Commercial Kitchen Ventilation

An Energy Efficiency Perspective!
Winnipeg Hospital (My first CKV project)
Design Approach:

• Reduced exhaust and makeup air (from 34,000 cfm to 12,000 cfm)
• Side panels and glass back wall for single island canopy
• Filter blanks in sections not over appliances
• Air-to-air heat recovery to preheat makeup
• Two-speed system (3000 ft/min duct velocity on high speed).
The Results

21 ft. single island canopy hood over baking line
27 ft. double island canopy hood over cooking line

- Concept Design 34,000 cfm
- Preliminary Design 21,000 cfm
- Final Design 11,000 cfm

Plus: 2-speed control and exhaust air heat recovery
Glass back wall
Predicting Energy Consumption

... and Cost for Commercial Kitchen Ventilation Systems
Outdoor Air Load Calculator and Fan Energy Estimator

Free Download: www.archenergy.com/AECHome/ckv/oac/default.htm
Climate Effect

1000 cfm Outdoor Air
24 hour per day
Heated to 65°F
Cooled to 76°F
70% RH

Heating/Cooling Load (kBtu/yr)
Hotel in San Francisco

...50,000 cfm exhaust from kitchens!
Makeup air temperature 70°F

Outdoor air temperature = 50°F
Simultaneous cooling!
Turned down all the duct stats!

$50,000 per year saving in gas alone!
Toronto Restaurant
Canopy Hood Over Gas Cookline
200,000 Btu/h Makeup Air Heater
MUA Discharge Temperature

75°F
(24°C)
Heating Load vs. MUA Temperature

1000 cfm, 24-hour operation, 365 days per year in Toronto

50% reduction

MUA Temperature (deg F)

Annual MUA Heating (kBtu/yr)
Example: Properly Set Duct Stat

13° C
Heating Load vs. MUA Temperature

1000 cfm, 12-hour operation, 365 days per year in Winnipeg

50% reduction
6.5.7.1 Commercial Kitchen Exhaust Systems

6.5.7.1.1 Replacement air introduced directly into the hood cavity of kitchen exhaust hoods shall not exceed 10% of the hood exhaust airflow rate.

6.5.7.1.2 Conditioned supply air delivered to any space with a kitchen hood shall not exceed the greater of:
   a) the supply flow required to meet the space heating or cooling load
   b) the hood exhaust flow minus the available transfer air from adjacent spaces. Available transfer air is that portion of outdoor ventilation air not required to satisfy other exhaust needs, such as restrooms, and not required to maintain pressurization of adjacent spaces.

6.5.7.1.3 If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 5,000 cfm then each hood shall have an exhaust rate that complies with Table 6.5.7.1.3. If a single hood is installed over appliances with different duty ratings, then the maximum allowable flow rate in each section of the hood shall not exceed the Table 6.5.7.1.3 values for the appliance duty ratings in that section of the hood. Refer to ASHRAE Standard 154 for definitions of hood type, appliance duty, and net exhaust flow rate.

<table>
<thead>
<tr>
<th>Type of Hood</th>
<th>Light Duty Equipment</th>
<th>Medium Duty Equipment</th>
<th>Heavy Duty Equipment</th>
<th>Extra Heavy Duct Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall-mounted canopy</td>
<td>140</td>
<td>210</td>
<td>280</td>
<td>385</td>
</tr>
<tr>
<td>Single island</td>
<td>280</td>
<td>350</td>
<td>420</td>
<td>490</td>
</tr>
<tr>
<td>Double island (per side)</td>
<td>175</td>
<td>210</td>
<td>280</td>
<td>385</td>
</tr>
<tr>
<td>Eyebrow</td>
<td>175</td>
<td>175</td>
<td>Not allowed</td>
<td>Not allowed</td>
</tr>
<tr>
<td>Backshelf/Pass-over</td>
<td>210</td>
<td>210</td>
<td>280</td>
<td>Not allowed</td>
</tr>
</tbody>
</table>

Exception:
   a) At least 75% of all the replacement air is transfer air that would otherwise be exhausted.
Hoods are not created equal...
The setup...
The Standard Challenge!
Heavy-duty appliance challenge
With and without partial side panels
Mixed-duty appliance challenge

...includes walk-by test
ASHRAE Standard 90.1
Walk by test – C&C failure
Capture and Containment Exhaust Airflow Rate [cfm]

- Generic Hood
- Max Overhang
- Manufacturer 1
- Manufacturer 2
- Manufacturer 3
- Manufacturer 4
- Manufacturer 5
- Manufacturer 6
- Manufacturer 7
- Manufacturer 8

ASHRAE Standard 90.1
Exhaust Air Heat Recovery in Kitchen Ventilation?
Air-to-Air Heat Recovery Unit
What Are the Challenges for Using Air-to-Air Energy Recovery for Commercial Kitchen Ventilation (CKV) and 90.1 Compliance?
If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 5,000 cfm then it shall have one of the following:
a) At least 50% of all replacement air is transfer air that would otherwise be exhausted.
b) Demand ventilation system(s) on at least 75% of the exhaust air. Such systems shall be capable of at least 50% reduction in exhaust and replacement air system airflow rates, including controls necessary to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent and combustion products during cooking and idle.
c) Listed energy recovery devices with a sensible heat recovery effectiveness of not less than 40% on at least 50% of the total exhaust airflow.
Exhaust Air Heat Recovery

Can It Be Applied to Commercial Kitchen Ventilation?
Air-to-Air Heat Recovery Unit
Air-to-Air HX – Toronto Restaurant
36% reduction = $22,600 per year!
(at $1.30/therm)
Flue Gas Heat Recovery

Exhaust Air
Cool Flue
Cooking Effluent
Flue Gases
Hot Water Out
Cold Water In
Fryer Energy Input
Fryer Flue Heat Exchanger
DCV, Heat Recovery & Strategic Introduction of MUA could potentially...
Applying Demand Ventilation Control to Commercial Kitchen Ventilation

1. In section 8.2.1.1 revise to read as follows:

   **8.2.1.1** The air velocity through any duct shall be not less than 152.4 m/min (500 ft/min).
Demand Controlled Ventilation (DCV) Strategies

- controlled on a time-of-day basis (EMS?)
- proportional to appliance energy use
- controlled by exhaust temperature
- controlled by sensing smoke or steam produced by cooking process
- controlled by measuring cooking surface temperature or activity
- controlled by direct feedback from cooking equipment (NAFEM Online Protocol)
- controlled by combinations of the above
Appliance Control

No Load - Low Speed!

2-Speed Fan Interlocked with 2-Sided Griddle
Demand Ventilation Control Technologies

Duct Temperature Sensor & Infrared Sensors

Duct Temperature Sensor & Smoke Detection

Duct Temperature Sensor
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)
Exhaust System (with EMS)

Average Energy Rate (kW)

- Exhaust Fan 1 (4000 CFM)
- Exhaust Fan 2 (4500 CFM)
- Make-Up Fan

Time of Day

12:00 AM  2:00 AM  4:00 AM  6:00 AM  8:00 AM  10:00 AM  12:00 PM  2:00 PM  4:00 PM  6:00 PM  8:00 PM  10:00 PM  12:00 AM
Total Daily Fan Energy

Original System

Original System with EMS

Retrofit System with Controller

Daily Fan Energy (kWh/day)

$3250 savings @ $0.10/kWh

$4875/yr @ $0.15/kWh
Casual Dining Restaurant
Exhaust Fans without DVC

- EF #2 Left: 15 kWh/Day
- EF #1 Right: 22 kWh/Day

- EF #2 Left: 1.3 kW
- EF #1 Right: 0.9 kW
Exhaust Fans with DVC

- 7 kWh/Day
- 5 kWh/Day

- 2.2 kW (without DVC)
- 0.7 kW (with DVC)
Large Hotel Kitchen
The Kitchen: 24/7
Front Line
Exhaust and Makeup Fan Power

Without DVC

Avg. Reduction = 8.7 kW

12:00 AM 1:15 AM 2:30 AM 3:45 AM 5:00 AM 6:15 AM 7:30 AM 8:45 AM 10:00 AM 11:15 AM 12:30 PM 1:45 PM 3:00 PM 4:15 PM 5:30 PM 6:45 PM 8:00 PM 9:15 PM 10:30 PM 11:45 PM

With Melink 5.3 kW
W/O Melink 14 kW
Combined Exhaust Fans

Without DVC

With DVC

Reduction = 5.1 KW
Rear Exhaust Fan - Typical Day Power Profile

Fan Power Reduction = 2.2 kW
California DCV Case Studies

Average Exhaust Fan Speed Reduction - 26%

Average Total Fan Power Reduction - 57%
Future of DCV For Commercial Kitchens

By Don Fisher, P.Eng., Associate Member ASHRAE; and Rich Swierczyna, Associate Member ASHRAE; Angelo Karos
CAUTION:
The CKV system must work effectively as single-speed system before DCV is applied.
If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 5,000 cfm then it shall have one of the following:

a) At least 50% of all replacement air is transfer air that would otherwise be exhausted.

b) Demand ventilation system(s) on at least 75% of the exhaust air. Such systems shall be capable of at least 50% reduction in exhaust and replacement air system airflow rates, including controls necessary to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent and combustion products during cooking and idle.

c) Listed energy recovery devices with a sensible heat recovery effectiveness of not less than 40% on at least 50% of the total exhaust airflow.
DCV Recap…

• With the specification of a DCV system, there is no need to take chances with a design exhaust ventilation rate that is too low.

• Effective commissioning of a DVC system can maximize its performance.

• The CKV system must work effectively as single-speed system before DCV is applied.

• Until appliances communicate directly with the DCV system, the DCV technology application will not realize its full “return on investment” potential.

• The DCV system should integrate with the EMS.
Energy Management Systems

Wiring the Intelligent Kitchen
The Energy Efficient McDonald’s (T.E.E.M)
### TABLE 3
Summary of Estimated Savings, Estimated Installed Costs, and Payback Period for Technologies Applied at the Demonstration Restaurant

<table>
<thead>
<tr>
<th>Technology</th>
<th>Estimated Savings ($)</th>
<th>Estimated Incremental Installed Cost ($)</th>
<th>Payback Period (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controllable ballasts</td>
<td>702</td>
<td>620</td>
<td>0.9</td>
</tr>
<tr>
<td>Low-temperature occupancy sensors</td>
<td>327</td>
<td>340</td>
<td>1.0</td>
</tr>
<tr>
<td>Two-speed exhaust fan*</td>
<td>230</td>
<td>400</td>
<td>1.7</td>
</tr>
<tr>
<td>Energy management system*</td>
<td>3254</td>
<td>12,000</td>
<td>3.7</td>
</tr>
<tr>
<td>High-efficiency air conditioning*</td>
<td>480</td>
<td>600</td>
<td>1.3</td>
</tr>
<tr>
<td>Kitchen evaporative cooling*</td>
<td>648</td>
<td>1200</td>
<td>1.9</td>
</tr>
<tr>
<td>Play area evaporative cooling*</td>
<td>936</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Evaporative precoolers on AC units*</td>
<td>76</td>
<td>1000</td>
<td>13.2</td>
</tr>
<tr>
<td>Spectrally selective glazing†</td>
<td>3950</td>
<td>6000</td>
<td>1.5</td>
</tr>
</tbody>
</table>

* Energy savings for these technologies were dependent on the location and weather at the demonstration project.
† The savings for the spectrally selective glazing includes $450 for energy savings and $3500 for reduced capital cost of air-conditioning units.
The EMS system was absolutely crucial to the success of the TEEM project.
It's easy to believe that in 10 years every restaurant will have an energy management system

Don Fisher and Richard Young
It's easy to believe that in 10 years every restaurant will have an energy management system.
Question: Have you been involved in a project that included an Energy Management System?

Yes? No?
Question: If your answer was yes, was your experience with the EMS a positive one?

Yes?  No?
What were the challenges?

Hassle for the Operator
What were the challenges?

Slow Communications
Call Centers
What were the challenges?

Proprietary communications protocol

EMS companies did NOT understand restaurants (or really care)
Expensive to Install and Quickly Obsolete
16 Years later...
Many Technological Advances

Small Inexpensive Electronics
Wireless and the Internet
Handheld Devices
And...other positive influences:

Higher Energy Prices       Renewed Interest
Information Boom – this is no longer “weird”

Small and nimble tech companies with more understanding of restaurants.
It's a little embarrassing that your car has more intelligence than your cookline.
Still…adoption of EMS systems remains minimal.
Question: Do you feel that EMS systems will be standard equipment in restaurants in the next 10 years?

Yes?  No?
What will make EMS practical?

1. Controls integrated into smart appliances
   – NAFEM Protocol
2. Adaptive logic – don’t bug the humans
   – Nest Thermostat

3. Continuous commissioning of systems
4. Control of more systems – CKV?
The POS is a complex, adaptive, control system that has been in every major chain restaurant for years.
Technological and operational trends suggest that the EMS system is not far behind.