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Kitchen Hoods

Using Demand Ventilation

By Stephen K. Melink, P.E., Member ASHRAE

Today's kitchen ventilation systems are about more than heat and smoke removal, fire protection, and lowest first cost. Food-service establishment owners and operators have become more sophisticated and demanding, so they want systems that are more energy efficient and require less maintenance. In addition, they want kitchens to be more comfortable while complying with more stringent indoor air quality standards. Finally, owners and operators want reduced noise levels and improved fire safety.

Four Automatic Control Strategies

Until a few years ago, kitchen ventilation controls mainly consisted of a manual on/off switch and a magnetic relay or motor starter for each fan. Exhaust and makeup fans either operated at 100% speed or not at all. Occasionally, the independent operator upgraded to a manual two-speed system that relied on cooks to switch from low- to high-speed and vice versa. Today's state of the art is microprocessor-based controls with sensors that automatically vary fan speed based on cooking load, time of day, kitchen comfort, and indoor air quality.

Control Strategy 1. The first strategy is based on the energy *input to* the cooking appliances. The idea is that the more energy appliances use, the more ventilation probably is needed. This involves installing sensors/transmitters on the gas and/or electric lines to monitor energy consumption, and variable-frequency drives to vary the fan speeds accordingly. To date, this approach has not gained wide acceptance because codes require certain minimum velocities and air quantities during times of cooking, and the sensors/transmitters are not smart enough to detect what is happening at the cooking surfaces. For the same reason, performance has been questionable since it is possible for the appliances to be calling for gas/electric when no cooking is taking place, and vice versa. Finally, this approach requires considerable field integration between cooking appliances and the kitchen ventilation control system.

Control Strategy 2. The second control strategy is based on the energy and effluent *output from* the cooking appliances (i.e., the more heat and smoke/vapors generated, the more ventilation needed). This involves installing a temperature sensor in the hood exhaust collar and an optic sensor on the end of the hood, and variable-frequency drives to vary the fan speeds accordingly. A temperature sensor also can be installed in the

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◀ *Slowing down hood fans during non-cooking periods saves energy, wear and tear on HVAC equipment, and reduces the entrainment of grease in the duct, among other benefits.*

makeup air collar and front face of the hood to further improve the intelligence collected about what is occurring and what should occur from a ventilation standpoint. This approach is the only one that addresses code concerns because the optic sensor can detect the presence of smoke/vapors and thus, cooking conditions. Furthermore, the strategy is responsive to the loads (heat and smoke/vapors) that dictate a hood be used in the first place. And finally, it facilitates an easy and low-cost installation since the hood becomes a self-contained intelligent system that can be provided in a turnkey fashion from the hood manufacturer.

Control Strategy 3. The third control strategy is based on time of day. While time of day is the most indirect control variable of the three strategies, it is the simplest approach if the cooking schedule is very predictable with little or no part-load conditions. However, based on the author's experience, most restaurants, supermarkets, institutions, and other food-service facilities have an unpredictable cooking schedule with significant part-load conditions. The real merit of this approach comes into play if it's combined with either Control Strategy 1 or 2. Then, the system can be programmed so the fans operate at 100% speed during lunch and dinner hours, and the fans can be allowed to vary speed based on the reduced load before, between, and after these critical cooking periods.

Control Strategy 4. The fourth control strategy is based on the cook manually turning appliances on and off, or opening lids to clamshell griddles, kettles, and ovens. This approach is more dependent on the number and type of appliances than the other three and therefore somewhat limited in application. However, it can work well for a small, dedicated hood over a single appliance. For example, McDonalds uses this control strategy for the hood over its clamshell griddle. When the top of the grill is closed and the standby button is pressed, the fan operates at low speed. When the top is opened, it operates at high speed. As with the time of day strategy, it can be an effective addition when combined with either Control Strategy 1 or 2. The main drawback is the field integration required between the cooking appliances and the hood control system, and the need for operator assistance.

In Depth Look at Control Strategy 2

A typical sequence of operations for this strategy is as follows: the cook presses a light and fan switch in the morning to turn on the system, which is the same as with a conventional hood. The exhaust and makeup fans go to a preset minimum speed of 10% to 50%. When the cooking appliances are turned on, the fan speeds automatically increase in proportion to the exhaust air temperature. When cooking takes place (as evidenced by smoke/vapor detection inside the hood), the fan speed increases to 100% until the effluent is completely removed. Then, the fans gradually slow down to the speed dictated by the exhaust temperature. The cook presses the light and fan switch at the end of the day to turn off the system.[1]

Behind the scenes, a microprocessor-based system can be performing many other tasks. It can be programmed to automatically turn on and off each day based on time and temperature. It can determine the optimum temperature span based on the maximum exhaust temperature; it can compare the outside air temperature with the kitchen ambient temperature and speed up the fans if the conditions are right for economizer-like free cooling; it can output a signal to control a modulating outside air damper; it can speed up the fans to a new and higher minimum speed when there is a call for heating or cooling to ensure proper operation of a conditioning MUA unit; it can speed up the fans periodically to determine what speed results in the lowest net heat gain to the space; it can speed up the fans during select hours of the day; it can slow down the fans during winter conditions to allow some convective heat spillage and provide free heating to the space; it can speed up the fans if, say, the lid of a kettle is opened with the use of a contact switch or relay; etc. Finally, the cook still has a manual override switch to send the fans to full speed if desired for any reason, with a timer to ensure it switches back to the auto mode to save energy and improve comfort.

Improving Energy Savings

The problem with conventional constant-volume systems is the fan energy and conditioned air waste that occurs during idle, non-cooking periods. Countless times this author has been on the roof of a restaurant or supermarket, and observed cool air being thrown away by one or more exhaust fans while the adjacent air-conditioning units are running as hard as they can to condition the hot, humid makeup air. The American Gas Association estimated in 1990 that more than $2 billion of energy was being wasted every year due to excessive ventilation rates in the U.S. food-service industry alone.

The energy savings associated with slowing down the fans during idle, non-cooking conditions is a function of several variables, including design air quantities, fan brake horsepower, type of makeup air equipment, hours of operation, duty cycle, gas and electric rates, and geographic location. The more these variables favor a demand-ventilation control strategy, the greater the savings.

Calculating the fan energy savings is straightforward since a simple cube relationship exists between fan speed and brake horsepower. However, calculating the heating and air-conditioning savings can be more tedious. Fortunately, an outdoor air load calculator (OALC) is available as freeware at www.archenergy.com/ckv/oac/default.htm that simplifies the analysis.[2]

After the fan energy and heating and air-conditioning savings are calculated, the results must be weighed against the incremental installed cost of the demand-ventilation control system being considered. Generally, the more intelligent the control strategy, the higher the installed cost. However, the more intelligent the control strategy, the higher the operating savings. Therefore, do not assume that a simple low-cost strategy, such as time-of-day, will yield a faster payback than a more expensive system. In fact, the payback often can be faster on the more intelligent system since the fan speeds can operate at lower thresholds without concern about heat and smoke spillage.

The calculated payback typically ranges between one and three years depending on the application and the previously mentioned variables. This author's experience is that restaurants prefer paybacks within this range because their industry is very first-cost driven. However, institutions such as hospitals and schools usually accept slower paybacks because they are more operational-cost driven.

More utilities are recognizing the energy-saving potential of kitchen demand ventilation systems. While other types of variable air volume (VAV) systems typically are justified on the basis of fan energy savings only, utilities are realizing this is only a fraction of the savings when it comes to kitchen VAV systems. Given the larger heating and air-conditioning savings associated with these controls, many are providing incentives and rebates that are worth half their installed cost.

Another way to reduce the first cost of these demand ventilation controls and hasten the payback is to specify direct-drive fans. Properly engineered direct-drive fans solve one of the largest problems in the restaurant industry — belt maintenance. In addition, they are 8% to 15% more energy-efficient than belt-drive fans since there are no belt losses. The main reason direct-drive fans often were not used in the past is there was no means to adjust fan speed and air balance the hood. However, with variable-frequency drives (VFDs) becoming more popular, their incremental cost over magnetic motor starters can be justified on the benefits of direct-drive alone. In other words, treat direct-drive fans and VFDs — which are essentially electronic motor starters — as a separate value proposition. Then it's possible to deduct the VFDs incremental cost over magnetic motor starters from the cost of the demand ventilation controls.

Premise: Capture is good, even when overventilating; spilling is bad, no matter how little.

The problem is that the exhaust is only half of the ventilation picture. Makeup air is the other half.

Exhaust Flow Rates Only

A = Underventilation
B = Proper Capture and Containment
C = Overventilation

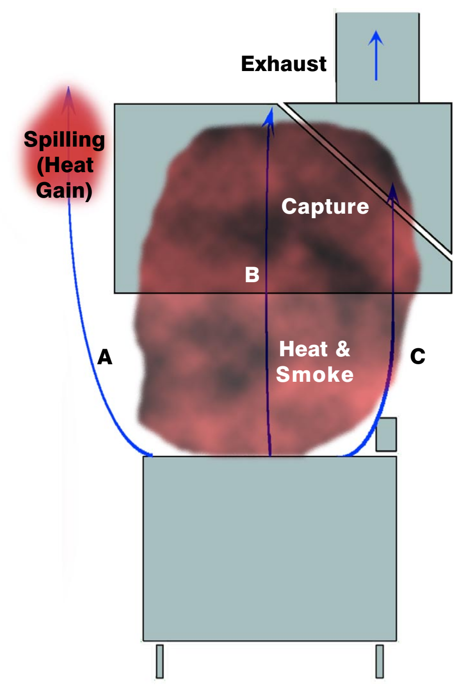


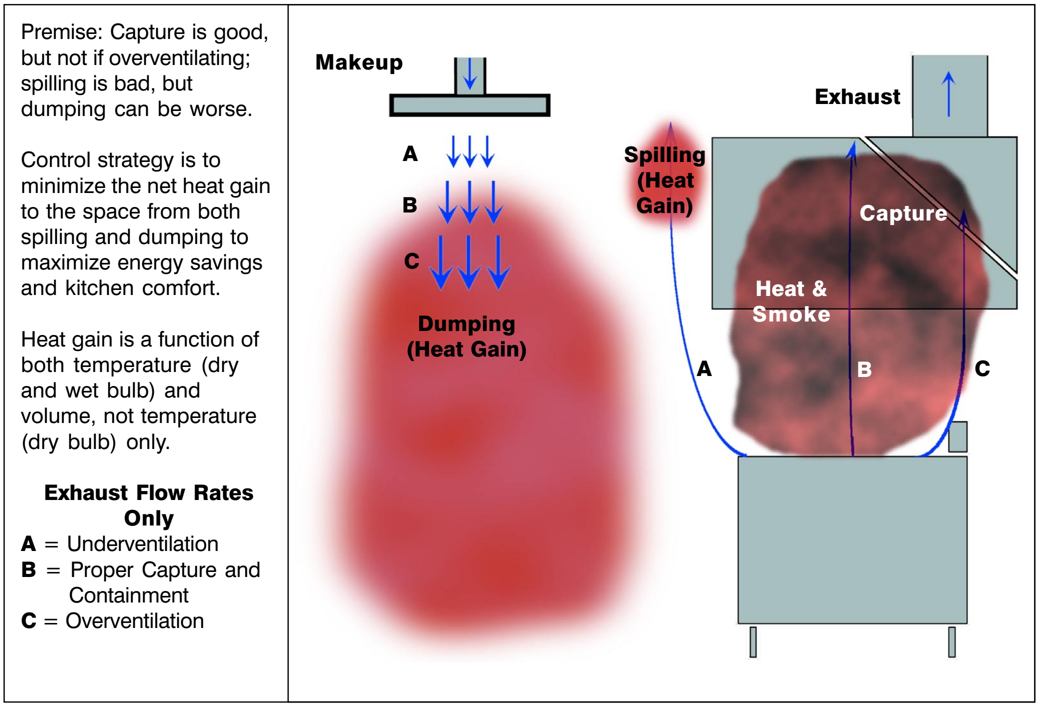
Figure 1: Conventional approach to hood performance.

Improving Kitchen Comfort

Constant-volume ventilation systems can wreak havoc on comfort levels inside a food-service facility. Whether outside air is drawn in unintentionally through the front doors due to a negative building pressure or is supplied intentionally by a makeup fan serving the kitchen, the sensible and latent load can be as overwhelming to the occupants as it can be to the heating and air-conditioning system. This is especially the case in southern climates in the U.S. during mid-afternoon when the outside air load is at its maximum and the cooking load is typically at its minimum, i.e., between 2 to 5 p.m.

Industry research has been documenting the problem of underventilation in recent years. Video clips showing a hood spilling heat can be compelling to someone concerned only with capture and containment. However, little has been documented about the opposite and more prevalent problem of overventilation. When hoods are exhausting more conditioned air than required because of a reduced appliance load underneath, the associated makeup air (MUA) systems are usually *dumping* more outside air back into the kitchen than necessary. In fact, this differential outside air load being dumped back into the building often can be greater than any slight amount of heat spillage that is occurring at the front of the hood. Therefore, a next step for the industry is to expand its model beyond the hood and capture and containment to include the kitchen and minimizing net heat gain to the space.

Today's controls are smart and powerful enough to compare the effects of any possible "spilling" against the much more likely "dumping." It is not necessary to have an overly sophisticated system that measures the air quantity and temperature of both loads to accomplish this. For example, a simple algorithm can increase fan speeds 10% for five minutes every hour to see if the temperature in the kitchen goes up or down. This would be in addition to the algorithm that controls fan speed based on the exhaust temperature alone. The premise is that if the kitchen temperature goes up, then the effects of dumping are greater than the effects of any spilling. If the kitchen temperature goes down, then the effects of spilling are worse than the effects of dumping, and the fan speed stays at the higher level.



Premise: Capture is good, but not if overventilating; spilling is bad, but dumping can be worse.

Control strategy is to minimize the net heat gain to the space from both spilling and dumping to maximize energy savings and kitchen comfort.

Heat gain is a function of both temperature (dry and wet bulb) and volume, not temperature (dry bulb) only.

Exhaust Flow Rates Only

A = Underventilation
B = Proper Capture and Containment
C = Overventilation

Figure 2: System optimization approach to hood performance.

Benefits

Several advantages come from slowing down hood fans during idle, non-cooking periods.

- The first is a significantly quieter kitchen. When the fans run at 80% speed, the air noise generated at the grease filters decreases more than 20%. When the fans run at 50% speed, air noise is virtually eliminated. The result is a more tolerable work environment. This benefit also applies to customers when hoods are located in the front of the house.
- The second advantage is the reduced wear on the HVAC equipment. Soft-starting the hood fans with VFDs extends belt life, and reducing the outside air load on the kitchen air-conditioning units reduces compressor run time and extends its life as well (this also can apply to refrigeration units inside the kitchen). In addition, reducing the makeup airflow decreases the rate at which the filters become dirty and need to be cleaned or replaced.
- Third is the reduced entrainment of grease up the duct, into the fan, and into the atmosphere and roof. Slowing down the exhaust fans and reducing the duct air velocity allows the grease to drain back to the hood and into grease cups, where it can be most easily disposed. Source removal of grease is preferred to purposely contaminating the rest of the system and top of the building.
- Fourth is the ability to prevent the MUA unit from heating at the same time the kitchen air-conditioning unit is cooling.^{3} This is a problem with conventional systems since one is typically controlled by an outside thermostat and the other is controlled by an inside thermostat. An intelligent demand ventilation system will work in concert with, rather than fight against, the kitchen air-conditioning system.

• Fifth is the opportunity to reduce capital construction costs by decreasing the size of the installed HVAC equipment.[4] The less hot/humid makeup air being dumped into the kitchen during the middle of the afternoon when the outside air load is at its peak but the cooking load is potentially at its minimum, the less cooling capacity required.

• Sixth is the potential to improve capture and containment of any convection heat from the cooking appliances when the makeup air velocities are reduced.[5] This is because makeup air velocities and the turbulence and cross-drafts they can create are as important to achieving proper hood performance as the exhaust rate itself. Most hoods are designed with close-proximity makeup air systems.

• Seventh is the opportunity to educate and train operations personnel to turn down or off any cooking appliances that are unnecessary during slow periods. This not only saves appliance energy, but it also increases the demand ventilation savings.

• Eighth is the opportunity to specify direct-drive fans and eliminate the notorious weak link in the entire kitchen ventilation system — the belt.[6] As mentioned, direct-drive fans also eliminate belt losses that can account for an additional 8% to 15% increase in fan operating efficiency, according to most fan manufacturers.

• Ninth is the opportunity to improve kitchen fire safety. Since the exhaust temperature is being continuously monitored with an intelligent demand ventilation system, that information can be used to sound an alarm and/or shut-off cooking appliances if the temperature starts to approach the fusible link rating of the fire suppression system. This offers a proactive solution to a cooking appliance going out of control. It can also reduce or eliminate the costs associated with the fire suppression system activating, i.e., cleanup, recharging, idle labor, loss of food, and loss of business.

Installation and Maintenance

A well-engineered demand ventilation control system is easy to install in new construction and retrofits. For new construction, the hood OEM should mount the sensors on each hood and the processor, and VFDs in an end-cabinet on one of the hoods. The only field labor required beyond a conventional system is running control wiring from the hood sensors to the processor.

For retrofits, an electrician should mount the sensors on each hood and the processor in a safe but convenient location. The VFDs should be installed on the output side of the existing motor starters and the control wiring run. Typical installation time is four labor hours per hood, which is similar to installing a hood fire suppression system.

Finally, a well-engineered system is easy to maintain. The only maintenance needed is a weekly or monthly cleaning of hood sensors to ensure optimum performance. Wiping down these sensors should take less than a minute.

Codes

Codes have recently recognized that demand ventilation is the way of the future. The International Mechanical Code (IMC) was modified in 2003 to add the following exception to Section 507.1*: Net exhaust volumes for hoods shall be permitted to be reduced during no-load cooking conditions, where engineered or listed multi-speed or variable-speed controls automatically operate the exhaust to maintain capture and removal of cooking effluents as required by this section.*

In addition, NFPA 96 Section 8.2.1.1was modified in 2002 to allow the minimum air velocity through any exhaust duct to be reduced from 1,500 fpm to 500 fpm (7.6 to 2.5 m/s).[7]

Many experts believe these two code changes will allow the demand ventilation floodgates to open wide. It has taken years of research and patience for codes to become more performance-based and less prescriptive. Now, codes are no longer a limiting factor to energy-efficient operation of kitchen ventilation systems.

Conclusion

Thousands of demand ventilation controls for commercial kitchen hoods have been installed in recent years, but the market is still relatively young. Supermarkets have been especially progressive because their deli/bakery departments have highly variable cooking loads. Also, supermarkets have energy managers on staff that already understand and appreciate the benefits of variable-speed technology. Institutions such as hospitals, nursing homes, schools, universities, and government are also suitable applications because of their typically large hoods and long operating hours. Restaurant chains are more application-specific since many have smaller hoods and more steady-state cooking operations. However, as energy costs continue to increase and restaurant chains become more aware of the secondary benefits of demand ventilation, smart hoods gradually will become the standard.

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