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RESIDENTIAL KITCHEN VENTILATION— A GUIDE FOR THE SPECIFYING ENGINEER

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ABSTRACT

The evolution of residential kitchen ventilation is examined and the importance of kitchen range hoods in today's ventilation systems is reviewed as an aid to the specifying engineer. Home cooking produces liquid and solid particles, odors, airborne moisture, heat, and sometimes gas combustion products. How the residential range hood handles these problems is revealed, and the results of various testing programs are given. The proper application of range hoods relative to sizing, room location, and proper ductwork is discussed. The rating methods and standards for hoods are explained and related to real life. The issues of range hood noise and energy conservation are reviewed and answers are provided on how to handle these issues. Current standards and codes dealing with kitchen ventilation are reviewed. The future of kitchen ventilation in home construction is predicted and discussed.

INTRODUCTION

Cooking generates pollution, so the history of kitchen ventilation goes back to early times. History can provide insights into the mechanics of the ventilation process. By quantifying the parameters associated with cooking and ventilation, problems will be solved easily and effectively.

History of Kitchen Ventilation

Kitchen ventilation has always been important to comfort and health, but people have only recently become much more aware of it. Even in the stereotyped tepee of the early Native Americans, there was a flap in the top to let the smoke out. Early American settlers used fireplaces for cooking, where the convective currents flowed up the chimney and makeup air came in through the cracks in the structure.

Many of us remember when open windows provided the needed ventilation. They were replaced by through-the-wall fans, often equipped with a pull chain; even those have been around for a couple of generations.

In the 1950s the first version of an effective working kitchen range hood appeared. It was a separate metal hood, mounted over the cooking range. The traditional fan was installed through the wall just below the hood. The hood provided an inverted sump to capture the convective flow and the fan extracted the captured air. It actually worked well and revolutionized residential kitchen ventilation.

Today's powered residential range hood came into being when engineers unitized the hood, putting the fan inside the hood at the factory, so their company could sell one product where before they had sold two. With the addition of an effective light for the cooking surface, the present standard configuration of the product appeared.

Ductless hoods, although not ventilating devices, must be mentioned as part of kitchen ventilation history. They appeared on the scene just after the Nautilus submarine traveled under the polar ice cap in the 1950s. There was great public awareness of the use of activated carbon (charcoal) as an adsorbent for maintaining the quality of the air on board the submarine. The time was ripe for the introduction of the "charcoal" range hood. Today those hoods are sold in considerable volume, even though their contribution to improved residential air quality is not exciting. In fact, manufacturers of ductless hoods make no claims for their performance as ventilating equipment.

Kitchen Ventilation Is Important to Residential Air Quality

It is important now for ASHRAE engineers to appreciate the importance of kitchen ventilation in the total scheme of residential indoor air quality. Residential air quality is becoming increasingly important to the public. They are demanding better ventilation in their homes, and specifying engineers need to be proficient in designing systems that will meet their expectations.

How will ASHRAE meet this challenge? It is already doing so. It started with a new interest in residential energy conservation. ASHRAE responded appropriately by splitting ASHRAE Standard 90, Energy Conservation in New Building Design, into 90.1 (larger buildings) and 90.2 (residential). That was a landmark of sorts, a significant venture by ASHRAE into the residential field. As with energy, it is now appropriate to emphasize the residential aspects of ventilation. ASHRAE Standard 62, Ventilation for Acceptable Indoor Air Quality, covers both commercial and, to some degree, residential applications, but residential information is scanty and is written as an offshoot of commercial. It is important that

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residential ventilation should gain its own coverage because the residential concerns are unique.

With improved energy performance of residential building construction, it has become apparent that residential ventilation has two distinct parts:

1. continuous ventilation, directed toward those pollutants that are produced continuously, including such sources as respiration, perspiration, and emissions from building materials, and
2. intermittent ventilation, directed toward those pollutants that are produced intermittently, including those produced by showering, cooking, bathroom use, and smoking.

Why are there two parts? First, the intermittent pollutants must be controlled as part of source mitigation, the first step toward indoor air quality. If not mitigated, the contaminants can be harmful, either causing damage or introducing harmful pollutants through recirculation, so intermittent ventilation is required in the kitchen if continuous ventilation is to work satisfactorily.

Second, continuous ventilation must be at a relatively low rate because of energy costs, but that low rate is inadequate to control intermittent pollutants because of the high generation rates. Cain et al. (1979) found that some contaminants (tobacco smoke) are not controlled by ventilation rates of a fraction of an air change per hour. It is not practical to control high concentrations of intermittent pollutants with continuous ventilation because economics and comfort do not permit the necessary high rate of ventilation.

History helps emphasize the distinction between the character of continuous and intermittent ventilation. The continuous ventilation of pre-oil-embargo houses was provided by natural infiltration, usually found to be between 0.5 and 2.0 air changes per hour (ach). Intermittent ventilation in those same houses was usually provided by an openable window in the kitchen and bath (with mechanical ventilation as an acceptable alternative in most codes and standards).

Today continuous ventilation is sometimes provided by "whole house" systems with a ventilation rate of 0.3 to 0.5 air changes per hour. Intermittent ventilation in these houses is provided through kitchen range hoods and bathroom exhaust fans. If the high concentrations of intermittent pollutants are not mitigated, the continuous ventilating system cannot provide the expected air quality within a reasonable period of time.

So ventilating range hoods are important, and it is timely to report on some of the functional measuring and testing that has been done to quantify range hood ventilation performance. Often in the past, specifying engineers were not involved in the specification of residential hoods, which was acceptable because the infiltration rate was high and the occupants were not as knowledgeable as they are today. Now people know more about indoor air quality, and today's houses don't leak enough to cover up problems. Specifying engineers must and will become involved.

This paper will explain how to be successful when specifying intermittent kitchen ventilation and why, especially for the engineer, the necessary recommendations are made.

FACTORS RELATED TO KITCHEN VENTILATION

To deal effectively with kitchen ventilation, a knowledge of cooking contaminants is essential. Then the performance of hoods against those contaminants can be evaluated and a method of quantitatively measuring that performance can be developed.

Contaminants in the Kitchen

What is the character of kitchen contamination? First, the contamination is produced at a high level of concentration over a short time. Second, there are a variety of contaminants involved, including particulate matter, moisture, heat, odors, and gases, and this variety of contaminants can be produced in a variety of combinations.

Particles can be formed in several ways. Both solid and liquid particles are generated in cooking. The solid particles are usually a result of an error in cooking that causes the food to burn, generating carbonaceous particles. Vegetables in particular are of a cellulosic nature, and they readily form these solid particles when burned. These "burning" incidents are infrequent but still must be kept in mind because particles are produced.

The liquid particles formed are the most important. They are produced in two distinct size ranges. The large liquid particles form through minor explosions within the cooking vessel, and they are visible as they move through the air and spatter on the surrounding surfaces. The explosions occur when water contained within the food is introduced into hot liquid grease or oil. The high temperature of the oil causes the water contained in the food to flash over explosively into steam, spattering the liquid grease. The size of the particles formed this way ensures that most will quickly fall back onto the adjacent surfaces due to gravitational forces, but some can become airborne and drift about before falling. These particles are too large to be removed by residential ventilation equipment, but fortunately they do not go far past the immediate cooking area.

In contrast, the more common liquid particles are very small. They remain airborne and drift about before settling on walls, drapes, and other surfaces throughout the home. These particles are generated by a different process. When the oils from cooking are heated to elevated temperatures, there is evaporation. A mixture of warm air and warm evaporated oil molecules is carried upward away from the cooktop by the thermal currents generated by the hot surfaces of the cooktop. As the mixture travels the short distance into a cooler region of the room, the evaporation is reversed. The oil vapor condenses into a liquid and is converted into very small particles. The particle formation process depends on both the thermodynamics of the system and on the available nucleation potential of the system. There follows a small amount of agglomeration, but most of the condensed particles remain very small.

There is a difference of several orders of magnitude in the mass and volume of the particles produced by the condensation mechanism and the explosive spatter mode. Studies of the spatter particles show them to be in the 10 to 100 micrometer (μm) range, and 50% are less than 80 μm in diameter (Annis and Annis 1964). These heavy spatter particles fall to nearby surfaces due to gravity. Small condensation particles have been measured by the authors and have been found to be in the range of 0.01 to 3.0 μm. These particles float in the air and are moved around by Brownian motion and convective currents. They are typical aerosols with very slow settling rates, while particles larger than 5 μm settle rapidly.

Typical settling rates for particles of various size are given below:

Particle Size (micrometers)	Time to Fall One Foot in Still Air (minutes)
0.3	1,100.0
1.0	122.0
5.0	6.0
10.0	1.6
20.0	0.43
100.0	0.021

This information is based on Stokes' law and assumes particles in still air that are not being influenced by other forces such as thermal currents and electrostatic charges. The condensed particles tend to remain airborne almost indefinitely, even if they leave the house by exfiltration, until they agglomerate into larger particles and fall or are attracted to the surrounding surfaces by electrostatic or thermal forces.

Typical particle sizes for some materials are

—Tobacco smoke averages 0.3 μm in diameter.
—Dust ranges from 0.01 to 20 μm in diameter.
—Pollen ranges from 10 to 100 μm in diameter.
—The point of a straight pin is 75 μm in diameter.
—Human hair is 100 μm in diameter.

Volatilized kitchen oil particles are in the same size range as tobacco smoke and some dust, and they settle at the same rate.

Particles are not visible individually unless they are greater than about 10 μm in diameter. Massive numbers of very small particles can be seen as a cloud. The bluish color indicates the suspended particles are 0.3 to 0.4 μm in diameter. At that size they are the same size as the wavelength of visible blue light and the light-scattering effects are particularly intense (Sarnosky 1987). This was remarkably obvious in some of the work done on particle generation.

In the study of kitchen contaminants and particulate matter, we measured particle size using a quartz crystal cascade microbalance particle impactor. This is a 10-stage, cascade-type particle separator that uses two tuned collecting crystals in a 10-kHz oscillator in each stage to measure the mass collected. It provided multiple consecutive samples of particle concentration in a short time and was a self-contained portable instrument that was easily moved from the laboratory to a residential kitchen for study in both situations.

Our first particle studies were conducted in a simulated scaled-down kitchen. A nonabsorbent sealed room was constructed as shown in Figure 1.

In studying particles, fresh corn oil was heated to cooking temperatures (400°F) for 30 to 60 minutes and particle concentration in the room was measured. When the concentration level stabilized, the heat was discontinued and concentrations monitored over a period of 4 to 72 hours. From these tests we determined particle size, particle production rate, saturation time, and decay rate of particle concentration. Figure 2 shows the persistence of very small particles in the room over several hours.

We then studied particle generation in a 40-year-old house. The cascade impactor was set up in the kitchen and particle generation measured as a result of cooking typical foods such as bacon, pancakes, eggs, french fries, and hamburgers. Figure 3 shows the particle concentration levels in the kitchen. Our conclusions from these studies show there is a preponderance of particles less than 1.2 μm in diameter that are generated and continue to persist in the kitchen. Unless these particles are removed, they will eventually settle on the available surfaces and lead to soiling, residual odors, and other problems.

The cooking process also can generate excessively large quantities of water vapor. The ubiquitous nature of this water vapor causes it to mix readily into the immediate area and to diffuse rapidly, establishing a high humidity level throughout the dwelling. Excessively high moisture content in the home can be a problem, as was dramatically shown by the difficulties experienced with some prefabricated home units in Wisconsin and Minnesota.

That situation came to public attention after a physician correlated an abnormally high incidence of respiratory problems and general malaise with a specific part of the community where all the houses were prefab units built by the same firm (which is no longer in business). The houses were of modest size and were unusually airtight. Further investigation showed a high population per square foot of living space and inadequate ventilation

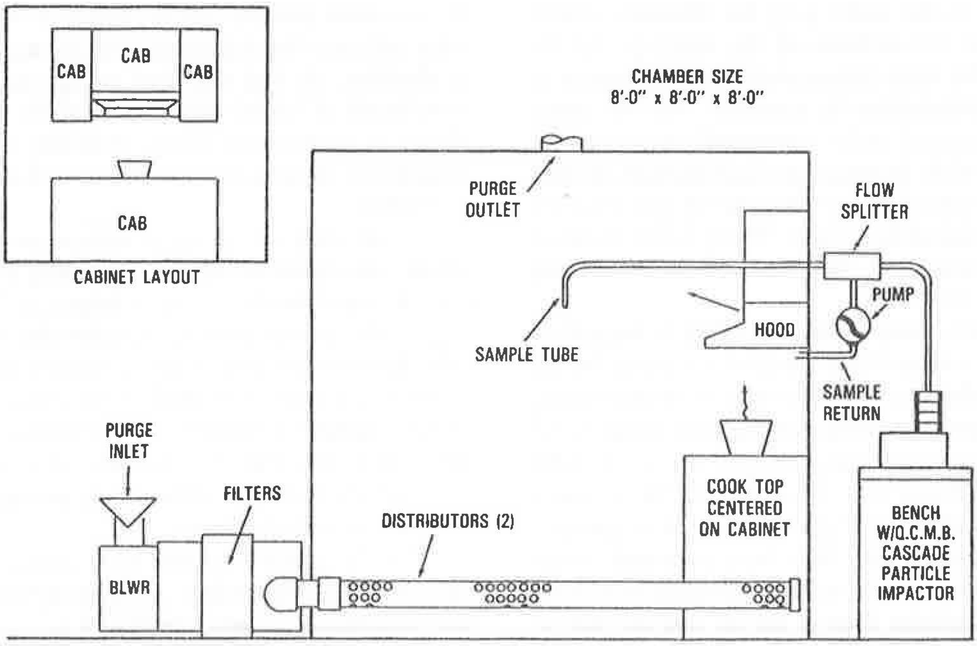

Figure 1

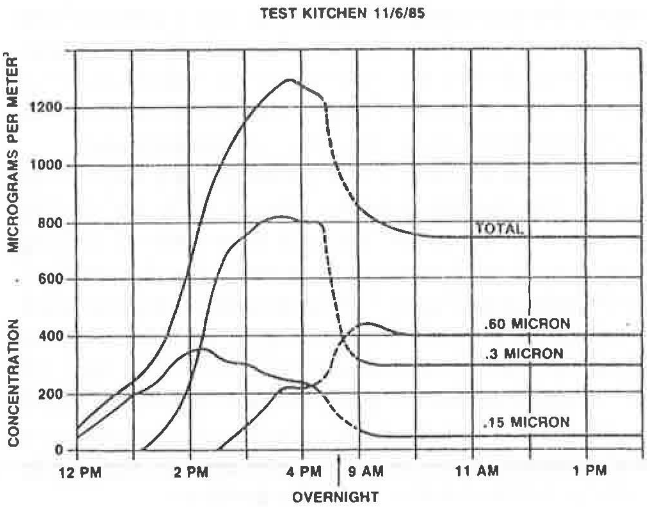

Figure 2

practices. Upon opening the exterior wall cavities, it was determined that a high proportion of the buildings had structurally significant dry rot even though the houses were only a few years old. The wall damage was usually in the area of the bathroom, but humidity from cooking was identified as a culprit also. This is a dramatic example of how both human health and building structure can be endangered by poor ventilation practices.

Related studies were conducted by the Home Ventilating Institute (HVI) (Wolbrink et al. 1979) on the mitigation of excessive moisture in bathrooms. The results emphasize the need for an adequate level of mechanical ventilation to relieve this problem. The decay rate of the

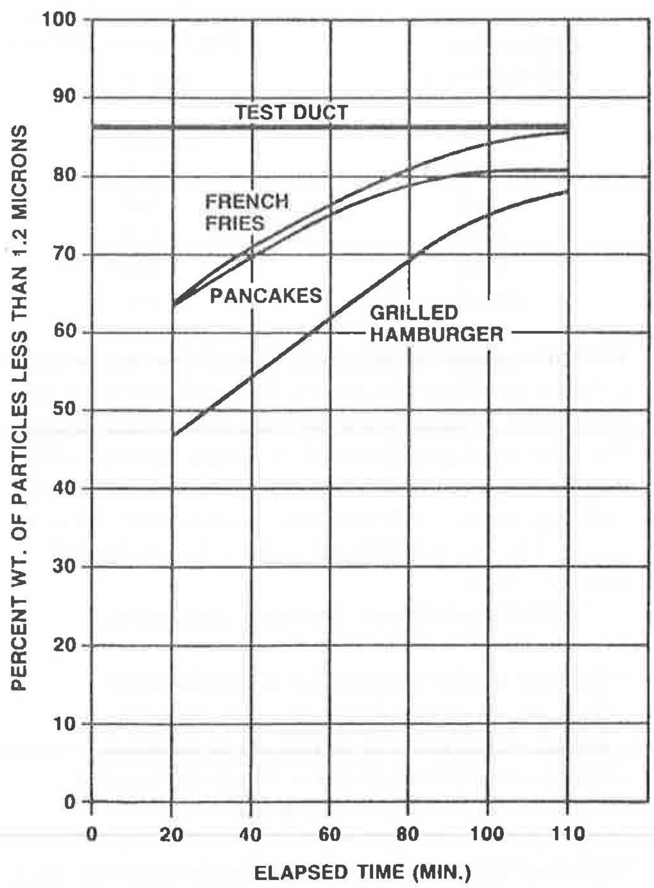

Figure 3

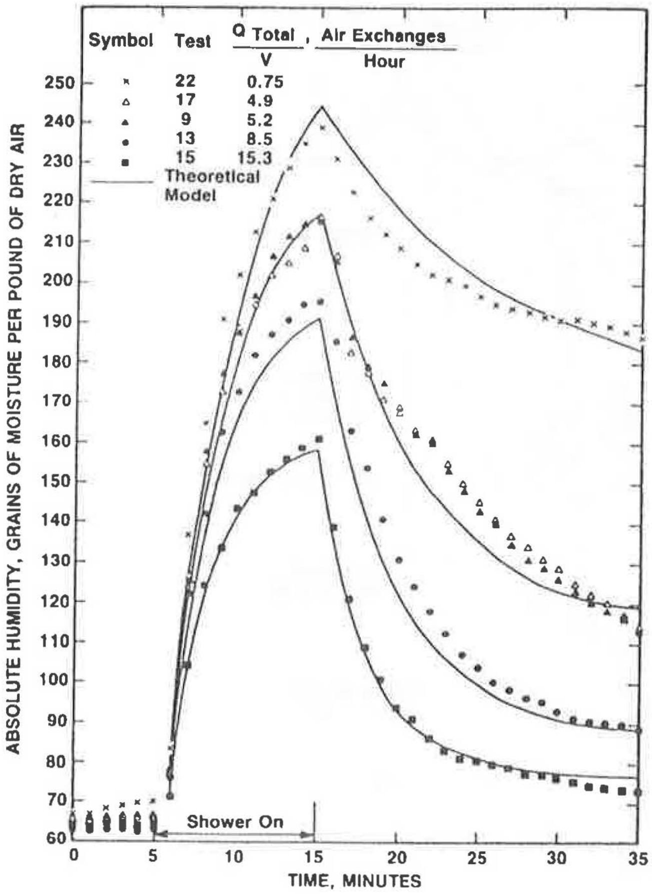

Figure 4 *Absolute humidity vs. time for various mechanical ventilation rates.*

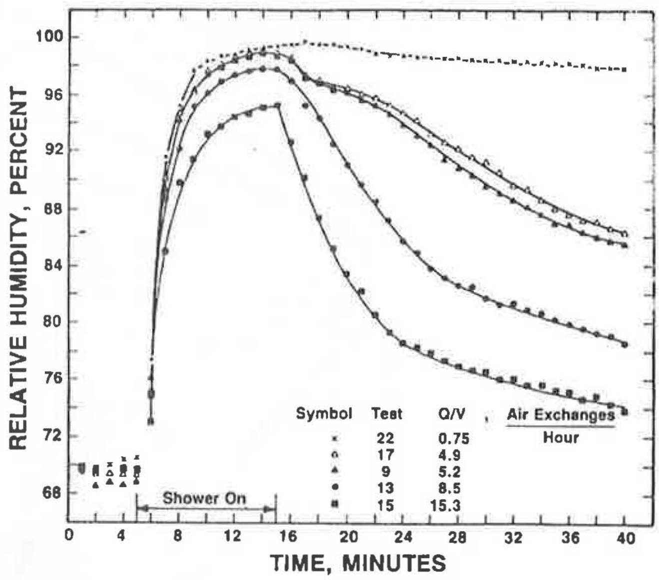

Figure 5 *Relative humidity vs. time for various mechanical ventilation rates.*

moisture content in a space, relative to air change rate, is shown in Figures 4 and 5. This graphically illustrates the value of good intermittent ventilation for controlling moisture in the home.

A third result of residential cooking is odors. Some of the odors produced by cooking can be pleasant and therefore desirable and have no need to be controlled. The objectionable odors have been studied, but the technology of controlling these odors has not yet been developed to the point where it can be done economically other than by mechanical ventilation—that is, by ventilating the odors out in the range hood airstream.

The heat generated by cooking can cause discomfort in the kitchen, and it is best to control it at the source. The heat rising off the cooktop forms a plume that is carried upward to be captured and exhausted by the range hood if it is there. If there is no hood, or if the hood is not used, the heat diffuses through the living space.

The products of combustion generated by gas cooking can be hazardous to health if combustion is faulty. Acceptable limits of these hazardous materials have been published for carbon monoxide, carbon dioxide, nitric oxide, nitrogen dioxide, sulfur dioxide, and formaldehyde. With the tight homes being constructed today, it is increasingly difficult to maintain these limits. It is recognized that range hoods can alleviate the problem (Traynor et al. 1981), but they are often not used because of the noise.

This presents the ideal opportunity for the specifier. Good quality hoods can be specified that will eliminate the traditional complaint that the hood is too noisy to use.

The Kitchen Related to the Residential Environment

If the pollutants described in detail above are not exfiltrated or mitigated, they will spread throughout the entire house. The rate of diffusion and mixing will vary as a function of the type of heating/cooling system, the size of the house, the configuration of the house, etc., but eventually the entire space will reach an equilibrium concentration level that will not be satisfactory, especially if the house is tightly built.

THE RANGE HOOD AS THE SOLUTION TO THE PROBLEMS

How does the kitchen range hood solve the problem of pollution generated by cooking? A number of factors are involved in the relationship between the range hood and cooking, but they can be dealt with if divided into issues of design and issues of application. The design is obviously in the control of the manufacturer and its engineers. The application of the hood usually does not get the attention required from the installer or user, so the specifying engineer involved in the design of the residential mechanical system must assume this responsibility and will benefit from further understanding of hood performance.

How Range Hood Capture Was Measured

The principal function of a hood is to capture and hold the cooking effluent within itself so the fan can move

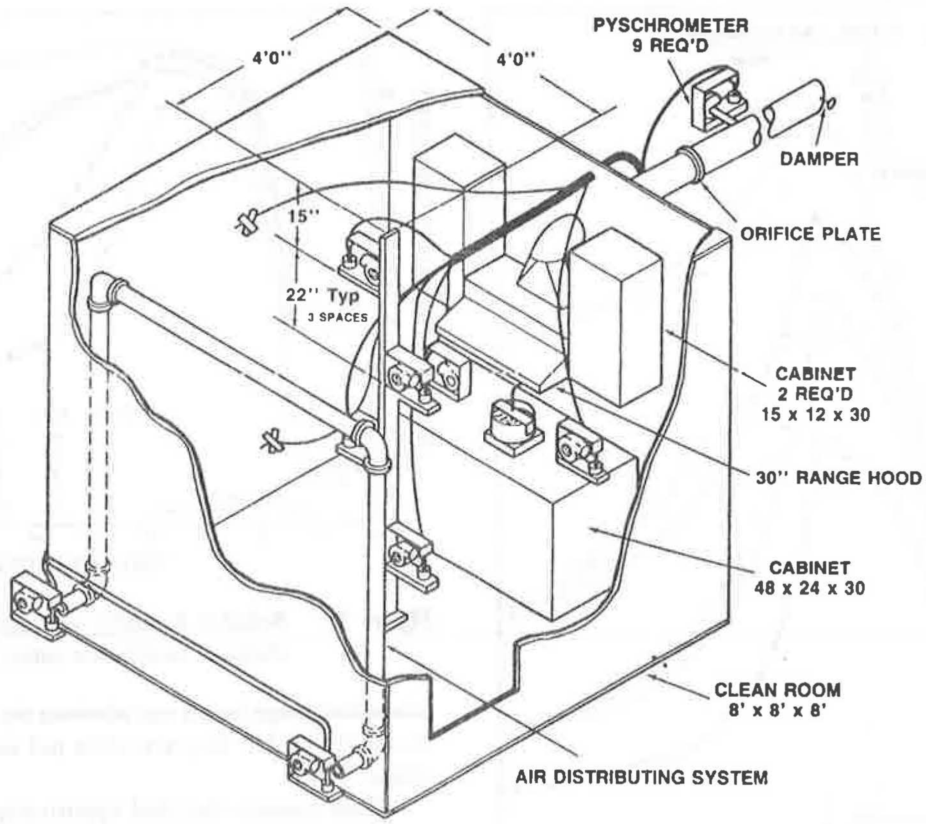

Figure 6

it out of the kitchen. It functions like an inverted basement sump pump. The sump holds the water and the pump moves it out. It is therefore important to design the hood so it has enough inverted volume to hold the cooking effluent. It must be easy for the effluent to enter the hood, which calls for an open perimeter. The front-to-back dimension of the hood is important; it must extend far enough forward to cover the thermal plume generated by the cooktop but not so far forward that it will interfere with vision or food preparation.

The capture function applies to residential hoods, but commercial hoods utilize a completely different mechanism to control pollutants—they use velocity to accomplish capture. The residential hood is a gravity capture device. (We sometimes call it a "Newtonian" hood.)

It is apparent that many factors govern the ability of the hood to capture cooking effluent, but to quantify the combined capture capability of a hood, a test standard was established. There is, at this time, an effort under way to have this established as an industry test standard.

Hood capture testing is accomplished in a sealed test room built of nonabsorbent materials. The room is 8 ft × 8 ft × 8 ft (Figure 6). Water vapor is used as the test medium and is produced by boiling water on a cooktop. Hood capture is determined by measuring the amount of vapor added to the room as opposed to that captured by the hood and removed from the room. Wet- and dry-bulb temperatures are measured at locations throughout the test room, and the mean value of water concentration in the room is thus determined. Wet- and dry-bulb temperatures of air entering and leaving the room are measured and water vapor content is likewise determined. This information is combined in the rate flow equilibrium calculations to give a final hood capture efficiency.

The derivation of hood capture efficiency is based on the concept that efficiency is the ratio of moisture captured by the hood to moisture produced by the source.

Using Figure 7 this can be stated as

$$H = \frac{N_E}{N_P} \qquad (1)$$

or, for convenience in measuring and calculating,

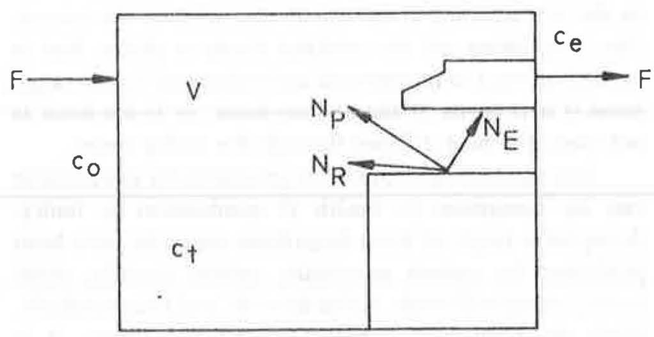

Figure 7

$$H = \frac{N_P - N_R}{N_P} \qquad (2)$$

where

H = hood capture efficiency (per unit),
N_P = total production rate of moisture from source (lb water/min),
N_E = rate of moisture captured by hood (lb water/min),
N_R = rate of moisture escaping to room (lb water/min).

The general transient expression of the mass balance of moisture associated with the test room (referring back to Figure 7) is given by

$$V\frac{dc}{dt} = N_P(1-H) - Fc \qquad (3)$$

where

V = room volume (ft^3),
c = moisture concentration (lb water/lb air),
t = time (min),
F = flow rate in and out of room (lb air/min).

The solution to this equation is

$$c_t = e^{-\frac{t}{T}}\left[c_i - \frac{Fc_o + N_R}{F}\right] + \frac{Fc_o + N_R}{F} \qquad (4)$$

where

c_t = moisture concentration at time t (lb water/lb air),
c_i = initial moisture concentration in room (lb water/lb air),
c_o = moisture concentration outside room (lb water/lb air),
c_e = moisture concentration leaving room (lb water/lb air),
e = natural log base (2.71828),
T = time constant of space (min/air change), defined as

$$T = \frac{V\rho}{F} \qquad (5)$$

where

ρ = air density (lb/ft^3).

At steady-state conditions with nonsaturated air, $t = \infty$, $e^{-t/T} = 0$, and Equation 4 becomes

$$c_t = c_s = \frac{Fc_o + N_R}{F} \qquad (6)$$

where

c_s = moisture concentration at steady state (lb water/lb air).

Rearranging and combining Equations 2 and 6,

$$c_s - c_o = \frac{N_R}{F} = \frac{N_P(1-H)}{F}. \qquad (7)$$

Rearranging shows

$$H = 1 - \frac{F}{N_P}(c_s - c_o). \qquad (8)$$

Also at steady state, as illustrated by Figure 8,

$$c_e F = c_o F + N_P. \qquad (9)$$

Rearranging shows

$$\frac{F}{N_P} = \frac{1}{c_e - c_o}. \qquad (10)$$

Substituting into and combining with Equation 8,

$$H = 1 - \frac{1}{c_e - c_o}(c_s - c_o). \qquad (11)$$

And, finally,

$$H = 1 - \frac{c_s - c_o}{c_e - c_o}. \qquad (12)$$

Thus, efficiency is given in terms of moisture concentration at the various stations. The value of the concentration can be found by using the measured wet-bulb and dry-bulb temperatures.

The humidity ratio, W, in pounds of water per pound of air, is given in *ASHRAE Fundamentals* (ASHRAE 1985), page 6.13, as

$$W = \frac{(1093 - 0.556\,t_w)\,W^* - 0.240\,(t_d - t_w)}{1093 + 0.444\,t_d - t_w} = c \qquad (13)$$

where

t_d = dry-bulb temperature (°F),
t_w = wet-bulb temperature (°F),
W^* = saturation humidity ratio at t_w from Table 1, page 6.2.

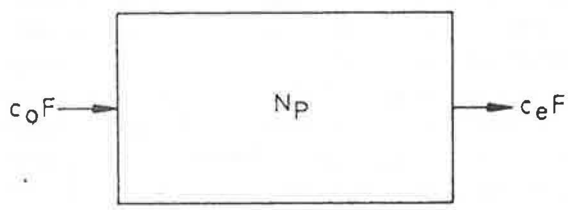

Figure 8

Using measured t_d and t_w for air entering, leaving, and in the room, it is possible to find c_o, c_s, and c_e using Equation 13. These values of c are then used in Equation 12 to find hood capture efficiency.

Using this test setup, we were able to test hundreds of variations in the parameters mentioned to arrive at optimum and economical hood shape designs. Hood capture efficiencies range between 50% and 90%, depending on the shape and size of the hood.

How Hood Airflow Performance Is Measured

The second factor in hood design is the airflow rate. Over the years we have found that flow rates from 50 cfm (cubic feet per minute) to 350 cfm can accommodate most consumers' demands. Test hoods placed in typical houses showed the average normal setting for a variable-speed controlled hood to be at 100 cfm. For a high-quality hood that relies on Newtonian capture, the ideal would be a variable-flow hood that can produce 50 to 350 cfm and run quietly and efficiently at 100 cfm. To produce this airflow, either a centrifugal blower system or a fan blade system is used. The latter is inexpensive but runs at high speeds and is noisier. Further, it develops a rather flat pressure/volume curve where small increases in duct back pressure produce large losses in airflow. The superior centrifugal blower, although more expensive, runs at slower speeds and is quiet. It also can produce a steep pressure volume curve where increases in duct back pressure result in small losses in airflow. A typical example of fan curves for these two systems is shown in Figure 9; note particularly the effect of changes in duct back pressure.

Both units are designed to deliver 200 cfm at 0.1 in. static pressure. This represents 30 equivalent feet of 3¼ × 10 in. duct, typically a wall cap and 5 feet of metal duct. If a wall cap and a long run of flexible duct with bends is used, 100 equivalent feet of duct would result. Notice that the blower wheel system loses 30 cfm but the blade system loses twice as much, 60 ft^3/min. The relative difference in losses would be even greater when the hood is run at a low speed.

The best hood, then, uses a centrifugal blower system with a speed control allowing control between 50 and 350 cfm. The economy builder (or price) item usually uses the fan blade system with a two-speed motor producing 80 to 150 cfm. To design a hood to accurately and reliably meet these parameters requires an accurate air test chamber, dynamometers, and other related equipment. A good air test chamber should be constructed to the requirements of ASHRAE Standard 51-85 (AMCA 210-85) and test results calculated accordingly. Accurate and calibrated pressure gauges and flow-measuring nozzles also should be used. Good electrical measuring and regulating equipment is required for reproducible test results. The same applies to speed-measuring equipment, barometers, and temperature-measuring devices.

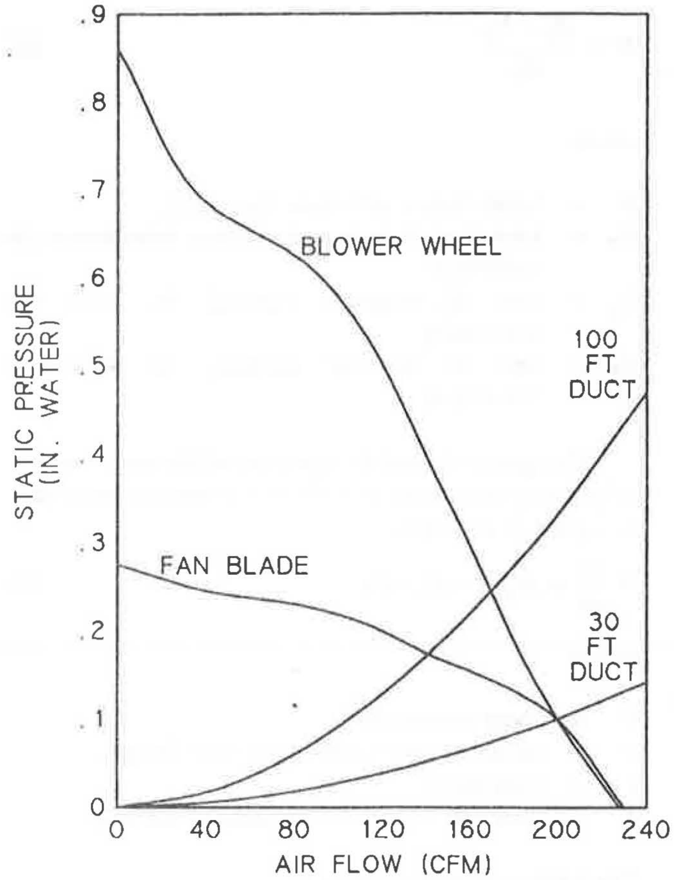

Figure 9

To obtain a motor that can repeatedly drive the fan at a consistent speed, a speed torque curve must be developed using a dynamometer and the motor performance so specified and periodically verified. The response of the motor to the speed controls also must be investigated and specified.

Application Factors

Having designed and specified the ideal hood, the application of this hood is the next concern. Good instructions for installation are a must. It is best if the designing engineer prepares the first draft and approves the final draft of these instructions.

The Home Ventilating Institute (HVI) recommends a hood be installed 21 to 24 inches above the cooktop surface, and 21 inches will certainly give the best hood capture. The HVI also recommends a minimum of 40 cfm per lineal foot of wall-mounted range hood, so a 36-inch hood should deliver a minimum 120 cfm. In planning a kitchen, a wall-mounted range and hood will reduce the effect of drafts and air currents on the hood and improve its capture efficiency and performance.

Ducting the hood to the outside must be done carefully; the minimum length of duct should be used as well as the minimum number of elbows and transitions. The duct size specified by the manufacturer is a minimum, and the use of flexible duct should be discouraged. We recently had a complaint from a contractor who was trying to use 4-inch flexible duct on a 500-cfm fan where 6-inch duct was specified. The user was very dissatisfied with fan output! *ASHRAE Fundamentals* is an excellent source of information and is our prime reference when dealing with inquiries on ducting. There is no good information on terminal fittings, such as wall caps or roof caps, and the losses they generate. This is because of the great variation between the products of different manufacturers.

We recently ran some system resistance tests on several wall caps used on 6-inch duct as part of a redesign project. A set of system resistance curves is shown in Figure 10. The first curve (1) shows the old design and the second (2), the new. We were able to decrease resistance by 33% at high flow volumes. The fifth curve (5) shows a system curve with an even better (lower) system resistance. This unit does not have a weather hood, a damper flap return spring, or a bird screen. It will let air out easily but also will let in weather and birds and will clatter excessively in a wind if on the leeward side. What all this suggests is that it is best to utilize a terminal fitting designed for weather protection and incursion protection and designed to provide positive closure. Usually the terminal fitting offered by the hood manufacturer will work best with the hood.

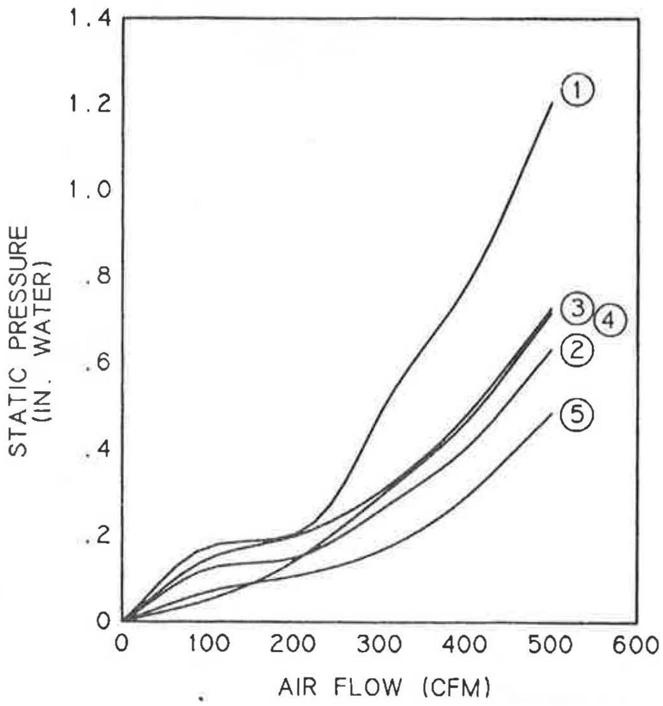

Figure 10

Downdraft Ventilation

Recent trends in cooking appliances have led to the development of the downdraft system. Some cooktops now have an air inlet grille leading to an air-moving device that exhausts air over and off the cooktop, sending it down and out. These devices do not work on the thermal plume or Newtonian capture principle; rather, they depend on the velocity capture principle where the contaminants are carried along by air moving fast enough to overcome convection. The disadvantage of this system is that much higher airflows are required to achieve this velocity, which means larger, more expensive blowers. Also, the fast-moving air cools the food being cooked and also may cool the gas or electric heating elements, slowing the cooking process.

Downdraft units answer a need in island or peninsula cooking installations where an updraft hood would be difficult to install and the downdraft can vent through the floor and out the side wall. There are downdraft units today that are not integral with the cooktop but are mounted separately behind or beside the cooktop. These suffer from the same problem of having a high-velocity air system that retards the cooking process. There are models that lessen this problem by having the air inlet move to a 6- to 10-inch height above and behind the cooktop. Combining this feature with a speed control to adjust to the required minimum airflow can result in acceptable performance. Figure 11 shows such a unit.

Range Hood Performance Ratings and Certification

The HVI has established a method for rating hoods and fans so they may be compared. Many years ago it was agreed that ventilating products would be given a single-number rating of airflow (cfm) at a static pressure of 0.1 inch of water. Through-the-wall fans would be rated at 0.03 inch of water. A single number is easily understood in the field, especially when no engineer is involved in the design and specification of a dwelling.

It was decided by the HVI that the products would be tested in an engineering laboratory. This testing would follow the procedure outlined in ASHRAE Standard 51 (AMCA 210).

It was also decided that hoods would be rated for sound output with the sound reported in sones. Sones were chosen over decibel ratings for their simplicity and linearity. A rating of 4 sones is perceived as twice as loud as 2 sones. The setup for the sound ratings was developed by the engineering committee of the HVI. Testing is done in a 5,755 ft^3 reverberation chamber constructed with hard (reverberant), nonparallel surfaces. An anechoic muffler is used on the discharge of the chamber. Testing compares a reference sound source, background level, and the tested devices over a frequency range including 24 octave bands with center frequencies between 50 and 10,000 Hz. This information is recorded and combined to give a measure of the sound experienced by a person 5 feet from the test fan. The final result of this testing is a fan sound rating in sones. The exact mathematics is available in the HVI sound test procedure (HVI 1989).

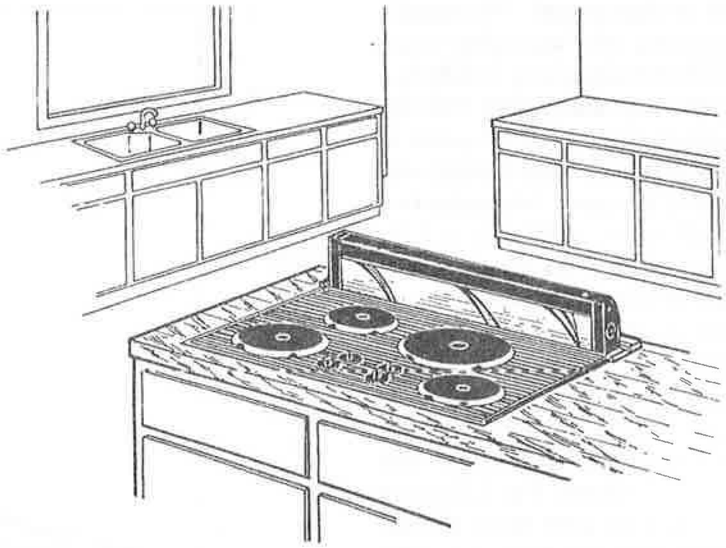

Figure 11

Additional Factors

The results of the airflow testing and sound tests are published in the HVI Certified Products Directory, published annually. The directory is a good means for making comparisons between different hoods and can aid in hood selection.

In real life, the 0.1-inch static pressure does not always represent typical installations. Long duct runs, elbows and transitions, terminal fittings, and flexible duct can all increase the resistance to flow and should be considered when selecting a range hood. The sound rating is only a guide to use for comparing hoods. The actual mounting and surroundings will have a significant influence on the actual sound heard in an installation.

The complaint heard most frequently about residential range hoods is related to the noise level of the hood. There are a number of possible reasons for this, and poor design certainly can be one of the reasons. A good design should have vibration isolation properly applied. It also should minimize large unsupported sheet metal panels. It should avoid placing moving parts very close to stationary parts (blade note). It should pay particular attention to the electrical motors used in the hood; a poorly designed and used motor can be the worst offender in noise generation. An overexcited motor can result in excessive 60-Hz hum. Clearance problems and eccentricity can produce "beat" frequencies.

The actual installation also may contribute to noise problems. Loose mountings can cause excess vibration, which generates excess noise. Mounting to poorly constructed and poorly installed cabinets also can contribute to noise. Periodic cleaning helps to keep rotating parts in balance and therefore quiet. Blocked discharge ducts can cause internal mixing, drumming, and noise. In the ideal condition, the hood should be controlled so the speed can be adjusted to produce just enough airflow to remove the contaminants. That minimizes air noise. If a homeowner forgets the hood is on, you have a successful hood installation.

Energy Consumption through Kitchen Ventilation

Energy consumption for intermittent kitchen ventilation consists of two components. The first is the cost of heating (or cooling) the makeup air required as a result of the hood's exhaust. The second is the direct cost of electricity to run the fan in the hood.

Since infiltration is always present, it is difficult to determine exactly how much to ascribe to range hood makeup air requirements. It has been reported that venting a clothes dryer did not significantly affect the infiltration rate (Olsen 1986). Nevertheless, a worst-case calculation can be made if one assumes that all of the makeup air is "new" infiltration. For a complete heating season, the cost of heating makeup air using gas heat in any location can be calculated using the following equation:

$$R = Q \rho t c_p Y \$_t \frac{60\times10^{-5}}{E} \qquad (14)$$

where

R = total annual cost for the heating season (\$/year),
Q = flow rate of exhaust (ft^3/min),
ρ = density of air (lb/ft^3),
t = average daily running time of exhaust (h/day),
c_p = specific heat of air (Btu/°F/lb),
Y = annual total heating degree-days for locality (°F · days/year),
$\$_t$ = cost per therm of energy (\$/100,000 Btu),
E = heating system efficiency (unit/unit).

The cost is so low that it often comes as a surprise. If, for a very conservative example, it is assumed that

Q = 100 ft^3/min,
ρ = 0.075 lb/ft^3,
c_p = 0.241 Btu/°F/lb,
t = running time of 1 h/day,
Y = 6,000 degree-days,
$\$_t$ = \$0.65 per therm (100,000 Btu)
E = 0.65 efficiency,

then the total annual cost of reheat for the heating season is \$6.50! To that can be added the cost of power for running the fan, F,

$$F = Wtd\$_k 10^{-3} \qquad (15)$$

where

F = total heating season cost for electricity to run the fan (\$),
W = power consumption of the fan (W),
t = average daily running time of exhaust (h/day),
d = annual heating days per year (days/year),
$\$_k$ = cost of electricity (\$/kWh),

which, for the conservative example, comes to \$1.50, plus the reheat cost of \$6.50 from above, for a total heating season cost of approximately \$8.00.

A "real world" calculation is readily done, assuming a bath fan for an hour per day, using values for Milwaukee, Wisconsin, in 1991:

Q = 70 ft^3/min,
t = 1 h/day,
Y = 7,206 degree-days,
$\$_t$ = \$0.3660 per therm (100,000 Btu),
E = 0.75 efficiency,
W = 70 watts,
d = 140 days/year,
$\$_k$ = \$0.0644 per kWh.

Calculating results in a total heating season cost of \$3.30!

THE FUTURE OF KITCHEN VENTILATION

Briefly, future trends in kitchen ventilation can be outlined as follows:

- Awareness will move consumers away from ductless hoods and toward ducted units.
- Downdraft ventilation will continue to be used, driven by kitchen design style, but performance can suffer because it is anti-Newtonian.
- Automatic control of hoods is technically feasible and will grow.
- Ventilation standards will begin to differentiate between houses heated by circulating vs. radiant heating systems.
- ASHRAE Standard 62 will recognize that low-level continuous ventilation is not the equivalent of intermittent ventilation, but that it can substitute for it if the system is carefully engineered and installed.
- Continuous ventilation of the whole house will cease to be the novelty it is today and will frequently be found in new construction. It will be accompanied by range hoods and bath fans for mitigation of high concentrations of intermittent sources.

SUMMARY

Kitchen contaminants are both gases and particles of a size similar to those found in cigarette smoke.

The function and performance of conventionally configured (updraft) range hoods has been studied and measured. They are very effective at controlling the release of the contaminants into the rest of the living space.

The two functions (capture and flow) upon which a hood depends for its performance are easily measured and identified.

An industry rating system and a knowledge of hoods are helpful in selecting and applying hoods for effective control of cooking contaminants at the source. It is best to select a hood that has a large, unobstructed capture sump. It is also important to select a hood that has a published (certified) air delivery higher than the minimum so it can be turned down to a lower flow rate for quieter performance. That will encourage the homeowner to use the hood and enhance indoor air quality.

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