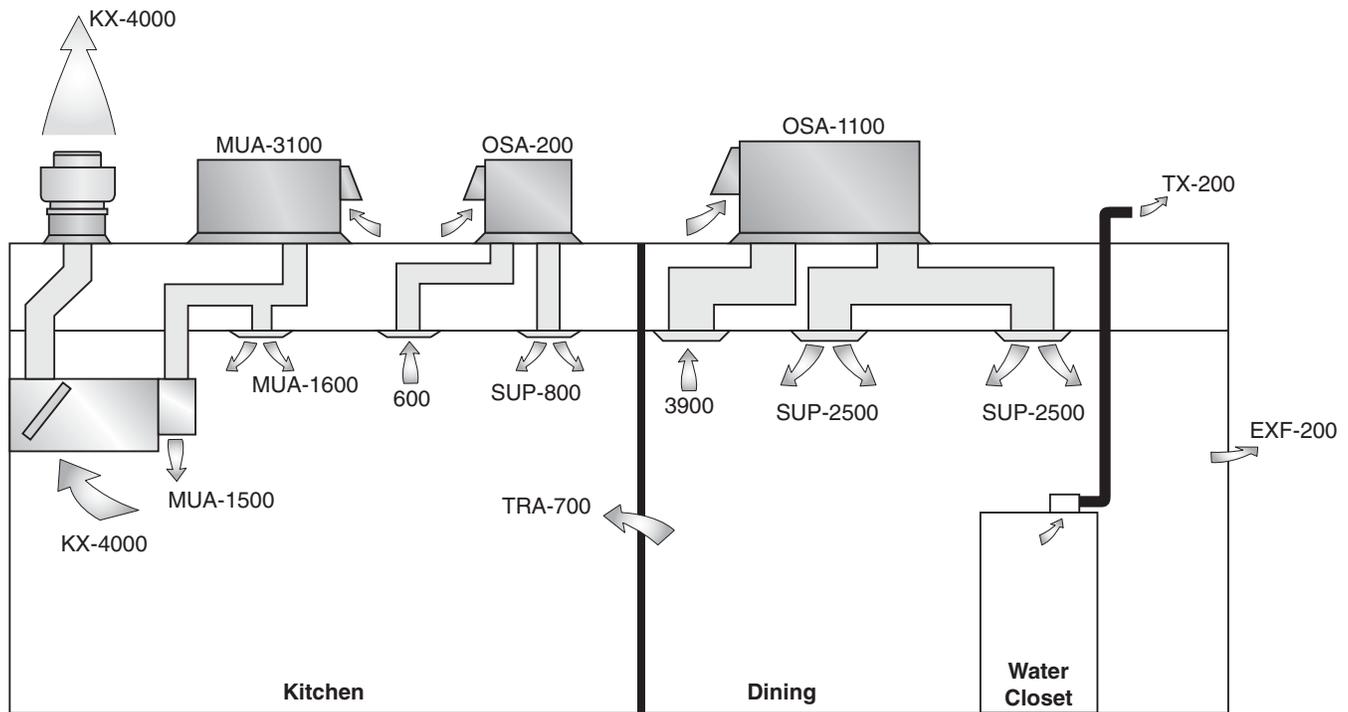
**Air Balance (units of cubic feet per minute (cfm))**

Kitchen Systems	Airflow In	Airflow Out
KX - Exhaust		4000
MUA - to Hood	1500	
MUA - to Kitchen	1600	
SUP - HVAC Supply	200	
<b>Total</b>	<b>3300</b>	<b>4000</b>

Dining Room Systems	Airflow In	Airflow Out
OSA - Outside Air	1100	
TRA - Transfer Air to Water Closet		200
Transfer Air to Kitchen		700
<b>Total</b>	<b>1100</b>	<b>900</b>

Net=4000-3300= 700 transfer (TA) from dining

Net = 1100-900 = 200 Exfiltration



**Figure 28**

## EXHAUST AND SUPPLY RATE TESTING APPARATUSES

An AMCA test and balance uses a pitot tube to measure air velocities in the duct. However, codes require a fully-welded duct for kitchen exhaust systems, therefore prohibiting penetration of the duct when using a pitot tube. The following two apparatuses are nonintrusive alternatives to measuring air velocities in kitchen ventilation systems.

### AIRDATA™ Multimeter by Shortridge Industries

The Shortridge multimeter is a new alternative to the rotating vane anemometer. This meter can measure airflow, velocity, pressure, and temperature quite easily. It consists of two main components, the velgrid to sense the airflow and the meter itself. Additionally, it can store up to 200 readings and automatically senses the temperature of the air so that it can account for the local air density when taking readings. Different conversions for different types of filters are required in order to

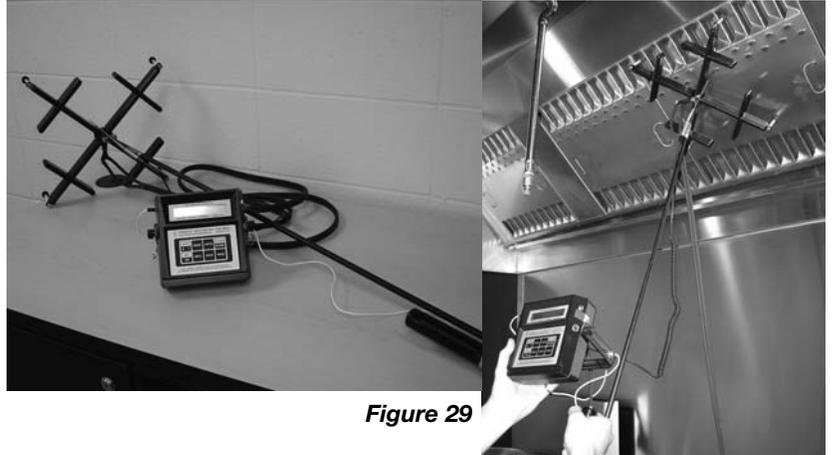


Figure 29

convert the reading from feet per minute to cubic feet per minute. Greenheck has charts with instructions to do so for its filters. **Figure 29** is an illustration of the Shortridge setup and operation.

### Rotating Vane Anemometer (RVA)

The RVA is used for measuring air velocities, shown in **Figure 30**. Moving air rotates fan blades, which is converted to an air velocity reading on the instrument. When measuring hood filter airflow, take 6 readings per filter, then average the readings. The RVA should be 2 inches from the filter and perpendicular to airflow direction. The RVA is also directional, the arrow should point in the direction of airflow travel. Airflow velocity can be converted to CFM by multiplying a correction factor to the average filter velocity. The appropriate CFM reading can be obtained from each filter in the hood, the total hood CFM can be measured by adding each filter CFM.



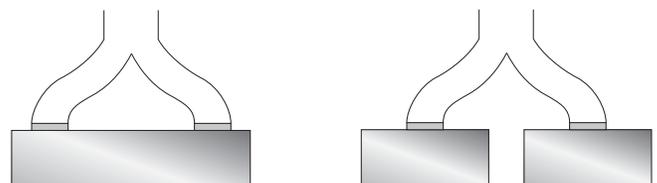
Figure 30

### Exhaust Air Balancing Baffle (EABB)

The Exhaust Air Balancing Baffle is a simple device offered as a Greenheck option that enables balanced airflow of multiple duct collars in long hoods, double island hoods, or in multiple hoods running from a single fan as shown in **Figure 31**. When a different airflow is needed, the baffle can be adjusted to change the size of the collar opening. The hood should be tested to ensure proper airflow after each adjustment. See **page 22** for static pressure calculations.



Figure 31



## Checking for Balance

Every hood with an EABB has a range for its static pressure. The low number in this range is given by the standard calculation for hood static (static that is printed with the CAPS submittal). The maximum increase above the low number can be calculated from the duct velocity at the low static (also provided on the CAPS submittal). This is then added to the low number to get the highest static pressure possible with an EABB.

The maximum potential increase in static is given in the graph or can be calculated from:

$$\text{Max. Inc.} = 0.00000036 \times (\text{Duct velocity})^2$$

After the range for each hood is calculated, it should be compared to the hood with the highest static pressure. If the highest hood falls inside of the range, then the hoods can be balanced with the EABB. If it is higher than the range, the hoods cannot be balanced.

### Example 1:

Hood 1: Ps = 0.58 inH<sub>2</sub>O  
Duct Velocity = 1900 fpm

Hood 2: Ps = 0.44 inH<sub>2</sub>O  
Duct Velocity = 1800 fpm

Hood 2 has the lower Ps, at 1800 fpm the maximum increase in Ps is 1.17. The range for hood 2 is 0.44 to 1.61. Hood 1 is less than 1.61 so these hoods can be balanced.

### Example 2:

Hood 3: Ps = 2.00 inH<sub>2</sub>O  
Duct Velocity = 2000 fpm

Hood 4: Ps = 0.44 inH<sub>2</sub>O  
Duct Velocity = 1500 fpm

Hood 4 has the lower Ps, at 1500 fpm the maximum increase in Ps is .81. The range for hood 4 is 0.44 to 1.25. Hood 3 is higher than 1.25 so these hoods cannot be balanced.

**Note 1:** For many systems, an EABB may not be needed on the hood that has the highest static pressure. The exception to this is if the individual ductwork has uneven static pressures.

**Note 2:** When sizing the fan, use the static pressure from the highest hood and sum the cfm from all the hoods.

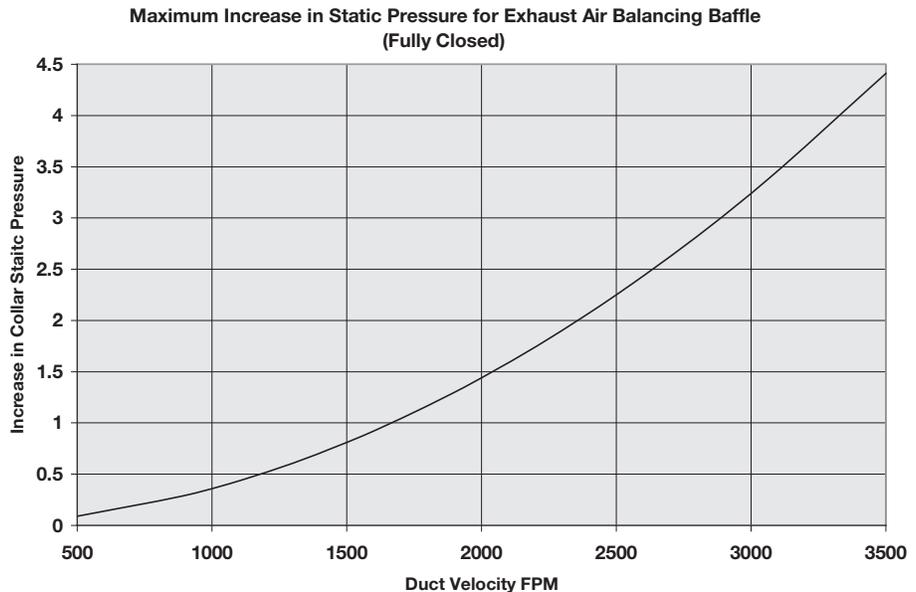


Figure 32

## GREASE EXTRACTION

The removal of grease from the exhaust airflow is a very important part of commercial kitchen operation. Without proper filtration, grease will:

- Collect in the exhaust plenum and ducts creating:
  - A fire hazard
  - An increase in the frequency of costly duct cleaning
- Collect on the fan causing it to become unbalanced and lead to premature failure
- Create odor in or near the restaurant
- Collect on the rooftop causing deterioration of roof materials
- Collect on the rooftop equipment and cooling coils

These problems can be greatly reduced through the use of proper grease filtration devices.

### History

For years, the commercial kitchen industry has been without a standard for rating filtration devices. This has led to many manufacturers listing efficiency ratings of 90% on their filters. These claims are made from the old Navy test, ULC 710, and UL 1046 grease loading safety tests required for all filters in TYPE I hoods which are inaccurate because grease particle size is not taken into account. Research started in the mid 1990's to develop a standard test that would account for particle size with filter efficiency. With this standard, grease filters will be directly comparable.

### Grease Emissions

When food is cooked it releases grease, water, vapor and combustion by-products from the energy source or food products that are burnt or changed by chemical reactions during the cooking process. These emissions are vapor and particulate matter that are exhausted through the kitchen exhaust system. This particulate clings onto ducts, fans, and roofs.

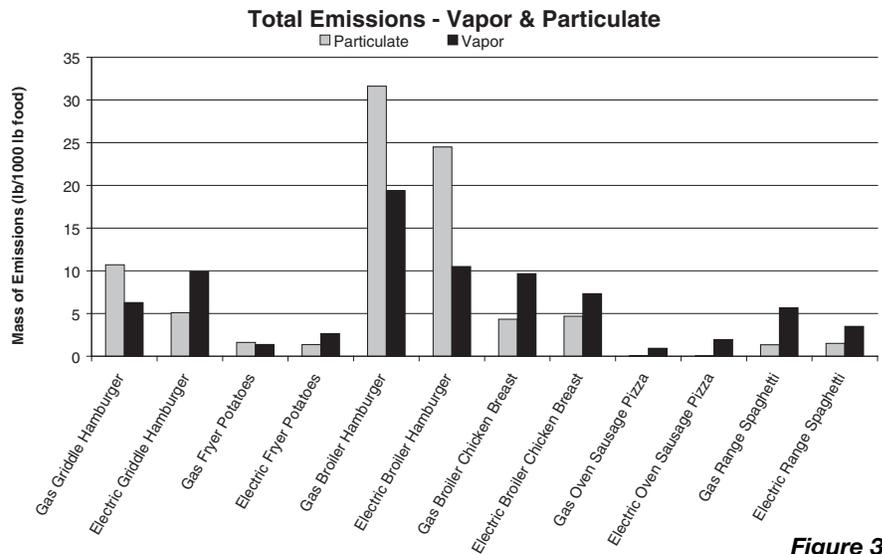
Grease particulate is liquid or solid particles of grease that have become suspended in the air. The particulate can range in size from .01 to 100  $\mu$

( $\mu$  = microns). A human hair = 100 microns. Grease vapor refers to grease in the gaseous state that is much smaller than grease particulate. Vapor is condensable and may condense into grease particulate or remain in a vapor state while being exhausted into the atmosphere. **Figure 33** shows the amount of grease particulate and vapor produced when cooking 1000 lbs. of different foods on different types of cooking equipment.

Theoretically, emissions down to 0.01  $\mu$  can be filtered out of the airstream, however, vapors cannot be filtered using traditional filters. Grease particulate larger than 10 - 20  $\mu$  is too heavy to remain airborne and will drop out of the airstream. Most grease filters operate between 1 - 10  $\mu$ .

### Cooking Equipment

Another important concept to understand is the variation of emissions given off by different cooking equipment. A study was done in 1998 by the University of Minnesota for ASHRAE, report 745-RP, which identified the type and size of grease emitted from various cooking equipment. Different amounts of various sized particles are emitted from the cooking equipment depending of the type of equipment being used and type of food being cooked. Appliances that produce a large heat load typically produce a larger amount of emissions. The total shaded region in **Figure 35** shows the mass of emissions vs. particle size for a griddle.

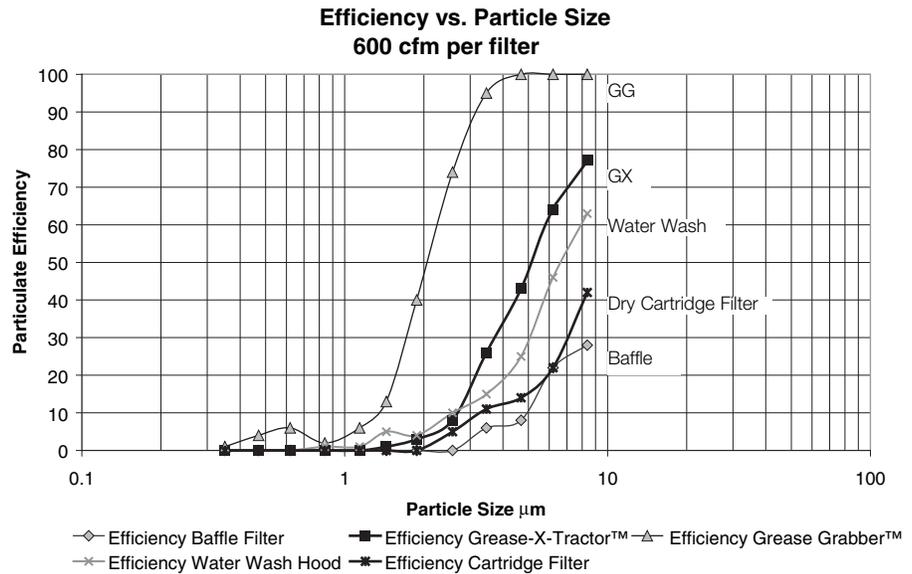


**Figure 33**

## Filter Efficiency

Filters can seldomly be given a single meaningful efficiency number. This is because a filter has a different efficiency for different size particles, different flow rates, and different phase of particles. A filter that is 90% efficient at removing 5  $\mu$  particles may only be 75% efficient at removing 1  $\mu$  particles.

A fractional efficiency curve is a graph that gives the efficiency of a filter over a range of particle sizes. Fractional efficiency curves are created by subjecting a test filter to a controlled distribution of particles and measuring the quantity of particles at each given size before and after the filter. The amount of reduction in particles is used to calculate the efficiency at each given size. **Figure 34** shows the particulate efficiency curves for different 20 x 20 filters at 600 cfm per filter.



**Figure 34**

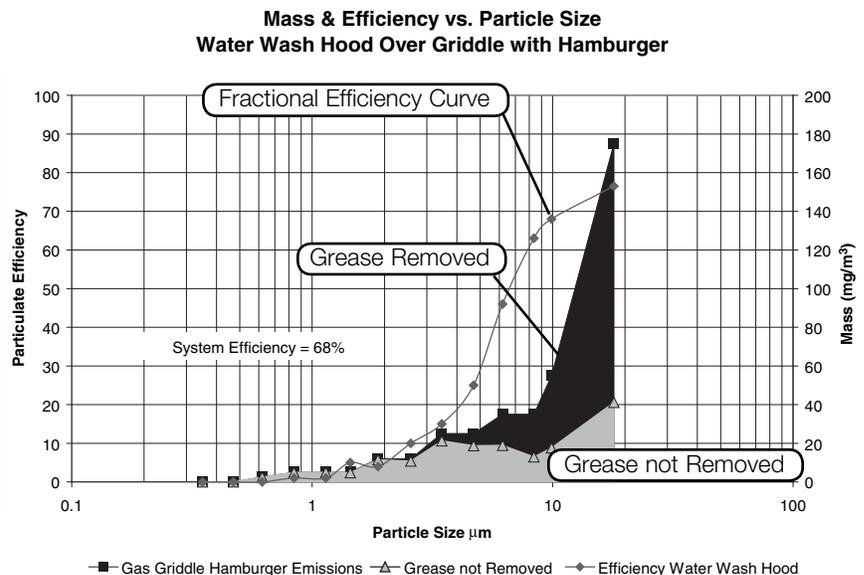
## Interaction of Cooking and Filtration

The amount of grease particulate removed and the amount of grease particulate exhausted into the ductwork can be calculated by multiplying the efficiency at each point along the curve by the mass emissions from each type of cooking equipment. The ratio of particulate matter removed to total particulate matter generated gives system efficiency for that range of particle sizes for a specific cooking application. It is important to remember that the graphs and efficiencies shown here are only for grease in the particulate form. There is also a vapor component of the grease that is being exhausted. Some of the vapor condenses and is removed as particulate prior to the filter. Some of the vapor condenses in the duct and accumulates on the ductwork and fan. Using **Figure 35** and the new understanding of filter efficiency, it is possible to determine the total amount of grease removed for the different systems. When cooking hamburger on a gas griddle the baffle filter has a particulate system efficiency of 33%. When vapor is included the total system efficiency drops to 19%. The Grease-X-Tractor™ drops from 77% for particulate system efficiency to total system efficiency of 46%. The Grease Grabber™ goes from 99% to 62%.

## Types of Filters and Efficiencies

### Interpreting the Graph

**Figure 35** represents the efficiency of a water wash hood. Each filter type has a graph similar to this. The overall shaded area represents the amount of grease emissions given off from the cooking equipment. The dark shaded area represents the amount of grease taken out of the airstream by the filter. The lightly shaded area represents the grease particulate that escaped past the filter. The ratio of dark shading to light shading at a particular particle size is represented by the fractional efficiency curve. Filters with higher efficiencies will have more of the total shaded area darkened. This can be seen in **Figures 35-38**.



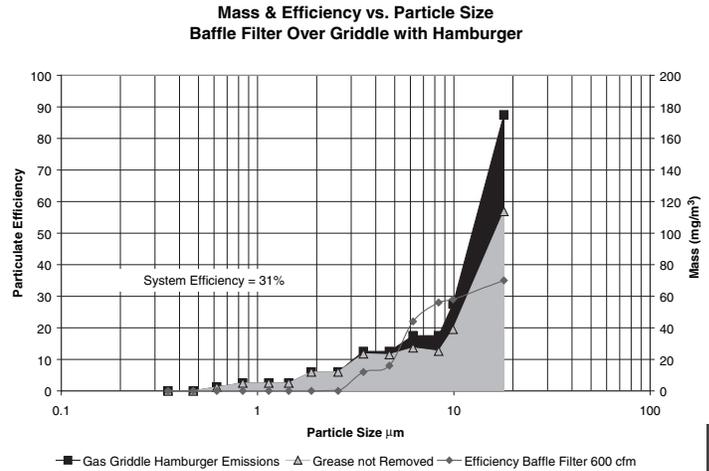
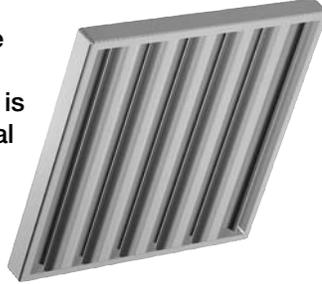
**Figure 35**

## Water Wash / Dry Cartridge Hoods

These hoods have the filtration system built into the hood and are 50% efficient at about 6.5  $\mu$ . The point at which a filter is 50% efficient is called its cut point. This shows that the water wash / dry cartridge hoods are still dependent on inertial impaction. Their higher efficiencies than the baffle filter are also reflected by a much higher static pressure. Typical pressure drops for a 9 ft. x 4 ft. hood at 2050 cfm will be 1.1-1.3 in. wg. See **Figure 35**.

## Baffle

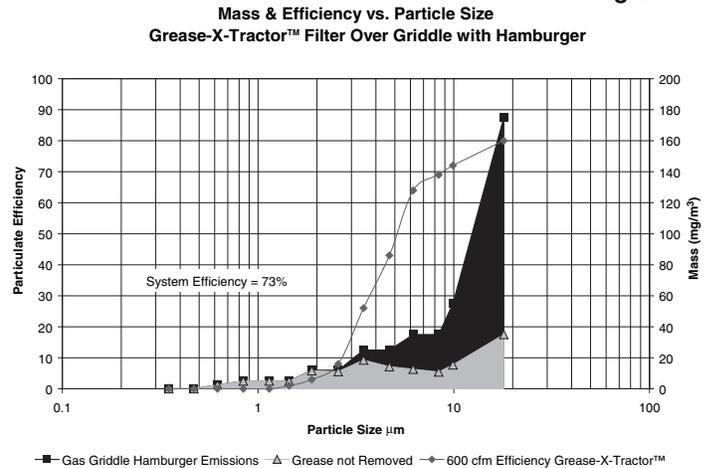
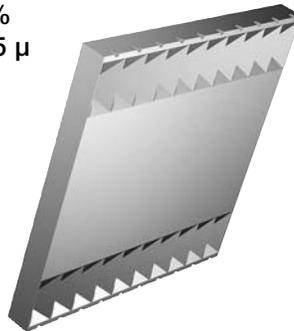
The efficiency curve for the baffle filter and the cartridge filter shows that at 8  $\mu$  its ability to remove particulate is 30%. Baffle filters use inertial impaction, which is the principle of the particle's momentum throwing the particle out of the airflow as it changes direction, to remove grease from the airflow. Typical pressure drops for a 9 ft. x 4 ft. hood at 2050 cfm will be 0.5-0.6 in. wg. See **Figure 36**.



**Figure 36**

## Centrifugal Filter

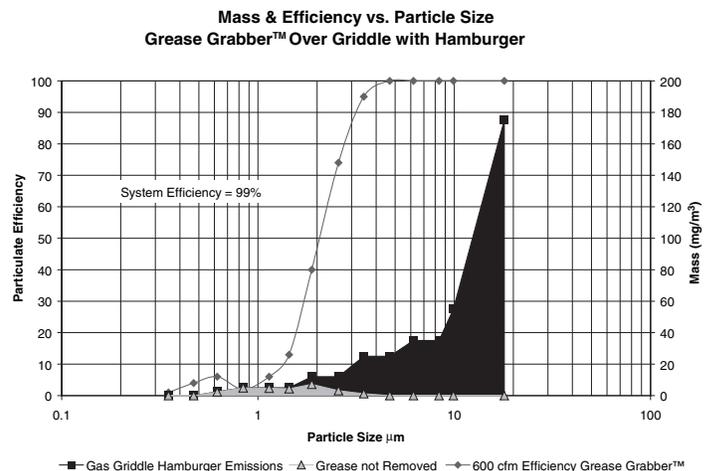
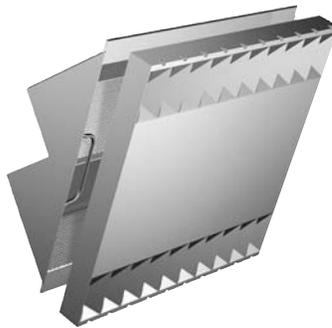
The Grease-X-Tractor™ is 50% efficient at 5  $\mu$ . A cut point of 5  $\mu$  is typical of a centrifugal filter. Its efficiency improves rapidly above 5  $\mu$  and drops below 5  $\mu$ . The use of centrifugal force rather than two-dimensional impaction allows the efficiency to be improved without a high penalty in static pressure. Airflow enters the filter's louvers and is spun in a chamber until it exits the back of the filter. Grease particles are thrown from the airflow during its helical path. The velocity of the airflow determines how small of a particle can be removed. The static pressure is between a baffle filter and a water wash hood. Typical pressure drops for a 9 ft. x 4 ft. hood at 2050 cfm will be 0.7-0.8 in. wg. See **Figure 37**.



**Figure 37**

## Multi-Stage Filtration

The Grease Grabber™ uses a centrifugal type filter as the primary stage of filtration along with a packed bead bed filter as the second stage. Interception is the main filtration mechanism which works by adsorption of grease particles as they come in contact with the packed bead bed. The Grease Grabber™ has a cut point at 2  $\mu$ . Its efficiency increases to near 100% at 7  $\mu$  and drops for particles smaller than 2  $\mu$ . This reduction in the size of particles that can be removed indicates that the Grease Grabber™ uses a combination of all filtration mechanisms. The static pressure drop is the highest of the filters evaluated but only slightly higher than water wash. Typical pressure drops for a 9 ft. x 4 ft. hood at 2050 cfm will be 1.1-1.3 in. wg. See **Figure 38**.



**Figure 38**

## FIRE SUPPRESSION SYSTEMS

### UL 300

Every commercial kitchen hood requires a UL 300 listed commercial fire system. In summary, UL 300 involves heating vegetable shortening or oil to an auto ignition temperature of 685° F or higher. After the oil has auto-ignited, it must remain in a pre-burn state for 2 minutes with the exception of griddles, which remain in a pre-burn state for 1 minute. The extinguishing agent is then applied to suppress the fire. If after 20 minutes no fire has returned, the fire suppression system successfully passes certification.

### Wet Chemical

Wet chemical fire suppression systems use a potassium based chemical extinguishing agent. The agent is discharged over the entire cooking battery and reacts with hot grease to form a blanket of foam in a process called saponification that seals the hazard depriving the fire of oxygen. The wet chemical system is available in two types:

#### Appliance Specific

These systems are designed specifically for appliances and require knowledge of the cooking battery under the hood. Specific nozzles and fusible links are chosen based on the type of appliance. The systems use a temperature rated fusible link to hold a scissors link together (*Figure 40*). When the fusible link melts, the scissors opens activating the system. This is a dedicated detection system that requires permanent equipment placement — if the equipment is moved or changed, re-piping is necessary.

#### Full Flood

Full flood systems require no prior knowledge of the cooking battery with the exception of shelves, salamanders, and upright broilers. Full flood systems have drops evenly spaced across the length, the spacing is dependent on the manufacturer's UL listing. The detection system is either a pneumatic tube (*Figure 41*) that runs the full length of the hood, or fusible link detection with the links evenly spaced along the length of the hood. The advantage of the full flood system is that cooking equipment can be moved and changed without having to alter the fire suppression piping. See *Figure 39* for an example of full flood coverage.

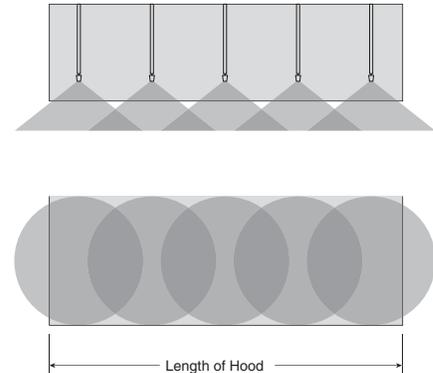


Figure 39

### Dual Agent

Dual agent fire suppression systems uses both wet chemical and water to suppress the fire. Similar to the other systems, a wet chemical agent is used to blanket the fire with foam followed by water to cool the hazard. By cooling the area the chance of a flare-up is reduced. Dual agent fire suppression systems are available both as appliance specific and full flood, and utilize a fusible link detection system.

Before choosing a type of dual agent fire suppression it is imperative that the water pressure at the jobsite be verified. The dual agent system requires 33 psi for large systems and continuous piping systems. For branch piping and average size systems, 22 psi of water pressure will be sufficient. Check with the fire system supplier to determine the required water pressure for the application.

### Water Spray

The Water Spray fire suppression system is an automatic system, designed to protect the cooking equipment, hoods, ducts, plenums, and filters in facilities designed with wet-pipe sprinkler systems. Once activated, the system provides a focused continuous water mist until it is manually turned off. Water spray fire suppression only discharges onto the fire area, not over the entire cooking battery. In 1997, UL removed the listing from the EA-1 fryer nozzles. Greenheck, with several other manufacturers, has developed the Dual Tech nozzle for use over fryers. The nozzle has self-contained chemical canisters that discharge on the fryer first, followed by water.

Due to the poor performance of water spray fire protection, many local and state codes prohibit the use of these types of systems. Thus, check with the local code authority on the job to get approval in writing before specifying and purchasing a water spray fire suppression system.

## DECISIONS TO BE MADE WHEN CHOOSING A FIRE SUPPRESSION SYSTEM

### Appliance Specific or Full Flood

Choose whether the system is to be designed using a full flood system without knowledge of the cooking battery (with the exception of shelves, salamanders, or upright broilers) or an appliance specific system.

#### If appliance specific, standard wet chemical or dual agent

Choose between wet chemical only or a dual agent with wet chemical and water. Be aware that dual agent is considerably more expensive and requires a water connection.

### Complete System or Pre-Pipe Only

Decide whether the hood should include the entire system or only piping drops and nozzles while remaining components are left for field installation. Some manufacturers and systems may only offer the product as a complete system. The pre-pipe option allows for concealed, pre-piping of the hood, and the flexibility of choosing your local fire system distributor to complete your system.

### Hood Mounted or Remote

Choose to have the system mounted in a cabinet at the end of the hood or remotely mounted at another location in the kitchen or utility room. If remote mounted, be advised that there are limitations on the distance the cabinet can be mounted from the hood.

### *Other considerations that may or may not apply:*

**Gas Valve** — If all electric appliances, a valve is not needed. If using gas appliances, a mechanical or electric shut-off valve must be selected to stop the flow of fuel to the cooking appliances in the event of a fire.

**K-Class Fire Extinguisher** — Most codes require a separate fire extinguisher mounted on the wall of the kitchen.

**Permits** — License fee required by the local authority — sometimes multiple permits are required — municipality as well as state. Check with the local authority having jurisdiction for local requirements.

**Testing** — The authority having jurisdiction observes a system performance test. Usually only a “puff” or air test is required. Air is blown through the system to ensure there are no obstructions in the piping.

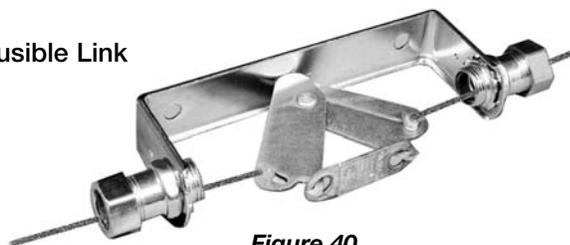
Sometimes a bag or a dump test is required. Chemical is released through the system as would be in an actual fire situation and caught in a bag or bucket at each nozzle. The chemical is weighed to make sure the proper amount has been released. Many times dump tests require additional cost to flush the pipes and nozzles. Check with the local authority having jurisdiction for local requirements.

### Fire System Detectors

Most fire systems use a fusible link (*Figure 40*) installed in the exhaust plenum above each piece of cooking equipment. In the event of a fire, the heat will melt the metal link which has a specific melting point ranging from 165° F - 500° F, thus triggering the fire system.

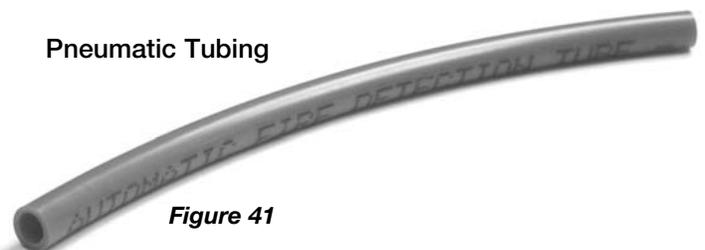
Pneumatic tubing (*Figure 41*) is another detection device that can be used in both appliance specific and full flood systems. The tubing runs the entire length of the hood and in the event of a fire, the tube will melt at 435° F releasing the pressure in the line triggering the fire system.

Fusible Link



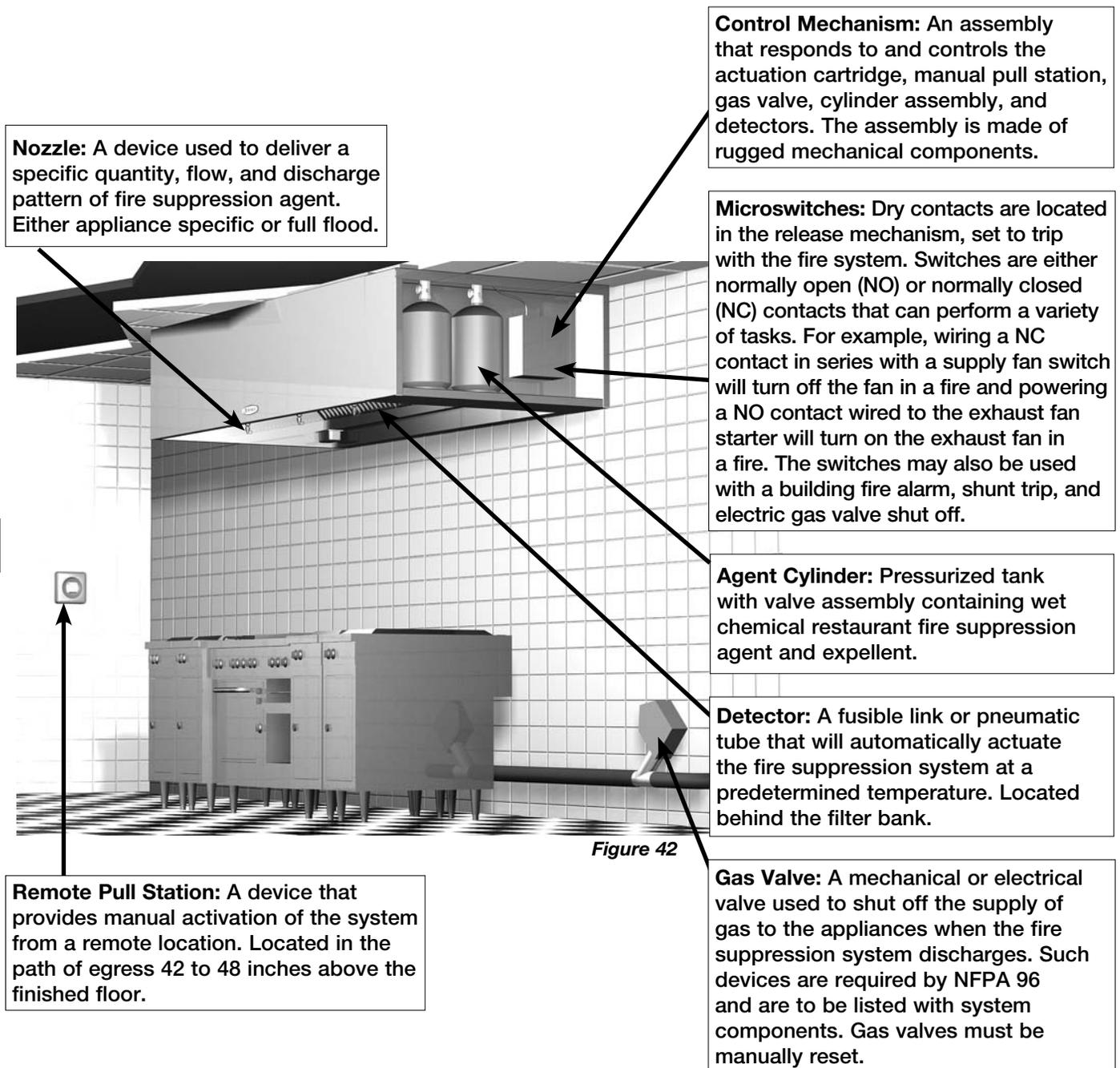
*Figure 40*

Pneumatic Tubing



*Figure 41*

Below is an example of a typical fire suppression system in a hood



### Exhaust Duct Fire Dampers

The primary purpose of the damper is a secondary back-up to the fire suppression system. If that system fails and allows enough heat to escape into the exhaust duct, the fire damper will close and in some cases shut down the exhaust fan. The most common fire damper has a fusible link actuator.

Fire dampers in the exhaust duct are not required in most areas. However, a few local code authorities may require them, so be sure to look into the requirements in the area of construction.

### Supply Duct Fire Damper

Like the exhaust damper, the supply dampers offer protection from a spreading fire. Many times, when the fire suppression system is activated, power is cut to the supply fan to prevent feeding the fire with forced oxygen. Using a fusible link fire damper to close off the supply duct can reduce the threat of greater fire damage. Again, few code authorities require fire dampers and in many cases they may not be permitted.

## ENERGY MANAGEMENT SYSTEMS

### Variable Volume

Would you buy a car without a throttle? Not likely. So why buy a kitchen ventilation system without a means to vary its exhaust and supply airflow to meet the demands of the kitchen? Today, society is becoming more concerned with energy conservation and depleting natural resources. Twenty-five percent of energy costs in a food service operation are consumed by conditioning outside air. Driving such costs is the fact that kitchens can have twenty or more air changes per hour. Installing a variable volume system will allow for the exhaust and supply units to ramp up and down depending on the cooking load which will generate the best efficiency the system is capable of. There are four types of variable volume systems ranging from a manual, simplistic set-up to an advanced control system with multiple sensors.

Varying both the exhaust and the supply will vary the amount of air that needs to be conditioned. In some cases, a variable system can reduce the costs associated with conditioning make-up air by up to 50%. A cost analysis as shown in *Figure 44* can be done to determine how long before a system will pay for itself.

#### Manual system with a single-phase 2-speed motor (high or low)

- No temperature sensor
- Low speed (exhaust and supply fan)
- High speed (exhaust and supply fan)
- 100% override to high speed
- Standard motor starters with 2-speed fans (single-phase)

The manual system uses a two-speed fan with no input sensors to vary exhaust and supply rate. The person using the system determines the two settings (high or low). This system is the lowest cost of all variable volume systems. To design this system select a two-speed exhaust and two-speed supply fan motor. A two-speed switch will need to be mounted on the hood for easy access. Some jurisdictions may not allow this type of system so check with your local AHJ before specifying.

#### Automated system with a single-phase 2-speed motor (high or low)

- Temperature sensor in the duct collar as input device
- Low speed (exhaust and supply fan)
- High speed (exhaust and supply fan)
- Fire system warning alarm tripped at a set temperature
- Fire system activated which also turns off supply fan
- 100% override to high speed
- Standard motor starters with 2-speed fans (single-phase)

The automated system also uses a two-speed motor to vary exhaust and supply rate, however, a temperature sensor in the duct collar determines what rate the fan is running. When the cooking equipment generates enough heat, the fan will ramp up automatically from low to high or can be manually overridden to high speed. To design this system select a two-speed exhaust and two-speed supply fan motor. This option will include a duct mounted temperature sensor, controller, and a three position switch.

#### Control System for 3-phase motors with variable speed (temperature sensors)

- Temperature sensor in the duct collar as input device
- Exhaust and supply speeds vary with the temperature
- Fire system warning alarm tripped at a set temperature
- Fire system activated which also turns off supply fan
- 100% override to high speed
- Variable frequency drives (exhaust and supply)

The control system varies the frequency of the motor drives according to the temperature seen in the duct collar. Instead of high or low, this system will run at the optimum performance. This option will include a duct mounted temperature sensor, I/O processor, frequency motor drives, and a keypad.

### Advanced Control System (temperature and optic sensors)

- Temperature sensor in the duct collar as input device
- Exhaust and supply speeds vary with the temperature
- Infrared sensor in capture area (for cooking surges)
- Variable Frequency Drives (VFD) ramp to high with smoke density increase
- Fire system warning alarm tripped at a set temperature
- Fire system activated which also turns off supply fan
- 100% override to high speed
- Variable frequency drives (exhaust and supply)

The advanced control system varies the frequency of the motor drives according to the temperature seen in the duct collar, and it uses a infrared sensor to detect smoke density. Once the infrared beam is broken, caused by a surge in the cooking effluent, the system will ramp to 100% instantly for a set period of time. The system will return to the speed at which the temperature dictates when the smoke has been removed. This system can be overridden to 100% and can be linked to the fire system.

### Advanced Variable Volume System

1. **I/O Processor:** Controls the lights, fans, and up to four hoods. It communicates to the electronic motor starters (VFDs) and can be manipulated using the keypad.
2. **Electronic Motor Starter (VFD):** Receives a start/stop command and a 4-20ma signal from the I/O processor. It varies the fan motor speed between a minimum and maximum setting.
3. **Keypad:** Provides daily operation functions and setup features.
4. **Temperature Sensor:** Located in the duct collar behind the filters, it monitors the duct temperature. A signal is then transmitted to the I/O processor in order to vary the fan speed in proportion to the actual heat load.
5. **Optic Sensors:** Monitor when actual cooking is taking place. After a 7% reduction is detected a signal is sent to the I/O processor to bring the fan motor to full speed until all the effluent is exhausted.

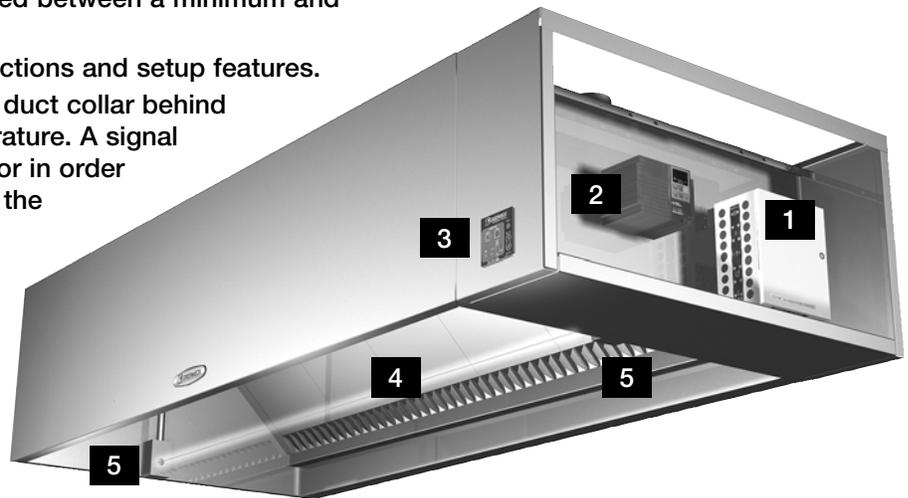


Figure 43

### Payback Analysis

- **CFM Reduction:** Typically ranges from 10% to 50% of design volume
- **Hood operating hours:** Typically ranges from 12-24 hours per day or 4,380-8,760 hours per year
- **Average energy costs:** \$2 per cfm/year can be used for estimating conditioning make-up air costs
- **Initial variable system cost:** \$3,500

Without Variable Volume		With Variable Volume	
Wall Canopy Hood	15 L x 5 W x 2 H (ft.)	Wall Canopy Hood	15 L x 5 W x 2 H (ft.)
Design exhaust volume	5000 cfm	Design exhaust volume	5000 cfm
CFM reduction	None	CFM reduction	2500
Hood operating hours per year	6750 hours	Hood operating hours per year	6750 hours
Average climate and energy costs	\$2/cfm/year	Average climate and energy costs	\$2/cfm/year
Est. total operating cost/year	\$7500	Est. total operating cost/year	\$3750
		Annual savings	\$3750
		Payback Period (initial cost/annual savings)	0.9 years

Figure 44

7

## UNIT SELECTION: EXHAUST FAN SELECTION

Exhaust fans are an integral component of commercial kitchen ventilation. When the wrong fan is chosen, the system can have inefficient performance and could lead to premature fan failure. These fans must be able to withstand heat and grease laden air and are made differently than an ordinary fan. Fans in grease environments must carry the UL 762 label, which rates them for grease and heat applications. The fan must overcome the losses of the system and be sized to move the correct amount of air. The fan wheel best suited for grease applications while still maintaining air movement at higher static pressures is a centrifugal backward inclined wheel. Also, centrifugal wheels have endurance to withstand grease loading. The following fans use a centrifugal wheel all capable of static pressures up to 5 in. wg.

### TYPES OF FANS

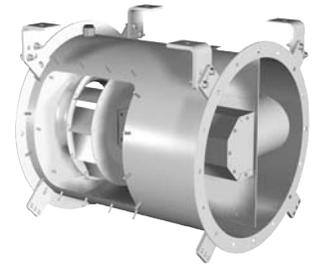
#### Upblast

Upblast fans are the most common type of kitchen exhaust fan. They use a centrifugal backward inclined fan wheel, are either direct drive or belt driven with an isolated motor, and can be roof or sidewall mounted. The belt driven units have adjustable pulleys for final system balancing. Be sure to check the current load (amps) on the fan motor after a change has been made. Small increases in fan speed results in large power increases required by the motor. Grease drains/traps should be used on the fan to collect grease that has passed through the filtration system and may cause roof damage. A vented curb may be required in heat applications such as kitchen ventilation. Hinged curb cap and cleanout ports allow easy access to the inside of the fan and duct.



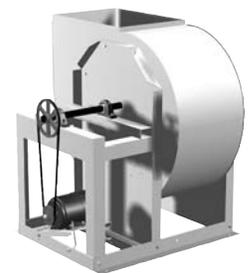
#### Inline

Inline exhaust fans use a centrifugal backward inclined fan wheel and are mounted as part of the ductwork, usually inside the building. Access panels are located on the housing allowing disassembly of the fan without removal from the ductwork. These fans are best suited for applications where mounting a fan on the exterior of the building is not possible. Examples would be a high-rise building where penetrating multiple floors with ductwork would not be feasible or a building where a fan would detract from its visual appearance. Inline grease fans have an isolated motor, adjustable pulleys, and two grease drain plugs with the capability of being mounted horizontally or vertically.



#### Utility

Utility fans offer a variety of discharge positions and can be mounted inside or outside of the building, offering flexibility with respect to duct design. Although utility fans use a centrifugal backward inclined type wheel, the airflow pattern is changed such that the air is turned 90° as it passes through the fan. This must be considered when designing the ductwork layout. An isolated motor compartment and adjustable pulleys offer flexible speed adjustment for final system balancing, but check the current load (amps) on the motor after each adjustment.



### Fan Selection

A fan should be selected based upon a variety of criteria. First, decide which type of fan is best suited for the application. Next, determine airflow requirements (see determining exhaust rate) and system static pressure (see ductwork and pressure loss). Third, consider the fan sound level. For example, for two fans that produce the same airflow rate, the fan with the larger fan wheel will be running at a lower RPM, thus producing less sound. A fan's sound level at various operating points can be obtained from the fan manufacturer and are given in either decibels or sones. Choose the appropriate voltage and phase for the power going to the motor.

Each fan has a set of fan curves based on airflow, system resistance, motor power, and fan speed. It is crucial to choose a fan within the limits given by the fan manufacturer on the fan curves. The curve that represents system resistance begins at the origin and has an increasing slope on the fan performance graph. The curve that begins at a higher static pressure at zero airflow and tapers to zero pressure with increasing airflow is the fan performance curve. This is a line of constant fan RPM. To find the correct fan, operating points must fall on the fan performance curve to the right of the system resistance curve.

## SAMPLE FAN SELECTION

Given the following information, **Figure 45** illustrates the properties of two fans that meet the criteria. However, it has yet to be determined which fan is better for this application. **Figure 46** will aid in that process.

Required Specifications:

1. Upblast Fan
2. 2500 cfm of airflow
3. 0.25 in. wg static pressure

Fan Manufacturer Data													
Model	Relative Cost	Volume (cfm)	Fan RPM	Tip Speed (ft./min)	OV (ft./min)	Operating Power (hp)	Motor Size (hp)	Opening Width (in.)	Opening Length (in.)	Weight (lbs.)	Baffle	dBA	Sones
1	1.19	2500	1260	6103.0	856	.88	1	20.5	20.5	125	No	66	14.7
2	1.35	2500	838	5375	665	.91	1	26.5	26.5	174	No	63	12.7

Figure 45

### Analysis and Selection:

Once airflow and static pressure have been determined from the hood calculations, this data can be entered into the manufacturer's fan selection guide. **Figure 45** represents two possible fans to select from. Usually more fans are available to choose from, but only two are represented to simplify this example. From the manufacturer's data, choose a fan based on these categories. **Relative cost:** a lower relative cost is always a better choice. **Operating power vs. motor size:** make sure the operating power does not exceed the size of the motor. **Sones or decibels:** used to measure the sound of the fan while operating. A lower sound level (lower number) is usually desirable. **Tip speed or Fan RPM:** represents how fast the fan is turning. A slower turning fan wheel is usually quieter. The volume (CFM) will be set where specified.

More importantly, pick a fan based on the fan curves using **Figures 46**. Curve A represents the system resistance curve. Think of this curve as a boundary. A fan will be unstable while operating to the left of this curve. Curve B represents where the fan will operate given the operating conditions. Curve C is the fan performance curve at a given RPM. Where curve B and C intersect is the operating point and any fluctuation in the system will cause the fan to vary its operating point along Curve C. For example, if static pressure increases in Model 1, Curve B will shift towards Curve A. That is why it is important to select Model 1 over Model 2. Fan Model 1 has room to account for system variances where Model 2 can only see a small increase in static pressure before the fan becomes unstable. It is also beneficial to choose a fan operating on a greater Curve C slope. Model 1 operates on a greater Curve C slope. Model 1 can see a greater static pressure increase than Model 2 before going unstable. The dashed line represents brake horsepower.

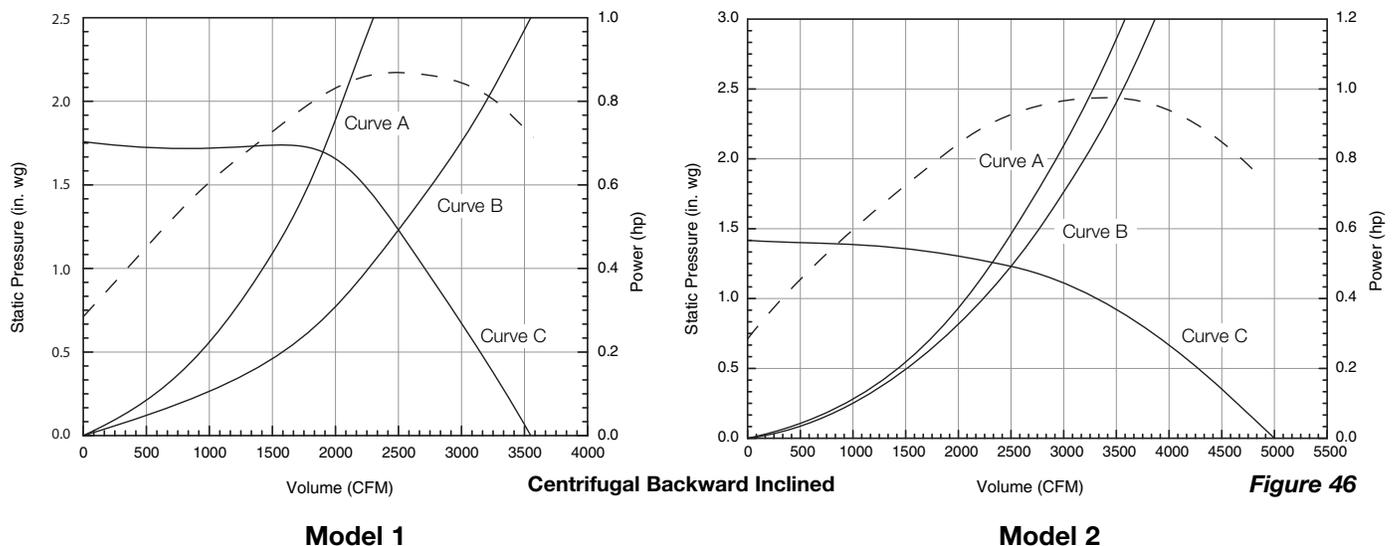


Figure 46

## UNIT SELECTION: MAKE-UP AIR SELECTION

The purpose of make-up air, supply air, and several ways to introduce it were thoroughly discussed in an earlier section of this guide. There are several types of make-up air units (MUA) used to bring supply air into the building that will be discussed in this section.

### Types of Make-Up Air

**Untempered** — The unit introduces outside air directly into the building without heating or cooling it. These units have a low up-front cost, use less energy to operate, and are often ideal for tempered climates that remain comfortable most of the year.



### Heating

**Direct Gas** — The most common units, especially in the northern half of the United States, are the direct gas-fired units. These units provide outside air that is usually untempered in the summer months and heated in the fall, winter, and spring months. They have an operating efficiency of nearly 100% because the flame is directly in the airstream. Some efficiency is lost in the combustion process. A temperature sensor is set in the unit to regulate the heating cycle. Direct gas-fired units move the air directly over a burner to obtain the desired leaving air temperature. A unit that is running too slowly is likely to introduce unwanted by-products into the building airstream.

Fortunately, many manufacturers have the ability to operate their units at 70-50% of the total airflow. A modulating damper at the inlet maintains a minimum airflow velocity of 3000 fpm across the burner. It is important to verify the heat and airflow turndown with the manufacturer to prevent costly redesigns.

**Indirect Gas** — Similar to direct gas-fired, indirect gas-fired units also heat the air when needed or otherwise bring in untempered outdoor air during warm months. This process uses a heat exchanger which is 80% efficient. Gas is fired through a clamshell or S-tube heat exchanger. Heat is then transferred to the air as it passes over the clamshell or tubes while combustion by-products are vented to the outdoors.

**Steam Coil** — Air reaches its leaving temperature by flowing over steam-heated radiator coils. Steam from a boiler system can be tied into a series of coils in a make-up air unit. This allows the use of steam in heating air during cold periods.

**Hot Water** — Hot water can be used similar to a steam coil but is uncommon in kitchen applications.

**Electric Heating** — Electric-heating coils can be placed in a heater control cabinet on a make-up air unit to provide heat during cooler periods of the year. However, electric heat can be costly.

### Cooling

**Direct Expansion** — This method of cooling utilizes refrigerant gas in a cooling coil. Air is cooled as it travels across the coil. This method is commonly used with direct gas-fired and indirect gas-fired units when both heating and cooling is desired.

**Evaporative Cooling** — Evaporative cooling is inexpensive and works well in areas that are hot and dry. The hot, dry air is passed through a moistened media and cooled using the principle of evaporation. Heat is needed to cause evaporation, thus heat is pulled from the hot air passing over the media. This is an easy addition to any make-up air unit to provide inexpensive and efficient cooling.

**Chilled Water Coil** — Just the opposite of the hot water coil, chilled water runs through a set of coils cooling the air as it passes over them. An easy and relatively inexpensive option if already using chilled water cooling to condition a building.

In many cases, heating is required more often than both heating and cooling. Additionally, a building may have an air conditioning system already in place that can supply enough cool air to the kitchen during warm days eliminating the need for cooling. However, heating and cooling options can be combined into one make-up air unit. It is best to consult the manufacturer for a full list of heating and cooling options.

## Selecting and Customizing

The 3 steps to selecting a base make-up air unit include:

1. Determine required tempering options. If required, decide which type of heating and/or cooling.
2. Determine required supply airflow.
3. Determine external static pressure.
4. Select the proper motor voltage for the application.

There are many different options to accessorize the unit, but the three steps above will aid in selecting the proper base model. Two of the most common accessories are filter choices and combination curbs. Different manufacturers offer a choice of filter type to be used on the inlet of the make-up air unit. Consider efficiency, cost, durability, and the ability to clean when choosing the proper filter for an application. It is usually wise to consider a combination curb if possible when selecting make-up air unit ducts. Combination curbs offer the benefit of requiring only one roof penetration for the supply and exhaust ducts. In this case, it is important to ensure enough roof space such that the inlet of the make-up air unit is able to be mounted 10 ft. from the exhaust fan outlet per NFPA 96 standards. **Figure 47** shows an example of a typical commercial kitchen make-up air unit given the following information.

Required Specifications:

1. Direct gas-fired make-up air unit
2. 2000 cfm of airflow
3. 0.25 in. wg static pressure (external)

Make-Up Air Manufacturer Data											
Model	Volume (cfm)	Ext. SP (in. wg)	Total SP (in. wg)	Fan RPM	Operating Power (hp)	Motor Size (hp)	Heat LAT (°F)	Htg. Input (MBH)	Htg. Output (MBH)	dBA	Sones
1	2000	.25	.989	1214	.89	1	70	208.3	191.7	67	14.7
2	2000	.25	.912	786	.55	.75	70	208.3	191.7	63	11.8

Figure 47

Make-Up Air units must be selected based on the power of the motor, the fan speed, static pressure, sound level, and fan performance curves (**Figure 48**). Volume and static pressure are determined from the system and drive fan selection. Make sure the motor operating power does not exceed the motor size. Choose a fan that will be quiet (lower sones or decibels), but above all, be sure to look at the fan curves. Curve B must fall to the right of Curve A, otherwise instability will occur. Curve A represents the boundary for the fan, Curve B shows where the fan is operating given the operating conditions, and Curve C represents fan performance at a particular fan speed. Choose a fan where Curve B falls far to the right of Curve A (Model 1). Curve B for Model 2 falls too close to the fan boundary (Curve A), thus a system variation may cause the fan to become unstable. The dashed line represents fan brake horsepower. These curves differ from the exhaust fans (**Figures 48**) because a forward inclined fan wheel is used for make-up air units.

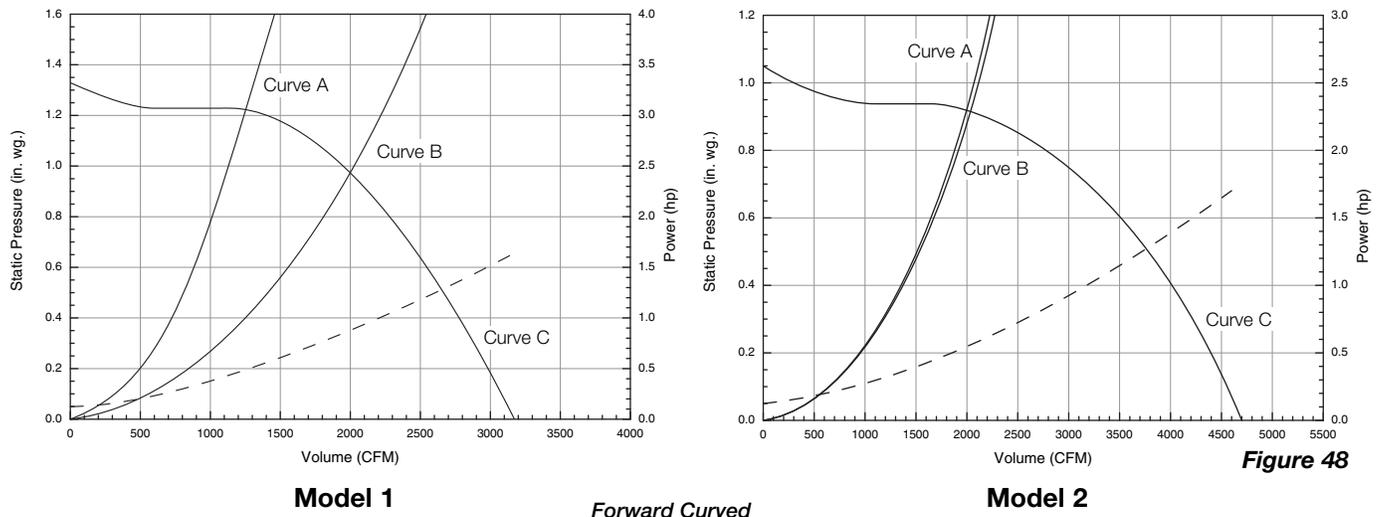


Figure 48

## DUCTWORK AND PRESSURE LOSSES

### General Requirements

Commercial kitchen exhaust ductwork for a TYPE I kitchen hood is much different from regular building ductwork. This ductwork carries hot, grease laden air out of the building. For this reason, these types of ducts are subject to strict standards through NFPA 96. Some general guidelines are as follows:

- Use 16 gauge carbon steel or 18 gauge stainless steel (minimum thickness)
- All joints and seams to be fully-welded and liquid tight
- Ductwork shall lead directly to the building exterior
- Follow clearance to combustibles (see Glossary on page 48)
- Minimum airflow of 500 fpm through ductwork
- Ductwork shall not be interconnected with any other type of building ductwork
- To prevent accumulation of grease in horizontal ductwork, cleanout ports are required every 20 feet, and the duct should slope towards the hood 0.25 inches every foot for duct runs under 75 feet. Runs greater than this require a slope of 1 inch per foot.

Note: These are only a few of the requirements; NFPA 96 and local codes should be consulted before duct design. Type II kitchen hoods use regular ductwork and do not follow these guidelines.

### Design

A consideration when designing ductwork is finding the optimum flow rate through the duct. This is done to reduce grease particles from settling in the ductwork. Hood exhaust flow rate (cfm) should be known from the hood selection process, therefore duct size can be calculated. Choose a duct velocity between 1000 and 2000 fpm and use Eq. 1-3 to determine duct areas and velocities. Duct velocities above 2000 fpm create unwanted noise and duct sizes are too large for velocities below 1000 fpm.

$$\text{Eq. 1} \quad \left( \frac{\text{CFM} * 144 (\text{in}^2 / \text{ft}^2)}{\text{Duct Velocity (fpm)}} \right) = \text{Duct Area (in}^2)$$

$$\text{Eq. 2} \quad \text{Duct Area (ft}^2) = \left( \frac{\text{Duct Height (inches)} * \text{Duct Width (inches)}}{144 (\text{inches}^2 / \text{ft}^2)} \right)$$

$$\text{Eq. 3} \quad \text{Duct Velocity (fpm)} = \left( \frac{\text{Airflow (cfm)}}{\text{Area (ft}^2)} \right)$$

### Duct Pressure Loss

The largest consideration in duct design is pressure loss. Pressure loss through the hood, filters, and duct collars are determined experimentally and given by the hood manufacturer. **Pressure loss for straight galvanized duct runs with a velocity of 1500 fpm and an area of 1.5 sq. ft. may be assumed to be 0.0019 in. wg per foot of duct.** If further accuracy is desired, consult ASHRAE Handbooks. **Figure 50 and 51** list pressure losses through expansions and contractions, while **Figure 52 through 54** list pressure losses for various types of elbows and joints. Round elbows should always be used in place of mitered joints to reduce pressure loss. Total system pressure loss can be obtained by adding all losses in the system. Note, there may be more than one hood system per exhaust fan. Also note, standard air conditions were assumed for all pressure calculations.

### System Effects

System effects are losses that occur due to the design of duct systems. There is no good way to calculate the pressure loss associated with this phenomenon, but there are ways to prevent it. One of the largest contributors to system effects is an elbow just before termination into the exhaust fan. This elbow creates turbulence at the fan, causing fan performance to suffer. See **Figure 49**. A minimum distance of three fan wheel diameters must be between the bend and the fan inlet.

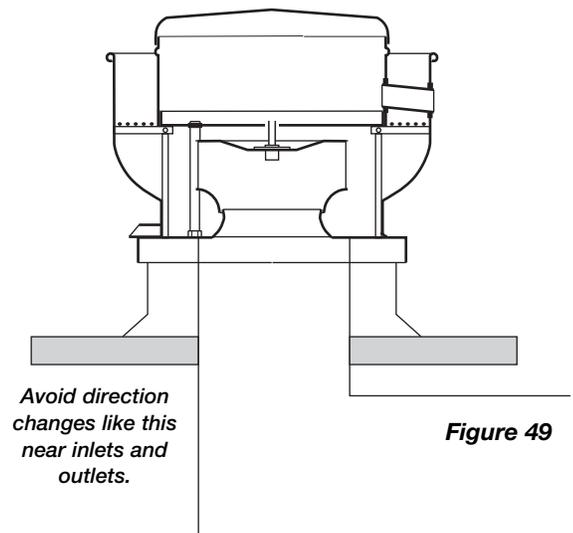


Figure 49

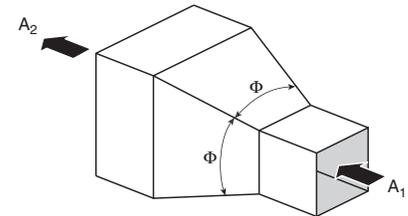
## Pressure Loss of Duct Components

To determine pressure loss in a duct system, the pressure losses in each part of the duct must be known. This section contains the pressure losses (in. wg) for a few common types of ductwork joints and connections. Most joints must be sized in order to achieve an accurate pressure loss. A simple area ratio, angle of a bend, or radius of a curve must be determined in order to calculate pressure loss. Use the dimensions of the figures to determine pressure loss from the tables. These Figures assume a duct velocity of 1500 fpm. Pressure loss changes with duct velocity, therefore, Eq. 2 can be used to adjust the pressure loss according to the actual duct velocity. Determine the pressure loss from the table at 1500 fpm and insert the new velocity into the equation. See duct example on page 38.

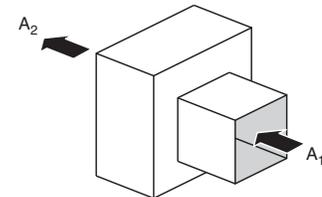
$$\text{Eq. 4} \quad \left( \frac{\text{New Velocity (fpm)}}{1500 \text{ fpm}} \right)^2 * \text{Loss from Table (in. wg)} = \text{New Pressure Loss (in. wg)}$$

Expansion and Contraction joints are used to change the duct velocity by increasing or decreasing the duct size. To determine pressure loss, find the area of the duct on both sides of the joint, then find the ratio of the areas. Determine the angle of the transition, then use the table to find the pressure loss.

Expansion Loss (in. wg) @ 1500 feet per min								
	$\phi$							
$A_2/A_1$	16	20	30	45	60	90	120	180
2	0.0253	0.0309	0.0351	0.0407	0.0435	0.0449	0.0463	0.0421
4	0.0505	0.0603	0.0702	0.0786	0.0856	0.0884	0.0884	0.0884
6	0.0589	0.0659	0.0814	0.0954	0.1010	0.1066	0.1066	0.1052
10	0.0589	0.0687	0.0828	0.0982	0.1122	0.1221	0.1193	0.1207



Gradual Expansion

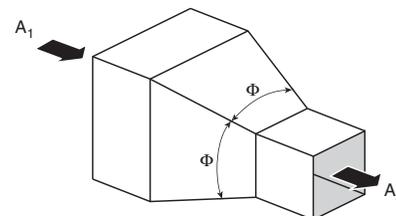


180° Expansion

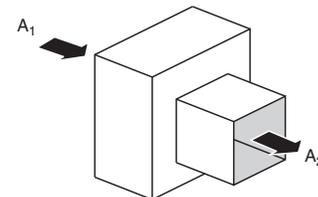
Figure 50

### Duct Expansions

Contraction Loss (in. wg) @ 1500 feet per min							
	$\phi$						
$A_2/A_1$	10	15-40	50-60	90	120	150	180
2	0.0070	0.0070	0.0600	0.0168	0.0253	0.0337	0.0365
4	0.0070	0.0056	0.0700	0.0239	0.0379	0.0491	0.0575
6	0.0070	0.0056	0.0700	0.0253	0.0393	0.0505	0.0589
10	0.0070	0.0070	0.0800	0.0267	0.0407	0.0519	0.0603



Gradual Contraction



180° Contraction

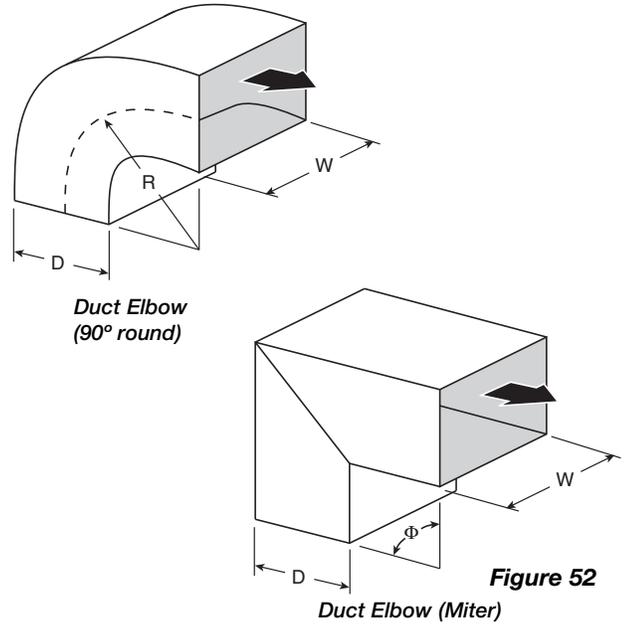
Figure 51

### Duct Contractions

The 90° elbow is a very common type of joint in duct systems. Determine the dimensions of the duct and the radius of the bend. Two ratios must be obtained, radius over depth (R/D) and the aspect ratio, width over depth (W/D). Use **Figure 52** along with the ratios obtained to determine pressure loss. Joints with no radius are called Miter Joints.

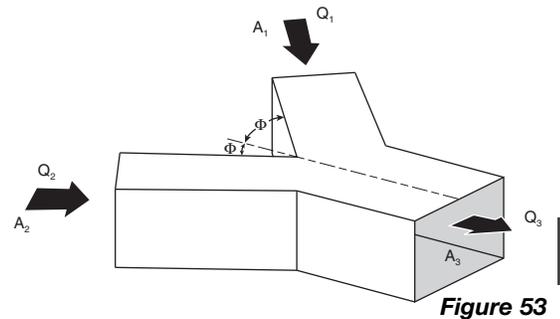
Elbow Losses (in. wg) @ 1500 feet per min						
	Aspect Ratio (W/D)					
R/D	0.25	0.50	1.00	2.00	3.00	4.00
Miter	0.2105	0.1852	0.1613	0.1459	0.1291	0.1207
0.5	0.1908	0.1698	0.1473	0.1333	0.1179	0.1108
1	0.0631	0.0393	0.0295	0.0295	0.0281	0.0267
1.5	0.0393	0.0253	0.0182	0.0182	0.0168	0.0168
2	0.0337	0.0210	0.0154	0.0154	0.0140	0.0140
3	0.0337	0.0210	0.0154	0.0154	0.0140	0.0140

Use Figure 52 for dimensions.



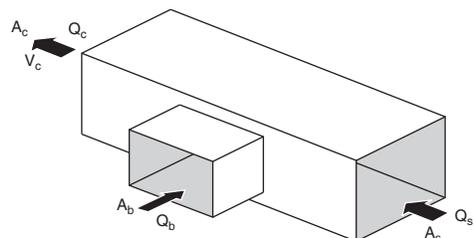
Pressure Loss in a Y-Type Connection (in. wg)											
	$Q_a/Q_c$ or $Q_b/Q_c$										
$\phi$	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
15	-0.3718	-0.2717	-0.1859	-0.1101	-0.0429	0.0143	0.0586	0.0958	0.1216	0.1387	0.1430
30	-0.3003	-0.2145	-0.1430	-0.0758	-0.0143	0.0400	0.0987	0.1301	0.1573	0.2002	0.2288
45	-0.1859	-0.1330	-0.0787	-0.0229	0.0286	0.0801	0.1316	0.1802	0.2288	0.2860	0.3289

A Y-Type connection is used to bring two ducts into one. It is often used to combine two hood systems or two duct collars to one duct branch. First, determine the flow rate of the two branches  $Q_1$  and  $Q_2$  (cfm). Add the two to get  $Q_3$ . Divide  $Q_1$  by  $Q_3$  to obtain a ratio. Then determine the angle of the branches. Select a pressure loss from the table using the ratio and the angle of the branches.



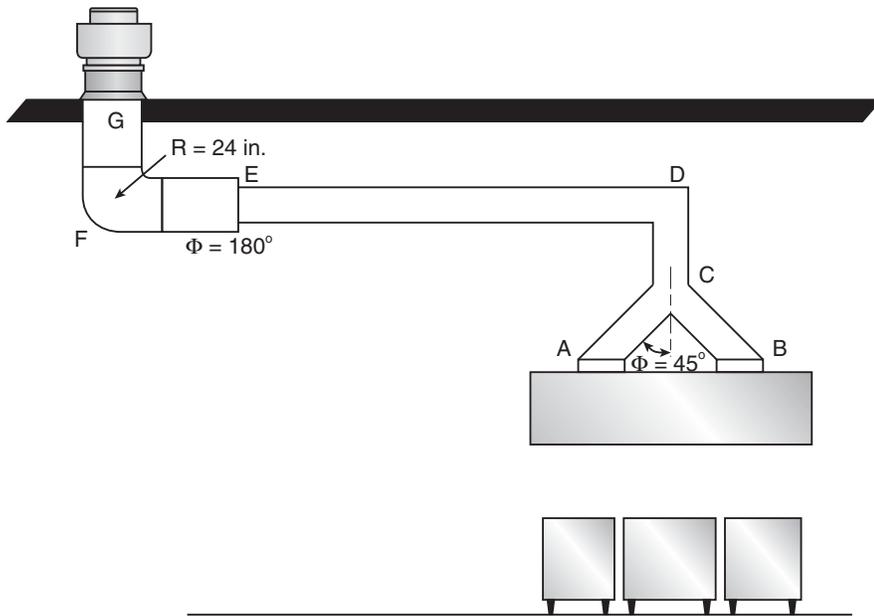
Pressure Loss in a Tee-Type connection (in. wg)										
	$Q_b/Q_c$									
$V_c$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
<1200	-0.1052	-0.0744	-0.0042	0.0463	0.1445	0.1543	0.3016	0.4111	0.5865	0.6706
>1200	-0.0968	-0.0295	0.0323	0.0940	0.1642	0.2329	0.3746	0.4714	0.5514	0.7197

A tee-type connection is for ducts running into other ducts. Such a connection could be made between two hoods or for hoods with multiple duct collars.  $V_c$  represents the velocity of the combined airstreams in fpm.  $Q_b$  represents the airflow connecting to the main duct run, and  $Q_c$  represents the combined airflow in the main duct run after the airflows have combined.



Note: Assumes  $A_b/A_c=0.5$  and  $A_s/A_c=1$  **Figure 54**

## Exhaust Duct Pressure Loss Example



### Duct System Key

Hood: 3000 cfm,  $P_s=0.55$  in. wg

- A 10 x 12 Duct Collar
- B 10 x 12 Duct Collar
- C Y-Type Connection
- D 90° Elbow (Miter)
- E 180° Expansion
- F 90° Elbow
- G Fan Inlet

Total length of ductwork = 40 ft

## Duct Sizing

### Hood:

- 3000 cfm, 2 duct collars 10 in. x 12 in. each
- 3000 cfm / 2 ducts = 1500 cfm per duct
- Use Eq. 3 to find the area of a 12 in. x 10 in. duct collar :  $\left( \frac{(12 \text{ inches} * 10 \text{ inches})}{144 (\text{inches}^2/\text{ft}^2)} \right) = 0.833 \text{ ft}^2$
- Use Eq. 2 to find duct collar velocity:  $\left( \frac{1500 \text{ cfm}}{0.833 \text{ ft}^2} \right) = 1800 \text{ fpm}$

### Determine Main Duct Sizes

#### Duct Run from D to E: Total CFM = 3000 cfm

- Duct size out of Y-Type Connection is 12 in. x 20 in. Maintain duct dimension
- Use Eq. 3 to find area:  $\left( \frac{(12 \text{ inches} * 20 \text{ inches})}{144 (\text{inches}^2/\text{ft}^2)} \right) = 1.666 \text{ ft}^2$
- Check duct velocity using Eq. 2:  $\left( \frac{3000 \text{ cfm}}{1.666 \text{ ft}^2} \right) = 1800 \text{ fpm}$

#### Duct Run from E to G: Total CFM = 3000

- Lower duct velocity by adding an expansion joint
- Arbitrarily choose a duct velocity: 1000 fpm
- Use Eq. 1 to determine duct size:  $\left( \frac{3000 \text{ cfm} * 144 (\text{in}^2 / \text{ft}^2)}{1000 \text{ fpm}} \right) = 432 \text{ in}^2$
- Choose one dimension of the duct: 24 inches. Divide the duct area by the chosen dimension:  $432 \text{ in}^2 / 24 \text{ in.} = 18 \text{ in.}$  Therefore, the duct dimensions will be 18 in. x 24 in.
- The new duct area will be:  $\left( \frac{(18 \text{ inches} * 24 \text{ inches})}{144 (\text{inches}^2/\text{ft}^2)} \right) = 3 \text{ ft}^2$

**Pressure Loss** (⇒ Represents values retrieved from tables)

$$\text{Rectangular Duct Loss} = \text{Duct Length} * \text{Loss per foot: } 40 \text{ feet} * 0.0019 \frac{\text{in. wg}}{\text{ft}} = \mathbf{0.076 \text{ in. wg}}$$

$$\text{Hood } P_s = \mathbf{0.550 \text{ in. wg}}$$

**Joint C: Y-Type Connection Joint**
*Reference Figure 53*

- Area A = Area B, Area C = 2 \* Area A
- $\phi = 45^\circ$ ,  $\frac{Q_1}{Q_3} = \frac{1500 \text{ cfm}}{3000 \text{ cfm}} = 0.5 \Rightarrow \mathbf{0.0801 \text{ in. wg}}$
- Since Area C = 2 \* Area A : duct size above Y-Type Connection is 12 in. x 20 in.

**Joint D: 90° Elbow Joint**
*Reference Figure 52*

- Duct dimensions are: W=20 inches, D=12 inches (determined by Y-Type Connection)
- $\frac{R}{D} = \frac{0}{12} = 0$  (Miter),  $\frac{W}{D} = \frac{20}{12} = 1.666 \approx 2 \Rightarrow 0.1459 \text{ in. wg}$
- Correction for duct velocity of 1800 fpm:  $\left(\frac{1800 \text{ fpm}}{1500 \text{ fpm}}\right)^2 * 0.1459 \text{ in. wg} = \mathbf{0.2101 \text{ in. wg}}$

**Joint E: 180° Expansion Joint (use areas calculated previously)**
*Reference Figure 50*

- $\phi = 180^\circ$ ,  $\frac{A_2}{A_1} = \frac{3 \text{ ft}^2}{1.666 \text{ ft}^2} = 1.8 \approx 2 \Rightarrow 0.0421 \text{ in. wg}$
- Correction for duct velocity of 1800 fpm:  $\left(\frac{1800 \text{ fpm}}{1500 \text{ fpm}}\right)^2 * 0.0421 \text{ in. wg} = \mathbf{0.0606 \text{ in. wg}}$

**Joint F: 90° Elbow Joint**
*Reference Figure 52*

- $\frac{W}{D} = \frac{24 \text{ inches}}{18 \text{ inches}} = 1.333 \approx 1$ ,  $\frac{R}{D} = \frac{24 \text{ inches}}{18 \text{ inches}} = 1.33 \approx 1$  (use worst case)  $\Rightarrow 0.0295 \text{ in. wg}$
- Correction for duct velocity of 1000 fpm:  $\left(\frac{1000 \text{ fpm}}{1500 \text{ fpm}}\right)^2 * 0.0295 \text{ in. wg} = \mathbf{0.0131 \text{ in. wg}}$

**Total Pressure Loss**

$$(0.076 + 0.55 + 0.0801 + 0.2101 + 0.0606 + 0.0131) \text{ in. wg} = \mathbf{0.9899 \text{ in. wg}}$$

## UTILITY DISTRIBUTION SYSTEMS

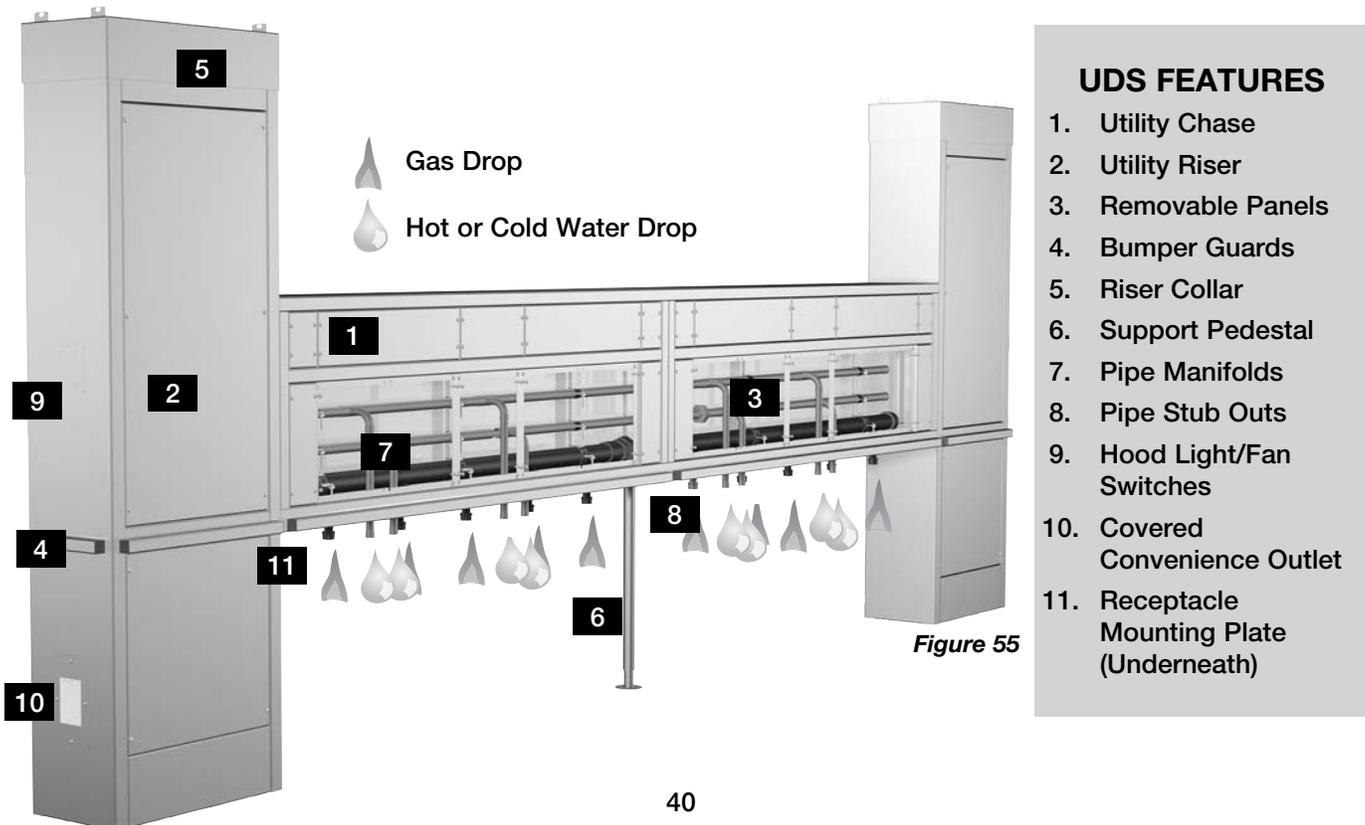
### Utility Distribution System

A Utility Distribution System (UDS) is a pre-engineered delivery system for the cooking equipment's utilities. It eliminates custom designed contractor built walls to bring the utilities to the cooking appliances. To build a contractor wall, engineers and consultants have to work together to design the utilities into the wall dependent on the cooking line-up. Plumbing, electrical and general contractors all have to work together to install the utility wall. Custom built utility walls are built for a specific cooking line-up and require hours of coordination to be built in the field. If that line-up changes, the electrical and plumbing have to be changed to accommodate for the new line-up.

Greenheck's FlexConnect™ UDS provides ¾ inch hot and cold water drops every 24 inches and alternating ¾ inch and 1¼ inch gas drops every 12 inches. The owner might not need all of these drops immediately, but if changes to the cooking line are made due to menu or staff preferences, FlexConnect has the extra utility drops designed into the system. This built-in flexibility allows equipment changes as needed throughout the restaurant's life without costly re-piping charges. Equipment can be moved as needed, anytime, anywhere without the headache. With a contractor built wall, changes to the cooking line become cost prohibitive and difficult with wall penetrations and multiple trade involvement. Disconnects and outlets allow the cooking equipment to be easily moved for cleanup and inspections. Convenience duplex outlets are placed in every riser providing the flexibility to use other electrical equipment. Greenheck's UDS is manufactured of 16 gauge 304 stainless steel to provide superior strength. With a contractor built wall, outlets are often inaccessible, and utility outlets are difficult to clean around often trapping dirt and grease. Contractor built walls are built of drywall and wood studs which hold moisture and may cause health risks in the kitchen.

Incoming services are brought in through the two vertical risers, either dropping from the ceiling or extending up through the floor. Each service has its own compartment within the unit. Water and gas services can be plumbed in the riser with main service shut-off valves that allow one final connection in the field. Mechanical or electrical emergency shut off valves can also be installed for the gas service. Depending on the cooking equipment, looped gas can be used if the unit is longer than 20 feet.

A UDS is classified as a kitchen appliance with a 7 year depreciation life. A contractor built wall has a depreciation life of 31 years. When the customer's lease has ended, a UDS can be removed from the premises for use in another location. A contractor built wall is a leasehold improvement. If a move is made to a new location, another wall must be built. UDS systems have been pre-tested and approved as a code compliant appliance, thus installation and inspection are quickly completed.



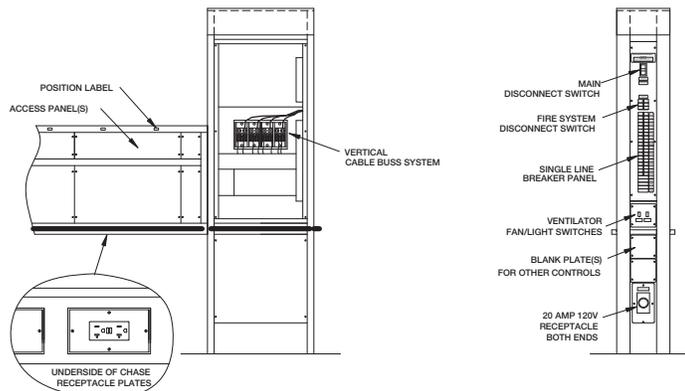
Greenheck's FlexConnect™ UDS is available in four different options; base unit, receptacle only (Electrical option 1), a complete wiring (Electrical option 2), and custom units. FlexConnect™ base and optional equipment packages allow for fast lead times and lower prices while custom units can be designed to meet any need.

### FlexConnect™ Design Options

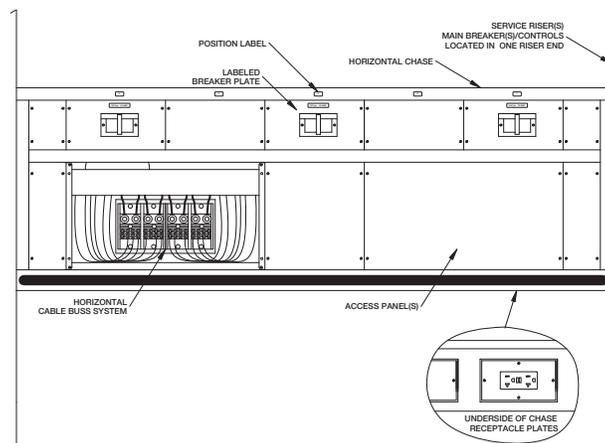
1. **Base Unit** — This unit includes plumbing for gas and water service. **No electrical package, but unit can be field wired by the electrical contractor.** To design this system the following must be provided: Desired UDS length, hood hanging height, and if plumbing accessories are required, provide appliance requirements (gas and water ball valve sizes).
2. **Electrical Option 1** — Base unit with receptacles every 12 inches along the bottom of chase. They are sized to the cooking equipment but are not wired. **Field wiring is required by electrical contractor.** To design this system the following must be provided: Desired UDS length, hood hanging height, appliance requirements (gas and water ball valve sizes, voltage, amps, phase).
3. **Electrical Option 2** — Base unit with receptacles fully wired to either a panelboard or point of use electrical system. To design this system the following must be provided: Desired UDS length, hood hanging height, appliance requirements and location (gas and water ball valve sizes, voltage, amps, phase).

Optional equipment for FlexConnect™ units:

- Ball valves for plumbing
- Gas restraining devices
- Cord and plug set
- Main and fire disconnect breakers
- Hoses and quick disconnects
- Pressure gauges
- Mechanical gas valve
- Superswivel for gas hoses



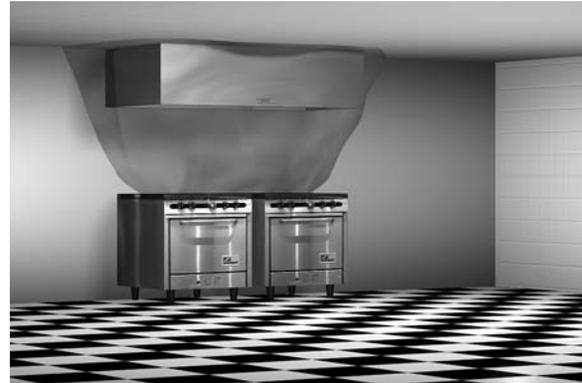
Elevation view of typical FlexConnect™ system with panelboard



Elevation view of typical FlexConnect™ system with point of use breakers

## DESIGN CONSIDERATIONS

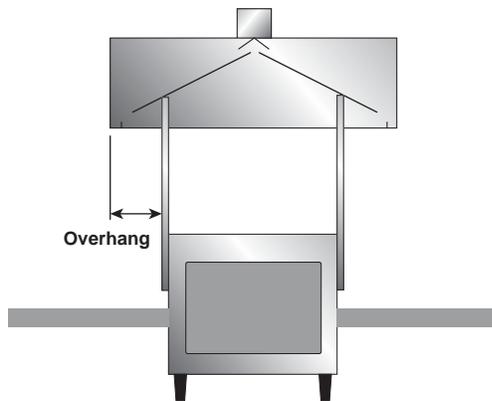
When designing a kitchen ventilation system, there are a number of ways to enhance hood performance. Even though many of these considerations are not required, it is still a good idea to make sure the system being designed meets these considerations.



### 1 & 2. Overhang Requirements

- A minimum overhang of 6 inches is required by code
- Increase the overhang for heavy duty cooking appliances

- Increasing overhang increases hood performance
- Add a free foot area (See [page 11](#))
- Insufficient overhang results in poor capture and additional heat gains in the kitchen



Recommended Overhang (Units in Inches)			
	Front	Sides	Back
Combi Oven	18	6	-
Dishwasher	18-24	6	18
Equipment Under Wall Canopy	12	6	-
Equipment Under Single Island	12	12	12
Equipment Under Double Island	12	12	-

### 3. Dishwasher Overhang

- 12 inches minimum overhang on sides with doors
- Spilling may occur when dishwasher door is opened
- 18 inches is recommended to minimize spillage

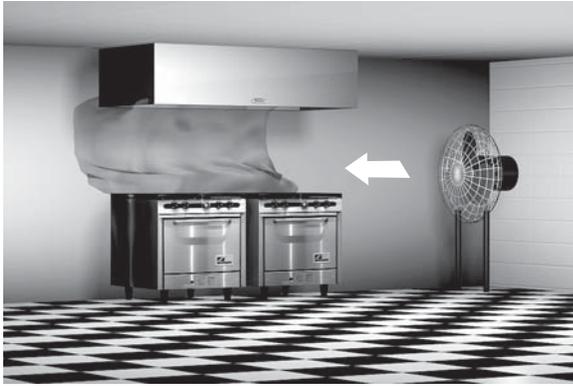


### 4. Hood Hanging Height Affects Capture and Containment:

- 6 ft. 6 in. (78 inches) recommended
- 7 ft. 0 in. (84 inches) allowed but requires more overhang or more exhaust airflow
- Higher hanging heights may create problems

### 5. Extraneous Air Currents can have enough force and velocity to push the contaminated air out from under the hood:

- Keep air currents to a minimum. NO fans for spot cooling.



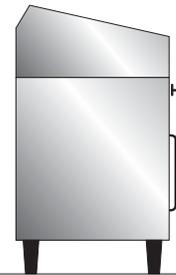
**6. Cross Drafts**

- The use of portable fans to improve employee comfort should be avoided



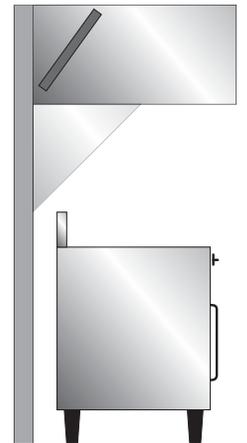
**8. End Skirts**

- End skirts are strongly recommended
- Enhance capture and containment
- Reduces the effect of cross-drafts and equipment surges
- Full end skirts reduce overhang requirements and required exhaust airflow



**7. Cooking Equipment Extensions**

- Extensions or deflectors can dramatically improve capture and containment
- Works especially well on island configurations

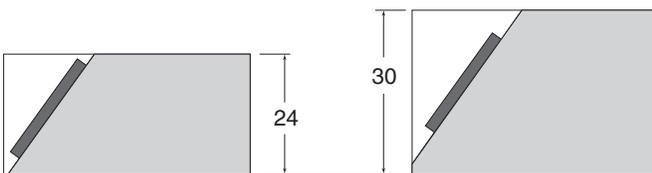


**9. Full End Skirts**

Installed on a well balanced system can reduce exhaust airflow up to 10%.

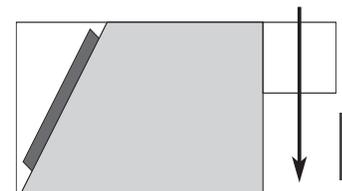
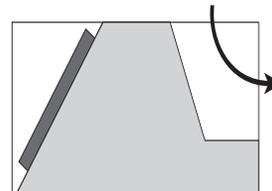
**Mini Skirts**

Installed on a well balanced system can reduce exhaust airflow up to 8%.



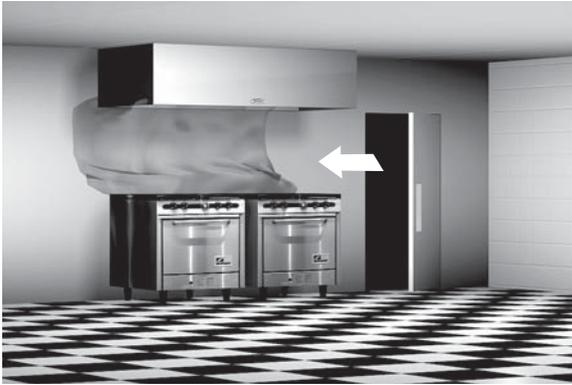
**10. Hood Volume: 24 inches vs. 30 inches**

- 30 inches provides a larger capture tank for surges
- Most important over char-broilers



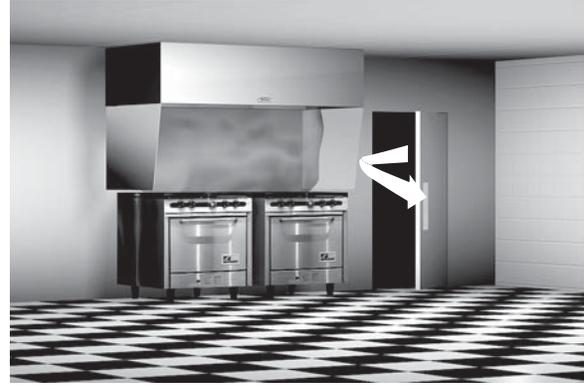
**11. Internal Supply Plenum vs. Exhaust Only**

- Exhaust only has a larger capture tank for surges
- Use exhaust only with external supply plenums
- Most important over char-broilers



**12. Open Doorways**

- Cause capture problems in the hood due to cross drafts



**13. Utilizing Endskirts in Doorways**

- Installing mini or full end skirts can reduce the effects of the cross drafts caused by open doorways



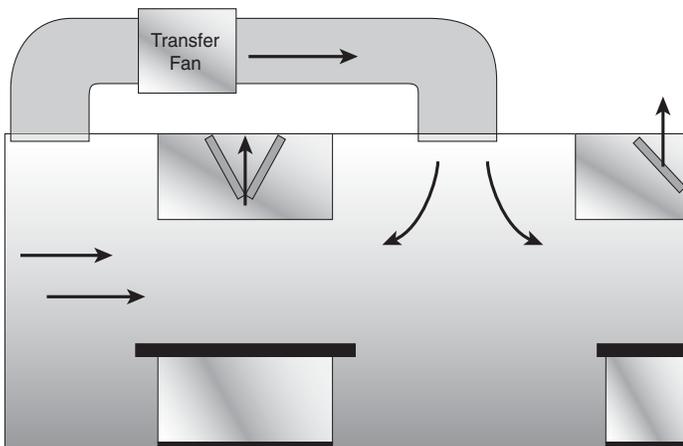
**14. Door Swing Direction**

- Moving hinges to the opposite side of the door may be a simple and economic way to improve hood capture



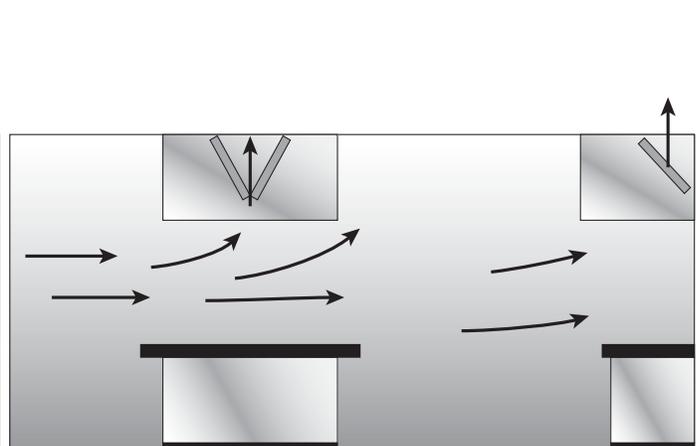
**15. Partition Walls**

- Adding a partition between the door and the hood can improve hood capture



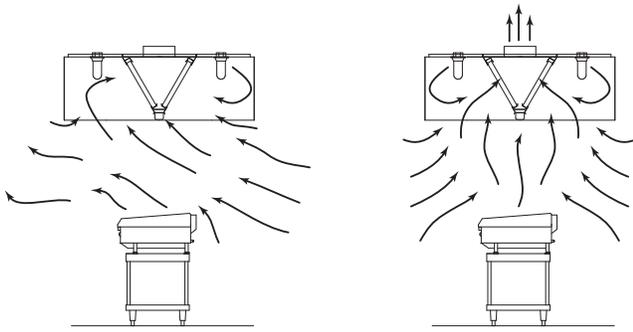
**16. Even Supply Air Distribution**

- Supplying air equally from all sides of the hood will enable efficient capture and containment



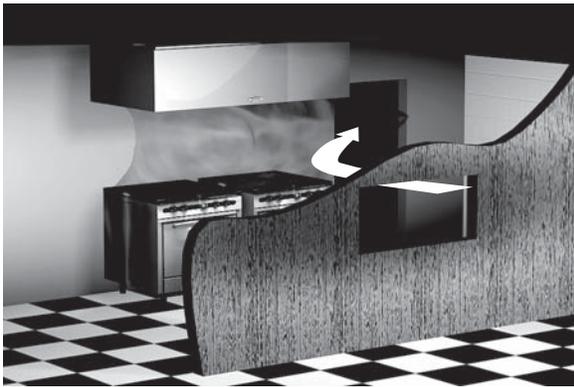
**17. Uneven Supply Air Distribution**

- As illustrated, uneven supply air will induce spilling



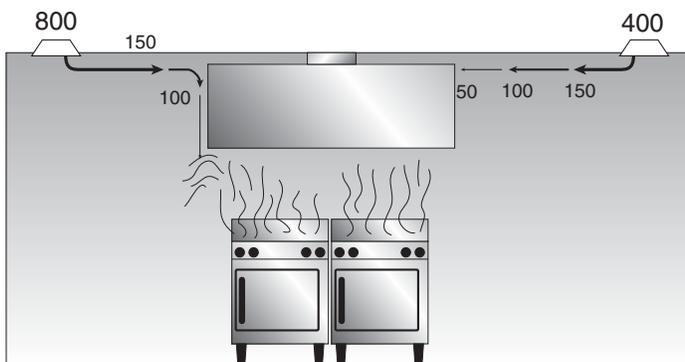
**18. Even Supply Air**

- Bringing in supply air evenly on all sides of the hoods will enable capture and containment at lower airflow



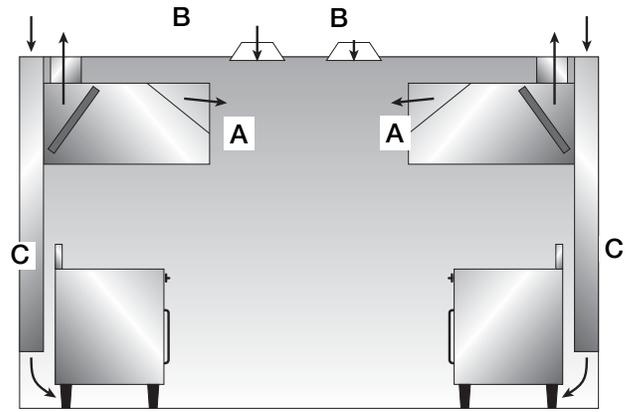
**20. Drive-Thru/Pass-Thru**

- Supplying sufficient make-up air will eliminate air currents through pass-thru and drive-thru windows.
- Keep airflow from pass-thru and drive-thru windows at 50 fpm maximum



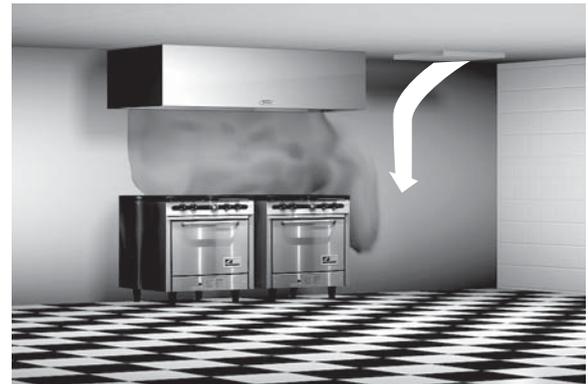
**22. 4-Way and Throw Distance**

- Keep the airflow below 75 fpm at the hood, although recommended to be at 50 fpm maximum



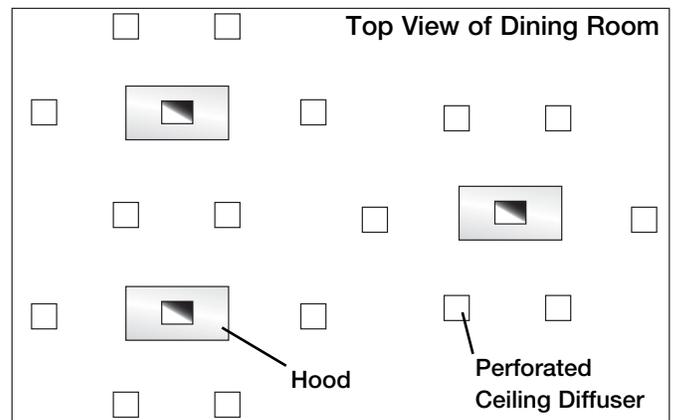
**19. Hoods Facing Each Other (avoid if possible)**

- If situation A occurs, use perforation in face
- Use B with perforation, no 4-way diffusers
- Along with B, use C (back supply plenum)



**21. 4-Way Diffusers (#1 Design Problem)**

- Locate 4-way diffusers at a minimum of 10 ft. from hood
- Perforated low throw or 3-ways will reduce capture problems



**23. Japanese Steak House (Show Cooking)**

- Hoods located in dining room, not in kitchen
- Use perforated ceiling diffusers throughout the entire dining area to reduce cross drafts

## APPENDIX: TROUBLESHOOTING

### ITEMS TO CHECK

### POSSIBLE SOLUTIONS

**Problem: Pilot lights are blown out or cooking equipment is cooled by make-up air**

Are there drafts from make-up air?	Try turning off or reducing the amount of make-up air; Block off portions of the supply to direct air away from the problem area (test with cardboard first); remove any obstructions in front of supply that directs air toward the cooking equipment
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**Problem: Cold air can be felt by the cook at the hood**

Is this a short-circuit hood?	Turn off or reduce the amount of air supplied to the short-circuit
Is this an air curtain hood?	Turn off or reduce the amount of air supplied to the air curtain; heat the supply air
Is the make-up air part of the hood or an attached plenum?	Try turning off or reducing the amount of make-up air; heat the supply air
Is the hood capturing?	Hood is not drawing enough air; refer to determining exhaust rate and design consideration to ensure proper design (pages 8 to 14)
Is this an air curtain hood?	Turn off or reduce the amount of air supplied to the air curtain ( <i>Figures 15-17</i> , page 16 and 17)
Is the make-up air part of the hood or an attached plenum?	Try turning off or reducing the amount of make-up air; Heat the supply air

**Problem: Grease is running off the hood**

Is there grease on top of the hood?	Exhaust duct is not correctly welded
Is the caulk missing or damaged?	Clean problem area and recaulk
Is the grease cup inserted properly?	Put grease cup back in place
Is the exhaust fan running in the correct direction?	See fan manufacturers instruction manual for proper direction/rotation
Are the filters in place?	Replace missing filters, slide them tight together
Is the hood over exhausting?	Slow down fan (See fan installation manual)

**Problem: Exhaust fan is not operating or is not operating at design levels**

Is the fan receiving power?	Replace fuses, reset circuit breakers, check disconnect
Is the belt loose or broken?	Replace or tighten belt
Is the fan rotating in the correct direction?	Have the electrician correctly wire the fan
Is the make-up air operating?	Problems with make-up air may interfere with exhaust fan - check the manufacturers installation manual and assume increases in pressure, decrease cfm
Does the airflow need to be increased?	Adjust or replace pulleys to increase fan speed, install a larger motor
Does the fan vibrate?	Clean the fan wheel/blade; replace fan wheel if damaged, check for loose bolts, check for broken or damaged components, check for rags and other foreign objects

**ITEMS TO CHECK**

**POSSIBLE SOLUTIONS**

**Problem: Cooking odors in the dining area**

Is the hood capturing?	Hood is not drawing enough air; refer to determining exhaust rate and design consideration to ensure proper design (pages 8 to 14)
Is there a cross draft through doors between the kitchen and dining area?	Decrease make-up air in the kitchen; increase exhaust air through hood

**Problem: Hood is full of smoke. There is smoke spilling out of the edges of the hood.**

Is the fan operating at design levels?	See determining exhaust rate and exhaust fan selection (pages 31 to 32)
Is the fan correctly sized?	Refer to test and balance report and compare with findings from the exhaust rate calculations
Are the filters in good condition?	Clean filters, replace damaged filters, and properly position them
Is there sufficient make-up air? (Kitchen should be a slight negative but not excessive; check to see if there is a strong draft through an open door)	Check make-up air unit, increase make-up air, ensure that make-up air is evenly distributed through the kitchen
Does the current cooking equipment battery match the original design?	Adjust or replace fan to match the cooking load
Are there multiple hoods on one fan?	One hood may be over exhausting and the other not drawing enough; restrict second hood using a balancing baffle to balance the airflow
Are there closed fire dampers in the duct?	Open fire dampers
Is the ductwork too complex or too small?	Replace fan that can handle higher static loads or modify the ductwork
Is the ductwork obstructed?	Clear obstruction
Is this a short-circuit hood?	Turn off or reduce the amount of air supplied to short circuit

**Problem: Smoke blows away before reaching the bottom of the hood**

Are there pass-thru windows near the hood?	Adjust the amount and locations of make-up air to eliminate drafts through the pass-thru windows
Is this an air curtain hood?	Turn off or reduce the amount of make-up air
Is the make-up air part of the hood or an attached plenum?	Try turning off or reducing the amount of make-up air; block off portions of the supply to direct the air away from the problem area. (test with cardboard)
Are there cooling fans directed at the hood or cooking equipment?	Turn off fans
Are there ceiling diffusers directing air at the hood?	Move diffusers to a more neutral area or replace with a diffuser that directs air away from the hood
Are there open windows or doors?	Close windows and doors
Are there cross drafts or other side drafts?	Find the source of the draft and eliminate it; consider adding end skirts to the hood (test with cardboard); increase overhang
Is the hood near a main walkway?	Add end skirts to the hood (test with cardboard first); increase overhang on spilling edges

## GLOSSARY

**Authority Having Jurisdiction (AHJ):** The organization, office, or individual responsible for approving equipment, installation, or a procedure in local jurisdictions.

**Backward Inclined:** A fan wheel with blades that lay back in the direction of rotation. That is, the edge of the blade closest to the center axis of rotation will pass a given point before the rest of the blade.

**Centrifugal Fan:** Fan which moves air away from the center of the wheel to the outer edge in a radial orientation.

**CFM:** A volume flow rate, cubic feet per minute.

**Char-Broiler:** An open grill with gas heated briquettes or electric strip heaters. Temperature rating 600°F.

**Clearance to Combustibles:** The airspace required between any hood surface and adjacent surfaces (walls, ceilings, etc.) See NFPA 96, IMC, and local codes for airspace requirements.

**Contaminated Air:** The unwanted by-products of cooking such as heated air, grease vapors, water vapor, smoke, gas combustion by-products and the air affected by these items.

**Centrifugal Action:** The act of using centrifugal force while spinning the air in a helical or corkscrew to separate solid particles from contaminated air.

**Exfiltration:** Air exiting a space due to positive pressure.

**FPM:** Feet per minute, defines the speed of the air.

**Fryer:** Kettles mounted in a floor or bench mounted unit heated by gas or electricity. Food is cooked by being immersed in a kettle full of heated oil. Temperature rating 400°F.

**Griddle:** A unit with a thick, flat, steel plate heated by gas or electricity for cooking by dry heat. Temperature rating 400°F.

**Hood Face Area:** The area of the hood, measured at the inside, lower canopy entrance, expressed in square feet.

**Inertial Impaction:** As grease laden air passes through a filter that causes a change in direction of the air, the grease is thrown out of the airstream and sticks to the filter upon impact.

**Interception:** As grease laden air passes through a bead bed filter, the particle contacts the filter media where upon impact the grease is collected while the rest of the air continues its path of travel.

**K-Class Fire Extinguisher:** Portable wet chemical fire extinguisher designed to suppress grease fires found in kitchens. It utilizes the same chemicals found in the fire suppression systems.

**Kitchen Ventilation System:** Hoods, fans, make-up air units, and other accessories that comprise the system for ventilating a kitchen.

**Minimum Capture Velocity:** The velocity of air in feet per minute required to contain smoke, grease vapors, steam, or heat.

**Minimum Face Capture Velocity:** The velocity of air in feet per minute required across the face of the hood to contain smoke, grease vapors, steam, or heat in the regions outside the updrafts.

**Oven:** A chamber used for baking, heating or drying foods. Temperature rating 400°F.

**Overhang:** The areas of the hood that project beyond the cooking equipment, measured from the internal perimeter of the hood.

**Payback Period:** The time for the annual savings to equal the initial cost of an investment.

**Proximity Hood:** Also referred to as a low wall or backshelf hood. Typically used for low to moderate temperature counter-height equipment.

**Qc:** Amount of contaminated air generated by a heated cooking appliance.

**Qf:** Amount of air required to contain sudden surges, cross drafts, and turbulence above and beyond Qc.

**Range:** A stove with spaces to cook several things at the same time. Temperature rating 400°F.

**Rate of Return:** The rate of earnings received above the initial cost of an investment compounding annually. (Usually expressed as a percentage)

**Schlieren Imaging:** An advanced visualization tool that allows the eye to see changes in air density such as the heat rising off of appliances.

**Solid Fuel:** Charcoal, wood, or other natural burning cooking sources. Temperature rating 700°F.

**Spilling:** The act of contaminated air escaping from a kitchen hood.

**Surges:** Large quantities of contaminated air generated by abnormal conditions.

**Thermal Updraft:** The upward movement of air due to a change in density. (Temperature drives density changes).

**Variable Volume:** A control system that varies the amount of airflow a kitchen ventilation system exhausts and makes up based on the cooking load.

**Wet Chemical Agent:** The suppression agent for wet chemical fire suppression system that suppresses fire by asphyxiating the fire. Usually made up of a solution of water and potassium carbonate-based chemical, potassium acetate-based chemical, potassium citrate-based chemical or a combination thereof that forms the extinguishing agent.

## QUICK REFERENCE GUIDE

	LIGHT	MEDIUM	HEAVY	EXTRA-HEAVY
Equipment (Greenheck's Appliance Classification)	Gas & Electric Ovens Gas & Electric Steamers Gas & Electric Ranges Food Warmers Pasta Cookers Pizza Ovens Non-Cooking Appliance Smoker Rotisserie	Combi-Ovens Gas & Electric Fryers Griddles Tilting Skillets Tilting Braising Pans Grill Hibachi Grill Salamander	Upright Broiler Electric Char-Broiler	Gas Char-Broiler Mesquite Infrared Broiler Lava Rock Char-Broiler Wok Chain Broiler
Greenheck Method (updraft velocity in feet per minute)	50	85	150	185
International Mechanical Code 2003 Edition (cfm per linear foot)	200	300	400	550

Appliance Classifications and Respective Updraft Velocities and Code Factors.

### GREENHECK METHOD

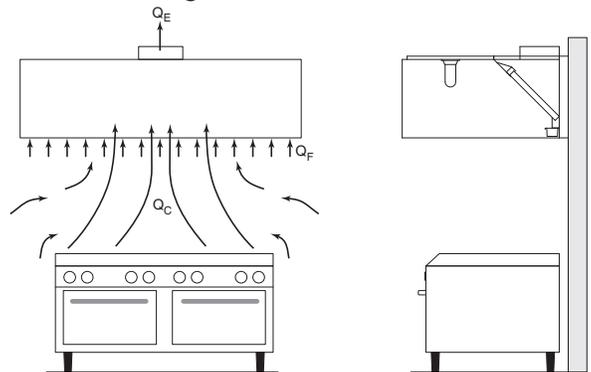
Steps 1 through 4 are the steps required to obtain the total exhaust rate using the Greenheck Method. See page 14 for an example calculation.

**1. The first step is to determine the appliance area (A)**

$$\text{Appliance Area} = \left( \frac{(\text{Length (inches)} * \text{Depth (inches)})}{144 \text{ inches}^2} \right)$$

OR

$$\text{Appliance Area} = \text{Length (feet)} * \text{Depth (feet)}$$



**2. The second step is to determine the quantity of contaminated air**

$$Q_C = \text{Area (feet}^2) * \text{Thermal Updraft Velocity (feet per minute)}$$

$Q_C$  - Quantity of contaminated air generated by the cooking equipment. Identify the appropriate updraft velocity and multiply it by the area of the appliance.

**3. The third step is to determine the quantity of air to contain surges including the free foot area consideration**

$$Q_F = (\text{Total Area of Hood less free foot} - \text{Total Area of Appliances}) * 50 \text{ fpm}$$

$$\text{Hood Area} = \left( \frac{(\text{Length (inches)} * \text{Width (inches)})}{144 \text{ inches}^2} \right)$$

OR

$$\text{Hood Area} = \text{Length (feet)} * \text{Width (feet)}$$

$Q_F$  - Quantity of air required to contain surges and drafts. Use the minimum updraft velocity of 50 fpm and multiply it by the difference in area between the hood containment area and the appliance area.

**4. The fourth step is to determine the total airflow volume**

$$Q_E = Q_C + Q_F$$

## QUICK REFERENCE GUIDE

### GREENHECK AIRFLOW VOLUME PER LINEAR FOOT (CFM/LINEAR FOOT)

HOOD TYPE	LIGHT	MEDIUM	HEAVY	EXTRA - HEAVY
Wall Canopy	200	250	350	450
Backshelf	150	200	300	N/A

*Note: 1. Double Island hoods are considered two wall canopy hoods  
 2. Single Island hoods need to be multiplied by the hood factor after using the wall mounted canopy value*

#### Limits and Assumptions

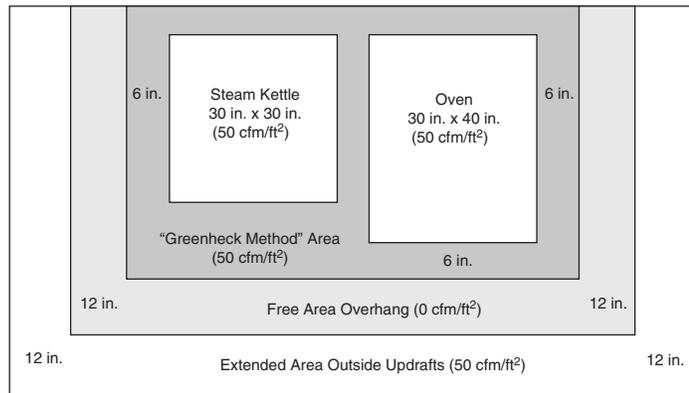
*(for cfm per lineal foot calculations)*

1. Used for hoods 54 in. or less in width
2. Cannot be used for pizza ovens
3. Cannot be used for cook chill
4. 6 ft - 6 in. hanging height
5. Vertical updrafts
6. Proper room ventilation
7. Proper overhangs

***This method is appliance specific.  
 See page 15 for an example calculation.***

### FREE FOOT AREA CONSIDERATION

The free foot area consideration allows the size of the hood to be increased by up to 12 inches beyond the minimum 6 inches on all sides of the hood without adding any additional airflow. **See page 11** for an example calculation.



### HOOD FACTORS

After calculating the total exhaust  $Q_E$  multiply by factors that pertain to the job, if any, to obtain a more accurate airflow rate. The airflow will increase or decrease depending on the factor. **See page 12** for an example calculation.

Condition	Multiplying Factor
Wall Canopy	1.0
Wall Canopy - Finished Back	1.3
Single Island - V-Bank	1.2
Double Island	1.0
Mini Skirts - 2x2	0.92
End Skirts - Full / Wall	0.90
Exhaust Only	1.0
Supply Plenums	1.1
Char-Broiler at end of Canopy or under a single island hood	1.2
Hanging Height 6 ft. 6 in.	1.0
Hanging Height 7 ft. 0 in.	1.1

## QUICK REFERENCE GUIDE

The table to the right ranks various ways of introducing make-up air into a kitchen, both tempered and untempered. To use the chart follow these steps:

1. Decide whether the goal is comfort or low cost.
2. Choose how to introduce make-up air into the kitchen per the column reflecting either comfort or cost.

Notice supply options that have superior performance are listed first and decrease in performance near the bottom of the list.

Goal is Comfort		Goal is Low Cost
Tempered MUA	<b>GOOD</b>	No Air Conditioning
Perforated Ceiling		Back Supply Plenum
Perforated Face		Air Supply Plenum
Back Supply Plenum		Perforated Face
Air Supply Plenum		Perforated Ceiling
Variable Supply Plenum		Variable Supply Plenum
Register Face		Air Curtain
4-Way Diffuser		Short Circuit
Short Circuit		Register Face
Air Curtain		<b>BAD</b>

The table to the right lists the various methods of supplying air to the space. The recommended supply rate columns list the recommended airflow for each supply option in two ways.

Choose the appropriate supply option and use either the corresponding cfm/lineal ft or the velocity in feet per minute when designing or adjusting the system for maximum performance.

**Warning:** Portable fans are not a source of supply air nor should they be used for personal cooling. The use of portable fans in a kitchen will cause system failure!

	Supply Type	Dimensions (inches)	Recommended Supply Rate	
			cfm/linear ft.	fpm
<b>External</b>	Back Supply	6 wide	145	290
	Air Supply Plenum	12 wide	110	150
		24 wide	180	150
	Variable Supply Plenum	11 high 9 wide	160	150
	Face Supply Plenum	18 wide	150	150
<b>Internal</b>	Perforated Combination	16 high 8 wide	150	150
	Register Combination	12 high 8 wide	130	—
	Perforated Face	16 high	150	150
	Register Face	12 high	250	—
	Perforated Air Curtain	8 wide	75	—
	Register Air Curtain	8 wide	65	—
	Short Circuit	UL limits (not recommended)		

## QUICK REFERENCE GUIDE

### SUMMARY OF FUNDAMENTAL DESIGN CONSIDERATIONS

**Air Currents** — It is important to minimize air current velocities flowing into or out of the kitchen. These currents cause cross drafts that degrade system performance, ultimately bringing capture and containment problems.

**Circulating Fans** — Circulating fans should never be used in a kitchen environment. The high velocity airflow creates large cross drafts that will cause a kitchen hood to spill effluent and heat into the kitchen.

**Ceiling Diffusers or Registers** — 4-way diffusers should be avoided if possible. 3-way and 4-way diffusers should be a minimum of 10 feet from the hood if used. The best alternative is perforated diffusers to allow for minimal airflow velocity into the room without a specific direction.

**Diversity** - Research has shown that placement of the cooking equipment can affect system performance. High temperature equipment such as char-broilers should be placed in the center of the hood while griddles, ovens and ranges for example are better placed outside of the center when combined with high temperature appliances.

**Front and Back Overhang** — It is important to have the necessary hood overhang in order to obtain capture and containment. There are different recommended and required overhangs for different hoods and equipment. Be sure to investigate the overhang requirements.

**End Overhang** — Just as important as front and back overhang is the end overhang. End overhang has even more variations due to end conditions such as: walls, end skirts, hood type, and application. Be sure to investigate the overhang requirements.

**Traffic Patterns Next to Hood** — In a kitchen, objects and persons move in all different directions and magnitudes. This random motion can cause undesirable secondary air currents (cross drafts) that will cause the hood to spill.

**Correct Match of Hood to Equipment** — It is essential to understand what degree of cooking load an application will be producing in order to properly choose a hood and exhaust airflow rate. Before deciding on a hood type and airflow rate, determine what category the cooking equipment will fall into and what hood styles will manage that cooking load. (see chart on previous page)

**Proper Balance of Supply and Exhaust Airflow** — Balancing exhaust and supply air so that the kitchen is slightly negative to the surrounding rooms but the building is positive to the outside is crucial. A slightly negative kitchen to surrounding areas will contain effluent and odors to the kitchen. Maintaining a positive building pressure to the outdoors is essential to keep dust and insects out. A proper Test and Balance (T&B) should be conducted to ensure proper pressures.

**Supply Air Adjacent to the Hood** — Supply air should be brought in through several different sources. When too much air is brought through one source such as internal and external supply plenums, the velocity will be too high. At these velocities, turbulent air and negative air pockets around the lip of the hood will form and induce spilling. Please reference the supply air section on page 15 of this guide for recommendations on the amount of airflow per supply device.

**End Skirts** - Installing end skirts on the ends of a hood can generate tremendous cost savings and increased capture efficiency. Effects from cross drafts through open doorways and pass-thru windows can be reduced when an end skirt is present. The tendency for air to adhere to a surface as it travels parallel to the surface is known as the Coanda Effect. Installation of either partial or full end skirts helps guide fumes into the hood. A small two by two foot end skirt can decrease the airflow required to capture by six to eight percent and full end skirts can decrease airflow requirements by up to ten percent. It is highly recommended to consider end skirts in all kitchen applications.

**NOTE:** Although this list contains some of the essential design considerations, there are several more that can greatly influence the performance of a commercial kitchen ventilation system.

## REFERENCES, CODES, AND INFORMATIONAL SOURCES

### **AMCA — Air Movement and Control Association International, Inc.**

Their purpose is to give the buyer, designer, and user of air movement and control equipment assurance that published ratings are reliable and accurate. At the same time, the certification program assures manufacturers that competitive ratings are based on standard test methods and procedures, and are subject to review by AMCA International as an impartial view. Usually pertains to fans and make-up air units.

### **ASHRAE — American Society of Heating, Refrigerating, and Air-Conditioning Engineers**

An organization that strives to advance the science and technology of heating, refrigeration, and air-conditioning by doing research that leads to standards, codes and general considerations backed by research. ASHRAE Chapter 31 (ASHRAE 2003 HVAC Applications) explicitly discusses kitchen ventilation. ASHRAE Standard 154 provides design criteria for the performance of commercial cooking ventilation systems.

### **IMC — International Mechanical Code (2003 Edition)**

A set of codes regulating all different aspects of mechanical building design and the systems within. Kitchen ventilation systems and their components are predominantly covered in sections 506 through 509.

### **NFPA — National Fire Protection Association**

An organization whose standards and codes promote building safety by regulating or suggesting safe electrical and fire practices in building construction and the systems installed within.

NFPA 96 (2001 Edition) — is the standard specifically written for kitchen ventilation systems. NFPA 17A is the standard applying to the design, installation, operation, testing, and maintenance of wet chemical fire suppression systems.

### **NSF — National Sanitation Foundation**

This agency develops standards and criteria for equipment products and services that bear upon health. Equipment meeting these criteria will have an NSF label designating the product as one which complies with promoting public health and safety.

### **UL — Underwriters Laboratory, Inc.**

Underwriters Laboratories, Inc. is an independent, not-for-profit product-safety testing and certification organization. Many codes and local AHJ's require that equipment bear the UL label. The following UL tests correspond directly to kitchen ventilation equipment. UL 710 defines testing and labeling for fume hoods. UL 1046 defines testing and labeling for grease filters. UL 300 defines testing and labeling for kitchen fire suppression systems. UL 1978 defines testing and labeling for grease ducts. ULC defines testing and labeling for Canada. UL 762 is required for exhaust fans used in grease applications.

### **UMC — Universal Mechanical Code**

A set of codes regulating all different aspects of mechanical building design and the systems within. Similar to IMC code, but adopted by different jurisdictions.

## **APPENDIX: COMMERCIAL KITCHEN VENTILATION WEB SITES**

**Greenheck Fan Corporation**

<http://www.greenheck.com>

**Fisher Nickel and Commercial Kitchen Ventilation Laboratory**

<http://www.fishnick.com>

**American Society of Heating, Refrigerating, and Air-Conditioning Engineers**

<http://ashrae.org>

**National Fire Protection Association**

<http://www.nfpa.org>

**National Sanitation Foundation**

<http://www.nsf.org>

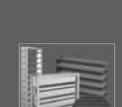
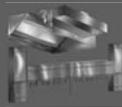
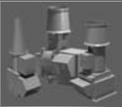
**Underwriters Laboratory**

<http://www.ul.com>

**Air Movement and Control Association International, INC. (AMCA)**

<http://www.amca.org>





## Our Warranty

Greenheck warrants this equipment to be free from defects in material and workmanship for a period of one year from the shipment date. Any units or parts which prove defective during the warranty period will be replaced at our option when returned to our factory, transportation prepaid. Motors are warranted by the motor manufacturer for a period of one year. Should motors furnished by Greenheck prove defective during this period, they should be returned to the nearest authorized motor service station. Greenheck will not be responsible for any removal or installation costs.

*As a result of our commitment to continuous improvement, Greenheck reserves the right to change specifications without notice.*

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Prepared to Support  
Green Building Efforts