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BUILDING CONSTRUCTION REGULATION IMPACTS ON COMMERCIAL KITCHEN VENTILATION AND EXHAUST SYSTEMS

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ABSTRACT

The energy use of facilities with commercial food service equipment is affected by building construction regulations. One major contributor to energy use and demand is the requirement for an exhaust system and the amount of exhaust required. This, in turn, impacts the HVAC system. This paper reviews building construction regulations, their basic differences, and their impact on exhaust and ventilation. In so doing, it focuses on the opportunity for reducing exhaust requirements, which could have a positive impact on HVAC systems' design and energy use.

A review of existing codes indicates an unusual lack of uniformity in the way commercial cooking equipment exhaust criteria are presented in codes and applied throughout the U.S. Many provisions do not recognize the quantity or quality of cooking process effluent. In so doing, they frequently disregard important differences in cooking process, level, or degree of hazard. Recognition of these differences can provide the basis for research, regulatory revision, and systems changes that can effect a reduction in energy use.

INTRODUCTION

Energy use of food service facilities is affected by the need to exhaust cooking-related heat and vapors to the building exterior. The amount of exhaust required will affect the energy use of the facility's heating, ventilating, and air-conditioning (HVAC) system because makeup air for the exhaust is derived from other conditioned spaces. In addition, the required HVAC system and equipment capacity can be increased due to the exhaust "load." If the amount of exhaust required for commercial food service operations is more than necessary and the system is oversized, then energy use and peak demand cannot be reduced.

Commercial kitchen design and equipment application need to address the following:

1. how ventilation air is supplied to the kitchen and how much is required;
2. the fuel source for cooking and its relationship to the ventilation and exhaust needed;
3. combustion product discharge through the exhaust system;
4. kitchen makeup air introduction and its use as exhaust;
5. convective air currents, their production by cooking equipment, and their effect on ventilation and exhaust effectiveness;
6. the need for ventilation and exhaust in relation to the type of cooking process being performed;
7. kitchen volume, equipment layout, and building design and their role in ventilation and exhaust system design and effectiveness;
8. filters used with cooking equipment and their resistance to airflow;
9. the manner in which heat, grease, or vapor production associated with cooking processes are classified;
10. ventilation and exhaust being matched to the type of cooking equipment, food being prepared, and specific hood design;
11. the need for new methods and guidelines for the calculation of ventilation and exhaust requirements based on equipment and the cooking process; and
12. the need for improved ventilation and exhaust system designs.

Building construction regulations establish criteria to address these points and, to a certain degree, establish minimum design strategies. Unfortunately, they are not always based on the latest research and technology, nor are they uniform across the U.S.

The following critical issues are found in and are addressed by building construction regulations:

- Requirements for exhaust hood installation and specific provisions for hood material, dimension, capacity, location, and clearance.
- Requirements for makeup and exhaust air associated with cooking processes.
- Amount and source of replacement air.
- Exhaust system construction and location.
- Distance between cooking surface, grease filter, and exhaust hood.

Building construction regulations dictate the following, which affect HVAC systems and energy use:

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- When, and if, hoods and exhaust system are required.
- Amount of, source, and systems for makeup and exhaust air.
- Construction aspects associated with a hood or series of hoods, which dictate the size of the hood and required exhaust.
- Construction aspects associated with an exhaust system or series of systems.
- When grease removal and filtration associated with cooking are needed.

COMPILATION AND ANALYSIS OF BUILDING REGULATORY PROVISIONS

Based on the issues identified as affecting HVAC systems and energy use, building codes, standards, and regulations were reviewed for applicable criteria. The documents reviewed represent a cross section of the criteria used throughout the U.S. and include the following:

1. Uniform codes of the International Conference of Building Officials (ICBO), which are used as a basis for most codes west of the Mississippi River as well as the state of Indiana.
2. National codes of the Building Officials and Code Administrators International, Inc. (BOCA), which are used as a basis for most codes east of the Mississippi River, north of North Carolina and Tennessee, and in parts of Oklahoma and Texas.
3. Standard codes of the Southern Building Code Congress International, Inc. (SBCCI), which are used as a basis for most codes east of the Mississippi River, south of Kentucky and Virginia, and in parts of Texas.
4. State-developed codes of Wisconsin, New York, and Michigan.
5. Major city codes of New York, Chicago, Phoenix, and Los Angeles.
6. National Fire Protection Association standards, which are referenced in the above documents as well as being adopted directly by many state and local regulatory agencies.
7. Applicable national product standards that are referenced in the above documents.

In assessing these provisions and relating them to commercial cooking ventilation, the definition of the cooking process and equipment as "commercial cooking" will determine the need for an exhaust hood and duct system. If none is required, then any byproducts of the cooking process will become an internal load of the building and no makeup air will be needed. If a hood is required, then the code will dictate the minimum exhaust, which will also affect the amount of makeup air required.

THE NEED FOR EXHAUST

- Under what conditions are commercial cooking exhaust systems and hoods required by codes?
- Is there a logical matching of effluent quantity and/or quality to the required exhaust?
- Can the exhaust be segregated to match different loads, or must the exhaust be based on the worst case in the cooking facility?

A review of these questions in relation to codes finds:

1. Building regulatory criteria consistently require hoods and exhaust systems if smoke- and grease-laden vapors are produced by the cooking equipment. In all but one case, there is no provision for considering the relative hazard based on quantity of effluent.
2. In the most conservative building regulatory provisions, all equipment associated with a commercial cooking operation must be served by a hood and exhaust system.
3. Cooking equipment, food preparation, and other aspects of commercial cooking operations that do not produce smoke- and grease-laden vapors are not consistently, uniformly, or appropriately addressed. This is primarily attributable to the failure to consider relative hazard in terms of quantity, quality, and diversity of cooking effluent production.
4. In all but two instances, the applicability of hood/exhaust requirements is uniform across all fuel types.
5. Fixed equipment is fully addressed, while portable equipment is less likely to be regulated, although the latter can produce more effluent needing exhaust than the former.

HOW MUCH EXHAUST AND MAKEUP AIR?

- Under what conditions do the requirements for commercial cooking exhaust systems and makeup air rates vary, if at all?
- Is there any logical relation between a required rate of exhaust and effluent production? If so, is it based on the worst case, or can the system be segmented to match differing cooking equipment or loads?

A review of these questions in relation to codes finds:

1. Building regulatory criteria that require minimum exhaust system flow rates do not accurately or appropriately address the variables that contribute to cooking effluent quantity or quality.
2. Minimum exhaust system flow rates directed at a worst-case assumption appear to sacrifice accuracy for the sake of regulatory simplicity.
3. Some codes allow different exhaust rates based on cooking source, anticipated load, and fuel source. While not necessarily appropriate in all cases, this

represents a major change in the "one rate-worst case" philosophy applied in other codes.

4. Performance testing and validation of exhaust systems are allowed as an alternative to meeting minimum exhaust system flow rates and, as such, provide a basis upon which to foster improved designs using less exhaust air.
5. Regardless of exhaust system provisions, the building regulatory official can require testing to validate performance and modification of the system if necessary. In other words, if the system does not work pursuant to the code, it must be made to operate properly.
6. After occupancy, the owner/operator assumes responsibility for exhaust system operation and could make changes in the exhaust system contrary to the criteria of the code.
7. The unique nature of commercial cooking exhaust system design strongly suggests elimination of prescriptive requirements and replacement by more systems engineering guidance, with regulatory acceptance based on effective operation.

The building regulatory criteria reviewed vary widely in their treatment of required amounts of exhaust air, methods of compliance, and their technical basis. This means HVAC system design and operation will vary widely, even in the same building type.

One regulatory approach bases the exhaust rate on the classification of cooking source and geometry of the hood and/or cooking surface interface. Others use equipment geometry to define the hood size and exhaust rate but do not differentiate between cooking sources. Still others use floor area of the kitchen as the basis for exhaust with no regard for equipment type, layout, or type or amount of effluent. Although basing their requirements on some parameter associated with the kitchen, all of the approaches can be considered prescriptive in nature. In addition, some of the criteria provide for performance testing to ascertain actual effluent containment and exhaust. While making it easy to calculate exhaust cfm and, hence, HVAC system load and capacity needs, some must be overstated.

To focus on the appropriate way to address exhaust needed and proper exhaust system performance, the parameters governing the amount of exhaust needed and the manner in which it is accomplished must be identified. Where they can be clearly identified, uniformly applied, and address a majority of situations in an appropriate manner, then prescriptive criteria are appropriate. Where the number of variables, their range of value, and their performance vary widely, then performance criteria are more appropriate. Unfortunately, in all too many situations, building regulatory criteria tend to be prescriptive for ease of application and use. To foster simplicity, they must apply to a majority of potential cases and, in simplification, tend to address the anticipated worst case. This translates into a worst case for the HVAC system load and energy use. Although most building regulations have an alternative (performance) approach to allow approval based on equivalency, that equivalency would still be based on the overly simplified and overstated prescriptive criteria and therefore has no positive effect on the HVAC system.

Parameters affecting hood design for smoke and vapor containment and release through an exhaust duct system include the following:

- Cooking equipment geometry, heat production, and fuel source, type, and location in relation to other equipment and spaces as well as rate and degree of use.
- The type of food being prepared, the manner in which it is prepared, and the type and amount of effluent produced in the cooking process.
- Layout of the food preparation area with respect to available floor area, access to the exterior, communication with other building areas, and the type and capacity of the serving HVAC system.

The primary objective for considering all these factors is to determine the exhaust rate needed to provide the appropriate capture and removal of effluent associated with the food preparation activity under consideration.

Consider a griddle 80 inches wide by 30 inches deep (having a 2,400-square-inch cooking surface area) used continuously throughout the day for cooking bacon, hamburgers, etc. The griddle is located along an exterior wall in a kitchen measuring 40 feet by 20 feet having an open pass-through to a restaurant counter/dining area. The minimum canopy hood (three open sides) exhaust rate for building regulatory conformance is shown in Table 1 and is based on the code criteria reviewed. These become exhaust rates that must be addressed by the HVAC system.

As previously mentioned, some of the building regulations also provide alternatives and allowances for engineered systems that could result in lower exhaust rates when capture and removal can be affected.

Interestingly, if a charbroiler of the same size were substituted for the griddle, the minimum exhaust may or may not change depending upon the regulatory criteria as shown in Table 2.

Although the equipment changed relative to heat input as well as production and type of effluent, the required exhaust changed in some cases and in others remained the same. This suggests that (1) most prescriptive criteria, which do not consider cooking equipment and type of effluent, are overstated when applied to other, less rigorous types of cooking effluent and/or (2) the UMC cooking source approach may be introducing an unnecessary safety factor for the more effluent-producing equipment rather than lowering the required rate for other situations that would be satisfied with a lower effluent.

TABLE 1
Comparison of Minimum Exhaust Requirements for 80-in. by 30-in. Griddle Installation with Canopy Hood under Different Codes

Building Regulation	Minimum Exhaust (cfm)	Basis
1988 UMC (2003(g))	1725.0 cfm (gas)	(75 x [cook area + 6 in. on open sides] ft^2)
	1380.0 cfm (electric)*	80% of above
1990 LAMC (2003(g))	2334.0 cfm (gas)	(50 x [open perimeter x 4.0 ft to hood lip] ft^2)
	1867.2 cfm (electric)*	80% of above
1990 NMC (M-503.5.1)	2300.0 cfm	(100 x [cook area + 6 in. on open sides] ft^2)
1988 SMC (308.6.2)	2300.0 cfm	
1990 CBC (81-7)	3200.0 cfm	(4.0 x kitchen floor area) ft^2
1990 NYCBC (C26-1207.2)	2400.0 cfm	(3.0 x kitchen floor area) ft^2
1990 WAC (ILHR 64.67(2)(a))	1600.0 cfm	(2.0 x kitchen floor area) ft^2
(ILHR 64.67(4)(b))	1667.0 cfm	(100 x cook area) ft^2

* ALL EQUIPMENT MUST BE ELECTRIC, OR GAS VALUE APPLIES

TABLE 2
Comparison of Minimum Exhaust Requirements for 80-in. by 30-in. Charbroiler Installation with Canopy Hood under Different Codes

Building Regulation	Minimum Exhaust (cfm)	Basis
1988 UMC (2003(g))	4600.0 cfm (gas)	(200 x [cook area + 6 in. on open sides] ft^2)
	3680.0 cfm (electric)*	80% of above
1990 LAMC (2003(g))	4668.0 cfm (gas)	(100 x [open perimeter x 4.0 ft. to hood lip] ft^2)
	3734.4 cfm (electric)*	80% of above
1990 NMC (M-503.5.1)	2300.0 cfm	(100 x [cook area + 6 in. on open sides] ft^2)
1988 SMC (308.6.2)	2300.0 cfm	
1990 CBC (81-7)	3200.0 cfm	(4.0 x kitchen floor area) ft^2
1990 NYCBC (C26-1207.2)	2400.0 cfm	(3.0 x kitchen floor area) ft^2
1990 WAC		
(ILHR 64.67(2)(a))	1600.0 cfm	(2.0 x kitchen floor area) ft^2
(ILHR 64.67(4)(b))	1667.0 cfm	(100 x cook area) ft^2

* ALL EQUIPMENT MUST BE ELECTRIC, OR GAS VALUE APPLIES

Consider an identical design using a 54-inch by 20-inch griddle in lieu of the 80-inch by 30-inch griddle and the same relationship of required exhaust to effluent production. Typical hamburger (2½ ounces) production for the former is 1,150 per hour, while the latter griddle's production is 3,200 per hour. On this basis, one could assume 3,200/1,150 or 2.78 times the smoke- and grease-laden vapor production capability with the larger griddle in any given hour. Table 3 shows the minimum exhaust for the smaller griddle.

While the larger griddle produces 2.78 times the effluent, the required minimum exhaust rate variance between these conditions changes by a factor that ranges from 1.00 (kitchen area does not change) to 1.93 (effect of griddle surface area). On this basis, one can conclude that the use of cooking area, while more appropriate than kitchen floor area, does not accurately correspond to grease, heat, and cooking vapor production. This is further highlighted when considering how the building regulatory criteria would apply to a single broiler and an upright double broiler. Since exhaust capacity is based on criteria such as hood dimensions and kitchen area, the regulatory criteria would not consider "stacking" of cooking surfaces and, therefore, would not differentiate between single and multilevels of equipment. Obviously, the capacity for food production will differ between an upright double broiler and a "single-story" unit having the same area projected in a horizontal plane. All the regulatory provisions reviewed, however, would only address a one-dimensional situation and do not address the capability for additional effluent production in these other cases.

The only code to establish some provision for effluent production and exhaust by cooking source is the Uniform Mechanical Code (UMC). To determine the rationale behind the criteria, the record of revisions to the UMC was reviewed.

The 1979 Uniform Mechanical Code (UMC) provided for minimum ventilation system exhaust for canopy-type hoods based on the following: for 4 exposed sides, 150 × hood area; for 3 exposed sides, 100 × hood area or 50 × hood perimeter open × distance from lower lip to cook surface.

For noncanopy hoods, the exhaust volume was required to be at least 300 cfm per lineal foot of cooking equipment. These provisions are essentially the same as those contained in the 1990 National Mechanical Code and 1988 Standard Mechanical Code.

No changes to these criteria were made in the 1980 or 1981 supplements to the UMC. The 1982 UMC did contain changes relating to segregation of cooking sources in terms of volumetric discharge for canopy hoods based on heat and smoke released by the equipment served. The revision was prepared under a safe-side philosophy

TABLE 3
Comparison of Minimum Exhaust Requirements for 54-in. by 20-in. Griddle Installation with Canopy Hood under Different Codes

Building Regulation	Minimum Exhaust (cfm)	Basis
1988 UMC (2003(g))	894.0 cfm (gas)	(75 x [cook area + 6 in. on open sides] ft^2)
	715.2 cfm (electric)*	80% of above
1990 LAMC (2003(g))	1566.0 cfm (gas)	(50 x [open perimeter x 4.0 ft. to hood lip] ft^2)
	1252.8 cfm (electric)*	80% of above
1990 NMC (M-503.5.1)	1192.0 cfm	(100 x [cook area + 6 in. on open sides] ft^2)
1988 SMC (308.6.2)	1192.0 cfm	
1990 CBC (81-7)	3200.0 cfm	(4.0 x kitchen floor area) ft^2
1990 NYCBC (C26-1207.2)	2400.0 cfm	(3.0 x kitchen floor area) ft^2
1990 WAC		
(ILHR 64.67(2)(a))	1600.0 cfm	(2.0 x kitchen floor area) ft^2
(ILHR 64.67(4)(b))	750.0 cfm	(100 x cook area) ft^2

* ALL EQUIPMENT MUST BE ELECTRIC, OR GAS VALUE APPLIES

TABLE 4
Comparison of Minimum Exhaust Requirements for Selected Cooking Equipment under Different Code Approaches

Type	Application	1979 UMC *	1985 UMC **
Electric charbroiler 20" x 32"	island	1467-1733 cfm	2347-2773 cfm
Gas charbroiler 20" x 32"	island	1467-1733 cfm	2933-3467 cfm
Electric charbroiler 20" x 32"	3 sides open	978-1200 cfm	1564-1920 cfm
Gas charbroiler 20" x 32"	3 sides open	978-1200 cfm	1956-2400 cfm
Electric fryer 16" x 30"	island	1225-1533 cfm	980-3067 cfm
Gas fryer 16" x 30"	island	1225-1533 cfm	1225-3067 cfm
Electric fryer 16" x 30"	3 sides open	817-1267 cfm	653-2027 cfm
Gas fryer 16" x 30"	3 sides open	817-1267 cfm	817-2533 cfm
Electric range 24" x 72"	island	3150-3200 cfm	1680-2560 cfm
Gas range 24" x 72"	island	3150-3200 cfm	2100-3200 cfm
Electric range 24" x 72"	3 sides open	2000-2100 cfm	1260-1600 cfm
Gas range 24" x 72"	3 sides open	2000-2100 cfm	1575-2000 cfm
Electric pizza oven 38" x 54"	island	3067-3437 cfm	1375-2453 cfm
Gas pizza oven 38" x 54"	island	3067-3437 cfm	1719-3067 cfm
Electric pizza oven 38" x 54"	3 sides open	2167-2292 cfm	917-1386 cfm
Gas pizza oven 38" x 54"	3 sides open	2167-2292 cfm	1146-1733 cfm

* Ranges are low/high corresponding to base and alternate formula in the code.
Hood dimensions based on code criteria for 6 in. overhang and 4 ft from hood lip to cooking surface.

** Not changed in 1988 edition.

because maximum exhaust capacity was supposedly required only when equipment for installation had not been defined or when charcoal- or grease-burning charbroilers were used. It was stated that other equipment would require less exhaust depending upon release of smoke and heat. The record also notes that equivalent performance can still be shown for alternative designs where these criteria are not specifically followed.

Revisions in the 1985 UMC included the addition of Section 2003(k) relating to performance testing of the exhaust system. The objective of this revision was to evaluate which design approaches would validate or indicate the need to revise the required exhaust quantities. (To date, no data have been published as a result of this effort and the underlying rationale.)

Initially one would consider the change to the UMC to recognize that equipment and the required exhaust are not the same in all cases and a reduction for lesser effluent producers was needed. In reality, the new criteria doubled the amount of exhaust previously required for charcoal- and grease-burning charbroilers and high-temperature appliances, such as deep fat fryers. For medium- and low-temperature applications, a reduction of up to one-half was effected depending on the calculational approach used. In addition, a further 20% reduction was included if all electric equipment was installed. Table 4 provides a comparison for various pieces of equipment.

Clearly some exhaust rates increased while others decreased. The amount of change can be tied to the type of equipment, geometry, and equipment dimensions. It is interesting to note, in relation to other building regulations, that some of the equipment classified as low-temperature (pizza oven) in the UMC is not even required to be hood ventilated by other codes. As such, exhaust in those instances is zero. The exhaust load is lost to the HVAC system, but it picks up a new internal load. Although an apparent step forward based on segmenting of equipment, the most recent UMC exhaust criteria appear to be consistently higher than previously stated and, in many cases, are more stringent than other comparative regulatory criteria based on a required exhaust rate. In a worst case, the UMC requires exhaust where other codes have no such requirement. If there are no apparent health and life safety concerns associated with the previous criteria, the necessity to double some exhaust rates and, consequently, HVAC system loads is questionable.

In addition to segmenting the required exhaust by cooking source, the UMC was also modified to consider fuel source. The 1982 analysis of revisions to the UMC does not, however, mention this issue or the rationale behind the change. Since gas equipment may generate more heat and there are products of combustion associated with gas equipment, some additional exhaust may be needed. Where minimum exhaust rates are overstated, the significance of not differentiating by fuel is overshadowed when considering the total flow through the exhaust. As total exhaust is reduced, such as for low- and mediumtemperature equipment in the UMC, the difference in effluent associated with fuel type becomes more significant. Some electric equipment would need very little, if any, exhaust, while comparable gas equipment would need some additional exhaust to serve any additional heat to the kitchen space and dilute and vent products of combustion.

Differences in required exhaust rates have also been addressed in manufacturers' designs. For instance, one manufacturer has published in product literature required airflows of 150 cfm per linear foot for electric fryers and 250 cfm per linear foot for gas fryers. The rationale is the difference in thermal load and thermal currents associated with the different equipment.

Another aspect of the codes that relates to differentiation and reduction in exhaust rate is the ability to obtain code approval based on alternative equivalency. One way to obtain building regulatory approval is to obtain an evaluation report from a model code group. The code group reviews test data, specifications, and other information upon which performance equivalency can be determined. If acceptable, a report is then issued that can be provided by the designer to building regulatory personnel when considering the particular equipment. Through this method, a number of manufacturers have received approval for different exhaust systems.

One other aspect relating to exhaust systems is air velocity for hood design. Although recommended by manufacturers at 100 to 150 fpm, some levels as low as 50 fpm can affect capture of cooking exhaust. Interestingly, the building regulations reviewed did not specifically address minimum air velocity or its measurement or verification. Until 1982 the UMC did contain a provision addressing minimum velocity for noncanopy hoods. This was subsequently deleted from the code because few building departments that enforce codes were equipped to measure air velocity.

The issue of the amount of exhaust air for a given application can also be addressed via performance language such as "designed to confine cooking vapors and residues within the hood" or "exhaust air volumes to be of sufficient level to provide for capture and removal of grease-laden cooking vapors."

Considering that some building regulations require an operational test of the system under load, the purpose of minimum airflows being specified in building regulations is unclear. In an ideal situation, a kitchen designer would use items such as practical experience, test data, specifications, etc., to achieve the goal to capture and remove smoke- and grease-laden vapor. After installation, the exhaust system would be placed under a cooking load and a determination of capture and removal made. If not sufficient, then adjustments and enhancements are made until satisfactory operation is achieved. Once the facility is occupied and operation is initiated, then continued maintenance will ensure continued satisfactory capture and removal. Ironically, while building regulatory criteria establish minimum exhaust rates and provide for capture verification, there is no requirement for continued testing or validation by the regulatory official once occupancy has occurred. One obviously assumes that operation and maintenance by the user will result in continued satisfactory operation.

Due to the number of variables associated with commercial kitchen exhaust system design, the general approach taken in the building regulations appears to be overly simplistic as well as inconsistent. It is simplistic because minimum exhaust rates are specified without regard for variables that affect production, capture, and removal of effluent. It is inconsistent because after providing the minimums, a verification test may be required and, if not satisfactory, the system must be changed until acceptable capture and removal is effected, even though it complied with the minimum code criteria. This, in a way, can be construed as an admission by the code that the minimum prescriptive criteria may be wrong to begin with. The owner/operator assumes responsibility for continued capture and removal maintenance.

Logically, the building regulatory criteria should provide prescriptive criteria upon which an acceptable degree of health and life safety can be achieved. Where the degree of health and life safety is dependent upon multiple variables, the building regulatory criteria do a disservice by oversimplifying the situation and then overcompensating to make sure all possible situations are addressed. It would appear more appropriate to reference some technical guidelines so that the designer can freely initiate and refine exhaust system designs within those guidelines. Then, prior to occupancy, the building regulatory official can validate performance under full load.

For instance, the state of Michigan provides that designs accepted under this scenario be available as case histories upon which to approve subsequent designs of a similar nature. If the system performs, then it should have every consideration for approval. If the system does not, then the building regulatory official has every right to withhold an occupancy permit until satisfactory capture and removal is accomplished. Such an approach would also have a positive impact on HVAC system design, capacity, and energy use by reducing the exhaust load the system must address.

RECOMMENDATIONS

Key to the issue is what commercial cooking equipment requires exhaust. Where exhaust is required, the associated airflow impacts building energy use and peak demand. The primary purpose of the exhaust system is to remove smoke- and grease-laden vapors that would pose a life safety problem if unventilated or allowed to be recirculated through the HVAC system. Other cooking byproducts include heat, odors, combustion products, and moisture that may or may not be considered acceptable for recirculation into the HVAC system or allowed to be unvented. In short, the quality and quantity of effluent at peak equipment use are presently not considered. Rather, based upon some indeterminant criterion, certain effluent types regardless of quantity must be captured by a hood and conveyed to the outdoors through an exhaust system.

Recognizing that each particular cooking process should generate and emit the same effluent, one would expect to find, and be able to support, one set of design criteria for use in determining if a hood and exhaust system are needed for each process. Each piece of equipment being operated at peak load could be evaluated as to grease/smoke/heat production and other effluent considerations. Based upon a specific set of rating criteria relating to the need for exhaust, each particular cooking equipment type could then be "effluent rated." The effluent rating would also depend upon the design and type of exhaust system.

To support such an approach, the following should be considered:

- Development of evaluation criteria and a test protocol to measure the amount and describe the quality of effluent from various cooking processes and equipment.
- Based on an assessment of fire and life safety considerations, determination of threshold values with which to define the relative hazard of various cooking effluents both qualitatively and quantitatively.
- Using information from the above, determination of which cooking processes and equipment clearly need exhaust and which do not.
- Testing of the equipment and cooking processes not identified above to ascertain if exhaust is needed and under what conditions.

Depending upon the cooking load, a certain amount of exhaust air must be provided to facilitate effluent capture and removal. The associated amount affects the building energy use directly because the air used by the exhaust system must be replaced by outside air that must be conditioned. In addition, where the makeup air is provided from other building areas, their energy consumption is affected as well. The criteria used to determine the necessary amount of exhaust air vary widely, are not uniform, and have no apparent sole source of technical support. Their advantage is the ease with which a determination of compliance can be made and as such they tend to be prescriptive and conservative.

Following the previous discussion on the need for exhaust, the quantity and quality of effluent can be used to define the amount, if any, of exhaust air needed. Where exhaust hoods are needed, but would serve different loads, the exhaust system could be staged to provide incremental exhaust rates based on the numerous loads, somewhat analogous to zoning HVAC systems as opposed to having one big zone and basing the load therein on the worst case. This would be distinctly different from the more general approach found in most codes, which provides a simple one-dimensional exhaust requirement. No differentiation of equipment type, load, or effluent quantity/quality is made, nor is the required exhaust allowed to change. Moreover, there is no allowance to modulate the exhaust rate to track effluent discharge as it changes with cooking load. The way around this has been through use of short-circuit hoods, which helps address the issue of makeup air with outside air but does not address the real issue of the proper amount of exhaust air.

If research is conducted to address these recommendations, there should be a basis upon which to determine how much, if any, exhaust air is needed. To facilitate consideration of exhaust air needs so as to effectively ventilate without overventilation, the following recommendations should also be considered:

- Use of an evaluation criterion and a test protocol to measure the exhaust efficiency associated with different equipment under different loads and under different hood designs. The results should provide some data upon which to formulate more effective criteria for determining required exhaust.
- Development of criteria for relating cooking equipment effluent, fuel source, and hood design to required exhaust. Such criteria should be supported by data that foster the segmentation of different loads under the hood and allow for exhaust modulation as cooking loads change.
- In light of the results of the above two recommendations, review of the need for makeup air and the sources to supply makeup air.

The codes can be changed when a reasonable research base is available. By changing the codes and making them more uniform, it will be far easier to address issues of kitchen ventilation. In addition, energy will be saved, not only on the exhaust system side, but on the HVAC system side from which replacement air is derived.