Scope and Application of ASTM 1704, Standard Test Method for Capture and Containment Performance of Commercial Kitchen Exhaust Ventilation Systems

The capture and containment exhaust air flow rates for the 10-foot wall canopy exhaust hood were determined under controlled laboratory conditions. The makeup air was supplied at low velocity (less than 60 ft/min) through floor-mounted, displacement diffusers along the wall opposite the front face of the hood. Appliances were positioned to maximize hood overhang and minimize the gap between the appliance and rear wall. The repeatability/accuracy of the reported values is considered to be ± 5% (e.g., ± 100 cfm at 2000 cfm).

The hood under test was configured with manufacturer-specified hood features (e.g., hood height and depth and/or volume of hood reservoir, number of duct collars, location and size of duct collars, effluent plume containment features or technologies) and manufacturer-specified installation options (e.g., side panels, back wall, rear seal) over the specified appliances operating under simulated cooking conditions. The common denominator for the different styles and configurations of wall-canopy hoods tested by the PG&E Food Service Technology Center is the 10-foot hood length over a standardized appliance challenge (i.e., a heavy-, medium-, light-, and mixed-duty appliance lines). The specifications of the hood and its installation configuration over each appliance line are detailed within the report.

The laboratory test setup was not intended to replicate a real-world installation of this hood where greater exhaust airflows may be required for the capture and containment of the cooking effluent. The objective of this ASTM 1704 testing was to characterize capture and containment performance of an exhaust hood in combination with the specified options within a controlled laboratory environment. The data in this report should not be used as the basis for design exhaust rates and specifications. Design exhaust rates must recognize UL710 safety listings, utilize the knowledge and experience of the designer with respect to the actual cooking operation, and compensate for the dynamics of a real-world kitchen.

Policy on the Use of Food Service Technology Center Test Results

Legal Notice

Captive Aire, Model 5424ND2
Wall-Mounted Canopy Exhaust Hood
Performance Report

Application of ASTM Standard
Test Method F 1704-05

Food Service Technology Center
(www.fishnick.com)
FSTC Report 5011.07.02

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Contents

Objectives and Scope

This report summarizes the results of performance testing a Captive-Aire, Model 5424ND2 Exhaust Hood at the Commercial Kitchen Ventilation Laboratory within the scope of the PG&E Food Service Technology Center program. The objectives were to:

(1) Evaluate the capture and containment performance of this exhaust only, wall-mounted canopy hood when challenged with light-, medium-, heavy-, and mixed-duty appliances under the controlled conditions of the ASTM Standard Test Method F-1704 [Ref 1].
(2) Measure and report the pressure drop across the hood as a function of airflow.
(3) Measure and report the filter velocity profile across the length of the hood.

Equipment

Hood Specifications

The Captive-Aire model # 5424ND2 canopy hood measured 10 feet wide by 4.5 feet deep by 2 feet high and was mounted to a transparent back wall. A 3.0 inch standoff behind the back panel was incorporated within the depth of the hood. The hood was equipped with six 19.5 inch wide by 15.5-inch tall stainless steel baffle-type grease filters, and exhausted through a 14.0-inch by 115.0 inch filter bank opening to a 32.0 inch wide by 14.0 inch exhaust collar. The back panel tapered directly from the bottom of the filter bank, 8.5 inches above the lower edge of the hood, to the vertical wall, 1.0 inch above the lower edge. The grease cup was mounted on the left side panel. The hood was equipped with a 1.0 inch enclosed, insulated, double-wall along the entire front and a 1.0 inch flange along the lower edge of each side. A solid triangle with a height of 5.0 inches and a base of 9.5 inches was located along the inside front panel, beginning 1 inch above the lower edge. The purpose of the triangle was to return the recirculating effluent plume towards the filter bank. The front lower edge of the hood was located at 78.0 inches above the finished floor. The hood setup over a heavy-duty broiler line is shown in Figure 1.

Figure 1. Captive-Aire 5424ND2 Wall-Mounted Canopy Hood Setup (Note Transparent Back Wall)

Side Panel Configuration

Partial side panels were used in some of the capture and containment evaluations. Three side panel options initially were evaluated to determine an optimum size. The side panels measured 50.0-inch by 50.0-inch by 45 degrees, 45.0-inch by 45.0-inch by 45 degrees, and 36.0-inch by 36.0-inch by 45 degrees. Sensitivity testing with the broiler line showed that the smaller of the three panel options was the preferred option based on performance and size. Subsequently, all side-panel tests in the matrix were conducted using this preferred panel configuration. A photograph with and without the side panels installed on the three-broiler cook line, along with a dimensioned drawing, is shown in Figure 2.

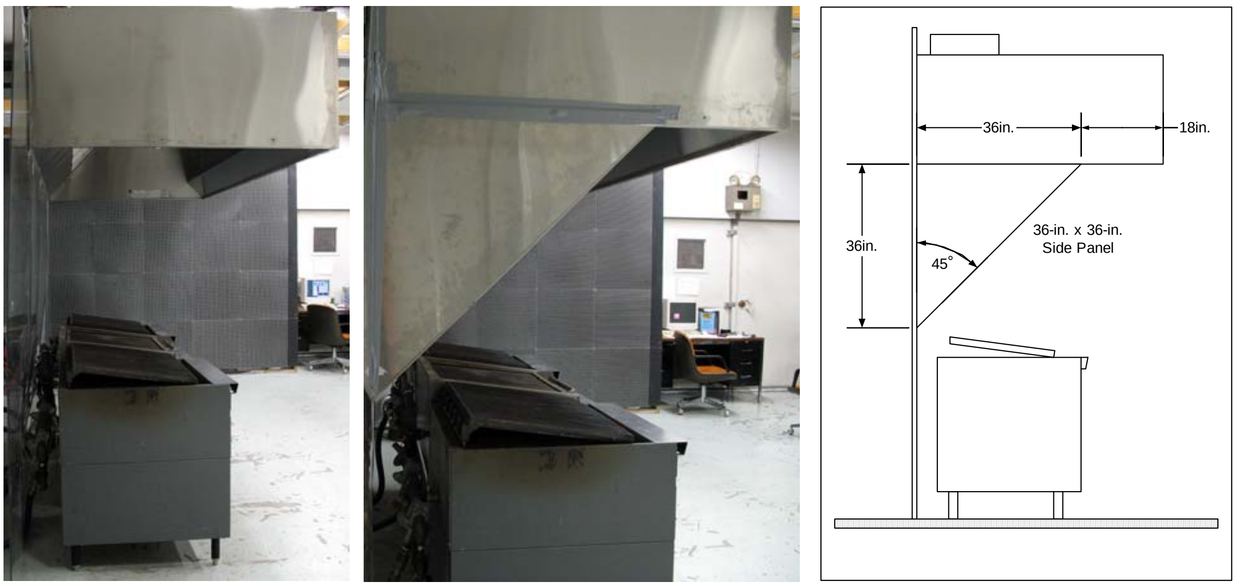

Figure 2. Side View with and without 36-inch x 36-inch Side Panels

Cooking Appliances

The appliances used to challenge this wall-mounted canopy hood were full-size electric ovens (light-duty category), 2-vat high-efficiency gas fryers, a three-foot gas griddle (medium-duty) and 3-foot underfired gas broilers (heavy-duty). For each setup, the appliances were operated under simulated heavy-load cooking conditions established by a recent ASHRAE research project [Ref 2] based on the heavy load testing per the ASTM Standard Test Methods for appliances [Ref 5,6,7,8]. The cooking appliance specifications are listed in Table 1.

Table 1 Cooking Appliance Specifications

	3-Ft. Gas Broiler	Full-Size Electric Convection Oven	2-Vat Gas Fryer	3-Ft. Gas Griddle
Rated Input	96,000 Btu/h	12.1 kW	160,000 Btu/h	90,000 Btu/h
Capacity	719 sq. in.	8.6 cu. ft	Two 50 lb. vats	1026 sq. in.
Height	37.0 in.	57.3 in.	45.3 in.	37.0 in.
Width	34.0 in.	40.0 in.	31.3 in.	36.0 in.
Depth	31.0 in.	41.0 / 38.0 / 42.0 in.	28.0 in.	37.0 in.

Hood/Appliance Overhang Relationship

The appliance lines were positioned in a "pushed back" condition with a minimum distance between the back wall and the rear of the appliance (i.e., rear gap), while allowing enough space for utility connections. Figure 3 illustrates the relationship between front overhang and rear gap. Table 2 shows the actual dimensions of front overhang and rear gap in the "pushed back" condition. Ovens remained in the 12.0-inch overhang position for all tests, as this was also the position of maximum "push back" and minimum rear gap.

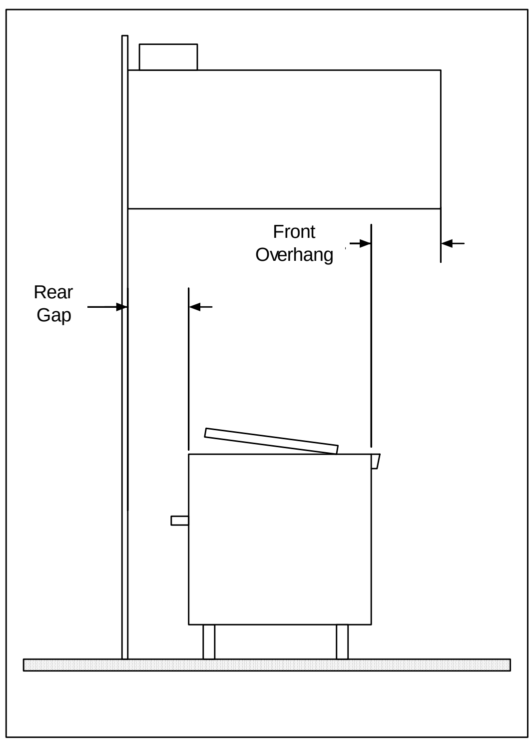

Figure 3. Relationship between Front Overhang and Rear Gap

Table 2 Hood/Appliance Overhang Relationships

	3-Ft. Gas Broiler	Full-Size Electric Convection Oven	2-Vat Gas Fryer	3-Ft Gas Griddle
Front Overhang to Appliance [in.]	18	12	22	12
Rear of Appliance to Backwall [in.]	5	1	4	5

Test Protocol

Capture & Containment Testing

"Hood capture and containment" is defined in ASTM F1704-05, *Capture and containment performance of commercial kitchen exhaust ventilation systems*, as "the ability of the hood to capture and contain grease laden cooking vapors, convective heat and other products of cooking processes." Hood capture refers to the products getting into the hood reservoir, while containment refers to these products staying in the hood reservoir and not spilling out into the space. "Minimum capture and containment" is defined as "the conditions of hood operation at which the exhaust flow rate is just sufficient to capture and contain the products generated by the appliance in idle and heavy load cooking conditions, or at any intermediate prescribed load condition."

For each capture and containment (C&C) evaluation, the exhaust rate was reduced until spillage of the plume was observed (using the airflow visualization techniques described below) at any point along the perimeter of the hood. The exhaust rate was then increased in fine increments until C&C was achieved. For most cases, single-test determinations were used to establish the reported threshold of C&C. This threshold C&C rate was used for direct comparisons across scenarios. In all evaluations, the replacement air was supplied from low velocity, floor-mounted diffusers along the opposite wall (Figure 8). The introduction of replacement air from such sources has been found to be optimum (i.e., the least disruptive) for the laboratory test setup [Ref 3].

A walk-by protocol was introduced to simulate operator movement in the restaurant in the vicinity of the hood during the cooking process. The procedure was used in the lab to emulate the effect of operator disturbance on capture and containment. For this assessment, a researcher walked a line 18.0 inches in front of the appliances with a 12.0-inch front overhang (i.e., 6.0 inches forward of the front of the hood) at a rate of 100 steps per minute. The exhaust rate was then increased to achieve capture and containment of the thermal plume under this dynamic challenge.

Airflow Visualization

The primary tools used for airflow visualization were schlieren and shadowgraph systems, which visualize the refraction of light due to air density changes. Since the heat and effluent generated by the cooking process change the air density above the equipment, the sensitive flow visualization systems provide a graphic image of the thermal activity along the perimeter of the hood. The front and left lower edges of the hood were monitored by schlieren systems located at a height that was centered between the typical 36.0-inch appliance height and the 78.0-inch hood height. The right lower edge of the hood was monitored using a shadowgraph system, located at the same height as the hood edge. Other flow visualization tools used to seed the thermal plume included smoke sticks and theater fog. Figure 4 shows a plan view of the laboratory with the relative positions of the hood and flow visualization tools.

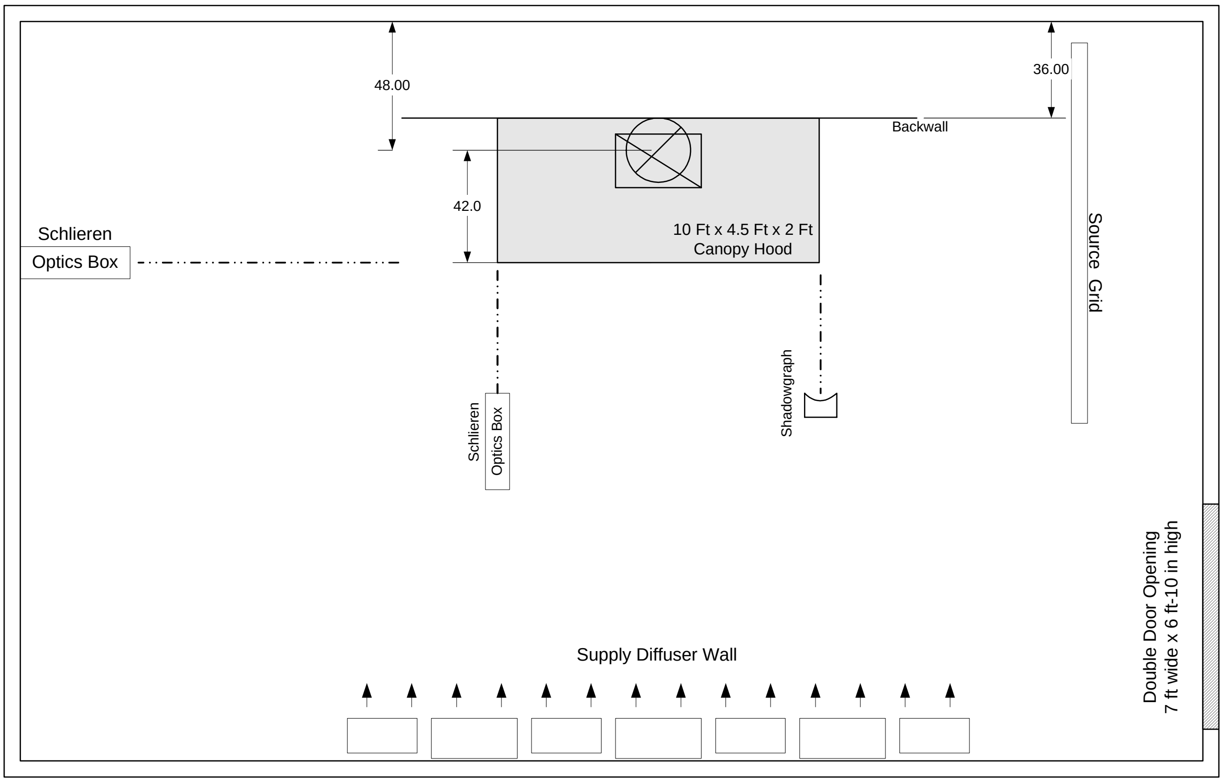

Figure 4. Plan View of Lab During Hood Evaluation

The airflow measurements in the laboratory are in compliance with the AMCA 210/ASHRAE 51 Standard [Ref 4]. The error on the airflow rate measurement is less than 2%. The repeatability of capture and containment determinations is typically within 5%.

Static Pressure Differential

The static pressure difference was measured between the laboratory and the exhaust collar of the hood. The pressure was taken at the exhaust collar with a 4.0-inch by 2.0-inch right-angle static pressure probe inserted at the center of the side of the 32.0-inch by 14.0-inch by 4.0-inch collar. The static pressure taps were located approximately 4 inches inside the exhaust collar wall and 2.0 inches above the top of the hood. The pressures were taken for five exhaust flow rates (1500, 2000, 2500, 3000, and 3300 cfm).

Filter Face Velocity Profile

The filter face velocity was measured with a 4.0-inch diameter, rotating vane anemometer (RVA) traversing flush against the filter. One-minute average readings were recorded for each filter traverse. The profiles were taken for two exhaust airflow rates, 2000 and 3000 cfm.

Appliance and Hood Configuration Test Matrix

The performance of the Captive-Aire model 5424ND2 hood was evaluated for 12 test conditions. Generally, each appliance line configuration was evaluated in a best practice “pushed back” condition with and without side panels. In addition, one test with the broiler challenge included a seal between the rear of the appliances and the wall. Another additional test was performed on the mixed appliance line to evaluate hood performance under a dynamic walk-by challenge. In this case, the exhaust rate was increased to achieve capture and containment under the disruption caused by operator movement. The following test matrices present the details of the test setups for the respective appliance lines. Each test condition is sequentially numbered for reference to the reported data.

Underfired Gas Broiler (Heavy-Duty) Test Matrix

The heavy-duty challenge was comprised of three 3-foot, gas underfired broilers. The front overhang was 18.0 inches in the pushed back condition and resulted in a rear gap of 5.0 inches. The hood was tested for each appliance location with and without side panels, in a static (no operator movement) condition. With the broilers in this configuration and the side panels installed, an additional evaluation was done with the 5.0-inch rear gap sealed between the broilers and the back wall at the height of the top of the appliance cabinet (Test 3). The test matrix for the heavy-duty broilers is shown in Table 3 and the setup illustrated in Figure 5.

Table 3. Underfired Gas Broiler (Heavy-Duty) Test Matrix

Test #	LH Appliance	LH Appliance Effective Front Overhang[1] [in.]	LH Appliance Effective Rear Gap [in.]	CTR Appliance	CTR Appliance Effective Front Overhang [in.]	CTR Appliance Effective Rear Gap [in.]	RH Appliance	RH Appliance Effective Front Overhang[1] [in.]	RH Appliance Effective Rear Gap [in.]	Side Panels	Side Overhang [in.]
1	Broiler	18	5	Broiler	18	5	Broiler	18	5	Without	6
2	Broiler	18	5	Broiler	18	5	Broiler	18	5	With	6
3	Broiler	18	5	Broiler	18	5	Broiler	18	5	With Side Panels & Rear Seal	6

Figure 5. Heavy-Duty Underfired Gas Broiler Line

Gas Fryer (Medium-Duty) Test Matrix

The medium-duty test matrix consisted of three 2-vat gas fryers (6 vats total). The front overhang was 22.0 inches and resulted in a rear gap of 4.0 inches. The hood was tested with and without side panels, in a static (no operator movement) condition. The test matrix for the medium-duty fryers is shown in Table 4 and the setup illustrated in Figure 6.

Table 4. Fryer (Medium-Duty Appliance) Test Matrix

Test #	LH Appliance	LH Appliance Effective Front Overhang[1] [in.]	LH Appliance Effective Rear Gap [in.]	CTR Appliance	CTR Appliance Effective Front Overhang [in.]	CTR Appliance Effective Rear Gap [in.]	RH Appliance	RH Appliance Effective Front Overhang[1] [in.]	RH Appliance Effective Rear Gap [in.]	Side Panels	Side Overhang [in.]
4	2-Vat Fryer	22	4	2-Vat Fryer	22	4	2-Vat Fryer	22	4	Without	6
5	2-Vat Fryer	22	4	2-Vat Fryer	22	4	2-Vat Fryer	22	4	With	6

Figure 6. Medium-Duty Gas Fryer Line

Full-Size Convection Oven (Light-Duty) Test Matrix

The light-duty test matrix consisted of one full-size electric convection oven and two full size gas convection ovens. As the electric oven idled, the gas ovens maintained the same operating temperature, and then the burners were turned off during the capture and containment evaluation [Ref 2]. The front overhang was 12.0 inches. In this configuration, the left oven had 4.0 inches between the convection motor and the back wall, the center oven had 1.0 inch between the motor and the back wall, and the right oven was flush against the back wall. The rear gap was measured from the rear of the convection fan motor to the back wall, except for the right oven that had its motor shrouded. The hood was tested with and without side panels, in a static (no operator movement) condition. The test matrix for the full-size ovens is shown in Table 5 and the setup illustrated in Figure 7.

Table 5. Full-Size Convection Oven (Light-Duty) Test Matrix

Test #	LH Appliance	LH Appliance Effective Front Overhang[1] [in.]	LH Appliance Effective Rear Gap [in.]	CTR Appliance	CTR Appliance Effective Front Overhang [in.]	CTR Appliance Effective Rear Gap [in.]	RH Appliance	RH Appliance Effective Front Overhang[1] [in.]	RH Appliance Effective Rear Gap [in.]	Side Panels	Side Overhang [in.]
6	Oven	12	4	Oven	12	1	Oven	12	0	Without	0
7	Oven	12	4	Oven	12	1	Oven	12	0	With	0

Figure 7. Light-Duty Full Size Convection Oven Line

2-Vat Fryer/Broiler or Griddle/Convection Oven (Combination-Duty) Test Matrix

The combination duty test matrix consisted of the 2-vat gas fryer in the left position, the 3-foot gas underfired broiler in the center position and the full-size electric convection oven in the right position. The performance of the hood was evaluated with and without side panels, in a static (no operator movement) condition, except for Test 10. For this test, hood performance was evaluated using a walk-by protocol. In Test 11 and 12, the broiler was replaced with a gas griddle. The test matrix for the combination-duty appliance line is shown in Table 6 and the setup illustrated in Figure 8.

Table 6. Fryer/Broiler/Convection Oven (Combination Duty) Test Matrix

Test #	LH Appliance	LH Appliance Effective Front Overhang[1] [in.]	LH Appliance Effective Rear Gap [in.]	CTR Appliance	CTR Appliance Effective Front Overhang [in.]	CTR Appliance Effective Rear Gap [in.]	RH Appliance	RH Appliance Effective Front Overhang[1] [in.]	RH Appliance Effective Rear Gap [in.]	Side Panels	Side Overhang [in.]
8	2-Vat Fryer	22	4	Broiler	18	5	Oven	12	1	Without	6
9	2-Vat Fryer	22	4	Broiler	18	5	Oven	12	1	With	6
10[2]	2-Vat Fryer	22	4	Broiler	18	5	Oven	12	1	With	6
11	2-Vat Fryer	22	4	Griddle	12	5	Oven	12	1	Without	6
12	2-Vat Fryer	22	4	Griddle	12	5	Oven	12	1	With	6

[2]Test condition was conducted with "walk-by" protocol.

Figure 8. Fryer/Broiler/Convection Oven Appliance Line

Results and Discussion

The capture and containment (C&C) results are presented below for the different appliance-line configurations.

Broiler (Heavy-Duty) Testing

The results of the gas broiler-line capture and containment testing are presented in Table 7. It was found that the exhaust rate required to capture and contain the thermal challenge from three broilers was 3100 cfm. When side panels were added to this condition, the threshold airflow rate for C&C was reduced to 2200 cfm. When the rear gap between the broiler cabinet and back wall was sealed, the C&C exhaust rate was reduced even further to 2100 cfm (210 cfm/ft).

Table 7. Capture and Containment Results for Broilers

Test #	LH Appliance	LH Appliance Effective Front Overhang[1] [in.]	CTR Appliance	CTR Appliance Effective Front Overhang [in.]	RH Appliance	RH Appliance Effective Front Overhang[1] [in.]	Side Panels	Side Overhang [in.]	C&C Exhaust Rate [acfm]	C&C Exhaust Rate [acfm/ft]
1	Broiler	18	Broiler	18	Broiler	18	Without	6	3100	310
2	Broiler	18	Broiler	18	Broiler	18	With	6	2200	220
3	Broiler	18	Broiler	18	Broiler	18	With Side Panels & Rear Seal	6	2100	210

Fryer (Medium-Duty) Testing

The results of the gas fryer capture and containment testing are presented in Table 8. It was found that the exhaust rate required to capture and contain the three 2-vat fryers (6-vats total) was 3000 cfm. The hood's ability to capture and contain was challenged by the strong thermal plume from the fryers' flue jetting up along the rear wall, then sideways along the rear of the hood, escaping at the rear corners. If side panels were added to this condition, the exhaust rate dropped to 1700 cfm (170 cfm/ft).

Table 8. Capture and Containment Results for Fryers

Test #	LH Appliance	LH Appliance Effective Front Overhang[1] [in.]	CTR Appliance	CTR Appliance Effective Front Overhang [in.]	RH Appliance	RH Appliance Effective Front Overhang[1] [in.]	Side Panels	Side Overhang [in.]	C&C Exhaust Rate [acfm]	C&C Exhaust Rate [acfm/ft]
4	2-Vat Fryer	22	2-Vat Fryer	22	2-Vat Fryer	22	Without	6	3000	300
5	2-Vat Fryer	22	2-Vat Fryer	22	2-Vat Fryer	22	With	6	1700	170

Full-Size Convection Oven (Light-Duty) Testing

The results of the full-size convection oven testing are presented in Table 9. It was found that the exhaust rate required to capture and contain three full-size convection ovens with and without side panels was 1400 cfm (140 cfm/ft).

Table 9. Capture and Containment Results Full-Size Convection Ovens

Test #	LH Appliance	LH Appliance Effective Front Overhang[1] [in.]	CTR Appliance	CTR Appliance Effective Front Overhang [in.]	RH Appliance	RH Appliance Effective Front Overhang[1] [in.]	Side Panels	Side Overhang [in.]	C&C Exhaust Rate [acfm]	C&C Exhaust Rate [acfm/ft]
6	Oven	12	Oven	12	Oven	12	Without	0	1400	140
7	Oven	12	Oven	12	Oven	12	With	0	1400	140

Fryer/Broiler or Griddle/Convection Oven (Combination-Duty) Testing

The results for the 2-vat gas fryer/3-foot gas broiler/full-size electric convection oven capture and containment tests are presented in Table 10. All evaluations were conducted at a static condition except for test 10, which incorporated a walk-by protocol. Test 11 and 12 were conducted with a griddle in place of the broiler.

The exhaust rate required to capture and contain a 2-vat fryer/3-foot broiler/full-size convection oven cook line was 2600 cfm. If side panels were added to this pushed back condition, the plume from the fryer flue was brought under control and the C&C exhaust rate dropped to 1800 cfm (180 cfm/ft).

Table 10. Capture and Containment Results for 2-Vat Fryer / Broiler / Full-Size Convection Oven Appliance Line

Test #	LH Appliance	LH Appliance Effective Front Overhang[1] [in.]	CTR Appliance	CTR Appliance Effective Front Overhang [in.]	RH Appliance	RH Appliance Effective Front Overhang[1] [in.]	Side Panels	Side Overhang [in.]	C&C Exhaust Rate [acfm]	C&C Exhaust Rate [acfm/ft]
8	2-Vat Fryer	22	Broiler	18	Oven	12	Without	6	2600	260
9	2-Vat Fryer	22	Broiler	18	Oven	12	With	6	1800	180
10[2]	2-Vat Fryer	22	Broiler	18	Oven	12	With	6	2800	280
11	2-Vat Fryer	22	Griddle	12	Oven	12	Without	6	2600	260
12	2-Vat Fryer	22	Griddle	12	Oven	12	With	6	1500	150

[2]Test condition was conducted with “walk-by” protocol.

A walk-by evaluation was conducted for the combination duty line with side panels. The increase in exhaust flow rate required to capture and contain the dynamically disturbed thermal plume was 2800 cfm (1000 cfm higher than the static condition).

The combination-duty appliance line was also evaluated with a griddle replacing the broiler in the center position. Without side panels installed, the measured C&C exhaust rate was 2600 cfm. With side panels added, the C&C exhaust rate was reduced to 1500 cfm (150 cfm/ft).

Static Pressure Differential Measured at Exhaust Collar

The static pressure drop between the laboratory and the exhaust collar was measured for five exhaust flow rates. The pressure drop across the hood ranged from 0.07 in. of water at 1500 cfm to 0.48 in. of water at 3300 cfm. At 2500 cfm the pressure drop was 0.26 in. of water. The results are presented in Table 11.

Table 11. Hood Static Pressure Readings at Exhaust Collar

Exhaust Flow Rate [acfm]	Hood Static Pressure at Exhaust Collar [inches of water]
1500	0.07
2000	0.15
2500	0.26
3000	0.39
3300	0.48

Figure 9 presents the static pressure versus airflow curve. The data reflects a typical pressure versus airflow relationship.

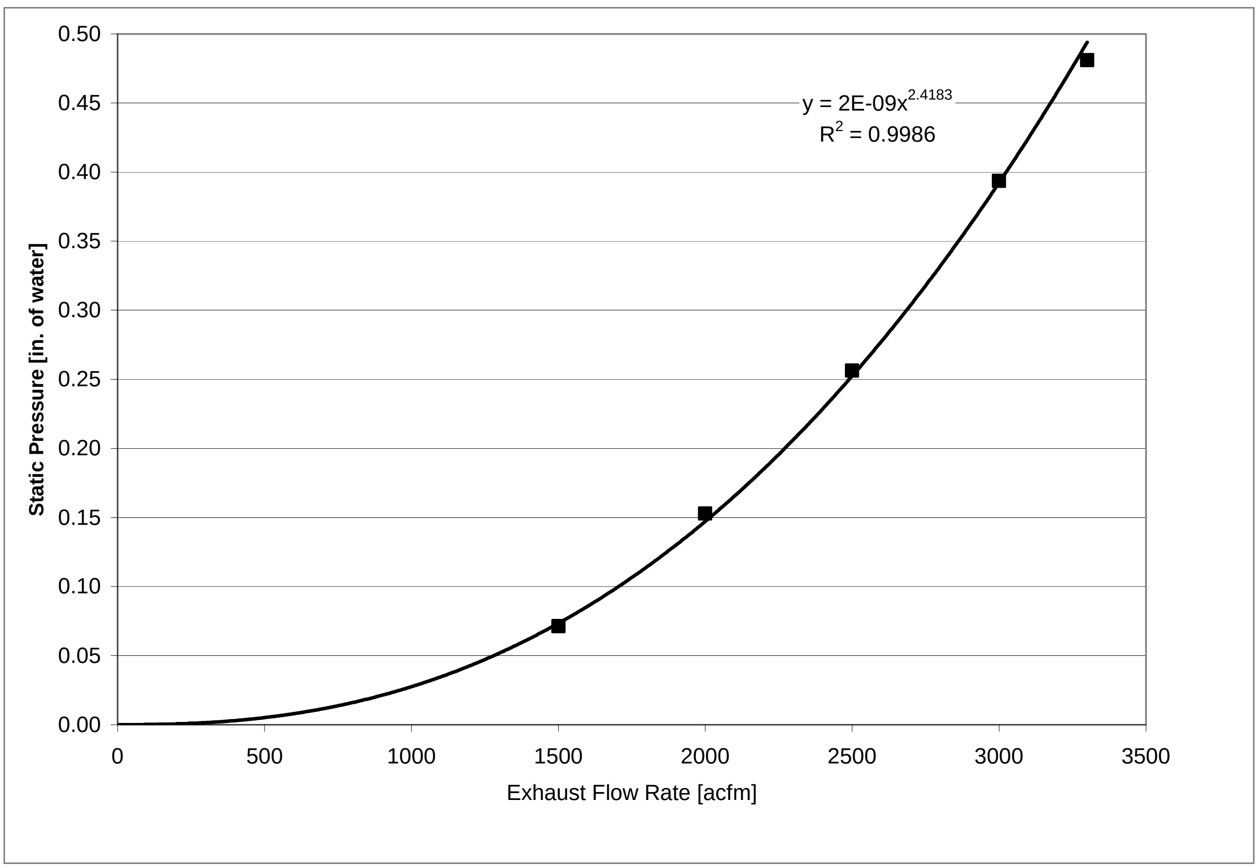

Figure 9. Static Pressure Differential Measured at the Exhaust Collar

Filter Face Velocity Testing

Filter face velocity readings were taken for each of the six filters at two exhaust flow rates. For the 2000 cfm exhaust rate, the filter velocities ranged from 205 to 249. For the 3000 cfm exhaust rate, the filter velocities ranged from 312 to 361 fpm. The results are presented in Table 12 and a velocity profile is shown in Figure 10.

Table 12. Filter Face Velocity Readings

Exhaust Flow Rate [acfm]	Left Filter #1 Velocity [fpm]	Filter #2 Velocity [fpm]	Filter #3 Velocity [fpm]	Filter #4 Velocity [fpm]	Filter #5 Velocity [fpm]	Right Filter #6 Velocity [fpm]	Avg. Filter Velocity [fpm]	Standard Deviation [fpm]	Standard Deviation [%]
2000	205	217	247	249	218	218	226	18	8
3000	312	331	348	361	329	324	334	18	5

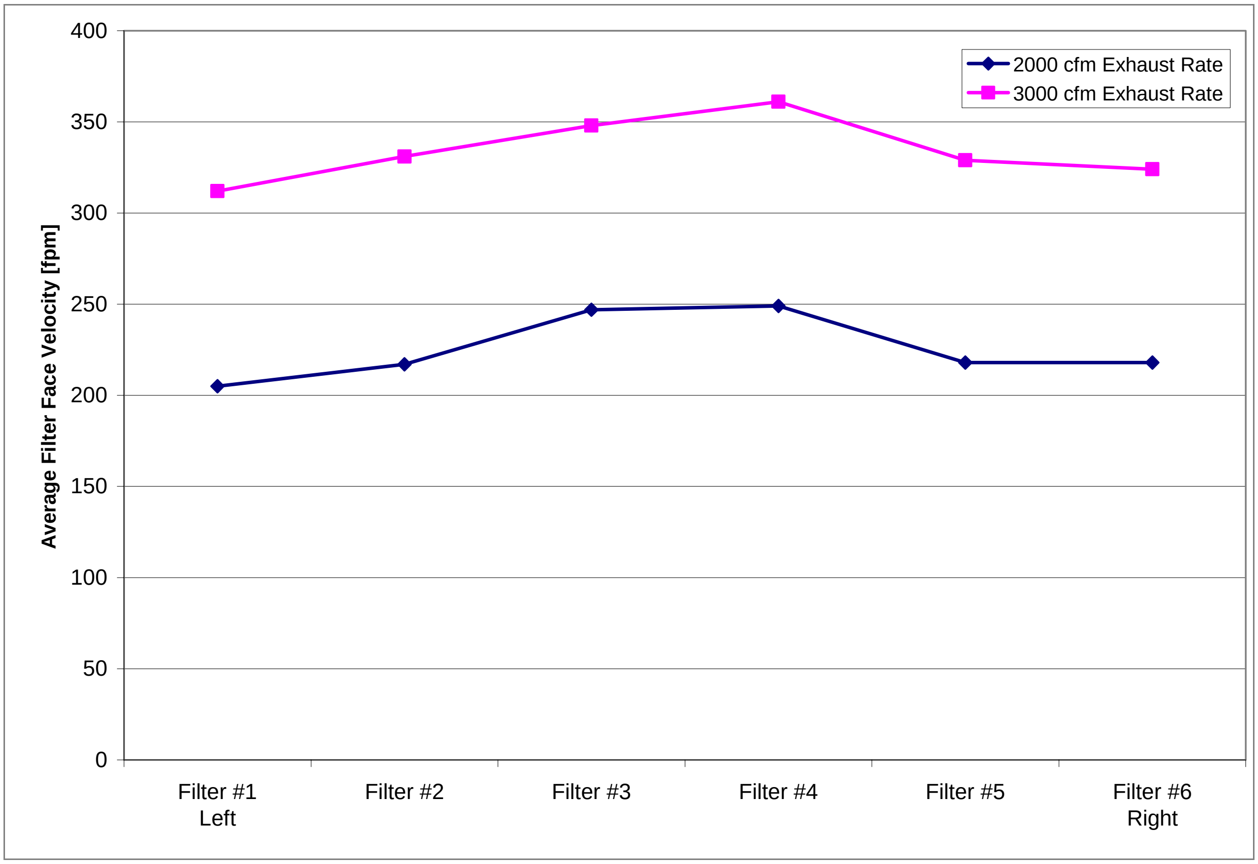

Figure 10. Filter Face Velocity Profiles

For both exhaust rates, the profiles show that the velocity was at a maximum in the center of the hood (slightly higher for the filter located right of center below the exhaust collar) and a minimum towards the ends. The large 32.0-inch by 14.0-inch exhaust collar helped to achieve a uniform plenum pressure and relatively flat filter face velocity profile. For the 2000 cfm exhaust rate, the average filter velocity was 226 fpm. The velocity increased to 249 fpm near the exhaust collar and dropped to 205 fpm at the left end filter. For the 3000 cfm rate, the average filter velocity was 334 fpm, with a center velocity of 361 fpm and an end velocity of 312 fpm.

Summary of Results and Conclusions

Figure 11 and Table 13 summarize the results for the capture and containment testing. The test numbers in Figure 11 refer to the first column of Table 13 and associated test condition. Overall, the capture and containment airflow rates ranged from a low of 1400 cfm (140 cfm/ft) to a high of 3100 cfm (310 cfm/ft).

The dramatic benefit of side panels was demonstrated for all appliance combinations tested except the oven line, which remained unchanged. With the 36-inch x 36-inch x 45-degree panel installed on both ends of the 10-foot, wall mounted Captive-Aire hood, the capture and containment flow rate was 2200 cfm (220 cfm/ft) for the three gas broilers. When a rear shield was installed (between the rear of the appliance and the back wall), the capture and containment flow rate dropped to 2100 cfm (210 cfm/ft). Based on testing experience of the CKV/FSTC research team and data from the ASHRAE study [Ref 2], this is considered to be a very low threshold of capture and containment for a heavy-duty appliance challenge.

The multi-duty line was incorporated into the test matrix to reflect a cooking equipment challenge in a real-world, casual dining kitchen. In this case, the capture and containment rate was 2600 cfm (260 cfm/ft) without side panels. When the side panels were installed, the capture and containment flow rate dropped to 1800 cfm (180 cfm/ft). When the griddle was substituted for the broiler under static test conditions, a capture and containment rate of 1500 cfm (150 cfm/ft) was recorded. Under the dynamic walk-by condition for the multi-duty line with the broiler, the capture and containment exhaust rate increased to 2800 cfm (280 cfm/ft). Based on the experience of the CKV/FSTC research team, this exhaust rate is believed to be the representative design rate for a multi-duty appliance line.

The static pressure differential measured at the exhaust collar, varied from 0.07 to 0.39 in. of water between 1500 to 3000 cfm (150 to 300 cfm/ft) of exhaust airflow. At 2500 cfm (250 cfm/ft) the measured static pressure difference was 0.26 in. of water.

The measured filter velocities across the length of the exhaust hood showed an 8% standard deviation from the average measured velocity at 2000 cfm (200 cfm/ft) and 5% at 3000 cfm (300 cfm/ft), respectively.

Table 13. Summary of Capture and Containment Results

Test #	LH Appliance	LH Appliance Effective Front Overhang[1] [in.]	LH Appliance Effective Rear Gap [in.]	CTR Appliance	CTR Appliance Effective Front Overhang[1] [in.]	CTR Appliance Effective Rear Gap [in.]	RH Appliance	RH Appliance Effective Front Overhang[1] [in.]	RH Appliance Effective Rear Gap [in.]	Side Panels	Side Overhang [in.]	C&C Exhaust Rate [cfm]
1	Broiler	18	5	Broiler	18	5	Broiler	18	5	Without	6	3100
2	Broiler	18	5	Broiler	18	5	Broiler	18	5	With	6	2200
3	Broiler	18	5	Broiler	18	5	Broiler	18	5	With Side Panels & Rear Seal	6	2100
4	2-Vat Fryer	22	4	2-Vat Fryer	22	4	2-Vat Fryer	22	4	Without	6	3000
5	2-Vat Fryer	22	4	2-Vat Fryer	22	4	2-Vat Fryer	22	4	With	6	1700
6	Oven	12	4	Oven	12	1	Oven	12	0	Without	0	1400
7	Oven	12	4	Oven	12	1	Oven	12	0	With	0	1400
8	2-Vat Fryer	22	4	Broiler	18	5	Oven	12	1	Without	6	2600
9	2-Vat Fryer	22	4	Broiler	18	5	Oven	12	1	With	6	1800
10[2]	2-Vat Fryer	22	4	Broiler	18	5	Oven	12	1	With	6	2800
11	2-Vat Fryer	22	4	Griddle	12	5	Oven	12	1	Without	6	2600
12	2-Vat Fryer	22	4	Griddle	12	5	Oven	12	1	With	6	1500

[1]Front overhang measured from front of hood to front of appliance
[2]Test condition was conducted with "walk-by" protocol.

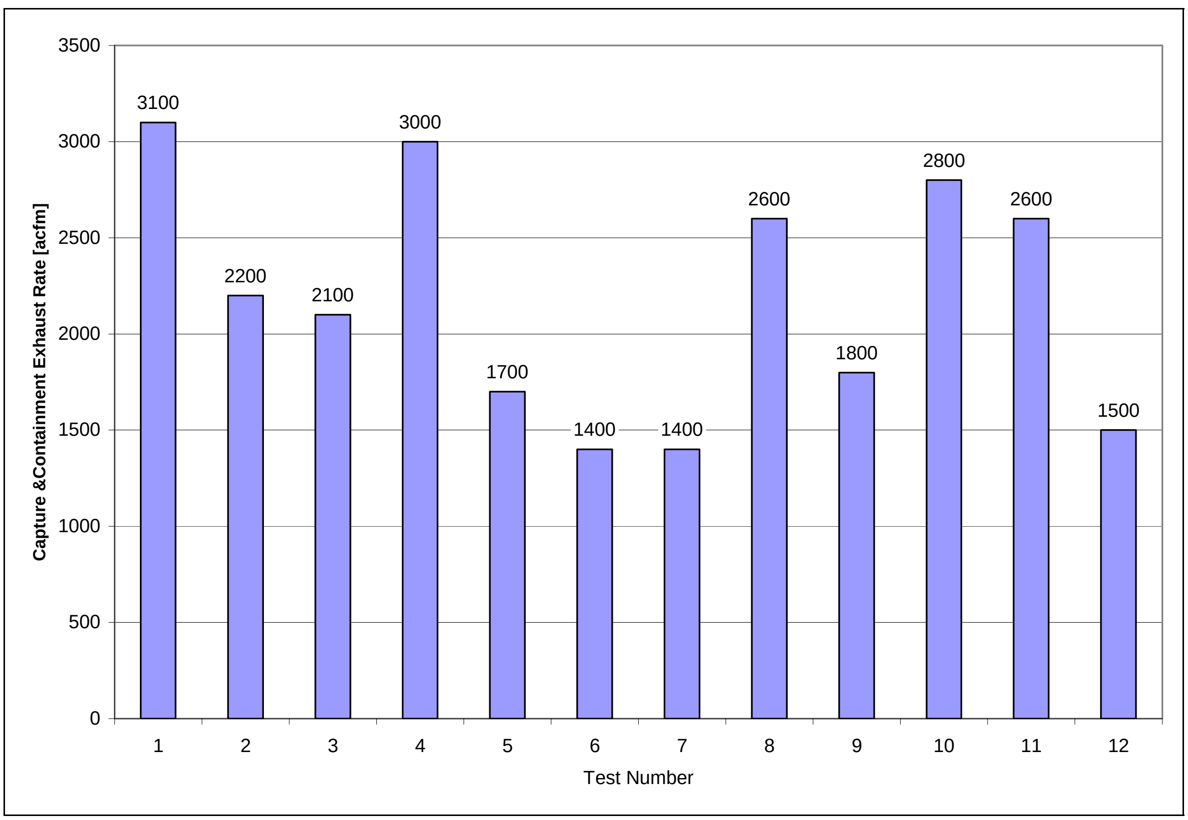

Figure 11. Summary of Capture and Containment Results

References

1. ASTM 2005. ASTM Designation F1704-05, *Capture and containment performance of commercial kitchen exhaust ventilation systems.* West Conshohocken, PA.
2. Swierczyna, R.T., P.A. Sobiski, D. Fisher. 2005. *1202-RP Effect of appliance diversity and position on commercial kitchen hood performance*. ASHRAE, Atlanta, GA.
3. Brohard, G., D.R. Fisher PE, V.A. Smith PE, R.T. Swierczyna, P.A. Sobiski. 2003. *Makeup air effects on kitchen exhaust hood performance.* California Energy Commission, Sacramento, CA.
4. Air Movement and Control Association, Inc. and American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc. *Laboratory methods of testing fans for rating.* AMCA Standard 210/ASHRAE Standard 51, Arlington Heights, IL and Atlanta, GA.
5. ASTM 2005. ASTM Designation F1496, *Standard test method for performance of convection ovens*. West Conshohocken, PA.
6. ASTM 2005. ASTM Designation F1361, *Standard test method for performance of open deep fat fryers*. West Conshohocken, PA.
7. ASTM 2003. ASTM Designation F1275, *Standard test method for performance of griddles*. West Conshohocken, PA.
8. ASTM 2003. ASTM Designation F1695, *Standard test method for performance of underfired broilers*. West Conshohocken, PA.

Appendix A: Captive Aire Model 5424ND2 Hood Drawing