Commercial Kitchen Ventilation

Optimizing System Performance

…using *Green* Tips, Tricks & Technologies from FSTC Research!

What can make a hood work better?

9 times out of 10
it is NOT more exhaust!

What’s wrong with this installation?

Could This Hood Be Improved?

… or this one?

… or this one?

…close that gap!

…and add that side panel!


CAUTION
GARLAND

There are hoods everywhere that would benefit from a side panel


SERVICE

QSR tries a single canopy hood

Total exhaust = 2200 cfm

…but back to a 2-hood system

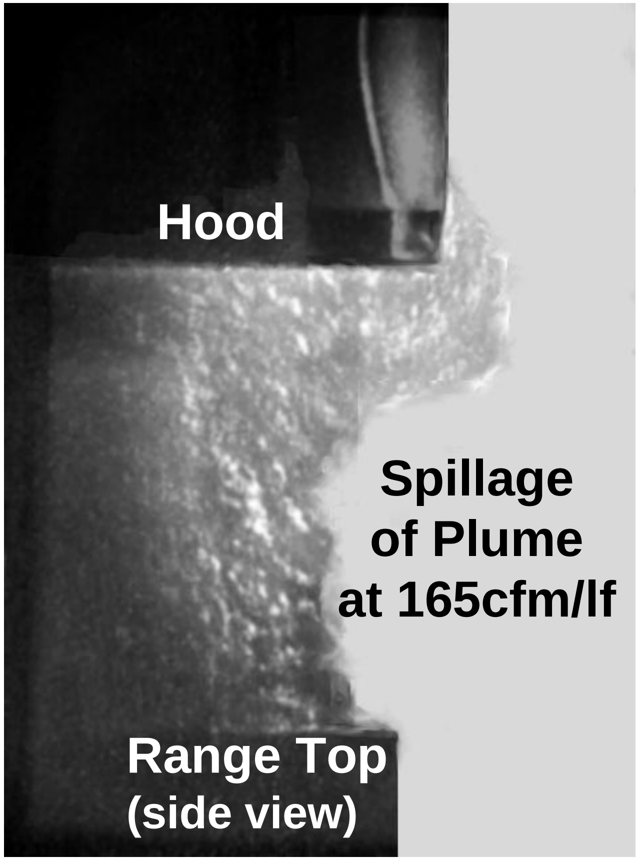
Total exhaust = 1600 cfm

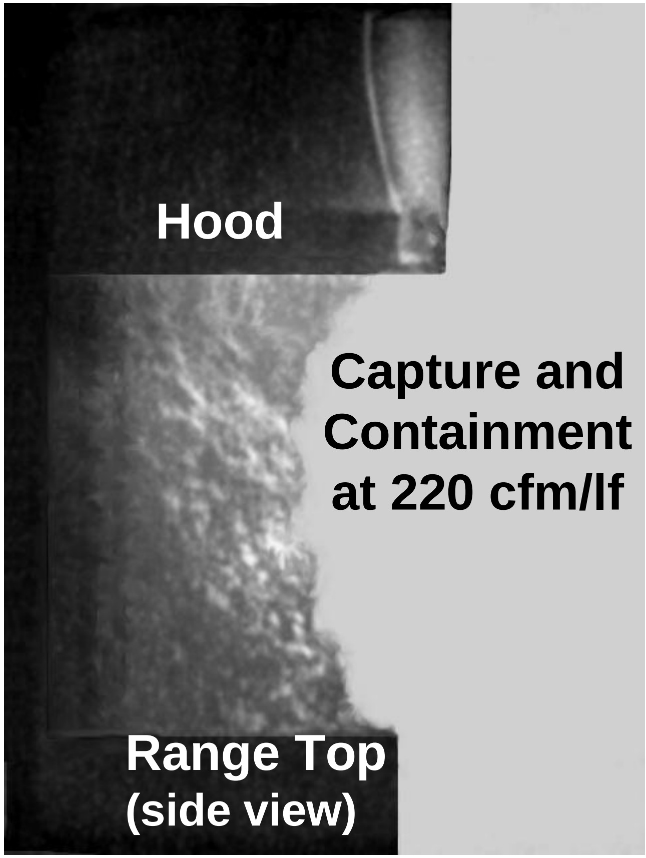
LEED design for another QSR

Exhaust Airflow = 600 - 1200 cfm

Food Service Technology Center has its own Commercial Kitchen Ventilation Lab

Schlieren Flow Visualization

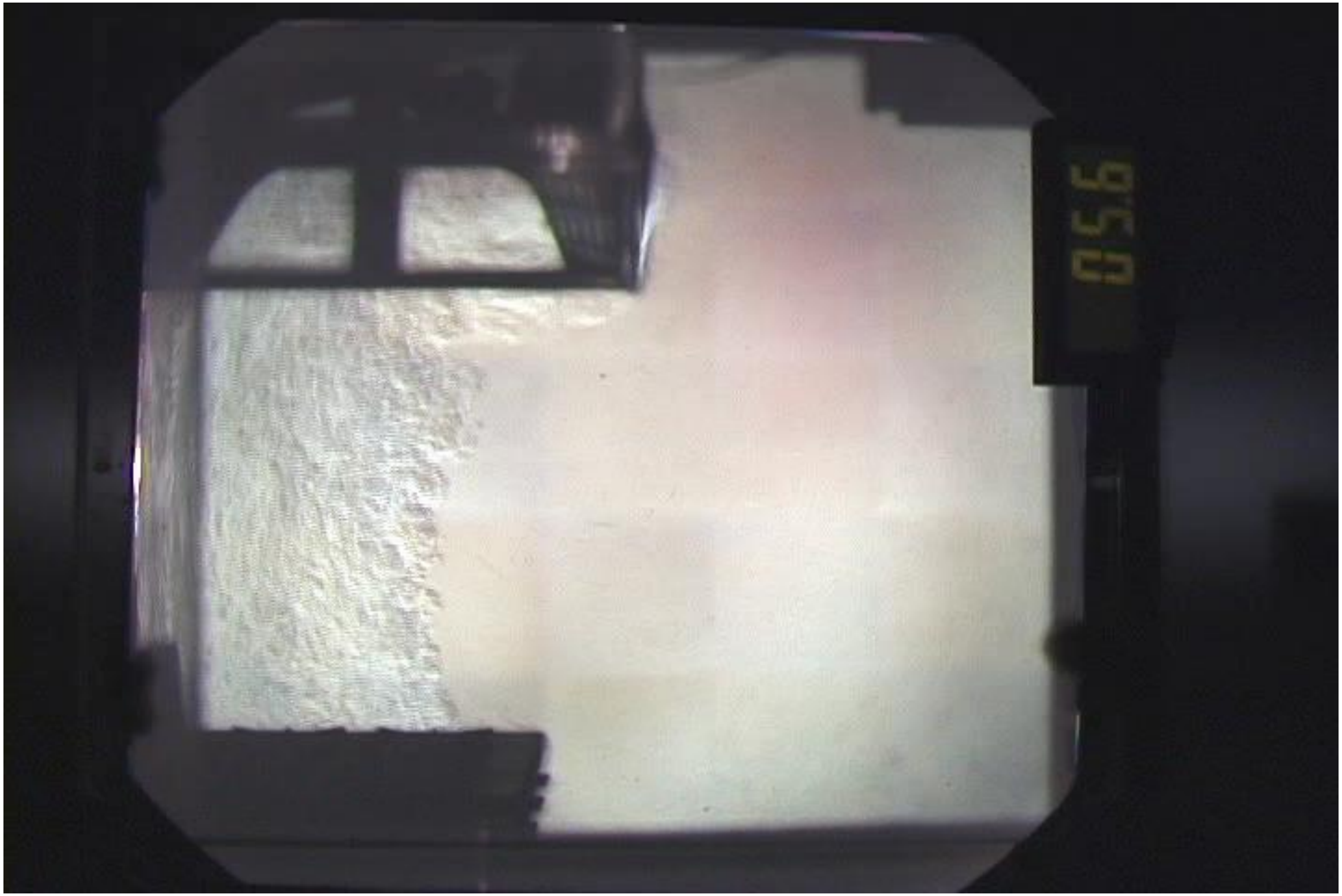




What the Eye Sees!

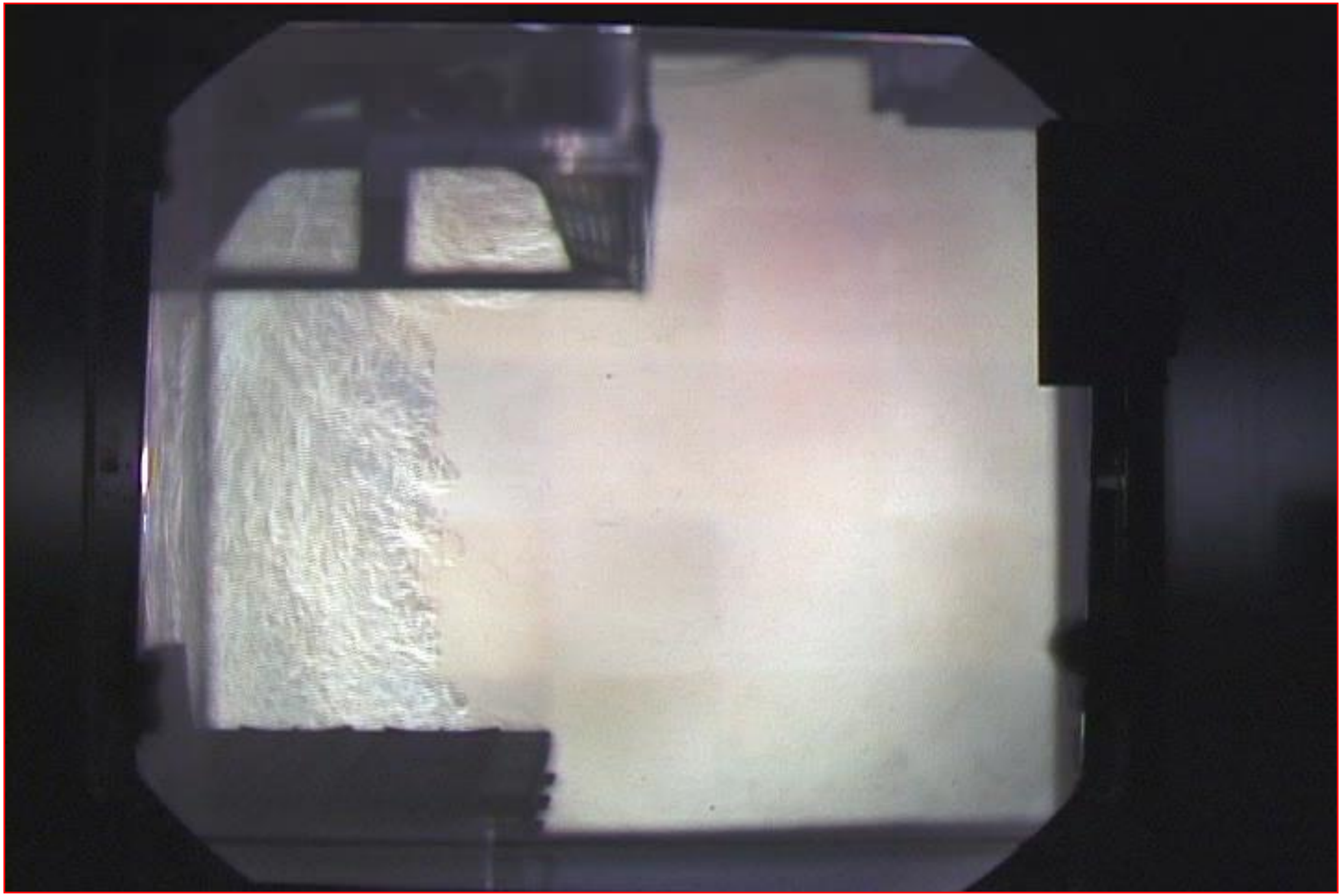
8-Ft Wall Mounted Canopy Hood

What the Camera Sees!



Hood Does Not Capture & Contain

Makeup Air Introduced at Low Velocity



Capture & Containment (C&C) @ 1400 CFM

CKV Optimization Strategies :

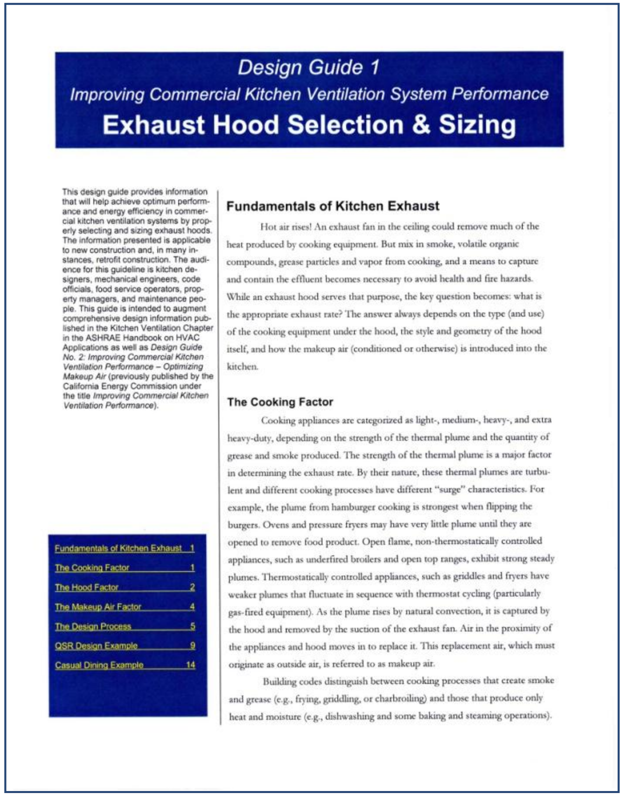
1. Reduce the exhaust ventilation rate

2. Optimize makeup air delivery to kitchen

3. Integrate the CKV system with the HVAC system

CKV/HVAC Optimization Strategies

1. Minimize design exhaust rate
   – Group appliances according to effluent production and associated ventilation requirements.
   – Engineered UL listed canopy hoods to increase effectiveness and reduce heat gain. Use proximity hoods where applicable.
   – Side panels and end walls!



Design Guide 1

Improving Commercial Kitchen Ventilation System Performance

Exhaust Hood Selection & Sizing

This design guide provides information that will help achieve optimum performance and energy efficiency in commercial kitchen ventilation systems by properly selecting and sizing exhaust hoods. The information presented is applicable to new construction and, in many instances, retrofit construction. The audience for this guideline is kitchen designers, mechanical engineers, code officials, food service operators, property managers, and maintenance people. This guide is intended to augment comprehensive design information published in the Kitchen Ventilation Chapter in the ASHRAE Handbook on HVAC Applications as well as *Design Guide No. 2: Improving Commercial Kitchen Ventilation Performance – Optimizing Makeup Air* (previously published by the California Energy Commission under the title *Improving Commercial Kitchen Ventilation Performance*).

Fundamentals of Kitchen Exhaust

Hot air rises! An exhaust fan in the ceiling could remove much of the heat produced by cooking equipment. But mix in smoke, volatile organic compounds, grease particles and vapor from cooking, and a means to capture and contain the effluent becomes necessary to avoid health and fire hazards. While an exhaust hood serves that purpose, the key question becomes: what is the appropriate exhaust rate? The answer always depends on the type (and use) of the cooking equipment under the hood, the style and geometry of the hood itself, and how the makeup air (conditioned or otherwise) is introduced into the kitchen.

The Cooking Factor

Cooking appliances are categorized as light-, medium-, heavy-, and extra heavy-duty, depending on the strength of the thermal plume and the quantity of grease and smoke produced. The strength of the thermal plume is a major factor in determining the exhaust rate. By their nature, these thermal plumes are turbulent and different cooking processes have different "surge" characteristics. For example, the plume from hamburger cooking is strongest when flipping the burgers. Ovens and pressure fryers may have very little plume until they are opened to remove food product. Open flame, non-thermostatically controlled appliances, such as underfired broilers and open top ranges, exhibit strong steady plumes. Thermostatically controlled appliances, such as griddles and fryers have weaker plumes that fluctuate in sequence with thermostat cycling (particularly gas-fired equipment). As the plume rises by natural convection, it is captured by the hood and removed by the suction of the exhaust fan. Air in the proximity of the appliances and hood moves in to replace it. This replacement air, which must originate as outside air, is referred to as makeup air.

Building codes distinguish between cooking processes that create smoke and grease (e.g., frying, griddling, or charbroiling) and those that produce only heat and moisture (e.g., dishwashing and some baking and steaming operations).

Download at:
www.fishnick.com

Hood Setup over Two Charbroilers

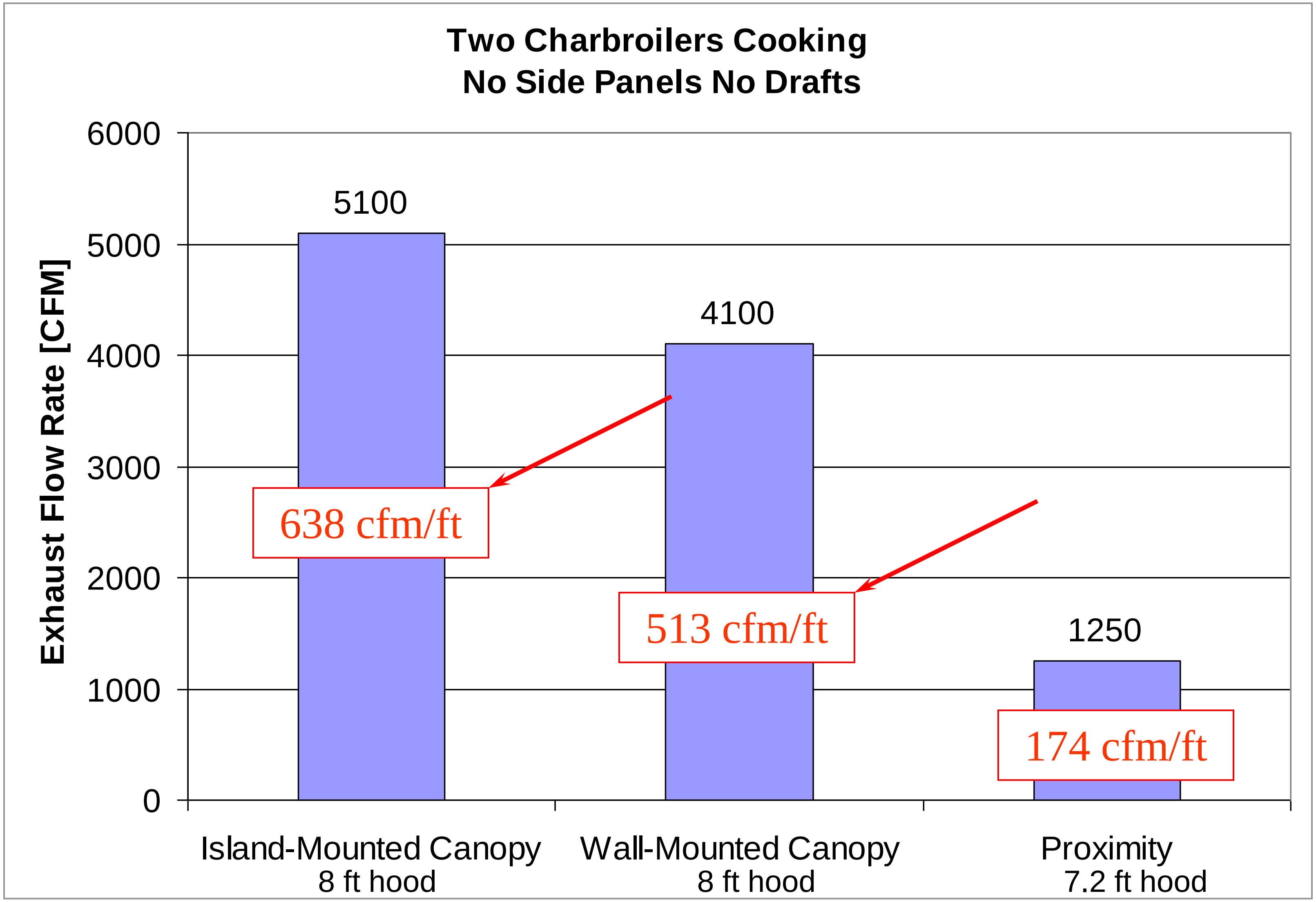
8-Foot Wall Mounted Canopy Hood

Single-Island Canopy with Displacement MUA (C&C 5100 cfm, 2 charbroilers cooking)

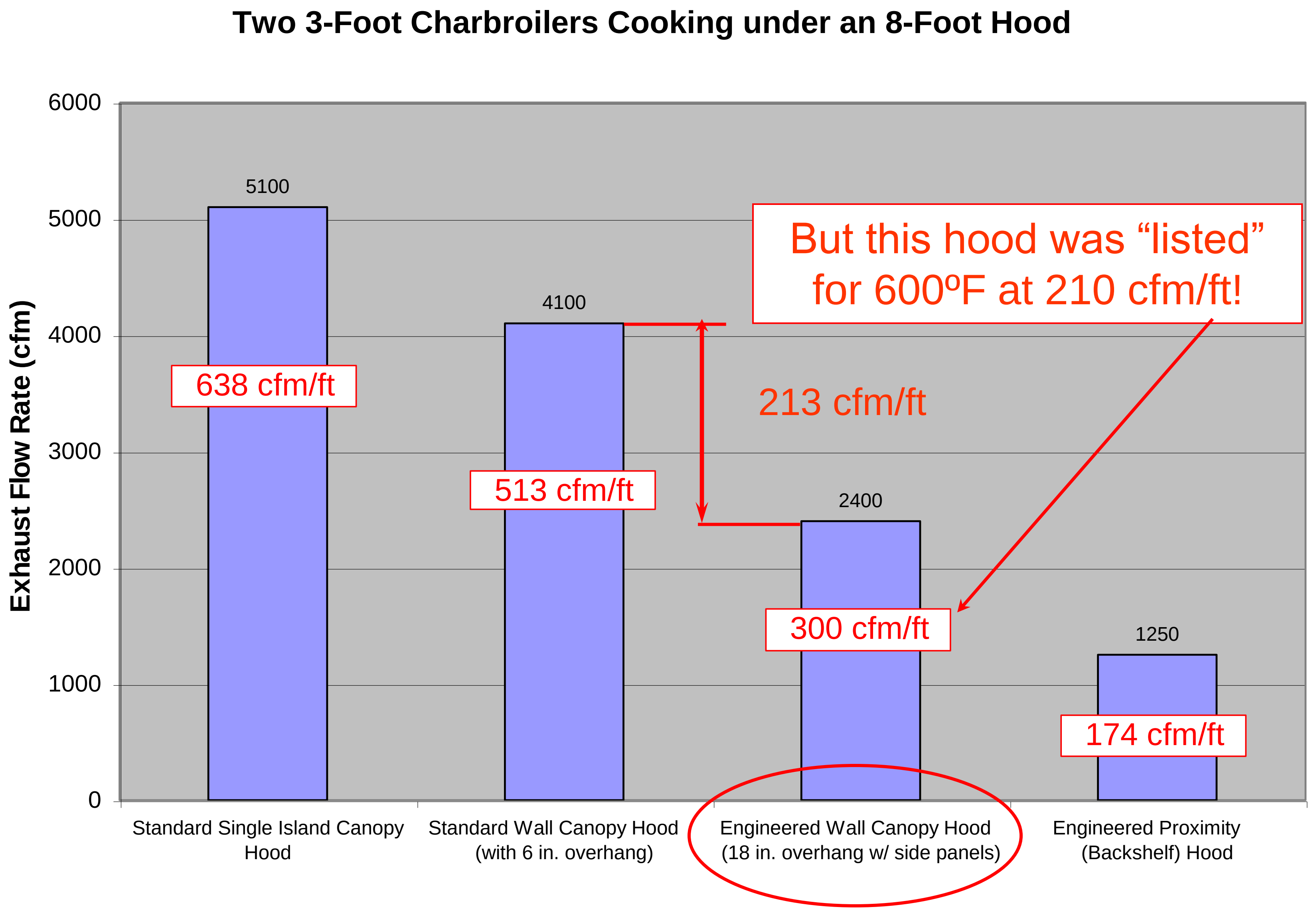
Wall Canopy with Displacement MUA
(C&C 4100 cfm, 2 charbroilers cooking)

Proximity Hood with Displacement MUA (C&C 1250 cfm, 2 charbroilers cooking)

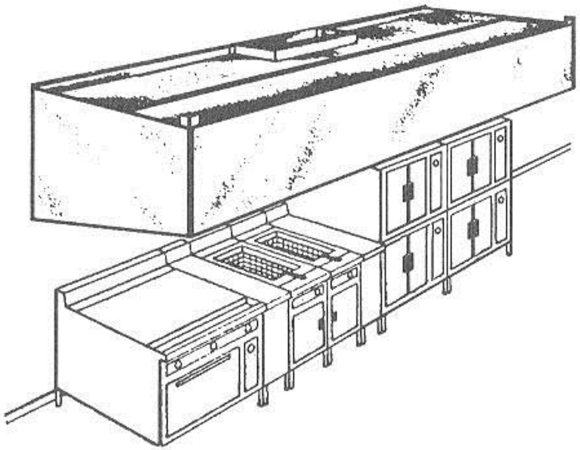
Hood Type Effect on C&C



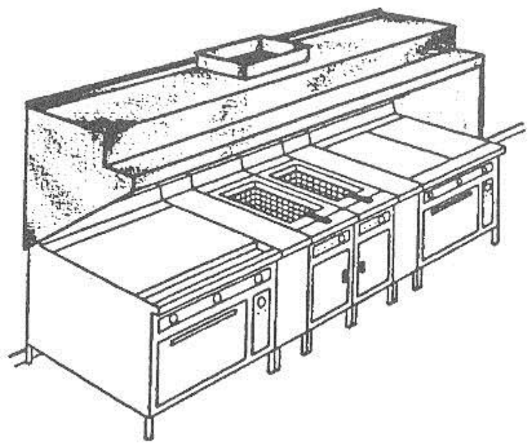
Add in an Engineered Wall-Canopy Hood



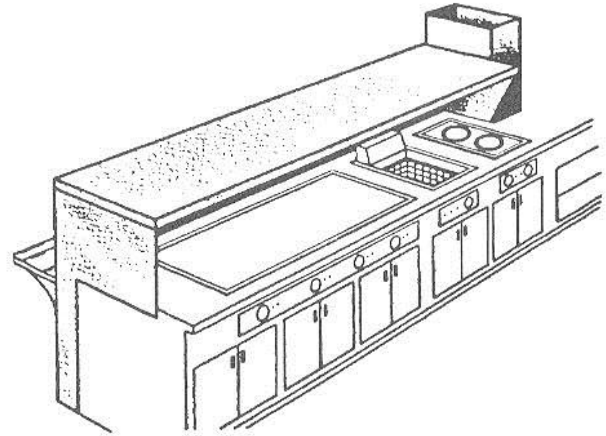
…let’s look at the single-island hood in the lab



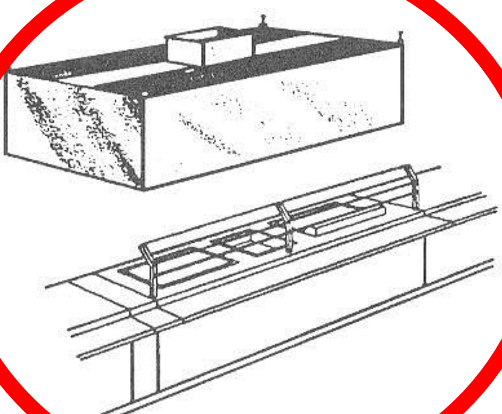
WALL-MOUNTED CANOPY



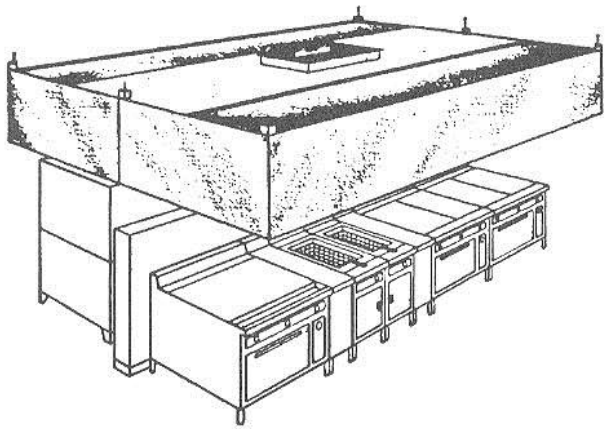
BACK SHELF



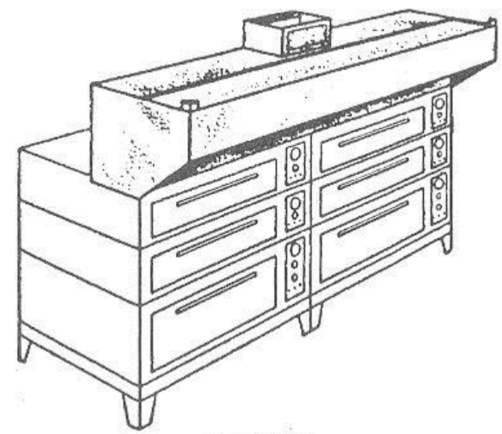
PASS-OVER



SINGLE-ISLAND CANOPY



DOUBLE-ISLAND CANOPY



EYEBROW

Single-Island Canopy Hood

Charbroiler @ 600ºF Idle Condition

Not that different from the real world!

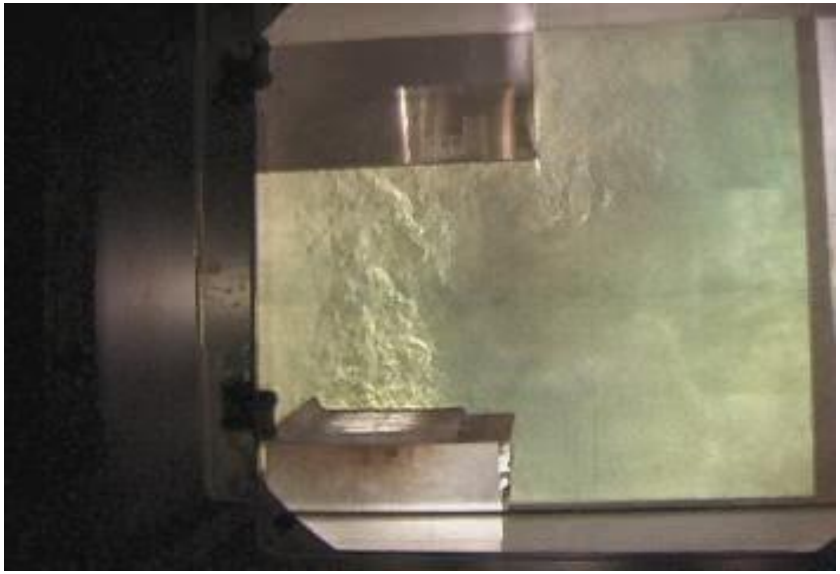
End View

12 inch front overhang

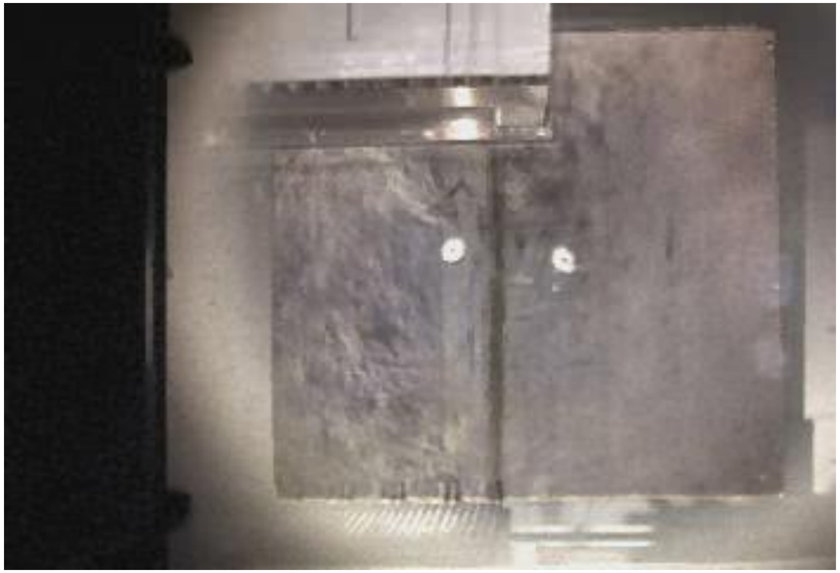
Front View

6 inch side overhang

Exhaust Rate: 300 cfm/ft



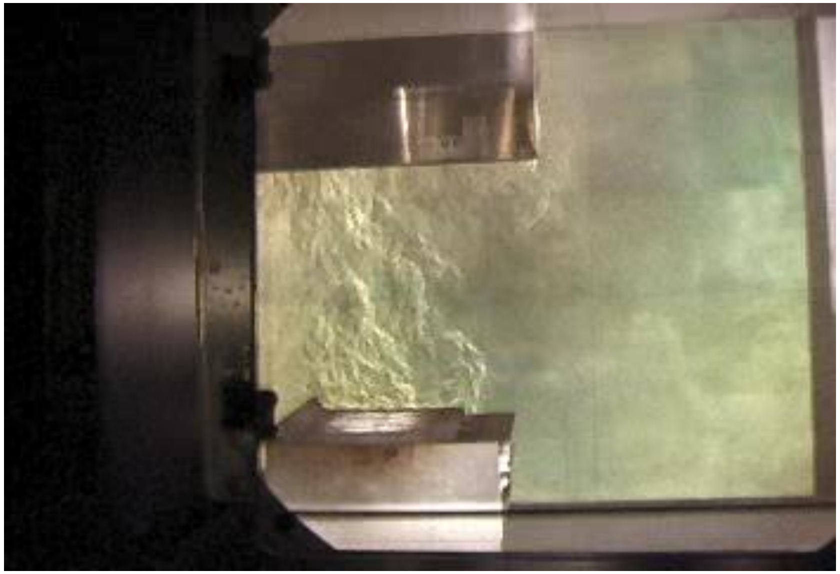
End View
(Spill on Front Edge)



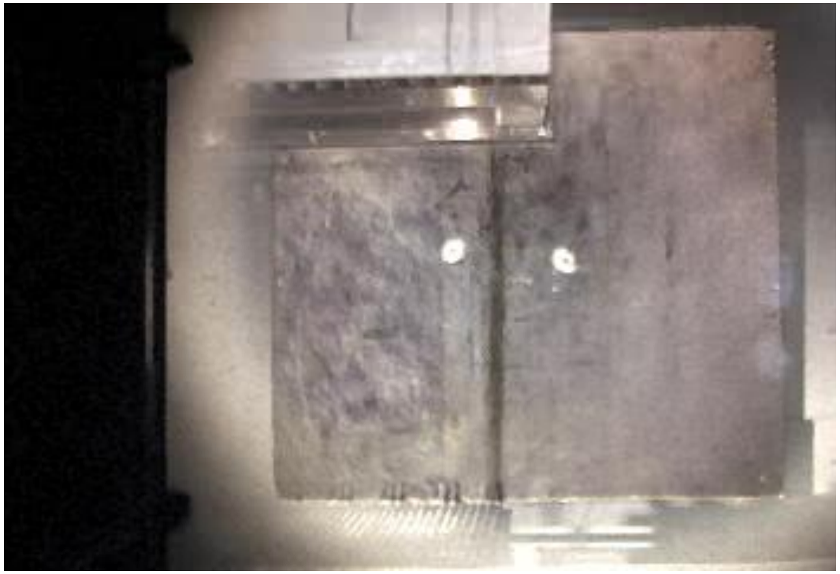
Front View
(Spill on Right Side)

4-Way Diffuser Set-up

Exhaust Rate: 300 cfm/ft
(with right 4-way turned on)

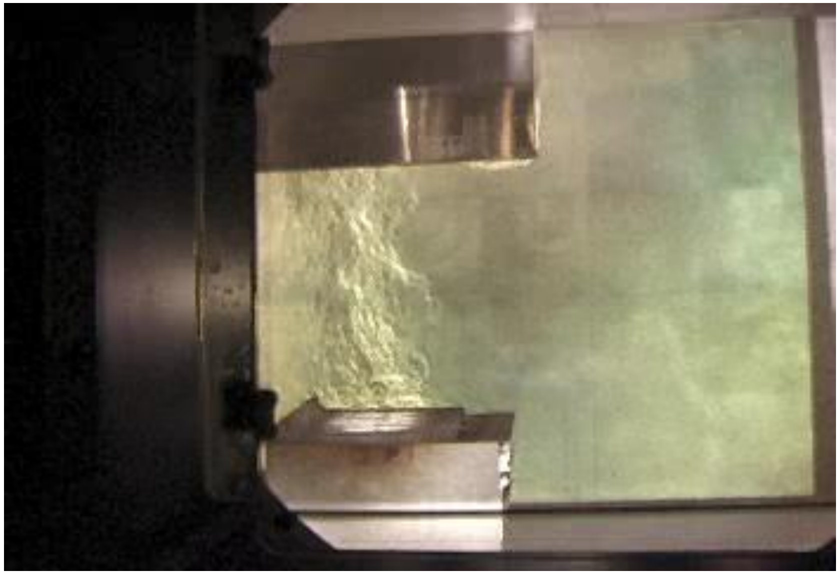


End View
(Spill on Front Edge)

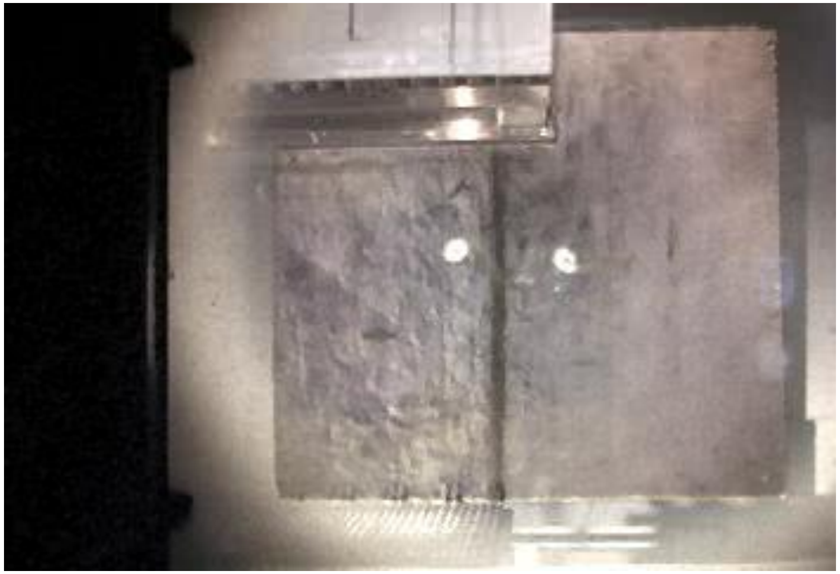


Front View
(Spill on Right Side)

Exhaust Rate: 500 cfm/ft

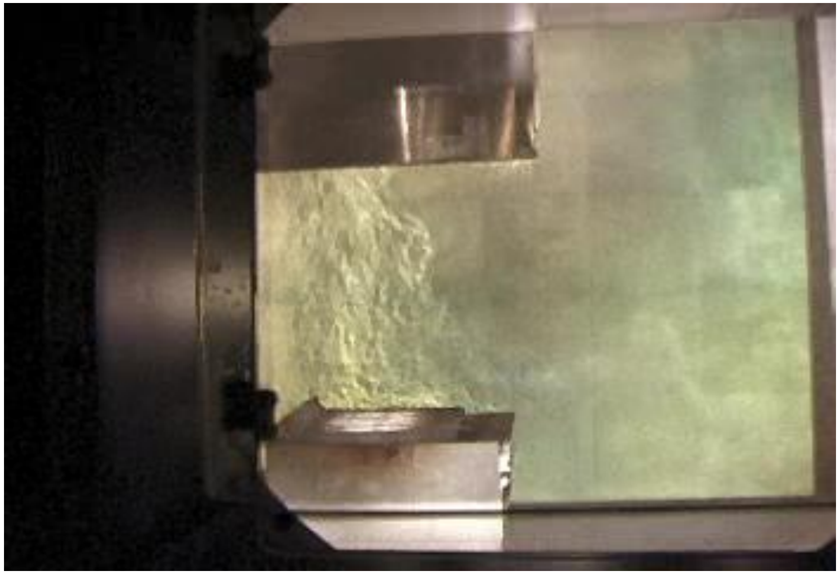


End View
(No Spill on Front Edge)

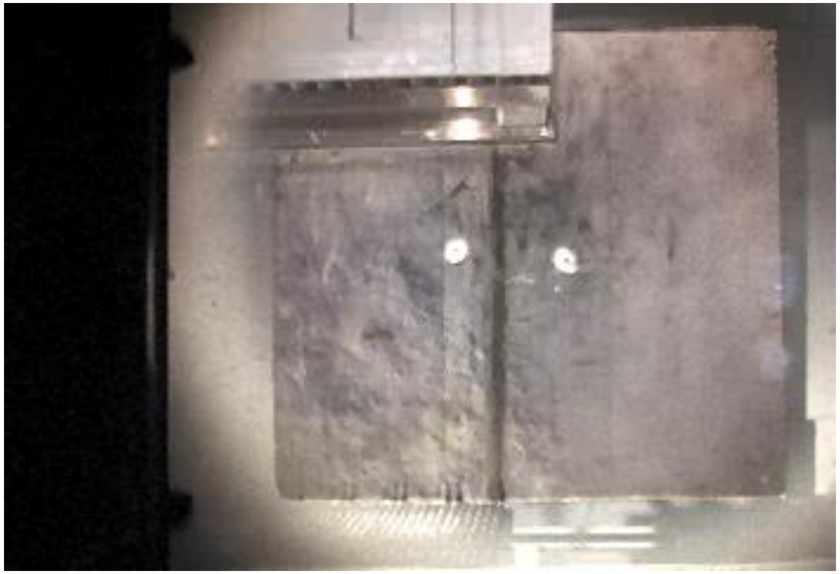


Front View
(No Spill on Right Side)

Exhaust Rate: 500 cfm/ft
(with right 4-way turned on)



End View
(No Spill on Front Edge)

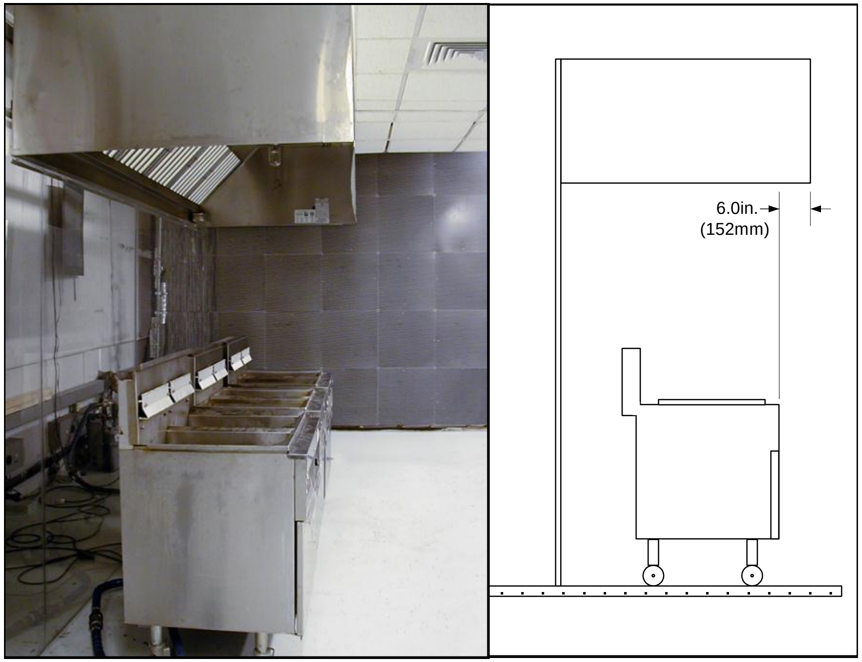


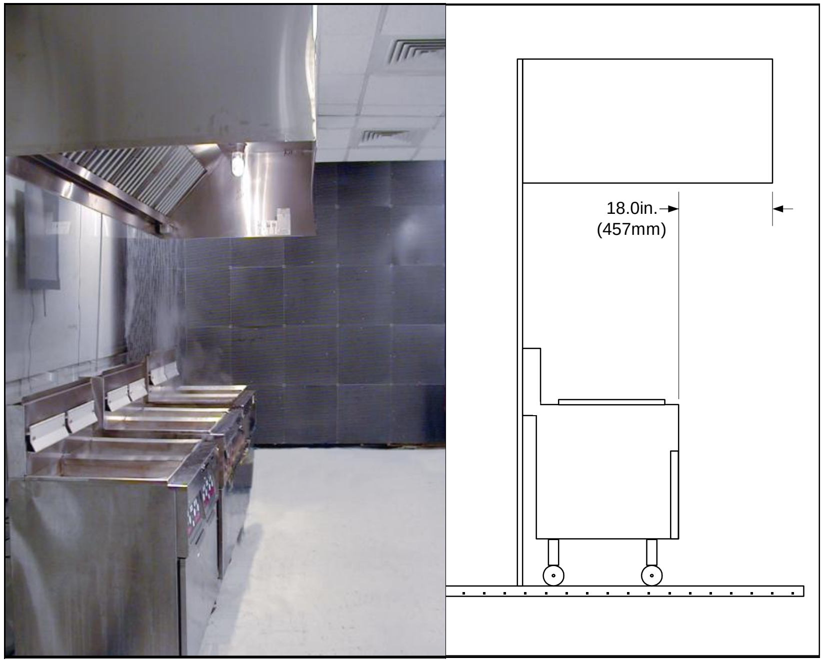
Front View
(Spill on Right Side)

Bottom Line:
Single-Island Canopy Hoods and Charbroilers Don't Mix Well!

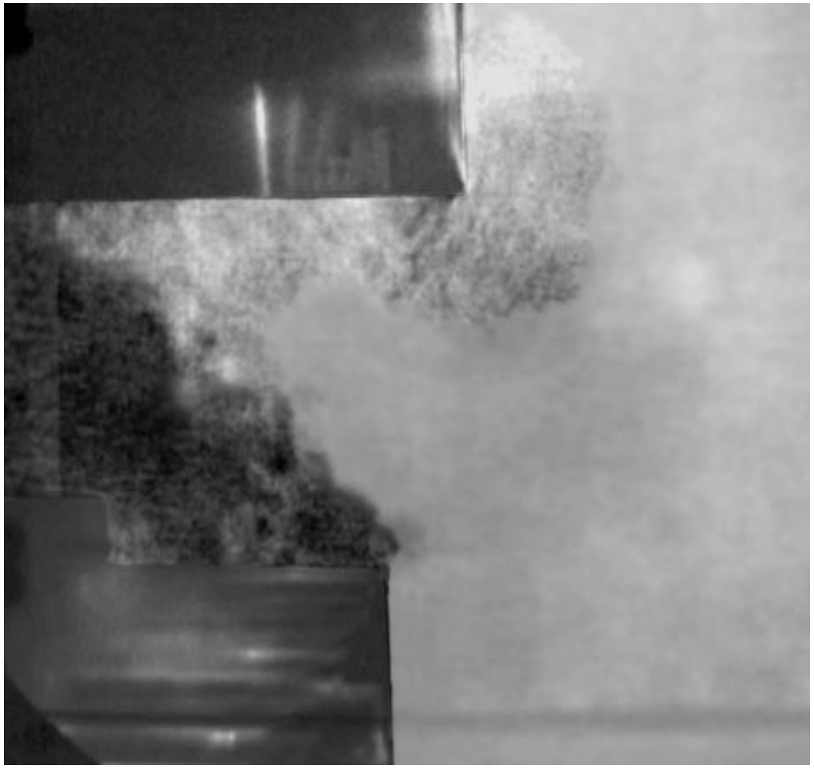
…let's go back into the lab

Overhang Impacts Hood Performance!





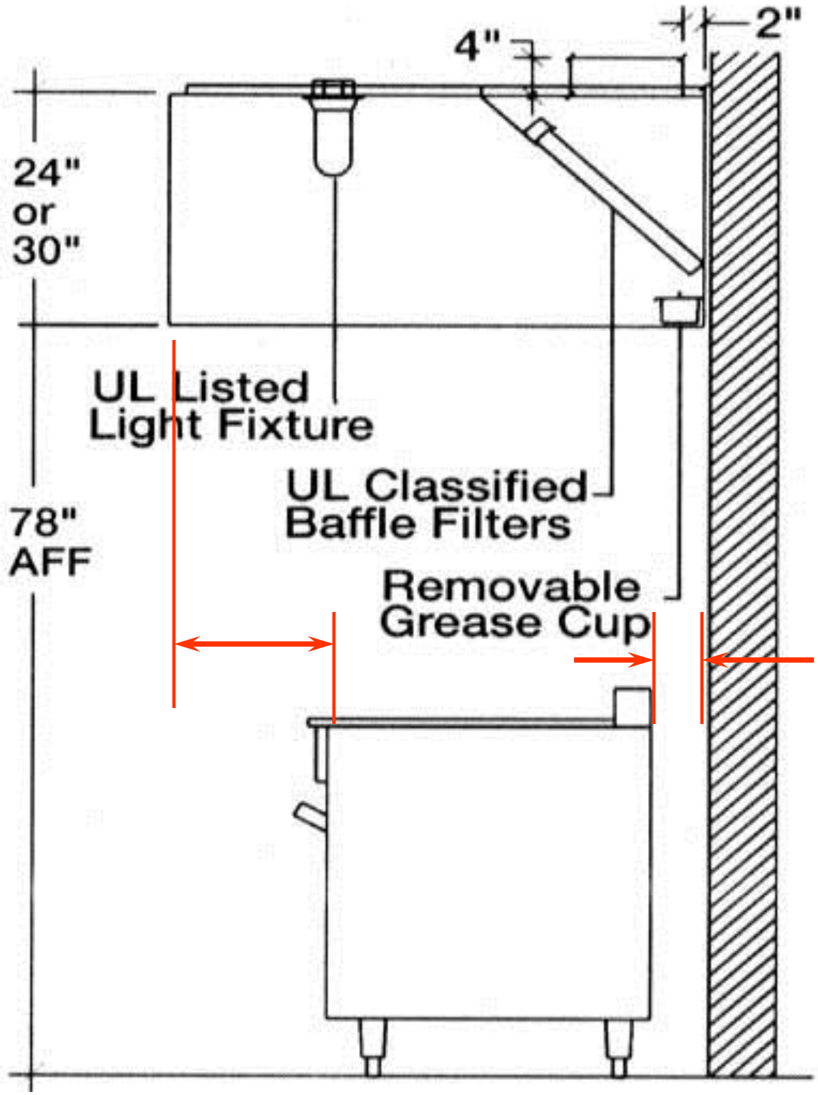
Overhang effect for 6 fryers under a 10-ft. wall canopy hood at 2400 cfm (240 cfm/ft)



6 inches of Front Overhang

18 inches of Front Overhang

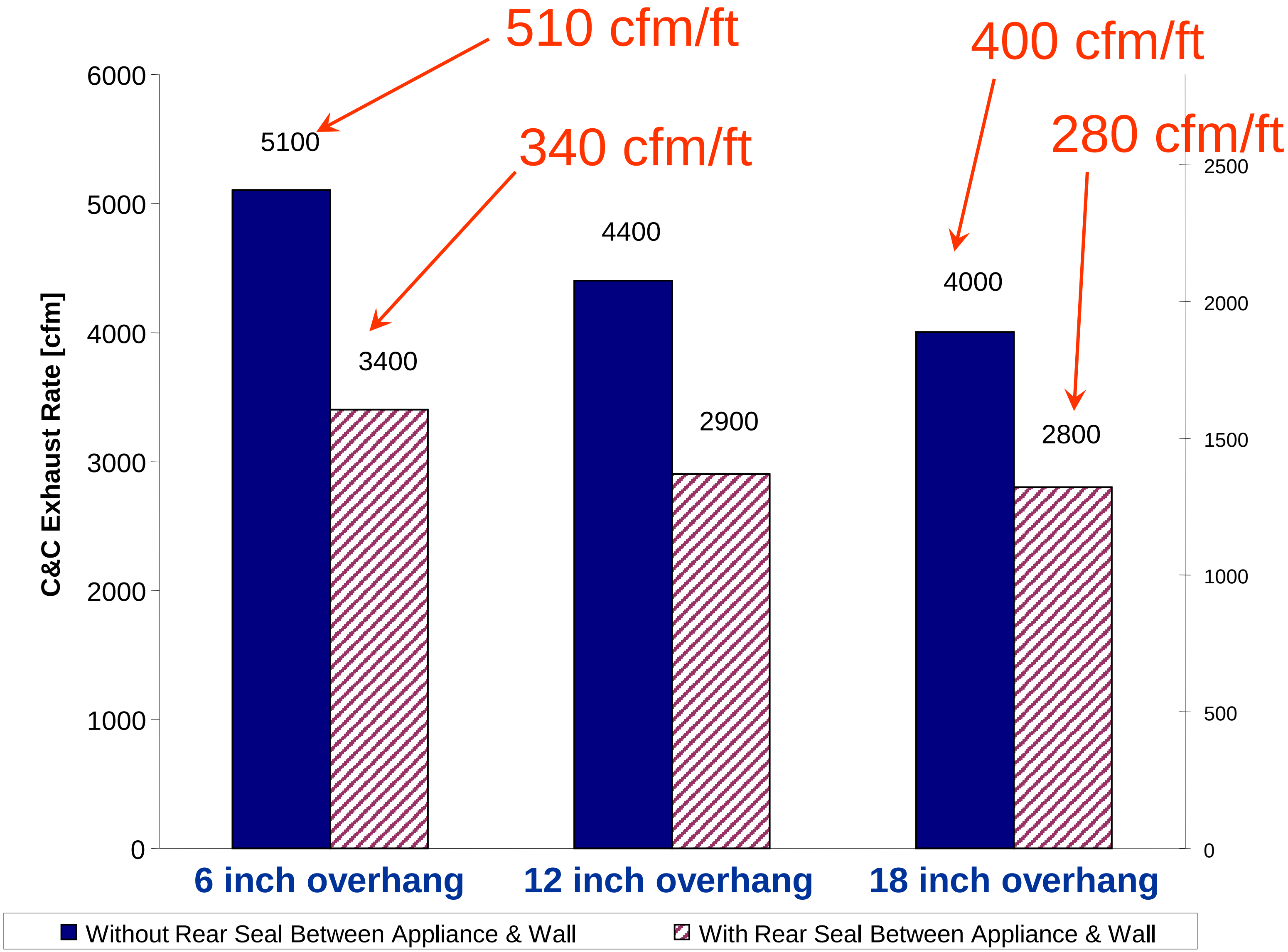
Overhang vs. Rear Gap



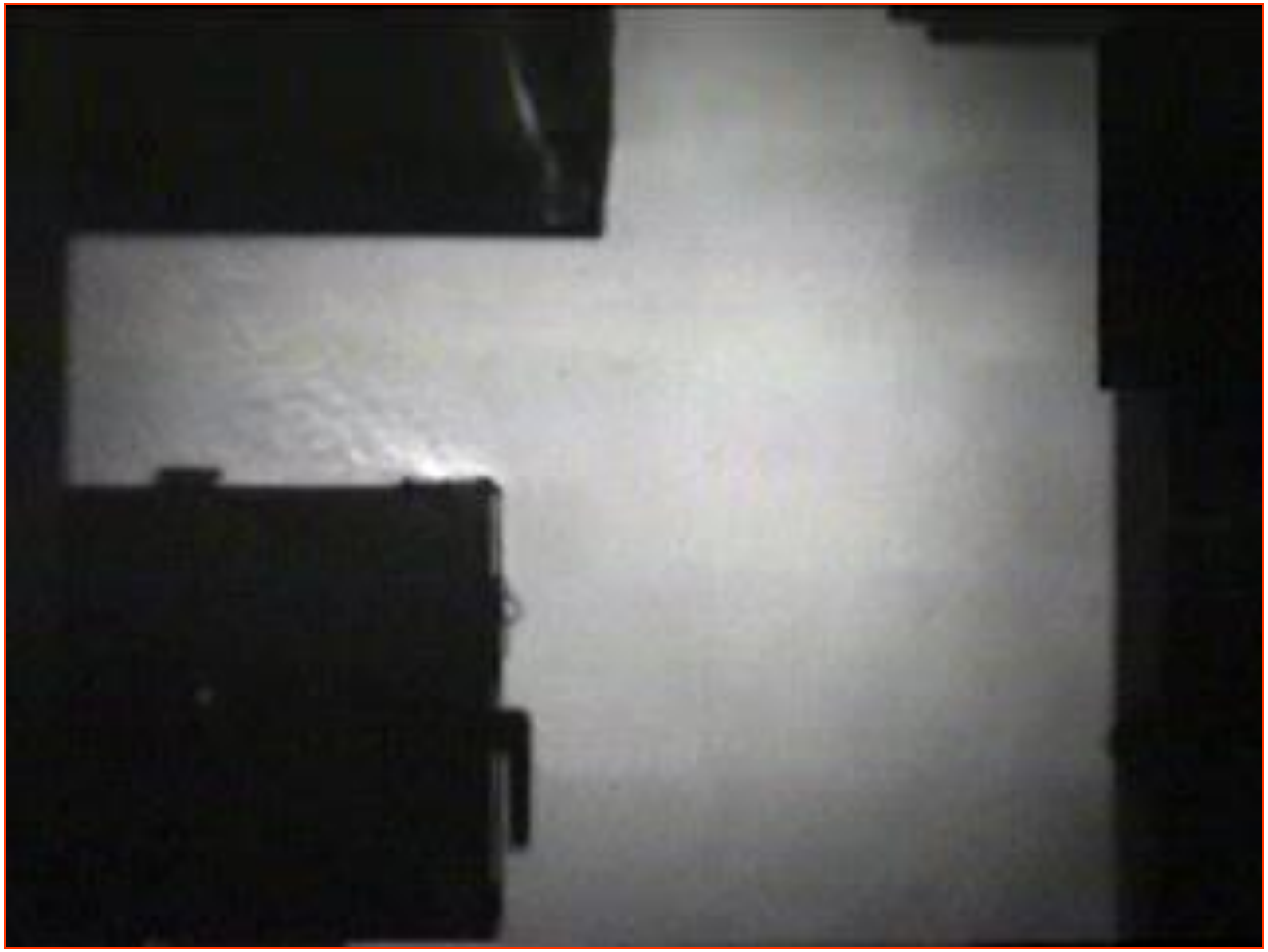
Rear Seal Investigation

Front Overhang to Appliance [inches]	Front Overhang to Cooking Surface [inches]	Distance Between the Rear of the Appliance and Backwall [inches]
0	6.0	16.5
6.0	12.0	10.5
12.0	18.0	4.5

Seal gap behind appliances!



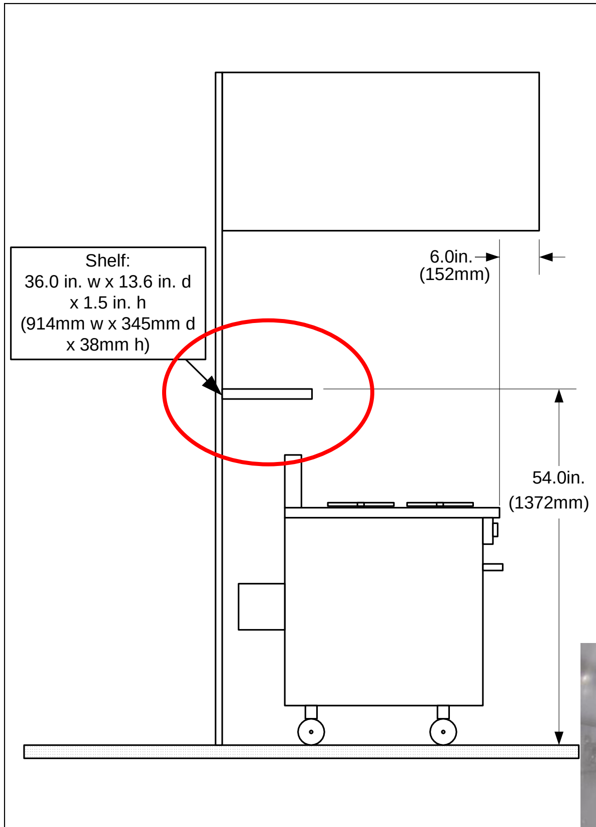
Dynamic Effect - Oven Door (6”)

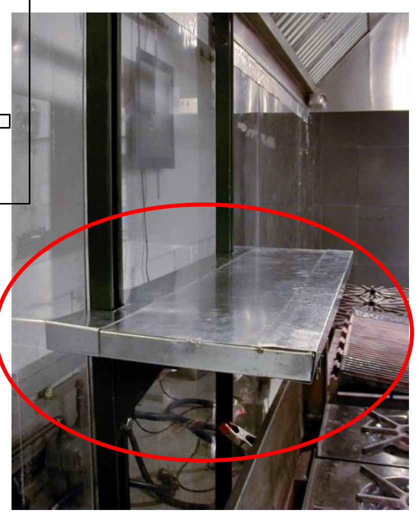


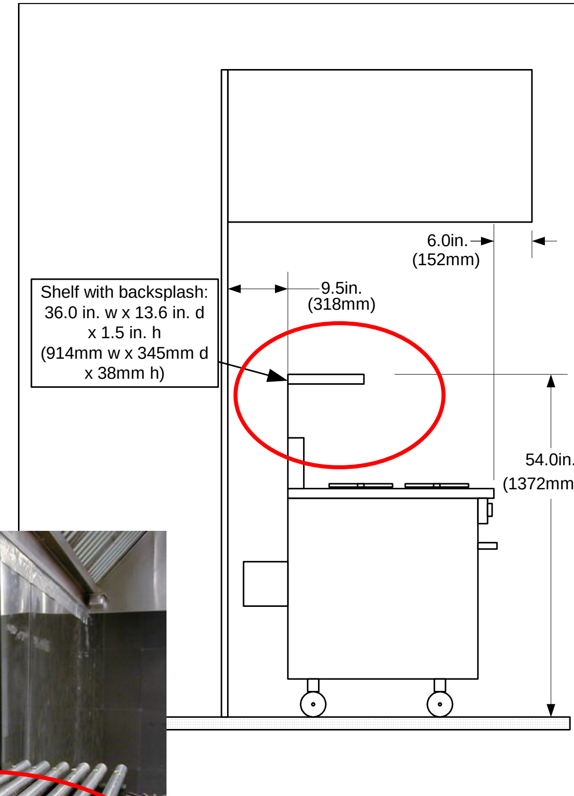
Dynamic Effect - Oven Door (18")

…easier “said” than “done”

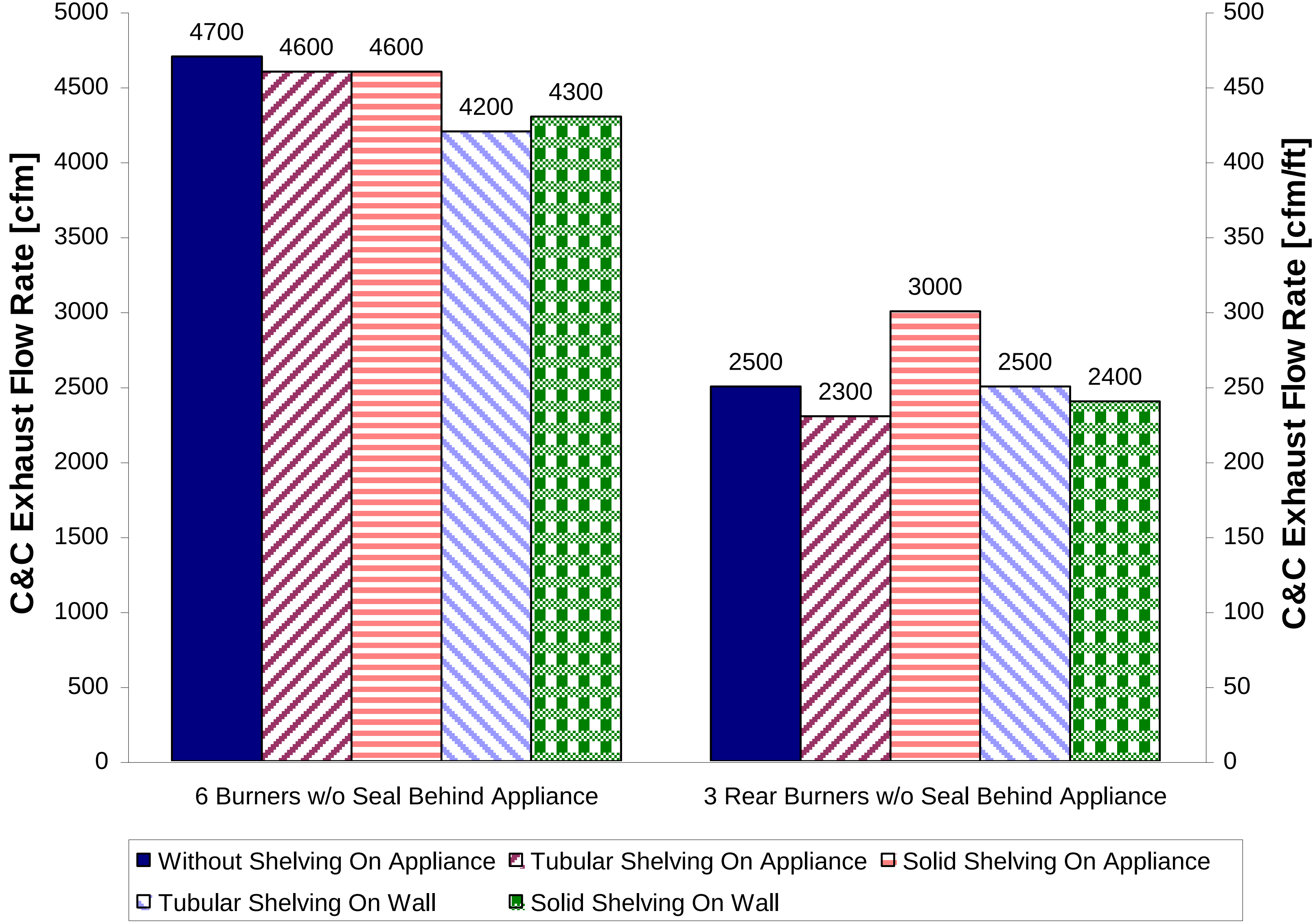
Shelving over a 6-burner Range





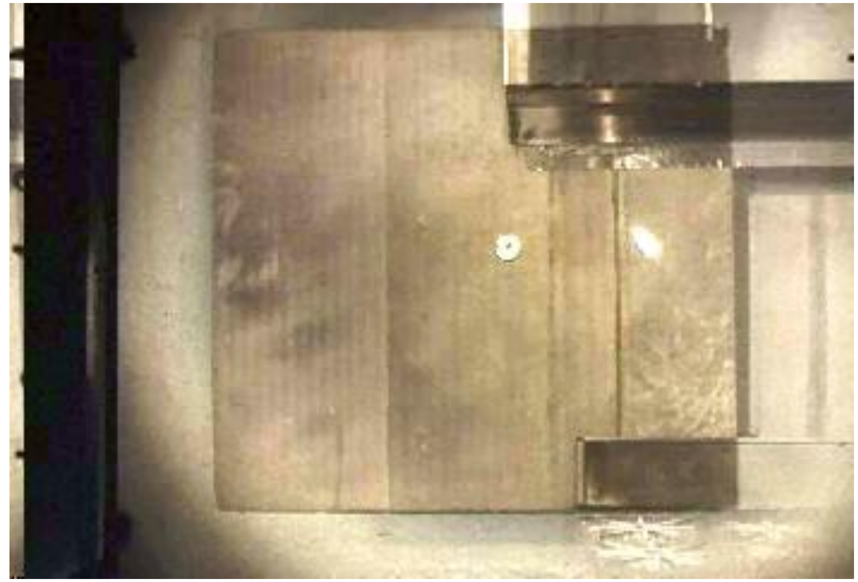


Shelving over a 6-Burner Range Results

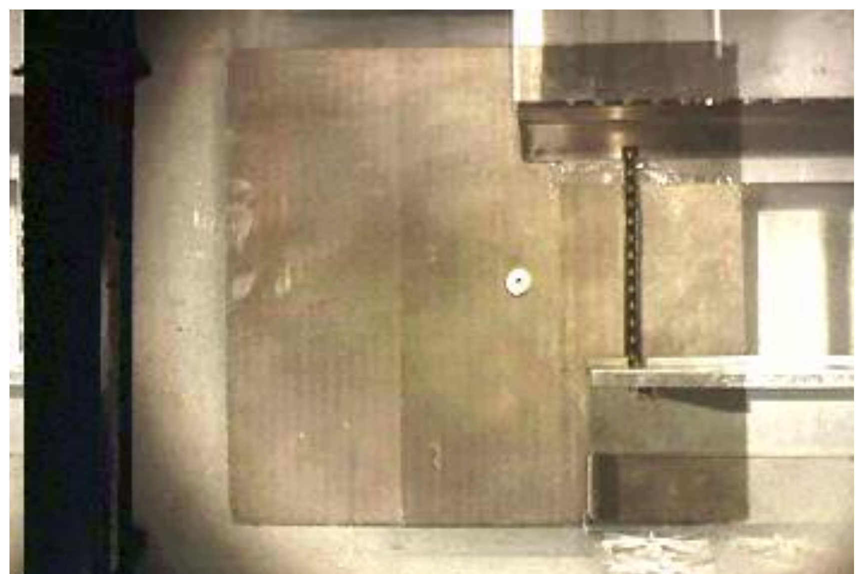


6-burner Range C&C Comparison
Without Shelf & With Solid Shelf

4700 cfm
(470 cfm/ft)



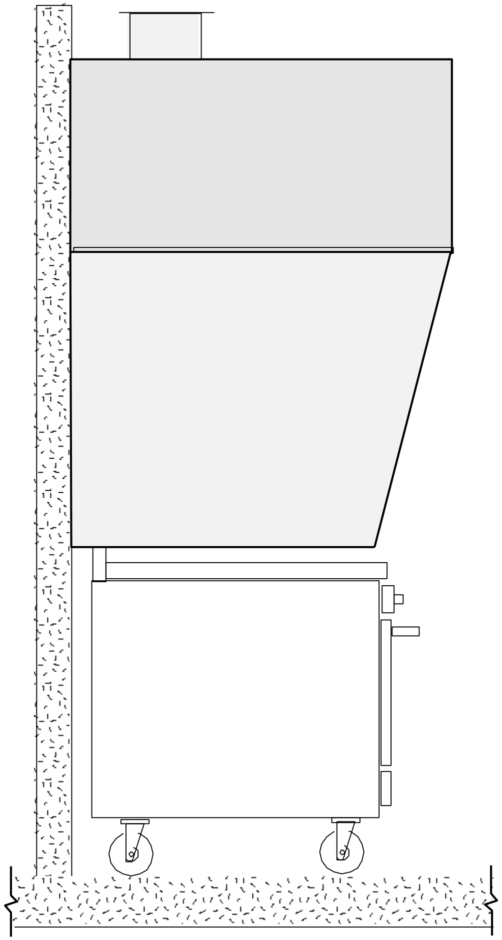
4600 cfm
(460 cfm/ft)

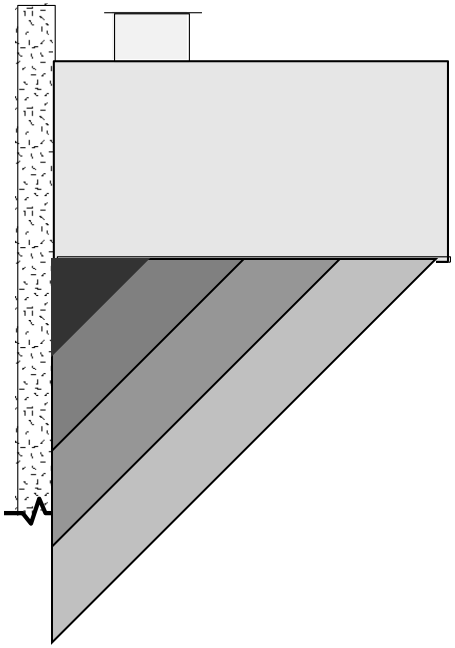


Side Panel Benefit

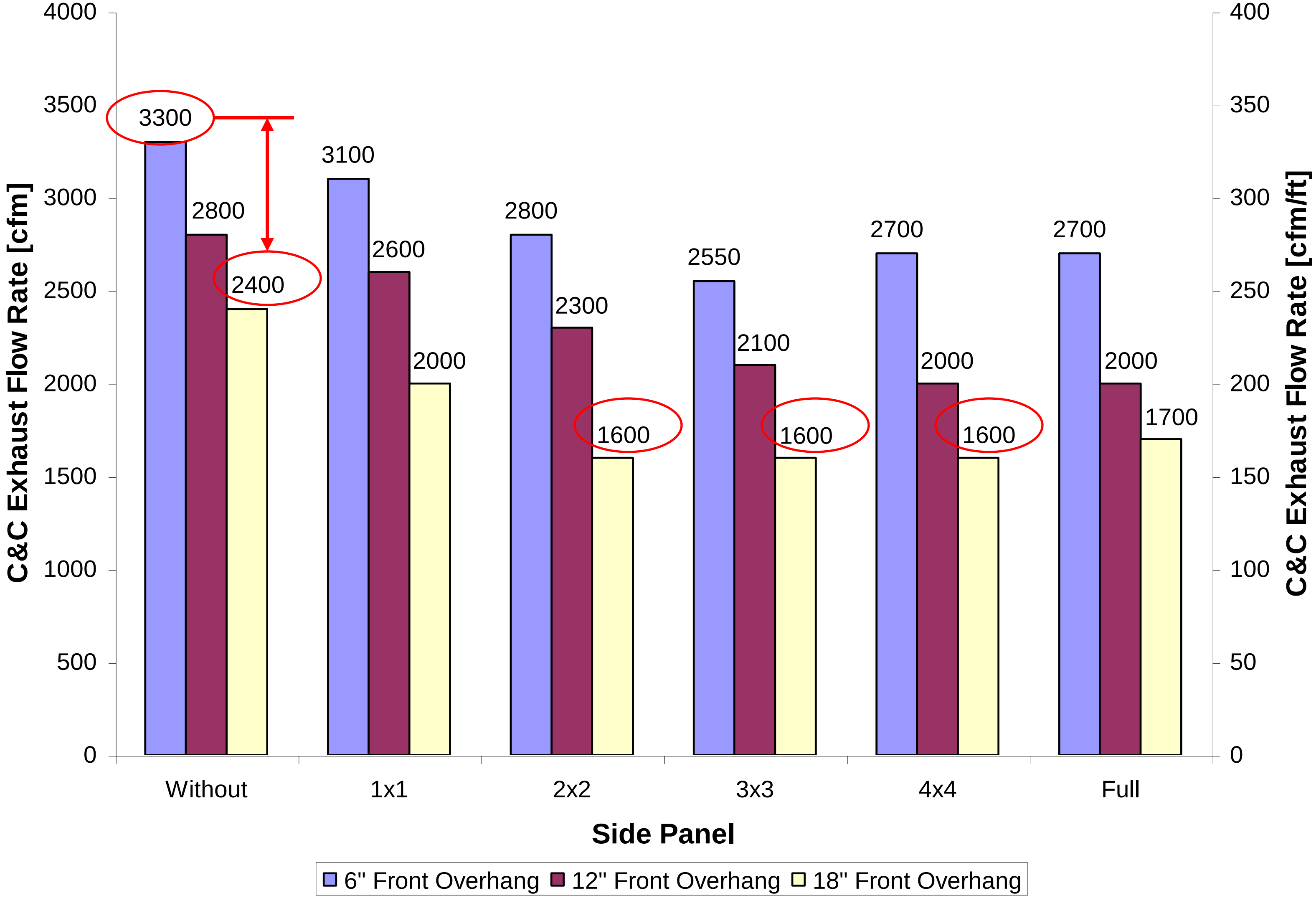
Effect on C&C from:

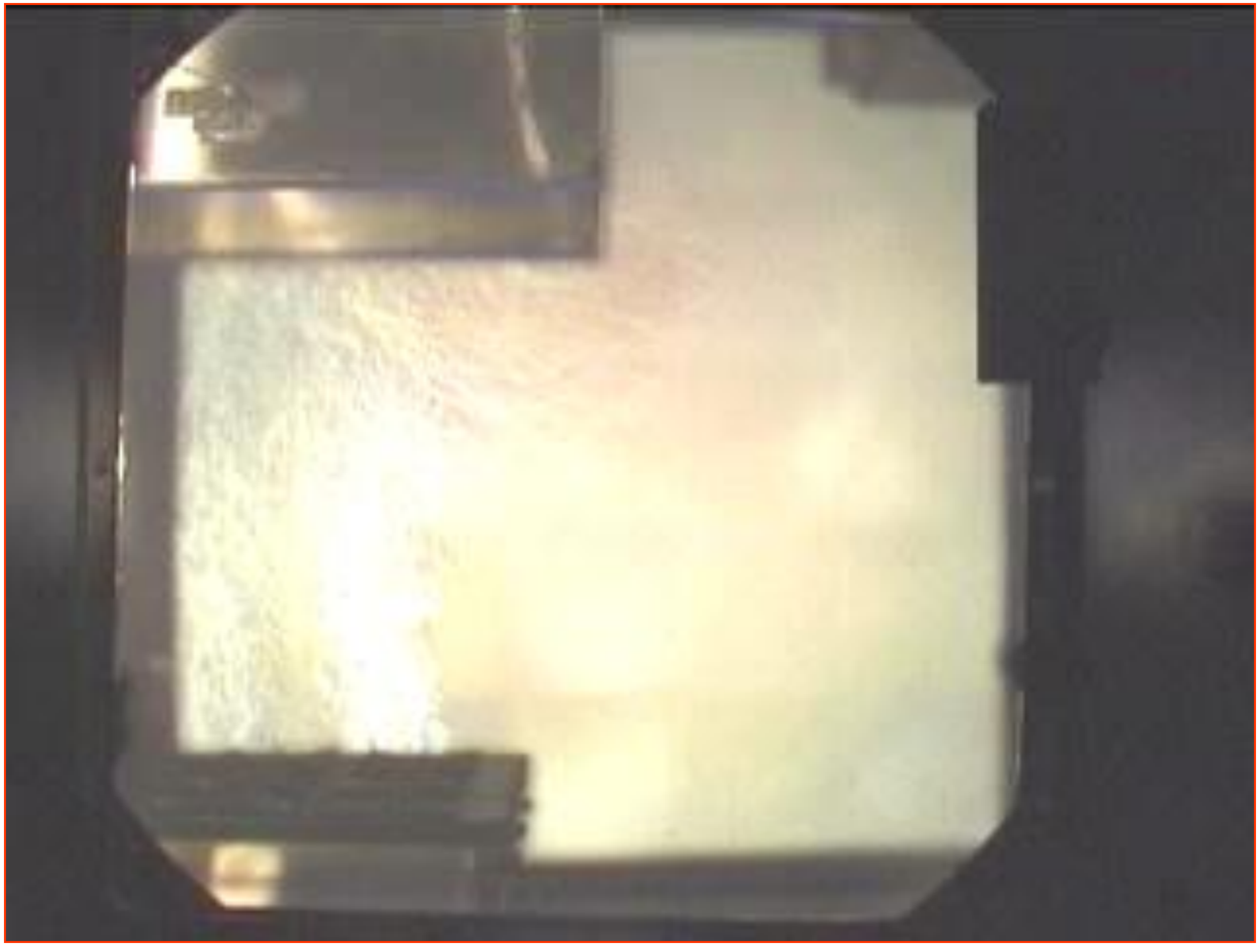
- •Full-side panels
- •4ft x 4ft tapered
- •3ft x 3ft tapered
- •2ft x 2ft tapered
- •1ft x 1 ft tapered





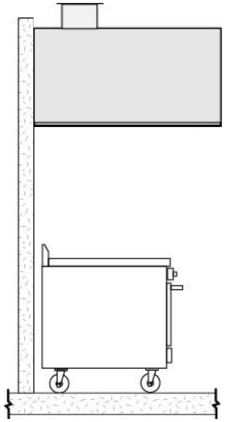
Side Panels/Overhang Results for Fryers

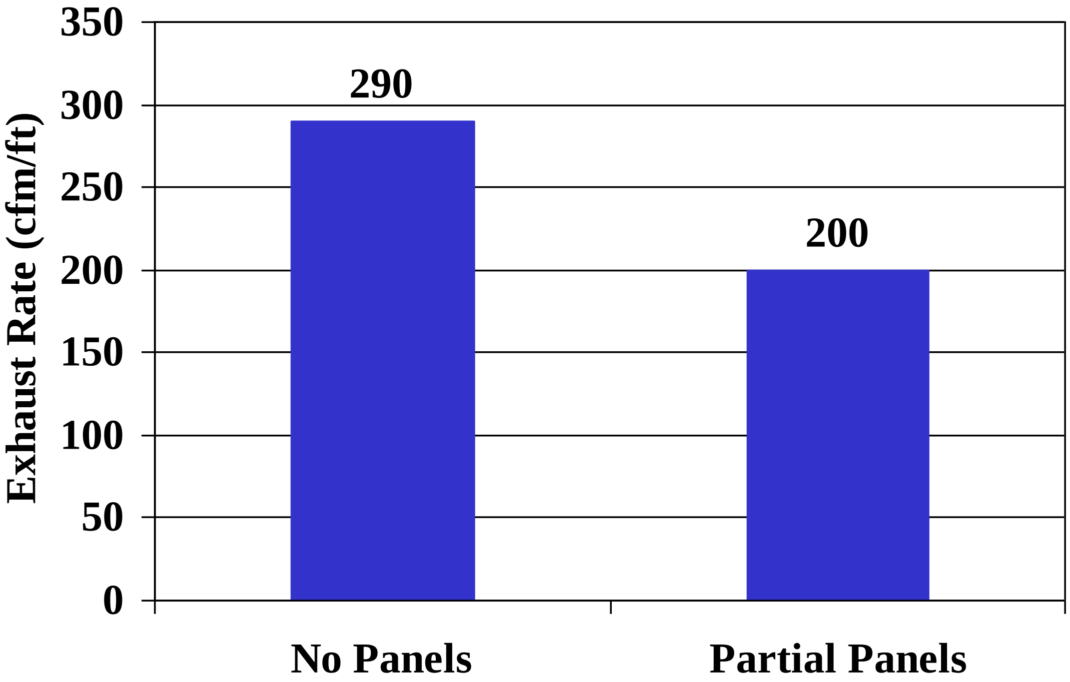


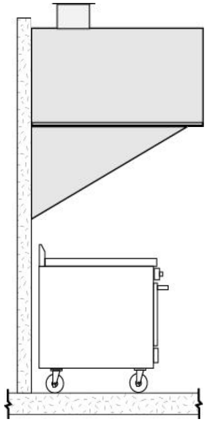


… partial end panels do the job!

Multiple configurations of appliances under various 10-ft. wall canopy hoods (approx. 90 tests) with and without partial side panels







30% reduction in airflow!

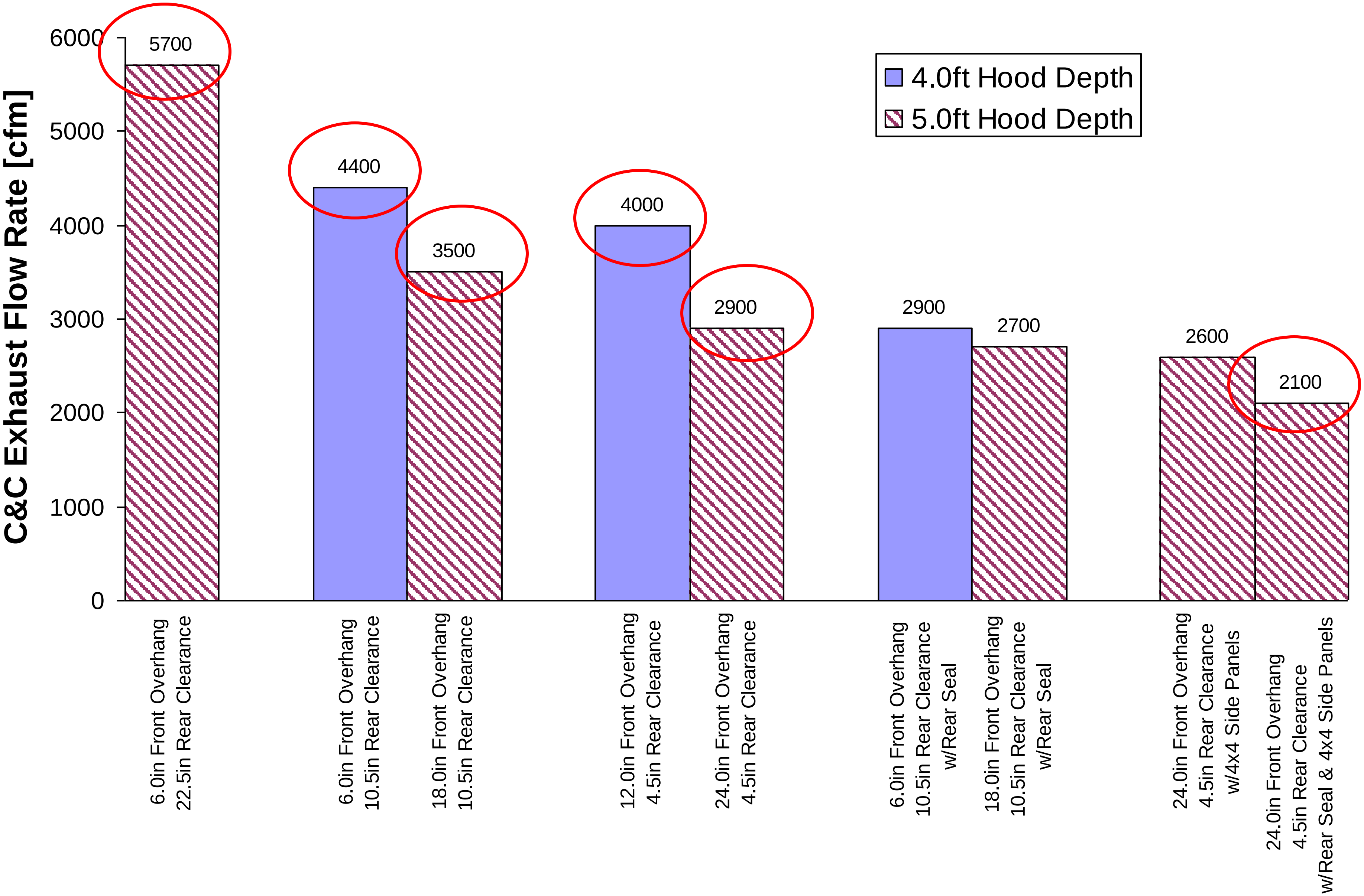
The Effect of Hood Depth

4 ft Depth Increased to 5 ft

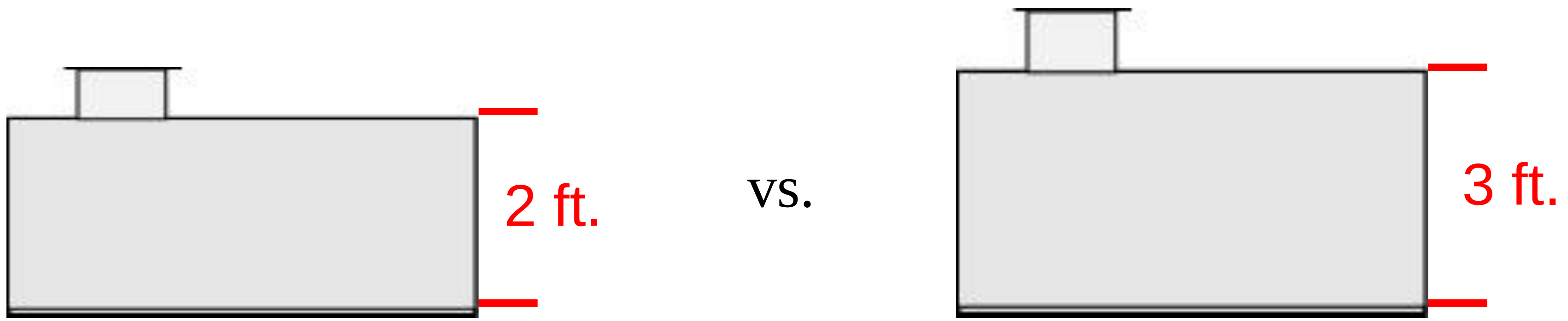
6 inch overhang

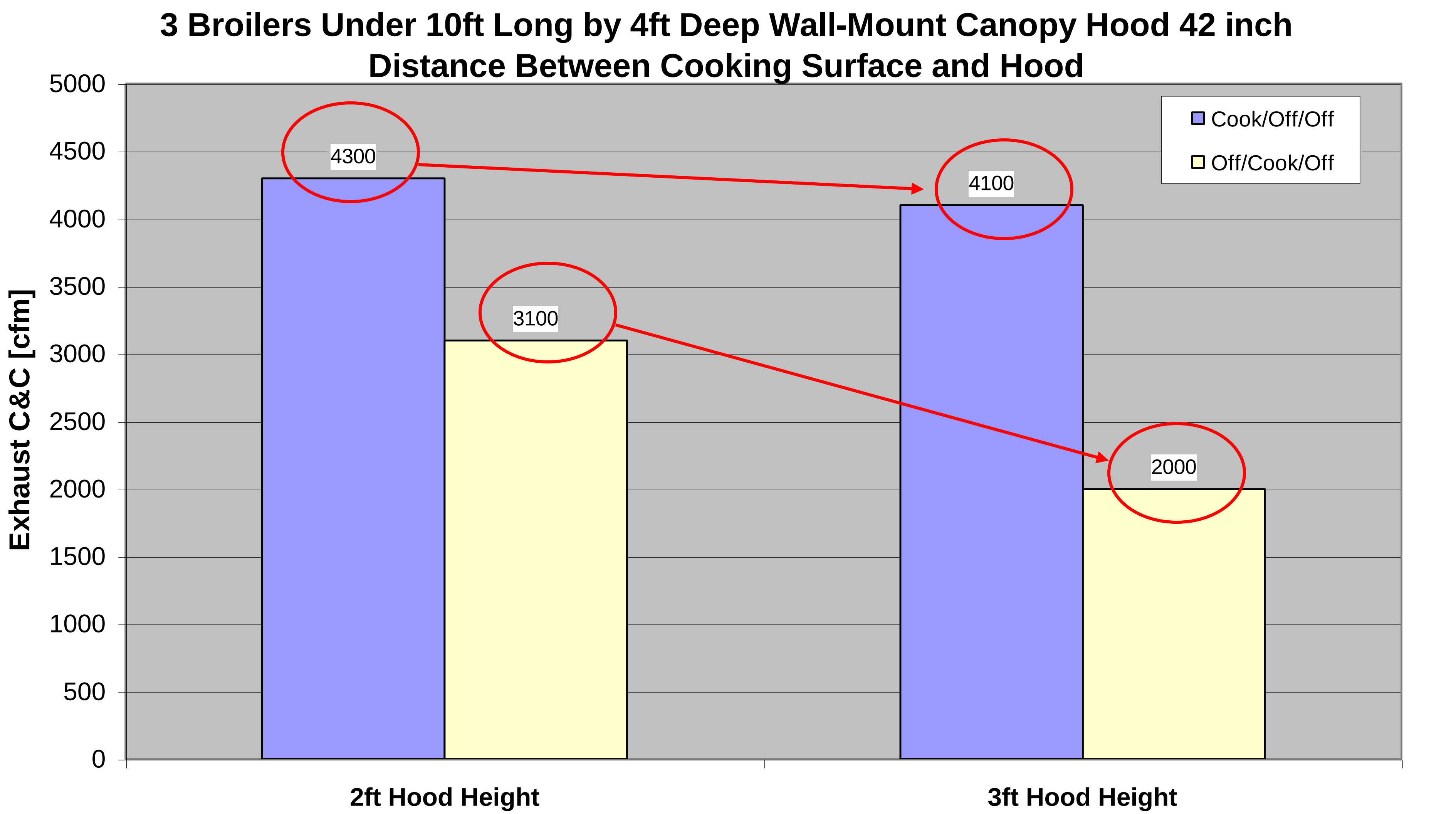
24 inch overhang

3 Charbroilers Cooking

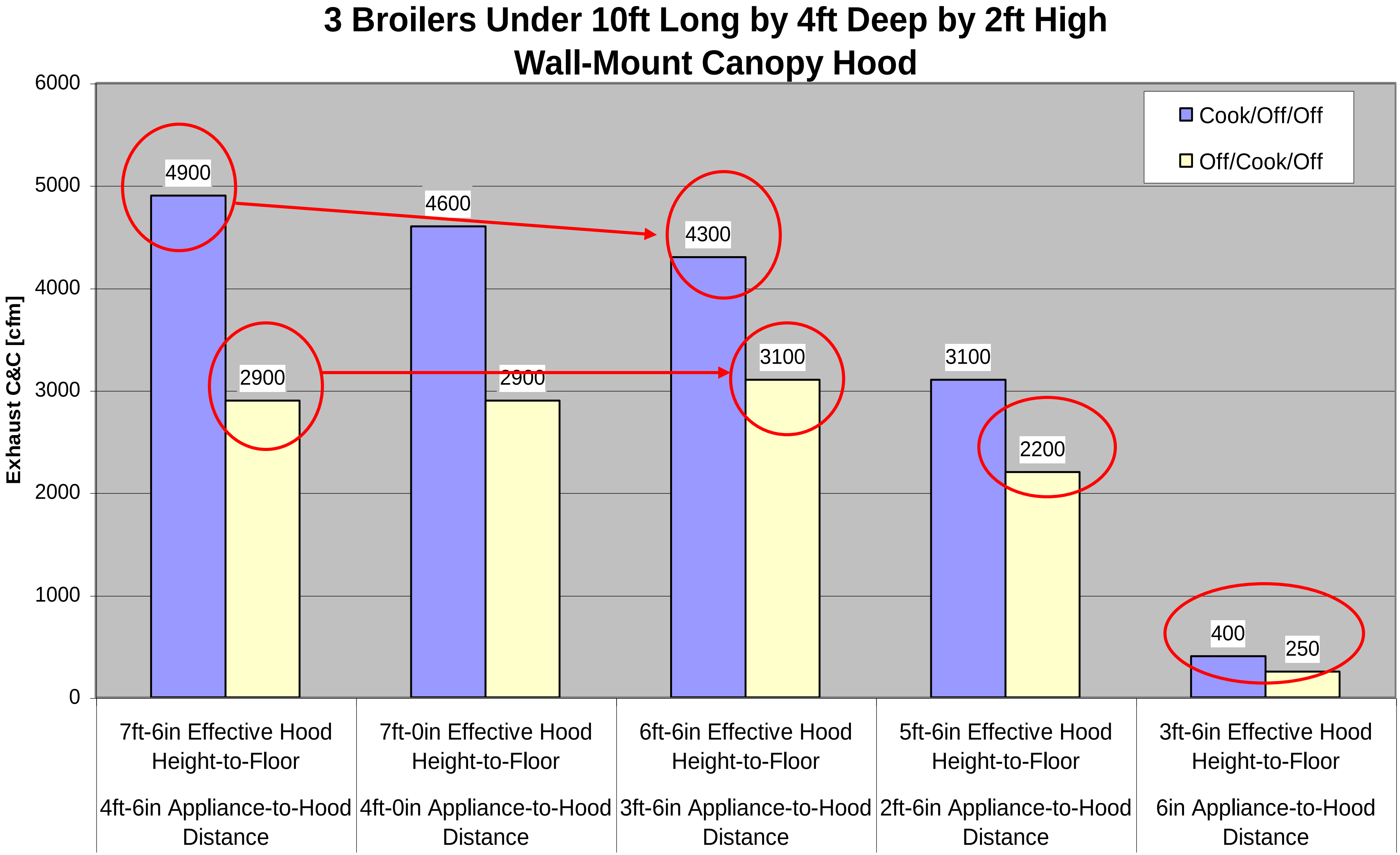


The Effect of Hood Height Itself




3 Broilers Under 10ft Long by 4ft Deep Wall-Mount Canopy Hood 42 inch Distance Between Cooking Surface and Hood
Exhaust C&C [cfm]
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Cook/Off/Off
Off/Cook/Off
4300
3100
4100
2000
2ft Hood Height
3ft Hood Height

The Effect of Hood Mounting Height



Total exhaust approx… 600 cfm

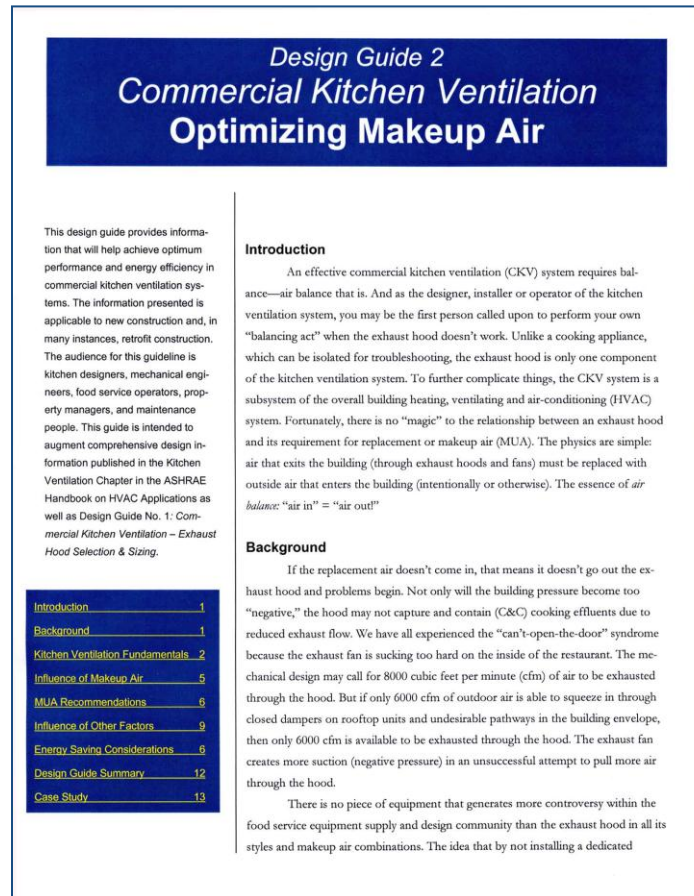
Hoods are not created equal…

Tools for the Tool Box:

- Bigger hoods
  - Deeper
  - Taller
- Push back equipment (minimize rear gap)
- Lower hoods (or proximity style where practical)
- Side panels, end panels, end walls!
- Heavy duty (broiler) in middle
- Light duty (ovens) on the end
- Don’t waste hood space over non-cooking
- Introduce makeup air at low velocity.

CKV/HVAC Design Strategies

2. Optimize makeup air delivery to kitchen
   - No short-circuit hoods!
   - Introduce replacement air at low-velocity



Design Guide 2
Commercial Kitchen Ventilation
Optimizing Makeup Air

This design guide provides information that will help achieve optimum performance and energy efficiency in commercial kitchen ventilation systems. The information presented is applicable to new construction and, in many instances, retrofit construction. The audience for this guideline is kitchen designers, mechanical engineers, food service operators, property managers, and maintenance people. This guide is intended to augment comprehensive design information published in the Kitchen Ventilation Chapter in the ASHRAE Handbook on HVAC Applications as well as Design Guide No. 1: *Commercial Kitchen Ventilation – Exhaust Hood Selection & Sizing.*

Introduction

An effective commercial kitchen ventilation (CKV) system requires balance—air balance that is. And as the designer, installer or operator of the kitchen ventilation system, you may be the first person called upon to perform your own "balancing act" when the exhaust hood doesn't work. Unlike a cooking appliance, which can be isolated for troubleshooting, the exhaust hood is only one component of the kitchen ventilation system. To further complicate things, the CKV system is a subsystem of the overall building heating, ventilating and air-conditioning (HVAC) system. Fortunately, there is no "magic" to the relationship between an exhaust hood and its requirement for replacement or makeup air (MUA). The physics are simple: air that exits the building (through exhaust hoods and fans) must be replaced with outside air that enters the building (intentionally or otherwise). The essence of *air balance:* "air in" = "air out!"

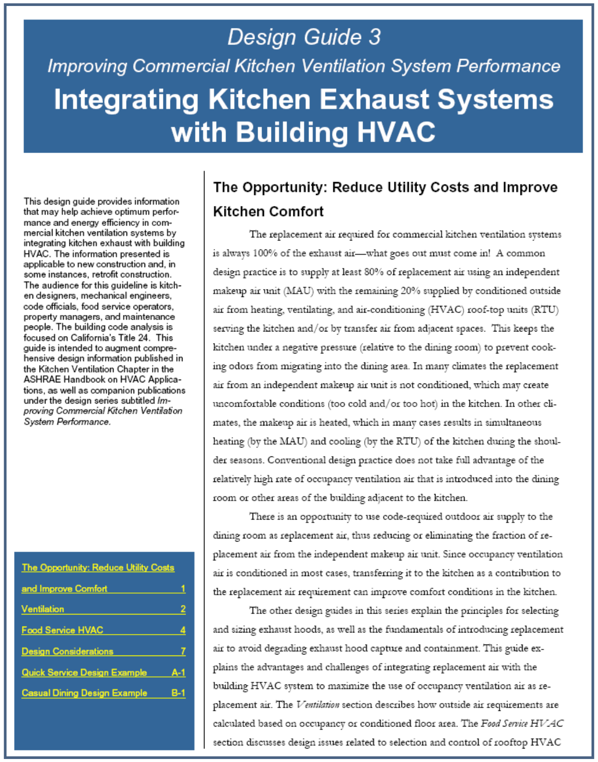
Background

If the replacement air doesn't come in, that means it doesn't go out the exhaust hood and problems begin. Not only will the building pressure become too "negative," the hood may not capture and contain (C&C) cooking effluents due to reduced exhaust flow. We have all experienced the "can't-open-the-door" syndrome because the exhaust fan is sucking too hard on the inside of the restaurant. The mechanical design may call for 8000 cubic feet per minute (cfm) of air to be exhausted through the hood. But if only 6000 cfm of outdoor air is able to squeeze in through closed dampers on rooftop units and undesirable pathways in the building envelope, then only 6000 cfm is available to be exhausted through the hood. The exhaust fan creates more suction (negative pressure) in an unsuccessful attempt to pull more air through the hood.

There is no piece of equipment that generates more controversy within the food service equipment supply and design community than the exhaust hood in all its styles and makeup air combinations. The idea that by not installing a dedicated

CKV/HVAC Optimization Strategies

3. Integrate the CKV system with the HVAC system
   - Maximize dining room outdoor air as replacement air for the hood/minimize local makeup air.
   - Consider using HVAC system to replace 100% makeup air.
   - Consider demand ventilation controls (DVC) to kitchen exhaust – integrate with MUA and/or HVAC outdoor air supply



Design Guide 3

Improving Commercial Kitchen Ventilation System Performance

Integrating Kitchen Exhaust Systems with Building HVAC

This design guide provides information that may help achieve optimum performance and energy efficiency in commercial kitchen ventilation systems by integrating kitchen exhaust with building HVAC. The information presented is applicable to new construction and, in some instances, retrofit construction. The audience for this guideline is kitchen designers, mechanical engineers, code officials, food service operators, property managers, and maintenance people. The building code analysis is focused on California's Title 24. This guide is intended to augment comprehensive design information published in the Kitchen Ventilation Chapter in the ASHRAE Handbook on HVAC Applications, as well as companion publications under the design series subtitled *Improving Commercial Kitchen Ventilation System Performance.*

The Opportunity: Reduce Utility Costs and Improve Kitchen Comfort

The replacement air required for commercial kitchen ventilation systems is always 100% of the exhaust air—what goes out must come in! A common design practice is to supply at least 80% of replacement air using an independent makeup air unit (MAU) with the remaining 20% supplied by conditioned outside air from heating, ventilating, and air-conditioning (HVAC) roof-top units (RTU) serving the kitchen and/or by transfer air from adjacent spaces. This keeps the kitchen under a negative pressure (relative to the dining room) to prevent cooking odors from migrating into the dining area. In many climates the replacement air from an independent makeup air unit is not conditioned, which may create uncomfortable conditions (too cold and/or too hot) in the kitchen. In other climates, the makeup air is heated, which in many cases results in simultaneous heating (by the MAU) and cooling (by the RTU) of the kitchen during the shoulder seasons. Conventional design practice does not take full advantage of the relatively high rate of occupancy ventilation air that is introduced into the dining room or other areas of the building adjacent to the kitchen.

There is an opportunity to use code-required outdoor air supply to the dining room as replacement air, thus reducing or eliminating the fraction of replacement air from the independent makeup air unit. Since occupancy ventilation air is conditioned in most cases, transferring it to the kitchen as a contribution to the replacement air requirement can improve comfort conditions in the kitchen.

The other design guides in this series explain the principles for selecting and sizing exhaust hoods, as well as the fundamentals of introducing replacement air to avoid degrading exhaust hood capture and containment. This guide explains the advantages and challenges of integrating replacement air with the building HVAC system to maximize the use of occupancy ventilation air as replacement air. The *Ventilation* section describes how outside air requirements are calculated based on occupancy or conditioned floor area. The *Food Service HVAC* section discusses design issues related to selection and control of rooftop HVAC

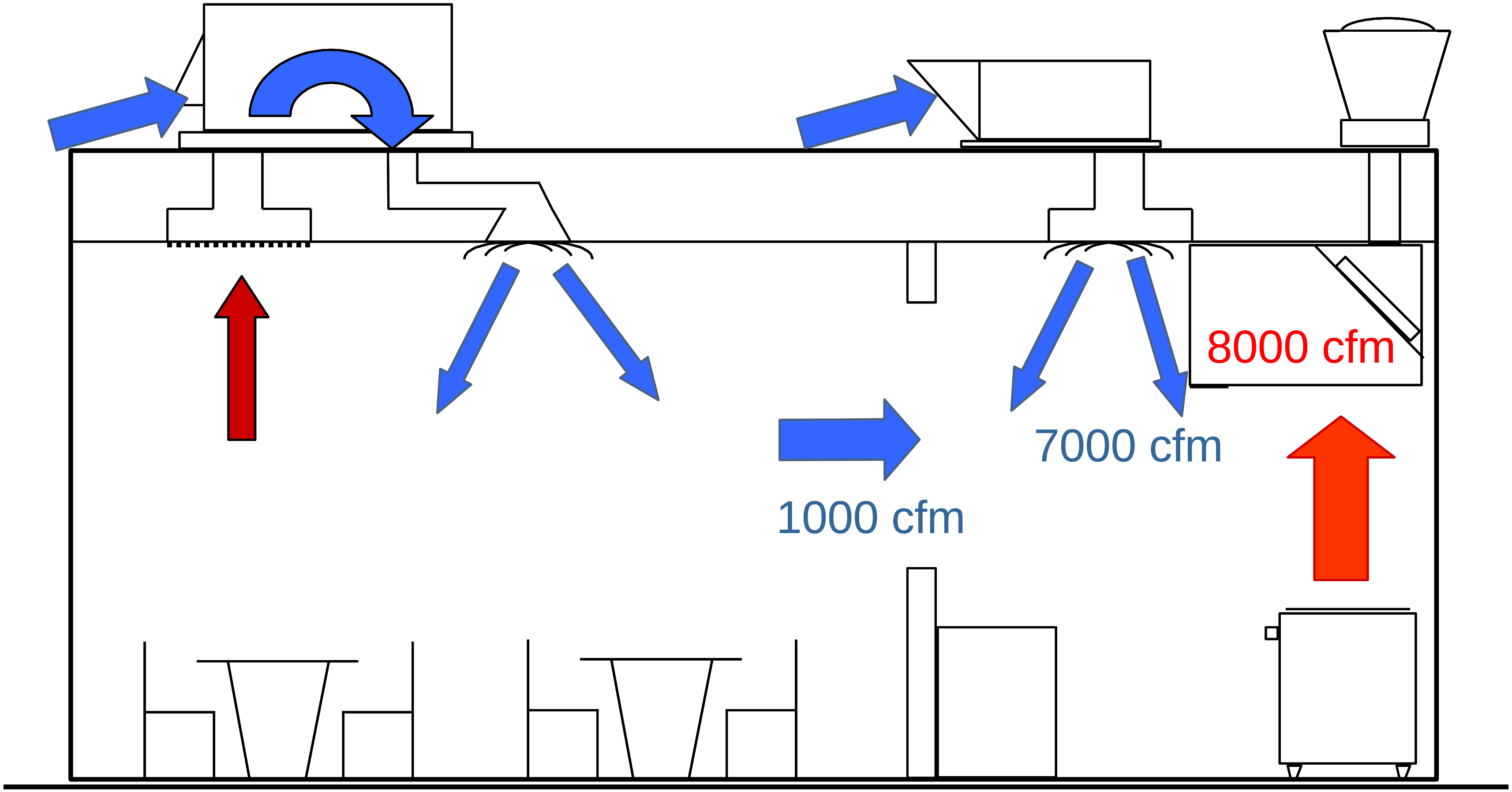
Free Download:

http://www.fishnick.com/equipment/ckv/designguides/

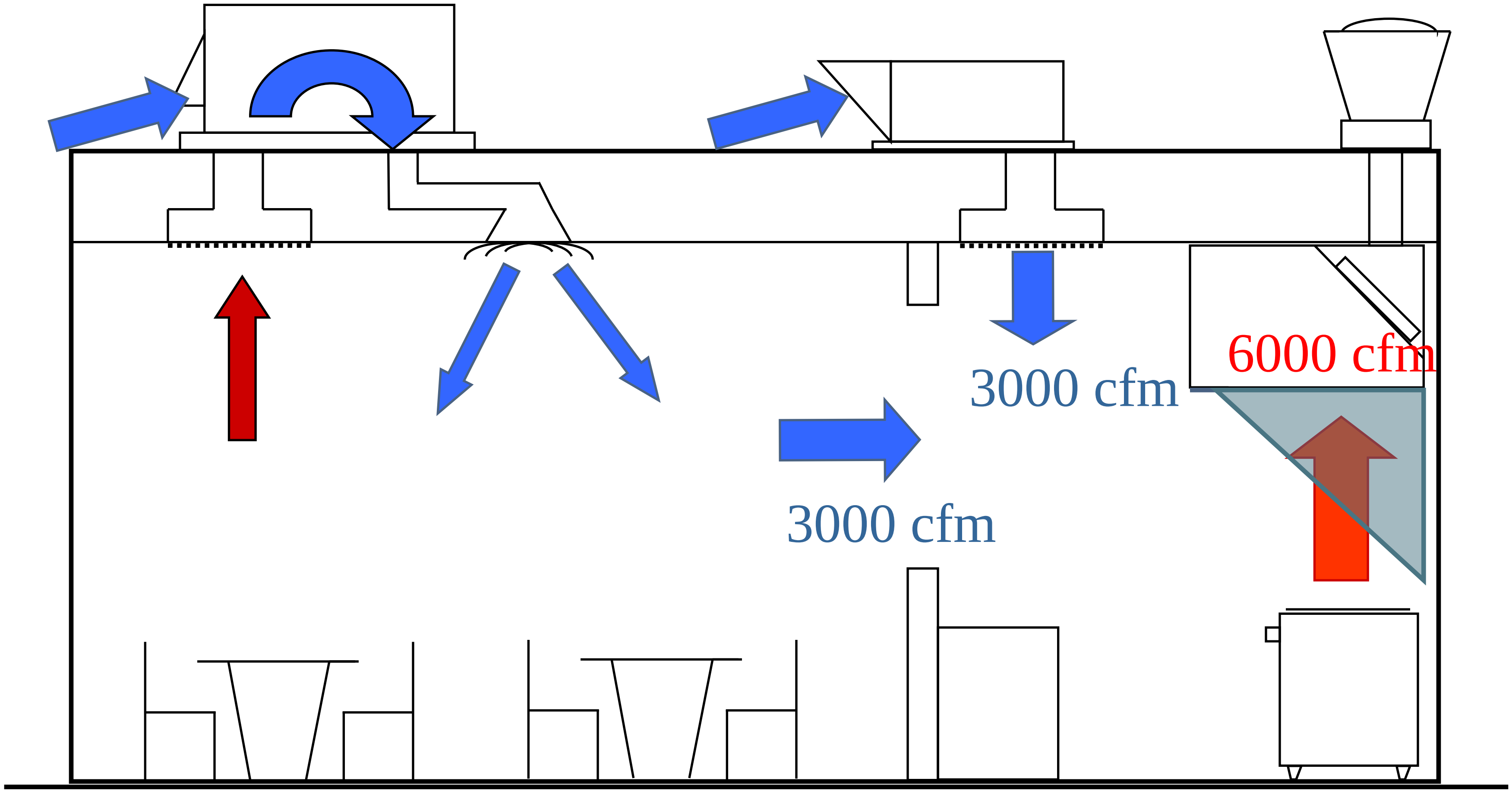
What does CKV-HVAC integration really mean?

Conversely, what does NOT integrating CKV with HVAC mean?

Non-Integrated Approach



Integrated HVAC with CKV!



The first question to be answered is:

How much occupancy ventilation air is available for use as transfer air?

1) 0.20 cfm x ft2

   or

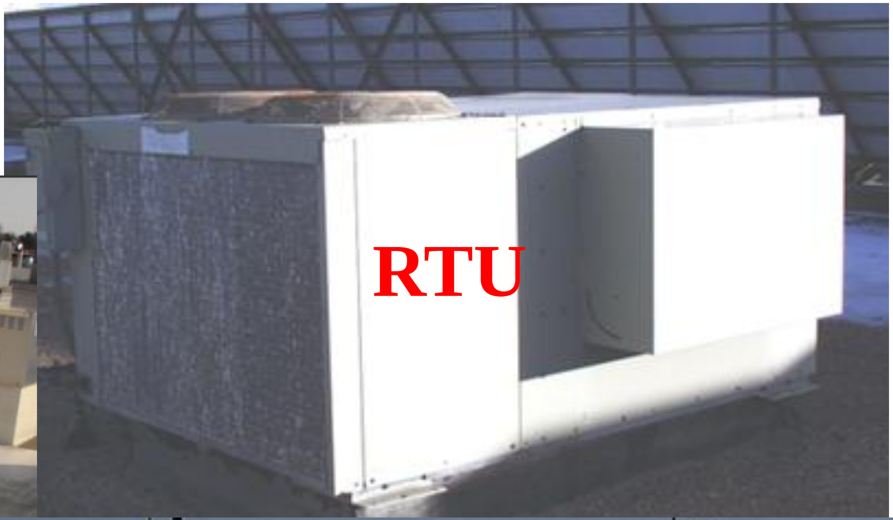
2) 15 cfm/person x maximum occupancy

Select the greatest of the two. In restaurants, 2) will always be the larger value.

The second question to be answered is:

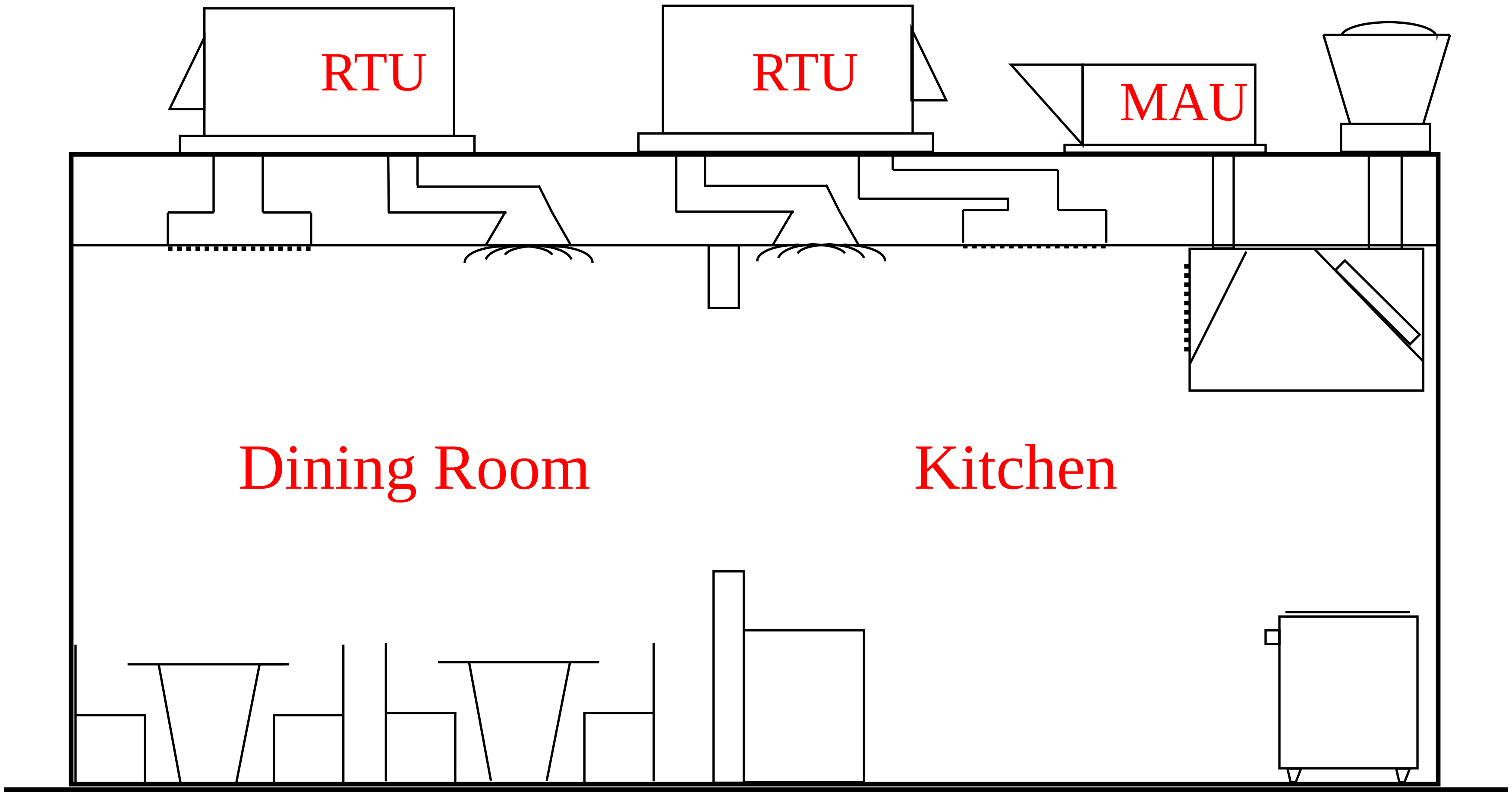
How will selecting and sizing of heating, ventilating, and air-conditioning (HVAC) equipment affect the availability of replacement air?

The answer varies significantly. A design could specify multiple 5 ton RTUs (to avoid economizers), larger RTUs to minimize cost, or a single 100% dedicated replacement air unit (RAU) to supply all ventilation air needs of the facility. The design guide discusses this in depth.

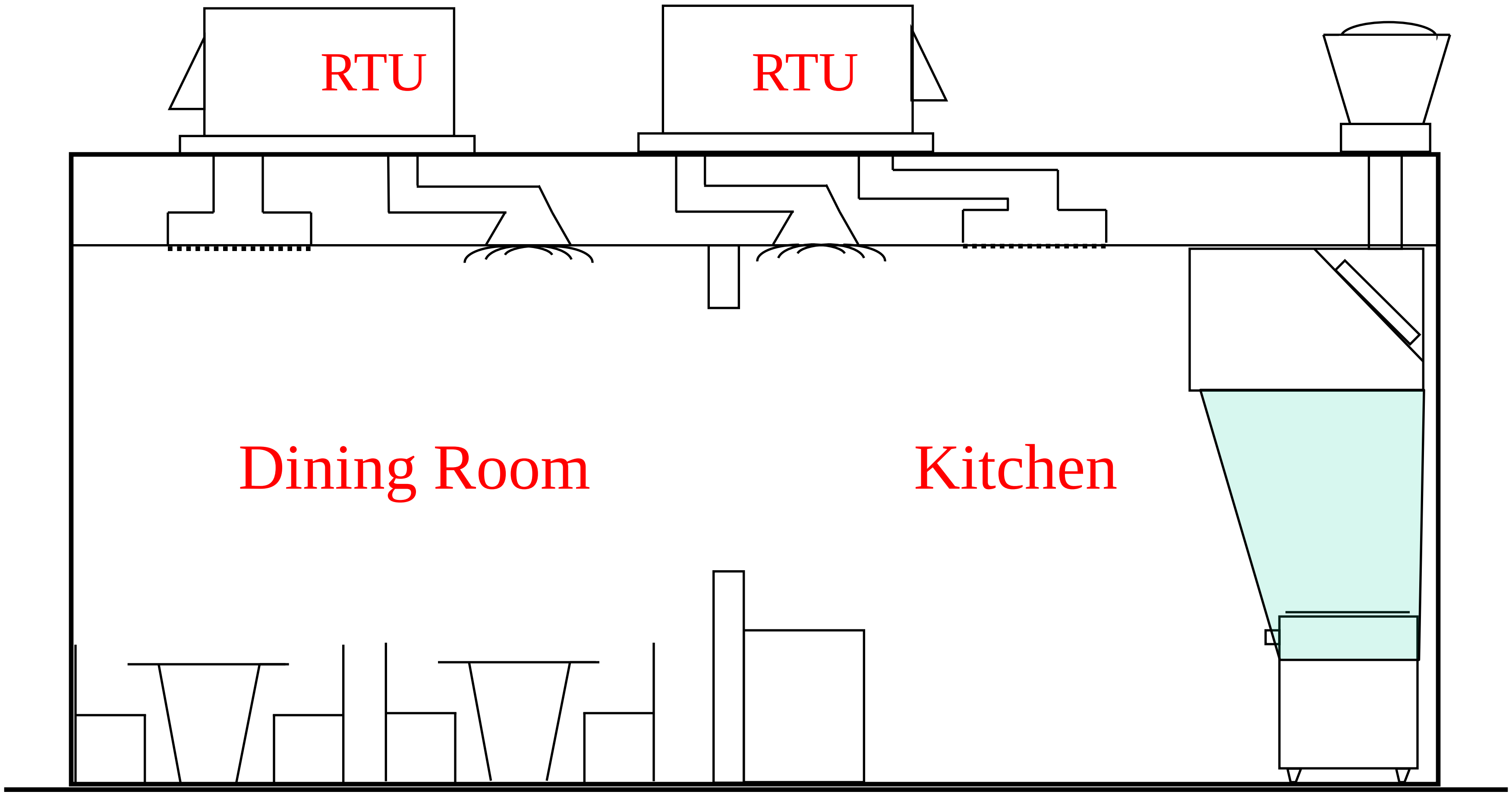


Ventilates, Cools, Dehumidifies & Heats Using 100% Outdoor Air

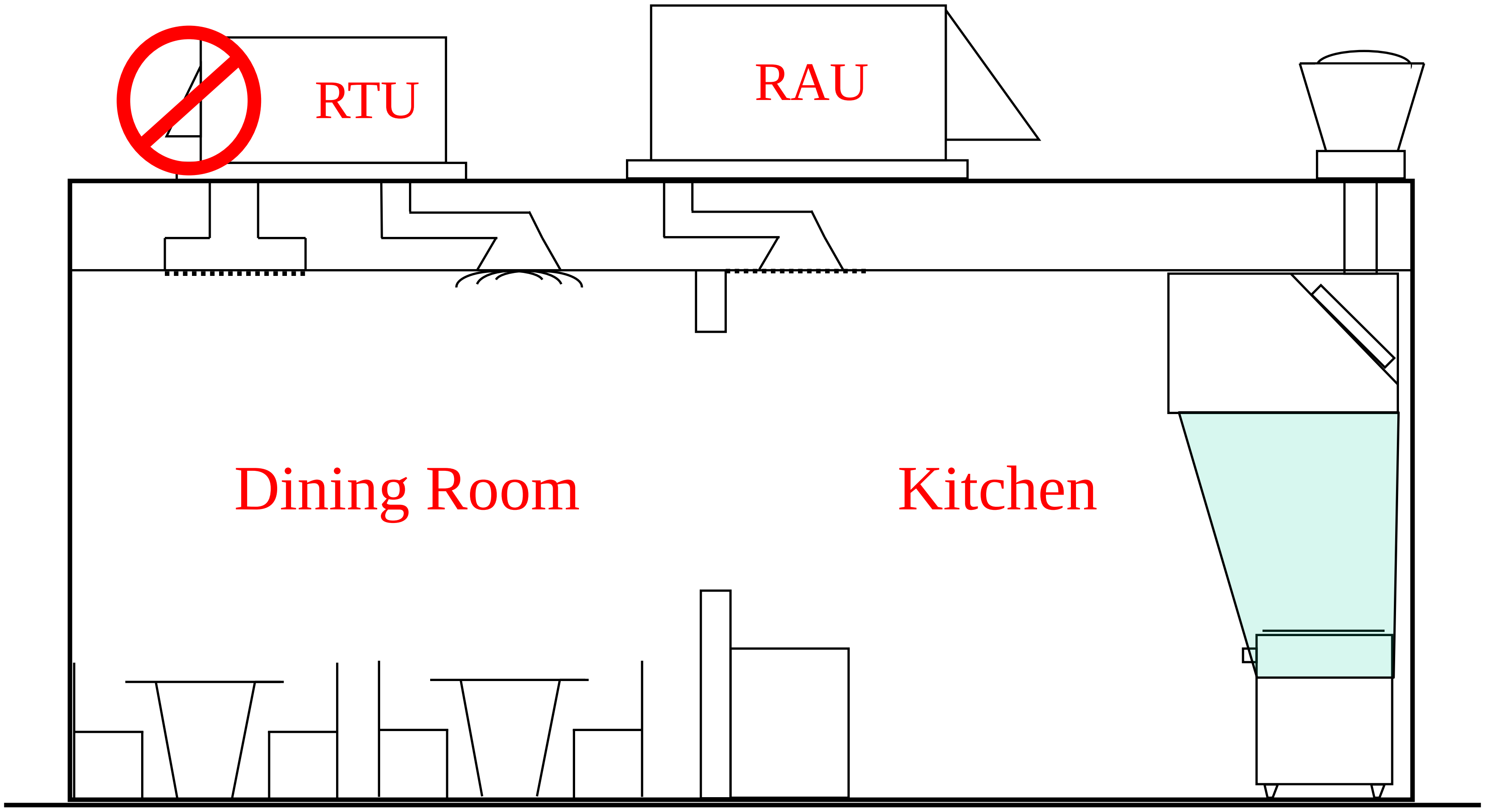
Replacement Air Strategy #1



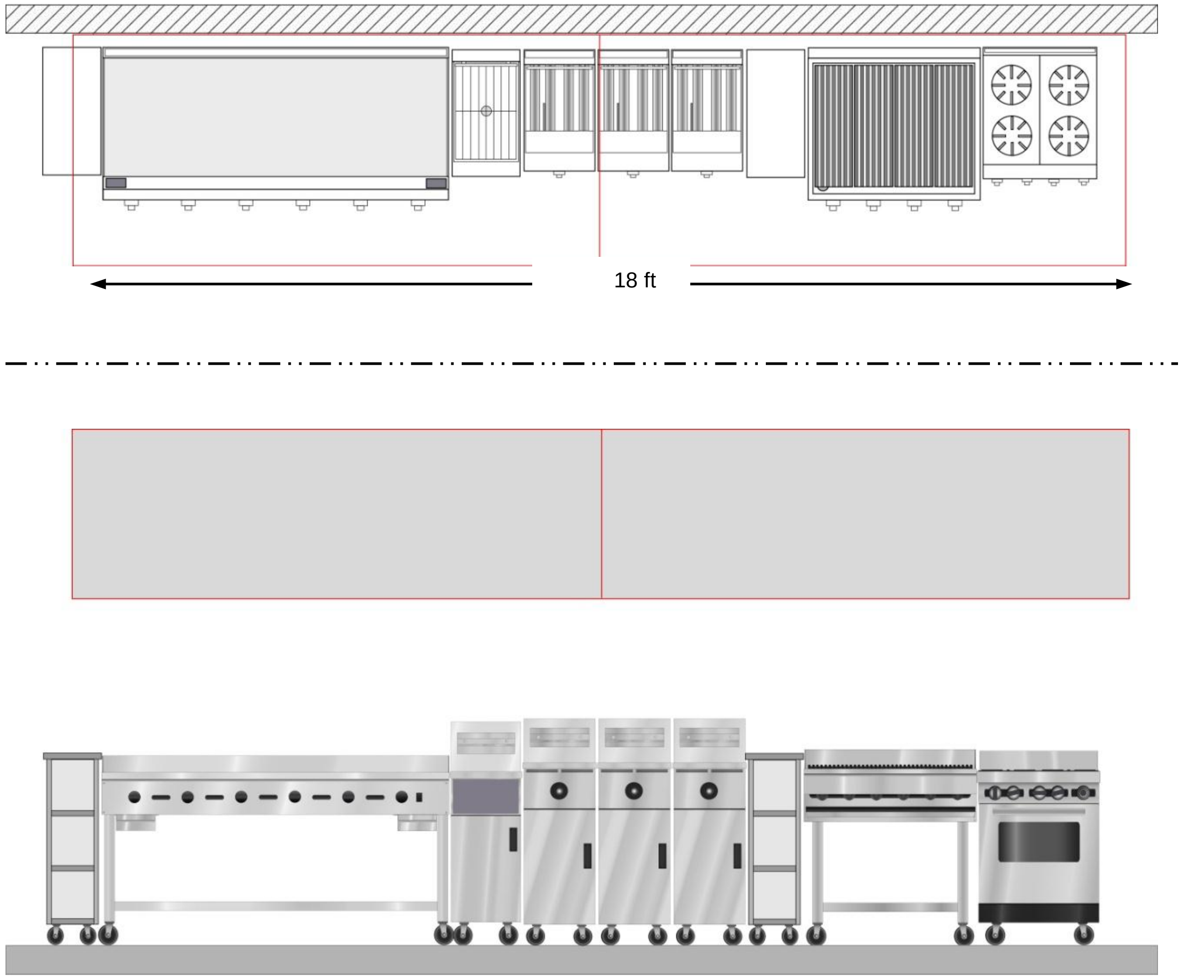
Replacement Air Strategy #2



Replacement Air Strategy #3



Base Case Cookline & Exhaust Hood

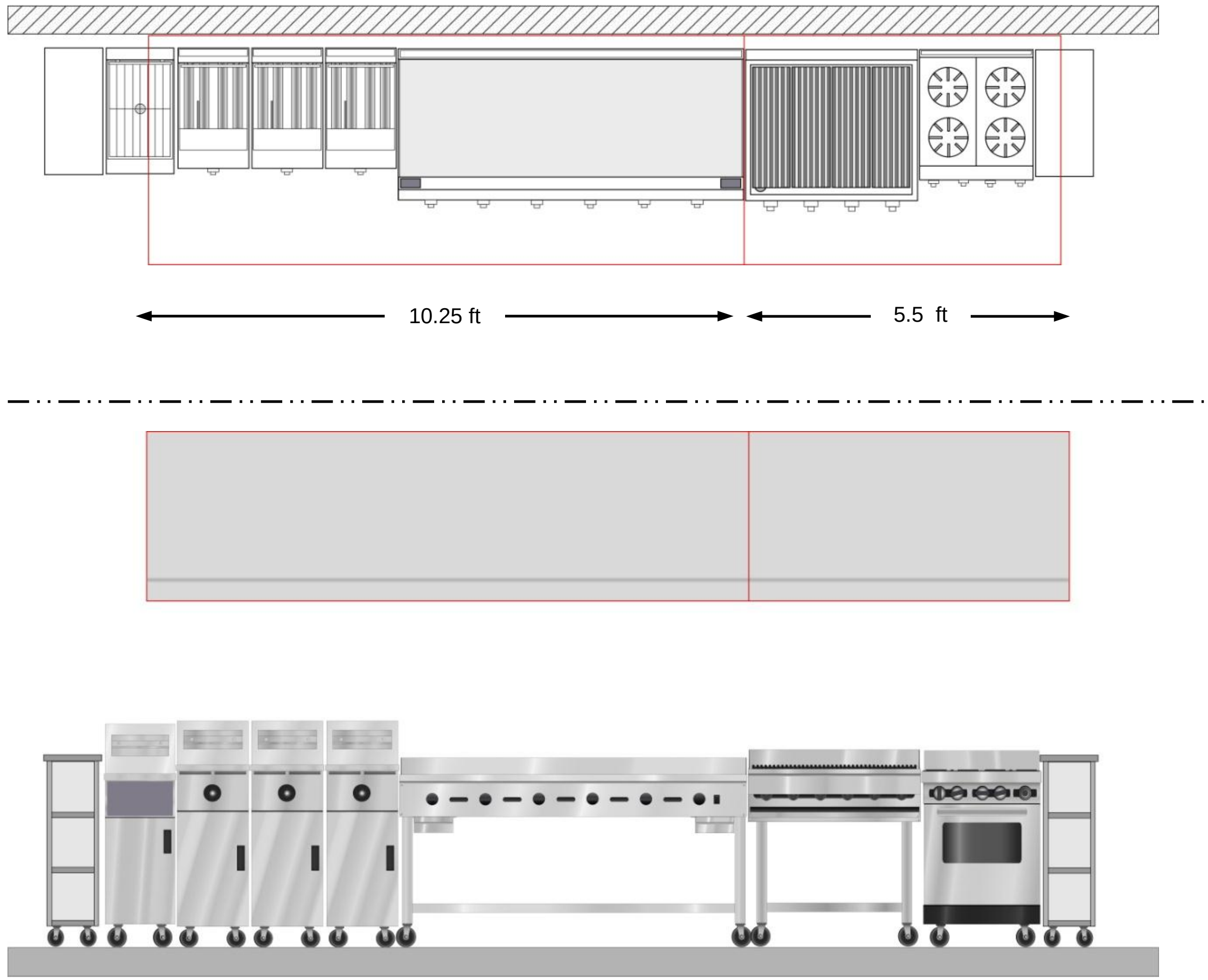


Design Exhaust = 7200 cfm (400 cfm/ft x 18 ft)

Table B-1. Casual Dining Base Case Air Balance.

Replacement and Exhaust Air	Maximum Outside Air for Occupancy (cfm)	Minimum Outside Air for Occupancy (cfm) 10% of Max	Outdoor (Replacement) Air Available for Kitchen Exhaust (cfm)	Exhaust Air (cfm)	Supply Air (cfm)	Nominal Cooling Capacity (refr. Tons)	Outside Air Fraction [OA/SA] %	SA cfm/ton
Dining Room Rooftop Unit #1 (RTU-1)	1050	125	400		4800	12	22%	400
Dining Room Rooftop Unit #2 (RTU-2)	675	80	200		3000	7.5	23%	400
Dining Room Rooftop Unit #3 (RTU-3)	675	80	200		3000	7.5	23%	400
Kitchen Rooftop Unit (RTU-4)	300	300	1200		4800	12	25%	400
Makeup Air Unit (sized at 80% of hood exhaust)			5800				100%	
Restroom Exhaust				300				
Dry Storage Exhaust				100				
Kitchen Hood Exhaust				7200				
Total	2700	585	7800	7600	15600	39	23%	
Net Outdoor Air for Building Pressurization			200					

Case I: Cookline & Exhaust Hoods



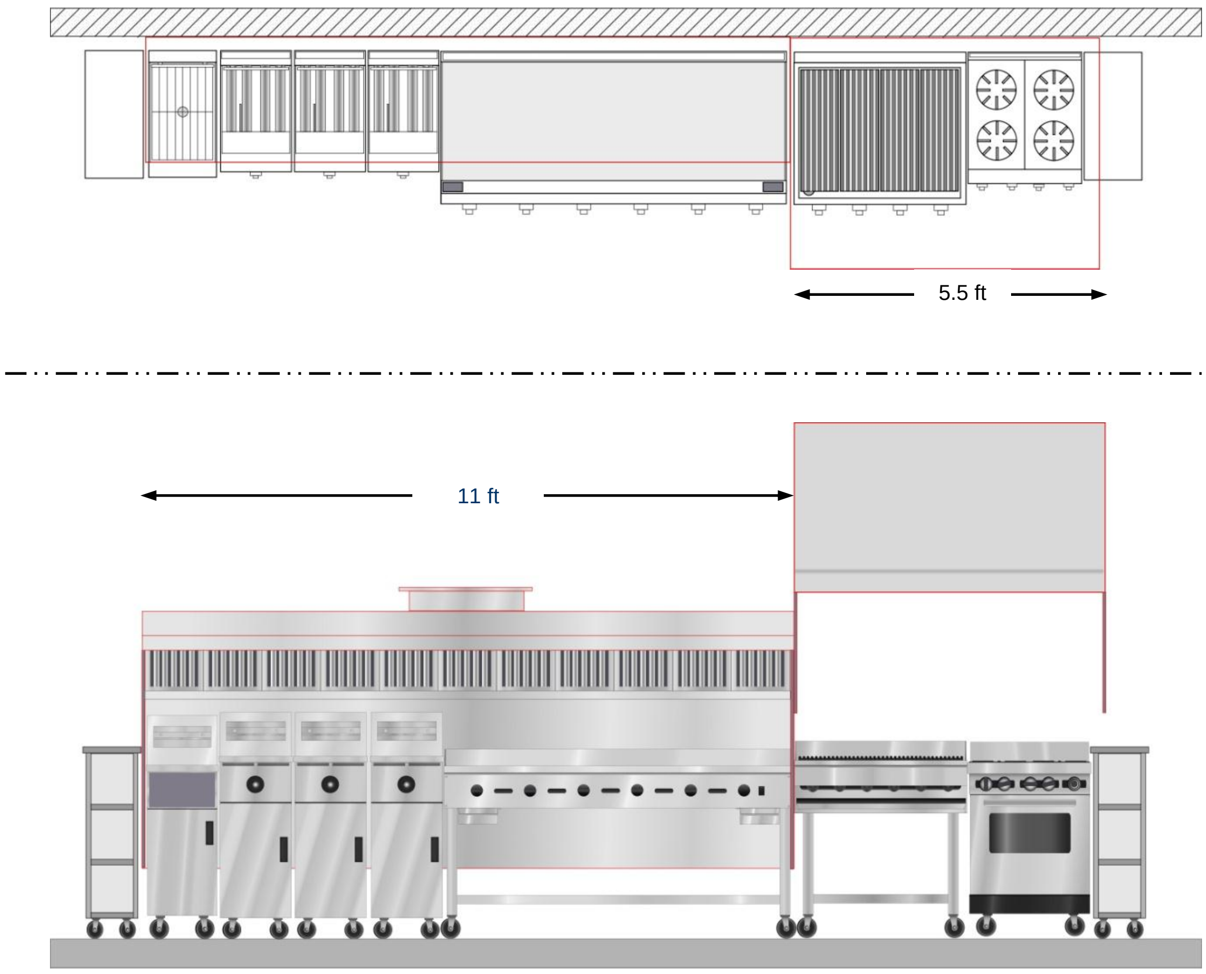
Hood over griddle & fryers: 10.25 ft. x 250 cfm/ft = 2,560 cfm
Hood over broiler & range: 5.5 ft. x 400 cfm/ft = 2,200 cfm
Total Exhaust Rate: 4760 cfm   Design @ 4800 cfm

Table B-2. Case I Optimized Design Air Balance with Engineered Hoods and MAU Size Reduced.

Replacement and Exhaust Air	Maximum Outside Air for Occupancy (cfm)	Minimum Outside Air for Occupancy (cfm) 10% of Max	Outdoor (Replacement) Air Available for Kitchen Exhaust (cfm)	Exhaust Air (cfm)	Supply Air (cfm)	Nominal Cooling Capacity (refr. Tons)	Outside Air Fraction [OA/SA] %	SA cfm/ton
Dining Room Rooftop Unit #1 (RTU-1)	1050	110	900		4800	12	19%	400
Dining Room Rooftop Unit #2 (RTU-2)	675	70	600		3000	7.5	20%	
Dining Room Rooftop Unit #3 (RTU-3)	675	70	600		3000	7.5	20%	
Kitchen Rooftop Unit (RTU-4)	300	300	600		4800	12	13%	400
Makeup Air Unit (sized at 33% of hood exhaust)			2600					
Restroom Exhaust				300				
Dry Storage Exhaust				100				
Kitchen Hood Exhaust				4800				
Total	2700	550	5300	5200	15600	39	17%	
Net Outdoor Air for Building Pressurization			100					

Without consideration for HVAC outdoor air, the MUA unit could have been sized at 80 to 90% or approx. 4000 cfm

Case II: Cookline & Exhaust Hoods



Custom backshelf hood over griddle & fryers: 11 ft. x 150 cfm/ft = 1,650 cfm
Custom canopy hood with full side panels over broiler & range: 5.5 ft. x 300 cfm/ft = 1,650 cfm
Total Exhaust Rate: 3,300 cfm

Table B-3. Case II Optimized Design Air Balance with Maximum Transfer Air and Eliminated MAU.

Replacement and Exhaust Air	Maximum Outside Air for Occupancy (cfm)	Minimum Outside Air for Occupancy (cfm) 10% of Max	Outdoor (Replacement) Air Available for Kitchen Exhaust (cfm)	Exhaust Air (cfm)	Supply Air (cfm)	Nominal Cooling Capacity (refr. Tons)	Outside Air Fraction [OA/SA] %	SA cfm/ton
Dining Room Rooftop Unit #1 (RTU-1)	1050	n/a	1200		4800	12	25%	400
Dining Room Rooftop Unit #2 (RTU-2)	675	n/a	700		3000	7.5	23%	
Dining Room Rooftop Unit #3 (RTU-3)	675	n/a	700		3000	7.5	23%	
Kitchen Rooftop Unit (RTU-7)	300	n/a	1200		4800	12	25%	400
Restroom Exhaust				300				
Dry Storage Exhaust				100				
Kitchen Hood Exhaust				3300				
Total	2700		3800	3700	15600	39	24%	
Net Outdoor Air for Building Pressurization			100					

Note: MUA unit has been eliminated!!!

CKV-HVAC Integration Recap:

1. Optimize hood design and reduce the design exhaust airflow rate.
2. Optimize makeup air delivery to kitchen – minimize impact on hood performance.
3. Maximize transfer air/minimize local makeup air.
4. Strive for 100% replacement air through HVAC units (versus using a conventional MAU unit without cooling), or…
5. Consider using a dedicated 100% replacement air unit (RAU).
6. Apply demand ventilation control of hoods where cost effective.

The Fan Factor!

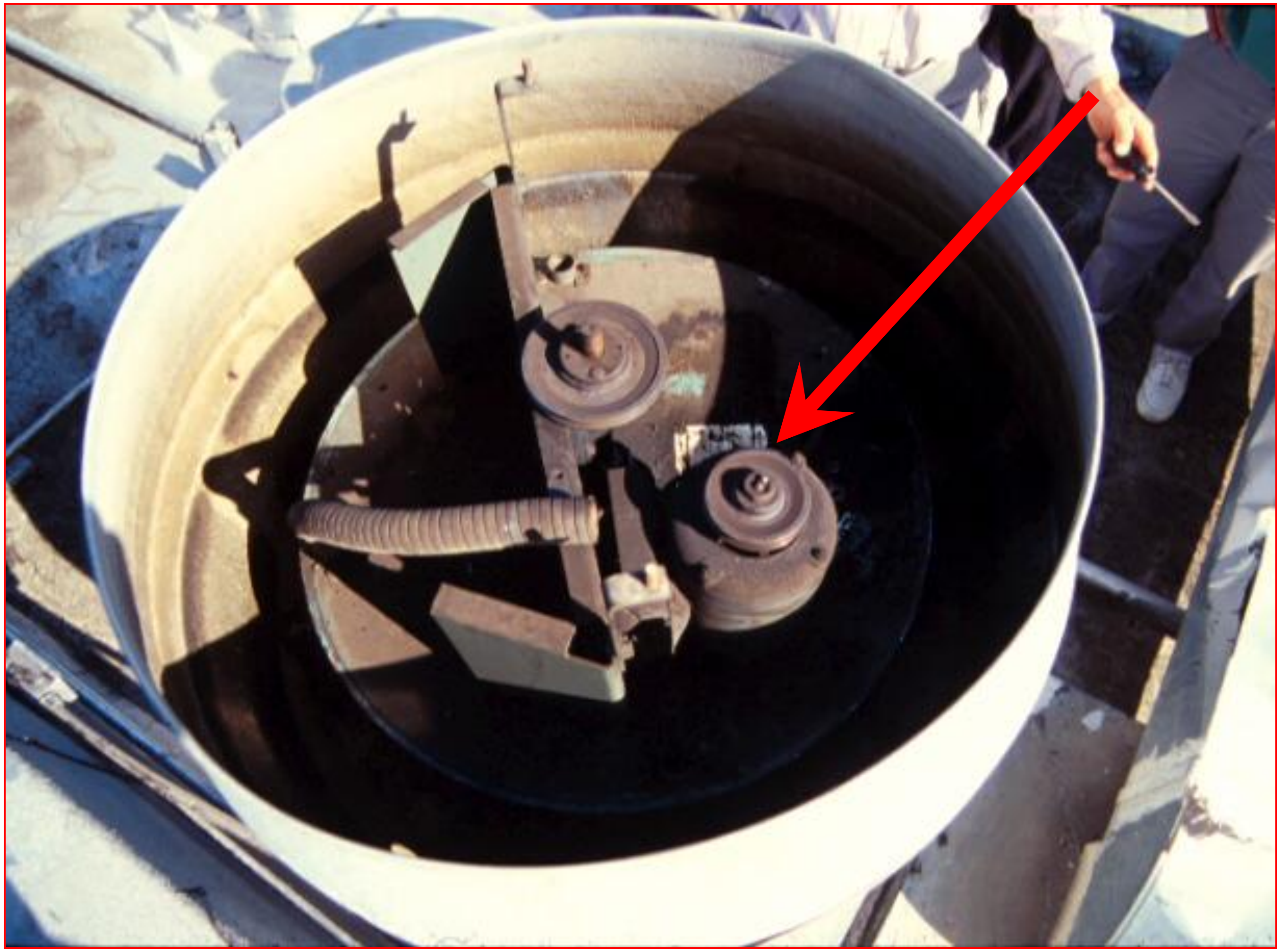
Hood static pressures* vary significantly (affecting fan energy directly)

Table 4 Exhaust Static Pressure Loss for Type I Hoods for Various Exhaust Airflows

	Hood Static Pressure Loss, inches of water			
Type of Grease Removal Device	**150 to 250 cfm/ft**	**250 to 350 cfm/ft**	**350 to 450 cfm/ft**	**500+ cfm/ft**
Baffle filter	0.25 to 0.50	0.50 to 0.75	0.75 to 1.00	1.00+
Extractor	1.00 to 1.35	1.30 to 1.70	1.70+	1.70+

*from the ASHRAE Handbook

Direct Drive Fans – the Future?



Variable Frequency Drives (VFD)

- Essentially electronic motor starters that replace magnetic starters
- Add flexibility to direct drive fans
- Separate Value Proposition from Demand Ventilation Controls (i.e., variable speed)

Now it time to consider….

Applying Demand Ventilation Control to Commercial Kitchen Ventilation?