1 Introduction

Objective & Scope

This technology review presents a comprehensive description and energy performance assessment of commercial cooking equipment. The focus is on the potential for improving the energy efficiency and overall performance of both gas-fired and electric appliances in support of utilities' marketing and energy conservation initiatives for this end-use sector. The ultimate goal is to stimulate the development of more energy efficiency equipment through collaborative efforts between utilities, research groups, end-users and manufacturers.

This edition is an update of a technology assessment prepared by Fisher Consultants (now Fisher-Nickel, inc.) under contract with the Canadian Gas Research Institute (CGRI) published in 1996.[1] Fisher-Nickel, inc. (www.fishnick.com) currently operates the Food Service Technology Center (FSTC) in San Ramon, California.

The glossary in Appendix A is provided so that the reader has a quick reference to the terms used in this study.

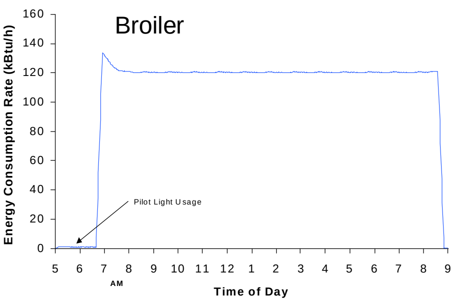
Appliance Categories and Types

The categories and types of cooking equipment described in subsequent sections of this report are listed in Table 1-1. Each section has been developed as a “textbook” style module complete with references. Subsequent to the 1996 edition of this report, the FSTC has expanded the performance database for several major categories of equipment including gas fryers, gas griddles, electric convection steamers, and underfired gas broilers.

Table 1-1. Appliance Categories and Types.

Category	Type
FRYER	Open Deep Fat Open Kettle Pressure Flat Bottom: – *chicken* – *fish* – *donut*
GRIDDLE	Single Sided: – *flat* – *grooved* Double Sided
BROILER	Underfired (Charbroiler) Overfired: – *upright* – *salamander* – *cheesemelter* Conveyor (chain)
RANGE	Range: – *open burner/element* – *hot top*
CHINESE RANGE	Traditional Wok North American Wok
OVEN	Standard Convection – *full size* – *half size* – *rack ovens* Combination Oven/Steamer Deck Conveyor Rotisserie – *rotisserie oven* – *rotisserie broiler*
STEAMER	Compartment Pressureless – *natural convection* – *boiler/steam generator based* Compartment Pressurized
STEAM KETTLE	Steam Kettle
BRAISING PAN	Braising Pan/Tilting Skillet

Background



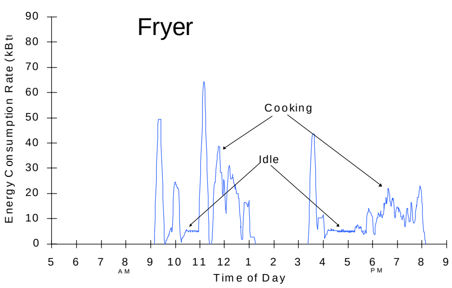


Figure 1-1.
Daily energy consumption profiles for a broiler and a fryer.

Energy Performance

Although the nameplate energy input of an appliance (Btu/h for gas and kW for electric) reflects available cooking “horsepower,” it is more difficult to estimate actual energy consumption for specific cooking appliances in a specific food service operation based on this rated input. While one understands that a cooking appliance may not draw power or consume gas at its peak input rate, it is not as easy to project the average rate of energy consumption for the various appliances that one might encounter in a restaurant kitchen. The amount of energy consumed by commercial cooking equipment is dependent on the operating time of an appliance, the cooking surface or cavity temperature (based on a selected thermostat setpoint) and/or heat-input setting (e.g., “high”, “medium” or “low” input energy control), the quantity of food being cooked and, for some appliances, the mode of operation. The relative dependence of appliance energy consumption on each of these variables is a function of equipment type and design, as well as on the usage of an appliance within a specific food service operation. For eight generic appliance types evaluated within the scope of an appliance energy end use monitoring project,[2] a large variation in the characteristic energy demand and consumption was documented. This also was reflected by the reported range in the duty cycles (i.e., from 12 to 92%) of appliance burners or elements for each category of equipment. The duty cycle of an appliance is defined as the average rate of energy consumption expressed as a percentage of the rated energy input or the peak rate at which an appliance can use energy. Figure 1-1 compares the daily energy profiles for two pieces of cooking equipment.

Thermostat vs. Non-Thermostat Control. Whether an appliance type incorporates a thermostat can impact significantly on the characteristic energy consumption of that appliance. For example, a gas broiler consumes energy at a rate that is close to its input rate as thermostat control is not incorporated. Characteristically different from the broiler is an appliance such as the fryer, which is thermostatically controlled. The average rate of energy consumption required to maintain the frying oil at approximately 350°F (177°C) is 15 to 20% of the rated energy input for fryers.[2]

Situation Analysis

A study[3] published by the U.S. Department of Energy titled *Characterization of Commercial Building Appliances* effectively summarizes the status of cooking technologies and foreshadows the importance of R&D initiatives designed to improve the performance of commercial cooking equipment:

All commercial food service equipment is represented in both gas-fired and electric models. The efficiency of commercially available gas-fired cooking equipment varies significantly depending on the specific manufacturer and model. There are no mandated minimum efficiency standards in this industry, and uniform test procedures for measuring actual cooking efficiencies are in the process of being developed (ref. Food Service Technology Center). The largest impact on the future efficiency of the installed base of cooking equipment will depend more on factors that influence the purchase decision criteria for the equipment than on technology developments. Quite simply, the installed base of commercial gas-fired cooking equipment efficiencies could be significantly increased if customers purchased more efficient models. However, the cost premium associated with the high efficiency cooking equipment does not always justify the resultant savings.

As a result, projecting future efficiencies, we need to consider customer trends and driving forces behind the more energy efficient system. Often times, the higher efficiency systems also provide better cooking performance, which is extremely important to the fast food chains. Electric powered cooking equipment has not changed in efficiency as dramatically as gas-fired models.

In addition to the low-first-cost economic pressure on the food service operator to purchase less efficient equipment, the general lack of objective performance data has slowed the development of energy efficient equipment. If the buyer is not exposed to accurate benchmark performance data, there is less incentive on the part of the manufacturers to improve equipment performance. As identified by the DOE study,[3] the absence of government legislation specifying minimum efficiencies for cooking equipment is another factor in the slow-development equation for improving the energy performance of cooking equipment.

Standard Test Method Development

In 1987, with co-funding by the Electric Power Research Institute (EPRI), the Gas Technology Institute (GTI), and the National Restaurant Association, the Pacific Gas and Electric Company undertook the development of uniform testing procedures to measure energy efficiency and evaluate the overall performance of gas and electric cooking equipment within the scope of the Food Service Technology Center project, operating in San Ramon, California.

When the FSTC research team completes a uniform testing procedure for a particular appliance category,[4-11] the document is submitted to the ASTM F 26.06 Food Service Equipment Subcommittee on Productivity and Energy Protocols. The testing procedure is then reviewed by this group of industry professionals before it is balloted by the main F 26 Food Service Equipment Committee. Once approved by the main committee, the testing procedure is submitted for Society ballot and published as an official ASTM Standard Test Method.

ASTM Test Methods Benefit Food Service Industry

The application of an ASTM Standard Test Method (STM) to cooking equipment provides end-users with performance parameters that can be used to compare the energy efficiency, production capacity, cooking surface/cavity uniformity, etc. of one piece of equipment with another. A unique aspect of the test methods is that the productivity (i.e., production capacity) and energy efficiency are determined from the same test using standardized food product under tightly controlled conditions. Figure 1-2 illustrates an ASTM test method being applied to a fryer.

From the perspective of energy efficiency, it is important to compare a gas appliance with other gas appliances and an electric appliance with other electric equipment. Since the energy efficiency of a gas appliance is inherently lower than it is for its electric counterpart, a purchaser must establish different minimums for gas and electric equipment. For example, an end-user might choose to specify a minimum full-load cooking-energy efficiency of 50% for gas fryers while requiring a minimum of 80% for electric fryers.

The specification of the production capacity (i.e., weight of food cooked per hour) should be the same for both gas and electric appliances, as the “work” that a cooking appliance is required to do for the end-user is the same. Similarly, performance parameters such as cooking surface/cavity temperature uniformity apply equally to gas and electric appliances. Idle energy rate is another important parameter in characterizing the energy performance, as appliances spend many hours in a ready-to-cook mode.

Figure 1-2.
ASTM test method applied to a fryer.
Photo: Fisher-Nickel, inc.

These test methods produce unbiased energy performance data that can be used to help end users and designers specify energy efficient equipment, qualify Energy Star® candidates and help determine minimum mandated standards for energy efficiency. Manufacturers use the test methods to benchmark and improve the efficiency and performance of their equipment. End users have used the test methods in partnership with their equipment suppliers to improve the efficiency of specific appliances they purchase.

Status of ASTM Test Methods

At the end of 2001, the FSTC had developed 30 standard test methods for the performance of commercial food service equipment. Standard test methods ratified by the ASTM F26 Committee on Food Service Equipment include:

Designation: F 1361 – 95

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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If not listed in the current combined index, will appear in the next edition.

Standard Test Method for Performance of Open Deep Fat Fryers[1]

This standard is issued under the fixed designation F 1361; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the evaluation of the energy consumption and cooking performance of open, deep fat fryers. The food service operator can use this evaluation to select a fryer and understand its energy efficiency and production capacity.

1.2 This test method is applicable to floor model gas and electric units with 35- to 60-lb frying medium capacity.

1.3 The fryer can be evaluated with respect to the following (where applicable):

1.3.1 Energy input rate (10.2),

1.3.2 Preheat energy and time (10.4),

1.3.3 Idle energy rate (10.5),

1.3.4 Pilot energy rate (10.6),

1.3.5 Cooking energy rate and efficiency (10.10), and

1.3.6 Production capacity and frying medium temperature recovery time (10.10).

1.4 This test method is not intended to answer all performance criteria in the evaluation and selection of a fryer, such as the significance of a high energy input design on maintenance of temperature within the cooking zone of the fryer.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ANSI Document:*[2]

ANSI Z83.13 American National Standard for Gas Food Service Equipment—Deep Fat Fryers

2.2 *AOAC Documents:*[3]

AOAC 984.25 Moisture (Loss of Mass on Drying) in Frozen French Fried Potatoes

AOAC 983.23 Fat in Foods: Chloroform-Methanol Extraction Method

2.3 *ASHRAE Documents:*[4]

ASHRAE Guideline 2-1986 (RA90) Engineering Analysis of Experimental Data

3. Terminology

3.1 *Definitions:*

3.1.1 *open, deep fat fryer, n*—(hereafter referred to as fryer) an appliance, including a cooking vessel, in which oils are placed to such a depth that the cooking food is essentially supported by displacement of the cooking fluid rather than by the bottom of the vessel. Heat is delivered to the cooking fluid by means of an immersed electric element or band wrapped vessel (electric fryer), or by heat transfer from gas burners through either the walls of the fryer or through tubes passing through the cooking fluid (gas fryer).

3.1.2 *test method, n*—a definitive procedure for the identification, measurement, and evaluation of one or more qualities, characteristics, or properties of a material, product, system, or service that produces a test result.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *cold zone, n*—the volume in the fryer below the heating element or heat exchanger surface designed to remain cooler than the cook zone.

3.2.2 *cooking energy, n*—total energy consumed by the fryer as it is used to cook french fries under heavy-, medium-, and light-load conditions.

3.2.3 *cooking energy efficiency, n*—quantity of energy to the french fries during the cooking process expressed as a percentage of the quantity of energy input to the fryer during the heavy-, medium-, and light-load tests.

3.2.4 *cooking energy rate, n*—average rate of energy consumed by the fryer while "cooking" a heavy-, medium-, or light-load of french fries.

3.2.5 *cook zone, n*—the volume of oil in which the fries are cooked. Typically, the entire volume from just above the heating element(s) or heat exchanger surface to the surface of the frying medium.

3.2.6 *heavy-load, n*—3 lb (1360 g) of fries, divided evenly into 1½-lb (680-g) loads and placed in two baskets for cooking.

3.2.7 *idle energy rate, n*—average rate of energy consumed (Btu/h (kJ/h) or kW) by the fryer while "holding" or "idling" the frying medium at the thermostat(s) set point.

3.2.8 *light-load, n*—¾ lb (340 g) of fries, all placed in one basket for cooking.

3.2.9 *energy input rate, n*—peak rate at which a fryer consumes energy, typically reflected during preheat.

3.2.10 *medium-load, n*—1½ lb (680 g) of fries, all placed in one basket for cooking.

3.2.11 *preheat energy, n*—amount of energy consumed (Btu (kJ) or kWh) by the fryer while preheating the frying medium from ambient room temperature to the calibrated thermostat(s) set point.

3.2.12 *preheat time, n*—time required for the frying

[1] This test method is under the jurisdiction of ASTM Committee F-26 on Food Service Equipment and is the direct responsibility of Subcommittee F26.06 on Productivity and Energy Protocol.

Current edition approved June 15, 1995. Published August 1995. Originally published as F 1361 – 91. Last previous edition F 1361 – 91.

[2] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[3] *Official Methods of Analysis of the Association of Official Analytical Chemists.* Available from the Association of Official Analytical Chemists, 1111 N. 19th St., Arlington, VA 22209.

[4] Available from the American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329.

1

1. *ASTM Standard Test Method for the Performance of Griddles*, Designation: F 1275-99
2. *ASTM Standard Test Method for the Performance of Open Deep-Fat Fryers, Designation: F 1361-99*
3. *ASTM Standard Test Method for the Performance of Steam Cookers, Designation: F 1484-99*
4. *ASTM Standard Test Method for the Performance of Convection Ovens, Designation: F 1496-99*
5. *ASTM Standard Test Method for the Performance of Range Tops, Designation: F 1521-96*
6. *ASTM Standard Test Method for the Performance of Double-Sided Griddles, Designation: F 1605-95*
7. *ASTM Standard Test Method for the Performance of Combination Ovens, Designation: F 1639-96*
8. *ASTM Standard Test Method for the Performance of Underfired Broilers*, Designation: F 1695-96
9. *ASTM Standard Test Method for the Performance of Single-Rack, Hot Water Sanitizing, Door-Type Commercial Dishwashing Machines, Designation: F 1696-96*
10. *ASTM Standard Test Method for the Performance of Commercial Kitchen Ventilation Systems, Designation: F 1704-99*
11. *ASTM Standard Test Method for the Performance of a Pasta Cooker, Designation: F 1784-97*
12. *ASTM Standard Test Method for the Performance of Steam Kettles, Designation: F 1785-97*
13. *ASTM Standard Test Method for the Performance of Braising Pans, Designation: F 1786-97*
14. *ASTM Standard Test Method for the Performance of Rotisserie Ovens, Designation: F1787-98*
15. *ASTM Standard Test Method for the Performance of Conveyor Ovens, Designation: F 1817-97*
16. *ASTM Standard Test Method for the Performance of Conveyor Dishwashing Machines, Designation: F 1920-98*
17. *ASTM Standard Test Method for the Performance of Pressure and Kettle Fryers, Designation: F 1964-99*
18. *ASTM Standard Test Method for the Performance of Deck Ovens, Designation: F 1965-99*
19. *ASTM Standard Test Method for the Performance of Chinese Wok Ranges, Designation: F 1991-99*
20. *ASTM Standard Test Method for the Performance of Booster Heaters, Designation: F 2022-01*
21. *ASTM Standard Test Method for the Performance of Rack Ovens, Designation: F2093-01*
22. *ASTM Standard Test Method for the Performance of Hot Food Holding Cabinets, Designation: F 2140-01*

23. *ASTM Standard Test Method for the Performance of Hot Deli Cases, Designation: F2141-01*
24. *ASTM Standard Test Method for the Performance of Drawer Warmers, Designation: F2142-01*
25. *ASTM Standard Test Method for the Performance of Refrigerated Preparation and Buffet Tables, Designation: F2143-01*
26. *ASTM Standard Test Method for the Performance of Large Fryers, Designation: F2144-01*
27. *ASTM Standard Test Method for the Performance of Rapid Cook Ovens, Designation Pending.*
28. *ASTM Standard Test Method for the Performance of Conveyor Broilers, Designation Pending.*
29. *ASTM Standard Test Method for the Performance of Conveyor Toasters, Designation Pending.*
30. *ASTM Standard Test Method for the Performance of Blast Chillers, Designation Pending.*

Under development (or consideration) at the FSTC are test methods for overfired broilers, salamanders, pre-rinse sprayers, powered pot washers, donut fryers, steam tables, food warmers, soft-serve ice cream machines, retherm ovens and a field test method for exhaust hoods.

Appliance Energy Efficiency

Appliance cooking-energy efficiency is a measure of how much of the energy that an appliance consumes is actually delivered to the food product during the cooking process. The ASTM test methods for measuring cooking appliance energy efficiency have been based on this fundamental definition and equations:

cooking-energy efficiency *— quantity of energy imparted to the specified food product, expressed as a percentage of energy consumed by the appliance during the cooking event:*

$$\eta_{cook} = \frac{E_{food}}{E_{appliance}} \times 100$$

where:

η_{cook} = cooking-energy efficiency
$E_{appliance}$ = energy into the appliance
E_{food} = energy to food
= $E_{sens} + E_{thaw} + E_{evap}$.

where:

E_{sens} = quantity of heat added to food product, which causes its temperature to increase from the starting temperature to the average bulk temperature of a "done" food product

= $(W_i)(C_p)(T_f - T_i)$

where:

W_i = initial weight of food product, lb (kg)

C_p = specific heat of food product, Btu/lb, °F (kJ/kg, °C)

T_f = final cooked temperature of food product, °F (°C)

T_i = initial internal temperature of food product, °F (°C)

E_{thaw} = latent heat (of fusion) added to the food product, which causes the moisture (in the form of ice) contained in the food product to melt when the temperature of the food product reaches 32°F (0°C)

= $W_{iw} \times H_f$

where:

W_{iw} = initial weight of water in the food product, lb (kg),

H_f = heat of fusion, Btu/lb (kJ/kg), and

= 144 Btu/lb (336 kJ/kg) at 32°F (0°C).

E_{evap} = latent heat (of vaporization) added to the food product, which causes some of the moisture contained in the food product to evaporate.

= $W_{loss} \times H_v$

where:

W_{loss} = weight loss of water during cooking, lb (kg),

H_v = heat of vaporization, Btu/lb (kJ/kg),

= 970 Btu/lb (2256 kJ/kg) at 212°F (100°C)

Table 1-2 lists the benchmark cooking-energy efficiencies that were compiled within the scope of this study. The cooking efficiencies are based on both measured and estimated performance of a cooking appliance under discrete full-load tests (e.g., oven) or full-load barreling tests (e.g., fryer) as described by the ASTM Test Methods. The source of the estimates are discussed in each appliance section. Of significance to this study's objective, are the relatively low efficiencies (e.g., 20 - 50%) for standard gas appliances. One would conclude that there is significant potential for raising the base efficiency of gas-fired cooking equipment.

It is important to recognize that cooking appliances are more efficient when they are cooking food at capacity (i.e., fully loaded). In the real world, appliances typically are not used to capacity for extended periods of time. Thus, part-load performance is an important parameter and has been incorporated within the ASTM testing procedures. Similar to other energy consuming equipment such as heat pumps or gas furnaces, the energy efficiency is reduced under part-load operation. The amount of time that an appliance is left idling in a ready-to-cook mode also adds to the denominator of the real-kitchen energy efficiency equation. Neither the part-load performance nor the in-kitchen utilization are reflected by the efficiencies in Table 1-2. Alternatively stated, the real-world energy utilization efficiencies of gas cooking equipment are very low (e.g., 5 - 10%).

Table 1-2. Benchmark Cooking-Energy Efficiency[a] Summary.

	Standard Gas	High Efficiency Gas	Electric
FRYER:			
Open Deep Fat	25 - 50	50 - 65	75 - 85
Pressure/Kettle	25 - 35	35 - 50	65 - 85
Flat Bottom	25 - 35	35 - 50	65 - 85
GRIDDLE	25 - 35	40 - 50	65 - 75
BROILER	15 - 30		35 - 65
RANGE TOP	25 - 30	45 - 60	65 - 85
WOK	15 - 30		50 - 70
OVEN:			
Std./Conv./Comb.	30 - 40	40 - 50	50 - 80
Deck	20 - 30		40 - 60
Conveyor	10 - 20		20 - 40
Rotisserie	20 - 30		50 - 60
COMPARTMENT STEAMER	30 - 40		60 - 80
STEAM KETTLE	40 - 60		80 - 95
BRAISING PAN	30 - 55		80 - 95

[a] Energy efficiencies are for full-load cooking scenarios

Gas/Electric Consumption Ratios

The ratio of energy consumption between a gas appliance and its electric counterpart is an energy performance parameter often used by the industry. Ratios of energy consumed by a gas appliance to its electric counterpart were reported by the Minnesota Study[12] and subsequently reported by the American Gas Association.[13] However, these ratios were based on full-load cooking tests applied to one gas and one electric appliance in each equipment category. Table 1-3 presents the energy ratios published by AGA.

Table 1-3. AGA Published Gas/Electric Energy Ratios.[13]

Appliance	Energy Ratio Gas to Electric
Broiler	1.4
Braising pan	1.8
Fryer, standard	2.0
Fryer, pressure	2.3
Griddle, flat	1.4
Griddle, grooved	1.4
Oven, convection	1.5
Oven, deck	2.2
Range, hot top	2.0
Range, open burner	2.0
Steam kettle	1.7
Steamer, atmospheric	1.5
Steamer, pressure	2.1

Although this data provided an excellent tool for comparing gas and electric appliance energy consumption (and cost), the fact that the ratios were based on full-load testing generated an optimistic comparison for some of the equipment categories. This is because the efficiency of a gas appliance under part-load operation may be less than it is under full-load conditions. Furthermore, the AGA ratios do not consider the fact that an appliance in an actual food service operation may spend much of its time idling or under light-duty operation.

The ratio of energy consumption between every gas and electric appliance combination in the same category is not a precise number—it can vary depending on the specific model of gas and electric appliance being compared and on the usage of the appliance in the commercial kitchen. It also is a function of the technology incorporated in either the gas or electric unit (e.g., infrared burners). For example, if one compares the least efficient electric griddle with the most efficient gas griddle, the energy consumption ratio will be lower (e.g., ratio = 1.5) than if one compares the most efficient electric griddle with the least efficient gas griddle (e.g., ratio = 2.5). However, a more representative ratio for all electric griddles compared to all gas griddles under typical real-world conditions may be somewhere in between (e.g., ratio = 2.0).

Estimates of real-world energy consumption ratios for gas and electric appliances are presented in Table 1-4 based on the average rate of energy consumption reported in the respective appliance sections. These average energy consumption rates were estimated using either an energy consumption model or typical appliance duty cycles estimated from available end-use monitoring data.

Table 1-4. Gas/Electric Energy Consumption Ratios.

	Average Energy Consumption		Energy Ratio
Appliance	Gas	Electric [a]	Gas/Electric
Deep-Fat Fryer	20	10	2.0
Griddle	23	10	2.3
Underfired Broiler	84	27	3.1
Range	48	17	2.8
Convection Oven	25	17	1.5
Compartment Steamer	32	17	1.9
Steam Kettle	50	27	1.9
Braising Pan	40	24	1.7

[a] Conversion Factor = 3.413 (kBtu/kWh)

Higher Efficiency

Potential for Efficiency Improvements

Although the application of advanced technologies could improve the performance and energy efficiency of the existing stock of food service equipment, the application of existing technologies, such as insulation, improved heat exchanger design, and enhanced control, may provide the greatest return over the short term.

Improved insulation. The addition of insulation around an appliance can reduce standby convective heat losses by as much as 25%. Some appliance groups such as ovens and steamers already incorporate some level of insulation, but many appliances do not. The addition of insulation is an inexpensive method for reducing stand-by losses and thereby improving light-load cooking-energy efficiency for appliances.

Improved heat exchanger design. The energy performance within each category or type of appliance varies significantly: first, depending on whether the appliance is gas or electric, and second, based on the applied heating technology. Due to the many possible arrangements of the combustion and heat exchanger systems, there are greater differences in efficiencies among gas appliances on the market than among electric appliances.

A major difference between high-efficiency and low-efficiency appliances is the effectiveness of their heat exchangers in transferring heat to the cooking surface, cavity or medium. This is especially pronounced in gas appliances that use indirect heating. It is estimated that improved heat exchanger designs could account for up to a 25% increase in cooking-energy efficiency for gas appliances. An example of this is the use of recirculation baffles on a gas fryer. Recirculation tubes, or recycle baffles, route the flue gasses through or around the sides of the frypot to provide a greater effective heat transfer surface for the hot gasses. More heat is transferred to the frying oil, yielding a 10% to 15% increase in efficiency.

Enhanced control. Appliances such as range tops and broilers are generally not amenable to timers or cooking computers, and therefore, controls for these appliances are typically simple. There is most often an infinite-control knob to regulate the input of each burner or element. The controls are calibrated in terms of the percentage of input, as the burner does not generally sense the temperature of the cooking medium. “Smart controls” that sense the presence of cooking loads offer potential improvements to these types of appliances.

Other appliances, such as fryers, griddles, and ovens, have the potential for more sophisticated controls. Quick service chains often specify elaborate "cooking computers" that sense time, temperature, and in some cases, relative humidity. These computers give the user a high level of control over the cooking process by defining various temperature curves and different programmable cooking cycles. The use of these controls allows for a more consistent food product and can reduce the energy consumption of the appliance. Another example is a control operation that provides a "soft landing" strategy. These controls reduce energy usage and improve cooking performance by minimizing overshoots of the desired temperature setpoint.

A commercial kitchen includes a great number of control systems, all operating independently of each other, and with no oversight beyond the restaurant staff and management. This leads to increased energy consumption because appliances are often turned on when they are not being used and there is no feedback mechanism to alert the restaurant owner that energy is being wasted. The food service industry has been slow to adopt the types of centralized computer control systems typical in most other industrial processes because of the cost, complexity and lack of a standardized approach.

NAFEM Online Kitchen Protocol

NAFEM

North American Association of Food Equipment Manufacturers

In 1999, the National Association of Food Equipment Manufacturers (NAFEM) joined forces with a group of appliance manufacturers and the major chain restaurants to define an industry-wide approach to the implementation of computer controls within the kitchen. The result of this on-line kitchen initiative was the publication of a standard data communications protocol. This standard allows the appliance manufacturers to configure their individual control systems for easy communication with a centralized control program. The energy related benefits of the on-line kitchen include better documentation of energy consumption, real-time diagnostics of equipment energy performance, and hands-off appliance scheduling based on demand for the food product. Details are available on NAFEM's web site at: www.nafem.org

The next step in the industry-wide implementation of the on-line kitchen is industry education and promotion. This process includes working with the chain restaurants to quantify the energy benefits of the on-line kitchen so that they can justify the initial capital cost. It also involves educating the non-chain food service operators who have not been a part of this process to date. Both of these goals can be achieved through a process of seminars, presentations, and demonstration projects. This protocol has major implications with respect to appliance R&D.

EPA Energy Star®

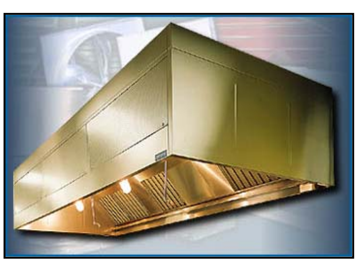
Possibly the greatest hurdle to improving the efficiency of commercial food service and refrigeration equipment is the lack of understanding (by both manufacturers and purchasers) of benchmark efficiency. If the buyer is not exposed to accurate efficiency data, there is less incentive on the part of the manufacturers to improve equipment performance. If the buyer does not realize that the most energy efficient appliance option may also be the best performer, the hurdle is even more difficult to knock down. Significant energy savings have been achieved in residential refrigeration equipment, yet proven energy savings technologies have not been implemented in the commercial markets. The labeling of residential refrigeration equipment with its energy usage, utility incentive programs and the Energy Star® program has helped to promote the buying of energy efficiency residential refrigeration equipment. The goal is to parallel these accomplishments in the commercial food service sector.

The Food Service Technology Center has established a working relationship with the EPA team responsible for Energy Star® initiatives in commercial food service. Our role to date has been to provide “behind-the-scene” technical support in establishing criteria to qualify commercial refrigerators and freezers for Energy Star®. Rachel Schmeltz, Energy Star® Program Manager was a speaker at the FSTC March 16 & 17, 1999 symposium on food service equipment—Investing in Performance—discussing EPA’s initial efforts with reach-in refrigerators and freezers. In September 2001, EPA announced Energy Star® for commercial refrigerators and freezers with seven participating manufacturers. This is the first appliance category within commercial food service to exhibit this distinction.

Strategies for expanding Energy Star® within commercial food service include:

- Introducing Energy Star® for commercial food service equipment on an appliance-by-appliance basis, working with the proactive manufacturers (who have had equipment tested by the FSTC) within each category. The FSTC would facilitate kick-off meetings with manufacturers and stakeholders in each equipment category.
- Move strategically into commercial cooking equipment, utilizing the portfolio of ASTM Standard Test Methods developed by the FSTC. Determine threshold efficiencies or energy saving criteria through the consensus of participating manufacturers. Start with appliances that the FSTC has a large database, manufacturer participation and/or energy saving potential (e.g., gas fryers, insulated holding cabinets, compartment steamers, low-flow prerinse sprayers, exhaust hoods/fans). These efficiency criteria will provide a foundation for the EPA Energy Star® Program accelerating the development and purchase of energy efficient appliances and systems for commercial food service.
- On the whole-building concept, utilize FSTC benchmarking and energy efficient design experience (e.g., McDonald's TEEM project) to establish criteria for Energy Star® labeling of restaurants.

Ventilation Requirements



Background

The need to exhaust heat and vapors associated with the operation of commercial cooking equipment directly impacts on the energy demand and consumption of food service facilities. It has been demonstrated that the HVAC load represents approximately 30% of the total energy consumed in a restaurant.[14] It has been further estimated[15] that the kitchen ventilation system can account for up to 75% of the HVAC load and, as such, often represents the largest single-system, energy consumer in food service operations. However, commercial kitchen ventilation (CKV) systems are typically designed, installed and operated with little consideration for energy efficiency. This can be attributed to the fact that designers are primarily concerned with the capability of the CKV systems to capture, contain and remove cooking contaminants, while the building owner's goal is to minimize both the design and installed cost of the HVAC system.

The problem is compounded by the lack of comprehensive design information for commercial kitchens. Although the ASHRAE handbooks are recognized as a fundamental source of information for designing HVAC systems, these handbooks lacked any design information for ventilating commercial cooking equipment prior to 1995. Thus, many designers specified exhaust ventilation rates based on the more prescriptive code requirements or experience. Although kitchen exhaust systems sized according to "rules-of-thumb" may be inadequate from the perspective of removing grease, odors and heat from the commercial kitchen—they may operate with a safety factor in exhaust flow rate that significantly increases the energy burden and operating cost.

Influence of Model Codes

As discussed above, guidelines for kitchen ventilation systems have been influenced strongly by model codes such as the Uniform Mechanical Code, Uniform Building Code, and up to 1973, the National Fire Protection Association (NFPA Standard No. 96), which list the required exhaust air quantities according to the type, placement and face area of the exhaust hood (Figure 1-3). More recently, the International Mechanical Code (IMC) is having influence and is being adopted by more "authorities having jurisdiction" around the U.S. Fortunately, efforts of the CKV industry have successfully impacted changes to the IMC that better reflect the results of recent research and consensus-based design practice. For example, the IMC now classifies cooking equipment as light duty, medium duty, heavy duty and extra-heavy duty from the perspective of exhaust requirements. The IMC also changed the prescriptive requirements from cfm/ft^2 of open-hood area to cfm/linear foot of hood to be more consistent with manufacturers' design guidelines and listings.

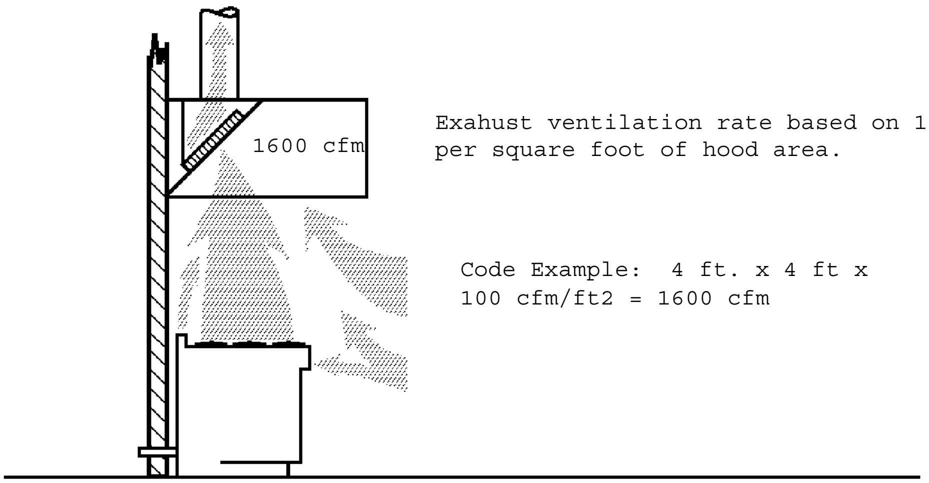


Figure 1-3.
Prescriptive code requirement for unlisted hood.

Listed Hoods

It is important to recognize that a large percentage of the CKV systems being installed today are designed and operated below the code-specified ventilation rates for unlisted hoods. Many of the commercially available exhaust hoods have been listed in accordance with UL 710[16] at airflow rates significantly below code (e.g., 300 cfm vs. 450 cfm per linear foot of hood for heavy-duty cooking) and are typically permitted by the “authority having jurisdiction.” The National Fire Protection Association's (NFPA) Standard 96 simply states, “exhaust air volumes for hoods shall be of sufficient level to provide for the capture and removal of grease laden vapors.”

An industry survey by the FSTC CKV research team suggests that 60 - 70% of the total installed base of kitchen hoods are listed hoods. Although there is general agreement within the industry that the exhaust rates dictated by code are excessive, there is no consensus regarding the potential for reduction in the design ventilation for UL-listed hoods. In fact, several manufacturers have suggested that their UL values may not be adequate for many applications. However, based on actual performance data or experience, listed hoods can be applied at design levels that are above the listed capacity, but below the code specified capacity (Figure 1-4).

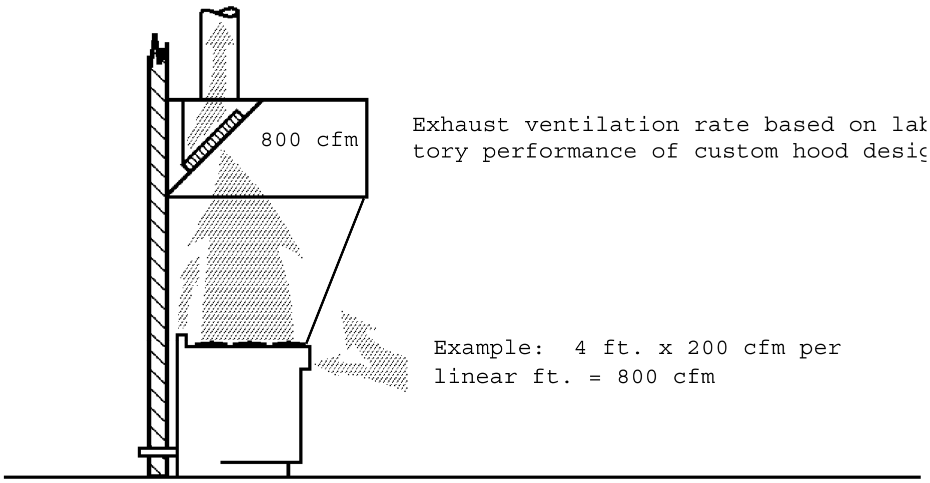


Figure 1-4.
Engineered requirements for listed hood (with side panels).

Short-Circuit Hoods

A controversial issue relates to the performance of what are referred to as "short-circuit" exhaust hoods. Alternatively referred to as "compensating," "no-heat," or "cheater" exhaust hoods, such systems were developed in an attempt to reduce the amount of conditioned makeup air required by an exhaust system designed to code. By introducing a portion of the required makeup air in an untempered condition directly into the exhaust hood itself, the net amount of conditioned air exhausted from the kitchen is reduced. Thus, the total exhaust capacity of the system will be able to meet conservative design requirements while the actual quantity of makeup air that needs to be heated or cooled is minimized. But if less "net" exhaust air is adequate, why not simply design the exhaust system to ventilate the cooking equipment at a reduced rate in the first place. A good idea, but the short-circuit hood continues to propagate within the industry. And in actual installations, the amount of short-circuited air often reduces the net ventilation to the point where spillage of cooking effluent occurs (Figure 1-5), compromising the kitchen environment.

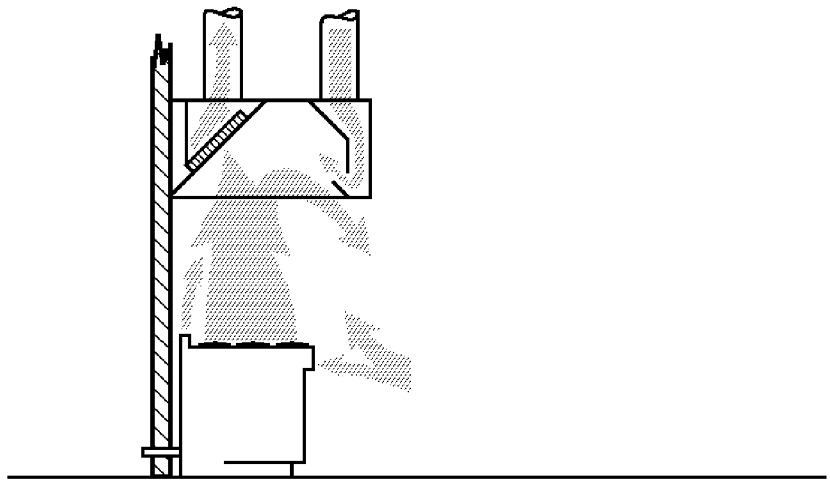
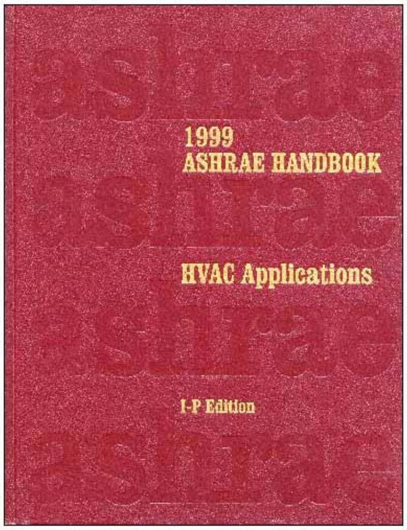


Figure 1-5.
Short-circuit hood illustrating potential for spillage.

Fortunately, one major proponent (manufacturer) of short-circuit hoods has redirected their marketing and design efforts towards exhaust-only systems over the last two years. The end of the short-circuit hood era is in sight!

ASHRAE Role



Technical issues and concerns related to kitchen ventilation have been discussed at ASHRAE forums, seminars, symposia and technical sessions for a number of years. “Standing room only” attendance has been the experience at these kitchen ventilation programs. Although several technical committees (TC’s) have served as sponsors, the number of individuals on any TC with a major interest in kitchen ventilation has been limited, as is the scope of existing TC's with respect to this topic. In an effort to focus ASHRAE's effort in this area, and to meet a perceived need of its membership, an ASHRAE technical committee on kitchen ventilation (TC5.10) was finally established. The mission of this committee on kitchen ventilation is to address the needs of ASHRAE membership with respect to the energy efficient control, capture, and effective removal of airborne contaminants and heat resulting from the cooking processes. The technical scope includes the introduction of supply and makeup air as it influences the contaminant control process, and the thermal environment in the cooking space.

This committee recently developed a new handbook chapter on kitchen ventilation,[17] a starting point for the designer of CKV systems. Unfortunately, there is still little guidance within the new handbook chapter with respect to the introduction of makeup air and the effect that a makeup air strategy will have on hood performance and/or energy consumption of the system—a subject of current research at the Wood Dale CKV lab funded by the California Energy Commission and coordinated by the FSTC.

There has been strong industry support of ASHRAE's involvement in kitchen ventilation, and a new Standard Project Committee, designated SPC 154P, is currently developing a Standard for Ventilation of Commercial Cooking Operations. The focus of the proposed ASHRAE standard will be towards optimizing the design and operation of the commercial kitchen ventilating systems with respect to system performance (e.g., capture and containment). Ultimately, the goal of the ASHRAE standard is to impact standardization of the mechanical codes across North America.

Exhaust Ventilation Rates

Exhaust flow rate requirements to capture, contain and remove the effluent vary considerably depending on the hood style, the amount of overhang, the distance from the hood to the cooking appliances, the presence and size of end panels, and the cooking equipment and food product involved. The hot cooking surfaces and product vapors create thermal air currents that are received or captured by the hood and then exhausted. The velocity of these currents depends largely upon the surface temperature and tends to vary from 15 fpm (0.076 m/s) over steam equipment to 150 fpm (0.76 m/s) over charcoal broilers. The actual required flow rate is determined by these thermal currents, a safety allowance to account for cross drafts and flare-ups, and a safety factor for the style of hood and configuration of makeup air system.

The approach ASHRAE takes is to categorize cooking equipment into four groups. While published equipment classification varies, and accurate documentation does not exist, the following reflects the consensus opinion of the membership of ASHRAE TC 5.10 and is listed in Chapter 30 of the 1999 ASHRAE Applications Handbook[17] as:

1. Light duty, such as ovens, steamers, and small kettles (up to 400°F (204°C))
2. Medium duty, such as large kettles, ranges, griddles, and fryers (up to 400°F (204°C))
3. Heavy duty, such as upright broilers, charbroilers, and woks (up to 600°F (316°C))
4. Extra heavy duty, such as solid fuel-burning equipment (up to 700°F (370°C)).

Acknowledging that variance in product or volume could shift an appliance into another category, the exhaust flow rate requirement is based on the classification of equipment under the hood. If there is more than one category, the flow rate is based on the heaviest-duty group, unless the hood design permits different volumes over different sections of the hood.

Listed hoods are allowed to operate at their listed exhaust flow rates by exceptions in the model U.S. codes. Most manufacturers verify their listed flow rates by conducting tests per UL Standard 710.[16] Minimum exhaust flow rates for listed hoods serving single categories of equipment vary from manufacturer to manufacturer, but are typically as shown in Table 1-5.[17] Actual exhaust flow rates for hoods with internal "short circuit" makeup air are typically higher than those in Table 1-5, although the net exhaust (i.e., total exhaust less short-circuit makeup air) may be similar.

Table 1-5. Typical Minimum Exhaust Flow Rates for Listed Hoods by Cooking Equipment Type.[17]

Type of Hood	Light Duty (cfm/linear ft)	Medium Duty (cfm/linear ft)	Heavy Duty (cfm/linear ft)	Extra Heavy Duty (cfm/linear ft)
Wall-Mounted Canopy	150 - 200	200 - 300	200 - 400	350 +
Single Island Canopy	250 - 300	300 - 400	300 - 600	550 +
Double Island Canopy (per side)	150 - 200	200 - 300	300 - 600	500 +
Eyebrow	150 - 250	150 - 250	---	---
Backshelf	100 - 200	200 -300	300 - 400	not recommended

Radiant Heat Gain to Kitchen

Heat gain from commercial cooking appliances may have a major impact on the air conditioning load and thermal comfort of a commercial kitchen. To estimate heat gain for building design of a commercial kitchen, engineers currently use Table 8 in Chapter 26 of the ASHRAE Handbook of Fundamentals.[18]

CKV Research

In parallel with the cooking appliance research conducted by the Food Service Technology Center, GRI and EPRI have funded separate commercial kitchen ventilation projects over the past decade. GRI's project was centered at the AGA Research Commercial Kitchen Ventilation Research Laboratory in Cleveland, Ohio. EPRI's Commercial Kitchen Ventilation Laboratory, formerly the McDonald's Corporation Air Lab, is in Wood Dale, Illinois. In 1994 these two programs collaborated in a round of inter-lab testing to validate the standard test method that became ASTM F 1704-96, *Standard Test Method for Performance of Commercial Kitchen Ventilation Systems*.[19] The FSTC coordinated the integration of research results from the two projects and the inclusion of new heat gain data in the ASHRAE handbook.[20] The CKV facility, managed by Architectural Energy Corporation, is now under the umbrella of the Food Service Technology Center program. The AGA Research facility has been decommissioned.

The Wood Dale CKV Lab applied a focusing schlieren flow visualization system to assess the capture and containment performance of hoods and appliances (Figure 1-6).[21] The schlieren flow visualization system is a major breakthrough for visualizing thermal and effluent plumes from hot and cold processes, particularly in food service. The word "schlieren" means "smear" in German; the optical effect encompassed by the word is best illustrated by the wavy visual pattern that can be seen in the exhaust stream of jet aircraft or over a hot asphalt parking lot during the summer. The system at the CKV lab is sensitive enough to detect the warm air coming off a person's body.

Figure 1-6.
CKV hood testing.
Photo: Architectural Energy Corp.

The schlieren flow visualization system allows non-intrusive investigation of hot air flow in real-time based on the refractive index dependency of air on temperature. Air in and surrounding the thermal plume from a cooking appliance changes its mass density and thereby its dielectric constant with temperature. This change in dielectric constant results in a change in refractive index, causing schlieren effect. Figure 1-7 shows still photos of a test condition. However, one of the real advantages of this flow visualization technique is the ability to document the dynamic flow patterns on videotape.

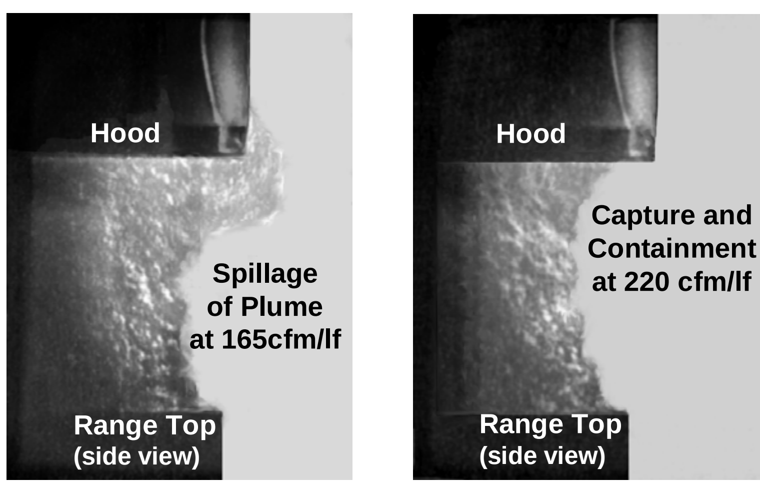


Figure 1-7.
Schlieren example.

Figure 1-8 presents thresholds of capture and containment (C&C) for different types of gas and electric cooking appliances determined using such flow visualization techniques in accordance with the new ASTM test method.[21] Each appliance was individually operating under a 5-foot (wide) by 4-foot (deep) wall mounted canopy hood. Makeup air for this exhaust-only hood configuration was supplied in non-obtrusive fashion from the far side of the laboratory. The C&C threshold flow rate was determined for a heavy-load cooking condition and under an appliance "idle" or standby condition as reported by the CKV lab in an ASHRAE paper.[22] As illustrated, there are significant differences between appliance types. In some cases, there are notable differences between fuel source and/or appliance usage (e.g., idle vs. cooking). It is important to note, however, that the comparison is based on one gas and one electric appliance in each category.

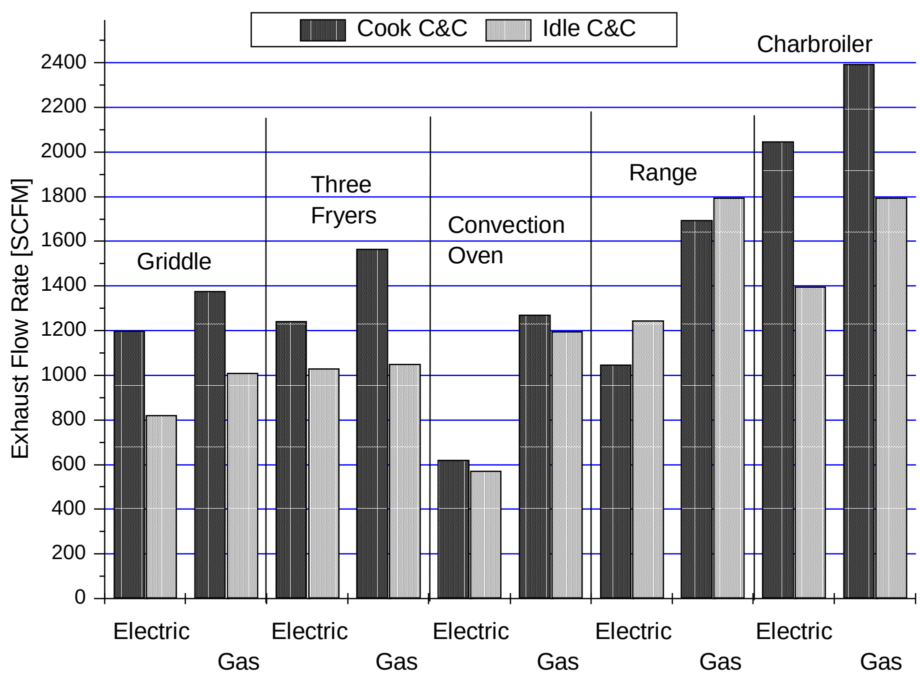


Figure 1-8.
Thresholds of capture and containment for a 5-ft wall-canopy hood.[21]

Conservation Potential

Although the opportunities for energy conservation and load management in CKV are large, the lack of publicly documented lab and field data has made achieving savings difficult. The FSTC estimates the connected kitchen ventilation exhaust capacity in the United States to be in the range of 2.5 to 3.0 billion cfm. Table 1-5 shows a summary by industry segment. Data published by Cahners Bureau of Foodservice Research shows that an estimated total of 737,000 food service facilities were in operation in 1992. The per unit exhaust volumes are estimates based on collective design experience and knowledge of installed systems by the authors. Note that the Canadian connected capacity is approximately 10% of the U.S., or 300 million cfm.

Total savings should range between 30% and 40%, with some facilities as high as 60%. Total cost savings across the industry could range from $1.0 to $1.5 billion per year. A reduction in CKV rates will improve energy efficiency in restaurants, lower restaurant demands (often at system peak hours), reduce capital construction costs by decreasing the size of installed HVAC equipment, and have a positive impact on the environment by reducing utility loads at the source and reducing effluent discharged from CKV systems to the atmosphere.

Table 1-6. Estimate of Ventilation Volumes by Facility Type in the U.S.

Industry Segment	Number of Units	Estimated Exhaust Per Unit (cfm/unit)	Total Exhaust (Million cfm)
Fast Food	180,125	3,000	540
Full Service	196,250	6,000	1,177
Educational	92,460	3,500	319
Health Care	63,730	3,500	219
Grocery & Retail	106,425	600	67
Lodging, Rec.	64,875	4,300	281
Other	33,300	4,400	146
Grand Totals	737,165	3,700	2,749

For example, 100 to 150 fpm (0.51 m/s to 0.76 m/s) face velocity is usually required, but levels as low as 50 to 75 fpm (0.25 m/s to 0.38 m/s) have been shown to be satisfactory[22] An experimental study[23] published by ASHRAE reported that for wall and island canopies, only 40 to 50% of the normal design flow was required to provide satisfactory capture of smoke generated at any location on or beside the cooking surfaces (Figure 1-3). These studies are consistent with research and development conducted by the McDonald's Corporation.[24] In general, their laboratory-based hood design and sizing procedures have allowed them to install exhaust systems that operate at an exhaust ventilation rate that is significantly less (e.g., 50%) than specified by model codes such as the International Mechanical Code (IMC).

In addition to the energy/load management benefits that can be achieved through a direct cfm reduction in exhaust capacity, significant benefits can be realized through integrated HVAC design strategies, engineered equipment, and enhanced system control and operation. Optimizing systems and operating strategies for foodservice facilities during retrofit and new construction will present additional opportunities that will not be at the expense of customer or employee comfort.

A simplified schematic of CKV system optimization is illustrated in Figure 1-9, where the target conservation and load management goals are realized through the development of new design guidelines and supporting changes to codes.

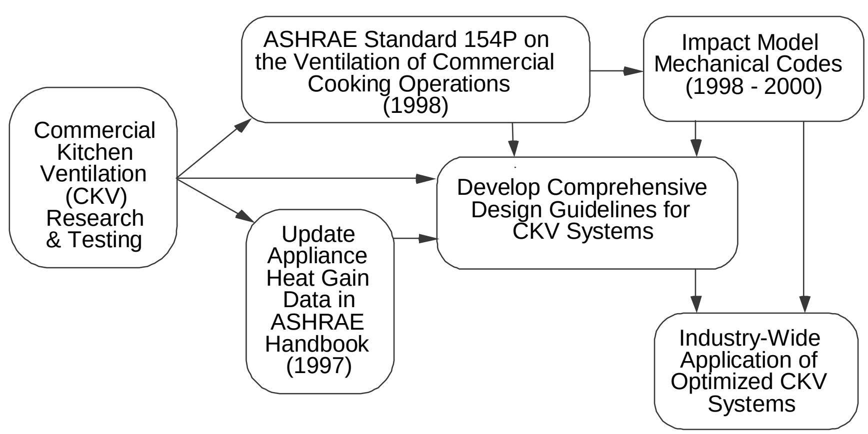


Figure 1-9.
Impact of CKV research on design guidelines.

Kitchen Ventilation Research/Utility Market Needs

The optimum design and operation of kitchen ventilation systems presents a great opportunity for reducing energy consumption and improving the workplace environment within commercial food service operations. However, the development of comprehensive design guidelines for commercial kitchen exhaust ventilation systems that would complement the new ASHRAE Handbook chapter, but targeted towards geographical or regional areas in the U.S. and Canada, is needed. Utility industry R&D efforts should focus on optimizing appliance/hood systems that will reduce both ventilation requirements and kitchen heat gain.

Emissions from Commercial Cooking

Clean Air Act

The Clean Air Act (CAA), first enacted by the U.S. Congress in 1967, oversees and regulates the impact of environmental stresses imposed by industries in the U.S. Most importantly, it facilitates the establishment and implementation of air pollution standards at federal and state levels. The Environmental Protection Agency (EPA) established the national ambient air quality standards (NAAQS) to define the specific levels of air quality that must be achieved for health reasons.

Air Quality Management Districts

The enforcement of the Clean Air Act in the U.S. has been delegated to local government regulatory agencies called Air Quality Management Districts (AQMD's). In areas of non-compliance with the CAA, the AQMD's were first created by state legislation. These local agencies were then mandated to develop strategies to control polluting sources and provide necessary resources to enforce the requirements of the CAA in daily industry operation.

The South Coast Air Quality Management District (SCAQMD) has jurisdiction over the four-county Los Angeles basin that is one of the most severe non-attainment areas in the United States for PM10 (particulate matter less than 10 microns in diameter) and ozone. The combination of severe air pollution and earlier EPA concerns over charbroiling operations gave rise to the first local regulation of restaurant emissions through Rule 219—a regulation requiring permitting of underfired broilers by SCAQMD. This regulation regulated underfired broilers for smoke and odor. This legislation, although still in effect, will be displaced by the more comprehensive Rule 1138 when it is enacted.

Restaurant Emissions

The argument is not that commercial cooking processes contribute to urban air pollution. What is being debated is just how much of the pollution is actually coming from restaurants and, furthermore, from which restaurants it is coming.

The variation in the types of restaurants, the diversity of menus and appliances, and the lack of consensus-based methods for measuring emissions from cooking processes[25] challenge the South Coast Air Quality Management District (SCAQMD) as they try to implement legislation that will reduce the contribution to air pollution from the food service industry in the Los Angeles basin. We can be assured that urban centers with increasing air pollution in both the U.S. and Canada are closely watching California.

A 1994 research report[26] takes a macro look at the picture, concluding that meat cooking contributes to 17% of the total carbonaceous aerosol emissions in the Los Angeles basin. It also was reported[27] that people in the United States consumed about 40% of their meat (including beef, port, lamb, poultry and seafood) in restaurants. If this ratio held true for California, a gross calculation would imply that 17% x 0.4 = 7% of the Los Angeles pollution was due to cooking meat in restaurants.

SCAQMD Restaurant Rule.
RULE 1138. CONTROL OF EMISSIONS FROM RESTAURANT OPERATIONS http://www.aqmd.gov/rules/html/r1138.html

Applicability:

This rule applies to owners and operators of commercial cooking operations preparing food for human consumption. The rule requirements currently apply to chain-driven charbroilers used to cook meat. All other commercial restaurant-cooking equipment including, but not limited to, underfired charbroilers may be subject to future rule provisions.

Requirement:

No person shall operate an existing chain-driven charbroiler on and after November 14, 1999 unless it is equipped and operated with a catalytic oxidizer control device, and the combination charbroiler/catalyst has been tested in accordance with the test method specified in subdivision (g) and certified by the Executive Officer. Other control devices or methods may be used, if found, in accordance with the test method specified in subdivision (g), to be as or more effective than the catalytic oxidizer in reducing particulate matter (PM) and volatile organic compounds (VOC) (as defined in Rule 102) emissions and certified by the Executive Officer.

Exemption:

- Exemption permit will be issued to those cooking less than 875 lb of meat per week.
- Demonstrate emissions from the automated charbroiler is less than 1 lb/day.

Emission Measurement. SCAQMD currently recognizes a modified EPA test method designated Method 5.1, *Determination of Particulate Matter Emissions from Stationary Sources Using a Wet Impingement Train* and a modified EPA test method designated Method 25.1, *Determination of Total Gaseous Non-Methane Organic Emissions as Carbon.*

Grease vapor and aerosols—the constant in restaurant emissions—represent a big part of the challenge as the standard industry test methods are applied to the restaurant exhaust stream. Of the two protocols, Method 5.1 for PM has demonstrated the best repeatability when emission measurements from the same cooking process are replicated. Method 25.1 continues to challenge researchers and source testing experts as they apply this test method to cooking effluent.

Characteristics of Cooking Effluent. The composition of the effluent from different food products being cooked on different types of equipment varies significantly. Furthermore, the composition of a specific food product itself may impact the composition of emission (e.g., 20% versus 30% fat content hamburger patties). A primary component (particularly the visible part) may include fly ash and smoke from the combustion of grease and solid fuels. But grease, existing as both an ultra-fine aerosol and a vapor, is a major component of the emission plume from a meat cooking process.

Best Available Control Technology (BACT). Control strategies that are considered candidates for reducing restaurant emissions include:

- Electrostatic precipitators (ESPs)
- High efficiency filtration/adsorption
- Catalytic converters
- Scrubbers
- Afterburners
- Any type of filtration equipment that reduces emissions
- Change in the cooking process/equipment

The pollutant-removal efficiency of such devices and strategies, when applied to restaurant exhaust, is not well documented. At this time, no consensus-based standard test methods exist for rating the performance of grease extraction or emission control equipment.

Depending on the design and size of the kitchen exhaust ventilation system, installed cost for the emission control package may range from $10,000 to $100,000, with little known about maintenance or durability. The more one pays for the equipment, the better one can expect it to work. But the cost of installing and maintaining an “industrial strength” air cleaning system that will do the job for the next 20 years may be much higher than the restaurant operator is prepared to spend. The food service consultant or engineer faced with specifying such equipment have their work cut out when they take on the design of a new facility where the “authority having jurisdiction” is demanding emission control.

Prognosis

The Restaurant Rule has become a reality in Southern California for restaurants using chain (conveyor) charbroilers. AQMD's in other areas that are in non-compliance with EPA's threshold limits for emissions may adopt similar legislation. High-volume restaurants using underfired broilers will be the next target for legislation.

On the longer term, exhaust ventilation systems with integrated emission control may become standard equipment for restaurants doing business in urban areas in the U.S. and Canada. The reality is that ventilating and controlling emissions from cooking equipment will become an integral cost of doing business in what is becoming a much more technically sophisticated industry.

Conclusions

Appliance energy performance data, which can help a utility implement successful energy conservation initiatives, also can effectively serve a utility's interests as it pursues market retention or expansion in the restaurant sector. The better one understands “how” a cooking appliance or process “performs,” the better one's position with respect to marketing the “use” of that appliance or process.

Overall recommendations include:

- Continuing commercial appliance testing programs (e.g., FSTC) that can be used to further benchmark energy performance in direct support of R&D projects for commercial cooking equipment.
- Using benchmark performance data as justification, developing an industry strategy that will influence the purchase-decision criteria so that customers will specify more energy efficient equipment.
- Developing and sponsoring training courses and workshops for the food service and utility industries based on this appliance technology review.
- Initiating research and development projects that will deliver the greatest return for R&D dollars invested (i.e., that achieve the largest efficiency gain for the largest percentage of equipment installed in food service facilities). The R&D focus needs to be on improving part-load perform-

ance of gas cooking equipment and reducing the cost premium associated with producing more efficient equipment. New equipment needs to be compatible with the NAFEM Online Kitchen Protocol.

- Collaborating with European utilities and research groups (such as Gaz de France) on appliance R&D initiatives.
- Developing a web-based appliance efficiency directory reporting data acquired through testing in accordance with the ASTM Standard Test Methods for evaluating the performance of commercial cooking equipment. Initially, such a directory would rely extensively on the efficiencies reported by FSTC and cover a fraction of the cooking equipment on the market. However, such an initiative would increase awareness in the industry, hence stimulate manufacturers to have their equipment tested in accordance with the ASTM test methods in other U.S. and Canadian laboratories. A natural extension is promoting Energy Star® as a voluntary labeling program.

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