ENERGY EFFICIENT SOLUTIONS FOR COMMERCIAL KITCHEN VENTILATION

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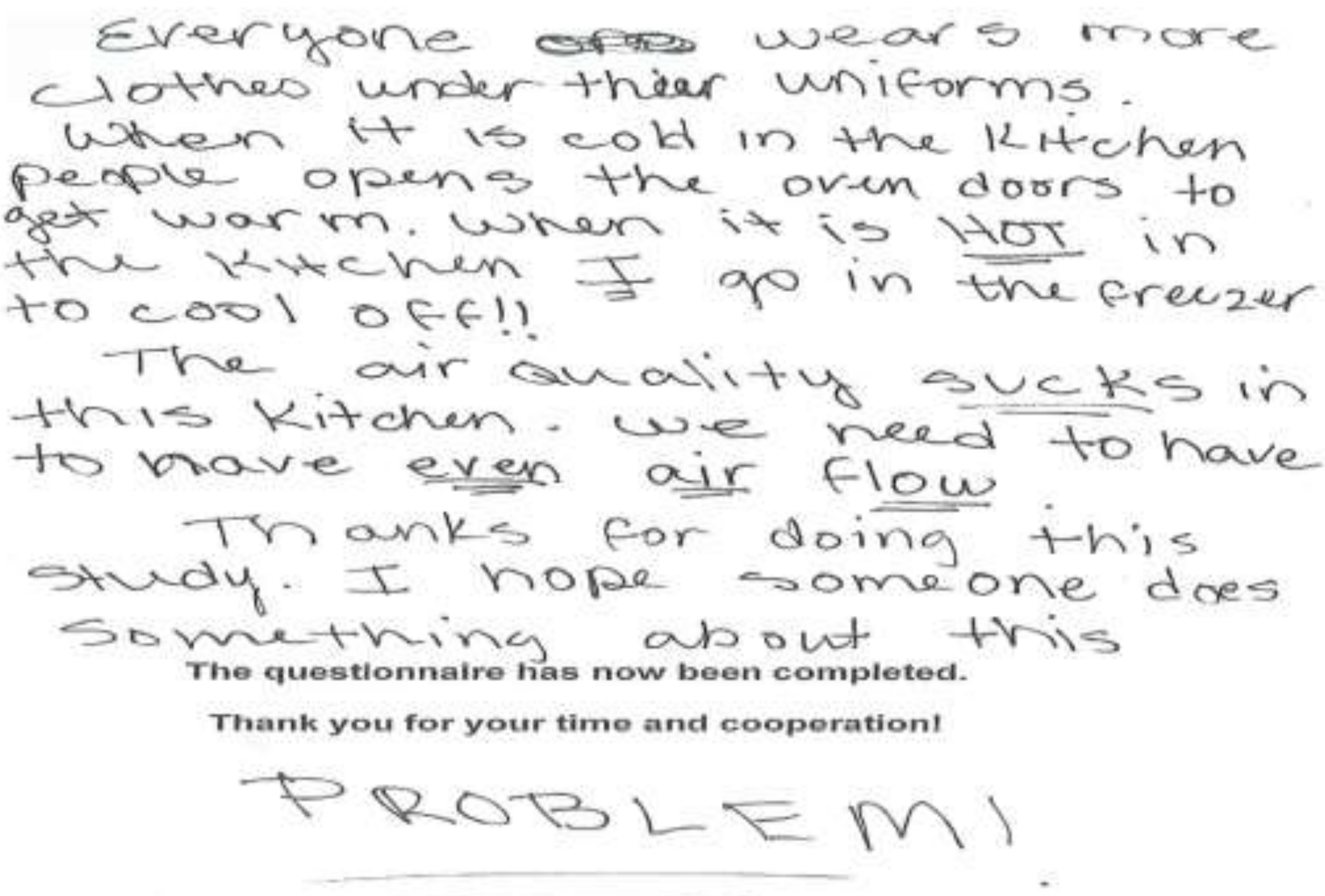
Facts

- Restaurants are among the buildings with the highest energy intensity in commercial sector.
- In the US alone there are 900 thousand restaurants employing over 12 million people
- Labor and training costs for restaurants continue to rise with the average employee turnover exceeding 100%

Thermal comfort survey



Everyone wears more clothes under thier uniforms.
When it is cold in the Kitchen people opens the oven doors to get warm. When it is HOT in the Kitchen I go in the freezer to cool off!!
The air quality sucks in this Kitchen. We need to have to have even air flow.
Thanks for doing this study. I hope someone does something about this

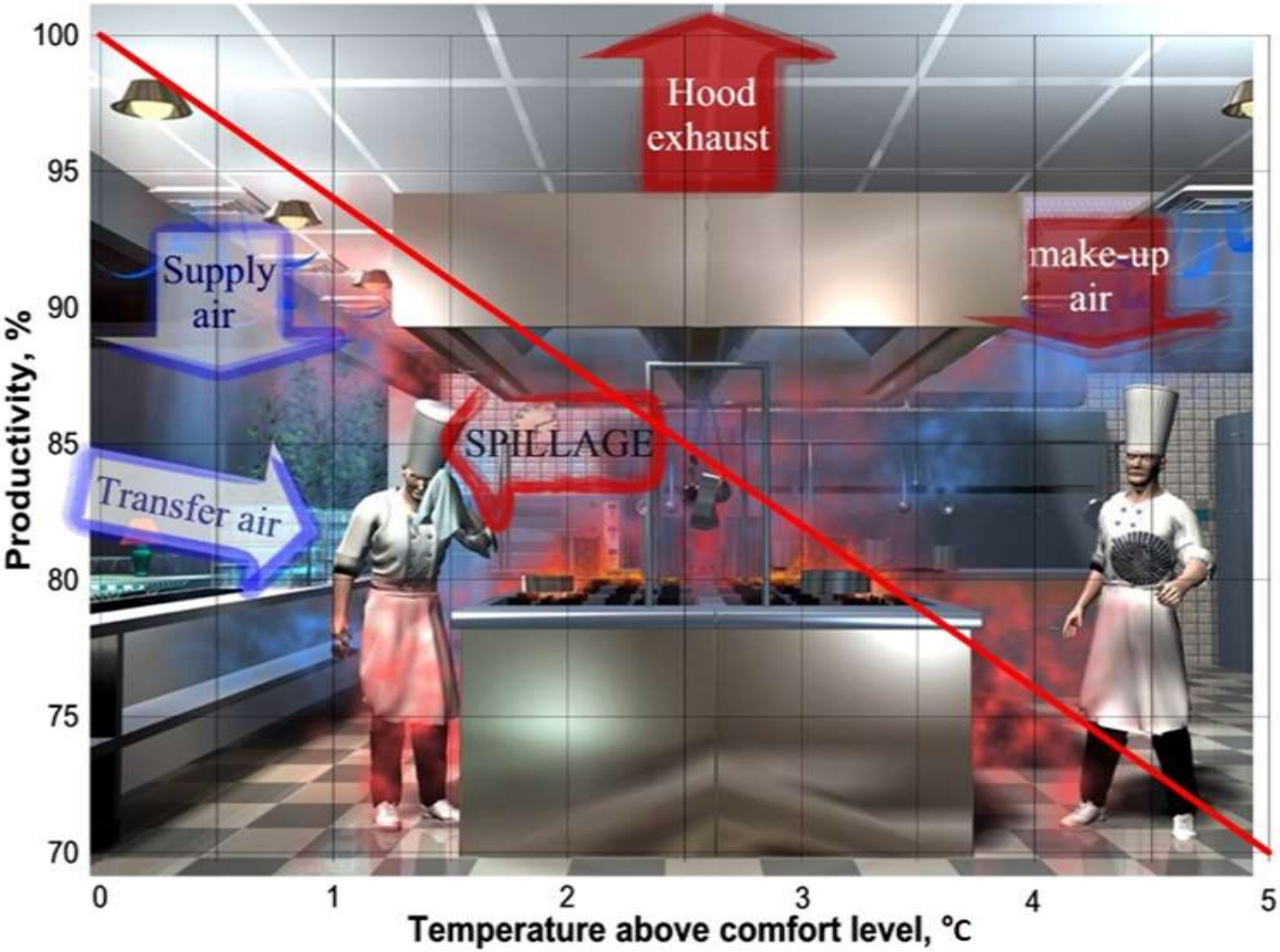
The questionnaire has now been completed.

Thank you for your time and cooperation!

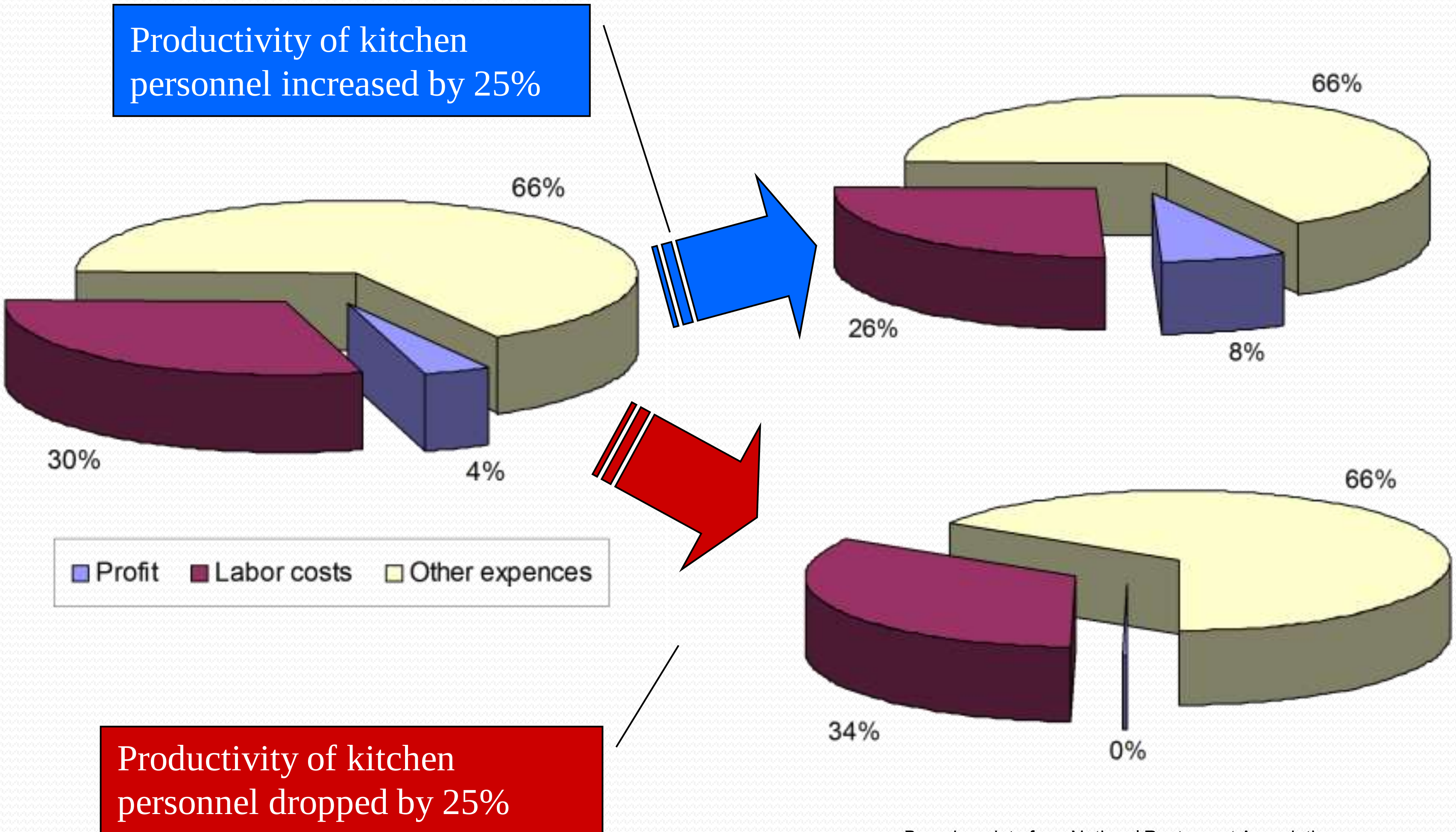
PROBLEM!

From ASHRAE report RP1469 “Thermal Comfort in Commercial Kitchens”

Thermal Comfort & Productivity

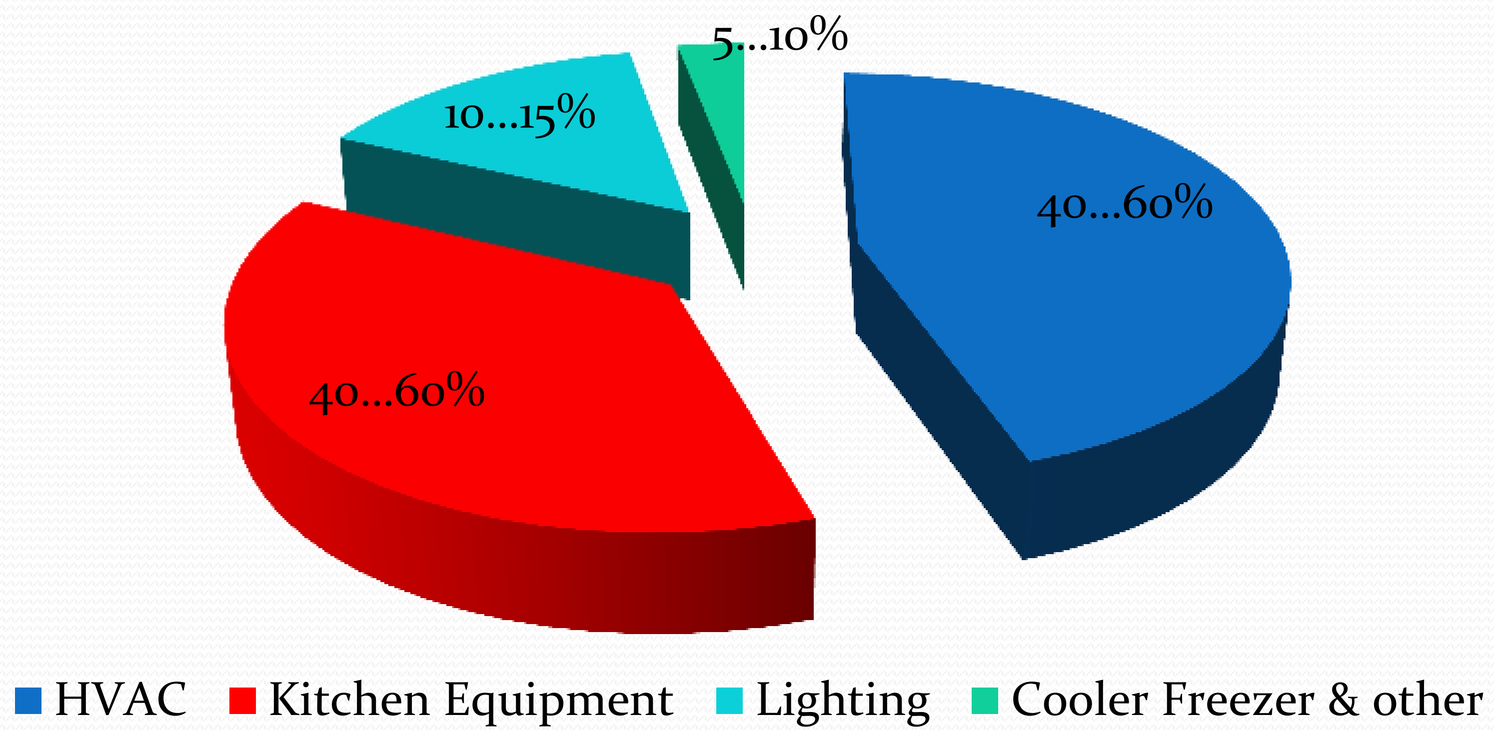


Effect of productivity on profit



Based on data from National Restaurant Association

“Typical” restaurant energy consumption



Cooking process and HVAC system contribute up to 80% of total restaurant energy consumption.

Start from the heat source – cooking equipment

- Low efficiency appliances with high energy output add more heat to space, require higher ventilation rates and result in higher HVAC energy consumption.
- Adding 10 kW to appliances energy input may double contribution to the whole building energy consumption to 20 kW due to its effect on HVAC system.
- Kitchen energy consumption is driven primarily by cooking process & equipment

More heat = more cooling

Use more efficient cooking process

- Convection ovens
- Induction cooking
- Use best-in-class ENERGY STAR and California utility rebate qualified appliances www.fishnick.com/saveenergy/rebates

Ventilation Design

- Customize ventilation design for the cooking process and equipment.
- Design objective is to minimize outdoor air usage whenever cooling or heating is required.

Energy and environmental impact of increasing outdoor airflow by 100 l/s

City, State	Electricity Consumption	Gas Consumption	CO^2 emissions
	kWh	kWh	kg
Innsbruck, AUT	590	5707	242,5
Helsinki, FIN	571	9107	262,1
Paris, FRA	592	4297	180,6
Berlin, DEU	606	5527	549,0
Rome, ITA	681	1371	439,2
Warsaw, POL	592	6586	846,6
Moscow, RUS	575	9070	429,5
Madrid, SPA	809	2678	466,8

Basis for calculation: Restaurant operates from 7:00 to 23:00 seven days a week. Electricity consumption is calculated based on energy required to operate supply and exhaust fans to move additional 100 l/s of air and energy consumption by compressor of refrigeration system to cool outside air in summer down to kitchen indoor air conditions (24°C, 50% relative humidity). Calculation of gas consumption is based on amount of gas required to heat the make-up air in winter to 18°C.

Ventilation design

How much exhaust is enough?

Bad practice!

Open the door and then switch on air conditioner!

Terminology

- **Replacement air** – all air supplied to the restaurant to compensate for hood exhaust

  Replacement Air = Total Hoods Exhaust

- **Make-up air** – outside air introduced to kitchen space to completely or partially compensate for hood exhaust
- **Transfer air** – air being transferred from adjacent spaces to kitchen to compensate for hood exhaust

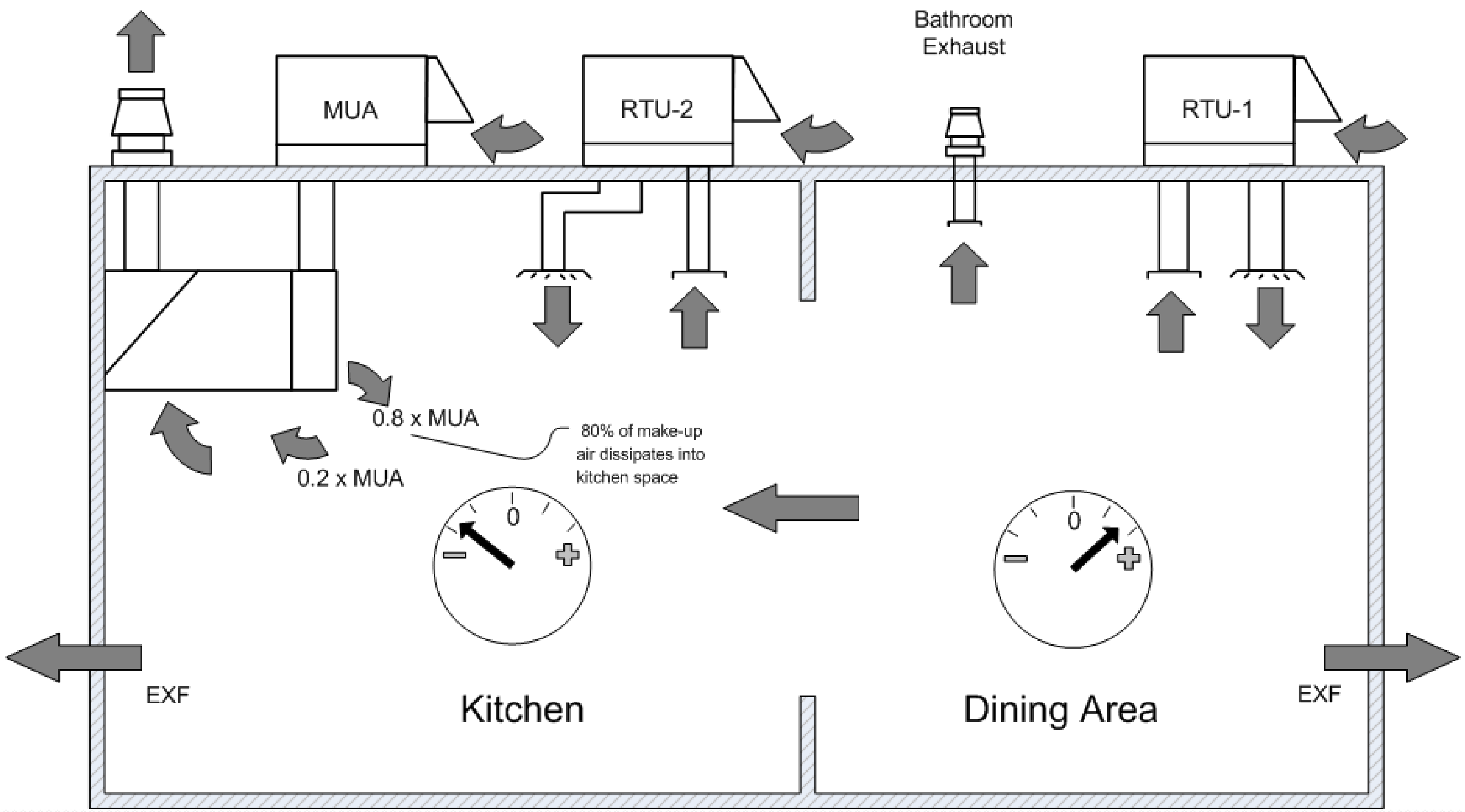
  Make-up Air + Transfer Air = Replacement Air

Ventilation Design

- Common mistakes:
  - front of the house (dining room) and back of the house (kitchen) are treated as two separate spaces with individual, often independent, ventilation systems.
  - often engineer attempts to minimize amount of outside air in the dining room while using massive amounts of it in the kitchen.

Common Design

- Using standard roof-top packaged equipment designed for offices and not prepared to deal with high enthalpy of return air and high outside airflows.

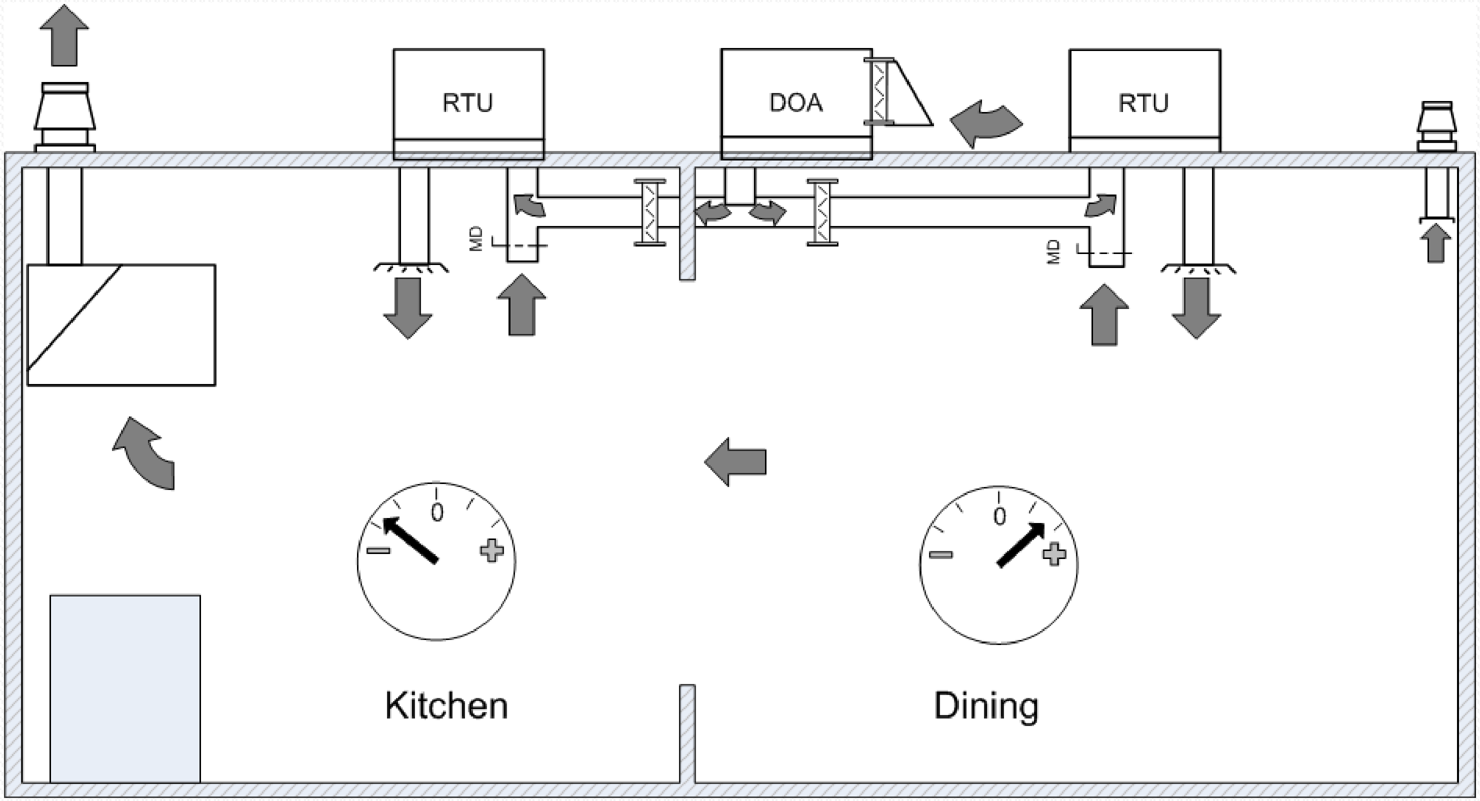


Ventilation Design

- Good practice:
  - Utilize whole building approach
  - Minimize use of outside air for the whole building
  - Utilize transfer air to compensate for hoods exhaust when available

Whole Building Approach

- Total requirement for outside air is calculated based on the dining room and kitchen demand.
- A dedicated outside air handling unit pre-treats all outside air for the building. OA moisture is no longer a problem.
- Control system optimizes whole building air conditioning system for minimum energy consumption



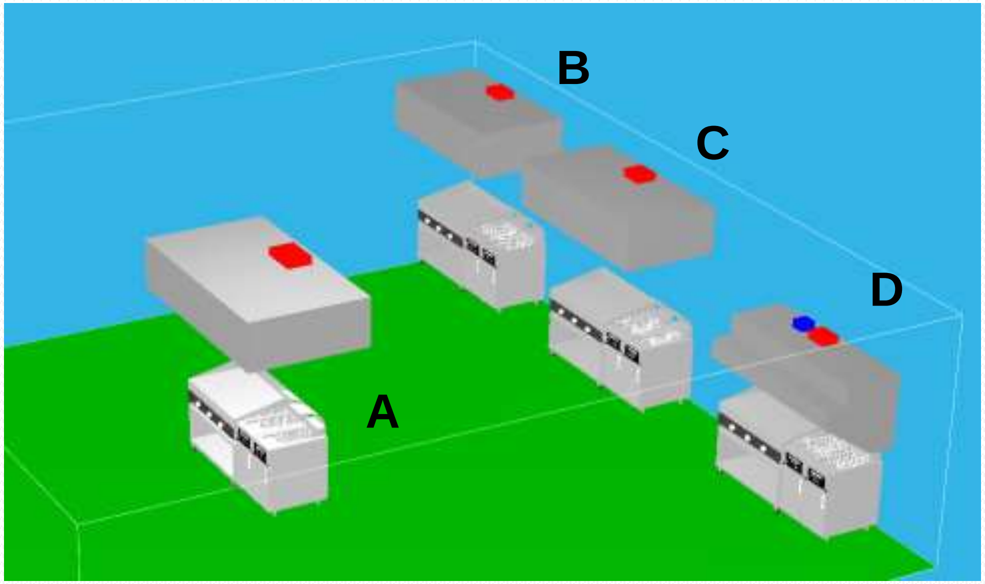
Minimize exhaust airflow

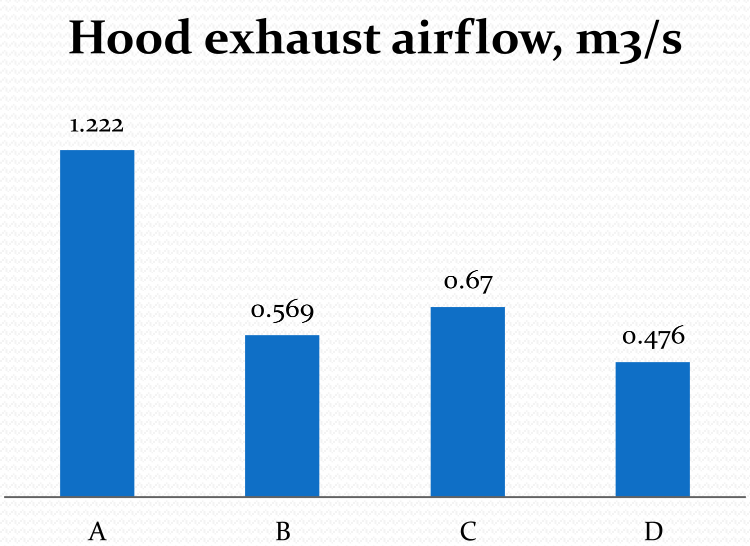
- Hood exhaust airflow defines HVAC energy consumption
- Reduction of hood exhaust airflow provides:
  - Saving of fan motor energy consumption
  - Reduction of HVAC system energy consumption to condition (heat and cool) replacement air

How to reduce hood exhaust airflow

- Position cooking appliances close to the walls, avoid island installations when possible
  - Enclose appliances with the walls
- Use high efficiency, close proximity hoods
- Use Demand-Controlled Ventilation (DCV)
- Use Efficient Air Distribution Systems
  - Thermal Displacement Ventilation TDV allows reducing hood exhaust airflow and improve thermal comfort

Appliance position in a kitchen and type of hood being used has a major effect on exhaust airflow





A – appliances in the middle of the space with canopy island hood; B – appliances in the corner with canopy wall hood; C – appliances at the wall with canopy wall hood; D – appliances at the wall with close proximity back-shelf hood.

Use high efficiency hoods

DCKV

Demand-Controlled Kitchen Ventilation

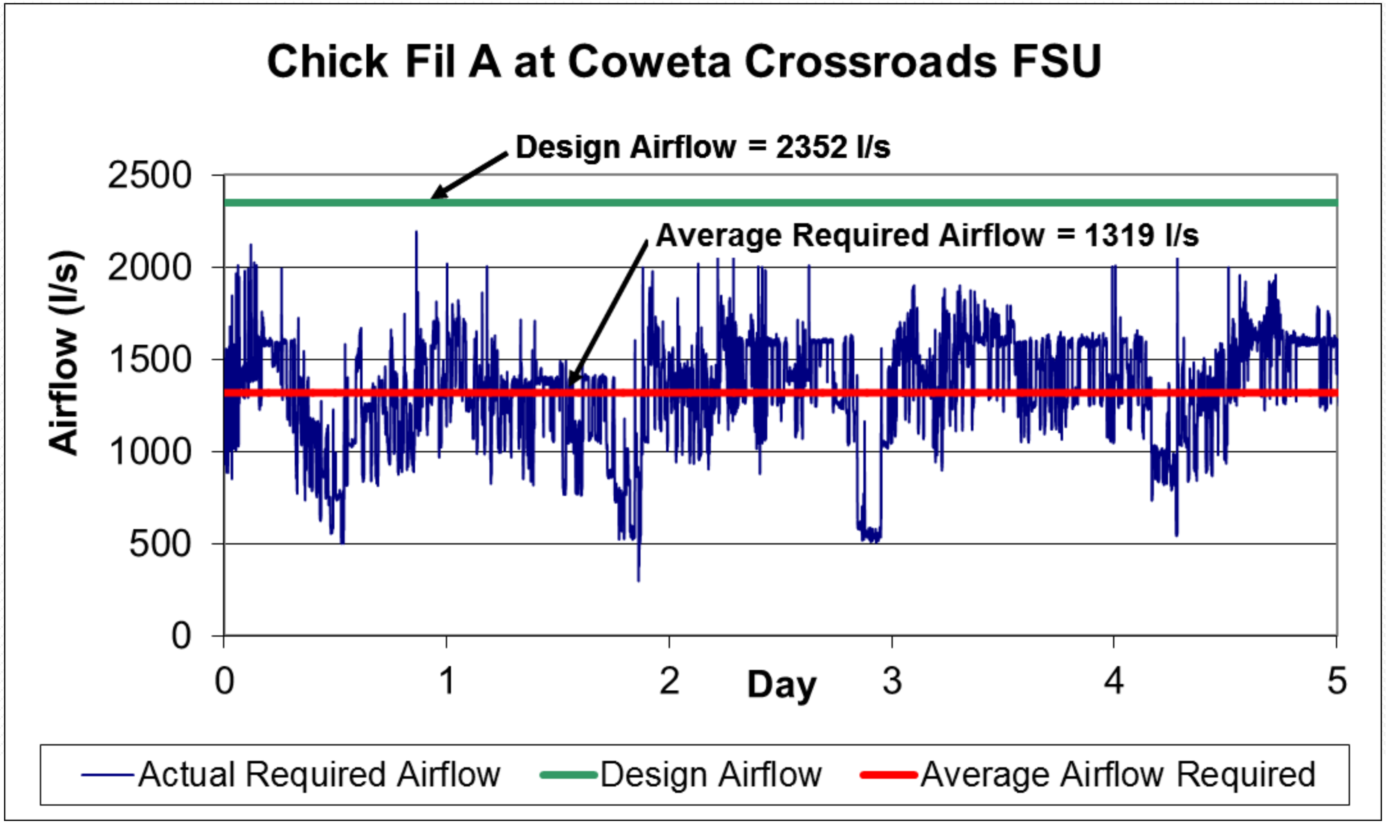
DCV
Demand-Controlled Ventilation

- DCV is a control system that regulates hood exhaust airflow and make-up air based on demand from cooking process.

Appliance status	Hood status
Cooking →	Operates at design airflow
Idle →	Modulates below design airflow
Off →	Off

Quick Serve / Chain Restaurants

43% Airflow Reduction



Overview of the DCKV study

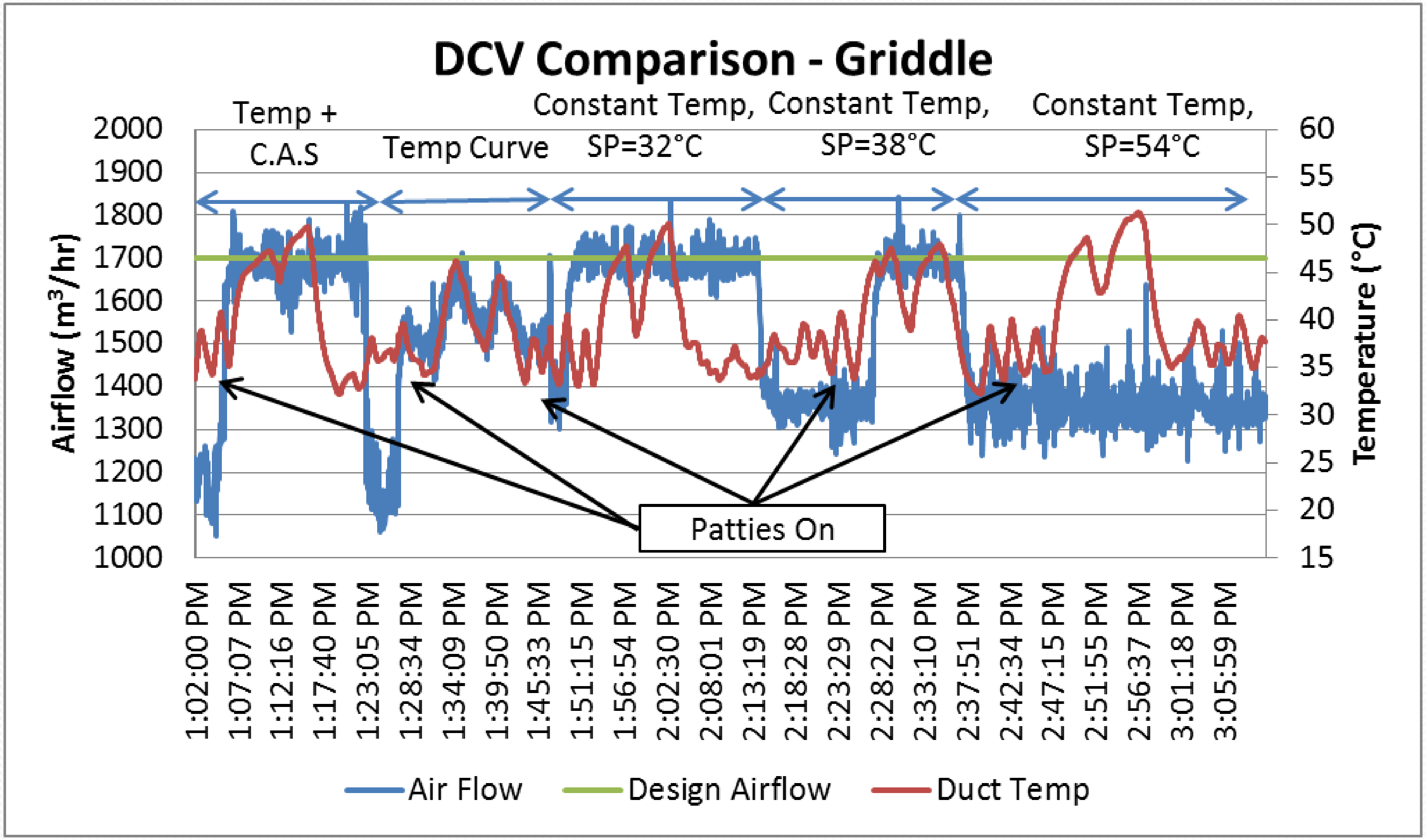
From "Demand Controlled Ventilation for Commercial Kitchens" ASHRAE Journal, November 2012

- One of the key challenges of implementing DCV systems in the field is to ensure that the hoods are operating at capture and containment (C&C) airflows when the appliances are in a cooking mode. Data is presented on how different appliances can require additional detection methods to ensure that the hood is running at a proper airflow.
- Secondly, a case study is presented on the design challenge of how to incorporate a DCV system in a restaurant which has a combination of hoods with dedicated exhaust fans and hoods that share exhaust fans; and how to optimize the energy consumption of these systems.

Two types of DCKV

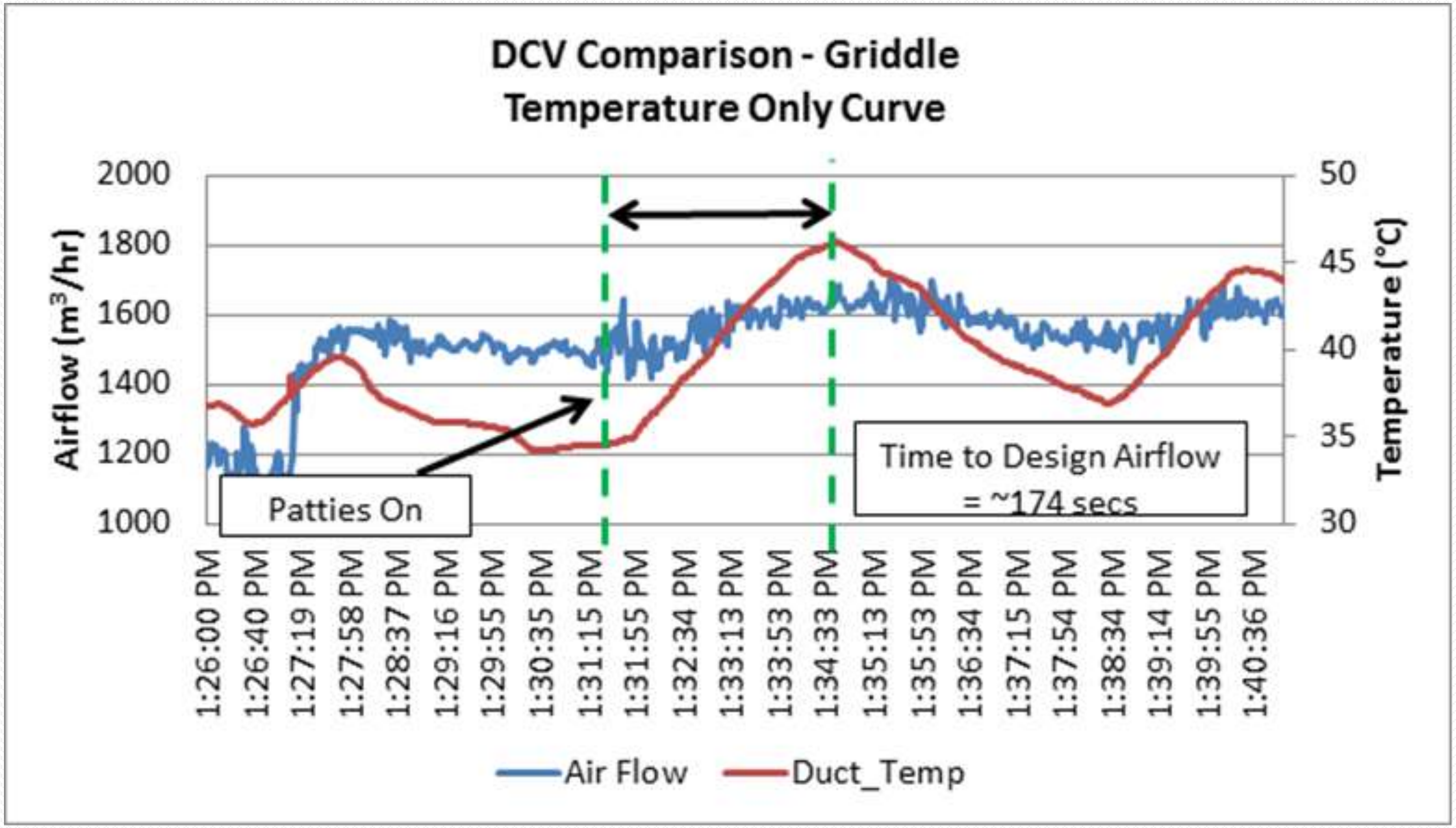
- “Temperature only”, without cooking activity sensor
  - Have lower energy saving potential due to limited ability to identify when cooking starts and ramp hood exhaust airflow to design airflow level
- With cooking activity sensors
  - These are more sophisticated systems that utilize additional sensors to identify appliance status

Griddle Testing

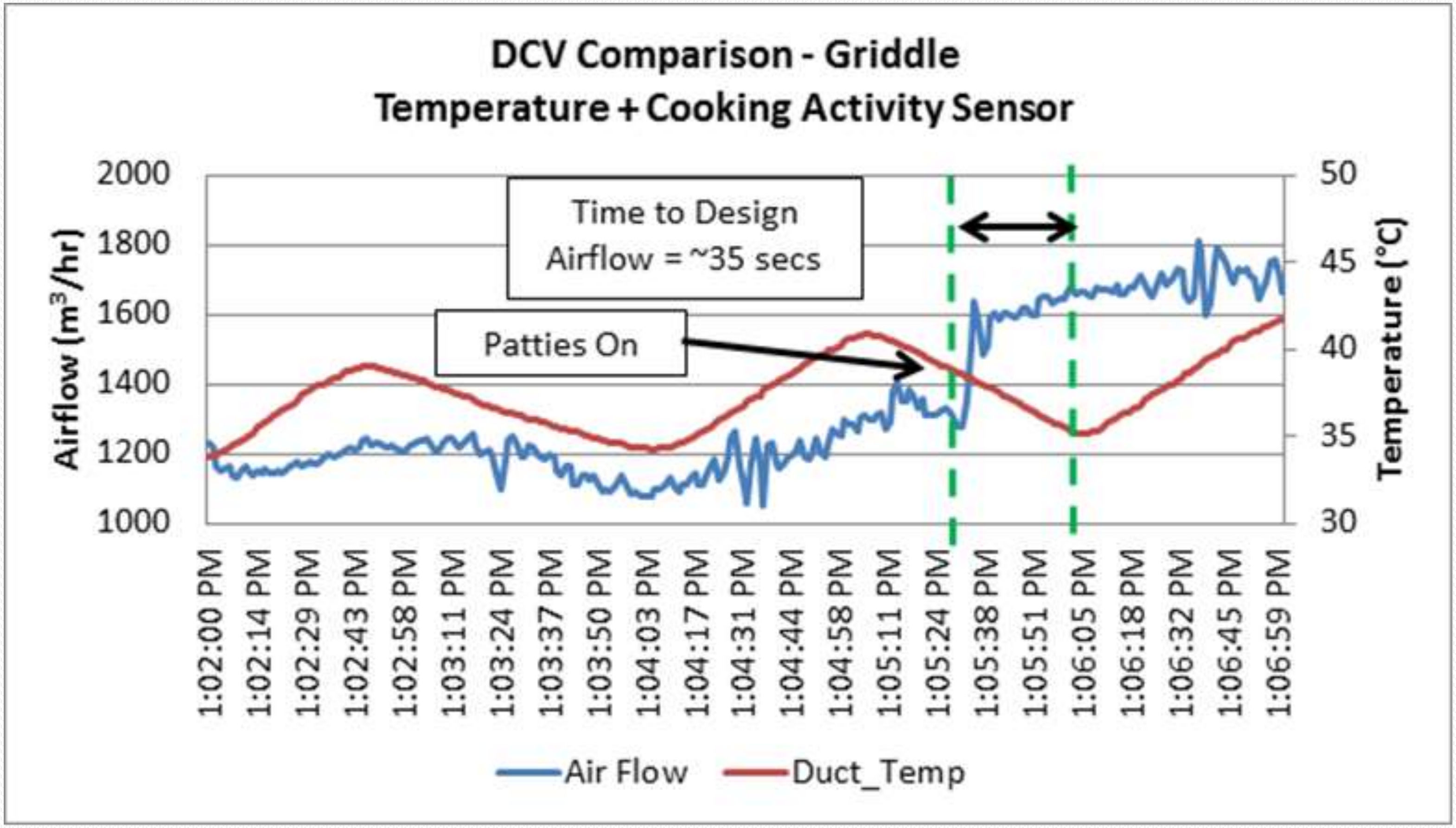


From "Demand Controlled Ventilation for Commercial Kitchens" ASHRAE Journal, November 2012

DCV Response Time temperature-only system



DCV Response Time system with cooking activity sensor



DCV Testing

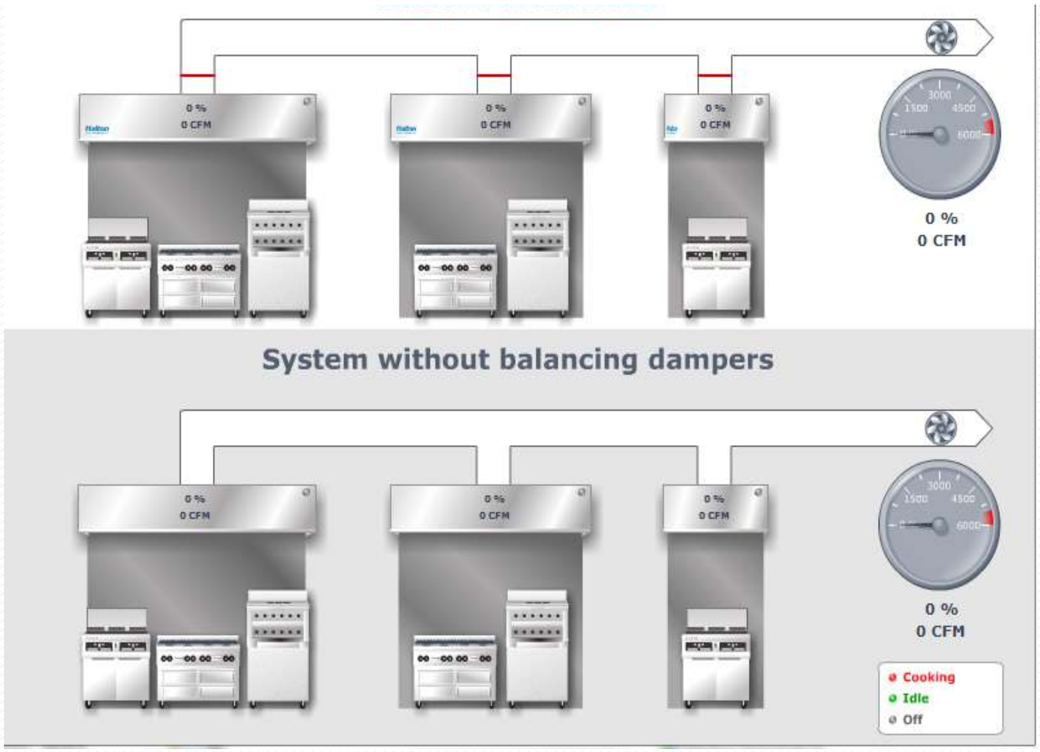
Comparison of time to reach design airflow.

Appliance	Time from start of cooking (seconds) when design airflow reached	
	System with Cooking Activity Sensor	Temperature Only System
Open Vat Fryer	23	NA
Griddle	35	174
Rethermalizer	26	NA
Pressure fryer	28	NA
Char-Broiler	23	NA

From “Demand Controlled Ventilation for Commercial Kitchens” ASHRAE Journal, November 2012

DKCV and balancing dampers

- Systems that couple multiple hoods to a single exhaust fan need a means of independently regulating exhaust airflow for each hood to maximize energy savings

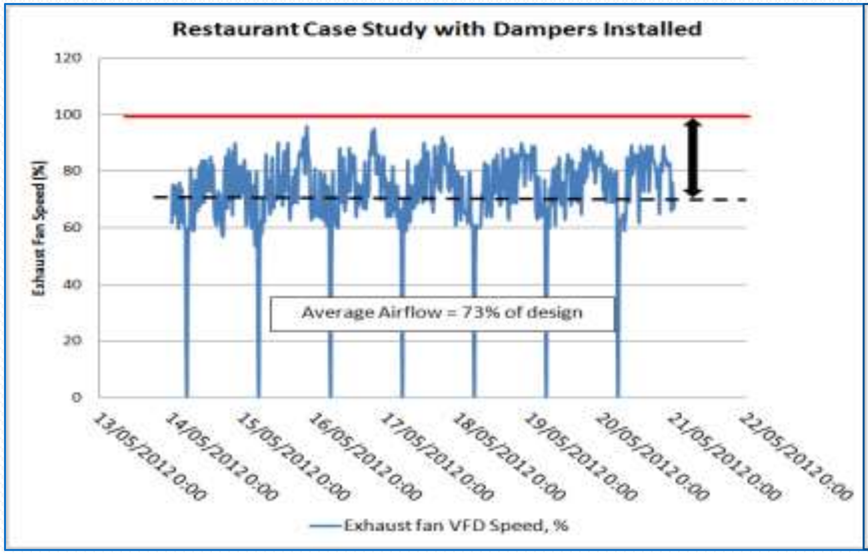


DCV Case Study

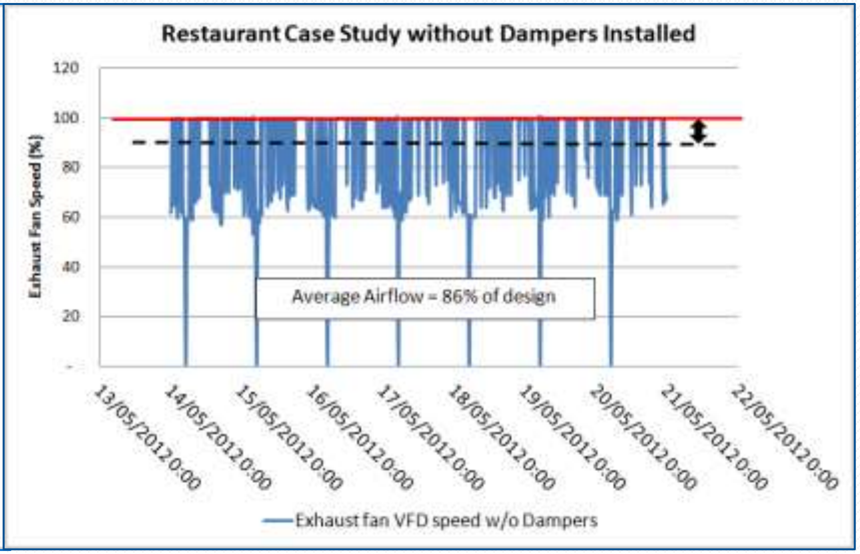
- Evaluated Site Configuration
  - Four canopy hoods attached to single exhaust fan
  - Demand control ventilation installed
  - Design Exhaust Airflow = 11,290 CFM (5.327 m^3/s)
  - Balancing dampers installed on each hood to independently regulate exhaust proportional to demand

DKCV case study

With dampers



Without dampers



Almost 2x airflow reduction for system with balancing dampers

From "Demand Controlled Ventilation for Commercial Kitchens" ASHRAE Journal, November 2012

DKCV Case Study

- Energy Impact

System	Savings			
	Heating [kWh]	Cooling [kWh]	Exhaust Fan [kWh]	Supply Fan [kWh]
DCV w/ dampers	38300	7425	38075	12692
DCV w/o dampers	12778	2475	15705	5235
Increased savings with dampers	25526	4950	22370	7457
	+200%	+200%	+142%	+142%
Location: Seattle, WA Operating Hours: 24/7 Heating EFF: 90% COP: 2.93				

From "Demand Controlled Ventilation for Commercial Kitchens" ASHRAE Journal, November 2012

Air Distribution

Mixing Ventilation

Thermal Displacement Ventilation TDV

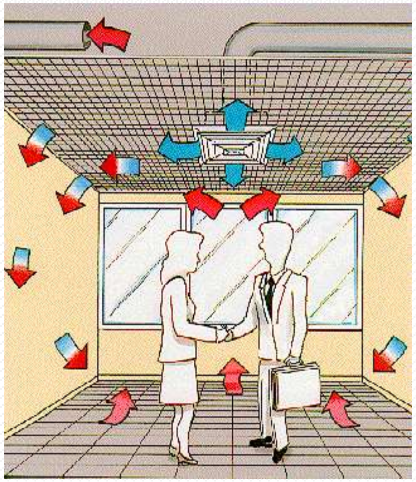
Air Distribution

- Air distribution system has important effect on hoods performance (C&C exhaust airflow)
- The higher velocity in the space, especially near the hood, the higher hood C&C airflow.

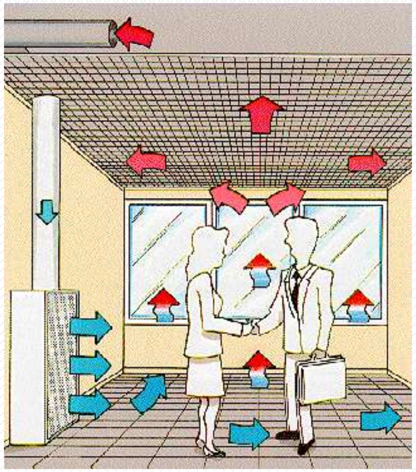
It is easy to extinguish a candle by blowing on it, but try sucking it in

Two types of air distribution systems

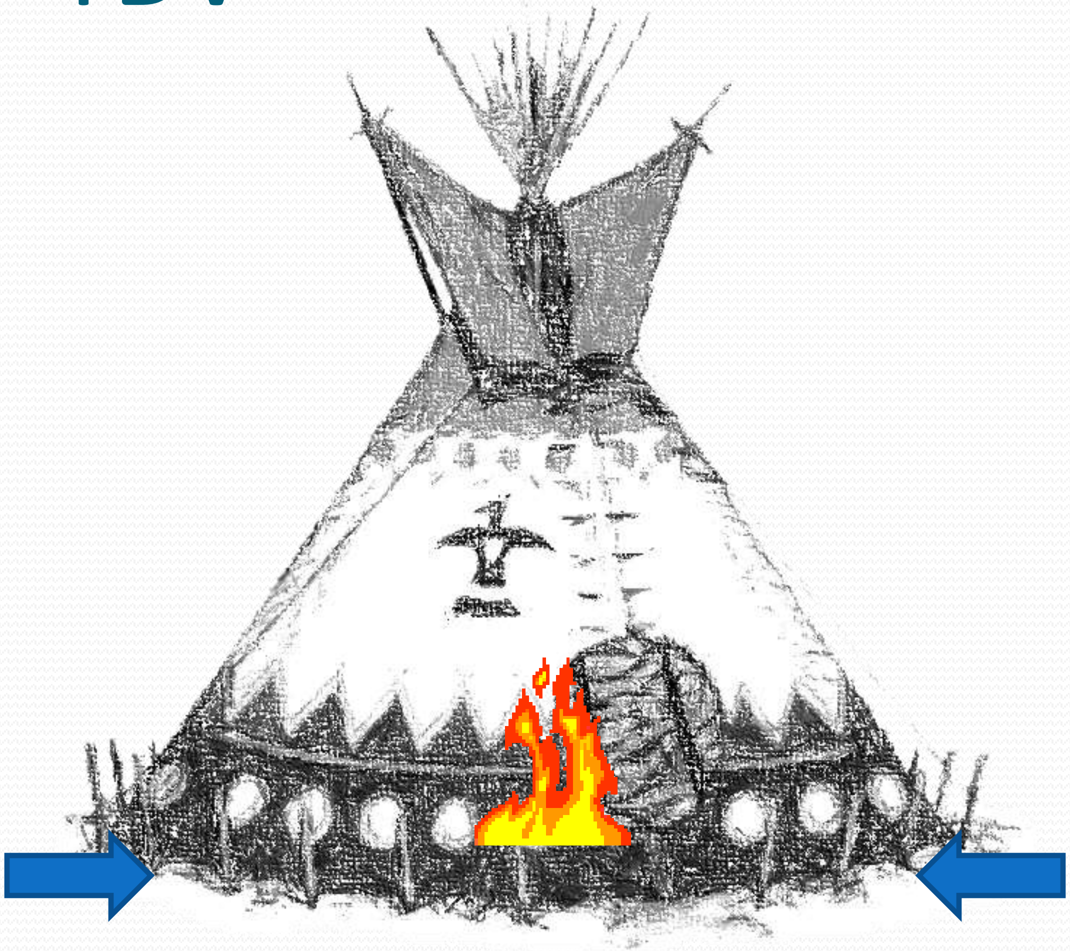
- Mixing Ventilation
  - Traditional mixing systems supply air at high velocity.
  - The goal is to thoroughly mix supply and room air to achieve a uniform space temperature.



- Thermal Displacement Ventilation (TDV)
  - TDV supplies cool fresh air with low velocity in the occupied zone
  - Natural buoyancy forces displace heat and contaminants into the upper, unoccupied part of the room

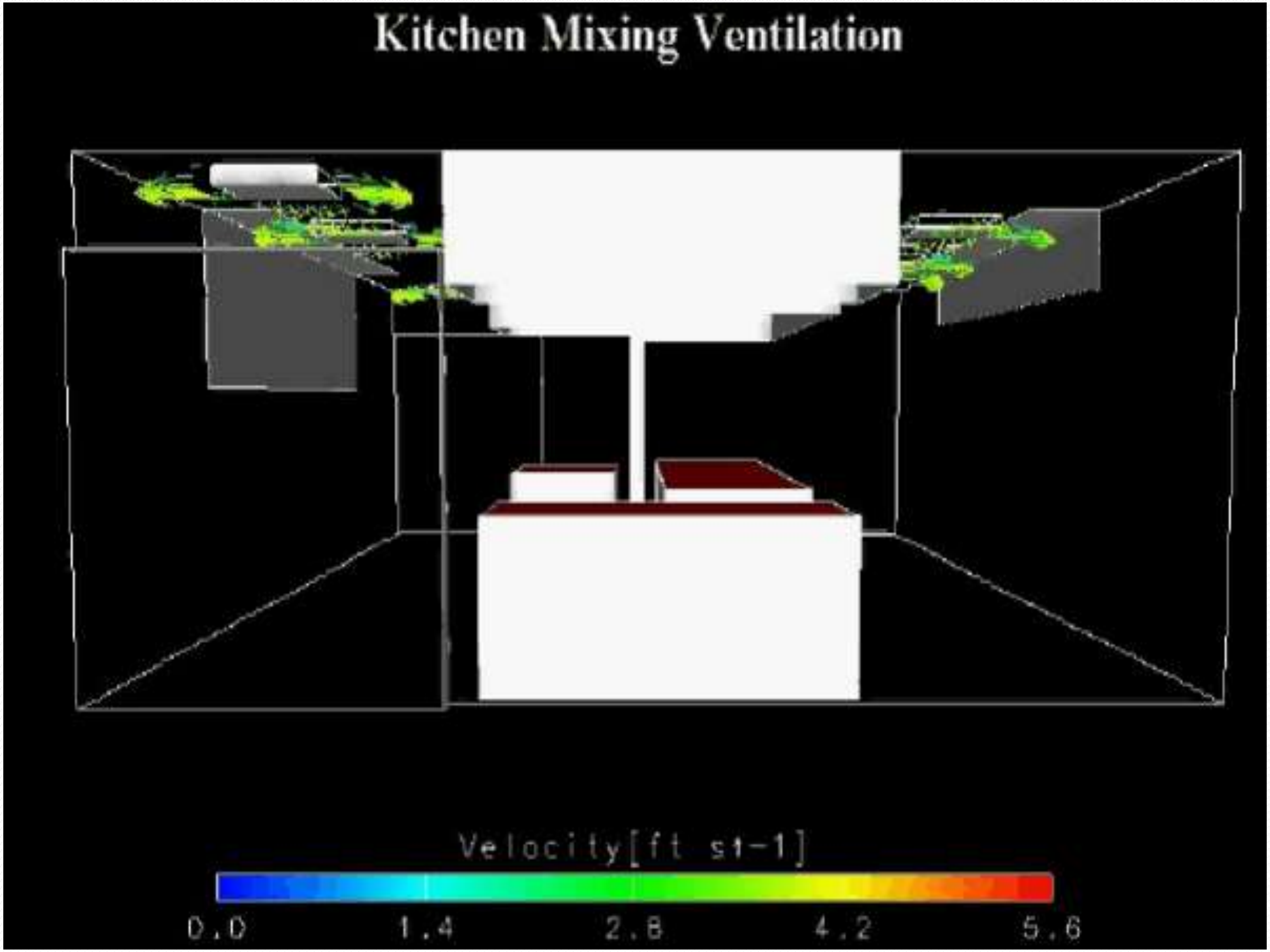


TDV

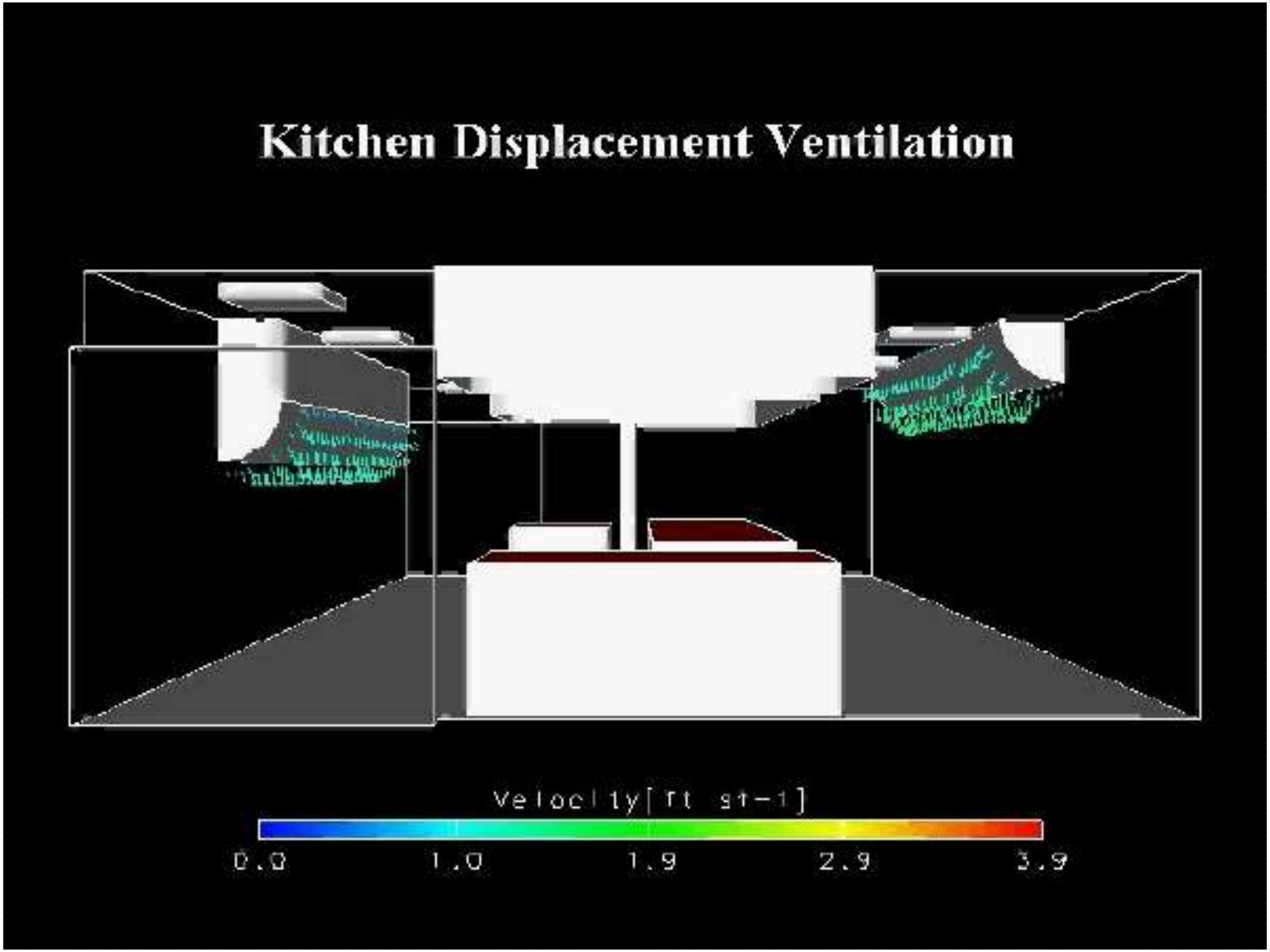


Supply air moves from low velocity diffusers towards the heat source and then rises to the upper part of the space in the heat plume above the heat source.

Mixing ventilation performance in kitchen



TDV performance in kitchen



Benefits of TDV

- TDV is a unique system because it allows improving indoor environmental quality and save energy at the same time
- TDV allows to reduce temperature in occupied zone by 2 - 5°C
- Hoods can operate at 15% lower exhaust airflow due to absence of cross-drafts

ASHRAE standards and CKV

ASHRAE 90.1

- Energy Standard for Buildings Except Low-Rise Residential Buildings
- Purpose: Establish the minimum energy efficiency requirements of buildings, other than low rise residential buildings, for: 1. design, construction, and a plan for operation and maintenance, and 2. utilization of on-site, renewable energy sources.
- Has been the benchmark for commercial building energy codes in the United States and a key basis for standards in more than 15 countries around the world.
- Has become Code Language since 2001
- Used and referenced extensively in Model Codes (IECC, IMC,…)
- Used for incentive and rebate programs
- Current Publication 2013 (3-year update cycle)
- Prerequisite for LEED certification

ASHRAE 90.1 in CKV

- 2010 Changes for Commercial Kitchen Ventilation
- Promotes efficient kitchen hoods and energy efficiency without penalizing indoor environment
  - Re-written with collaboration of TC 5.10 and restaurant industry experts
- Requires at least one energy conservation measure for kitchens that exhaust more than 5000 CFM (e.g. Heat recovery, demand control ventilation, maximum use of transfer air)
- Reduces exhaust requirements from the norm by 30% or more (e.g. norm by ASHRAE 154 Standard)

ASHRAE 90.1-2010

- ***6.5.7.1 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. (Short Circuit/Cycle Hoods)*
  - *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.*

Short-Circuit Hoods

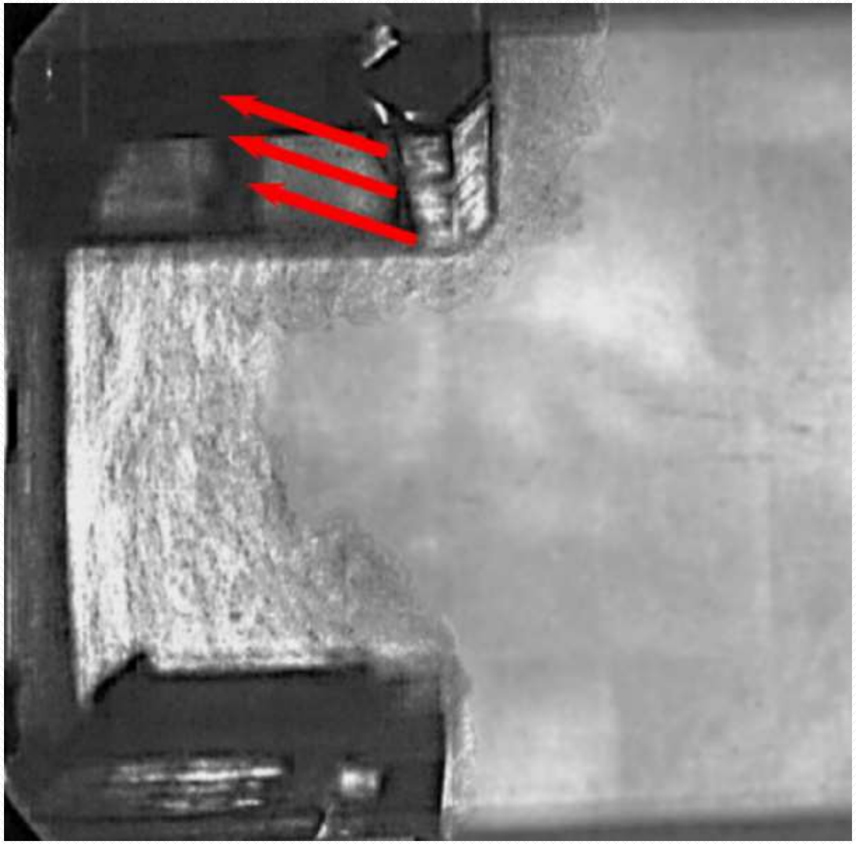


Photo from 2011 ASHRAE Handbook – HVAC Applications

- Still represent about 20% of the market
- Effectively abolished by current energy efficiency standards
- Not to confuse with high efficiency hoods with activated air curtain

ASHRAE 90.1-2010/13

- *6.5.7.1.3 If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 5,000 cfm (2360 l/s) then each hood shall have an exhaust rate that complies with Table 6.5.7.1.3. If a single hood, or hood section, is installed over appliances with different duty ratings, then the maximum allowable flow rate for the hood or hood section shall not exceed the Table 6.5.7.1.3 values for the highest appliance duty rating under the hood or hood section. Refer to ASHRAE Standard 154 for definition of hood type, appliance duty, and net exhaust airflow rate.*
  - *Exception: At least 75% of all the replacement air is transfer air that otherwise would be exhausted.*
  - **Major Change from 2007 Version**

ASHRAE 90.1-2010/13

- TABLE 6.5.7.1.3 Maximum Net Exhaust Flow Rate,

Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra Heavy Duty Equipment
Wall-mounted canopy	140	210	280	385
Single island	280	350	420	490
Double island (per side)	175	210	280	385
Eyebrow	175	175	Not Allowed	Not Allowed
Backshelf/ Pass-over	210	210	280	Not Allowed

ASHRAE 90.1-2010/13

- *6.5.7.1.4 If a kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 5,000 CFM (2360 l/s) then it shall have one of the following:*
  - A. *At least 50% of all replacement air is transfer air that would other wise 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.*

ASHRAE 90.1-2010/13

- *6.5.7.1.5 Performance Testing: An approved field test method shall be used to evaluate design air flow rates and demonstrate proper capture and containment of installed commercial kitchen exhaust systems. Where demand ventilation systems are utilized to meet 6.5.7.1.4, additional performance testing shall be required to demonstrate proper capture and containment at minimum airflow*

CKV standards in Europe

- Process is totally new for Europe : no standards were in place dealing with specificity of kitchen ventilation CEN decided to implement a series of standards (EN16282) dealing with this specificity divided in 9 parts :
  - Parts 1&9 are related to performance evaluation and test
  - Parts 2-8 related to manufacturing and installation of those equipment

CKV standards in Europe

- This series of standards is still in discussion, and should be issued in 2015 (hopefully)
- Part 1 is strongly inspired from German VDI2052-1999 which is commonly used in Europe for airflow rate calculation
- Part 9 is strongly inspired from ASTM 1704 from USA, and ad-hoc tests can be carried out in the laboratory in Bethune
- No design guide on energy efficient commercial kitchen is expected so far in Europe

CKV standards in Europe

- EN16282 will be released with 9 parts :
  - Equipment for commercial kitchens - Components for ventilation of commercial kitchens — **Part 1: General requirements including calculation method**
  - Equipment for commercial kitchens - Components for ventilation of commercial kitchens — **Part 2: Kitchen ventilation hoods; design and safety requirements**
  - Equipment for commercial kitchens — Components for ventilation in commercial kitchens — **Part 3: Kitchen ventilation ceilings; Design and safety requirements**
  - Equipment for commercial kitchens — Components for ventilation in commercial kitchens — **Part 4: Air inlets and outlets; Design and safety requirements**
  - Equipment for commercial kitchens — Components for ventilation in commercial kitchens — **Part 5: Air duct; Design and dimensioning**
  - Equipment for commercial kitchens — Components for ventilation of commercial kitchens — **Part 6: Aerosol separators; Design and safety requirements**
  - Equipment for commercial kitchens — Components for ventilation in commercial kitchens **— Part 7: Installation and use of fixed fire suppression systems**
  - Equipment for commercial kitchens — Components for ventilation — **Part 8: Installations for treatment of cooking fumes; Requirements and testing**
  - Equipment for commercial kitchens — Components for ventilation in commercial kitchens — **Part 9: Capture and containment performance of extraction systems - Test methods**

- Start optimization from cooking process and equipment
- Design ventilation system that is tailored for this particular cooking process, **minimize hood exhaust airflow**
- Use Demand Controlled Kitchen Ventilation to further reduce hoods exhaust airflow
- Implementation of Thermal Displacement Ventilation allows is beneficial in kitchen environment. It allows improving indoor environmental quality and save energy at the same time.

Menu for energy efficient design

Literature

- J. Zhang, D. Schrock, A. Livchak, B. Liu "Energy Savings For Quick Service Restaurants", ASHRAE Journal, Mar. 2011
- D. Schrock, J. Sandusky, A. Livchak "Demand-Controlled Ventilation for Commercial Kitchens", ASHRAE Journal, Nov. 2012
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- http://www.energycodes.gov/sites/default/files/documents/cn_kitchen_exhaust.pdf

Q & A