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!
There are hoods everywhere that would benefit from a side panel.
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

30% Design Airflow Reduction with DVC (temp only)
Exhaust Airflow = 600 - 1200 cfm
Food Service Technology Center has its own Commercial Kitchen Ventilation Lab
Schlieren Flow Visualization

Spillage of Plume at 165 cfm/lf

Capture and Containment at 220 cfm/lf
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
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!
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

Two Charbroilers Cooking
No Side Panels No Drafts

Exhaust Flow Rate [CFM]

- Island-Mounted Canopy: 5100 CFM (8 ft hood, 638 cfm/ft)
- Wall-Mounted Canopy: 4100 CFM (8 ft hood, 513 cfm/ft)
- Proximity: 1250 CFM (7.2 ft hood, 174 cfm/ft)
Add in an Engineered Wall-Canopy Hood

Two 3-Foot Charbroilers Cooking under an 8-Foot Hood

Exhaust Flow Rate (cfm)

- Standard Single Island Canopy Hood: 5100 cfm
- Standard Wall Canopy Hood (with 6 in. overhang): 4100 cfm
- Engineered Wall Canopy Hood (18 in. overhang w/ side panels): 2400 cfm
- Engineered Proximity (Backshelf) Hood: 1250 cfm

But this hood was “listed” for 600°F at 210 cfm/ft!
...let’s look at the single-island hood in the lab
Single-Island Canopy Hood
Charbroiler @ 600°F 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

<table>
<thead>
<tr>
<th>Front Overhang to Appliance [inches]</th>
<th>Front Overhang to Cooking Surface [inches]</th>
<th>Distance Between the Rear of the Appliance and Backwall [inches]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>6.0</td>
<td>16.5</td>
</tr>
<tr>
<td>6.0</td>
<td>12.0</td>
<td>10.5</td>
</tr>
<tr>
<td>12.0</td>
<td>18.0</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Seal gap behind appliances!

- **510 cfm/ft** for 6 inch overhang
- **340 cfm/ft** for 12 inch overhang
- **280 cfm/ft** for 18 inch overhang

![Graph showing C&C Exhaust Rate [cfm] for different overhangs and seal conditions.](graph.png)
Dynamic Effect - Oven Door (6’’)

![Oven Door Image]
Dynamic Effect - Oven Door (18”)

[Image of a shadow of a person next to an oven door]
...easier “said” than “done”
Shelving over a 6-burner Range

Shelf:
36.0 in. w x 13.6 in. d x 1.5 in. h
(914mm w x 345mm d x 38mm h)

Shelf with backsplash:
36.0 in. w x 13.6 in. d x 1.5 in. h
(914mm w x 345mm d x 38mm h)
Shelving over a 6-Burner Range
Results

C&C Exhaust Flow Rate [cfm]

6 Burners w/o Seal Behind Appliance
3 Rear Burners w/o Seal Behind Appliance

Without Shelving On Appliance
Tubular Shelving On Appliance
Solid Shelving On Appliance
Tubular Shelving On Wall
Solid Shelving On Wall

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

4700 cfm
(470 cfm/ft)

4600 cfm
(460 cfm/ft)
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

C&C Exhaust Flow Rate [cfm]

<table>
<thead>
<tr>
<th>Side Panel</th>
<th>6&quot; Front Overhang</th>
<th>12&quot; Front Overhang</th>
<th>18&quot; Front Overhang</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without</td>
<td>2800</td>
<td>3100</td>
<td>3300</td>
</tr>
<tr>
<td>1x1</td>
<td>2600</td>
<td>2800</td>
<td>2400</td>
</tr>
<tr>
<td>2x2</td>
<td>2300</td>
<td>2800</td>
<td>1600</td>
</tr>
<tr>
<td>3x3</td>
<td>2550</td>
<td>2100</td>
<td>1600</td>
</tr>
<tr>
<td>4x4</td>
<td>2700</td>
<td>2000</td>
<td>1600</td>
</tr>
<tr>
<td>Full</td>
<td>2700</td>
<td>2000</td>
<td>1700</td>
</tr>
</tbody>
</table>

C&C Exhaust Flow Rate [cfm/ft]

<table>
<thead>
<tr>
<th>Front Overhang</th>
<th>6&quot;</th>
<th>12&quot;</th>
<th>18&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>6&quot; Front</td>
<td>2000</td>
<td>2100</td>
<td>2000</td>
</tr>
<tr>
<td>12&quot; Front</td>
<td>2400</td>
<td>2200</td>
<td>2000</td>
</tr>
<tr>
<td>18&quot; Front</td>
<td>1800</td>
<td>1600</td>
<td>1600</td>
</tr>
</tbody>
</table>
... 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

C&C Exhaust Flow Rate [cfm]

- 4.0ft Hood Depth
- 5.0ft Hood Depth

- 6.0in Front Overhang 22.5in Rear Clearance
- 6.0in Front Overhang 10.5in Rear Clearance
- 18.0in Front Overhang 10.5in Rear Clearance
- 12.0in Front Overhang 4.5in Rear Clearance
- 24.0in Front Overhang 4.5in Rear Clearance
- 6.0in Front Overhang 10.5in Rear Clearance w/Rear Seal
- 18.0in Front Overhang 10.5in Rear Clearance w/Rear Seal
- 24.0in Front Overhang 4.5in Rear Clearance w/4x4 Side Panels
- 24.0in Front Overhang 4.5in Rear Clearance w/Rear Seal & 4x4 Side Panels

Flow Rates:

- 4400
- 3500
- 2900
- 2700
- 2600
- 2100
- 5700
- 2900
- 2700 2600
- 2100
- 5700
The Effect of Hood Height Itself

2 ft. vs. 3 ft.
3 Broilers Under 10ft Long by 4ft Deep Wall-Mount Canopy Hood 42 inch

Distance Between Cooking Surface and Hood

- 4300
- 4100
- 3100
- 2000

Exhaust C&C [cfm]

- Cook/Off/Off
- Off/Cook/Off
The Effect of Hood Mounting Height

3 Broilers Under 10ft Long by 4ft Deep by 2ft High
Wall-Mount Canopy Hood

Exhaust C&C [cfm]

<table>
<thead>
<tr>
<th>Height-to-Floor</th>
<th>Cook/Off/Off</th>
<th>Off/Cook/Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>7ft-6in</td>
<td>4900</td>
<td>2900</td>
</tr>
<tr>
<td>7ft-0in</td>
<td>4600</td>
<td>2900</td>
</tr>
<tr>
<td>6ft-6in</td>
<td>4300</td>
<td>3100</td>
</tr>
<tr>
<td>5ft-6in</td>
<td>3100</td>
<td>3100</td>
</tr>
<tr>
<td>3ft-6in</td>
<td>400</td>
<td>2200</td>
</tr>
<tr>
<td>4ft-6in Appliance</td>
<td>2900</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4ft-0in Appliance</td>
<td>2900</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3ft-6in Appliance</td>
<td>3100</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2ft-6in Appliance</td>
<td>3100</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6in Appliance</td>
<td>400</td>
<td>250</td>
</tr>
<tr>
<td>Distance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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.
2. Optimize makeup air delivery to kitchen
   - No short-circuit hoods!
   - Introduce replacement air at low-velocity
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

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!

6000 cfm

3000 cfm

3000 cfm

3000 cfm

6000 cfm
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

Dining Room

Kitchen

RTU

RTU

MAU
Replacement Air Strategy #2

Dining Room

Kitchen

RTU

RTU
Replacement Air Strategy #3

Dining Room

Kitchen

RTU

RAU
Base Case Cookline & Exhaust Hood

Design Exhaust = 7200 cfm (400 cfm/ft x 18 ft)
Table B-1. Casual Dining Base Case Air Balance.

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

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

Net Outdoor Air for Building                        | 100                                    |                                                     |                                                                |                  |                 |                                      |                                 |           |
Pressurization                                     |                                        |                                                     |                                                                |                  |                 |                                      |                                 |           |

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.

<table>
<thead>
<tr>
<th>Replacement and Exhaust Air</th>
<th>Maximum Outside Air for Occupancy (cfm)</th>
<th>Minimum Outside Air for Occupancy (cfm) 10% of Max</th>
<th>Outdoor (Replacement) Air Available for Kitchen Exhaust (cfm)</th>
<th>Exhaust Air (cfm)</th>
<th>Supply Air (cfm)</th>
<th>Nominal Cooling Capacity (refr. Tons)</th>
<th>Outside Air Fraction [OASA] %</th>
<th>SA cfm/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dining Room Rooftop Unit #1 (RTU-1)</td>
<td>1050</td>
<td>n/a</td>
<td>1200</td>
<td>4300</td>
<td>12</td>
<td>25%</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Dining Room Rooftop Unit #2 (RTU-2)</td>
<td>675</td>
<td>n/a</td>
<td>700</td>
<td>3000</td>
<td>7.5</td>
<td>23%</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Dining Room Rooftop Unit #3 (RTU-3)</td>
<td>675</td>
<td>n/a</td>
<td>700</td>
<td>3000</td>
<td>7.5</td>
<td>23%</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Kitchen Rooftop Unit (RTU-7)</td>
<td>300</td>
<td>n/a</td>
<td>1200</td>
<td>4300</td>
<td>12</td>
<td>25%</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Restroom Exhaust</td>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry Storage Exhaust</td>
<td></td>
<td></td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kitchen Hood Exhaust</td>
<td></td>
<td></td>
<td></td>
<td><strong>3300</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2700</td>
<td><strong>3800</strong></td>
<td>3700</td>
<td>15600</td>
<td>39</td>
<td>24%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Type of Grease Removal Device</th>
<th>Hood Static Pressure Loss, inches of water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150 to 250 cfm/ft</td>
</tr>
<tr>
<td></td>
<td>250 to 350 cfm/ft</td>
</tr>
<tr>
<td></td>
<td>350 to 450 cfm/ft</td>
</tr>
<tr>
<td></td>
<td>500+ cfm/ft</td>
</tr>
<tr>
<td>Baffle filter</td>
<td>0.25 to 0.50</td>
</tr>
<tr>
<td></td>
<td>0.50 to 0.75</td>
</tr>
<tr>
<td></td>
<td>0.75 to 1.00</td>
</tr>
<tr>
<td></td>
<td>1.00+</td>
</tr>
<tr>
<td>Extractor</td>
<td>1.00 to 1.35</td>
</tr>
<tr>
<td></td>
<td>1.30 to 1.70</td>
</tr>
<tr>
<td></td>
<td>1.70+</td>
</tr>
</tbody>
</table>

*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?