OPTIMIZING AIRFLOWS IN FOODSERVICE FACILITIES Part 2– Optimizing Exhaust Air

Many methods await when it comes to reducing exhaust rates. Fortunately, engineers can avail themselves of multiple tactics, from the hood specification to proper commissioning and air balance.

By Doug Horton, MS, MBA, CFSP

Part 1 of this series discussed optimizing outdoor air and optional dedicated makeup air for commercial kitchen exhaust systems. This article offers suggestions for optimizing exhaust airflows and introduces a velocity theory of hood operation by which performance of hood configurations and accessories such as end panels can be compared for like appliances and cooking loads.

MINIMIZING EXHAUST HOOD AIRFLOW

Beginning with the energy crises in the 1970s, restaurant chains have pursued reducing kitchen exhaust rates to reduce energy for exhaust fans and tempering makeup air while retaining acceptable exhaust hood performance. This article describes several techniques for reducing cooking exhaust rates:

- Specifying aerodynamic hoods;
- Adding hood end/side panels;
- Providing greater hood overhangs;
- Closing gaps behind appliances;
- Avoiding use of single island hoods;
- Optimizing appliance placement;
- Adding demand control kitchen ventilation (DCKV) systems;
- Properly commissioning and testing exhaust systems; and
- Providing and periodically verifying proper air balance.

Aerodynamic Hoods. The smoother the flow into and within exhaust hoods, the better the capture and containment perfor-

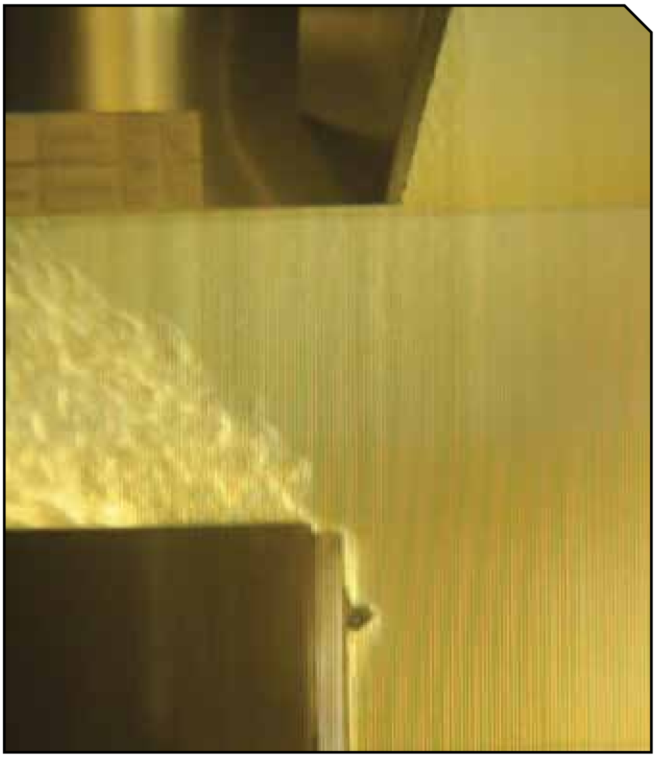


FIGURE 1. Schlieren flow visualization showing Coanda Effect moving effluent from a tall broiler rearward in hood.

mance. For wall canopy hoods, the Coanda Effect causes rising cooking effluents to move toward the backs of hoods as shown in Figure 1. To take advantage of this effect, well performing hoods provide smooth entrances into hoods and filters without interferences such as offsets.

Aerodynamic hood designs include many other beneficial features, such as a rear standoff for clearance to combustible construction, mechanical baffles to direct circulating effluent back toward filters, and highly efficient grease filters.

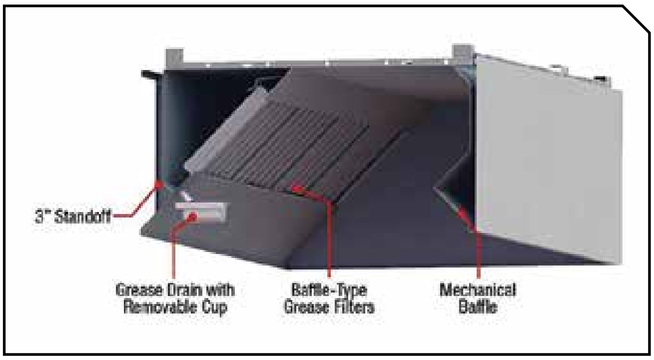


FIGURE 2. Modern aerodynamic exhaust hood.

End Panels. References 1 through 3 summarize tests of adding end panels to hoods to reduce exhausts. Reference 1 reported that installation of end panels to hoods improved hood performance in static conditions by 10% to 15%, and in dynamic conditions, such as robust cooking with cross drafts, exhausts were reduced up to 35%. The worth of end panels can also be evaluated with the velocity theory of hood operation, sidebar example 2, below. Effective end panel configurations include triangular quarter end panels and tapered full length vertical panels with insulated double walls to reduce heat transfer from cooking.

FIGURE 3. Photos of triangular quarter end panel and full end panel, tapered and double-wall insulated.

Note also that demanding fume hoods are provided with fully closed sides, which are comparable to full end panels on exhaust hoods.

FIGURE 4. Fume hood with the equivalent of full end panels.

Overhang. Given the horizontal variability of cooking effluents as they rise from appliances to hoods, greater hood overhangs over appliances increase the probability of capturing and containing effluents. Reference 3 tested increased front overhangs for light, medium, and heavy duty appliance lines, whereby exhaust requirements were reduced by 9% to 27%.

Importantly, from fire analyses by the author, greater overhangs also help assure that cooking fires are contained in the hood area protected by the fire suppression system. Table 1 provides suggested hood front and side overhangs for popular appliances under wall canopy hoods.

Equipment	Overhang	
	Front	Sides
Gas Charbroiler	18"-24"	12"
Fryer or Griddle	12"	6"-12"
Conveyor Oven	12"	12" beyond conveyor ends
Convection Oven	24"	6"
Combination Oven & Steamer	24"	6"
Upright Broilers	18"-24"	12"
Solid Fuel Cooking	24"	24"
Gas Wok	24"	24"
Dishwasher (Type II hood)	12"	24" inlet & discharge

TABLE 1. Recommended overhangs for principal commercial kitchen appliances.

Note that codes typically allow reduced side overhangs if hood ends are closed, such as with full end panels. Hood front overhangs should be greater for more robust appliances and appliances with opening doors. Significantly, hoods with greater overhangs are one time investments that increase capture performance perpetually.

Gaps behind appliances. Hood performance can be increased by pushing appliances as close to back walls as possible. Closing these gaps, such as with metal baffles, will reduce extraneous airflows entering hoods from behind appliances, which otherwise add to the quantity of air that must be exhausted. To facilitate moving appliances rearward, appliance utility pipes, hoses, and power outlets should be installed as close to back walls as possible or inset to not extend forward of back walls.

Single island hoods. Single island hoods are not recommended. In a test summarized in Reference 2, a particular wall canopy hood required 300-400 cfm/ft exhaust with heavy duty cooking appliances. When the same appliances and cooking were tested with the same hood mounted as single island, an exhaust rate in excess of 700 cfm/ft was required to achieve capture and containment. See also example 3 in the velocity theory sidebar.

Appliance placement. In Reference 3, gas fryers and griddles, and electric ovens on stands, were tested singly and in combinations under a 10-ft long wall canopy hood to evaluate the effects of appliance placement. The study confirmed that it's best to place heavier duty appliances in the middle of cooking lines and lower duty appliances at ends of cooking lines. The tests also confirmed that taller appliances at ends of hoods function as virtual end panels.

Taller hoods. Listed industry standard wall canopy hoods are typically 24 or 30 in tall. Where there is vertical space available, taller hoods have larger reservoirs and will better accommodate surges of cooking effluents such as from opening steamer and oven doors and placing baskets of fries in deep fat fryers.

Demand control kitchen ventilation. The idea of reducing kitchen exhaust during periods of reduced cooking has been pursued for decades, including via manual adjustments of multi-speed exhaust fans. Now, modern DCKV systems include electronic sensors, variable speed exhaust fans, and solid-state controls.

DCKV systems can also match reductions of exhaust air with reductions of dedicated makeup air, which can reduce energy for tempering makeup air proportionally. Because of the cubic relationship of centrifugal fan energy to fan speed and flow rate, reductions of fan speeds provide mathematically larger percentage reductions of fan energy. For example, reducing fan speed and exhaust rate by 20% provides a theoretical fan energy reduction of 49%. Figure 5 shows 24-hr exhaust profiles of a restaurant retrofitted with DCKV, showing the original exhaust rate before retrofit, optimal 100% exhaust rate for measured peak cooking load, and actual exhaust rate with DCKV system controlled by exhaust temperature sensed electronically at exhaust duct entrance.

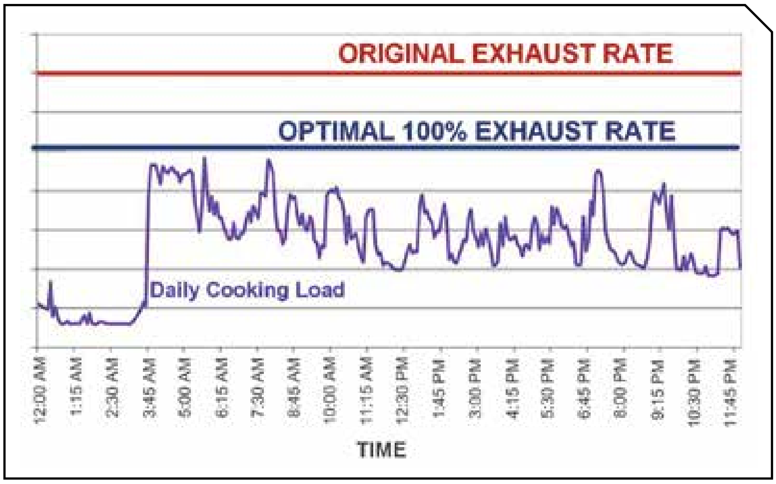


FIGURE 5. Comparative exhaust rates with a DCKV system.

Modern DCKV systems can also automate startups of exhaust fans in response to cooking appliances being turned on as typically required by mechanical codes. DCKV systems often control operation with variable frequency drives and inverter duty AC motors as illustrated in Figure 6.

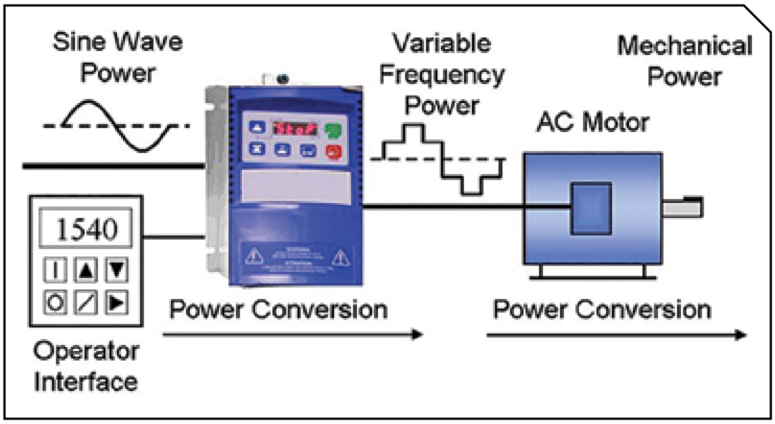


FIGURE 6. VFD control of AC exhaust fan motor.

HOOD COMMISSIONING AND PERFORMANCE TESTING

A reasonable guideline for setting exhaust rates is beginning with the UL listed exhaust rate for the average of appliance duties. Then, with full load cooking on all appliances, increase exhaust rates for full capture and containment of effluents.

Commissioning must include performance tests of each hood in accordance with IMC section 507.16 or similar requirements. The test should be run with all appliances at cooking temperatures and all supply and makeup fans on with building doors and windows closed. Hood capture and containment should be

VELOCITY THEORY OF HOOD OPERATION

Modern exhaust hoods take advantage of several physics principles explored by 18th-century scientists such as Bernoulli, Newton, Venturi, and others. For analyzing kitchen exhaust hoods, these principles can be incorporated into a theory of hood operation, which can be used to compare hood configurations and accessories for appliances and cooking operations. From a prominent manufacturer's testing, the theory provides over 90% accuracy.

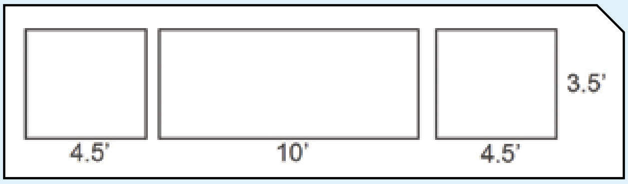
Venturi proved that for a given volume of fluid passing through a pipe, the fluid speed increases as the flow area decreases, and vice versa. In the case of kitchen exhaust hoods, the fluid is makeup air entering the hood to replace air being exhausted, and the flow area is the open sides of the hood from the tops of appliances to hood front, sides, and back if open.

If the makeup air enters faster, it creates a greater pushing force on the effluent to push it through the hood to the grease filters from which the low pressure created by the exhaust fan moves it through the filters and exhaust duct. Thus, hood efficiency is improved if the hood makeup entrance area is decreased.

Mathematically, the average makeup air velocity entering a hood, in ft per minute (fpm), can be determined by dividing the flow rate in cubic ft per minute (cfm) by the square ft (ft^2) of vertical area through which the air is flowing, as shown in several examples. Note that in classical physics, velocity indicates speed and direction, though we'll follow the common practice of using velocity to mean speed.

Example 1: Wall canopy hood. Consider a wall canopy hood that's 10-ft long, 4.5-ft deep, and 3.5-ft above appliances with no end panels. Assume a baseline exhaust flow rate of 300 cfm/ft x 10 ft of hood length = 3,000 cfm, to reliably capture and contain cooking effluents for a given cooking scenario. This is the baseline design from which alternate configurations can be studied. Below is a line drawing that shows the vertical profiles of makeup entry areas of this wall canopy hood, including the front and two open sides.

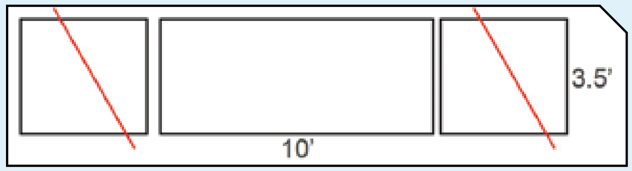
The open makeup air entry area is (4.5 + 10 + 4.5 = 19 ft) x 3.5



ft = 66.5 ft^2.

The average makeup airflow velocity is 3,000 cfm / 66.5 ft^2 = 45 fpm (rounded). This is a good number because research shows that cross drafts and other airflows will interfere with hood performance if greater than 50 fpm.

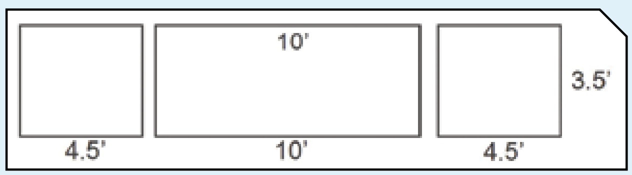
Example 2: Wall canopy hood with full end panels. Consider next the same hood with full end panels installed, such that all makeup air enters only the front of the hood.



When end panels are added, the flow area is 10 ft x 3.5 ft = 35 ft^2, and the average makeup velocity is this case is 3,000 cfm / 35 ft^2 = 85.7 fpm, increasing the makeup air velocity by 90%. The exhaust rate can now be reduced to obtain the same performance as the baseline hood. The lower exhaust rate is inversely proportional to the ratio of the velocities: 3,000 cfm x 45 fpm/85.7 fpm = 1,575 cfm, which provides an exhaust reduction of 48%.

Note that with longer hoods, the percentage reduction of exhaust by adding end panels is decreased. In the case of a hood 16 ft long, calculation similar to above shows that the exhaust would be reduced by 36% — less but still significant.

Example 3: Single island hood. Consider the baseline wall canopy hood installed as an island hood.



The makeup air area is (4.5 + 10 + 10 + 4.5 = 29 ft) x 3.5 ft = 101.5 ft^2. The average makeup air velocity is 3,000 cfm / 101.5 ft^2 = 29.6 fpm.

For the same performance as the baseline wall canopy hood, the single island hood exhaust must now be increased by the ratio of the respective makeup air velocities: 3,000 cfm x 45/29.6 = 4,560 cfm, which is 52% greater than the baseline exhaust!

Compared to the wall canopy with full end panels, the exhaust of the single island hood must be increased by 3,000 cfm x 85.7 fpm/29.6 fpm = 8,685 cfm, which is an increase of 289%. Accordingly, the velocity theory and vulnerability to cross drafts suggests that use of single island hoods should be avoided.

Example 4: Double island hood. If a double island hood is constructed by mounting two wall canopy hoods back to back, the reader can use the velocity theory to show that the performance of this hood configuration is equivalent to using two separate wall canopy hoods.

However, there are several disadvantages of using double island hoods:

- Mounting end panels on island hoods is impractical;
- Island hoods are more vulnerable to cross drafts than wall-mounted hoods;
- Front overhang distances are often reduced because of the size of gas and electric connections behind back to back appliances, including utility distribution systems; and
- Double island hoods are often undersized and fail to meet code or recommended overhang requirements, likely because of their size and bulky appearance.

evaluated by visual means, such as with artificial smoke puffers, smoke candles, or similar devices.

AIR BALANCE

After hood performance has been verified, using the air balance schedule in the building design drawings, it's important to obtain an initial certified air balance. Thereafter, air balance should be checked and adjusted periodically, particularly if operational changes required airflow changes.

From an engineering viewpoint, negative building pressure adds to the static pressure of exhaust systems, and depending on exhaust fan operation and the applicable fan curve, negative pressure can

FIGURE 7. Consequence of negative air balance.

reduce the exhaust flow rate and diminish exhaust hood performance. See Reference 4 for additional information on the effects of commercial kitchen pressure on exhaust system performance.

A slightly positive design air balance is recommended, such as 300-500 cfm for average-sized restaurants. Among other benefits, this will make doors easier to open, unlike the restaurant in the accompanying photo, with professional lettering on the front door advising customers to "pull hard" because the overall air balance is negative. **ES**

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IMAGE CREDITS:

Figures 1-3, 5-7, and Table 1 courtesy of CaptiveAire Systems, Inc. Figure 4 is from Wikipedia Commons.

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