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Commercial Kitchen Ventilation-Part 2

Optimization through cross disciplinary analysis

Most HVAC design engineering professionals plan to leave the kitchen space at pressure equilibrium with adjoining spaces, though some advocate up to a .02"W.C. negative (pressure) to better assure that cooking odors do not travel throughout the building. Migration of cooking odors outside of the kitchen or cafeteria is a sure indicator that the ventilation provided does not match the actual need.

Building codes establish exhaust and make up air (MUA) volumes by determining the perimeter area of the hood. They use the two dimensional plane defined by the total number of inches in depth times the total number of inches in length to arrive at total square inches of coverage. This number is divided by 144 to arrive at total square feet of coverage. Four different formulas are then applied depending upon the classification of equipment; low temp, medium temp, high temp and solid fuel. Units that use solid fuel for primary heat require their own dedicated type I hood and duct system. UL 710 is the exception to the perimeter methodology. Literally, immediately below the written requirement in the model code (UMC, SMC, IMC, etc.) is the statement: *"exception: listed grease extractors (hoods) shall follow the terms of their listings and manufacturer's installation instructions."* These "listings" indicate that the manufacturers product has passed the rigors of the UL 710 test methodology. UL 710 is a worst case ASTM testing methodology that is extremely comprehensive and tests everything from materials and fabrication techniques to flame out tests of components and sub assemblies. The test are based upon performance under worst case loading. Listed manufacturers engineer their hoods air movement requirements around the equipment placed beneath the hood. A broiler needs more exhaust than an oven, etc. Building officials must accept the UL 710 exception or cite a special hazard (as opposed to ordinary hazard) which would force a greater amount of ventilation. Exhaust and make up air (MUA) volumes, velocities and delivery methods are horribly intertwined and subject to enormous variability due to everything from menu and time of day to general HVAC operational effectiveness. The electric motors used to power exhaust and make up air fans for exhaust hoods and their MUA systems have historically been fixed speed utility sets or upblast fans. In order to change the volume of air being moved a pulley in the drive shaft must be "shived" or replaced. Variable speed units just recently became popular as part of a freeze strategy. Since backdraft dampers are illegal in ducts serving Type I hoods, variable frequency drive units have been used to ramp up the exhaust fan to a minimum hertz setting when temps in the duct drop below 40 degrees or so, indicative of a very cold outdoor air mass. The overwhelming majority of fans used for kitchen ventilation are either full *on*, or simply, *off*. It is cheaper that way and since codes do not allow for variable duct velocities outside of the 1500-2500FPM requirements, the need was not understood. Variable air volume controllers (VAV's) are motorized dampers that respond to automatic control signals. Parameters for programming the control of VAV's and fan operation are usually based upon anticipated needs. The vagaries of the commercial kitchen make this approach problematic. There are far too many variables, many of which change from one minute to the next. Conventional methods replace air to the room at the same rate at which it is exhausted. Ventilation capacities and volumes are expressed in terms of "CFM". One CFM is one cubic foot of air per minute. Code requires a parity between exhaust and MUA volumes, the prevailing wisdom being that one CFM exhaust equals one CFM of MUA. It is important to understand that the volume of one cubic foot of air does not portend to identify weight, density, or temperature of that air.

The following is an excerpt from a paper done by Don Fisher of Fisher Consulting titled "**OPTIMIZING THE DESIGN AND OPERATION OF COMMERCIAL KITCHEN VENTILATION SYSTEMS"**

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'A study conducted by the National Conference of States on Building Codes and Standards under contract with the Electric Power Research Institute documented the lack of uniformity in the way kitchen exhaust system design criteria and codes are applied across the country. This study, titled an Assessment of Building Codes, Standards and Regulations Impacting Commercial Kitchen Design, revealed:

"***a lack of correlation between effluent characteristics and exhaust requirements***. *Codes generally treat all cooking processes identically, although different processes may produce such varying effluents as heat, grease, vapor, odors, steam, or smoke. In addition, state codes frequently differ in how they regulate cooking processes that produce the same effluents. In general, many code provisions have no clear technical documentation, and available technical studies indicate that code ventilation requirements often substantially exceed actual needs."*

The report summary further states that:

The data indicate that codes and regulations should focus on effluent composition and source in determining appropriate ventilation requirements. Classifying effluents and determining the degree of hazard each presents would allow more efficient matching of effluents with exhaust needs. This could yield potential energy and peak demand savings.

ASHRAE commissioned research at the University of Minnesota has shown that most of the effluent from cooking consists of very tiny, hot and highly energized particles which for the most part, blow right past centrifugal filters. Aerosols and vapors condense or precipitate because of temperature change, not centrifugal force. The Mechanical Engineering department under the guidance of Thomas Kuehn, Ph.D. was also awarded the second in the series of studies which deals with duct velocities and the issues of condensation, precipitation of grease and *volatile organic compounds* (VOC's). The facts uncovered in this research will lay the foundation for the emergence of new kinds of optimized ventilation systems.

LAWS

There are two very different and distinct laws here. The first is the law of the land (building codes), which are legislatively and statutorily passed into law. The eternal laws are based upon facts and never change. They are the laws of nature, i.e., physics, chemistry, biology and microbiology. Air that is heated expands and rises above cooler air. This process is quantified by a law of physics known as the ***ideal gas law***. 10,000CFM of exhaust air balances with 10,000CFM of make-up-air (MUA) only when the temperature of the exhaust air is identical to the temperature of the MUA. Whatever volume of air is exhausted needs to be replaced with the correct volume of MUA in order to hold air pressure constant, given temperature differentials. Exhaust air is always hotter than MUA. Consequently, in order to comply with building codes you must pressurize the space. The codes authors did not think to accommodate the thermal expansion of air. The Ideal Gas Law is one of the four variables that affect optimization of commercial kitchen ventilation.

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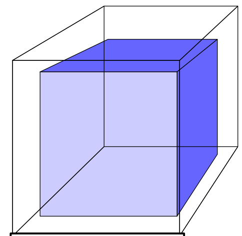
Ventilation variables

1. Ideal Gas Law
This law of physics defines how much a gas (like air) expands as it is heated.

PV=nRT


10%expansion for 50^{0}F rise.

P = Absolute pressure
V = Volume
n= number of moles of gas (eg.,air)
R = universal gas constant (a.k.a. Boltmanns law)
T = absolute temperature(Kelvin)

The generic form is: (Volume)x(pressure)/(moles)x(Temperature)

A cubic foot of 68^{0}F air expands 10% when heated to 120^{0}F. Thus, 10,000CFM of 120^{0}F air is equal to 9090CFM of 68^{0}F air, holding pressure constant. Conversely, 10,000CFM of 68^{0}F air becomes 11,000CFM of 120^{0}F air, holding pressure constant. A cubic foot of 68 degree air will expand 34.5% when heated to 250 degrees. The greater the differential between temperatures the greater the difference in volume at constant pressure.

2. Latent heat of steam
All food products have some water in them, much of which is turned to steam as the food cooks. This phase change and corresponding pressurization above the cooking surface needs to be accommodated if we hope to hold pressure constant in a room. Holding pressure constant, water expands 1500 times to become steam, thus a cubic foot of water becomes 1500 cubic feet of steam as water makes the phase change to steam. Boiling water at sea level is 212^{0}F. Steam at atmospheric pressure at sea level is also 212^{0}F , but contains 5.5 times more heat energy than the 212 degree water.

3. Combustion expansion
Food and all other organic materials are fuels, i.e., they burn. Grease from animal fats and from vegetable extracts is a low flash point accelerant. Apply enough heat energy (650-681^{0}F) and oxygen and they will spontaneously combust with a massive expansion in volume. Like other fuels, they generate CO and CO_2 during their combustion, both of which need to be exhausted from occupied spaces. Combustion of natural gas in the burner boxes of cooking equipment also causes pressurization which needs to be equalized through exhaust and MUA balance.

4. Turbulence
Turbulence is bad news in the kitchen. It is one of the operators greatest dangers to serving safe food. Turbulent air causes hot food to cool and cold food to warm while it mixes air borne contaminants and spores with exposed food items. NSF Std 7 is the performance standard for refrigerated prep tables. The FDA Food Code has specific time and temperature parameters for "hazardous" food items, and turbulence complicates everything.. Most turbulence in the kitchen is related to the method of delivering MUA and the shear volume of air being moved, especially when meeting perimeter type code requirements. Four way ceiling diffusers ought to be banned from use in commercial kitchens due their tendency to impinge air on foods that need to be kept at safe temperatures. Most kitchens are very turbulent and often hot. Food surfaces in contact

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with these conditions warm to a temperature midway between the coldest temperature at the bottom of the pan, and the temperature of the air blowing across it, reducing the safe holding time.

Summary

Optimization of commercial kitchen ventilation requires integration of design, plan review and inspection. Everyone involved with the design and specification of the food service space needs to collaborate. Furthermore, the variable physical and thermodynamic processes involved within the kitchen must be accommodated through engineering, monitoring and control. The topic of public safety is bigger than just ventilation or just health code or just fire code. There are costs and risks associate with each decision and each decision in one discipline may well impact safety or affordability in another. Next month we will complete the three part series on commercial kitchen ventilation. In the last of the series we will take a look at UL 710 and discuss the importance or fundamental research and the continuing education of both design professionals and regulators and take a look needed changes to our model codes. Please forward any comments or suggestions for future articles to

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