4 Broilers

Introduction

Broilers are the central appliance in many food service operations, both large and small. Depending on size and design, broilers are used for anything from melting cheese to cranking out large cuts of meat in vast quantities.

Underfired charbroilers can cook high volumes of meat and seafood with the characteristic smoke and flame that make them a showpiece as well as a workhorse. They are similar to a barbecue in that food is cooked on a grid placed over a radiant heat source. Uprights, salamanders and cheesemelters are each categorized as overfired broilers; they apply heat to the food from above and produce much less smoke and flame. These broilers range in size and ability from those that are used to broil thick steaks in quantity to those intended for melting cheese and/or browning food. Conveyor broilers apply heat to both the top and bottom of the food as it travels through the appliance on a steel belt. These appliances can broil many different types of food products in a quick, unattended cooking process. As well as incorporating different cooking methods, each type of broiler also varies in size and input rate to best suit its particular application in a given kitchen.

Figure 4-1.
A gas underfired char-broiler with overfired broiler below.
Photo: Magikitch'n

Figure 4-1 shows a typical 3-foot gas underfired charbroiler. This example features a grid below the burners that allows it to be used as a cheesemelter-type broiler as well.

By design, broilers are open to the kitchen and radiate a great deal of heat into the room. They tend to have high energy use and low efficiency, and represent one of the most expensive appliances to operate in a commercial kitchen. In addition, broiling—especially underfired broiling on a charbroiler—produces more smoke than comparable cooking methods by griddles. However, the flavor and appearance of broiled food is distinctive, and is often the selling point on the menu.

A significant innovation to come to market in recent years is the mechanized or conveyor broiler favored by high-volume fast-food chains for its high production capacity. Another innovation is the combination broiler/griddle such as the Clamshell® that is well suited to operations with varied menus such as family-style and steak or seafood restaurants.

Broilers are used to cook steak, fish, chicken, shishkebab and seafood as well as to brown food such as casseroles, to finish au gratin dishes and meringues, to reheat plated food and to melt cheese toppings. The desirable characteristics of broiling are striping (the marks created by the hot grill or "grid"), browning, searing, charring, crisping, and with cheese, melting. Depending on the desired final product, some cooking applications are only appropriate for certain types of broilers. Construction details and specific applications for each type are discussed under Types of Broilers.

Cooking Processes

The terms "underfired" and "overfired" refer to the position of a broiler's heat source relative to the food. In both cases the food is cooked using radiant heat, although the heat source may vary. All broilers use a "grid", which is the grill or grate on which the food is placed for cooking. When the broiler is standing by, the grid absorbs heat from the burners or elements, which is then conducted to the food placed on the cooking surface. In most types of broilers, the grid is hot enough to sear a pattern onto the product, and this is the most visually identifiable characteristic of broiling.

Gas is by far the most common fuel source. Some broilers use electric radiants or elements, and a few charbroilers use coal or wood for heat. Broilers are often idled throughout the day since they require preheating, which may take from 90 seconds to more than thirty minutes, depending on broiler type and design.

Types of Broilers

There are two major categories of broilers: underfired and overfired. Here the overfired category is further divided into uprights, salamanders and cheesemelters, following typical industry usage. Conveyorized broilers, characterized by burners both above and below the food product simultaneously, are treated as a third category. Additional material describes a hybrid broiler/griddle combination.

Underfired Broilers

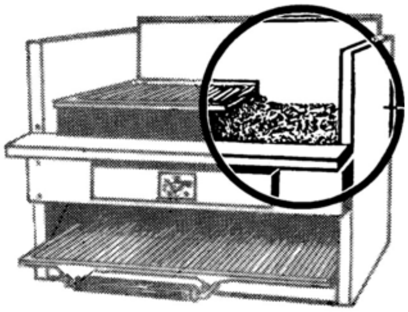

Figure 4-2.
Underfired broiler using rock to diffuse heat.
Photo: Magikitch'n

Underfired broilers are commonly referred to as charbroilers and hearth broilers. They have the highest input rate and production capacity among broiler categories (with the possible exception of some conveyor broilers). They resemble the familiar barbecue, using a heat source below a sturdy metal grid to cook food with a combination of radiant heat, conduction and convection. Charbroilers are showy appliances that produce flames and smoke while cooking, and are often positioned in the kitchen so that these effects will be visible to patrons. The charbroiler marks food with distinctive striping, and the smoke that the broiler creates lends a particular flavor to food. They are widely used to prepare steaks, chops, hamburgers, chicken and fish.

In construction, underfired broilers share several common elements. Food is placed on a metal "grid", a heavy-duty grill like that of a home barbecue. The grid commonly reaches temperatures of over 600°F (320°C) and conducts a significant amount of heat to the food. Below the grid, gas broilers have a set of atmospheric burners spaced every four to twelve inches along the width of the broiler. The flames are diffused by a bed of rock, ceramic briquettes, or a metal shield ("radiant") just above the burners (Figures 4-2 and 4-3). This material between the flame and the food converts some of the flame's energy to radiant heat. Electric charbroilers may have elements interwoven with the bars of the grid, or the elements may be sheathed inside the grid itself, in which case, heat transfer is almost entirely by conduction. As food cooks on an underfired broiler, drippings burn on hot elements, coals or radiants to create the charbroiler's characteristic flame and smoke. Unincinerated drippings are collected in a grease tray.

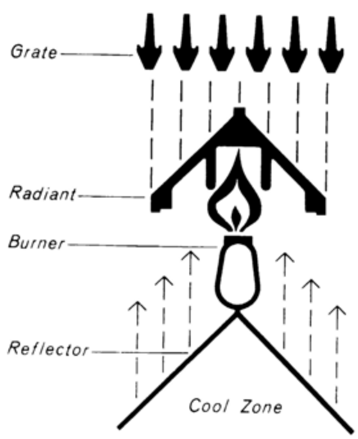

Figure 4-3.
Diagram of the "radiant" style of underfired charbroiler.
Photo: Vulcan-Hart Company

The charbroiler's smoke and flame are both a selling point to patrons and an issue of concern for operators. Charbroilers require significant ventilation, and in some areas the effluent from charbroiling is a focus for Air Quality Management District (AQMD) regulations. The design of the grid may affect smoke and flare up. Several manufacturers produce a grid made of bars that, in cross section, resemble a check mark: √. Each bar is said to act like a small gutter for grease, carrying it away from the flames and directing it towards the grease pan.

Grease also may be diverted by tilting the grid. Several broilers have a grid that slants toward the cook, or is adjustable between flat and tilted positions. This provides a temperature gradient from the front to the back of the broiler as it promotes grease runoff. One manufacturer uses a fan to blow air across the bed of ceramic coals to reduce flare up, and several more use water-filled grease pans.

Figure 4-4.

This broiler can be converted from ceramic stone to steel radiants.

Photo: Magikitch'n

Design of the heat source also may influence smoke and flare up. Gas charbroilers have traditionally diffused the burner's flames with a uniform layer of rock or ceramic coals that convert the flame's heat into radiant heat. A metal radiant directly over the burner and a reflector under it may allow more of the drippings to fall into the grease pan without burning, and shield the grease pan from the heat of the flame. This design has the additional benefits of eliminating the need to replace rock or coals periodically, while providing a faster preheat time. One manufacturer has addressed the situation by offering a broiler that is able to convert from ceramic stone to steel radiants (or vice versa) depending on the chef's preference (Figure 4-4). This conversion is in the form of a kit that can be installed by the operator.

Griddle manufacturers offer griddles with grooved plates as an alternative to charbroilers. These griddles sear food with the characteristic stripes of a broiler, but create no flame, produce far less smoke and use energy more efficiently than a broiler does; additionally, they radiate less heat into the kitchen and require less ventilation.

Overfired Broilers

Overfired broilers differ according to their typical uses and energy inputs. The highest input overfired broilers may be used to broil inch-thick steaks in volume, while those with the lowest input are designed specifically to warm food, melt cheese toppings and finish dishes by browning the top. All overfired broilers cook with a heat source that is positioned above the food, but there are three generally recognized categories delineated by the broiler's input rating and physical configuration. Upright broilers are high-input and generally freestanding. Cheesemelters are low-input broilers that may be countertop, wall mounted or installed above a rangetop. Salamander broilers span the input range between cheesemelters and uprights, and are usually mounted at eye level above a rangetop.

As is apparent from the data in Table 4-1, there is some overlap in the typical input ranges for the three categories of overfired broilers discussed below. In addition, manufacturers and operators may use several different terms to refer to the same category: "upright" broilers are also known as hotel broilers and floor broilers; "salamanders" are also called backshelf broilers.

Table 4-1. Typical Grid Dimensions, Input Rates and Input Densities for Underfired and Overfired Broilers.

Type of Broiler	Fuel	Grid Depth (in.)	Grid Width (in.)	Rated Input (kBtu/h)	Input Density (kBtu/h per ft^2)
Underfired	*gas*	14 – 35	13 – 122	30 – 240	16.7 – 28.8
	electric	18	18 – 30	21 – 46	3.0 – 6.6
Upright	*gas*	24 – 30	24 – 28	65 – 100	15.3 – 20.4
	electric	23	26	41	5.9
Salamander	*gas*	12 – 14	21 – 28	30 – 66	12.0 – 19.6
	electric	13 – 14	25	17 – 20	2.5 – 2.9
Cheesemelter	*gas*	13 – 15	24 – 70	18 – 60	7.8 – 10.1
	electric	13	20 – 42	8 – 16	1.2 – 2.4

Despite their differences, the three types of overfired broilers follow a similar plan. Food is cooked in a broiler cavity that resembles an oven without a door. The heat source may be gas radiants, infrared burners or electric elements mounted in the top of the cavity. Food is placed on top of a grid, which can usually be adjusted to vary the distance between the food and the heat source. Cooking is accomplished by radiant heat from above the food and heat conducted from the grid to the food. Below the food there is a grease pan to catch drippings.

An overfired broiler typically has a lighter-weight grid than a charbroiler, and the grid is shielded from the elements or burners when it is covered with

Figure 4-5.
Overfired upright broiler with two broiling decks.
Photo: Vulcan-Hart Company

product. The grid may not receive and retain as much heat from the burners as a charbroiler grid does, making conductive heating less significant in an overfired broiler.

The radiant heat in an overfired broiler is generated with electric elements, gas infrared burners or gas radiants. Some manufacturers use powered burners that force premixed gas and air through a ceramic infrared burner. The high heat generated by ceramic infrared burners may incinerate some of the smoke and grease that is formed during broiling and grease does not drip onto hot coals or radiants, thus overfired broilers produce less smoke than underfired broilers.

Upright Broilers. Upright broilers are heavy-duty freestanding overfired broilers. Their high input is in the same range as that of a charbroiler, and they can be used to prepare foods like steak and chicken quickly and in large quantities. They have the highest input rate and production capacity among overfired broilers. Manufacturers commonly offer two identical broiler cavities or "decks" stacked vertically as one unit (Figure 4-5). The grids slide out for loading and unloading, and can be raised towards the infrared burners in the top of the cavity or lowered for slower cooking. Two knobs on the left of the cavity control input to the burners. Ovens may also be stacked with an upright broiler. Some manufacturers mount a finishing oven above an upright broiler so that the heat source at the top of the broiler cavity doubles as a heat source in the bottom of the oven cavity.

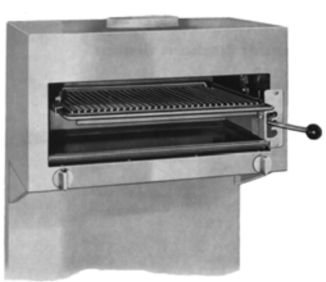

Figure 4-6.
A salamander broiler, mounted on a backshelf.
Photo: Garland

Uprights are constructed for heavy use. The grid is usually counterbalanced so that it can be easily raised and lowered to adjust cooking temperature. It also may pull out on slides against safety stops for loading and unloading. Uprights usually stand on a cabinet-style base, and some "modular" uprights can be placed on a stand or a countertop.

Salamanders. Salamanders are medium-duty overfired broilers. Their input range slightly overlaps that of both uprights and cheesemelters, but they are designed to fit above a rangetop on a backshelf. The broiling cavity is as wide as an upright's but not as deep, typically 12 inches (300 mm) instead of 24 inches (600 mm) deep. A typical salamander broiler is illustrated in Figure 4-6. Salamanders generally have a lower input rate to match their smaller size, and deliver slightly less energy to each square foot of the grid. They are intended to prepare the same range of foods as a high-input upright broiler, but at lower volume and without occupying floor or counter space.

In construction, the salamander closely resembles the upright broiler, but is often of lighter weight construction and materials. The grid is not as heavy, although it is usually counterbalanced and capable of sliding out for loading. Although salamanders are generally defined as medium-input broilers mounted on the backshelf of a range (as in Figure 4-6), some manufacturers advertise salamanders that also can be wall mounted or set on a countertop.

Figure 4-7.
A cheesmelter.
Photo: U.S. Range

Cheesemelters. Cheesemelters have the lowest input rate among overfired broilers, and are generally used to melt the cheese on top of foods such as Mexican and Italian dishes, pie and French onion soup. They are usually incapable of fully cooking food items like steak and chicken, and do not have grease pans to catch fat and drippings. In appearance they resemble salamanders, although they are generally smaller and have a more lightweight construction (Figure 4-7). This type of broiler is intended for a limited set of tasks, and so the grill adjustment is usually not as sophisticated as it is for other overfired broilers. The grid is a thin grill, which may not adjust to as many positions as a salamander's; in some cheesemelters it is fixed. It is not usually counterbalanced or mounted on slides, and typically does not have an external handle.

Figure 4-8.
Broiler range battery.
Photo: Vulcan-Hart Company

Cheesemelters may be mounted on a wall, a counter or on a backshelf like a salamander. Some cheesemelters are designed with the cavity open both front and back for use as a heated pass-through shelf. Some charbroilers include a cheesemelter underneath the burners to make use of the heat that is radiated downwards by the briquettes or rocks; cheesemelters may be incorporated in a similar fashion underneath the burners of a griddle in a restaurant range. Figure 4-8 shows a small griddle with an overfired broiler incorporated below it, as part of a range battery.

Conveyor Broilers

Conveyor or “chain” broilers employ both an overfired and an underfired heat source, cooking both sides of the food product at once. These broilers

Figure 4-9.
Conveyor broiler.
Photo: Nieco Corporation

are ideally suited to broiling hamburger patties in large quantities. Model sizes range from small, tabletop broilers favored by convenience stores to large-capacity broilers for fast-food operations. Conveyor broilers are available with an additional section specifically for toasting buns. Multiple-chain models are available so that more than one size patty or meat product such as chicken, steaks or hamburgers can cook at the same time. Instead of a chain, some models use a Teflon belt; this requires an optional “marking platen” to sear broiling stripes onto the food product. Conveyor broilers are available in both gas and electric models. Figure 4-9 shows a typical gas conveyor broiler.

Broiler/Griddle Combination Hybrids

Like conveyor broilers, combination broiler/griddles function as two-sided cookers. The unique Clamshell® broiler features a 24-inch (600 mm) wide stainless steel, infrared broiler-hood mounted on the left end of a griddle. This combination allows the operator to simultaneously grill, poach, broil, and sauté a variety of foods, ranging from breakfast menus to dinner entrees: lobster, oysters, shrimp, sandwiches, egg dishes, steaks, chops, and hamburgers.

Both gas and electric units are available in floor and countertop models. In addition to the flat-griddle plate, the manufacturer also offers a grooved-griddle plate and a combination grooved/flat plate.

Figure 4-10.
Gas combination griddle-broiler.
Photo: Lang Mfg. Co.

The gas broiler hood features a single infrared burner rated at 35,000 Btu/h that covers approximately four square feet of surface area. This model has a “marking grid”, a thin grill that when contacting the food, sears broiler stripes onto the product. The electric version is similar to the gas model, but uses quartz-halogen tubes as a source of infrared heat.

Lowering the broiler hood activates the burners automatically. When the hood is lowered, it is “full” on. No preheat time is required. When the hood is in the raised position, the burner is off. In the lowered position, there is a 3-inch (75 mm) gap between the broiler hood and the griddle surface. The Clamshell griddle-broiler is shown in Figure 4-10.

Controls

Most broilers do not have thermostats or timers to control the cooking process, and so demand the attention and experience of the operator. The amount of heat transferred to the food is adjusted by regulating the energy input to the broiler and changing the placement of the grid, or the food on the grid. Operators become familiar with hot and cold areas on the grid through experience, and these may be varied by adjusting the height of the grid in overfired broilers and by slanting the grid in some underfired charbroilers. Input is regulated manually with one or two controls on overfired broilers and often one control per burner on charbroilers (typically 2 burners per foot of broiler width).

Figure 4-11.
Underfired broiler with 9 control knobs.
Photo: Baker's Pride, Ltd.

The underfired gas charbroiler pictured in Figure 4-11 has one control for each burner; some charbroilers group burners into one or several zones. Total input for this 3-foot (900 mm) broiler is 126,000 Btu/h, a typical input rate for this type of broiler. Overfired broiler controls are simple, usually one or two knobs to adjust banks of elements or burners; like charbroilers, overfired broilers are not thermostatically controlled.

Conveyorized broilers are an exception in that they employ more sophisticated controls. With this type of broiler, the cook time and temperature are selected by the operator. Some conveyorized broilers have cooking computers that store time and temperature parameters for several products so that the operator need only load the broiler and press the appropriate button.

Energy conservation strategies

Broilers usually idle at full input so that they are ready to cook the instant they are needed. As a compromise between readiness and economy, some operators turn down the input to the broiler or turn off some sections altogether during slow periods; this can save significant amounts of energy. Some manufacturers have designed broilers with a weight-sensitive feature that turns the broiler down or off entirely until food is placed on the grid, when the broiler returns to full input. So far this strategy has been applied to a few of the smaller overfired broilers (salamanders and cheesemelters).

One manufacturer made an accessory for gas charbroilers that allowed broilers to idle at less than their full input rate without incurring a significant preheat time.[1] The "Broil-Master®" reduced gas flow when the broiler was on, but not cooking. When the operator was ready to cook, he pushed a button that restored full input to the broiler. The Broil-Master maintained this rate for a specified amount of time (e.g. 10 minutes) that covers most cooking events. If more food product was added to the grid, the operator pushed the button again to continue cooking. Results from in-kitchen testing of the Broil-Master control at Pacific Gas and Electric Company's production test kitchen are presented in the Broiler Performance section of this chapter.

Broiler Performance

Since broilers are not thermostatically controlled and manufacturers have established input rates based on peak production (i.e., high broiling temperatures that minimize cook time), they typically consume energy throughout the day at a rate that is close to their maximum input (e.g. 90% duty cycle). The end of a cooking event does not automatically return the broiler to an "idle" state, unlike other appliances that consume less energy to maintain a set temperature once the food load is removed. Furthermore, a charbroiler's flame does not remind the operator to turn the broiler off between loads because it is partially concealed beneath the grid and/or coals. Thus, a cooking-energy efficiency measured over the time span of the cooking event has less meaning for broilers than for other cooking appliances. However, measured discrete-load cooking energy efficiencies provide a benchmark as efforts are made to improve the performance of broilers.

The body of published information regarding broiler performance is rather thin, save for a 1983 University of Minnesota Comparative Gas/Electric Food Service Equipment Energy Consumption Ratio Study.[2] Partial results of this study, based on several gas and electric underfired charbroilers, is presented in Table 4-2.

Table 4-2. Underfired Broiler Cooking-Energy Efficiency.

	Gas	Electric
Cooking-Energy Efficiency (U of M method, %)	15 - 30	35 - 65

More recently, the Food Service Technology Center in San Ramon, California has developed test methods for the performance of underfired, overfired and conveyor broilers. The underfired broiler test method has been adopted as an official ASTM Test Method.[3] The test methods for overfired and conveyor broilers are in the process of ratification by ASTM. These test methods quantify all aspects of broiler performance—energy input rate, preheat energy consumption and time, idle energy rate (if applicable), cooking energy rate, cooking-energy efficiency, production capacity, temperature distribution—even the pilot energy rate on gas broilers equipped with standing pilots.

The following sections give an overview of the different aspects of the underfired charbroiler test method, although most of the concepts apply to all broiler categories.

Energy Input Rate

As previously shown in Table 4-1, the energy input rate of a broiler varies with broiler width and burner (input) density. The ASTM test method measures energy input rate to verify the manufacturer's nameplate rating and confirm that the broiler is operating properly.

Temperature Distribution

The ASTM test method measures the surface temperature distribution of an underfired broiler using ¼-inch thick carbon steel disks with thermocouple wires attached to their geometric centers (Figure 4-12). The broiler is operated at its full input rate and the average temperature of each disk is reported. The data can then be presented in a uniformity plot, as shown in Figure 4-13.

The plot in Figure 4-13 shows a substantial temperature drop off towards the front of the cooking surface, which is not unusual for broilers. Where a griddle may see a maximum difference of 50°F across its entire surface, a temperature variation of 200°F or more across the cooking area of a broiler would be considered normal. While at first this may sound like a problem, this temperature difference is often used to the operator's advantage. An experienced cook will place more delicate items such as chicken or shrimp on the cooler areas of the broiler, and use the hottest spots for heavier items, such as steaks or chops.

Figure 4-12. Thermocoupled steel disks.

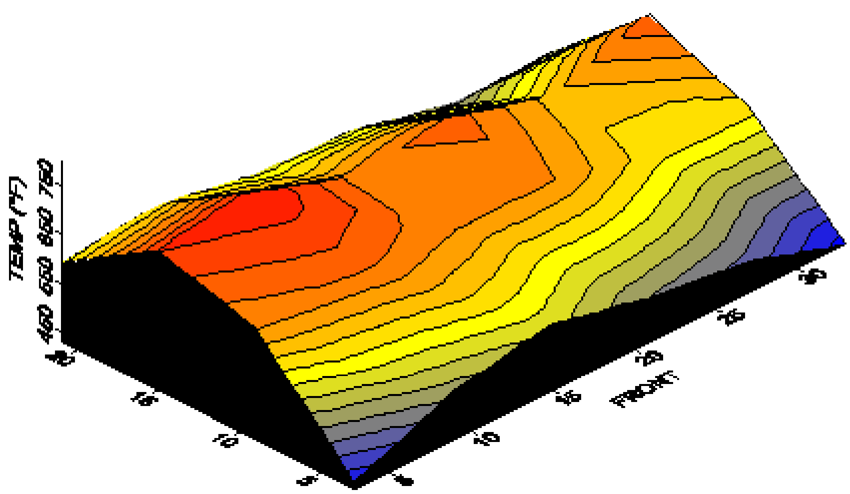

Figure 4-13. Underfired broiler temperature uniformity plot.

On the other hand, this introduces a learning curve for the operator that may be undesirable in certain operations, such as those with high employee turnover or operations utilizing entry-level cooks.

Preheat Energy Consumption and Time

While the energy used during preheat is relatively small when compared to the overall daily energy consumption of a broiler, the preheat time gives an accurate indication of how long the broiler needs to operate before it is ready for use. For gas underfired charbroilers, preheat times are typically 15 to 20 minutes.

Idle Energy Consumption

At the present time, almost every broiler type operates at or near its maximum input at all times. The exceptions, whose designs allow some type of energy rate reduction during periods of non-cooking, would be conveyor broilers and some of the lighter weight salamander/cheesemelters. So while most broilers would not need to have an idle energy rate test applied to them, the procedure is being incorporated into the ASTM Test Method in anticipation of new designs that allow a lower idle energy rate.

Cooking Energy Rate and Efficiency

The cooking energy rate indicates the rate of energy consumption during the cooking process. On an underfired broiler, this rate will be constant, since there is no cycling of the burners or heating elements as on most other appliances. To determine the energy efficiency of underfired broilers, the ASTM Test Method specifies cooking tests that use $^{1}/_{3}$-pound hamburger patties as the food product. Cooking-energy efficiency is the ratio of energy added to the patties and the total energy supplied to the broiler during cooking:

$$\textit{Cooking-energy efficiency \%} = \frac{E_{food}}{E_{appliance}} \times 100\%$$

Figure 4-14 shows the cooking energy efficiencies of several 3-ft gas underfired charbroilers tested in accordance with the ASTM Test Method.[4,5]

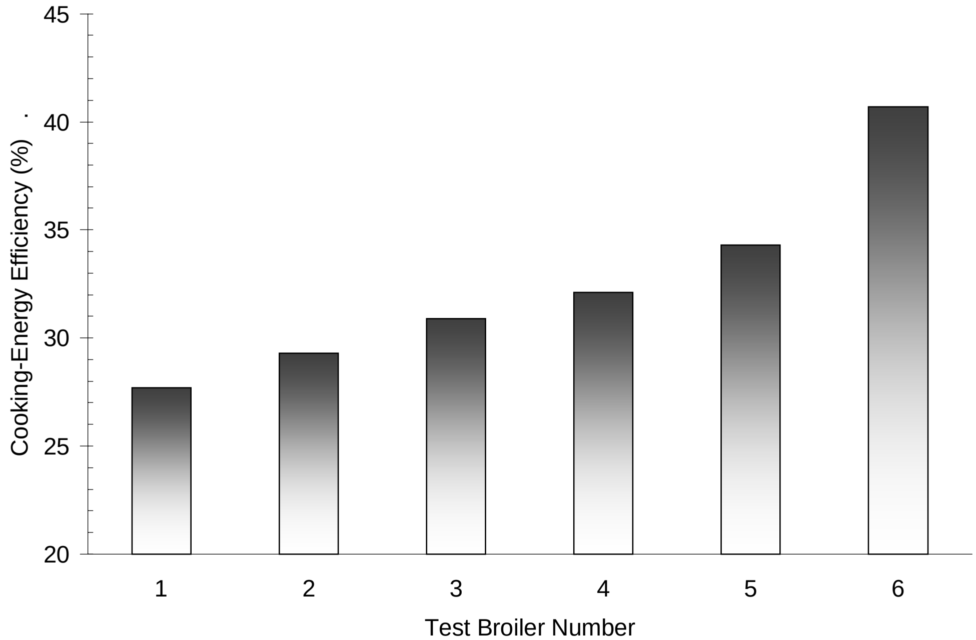

Figure 4-14.
3-ft. gas underfired charbroiler cooking-energy efficiencies.

These cooking-energy efficiencies were determined from cooking discrete loads of hamburger patties. However, the real-kitchen cooking-energy efficiency drops dramatically as the energy consumed by the broiler during periods of non-cooking is factored into the denominator of the energy efficiency equation.

For example, Pacific Gas and Electric Company's in-kitchen performance testing showed a gas underfired broiler used to cook 100 lb (45 kg) of food over an 8-hour period could consume 600 kBtu of energy.[6] Estimating that 300 Btu was required to cook each lb (kg) of food,[2] the total energy input to the food product over the eight-hour period would be only 30 kBtu. This translates to a real-world cooking-energy efficiency of only 5%, significantly less than the 25-35% efficiencies reported for discrete-load tests (Table 4-2 and Figure 4-14). Restated, only 5% of the energy consumed by an underfired broiler in an actual kitchen is delivered to the food product. The potential for energy-efficiency performance improvements in the design and usage of broilers is obvious.

Production Capacity

Production capacity indicates the amount of food (by weight) that can be cooked on a broiler in a given amount of time. Since the ASTM Test Method uses hamburger patties for the test product, production capacity is the weight, in pounds, of hamburger patties that can be cooked by the broiler in one hour (lb/h). This number is dependent on the size of the broiler and the length of the cook time. The production capacities of several gas underfired charbroilers are shown in Figure 4-15.[4,5]

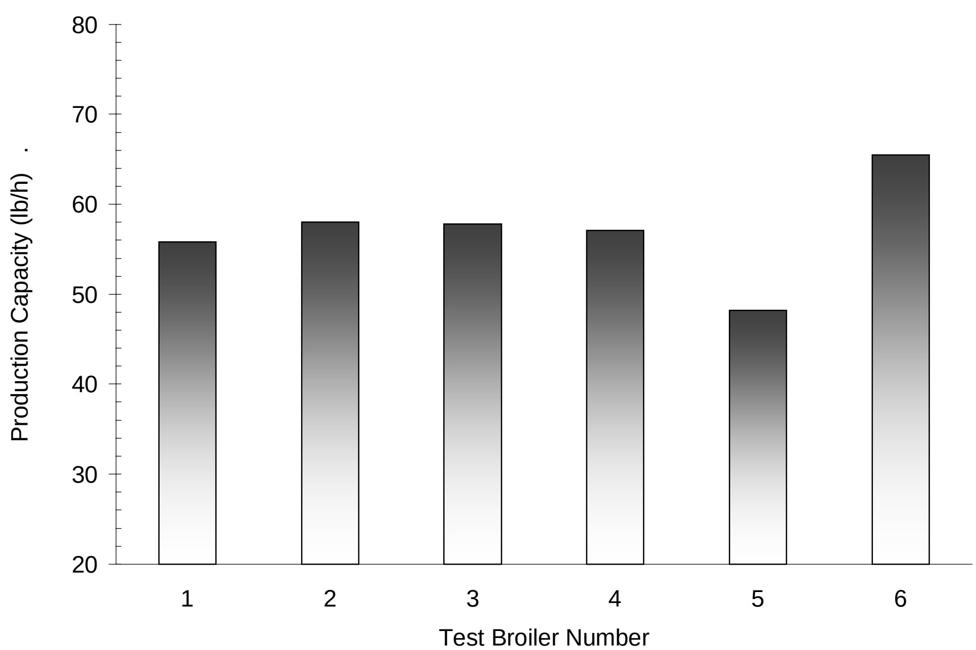

Figure 4-15.
3-ft. gas underfired charbroiler production capacities.

Broiler Energy Consumption

Projected energy consumption for gas and electric broilers are presented in Table 4-3 and 4-4. Based on Pacific Gas and Electric Company's in-kitchen monitoring at its production test kitchen, average energy consumption rates for underfired gas and electric broilers reflect duty cycles of 90% and 82%, respectively.[6-9] An appliance's duty cycle can be 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. Daily energy consumption for broilers was calculated by multiplying the median rated input for each broiler category by the respective duty cycle and the hours of operation. Projected annual energy consumptions were determined by assuming 6-day operations for 52 weeks.

Table 4-3. Projected Energy Consumption for Gas Broilers.

	Nominal Size	Rated Energy Input (kBtu/h)	Duty Cycle (%)	Avg. Energy Consumption (kBtu/h)	Typical Operating Hours (h/d) [a]	Annual Energy Consumption (kBtu) [b]
UNDERFIRED:						
Charbroiler	3 ft.	90-120				
(Median)		105	80 [c]	84	8	210,000
OVERFIRED:						
Upright	3 ft.	80-110 [d]				
Salamander	3 ft.	28-49				
Cheesemelter	3 ft.	20-39				
(Median)		65 [e]	70 [f]	46	8	115,000

[a] Operating hours or appliance "on time" is the total period of time that an appliance is operated from the time it is turned "on" to the time it is turned "off".
[b] The annual energy consumption calculation is based on the average energy consumption rate x the typical operating hours x 6 days per week x 52 weeks per year.
[c] The average energy consumption rate and typical hours of operation are based on data from monitoring two 3-ft gas charbroilers in a real-world food service operation.[6,7] An associated duty cycle of 80% was calculated .
[d] Typical range for single-deck overfired broiler.
[e] The median energy input rate for overfired broilers is based on the ranges for upright broilers, salamanders and cheesemelters.
[f] A 70% duty cycle has been assumed for overfired broilers based on the assumption that the usage pattern is somewhat less than underfired (e.g., charcoal) broiler operations. Also, typical operating hours were assumed to be the same for both appliance types.

Table 4-4. Projected Energy Consumption for Electric Broilers.

	Nominal Size	Rated Energy Input (kW)	Duty Cycle (%)	Avg. Energy Consumption (kW)	Typical Operating Hours (h/d)[a]	Annual Energy Consumption (kWh)[b]	Annual Energy Consumption (kBtu)[c]
UNDERFIRED:							
Charbroiler	3 ft.	10 - 12			6 - 14		
(Median)		11	70 [d]	8	10	24,960	85,200
OVERFIRED:							
Upright	3 ft.	11 – 17 [e]					
Salamander	3 ft.	5 - 12					
Cheesemelter	3 ft.	2 - 6					
(Median)		10 [f]	70 [g]	7	10	21,840	74,500

[a] Operating hours or appliance "on time" is the total period of time that an appliance is operated from the time it is turned "on" to the time it is turned "off".
[b] The annual energy consumption calculation is based on the average energy consumption rate x the typical operating hours x 6 days per week x 52 weeks per year.
[c] Conversion Factor: 1 kW = 3.413 kBtu/h.
[d] The average energy consumption rate and typical hours of operation are based on data from monitoring two 3-ft electric charbroilers in a real-world food service operation.[8,9] An associated duty cycle of 70% was calculated .
[e] Typical range for single-deck overfired broiler.
[f] The median energy input rate for overfired broilers is based on the ranges for upright broilers, salamanders and cheesemelters.
[g] An 70% duty cycle has been assumed for overfired broilers based on the assumption that the usage pattern is similar to underfired (e.g., charcoal) broiler operations. Also, typical operating hours were assumed to be the same for both appliance types.

Broil-Master® Control

The Broil-Master® control was evaluated over a 6-month period in a “before and after” installation on a 3-foot (900 mm) underfired charbroiler in Pacific Gas and Electric Company’s production-test kitchen.[1] With the control set to reduce the energy rate by 65%, monitoring showed that average energy consumption was lowered from 112,000 Btu/h to 83,000 Btu/h. This reduced the broiler’s duty cycle from over 90% to 70%. Unfortunately, the Broil-Master is no longer available, but the results of its performance are encouraging when considering the design of a broiler with turndown technology. Results of the Broil-Master testing are presented in Table 4-5, Figure 4-16 and Figure 4-17.

Table 4-5. Summary of Broil-Master® Energy Saver Performance.

	Without Energy Saver	With Energy Saver
Direct-fired Broiler [a]		
Data Collection	Sept-Dec 1994	Jan-Mar 1995
Days in Data Set	39	22
Production Energy Use (kBtu/day) [b,c]	1,270	839
Appliance On-Time (h/day)	11.3	10.1
Average Production Energy		
Consumption Rate (kBtu/h)	112	83.2
Duty Cycle (%)	94	70

[a] 65% energy input reduction, 10-minute timer “on time.”
[b] Energy consumption is based on an average gas heating value during the monitoring period.
[c] Includes preheat and idle energy over the hours of operation when the broiler was in use.

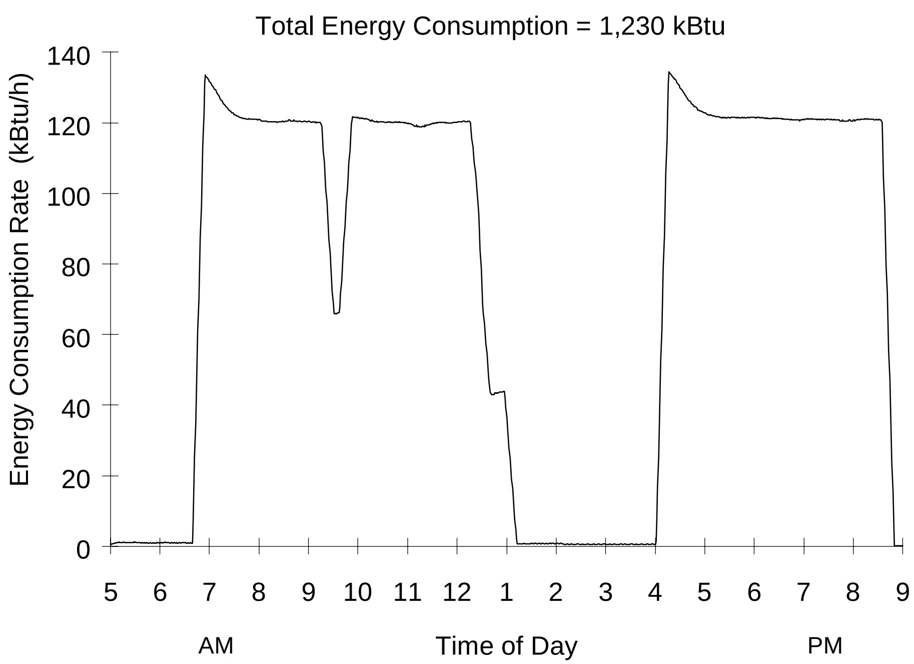

Figure 4-16.
Direct-fired broiler energy consumption profile before installation of the Broil-Master control.

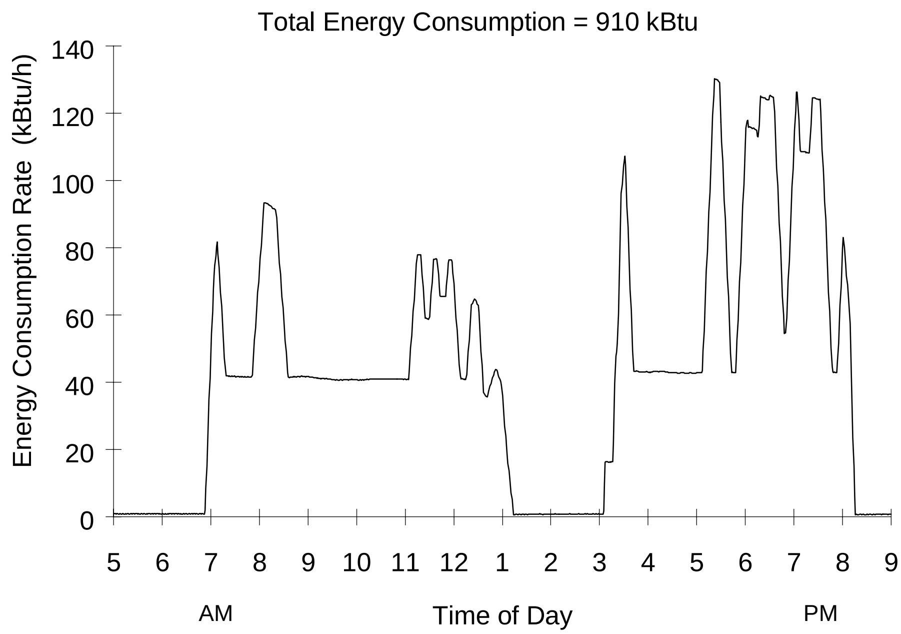

Figure 4-17.
Direct-fired broiler energy consumption profile after installation of the Broil-Master control.

Ventilation Requirements

The ventilation requirements for underfired broilers are greater than for other categories of cooking equipment, with the exception of woks and solid-fueled appliances. For example, typical ventilation rates for gas charbroilers operating under wall-mounted canopy hoods are in the range of 350-450 cfm (540-700 L/s) per linear foot of hood.

The radiant heat gain to the kitchen from broilers contributes significantly to the cooling load of a kitchen. Research has shown that an underfired broiler operating at an average energy rate of 78,000 Btu/h can radiate as much as 20,000 Btu/h to the surrounding space. This could represent several tons of additional cooling for a 3 to 4-ft (900 mm to 1220 mm) charbroiler.[10]

Research and Development

The high rate of energy consumption and associated low energy efficiency for gas broilers suggests that research and development efforts could quickly benefit the food service industry. The Food Service Technology Center was commissioned by Enbridge Gas Distribution to identify the elements of an advanced gas underfired charbroiler.[5] The advanced broiler project, conducted in collaboration with the Gas Technology Institute (GTI), will evaluate different technologies and designs in order to develop a gas underfired charbroiler that exhibits a marked increase in energy performance. While the goal of the project is to produce an advanced underfired (char) broiler, it is anticipated that the design of other broiler types may benefit from the research as well. Desirable characteristics of an advanced underfired broiler would include:

Improved Uniformity. Reduced variation in temperature across the cooking grid and more precise control over temperature in individual sections.

Reduced Energy Consumption. Allow the broiler to lower its energy input during idle periods and increase its energy efficiency during cooking.

Reduced Heat Gain. Increase operator comfort and potentially reduce the cooling load for the kitchen.

Lower Emissions. Reduce grease and smoke emitted by broiler.

Food Quality. Maintain the signature “charbroiled” food characteristics.

Research issues related to developing an advanced broiler include:

Grid/Burner/Heat Shield Design. Determine what characteristics allow optimal combination for highest energy and cooking performance.

Temperature Feedback. Determination of type and location of temperature sensing to allow temperature feedback from broiler.

Load Sensing. Allow detection of cooking and non-cooking periods.

Gas Valves/Burners. Modulating gas valves to allow turn down during idle when coupled with load sensing.

Control. Allow temperature adjustment, broiler turn down and communication compliant with NAFEM’s online kitchen protocol.

Lids. An optional lid to further energy reduction during idle, and potentially increase cooking performance. Explore the addition of forced convection or an air curtain for reduced cook times.

Integrated Ventilation. Develop a close-coupled integrated exhaust hood that can capitalize on reduced ventilation requirements during idle periods.

Industry Market Focus

Broilers represent a substantial load to gas utilities. In gas service territories, the electric broiler does not present a competitive advantage over gas equipment. However, the intense energy requirements of gas broilers and their potential (real or perceived) to contribute to urban air pollution could be considered a market threat. Conversely, the even more severe fuel costs and emissions from solid-fuel charbroilers present a marketing opportunity for gas broilers. In air-quality sensitive cities (e.g., Los Angeles), the future for solid-fueled appliances does not look good. Over the short term, gas broilers and rotisseries may represent a viable option to solid-fueled equipment (This is the strategy being adopted by The Keg and Swiss Chalet in Canada). However, the long-term viability of gas-fired broilers may be dependent on the design of more environmentally friendly equipment.

There is a clear need for gas utilities to promote energy-efficient broiler technologies to keep high operating costs from impacting negatively on the economic viability of a customer. In this vein, the gas industry needs to support development of broiler designs that are more environmentally friendly. With improved design, controls and operation, broilers could in fact, be more energy efficient than alternative appliances. Griddles, for example, will always have significantly less stand-by energy requirements.

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Information in this module also references Manufacturers Product Literature, catalogues, and appliance specification sheets.