

# Delicatessen Appliance Performance Testing

FSTC Report 5016.95.23

Food Service Technology Center Manager: Don Fisher  
Final Report, October 1995

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The information in this report is based on data generated at PG&E's Food Service Technology Center.

## Acknowledgments

The establishment of a Food Service Technology Center reflects PG&E's commitment to the food service industry. The goal of the research project is to provide PG&E's customers with information to help them evaluate technically innovative cooking appliances and make informed equipment purchases regarding advanced technologies and energy sources. The project was the result of many people and departments working together within PG&E and the overwhelming support of the commercial equipment manufacturers who supplied the cooking appliances for testing.

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## Executive Summary

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A major supermarket chain asked PG&E to test the energy efficiency of the appliances it uses at 900 of its in-store delicatessens in the United States and Canada. PG&E's marketing and sales employees worked with the Food Service Technology Center (FSTC) in San Ramon, California, to test combination ovens, fryers, and rotisseries.

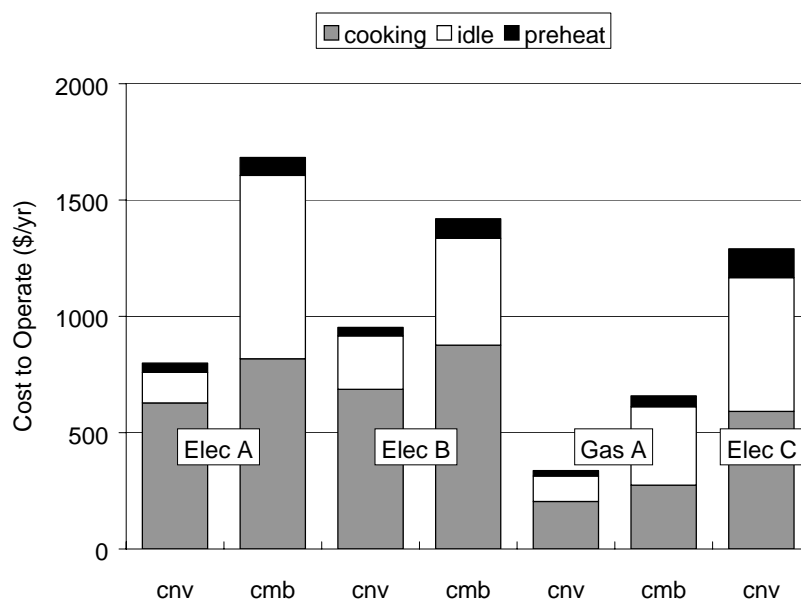
Fifteen appliances were tested under tightly controlled laboratory conditions, using the food products typically cooked at the customer's delis. The appliances include one electric cook-and-hold oven, three combination ovens (one gas and two electric), four kettle fryers (one gas and three electric), four pressure fryers (two gas and two electric), and three electric countertop rotisseries.

Energy consumption and cooking performance were evaluated, along with product features such as ease of use and cleanability. The ovens and rotisseries were tested with whole seasoned chickens and the fryers with breaded chicken pieces. FSTC researchers cooked more than 400 chickens and fried 300 pounds of drumsticks, breasts, wings, and thighs. And while some taste testing was part of the study, the majority of the chicken was donated to food kitchens in the area.

In addition to laboratory test data, the FSTC provided comparative cost analyses for different methods of cooking. The energy cost models were based on a 365-day operating year. These analyses will help the customer make better purchasing decisions by factoring appliance performance in with other necessary considerations, such as usability, reputation, and first cost.

## Executive Summary

The energy cost model for the combination ovens was based on cooking 80 whole chickens in two cycles for lunch and dinner. The model's typical day included 4.5 hours of idle time and one preheat. Figure ES-1 illustrates the cost differences between the combination ovens (Elec A and B, Gas A) and the cook-and-hold oven (Elec C). The combination ovens used significantly less energy in the convection mode. Unless the increased benefits of combination cooking (i.e., product yield, cook time) are required, the ovens should be used in the convection mode.



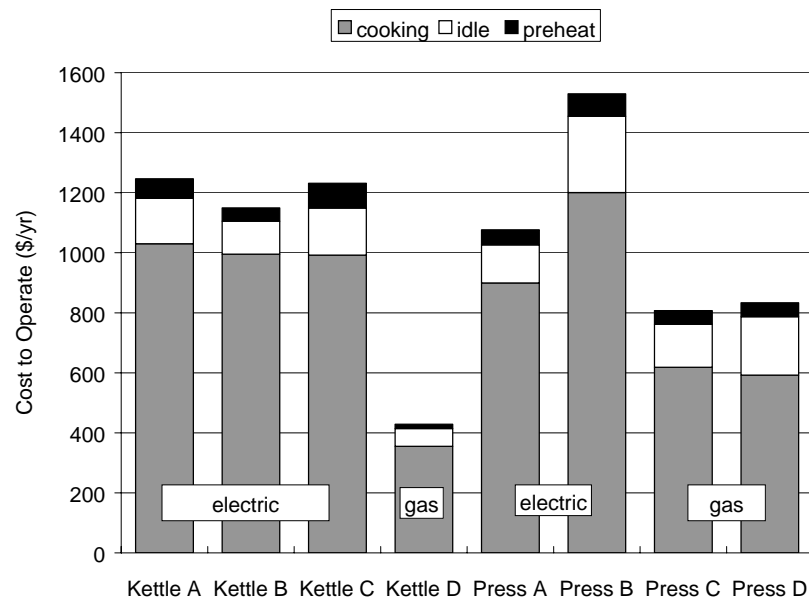
**Figure ES-1.**  
**Oven annual cost of operation.**

Notes: 1. Cost to operate is based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances.  
2. Combination ovens are Elec A, Elec B, Gas A. Cook-and-hold oven is Elec C.

The energy cost model for the fryers was based on cooking 150 pounds of chicken during the day. The model's typical day included 6 hours of idle time and one preheat for each fryer. Figure ES-2 illustrates the kettle and pressure fryers costs of operation. Kettle Fryer D had the lowest operating

## Executive Summary

cost and a competitive production rate (33 pounds per hour). In general, the pressure fryers had higher productivity than the kettle fryers, but this did not necessarily translate to a lower operating cost.



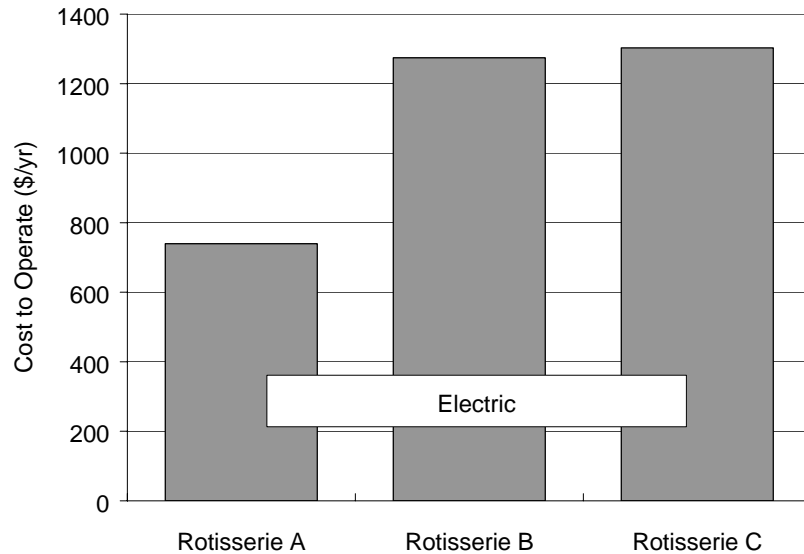
*Figure ES-2.  
Fryer annual cost of operation.*

Note: Cost to operate is based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances.

The energy cost model for the rotisseries was based on cooking 60 whole chickens per day. The model did not include idle cost because the units are turned off when not in use. This is an appropriate assumption since the rotisseries are placed in the front of the deli as display cookers. Likewise, the model did not include preheat cost because the chickens can be loaded into a cold rotisserie. Figure ES-3 illustrates the cost differences. Rotisserie A had a substantially lower operating cost because of its convection mode of heating (the other rotisseries used radiant heat only) and its much larger capacity (nearly double).

# Executive Summary

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*Figure ES-3.  
Rotisserie annual cost  
of operation.*

Note: Cost to operate is based on \$0.10/kWh.

Estimated costs are based on PG&E’s average energy costs: \$0.10/kWh for electricity and \$0.62/therm for gas. These rates are appropriate for the purpose of this PG&E study. The cost of gas and electricity will vary in other parts of the United States, and this will affect the operating cost of the appliances. Equipment selection should be based not only on estimated cost of operation but also on such as factors productivity, functionality, ease of use, cleanability, and first cost.

FSTC Manager

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# 1 Introduction

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## Background

The work force in the 1990s has less time and interest in preparing meals at the end of the day. Supermarkets are tapping into this market by offering precooked meals, such as roasted and fried chicken. Selecting cooking equipment to prepare these items at a minimal cost but with good performance increases the store's bottom line.

Earlier this year, a major food service customer asked PG&E to test the energy efficiency of the appliances it uses at 900 of its in-store delicatessens in the United States and Canada. PG&E's marketing and sales employees worked with the Food Service Technology Center (FSTC) in San Ramon, California, to test combination ovens, fryers, and rotisseries.

FSTC researchers visited stores, observed employees, and talked to their suppliers and managers to develop a model of typical appliance usage in the deli. With this information, the FSTC duplicated the deli's operation in the lab to obtain accurate, useful data.

The appliances were tested for energy consumption and cooking performance. Some appliances' product features, ease of use, and cleanability were also evaluated. Performance testing was conducted under tightly controlled laboratory conditions, using the food products typically cooked at the customer's delis. The ovens and rotisseries were tested with whole seasoned chickens and the fryers with breaded chicken pieces. FSTC researchers cooked more than 400 chickens and fried 300 pounds of drumsticks, breasts, wings, and thighs. And while some taste testing was part of the study, the majority of the chicken was donated to food kitchens in the area.

# Introduction

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In addition to laboratory test data, the FSTC provided comparative cost analyses for different methods of cooking. The energy cost models were based on a 365-day operating year. These analyses will help the customer make better purchasing decisions by factoring appliance performance in with other necessary considerations, such as usability, reputation, and first cost.

The glossary in Appendix A is provided so that the reader has a quick reference to the terms used in this report. Appendix B summarizes the test results for each group of appliances (ovens, fryers, and rotisseries).

## Objectives

The objectives of this study were to document the performance and cost of operation for 15 appliances under consideration by PG&E's customer for its deli operations. The appliances included the following:

- One electric cook-and-hold oven
- One gas and two electric combination ovens
- One gas and three electric kettle fryers
- Two gas and two electric pressure fryers
- Three electric countertop rotisseries

## Appliance Description

Specifications for the appliances tested are listed in Table 1-1 (ovens), Table 1-2 (kettle fryers), Table 1-3 (pressure fryers), and Table 1-4 (rotisserie ovens).

# Introduction

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*Table 1-1. Oven Specifications.*

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<b>Elec A: full-size</b>	
Rated Input	21.0 kW
Cooking Cavity Dimensions	23" x 21" x 28"
Capacity	20 whole chickens
Rack Configuration	Each rack holds 5 chickens at a 90° angle
Additional Features	Self-cleaning cycle, water hose
<b>Elec B: ¾-size</b>	
Rated Input	18.3 kW
Cooking Cavity Dimensions	23" x 27" x 21"
Capacity	20 whole chickens
Rack Configuration	Each rack holds 10 chickens at a 45° angle
Additional Features	Water hose
<b>Gas A: full-size</b>	
Rated Input	100,000 Btu/h
Cooking Cavity Dimensions	23" x 21" x 28"
Capacity	20 whole chickens
Rack Configuration	Each rack holds 5 chickens at a 90° angle
Additional Features	Self-cleaning cycle, water hose
<b>Elec C: full-size</b>	
Rated Input	12.7 kW
Cooking Cavity Dimensions	18" x 29" x 28"
Capacity	36 whole chickens
Rack Configuration	Each rack holds 12 chickens at a 90° angle
Additional Features	Water-injection cycle for cooking, water hose

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# Introduction

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*Table 1-2. Kettle Fryer Specifications.*

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<b>Kettle A</b>	
Rated Input	13.5 kW
Oil Capacity	48 lb
Additional Features	Automatic basket lift, cook timer, built-in oil filter, removable cover
<b>Kettle B</b>	
Rated Input	9.0 kW
Oil Capacity	40 lb
Additional Features	Automatic basket lift, frying
<b>Kettle C</b>	
Rated Input	10.0 kW
Oil Capacity	30 lb
Additional Features	Automatic basket lift, cook timer, built-in oil filter, removable cover
<b>Kettle D</b>	
Rated Input	43,300 Btu/h
Oil Capacity	32 lb
Additional Features	Automatic basket lift, frying computer programmable up to 8 menu items, built-in oil filter, removable cover

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# Introduction

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*Table 1-3. Pressure Fryer Specifications.*

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<b>Press A</b>	
Rated Input	12.0 kW
Oil Capacity	48 lb
Operating Pressure	11 psi
Additional Features	Cook timer, built-in oil filter
<b>Press B</b>	
Rated Input	11.3 kW
Oil Capacity	48 lb
Operating Pressure	12 psi
Additional Features	Frying computer programmable up to 10 menu items, built-in oil filter
<b>Press C</b>	
Rated Input	80,000 Btu/h
Oil Capacity	43 lb
Operating Pressure	12 psi
Additional Features	Frying computer programmable up to 10 menu items, built-in oil filter
<b>Press D</b>	
Rated Input	57,500 Btu/h
Oil Capacity	32 lb
Operating Pressure	14 psi
Additional Features	Cook timer

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# Introduction

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*Table 1-4. Rotisserie Oven Specifications.*

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<b>Rotisserie A</b>	
Rated Input	11.0 kW
Capacity	35 whole chickens
Equipped	7 double-spits
Heat Source	Convection with 2 halogen lamps, one in each upper corner
Additional Features	Cooking computer with hold cycle
<b>Rotisserie B</b>	
Rated Input	6.2 kW
Capacity	20 whole chickens
Equipped	5 skewers
Heat Source	4 cal rod elements, one in each corner of the cooking cavity
Additional Features	Planetary rotation of product
<b>Rotisserie C</b>	
Rated Input	7.7 kW
Capacity	20 whole chickens
Equipped	5 skewers
Heat Source	Cal rod elements with 2 halogen lamps, one in each upper corner
Additional Features	Cooking computer with hold cycle, planetary rotation of product

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## 2 Combination Ovens

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### Test Procedure

Initial testing included two electric combination ovens, designated Elec A and Elec B, and one gas combination oven, designated Gas A. An electric cook-and-hold oven, Elec C, was later added to the scope of the testing program. The combination ovens, which feature the option to cook chicken in either combination (cmb) or convection (cnv) mode, were tested in each mode. The cook-and-hold oven was tested in the cook mode only.

Prior to testing, each oven was connected to a calibrated energy meter, and the input rate was measured and compared to the nameplate value. The ovens were adjusted, where necessary, to bring the measured input rate to within  $\pm 5\%$  of the nameplate value to ensure that the ovens were operating in accordance with manufacturer specifications.

The ovens were instrumented with calibrated thermocouples for measuring oven cavity temperature during preheat, idle, and cooking tests. A thermocouple positioned in the geometric center of the oven was used to calibrate the oven's thermostat to the manufacturer's recommended cooking temperature (350°F for Elec A, Elec B, and Gas A, and 420°F for Elec C). Time and energy were recorded while the ovens preheated from room temperature to the cooking temperature, and the energy consumption rate was monitored while each oven maintained the thermostat setpoint for a minimum of 2 hours.

Elec A, Elec B, and Gas A were tested with twenty 2.75-pound whole chickens per load; oven Elec C was tested with 36 chickens, based on the manufacturer's recommendation. The test products were frozen and prerubbed with either barbecue sauce or lemon-herb seasoning.

# Combination Ovens

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The chickens were thawed to  $40 \pm 2^\circ\text{F}$ , placed on the oven's racks, instrumented, and cooked to an average whole-body temperature (including breasts, thighs, and drumsticks) of  $200^\circ\text{F}$ . This doneness criterion was established in the FSTC lab and assured a fully cooked product. Elec A, Elec B, and Gas A were tested at the manufacturers' calibrated thermostat set-points.

During the testing, energy, time, water consumption, oven temperature, and chicken temperature were measured and logged on a computer at 5-second intervals. Product weight was recorded prior to and immediately after each test to determine weight loss. Photographs of each test load were taken immediately after the load was removed from the oven to document product quality. All cooked chickens met the customer's specified product quality standards (color, taste, doneness).

Estimated costs are based on PG&E's average energy costs: \$0.10/kWh for electricity and \$0.62/therm for gas. These rates are appropriate for the purposes of this PG&E study. The cost of gas and electricity will vary in other parts of the United States, and this will affect the operating cost of the ovens.

## Test Results

### Preheat and Idle

The cost to preheat an oven in combination mode was about double the convection mode's cost because the boiler must be preheated in the combination mode. The cost of preheating Elec A and B was about the same in convection mode (about \$0.10) and combination mode (about \$0.20), whereas Gas A cost less (\$0.06 for convection mode and \$0.13 for combination mode). Elec C required the longest preheat time (16 minutes) and cost the most (\$0.34). Note that this oven was preheated to  $420^\circ\text{F}$ , not  $350^\circ\text{F}$ , based on the manufacturer's recommendation.

Idle energy costs are important because an oven is often in a standby or ready-to-cook mode. Table 2-1 reflects the costs to preheat and idle the ovens tested. For all three combination ovens, idle time in the combination

## Combination Ovens

mode cost significantly more than in the convection mode. Gas A in convection mode had the lowest idle cost at \$0.07/hour, with Elec A at \$0.08/hour and Elec B at \$0.14/hour. Elec C cost \$0.35/hour to idle at 420°F, with the moisture setting on 10.

*Table 2-1. Oven Preheat and Idle Costs.*

	Preheat			Idle	
	Time (min)	Energy <sup>a</sup>	Cost <sup>b</sup> (\$/preheat)	Energy Rate	Cost <sup>b</sup> (\$/hour)
Elec A (cnv)	3.7	1.1 kW	0.11	0.8 kW	0.08
Elec A (cmb)	6.2	2.1 kW	0.21	4.8 kW	0.48
Elec B (cnv)	4.3	1.0 kW	0.10	1.4 kW	0.14
Elec B (cmb)	10.1	2.3 kW	0.23	2.8 kW	0.28
Gas A (cnv)	7.0	10.4 kBtu/h	0.06	10.7 kBtu/h	0.07
Gas A (cmb)	9.9	20.7 kBtu/h	0.13	33.1 kBtu/h	0.21
Elec C (cnv)	16.1	3.4 kW	0.34	3.5 kW	0.35

<sup>a</sup>1 kBtu = 1,000 Btu

<sup>b</sup> Oven idle and preheat costs are based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances (therm = 100,000 Btu).

(1

### Cooking Energy

Energy use and subsequent cost per load are presented in Table 2-2. The combination ovens cost 30% more per load in combination mode than in convection mode (see Figure 2-1). Operation of Elec B cost approximately 8% more than Elec A in both the convection and combination modes. Gas A costs approximately 70% less per load than either Elec A or Elec B. Elec C cooked a larger sized load than the other three ovens; therefore, its cost per load is proportionally higher.

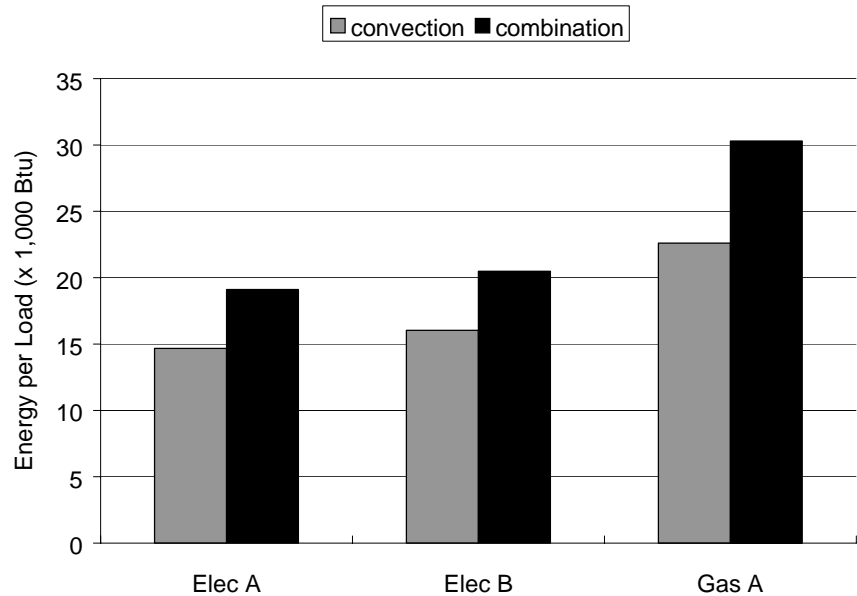
# Combination Ovens

*Table 2-2. Oven Cooking Energy Usage and Cost.*

	Energy Consumption <sup>a</sup>	Cost Per Load <sup>b</sup> (\$/load)	Average Input Rate	Duty Cycle (%)
Elec A (cnv)	4.3 kW	0.43	8.8 kW	48
Elec A (cmb)	5.6 kW	0.56	12.3 kW	56
Elec B (cnv)	4.7 kW	0.47	8.8 kW	65
Elec B (cmb)	6.0 kW	0.60	11.5 kW	85
Gas A (cnv)	22.6 kBtu/h	0.14	45.0 kBtu/h	50
Gas A (cmb)	30.3 kBtu/h	0.19	69.3 kBtu/h	69
Elec C (cnv)	7.3 kW	0.73	12.7 kW	100

<sup>a</sup>1 kBtu = 1,000 Btu

<sup>b</sup>Oven operating costs are based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances (1 therm = 100,000 Btu).



*Figure 2-1. Energy comparison for combination vs. convection cooking.*

Elec A, Elec B, and Gas A operated at 48% to 85% of their rated input during the cooking tests. Elec C, on the other hand, operated at 100% of its

## Combination Ovens

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rated input, because the oven thermostat was not satisfied during the cooking event. For this reason, the cost per load for Elec C includes both the cost to cook the chicken (\$0.65/load) and the cost for the oven to recover to its starting temperature (\$0.08/load). Oven temperature recovery and its relevance to loading and production is discussed in the following subsection.

### Cook Time and Production Rate

Table 2-3 lists the cook times and production rates for the four ovens. All chickens were cooked to an equivalent doneness based on internal temperature. The cook times in each combination oven were reduced by cooking the chickens in the combination mode, although the time difference varied from oven to oven. Cook time of Elec A and B was 1 to 2 minutes shorter in combination mode, and cook time of Gas A was 4 minutes shorter in combination mode. These reduced cook times raised the production rates: 4 pounds per hour in Elec B, 9 pounds per hour in Elec A, and 17 pounds per hour in Gas A. Elec A had the highest production rate in convection mode: 10 pounds per hour more than Elec B and 3 pounds per hour more than Gas A. Gas A had the highest production rate in combination mode: 5 pounds per hour more than Elec A and 24 pounds per hour more than Elec B.

Elec C had a significantly higher production rate (30-50%) partially because it was tested with 36 chickens per load; Elec A, Elec B, and Gas A were tested with 20 chickens per load. The temperature of Elec C registered 360°F at the end of the cooking event, and thus required a recovery period after the load of chicken was removed. The cook time for Elec C includes both the time for the load to cook (30 minutes, 50 seconds) and the time for the oven to recover to its starting temperature (3.5 minutes). Figure 2-2 illustrates the temperatures of each oven during the cooking tests.

# Combination Ovens

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*Table 2-3. Oven Production Performance.*

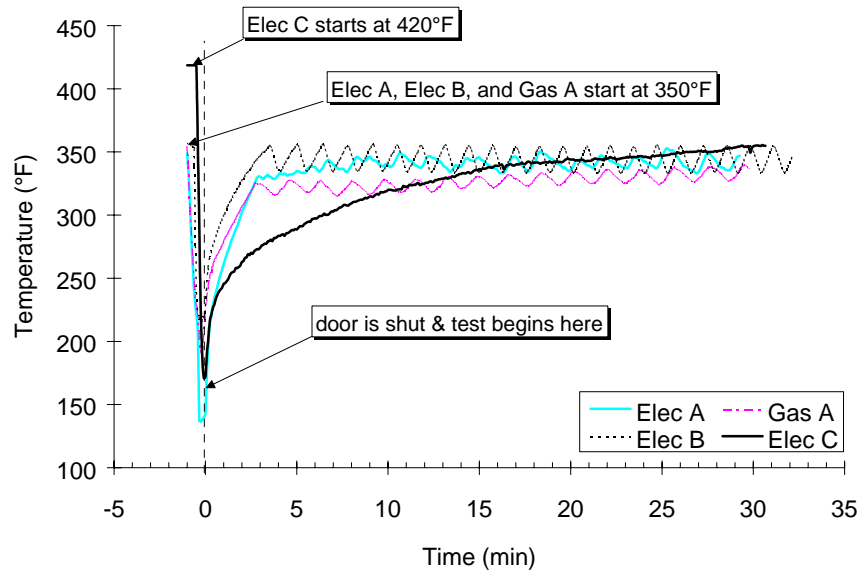
	Cook Time (min)	Production Rate (lb/h)	Water Usage (gal/load)	Weight Loss (%)
Elec A (cnv)	29.3	105	0.00	23.0
Elec A (cmb)	27.4	114	19.5	19.0
Elec B (cnv)	32.2	95	10.70	23.0
Elec B (cmb)	31.4	99	17.80	24.5
Gas A (cnv)	30.2	102	0.00	22.0
Gas A (cmb)	26.2	119	19.0	19.5
Elec C (cnv)	34.3	155	0.01	20.5

## Water Consumption

The ovens' water consumption for each load is listed in Table 2-3. The water used is primarily condensate cooling water, which is added to lower the temperature of the hot condensate water as it enters the drain.

Both Elec A and Gas A operate in convection mode with an *empty* boiler (i.e., no water is required); however, these ovens dump the 3 gallons in their boilers when they are switched from either combination or steam mode to convection mode. Elec C does not have a boiler, but adds moisture to the cooking cavity by spraying a variable amount of atomized water directly on the oven fan. This oven was operated with the controls set at 10 for the first 10 minutes of the test and on zero for the remainder of the test, as suggested by the manufacturer. The amount of water used on this setting without a load in the oven was approximately 5 ounces; however, the oven used only 1.5 ounces when loaded with chicken.

## Combination Ovens



*Figure 2-2.*  
*Comparison of oven temperatures during cooking tests.*

### Weight Loss

The product weight loss per load is summarized in Table 2-3. Weight loss includes both fat and moisture. Product weight loss in Elec A, Elec B, and Gas A was about 23% in the convection mode. Elec A and Gas A had a lower product weight loss in the combination mode (19%), whereas Elec B had a slightly higher loss (about 24%). Elec C had a weight loss of about 20.5%; however, FSTC researchers noted that several of the cooked chickens retained moisture in the pockets between the skin and the meat of the lower breast. This extra moisture drained off the chickens when they were removed from the racks, so the final weight loss may, in fact, be slightly higher. Because the delis do not sell their cooked chicken by the pound, weight loss is not crucial to their revenue; however, these figures are important as a reflection of product yield and oven performance.

### Energy Cost Models

# Combination Ovens

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To calculate the relationship between the various cost components and the annual cost of operation, FSTC researchers generated two models based on two typical operations: one cooking 80 chickens per day and the other cooking 120 chickens per day. A third model explored the potential savings if the ovens were turned off during the middle of the day, when not in use.

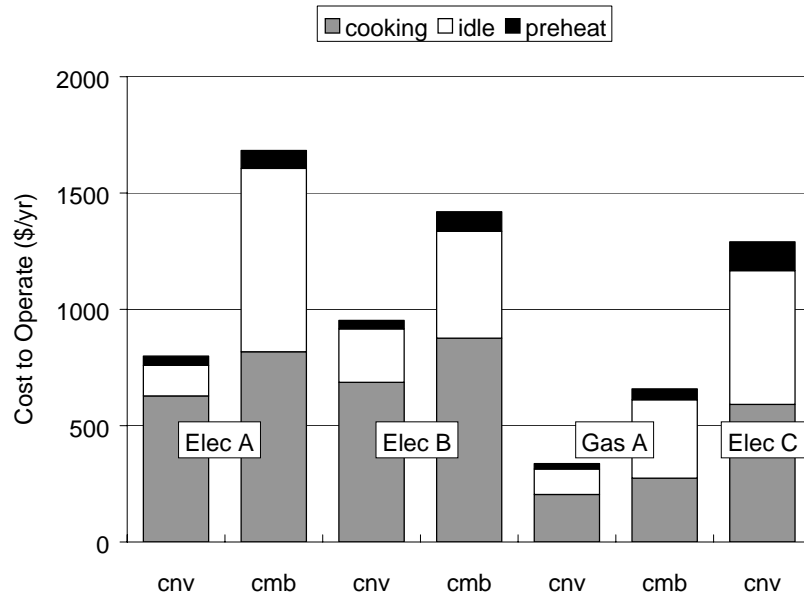
**Model 1 Assumptions:** 80 chickens per day (two loads in the morning, two loads in the afternoon), 4.5 hours idle time, one preheat per day over a 365-day operating year. This model approximates moderate loading of the ovens over the course of the day. The ovens remain on during the day, whether or not they are in use. Table 2-4 and Figure 2-3 detail the annual costs to operate the four ovens under the Model 1 scenario.

*Table 2-4. Oven Annual Cost to Operate Based on Model 1.*

	Cooking (\$/yr)	Idle (\$/yr)	Preheat (\$/yr)	Total (\$/yr)
Elec A (cnv)	628	131	40	799
Elec A (cmb)	818	788	77	1,683
Elec B (cnv)	686	230	37	953
Elec B (cmb)	876	460	84	1,420
Gas A (cnv)	205	109	24	337
Gas A (cmb)	274	337	47	658
Elec C (cnv)	592	575	124	1,290

Note: Oven operating costs are based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances.

# Combination Ovens



*Figure 2-3.  
Oven annual cost of  
operation based on  
Model 1.*

Note: Cost to operate is based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances.

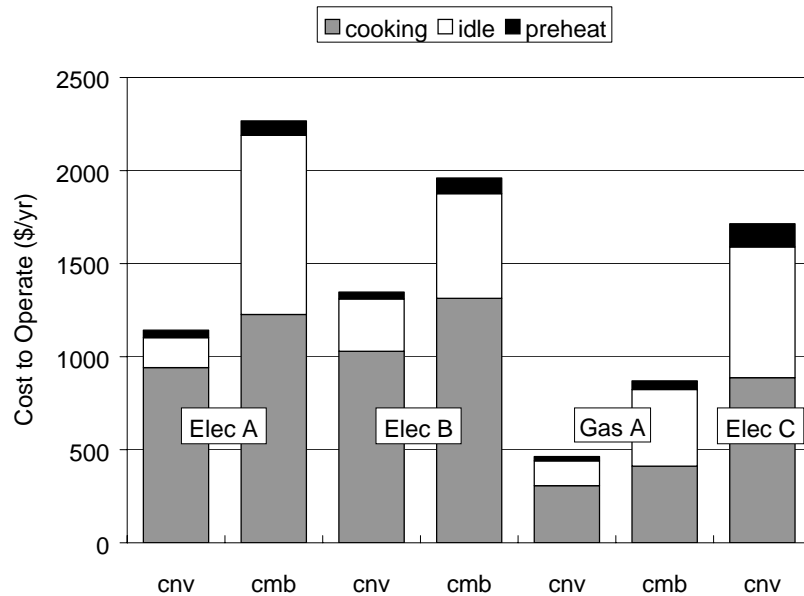
**Model 2 Assumptions:** 120 chickens per day (two loads in the morning, four loads in the afternoon), 5.5 hours idle time, one preheat per day over a 365-day operating year. This model approximates heavy loading of the ovens over the course of the day, and the ovens remain on during the entire day. Table 2-5 and Figure 2-4 detail the annual costs to operate the four ovens tested under the Model 2 scenario.

# Combination Ovens

*Table 2-5. Oven Annual Cost to Operate Based on Model 2.*

	Cooking (\$/yr)	Idle (\$/yr)	Preheat (\$/yr)	Total (\$/yr)
Elec A (cnv)	942	161	40	1,142
Elec A (cmb)	1,226	964	77	2,267
Elec B (cnv)	1,029	281	37	1,347
Elec B (cmb)	1,314	562	84	1,960
Gas A (cnv)	307	133	24	464
Gas A (cmb)	411	412	47	870
Elec C (cnv)	887	703	124	1,714

Note: Oven operating costs are based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances.



*Figure 2-4.  
Oven annual cost of  
operation based on  
Model 2.*

Note: Cost to operate is based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances.

## Combination Ovens

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**Model 3 Assumptions:** 120 chickens per day (two loads in the morning, four loads in the afternoon), 2 hours idle time, two preheats per day over a 365-day operating year. This model approximates heavy loading of the ovens and assumes that the ovens are turned off during the middle of the day when they are not in use. The model can be compared with Model 2 to determine savings with the ovens turned off. Table 2-6 and Figure 2-5 detail the annual costs to operate the four ovens tested under the Model 3 scenario.

*Table 2-6. Oven Annual Cost to Operate Based on Model 3.*

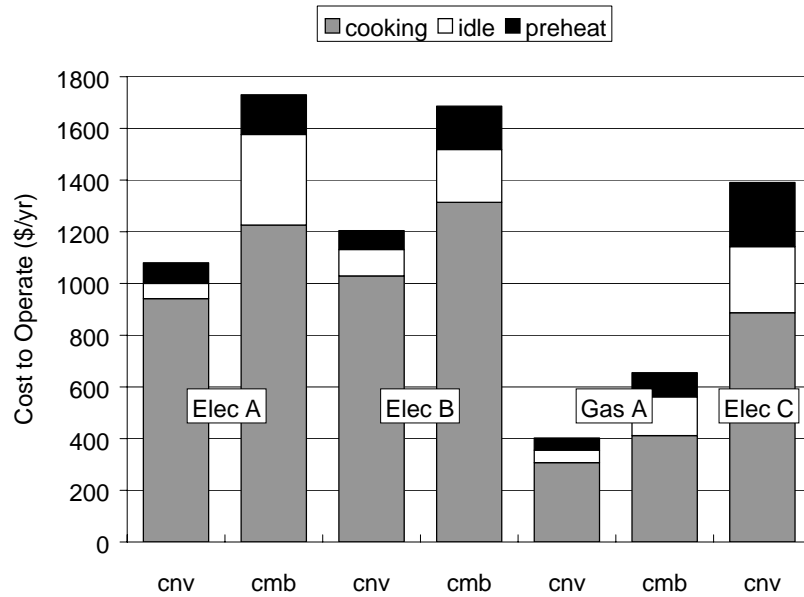
	Cooking (\$/yr)	Idle (\$/yr)	Preheat (\$/yr)	Total (\$/yr)
Elec A (cnv)	942	58	80	1,080
Elec A (cmb)	1,226	350	153	1,730
Elec B (cnv)	1,029	102	73	1,205
Elec B (cmb)	1,314	204	168	1,686
Gas A (cnv)	307	48	47	402
Gas A (cmb)	411	150	94	655
Elec C (cnv)	887	256	248	1,391

Note: Oven operating costs are based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances.

**Summary.** The three models illustrate different operating scenarios for the ovens, but the general cost trends remain the same. The combination ovens cost 40-60% more in combination mode than in convection mode, and the gas oven demonstrated the lowest cost of operation in either mode. Models 1 and 2 may represent more typical deli operating scenarios than Model 3; however, Model 3 can realize an average annual savings of 5-10% in convection mode and as much as 25% in combination mode. In convection mode, the annual cost of the gas oven was \$500 to \$900 lower than the electric ovens.

Table 2-7 presents energy costs based on the three models.

# Combination Ovens



**Figure 2-5.**  
*Oven annual cost of operation based on Model 3.*

Note: Cost to operate is based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances.

**Table 2-7. Comparison of Energy Cost Based on the Models.**

	Model 1 (\$/yr)	Model 2 (\$/yr)	Model 3 (\$/yr)
Elec A (cnv)	799	1,142	1,080
Elec A (cmb)	1,683	2,267	1,730
Elec B (cnv)	953	1,347	1,205
Elec B (cmb)	1,420	1,960	1,686
Gas A (cnv)	337	464	402
Gas A (cmb)	658	870	655
Elec C (cnv)	1,290	1,714	1,391

Note: Oven operating costs are based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances.

## Combination Ovens

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### Oven Loading/Cleaning

Each manufacturer supplied specially designed racks for cooking chicken in their respective ovens. These racks were designed to be removed from the oven before being loaded with product. Fully loaded racks were difficult to handle, sometimes requiring two people to place them into the ovens.

Table 2-8 compares the fully-loaded rack weights for oven's racks.

*Table 2-8. Comparison of Oven Racks.*

	Rack Dimensions	Chickens per Rack	Fully-Loaded Rack Weight (lb)
Elec A	14" x 22"	5	16
Elec B	13" x 20"	10	29
Gas A	14" x 22"	5	16
Elec C	18" x 26"	12	38

The combination oven's relative ease of cleaning gives it an operational advantage. Elec A and Gas A have self-cleaning cycles that require minimal operator work. They are cleaned using an off-the-shelf oven cleaner. Their boilers blow down by themselves and are easily maintained by adding a delimer in the port at the front of the oven. Elec B requires a special cleaner from the manufacturer and is cleaned by running the oven in steam mode for 10 minutes. The boiler in Elec B must be manually blown down every day and manually back-flushed every week. The delimer is added to the boiler through an opening in the back of the oven located behind a removable fan cover. The manufacturer of Elec C recommended a specific cleaning product that does not damage the aluminum inner walls. This product is sprayed on and steamed off in a manner similar to Elec B. Elec C requires no boiler maintenance. It adds moisture to the cooking cavity by spraying a small amount of atomized water directly on the fan.

## Combination Ovens

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### Conclusions and Recommendations

Gas A was the highest performing oven based on estimated annual cost and considering production rate/cook times. The electric combination ovens had similar operating costs; however, Elec A showed a higher production rate and lower average weight loss than Elec B. The annual cost to operate Elec C was comparable to Elec A and Elec B when operated in convection mode.

All combination ovens used significantly less energy in convection mode, and experienced only a minor decrease in productivity. Unless the increased benefits of combination cooking (i.e., increased product yield, and reduced cook time) are needed, the ovens should be used in convection mode.

## 3 Chicken Fryers

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### Test Procedure

Initial testing included four kettle fryers (three electric and one gas fryer), designated Kettle Fryers A (e), B (e), C (e), and D (g); and four pressure fryers (two electric and two gas), designated Pressure Fryers A (e), B (e), C (g), and D (g). Partially hydrogenated, 100% pure canola oil was used for all tests.

Prior to testing, each fryer was connected to a calibrated energy meter, and the input rate was measured and compared to the nameplate value. The fryers were adjusted, where necessary, to bring the measured input rate to within  $\pm 5\%$  of the nameplate value to ensure that the fryers were operating in accordance with manufacturer specifications.

The fryers were instrumented with calibrated thermocouples for measuring oil temperature during preheat, idle, and cooking tests. A thermocouple positioned in the geometric center of the frypot was used to calibrate the fryer's thermostat to a 325°F cooking temperature. Time and energy were recorded while the fryers preheated the oil from room temperature to 325°F, and the energy consumption rate was monitored while each fryer maintained the 325°F setpoint for a minimum of 2 hours.

Each cooking test load comprised 32 pieces of frozen, prebreaded chicken parts. The test product was stored in a walk-in freezer at -10°F. Fryer loading time was optimized so that the chicken's temperature was at  $0 \pm 5^\circ\text{F}$  when immersed in the oil. Each load comprised eight each breasts, wings, legs, and thighs. The load was submerged at once, then cooked to an average of 200°F. This endpoint ensured fully cooked pieces of chicken with no redness in the center.

# Chicken Fryers

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Energy, time, and oil temperature (kettle fryers) were measured and logged on a computer at 5-second intervals during the tests. In addition to temperature, weight loss of the cooked chicken pieces was recorded to ensure that each fryer performed an equivalent amount of work. Representative samples of cooked and uncooked chicken were analyzed for moisture to determine the effect of pressure frying.

Estimated costs are based on PG&E's average energy costs: \$0.10/kWh for electricity and \$0.62/therm for gas. These rates are appropriate for the purpose of this PG&E study. The cost of gas and electricity will vary in other parts of the United States, and this will affect the operating cost of the gas fryers.

## Test Results

### Preheat and Idle

Both Kettle Fryer C and Pressure Fryer D had lengthy preheats due to premature cycling of the thermostats. The fryers cycled off before reaching the set temperature and required several cycles to reach the 325°F setpoint.

Idle energy costs are important because a fryer often spends much of its time in a ready-to-cook mode. Table 3-1 presents the cost to preheat and idle the fryers. Because fryers have relatively low heat losses to the environment, they cost very little to idle. And in most cases, the fryers have a “standby” mode, which reduces the oil temperature to 250°F or less during idle periods. For idle periods of 2 hours or more, such a feature may be a valid energy-saving strategy.

### Cooking Energy

Energy use and subsequent cost per load is presented in Table 3-2. Pressure Fryer A cost an average of 16% less than the other electric fryers; however, the gas fryers averaged half the cost of the electric fryers to perform the same amount of work.

# Chicken Fryers

**Table 3-1. Fryer Preheat and Idle Costs.**

	Preheat			Idle	
	Time (min)	Energy	Cost <sup>a</sup> (\$/preheat)	Energy Rate	Cost <sup>a</sup> (\$/hour)
Kettle Fryer A (e)	8.0	1.8 kWh	0.18	0.7 kW	0.07
Kettle Fryer B (e)	7.6	1.2 kWh	0.12	0.5 kW	0.05
Kettle Fryer C (e)	23.5	2.3 kWh	0.23	0.7 kW	0.07
Kettle Fryer D (g)	8.9	6.5 kBtu <sup>b</sup>	0.04	4.4 kBtu/h <sup>b</sup>	0.03
Pressure Fryer A (e)	7.1	1.4 kWh	0.14	0.6 kW	0.06
Pressure Fryer B (e)	12.5	2.1 kWh	0.21	1.2 kW	0.12
Pressure Fryer C (g)	16.0	20.0 kBtu <sup>b</sup>	0.12	10.6 kBtu/h <sup>b</sup>	0.07
Pressure Fryer D (g)	23.2	20.5 kBtu <sup>b</sup>	0.13	14.3 kBtu/h <sup>b</sup>	0.09

<sup>a</sup> Fryer preheat and idle costs are based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances (1 therm = 100,000) Btu.

<sup>b</sup> 1 kBtu = 1,000 Btu

**Table 3-2. Fryer Cooking Energy Usage and Costs.**

	Energy Consumption	Cost per Load <sup>a</sup> (\$/load)*	Average Input Rate	Duty Cycle (%)
Kettle Fryer A (e)	2.0 kWh	0.20	6.3 kW	47
Kettle Fryer B (e)	1.9 kWh	0.19	6.0 kW	67
Kettle Fryer C (e)	1.9 kWh	0.19	5.3 kW	53
Kettle Fryer D (g)	11.1 kBtu <sup>b</sup>	0.07	34.2 kBtu/h <sup>b</sup>	79
Pressure Fryer A (e)	1.7 kWh	0.17	5.6 kW	46
Pressure Fryer B (e)	2.3 kWh	0.23	8.0 kW	71
Pressure Fryer C (g)	19.1 kBtu <sup>b</sup>	0.12	67.2 kBtu/h <sup>b</sup>	84
Pressure Fryer D (g)	18.0 kBtu <sup>b</sup>	0.11	55.3 kBtu/h <sup>b</sup>	96

<sup>a</sup> Fryer preheat and idle costs are based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances (1 therm = 100,000) Btu.

<sup>b</sup> 1 kBtu = 1,000 Btu

## Cook Time and Production Rate

# Chicken Fryers

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Table 3-3 lists the cook times and production rates for each fryer. All loads consisted of 32 pieces of chicken, weighing  $10.5 \pm 0.2$  pounds. In general, the pressure fryers cooked about 9% faster than the kettle fryers (based on the production rate). All loads were cooked to an equivalent doneness based on internal temperature and weight loss.

The cook time for the pressure fryers does not include the time required for the vessel to release pressure. This process takes an average of 30 seconds. Since the chicken is still immersed in the oil, this time has been factored into the overall production rates for the pressure fryers.

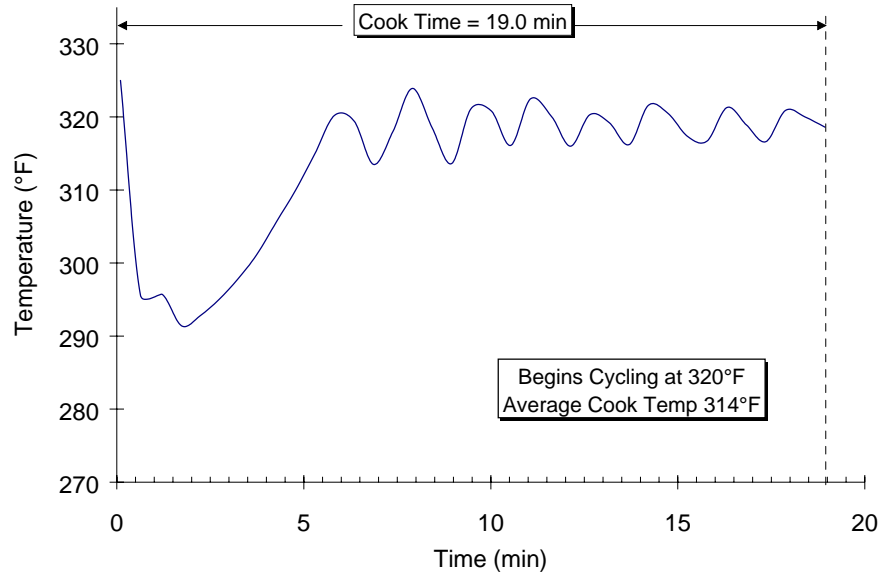
*Table 3-3. Fryer Cook Time and Production Rate.*

	Cook Time (min)	Production Rate (lb/h)
Kettle Fryer A (e)	19.0	33
Kettle Fryer B (e)	19.0	33
Kettle Fryer C (e)	22.0	29
Kettle Fryer D (g)	19.5	33
Pressure Fryer A (e)	18.0	34
Pressure Fryer B (e)	17.0	37
Pressure Fryer C (g)	17.0	37
Pressure Fryer D (g)	19.5	32

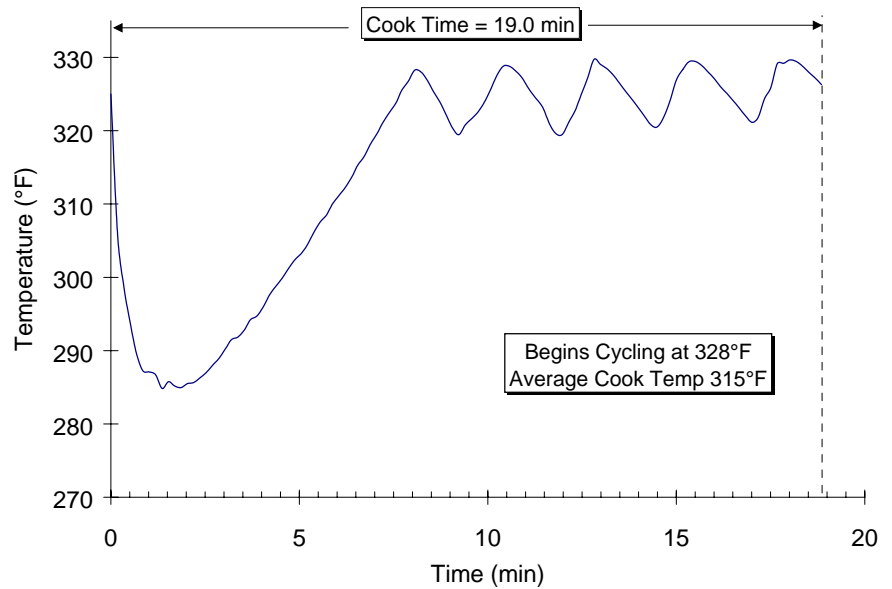
Figures 3-1 through 3-4 show oil temperature profiles for the kettle fryers while cooking. Average temperature during cooking is also reported for comparison. Kettle Fryer B had the highest average cooking temperature of the four fryers. Kettle Fryers A and C began cycling at a lower temperature than their setpoints, but the average temperature gradually increased over time.

# Chicken Fryers

**Figure 3-1.**  
*Cooking temperature profile for Kettle Fryer A (electric).*

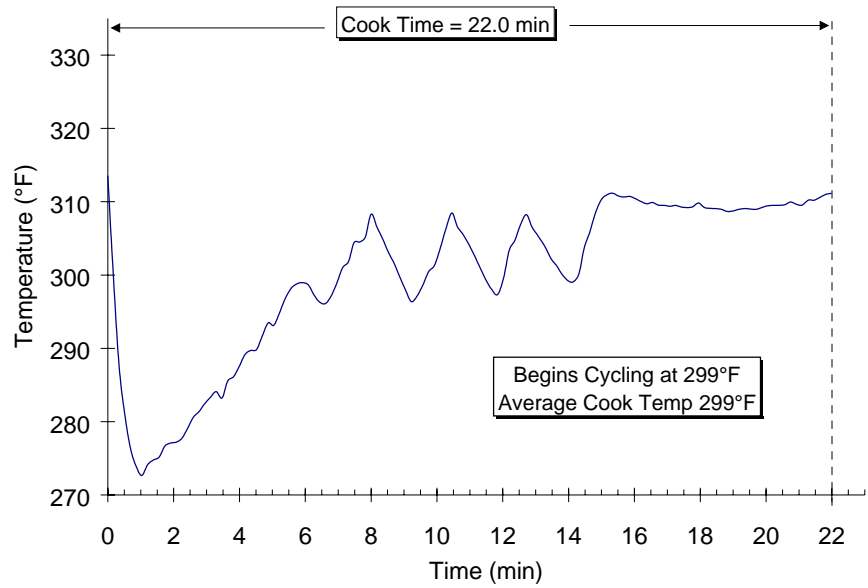


**Figure 3-2.**  
*Cooking temperature profile for Kettle Fryer B (electric).*

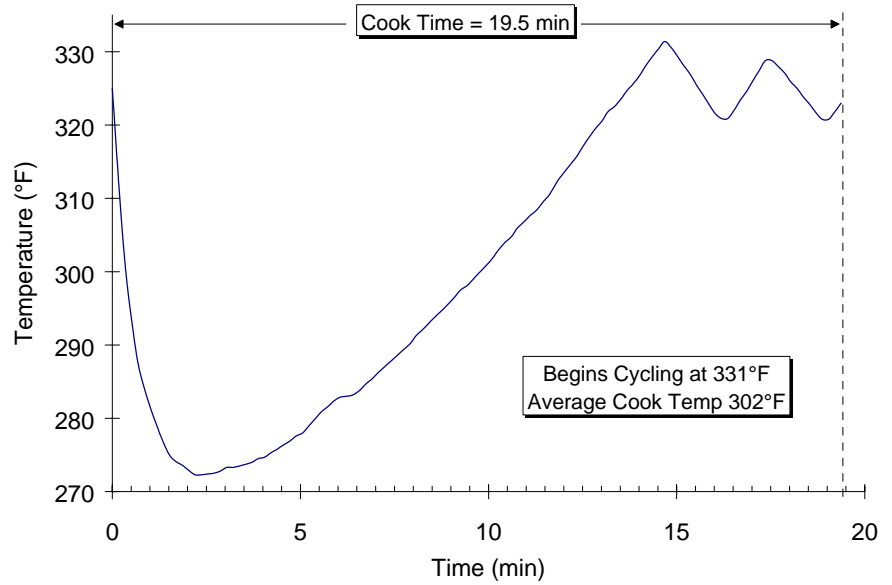


# Chicken Fryers

*Figure 3-3.*  
*Cooking temperature profile for Kettle Fryer C (electric).*



*Figure 3-4.*  
*Cooking temperature profile for Kettle Fryer D (gas).*



# Chicken Fryers

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## Moisture Analysis

Each load was cooked to an equivalent weight loss in the pressure and kettle fryers. Because the weight loss of the cooked chicken was the same for each fryer, moisture analysis provided a quick approximation of the oil absorbed by the chicken (see Table 3-4).

*Table 3-4. Moisture Analysis and Oil Absorption.*

	Weight Loss (%)	Moisture Loss (% by weight)	Oil Absorption (% by weight)
Kettle	26.7	39.8	13.1
Pressure	26.7	38.3	11.7

## Energy Cost Model

To calculate the relationship between the various cost components and the annual cost of operation, FSTC research engineers generated a simple model based on a typical day. Model assumptions include 150 pounds of chicken, 6 hours of idle time, and one preheat per day over a 365-day operating year. Table 3-5 and Figure 3-5 detail the annual costs of operation for the eight fryers tested under this scenario.

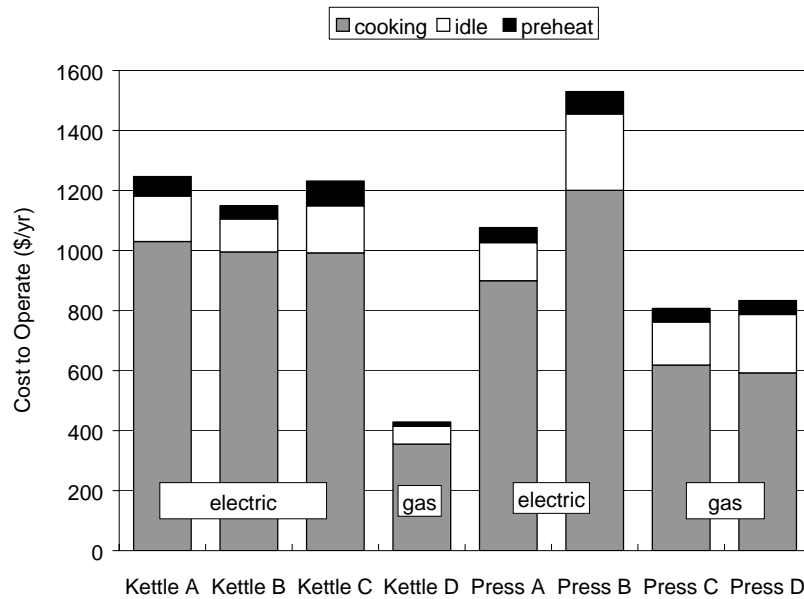
The gas fryers cost about half as much as the electric fryers. Kettle Fryer D had an even lower operating cost than the other gas fryers because of its higher efficiency design.

# Chicken Fryers

*Table 3-5. Fryer Annual Cost to Operate Based on Model.*

	Preheat (\$/yr)	Idle (\$/yr)	Cooking (\$/yr)	Total (\$/yr)
Kettle Fryer A (e)	65	151	1,030	1,246
Kettle Fryer B (e)	45	110	995	1,150
Kettle Fryer C (e)	83	156	992	1,232
Kettle Fryer D (g)	15	59	355	429
Pressure Fryer A (e)	50	127	899	1,077
Pressure Fryer B (e)	75	254	1,201	1,530
Pressure Fryer C (g)	45	144	618	807
Pressure Fryer D (g)	46	195	592	833

Note: Fryer operating costs are based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances.



*Figure 3-5. Fryer annual cost of operation based on model.*

Note: Cost to operate is based on \$0.10/kWh for electric appliances and \$0.62/therm for gas appliances.

## Conclusions

## Chicken Fryers

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Kettle Fryer D had the lowest operating cost of the tested fryers and displayed a competitive production rate (33 pounds per hour). Among the electric open fryers, Kettle Fryers A and B had shorter preheat times, higher production rates, and higher average cooking temperatures than Kettle Fryer C.

In general, the pressure fryers had higher productivity and less oil absorption than the kettle fryers. The two gas pressure fryers showed similar operating costs. Pressure Fryer C, however, had a 15% shorter cook time than Pressure Fryer D.

## 4 Rotisserie Ovens

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### Test Procedure

Initial testing included three electric countertop rotisserie ovens, designated Rotisseries A, B, and C. Each rotisserie was tested at full capacity (based on the manufacturers' recommendations) using 2.75-pound whole chickens.

Each rotisserie was connected to a calibrated energy meter, and the input rate was measured and compared to the nameplate value. The rotisseries were adjusted, where necessary, to bring the measured input rate to within  $\pm 5\%$  of the nameplate value. This ensured that the rotisseries were operating in accordance with manufacturer specifications.

Prior to testing, the chickens were thawed, spitted, instrumented, then returned to the refrigerator to stabilize at  $40 \pm 2^\circ\text{F}$ . The rotisserie was loaded at room temperature to control the starting condition of the food product. The chickens were cooked to an average internal breast temperature of  $190^\circ\text{F}$ , which corresponds to the  $200^\circ\text{F}$  average whole-body temperature used for the combination oven tests. This doneness criterion was based on in-lab evaluation and ensured fully cooked chicken. All three ovens were tested at the manufacturers' recommended temperature setting.

During the testing, energy and time were measured and logged on a computer at 5-second intervals. Product weight was recorded prior to and immediately after each test to determine weight loss.

Estimated costs are based on PG&E's average electric energy cost of  $\$0.10/\text{kWh}$ . This rate is appropriate for the purposes of this PG&E study. The cost of electricity will vary in other parts of the United States, and this will affect the actual operating cost of the rotisseries.

Preheat and idle costs were not considered in this study on the assumption that the units would be turned off when not in use.

# Rotisserie Ovens

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## Test Results

### Cooking Energy

Energy use and subsequent cost per load are presented in Table 4-1. Also included for reference are the manufacturers' recommended thermostat settings and loading scenarios. A cost per 100 chickens was calculated to normalize the test results. Rotisserie A cost half as much as the other rotisseries to perform an equivalent amount of work.

*Table 4-1. Rotisserie Cooking Energy Usage and Costs.*

	Rotisserie A	Rotisserie B	Rotisserie C
Thermostat Setting (°F)	350	500	350
Loading (chickens/load)	35	20	20
Energy Consumption (kWh)	10.13	11.64	11.90
Cost per Load (\$/load)	1.01	1.16	1.19
Average Input Rate (kW)	9.39	6.15	7.65
Duty Cycle (%)	85	100	100
Cost per 100 chickens (\$)	2.89	5.80	5.95

Note: Rotisserie energy costs are based on \$0.10/kWh.

### Cook Time and Production Rate and Weight Loss

Table 4-2 lists the cook times production rates and weight loss for the three rotisserie ovens. As mentioned earlier, all chickens were cooked to an equivalent doneness based on internal temperature. The larger capacity of Rotisserie A translated to two to three times the productivity of the other rotisseries.

Product weight loss includes both fat and moisture. Rotisserie A showed an unusually low weight loss, which *may* be attributed to an uncertainty in the measurements. Whole chickens typically lose 20-24% of their initial weight during cooking. Because the delis do not sell their cooked chicken by the pound, weight loss is not crucial to their revenue; however, these figures are important as a reflection of product yield and rotisserie oven performance.

# Rotisserie Ovens

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*Table 4-2. Rotisserie Production Performance.*

	Rotisserie A	Rotisserie B	Rotisserie C
Loading (chickens/load)	35	20	20
Cook Time (min)	67.2	118.9	97.9
Production Rate (lb/h)	78	25	29
Weight Loss (%)	17	24	24

## Energy Cost Model

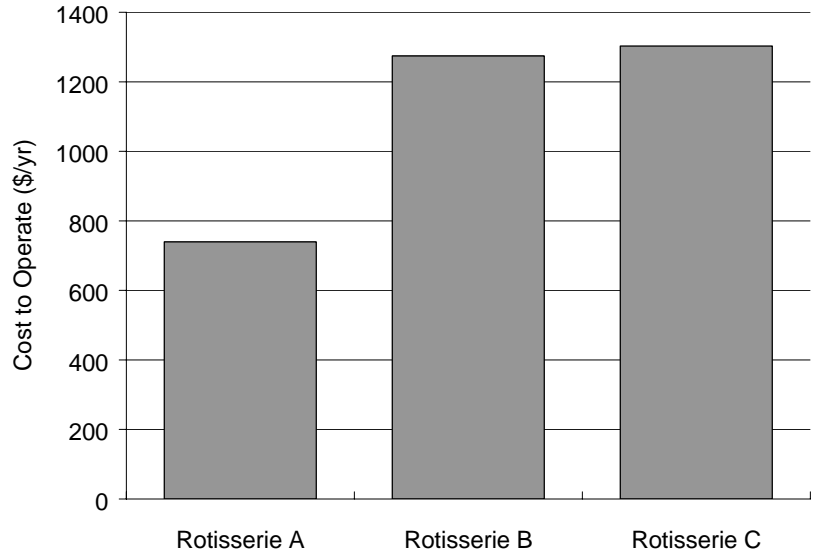
Estimated annual cost is based on cooking 60 whole chickens per day over a 365-day operating year, assuming no preheat or idle time. With nearly double the capacity, Rotisserie A can cook the 60 chickens in two cooking events, whereas Rotisseries B and C would require three separate cooking events. Figure 4-1 shows the annual costs to operate each of the three ovens tested under the model's scenario. Rotisserie A cost nearly half as much as the other rotisseries.

## Conclusions

Based on production rate, weight loss, and estimated annual cost, Rotisserie A was the highest performing oven. Its high productivity is attributed to its convection mode of heating and its much larger capacity (nearly double). Rotisseries B and C performed similarly in energy usage, productivity, and weight loss.

# Rotisserie Ovens

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*Figure 4-1.  
Rotisserie annual cost of  
operation based on  
model.*

Note: Cost to operate is based on \$0.10/kWh.

# Appendixes

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## A Glossary

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### **Average Input Rate (kW or Btu/h)**

Average Energy Input Rate

Average Energy Rate

The average rate of appliance energy consumption over a specified period of operation.

### **Cook Time (minute)**

The period of time required for an appliance to bring a specified food product to a specified “cooked” condition.

### **Cooking Energy Consumption (kWh or Btu)**

The total energy consumed by an appliance during a cooking event.

### **Duty Cycle (%)**

Load Factor

The average energy consumption rate (based on a specified operating period for the appliance) expressed as a percentage of the measured energy input rate.

$$\text{Duty Cycle} = \frac{\text{Average Energy Consumption Rate}}{\text{Measured Energy Input Rate}} \times 100$$

### **Idle Energy Rate (kW or Btu/h)**

Idle Energy Input Rate

Idle Rate

The rate of appliance energy consumption while it is “idling” or “holding” at a stabilized operating condition or temperature.

## Glossary

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### **Idle Temperature** (°F, Setting)

The temperature of the cooking cavity/surface (selected by the appliance operator or specified for a controlled test) that is maintained by the appliance under an idle condition.

### **Idle Time** (minutes, hour)

Idle Period

A period of time that an appliance is consuming energy at its idle energy consumption rate while maintaining a specified stable operating condition or temperature.

### **Measured Input Rate** (kW or Btu/h)

Measured Energy Input Rate

Measured Peak Energy Input Rate

The maximum or peak rate at which an appliance consumes energy, measured during appliance preheat or while conducting a water-boil test (i.e., the period of operation when all burners or elements are “on”).

### **Preheat Energy** (kWh or Btu)

Preheat Energy Consumption

The total amount of energy consumed by an appliance during the preheat period.

Note: The reporting of preheat energy must be supported by the specified temperature/ operating condition.

### **Preheat Time** (minute)

Preheat Period

The time required for an appliance to “preheat” from the ambient room temperature ( $75 \pm 5^\circ\text{F}$ ) to a specified (and calibrated) operating temperature or thermostat set point.

### **Production Rate** (lb/h)

Productivity

The average rate at which an appliance brings a specified food product to a specified “cooked” condition.

### **Rated Energy Input Rate** (kW, W or Btu/h, Btu/h)

Input Rating (ANSI definition)

## Glossary

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Nameplate Energy Input Rate  
Rated Input

The maximum or peak rate at which an appliance consumes energy as rated by the manufacturer and specified on the nameplate.

**Typical Day**

A sampled day of average appliance usage based on observations and/or operator interviews, used to develop an energy cost model for the appliance.

## B Data Summary Sheets

*Table B-1. Data Sheet for Combination Oven Testing.*

	Elec A (cnv)	Elec A (cmb)	Elec B (cnv)	Elec B (cmb)	Gas A (cnv)	Gas A (cmb)	Elec C
Energy (kWh)	4.30	5.60	4.70	6.00	--	--	7.30
Energy (Btu)	--	--	--	--	22,600	30,300	--
Cost (\$/load)	0.43	0.56	0.47	0.60	0.14	0.19	0.73
Input (avg. kW)	8.80	12.30	8.80	11.50	--	--	12.70
Input (avg. Btu/h)	--	--	--	--	45,000	69,300	--
Rated Input (kW)	18.20	21.80	13.50	13.50	--	--	12.70
Rated Input (Btu/h)	--	--	--	--	90,000	100,000	--
Duty Cycle (%)	48	56	65	85	50	69	100
Cook Time (min)	29.3	27.4	32.2	31.4	30.2	26.2	34.33
Production (lb/h)	105	114	95	99	102	119	115
Water Use (gal/load)	0	0.33	10.70	17.80	0	0.70	0.01
Weight Loss (%)	23.0	19.0	23.0	24.5	22.0	19.5	20.5
Idle Rate (kW)	0.80	4.80	1.40	2.80	--	--	3.50
Idle Rate (Btu/h)	--	--	--	--	10,700	33,100	--
Idle Cost (\$/hour)	0.08	0.48	0.14	0.28	0.07	0.21	0.35
Preheat Time (min)	3.70	6.20	4.30	10.10	7.00	9.90	16.10
Preheat Energy (kWh)	1.10	2.10	1.00	2.30	--	--	3.40
Preheat Energy (Btu)	--	--	--	--	10,400	20,700	--
Preheat Cost (\$/preheat)	0.11	0.21	0.10	0.23	0.06	0.13	0.34

Electricity = \$0.10/kWh  
Gas = \$0.62/therm

# Data Summary Sheets

*Table B-2. Data Sheet for Fryer Testing.*

	Kettle Fryer A	Kettle Fryer B	Kettle Fryer C	Kettle Fryer D	Pressure Fryer A	Pressure Fryer B	Pressure Fryer C	Pressure Fryer D
Energy per Load (kWh)	2.00	1.90	1.90	—	1.70	2.30	—	—
Energy per Load (kBtu)	—	—	—	11.10	—	—	19.10	18.00
Cost per Load (\$)	0.20	0.19	0.19	0.07	0.17	0.23	0.12	0.11
Cooking Energy Rate (kW)	6.30	6.00	5.30	—	5.60	8.00	—	—
Cooking Energy Rate (kBtu/h)	—	—	—	34.20	—	—	67.20	55.30
Rated Input (kW)	13.50	9.00	10.00	—	12.00	11.30	—	—
Rated Input (kBtu/h)	—	—	—	43.30	—	—	80.00	57.50
Duty Cycle (%)	47	67	53	79	46	71	84	96
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Cook Time (min)	19.0	19.0	22.0	19.5	18.0	17.0	17.0	19.5
Production (lb/h)	33.4	33.0	29.1	32.7	33.9	36.6	36.9	31.7
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Preheat Time (min)	19.0	19.0	22.0	19.5	18.0	17.0	17.0	19.5
Preheat Energy (kWh)	33.4	33.0	29.1	32.7	33.9	36.6	36.9	31.7
Preheat Energy (kBtu)	33.4	33.0	29.1	32.7	33.9	36.6	36.9	31.7
Preheat Cost (\$)	19.0	19.0	22.0	19.5	18.0	17.0	17.0	19.5
Idle Rate (kW)	19.0	19.0	22.0	19.5	18.0	17.0	17.0	19.5
Idle Rate (kBtu/h)	19.0	19.0	22.0	19.5	18.0	17.0	17.0	19.5
Idle Cost (\$/hr)	19.0	19.0	22.0	19.5	18.0	17.0	17.0	19.5

Electricity = \$0.10/kWh  
 Gas = \$0.62/therm

## Data Summary Sheets

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*Table B-3. Data Sheet for Rotisserie Testing.*

	Rotisserie A	Rotisserie B	Rotisserie C
Energy per Load (kWh)	10.10	11.60	11.90
Cost per Load (\$)	1.01	1.16	1.19
Cooking Energy Rate (kW)	9.40	6.20	7.70
Rated Input (kW)	11.0	6.20	7.70
Duty Cycle (%)	85.00	100.00	100.00
Cook Time (min)	67.2.0	118.90	97.90
Production (lb/h)	78.00	25.00	29.00
Weight Loss (%)	17.00	24.00	24.00

Electricity = \$0.10/kWh