Pitco Frialator® Model E14B
Electric Fryer Performance Test

Application of ASTM Standard

Test Method F 1361-95

Report 5011.95.12

FSTC Manager: Don Fisher

Final Report, March 1996

Prepared by:

Shawn Knapp

David Zabrowski

Prepared for:

Pacific Gas and Electric Company
Products and Services Department
444 Market Street, P.O. Box 770000
San Francisco, California 94177

CONTENTS

FIGURES

TABLES

POLICY ON THE USE OF FOOD SERVICE TECHNOLOGY CENTER TEST RESULTS AND OTHER RELATED INFORMATION

- The Food Service Technology Center (FSTC) is *strongly* committed to testing food service equipment using the best available scientific techniques and instrumentation.

- The FSTC is neutral as to fuel and energy source. It does not, in any way, encourage or promote the use of any fuel or energy source nor does it endorse any of the equipment tested at the FSTC.

- FSTC test results are made available to the general public through PG&E technical research reports and publications. All of these documents are protected under U.S. and international copyright laws.

- In the event that FSTC data are to be reported, quoted, or referred to in any way in publications, papers, brochures, advertising, or any other publicly available documents, the rules of copyright must be strictly followed, including written permission from PG&E *in advance* and proper attribution to PG&E and the FSTC. In any such publication, sufficient text must be excerpted or quoted so as to give full and fair representation of findings as reported in the original FSTC documentation.

PREFACE

Decisions involving the purchase of modern food service equipment are influenced by many factors. Cost is certainly a priority. Are extra features worth the additional cost? Performance considerations are crucial. Will advanced technology, fuel-efficient appliances show a good return on the investment? Should appliances be gas or electric? How much will they cost to operate? Can an appliance meet peak production demands? When selecting new equipment, the food service industry has historically relied on manufacturer specifications and limited test data. Since 1986, PG&E has been providing more reliable information through its Food Service Technology Center (FSTC) in San Ramon, California.

The appliance testing program at the FSTC was initiated to answer the questions that food service customers have about the performance of cooking appliances. Since its beginning in 1986, PG&E's FSTC mission has grown into a full-scale research program, combining the sophisticated instrumentation and controlled environment of a laboratory with the real-life conditions of a production kitchen. The FSTC comprises two distinct, but complementary, research components.

The first, integrated with PG&E's corporate Learning Center, is the production-test kitchen. This facility is a unique combination of a real food service operation and a test environment. As a production kitchen, it provides cafeteria-style breakfast and lunch and sit-down dinner for 500 customers a day. As a test kitchen, it is equipped to monitor the energy consumed by both gas and electric cooking appliances as they are used for routine menu production by the kitchen staff.

The second component is an appliance laboratory equipped with energy monitoring and data acquisition equipment, 60 feet of canopy exhaust hoods integrated with a utility distribution system, appliance set-up and storage areas, and a state-of-the-art demonstration and training facility. Within the center, the research team develops uniform testing procedures to evaluate the overall performance of gas and electric cooking equipment. These methods focus on measuring the energy consumption and production capacity of an appliance as it is used to cook standardized loads of typical food product.

After the research team develops a test procedure for a particular appliance category, it submits the document to the ASTM subcommittee F26.06 on Productivity and Energy Protocols, part of the F-26 Committee on Food Service Equipment. Once balloted and approved by the main F-26 Committee, the test procedure is submitted for society ballot and published as an official ASTM standard test method.

ACKNOWLEDGMENTS

The state-of-the art Food Service Technology Center reflects PG&E's commitment to the hospitality industry. The goal of the research project is to provide PG&E's food service 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 loan the cooking appliances for testing. Specific appreciation is extended to Pitco Frialator for supplying the FSTC with a model E14B electric fryer for testing.

PG&E's Food Service Technology Center acknowledges the support of the project's National Advisory Group. Participating organizations from the research community include the Electric Power Research Institute (EPRI), the Gas Research Institute (GRI), the American Gas Association Laboratories (AGAL), and Underwriters Laboratories (UL). Representing end users are the National Restaurant Association, McDonald's Corporation, Darden Restaurants, and the International Facility Management Association (IFMA).

EXECUTIVE SUMMARY

The Pitco Frialator® model E14B electric fryer incorporates immersion type, tubular heating elements. The elements can be raised to access the frying vat for cleaning. The fryer features an all-stainless steel frypot and solid-state electronic temperature controls for increased accuracy and reliability.

The fryer was tested under the tightly controlled conditions of the American Society for Testing and Materials' (ASTM) *Standard Test Method for the Performance of Open, Deep-fat Fryers*.[1] Fryer performance is characterized by preheat time and energy consumption, idle energy consumption rates, cooking energy efficiency, and production capacity. A summary of the test results is presented in Table ES-1.

Table ES-1

Summary of ASTM Test Method Results

Pitco Frialator E14B Electric Fryer

Rated Energy Input Rate (kW)	21.0
Measured Energy Input Rate (kW)	21.2
Water-Boil Efficiency (%)	90.0
Preheat to 350°F	
Time (min)	4.9
Consumption (kWh)	1.6
Rate to 350°F (°F/min)	56.0
Preheat to 350°F (with melt cycle on)	
Time (min)	9.3
Consumption (kWh)	1.7
Rate to 350°F (°F/min)	30.0
Idle Energy Consumption Rate @ 350°F (kWh)	1.0
Cooking Energy Efficiency (%)	
Heavy Load	83.0
Medium Load	76.6
Light Load	68.3
Production Capacity (lb/h)	62.0[a]
Recovery Time for Heavy Load (sec)	14

[a] Based on heavy-load test and a minimum 10-second preparation time between loads.

[1] American Society for Testing and Materials. 1992. *Standard Test Methods for the Performance of Open, Deep-fat Fryers*. ASTM Designation F 1361-95. Philadelphia: American Society for Testing and Materials.

Fryer cooking performance was determined by cooking three different loads—a heavy load (3 pounds), a medium load (1 pounds), and a light load (pound)—using -inch blue ribbon, par-cooked, frozen shoestring potatoes. All tests were conducted with partially hydrogenated 100% pure vegetable oil. Cook times for the different loading scenarios were 2 minutes 40 seconds for the heavy load test, 2 minutes 30 seconds for both medium- and light-load tests. Cooking energy efficiency was defined as the following relationship:

The ASTM standard test method uses "barreling" loading with the requirement to "set the next load into the fryer 10 seconds after removing the first load from the fryer or after the cook zone thermocouple indicates that the oil temperature has recovered to 340°F, whichever is longer." The term "barreling" refers to cooking one fry load after another. Barreling is done to maximize the production rate. The maximum production rate is based on cooking heavy loads (3 pounds). Fryer production rate is a function of both french fry cook time and frying medium recovery time.

Part load refers to any production rate less than a fryer's production capacity. Most restaurants cook smaller batches of french fries during non-peak periods. That is why part-load energy consumption is a valuable piece of the restaurant's total fryer energy usage. Figure ES-1 graphically summarizes the fryer's cooking energy efficiency at different production rates. Part load efficiency rapidly increases with a corresponding increase in the production rate and starts leveling at around 15 pounds per hour.

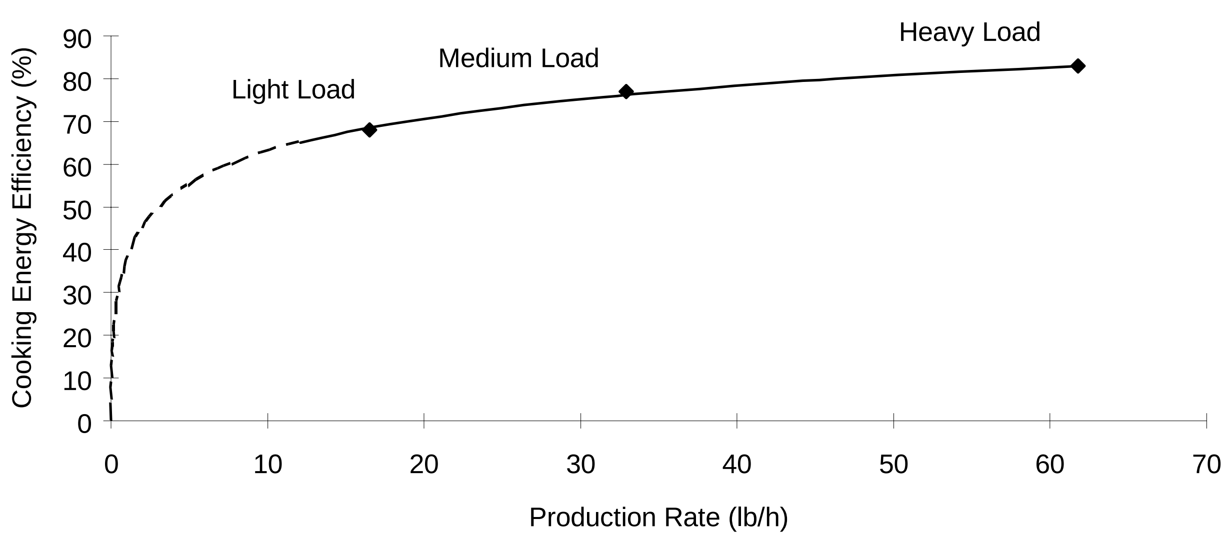

Figure ES-1. Fryer cooking energy efficiency.

The average energy consumption rate while cooking loads of french fries is illustrated in Figure ES-2. Included in the graph are the energy consumption rates and production rates for light (3/4 pound), medium (1 1/2 pounds), and heavy (3 pounds) load tests. Figure ES-2 can be used to calculate energy consumption for different production rates. For example, the average energy consumption rates at 10, 30, and 50 pounds per hour of french fry production are 3.0 kW, 6.8 kW, and 10.3 kW, respectively.

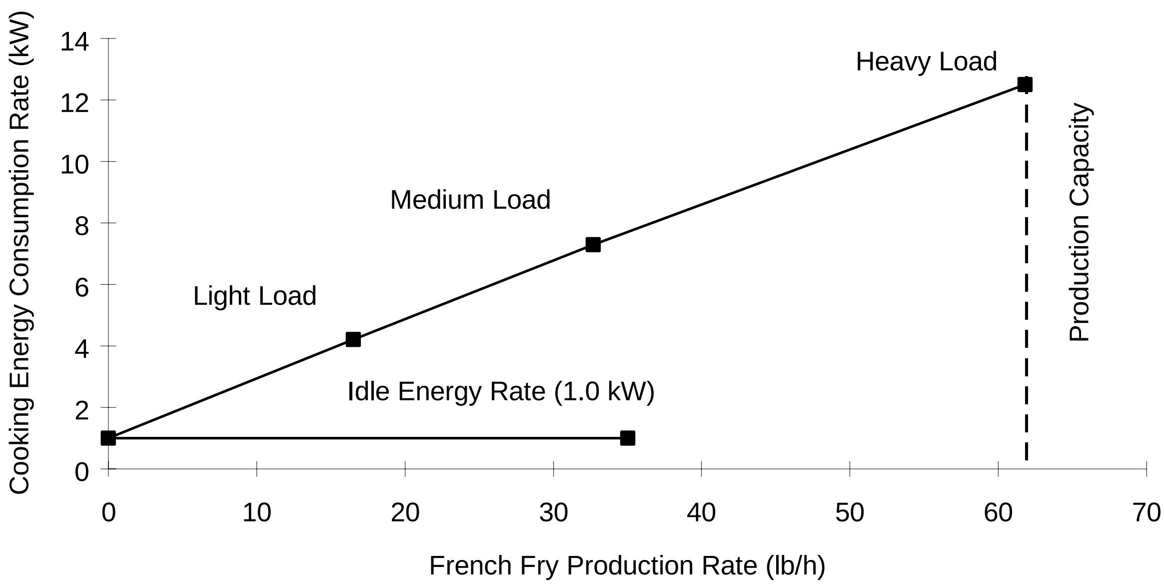

Figure ES-2. Cooking energy consumption rate during a typical heavy-, medium-, and light-load cooking test.

The Pitco electric fryer recorded the best preheat time and lowest preheat energy consumption to heat the frying medium from room temperature to 350°F (1.6 kWh in 4.9 minutes vs. 2.0 kWh in 7.7 minutes for other fryers tested). The fryer exhibited a slightly higher idle energy consumption rate (1.02 kW) than other fryers tested by the FSTC.[2,3,4]

---

[2] Pacific Gas and Electric Company. 1989. *Development and Application of a Uniform Testing Procedure for Open, Deep-fat Fryers*. Report 008-90.22 prepared for Research and Development. San Ramon, California: Pacific Gas and Electric Company.

[3] Pacific Gas and Electric Company. 1993. *Application of ASTM Standard Test Method F1361-91: Frymaster Fryer Model H-17CSC*. Report 5017.93.2 prepared for Products and Services Department, San Francisco.

[4] Pacific Gas and Electric Company. 1994 *Application of ASTM Standard Test Method F1361-91: TekmaStar Fryer Model FD-212*. Report 5011.94.2 prepared for Products and Services Department, San Francisco.

The fryer performed well in cooking tests, especially for light-load energy efficiency (68% vs. 66% for an average of electric fryers tested by the FSTC), exhibited competitive cooking energy efficiencies in all other loading conditions, produced a 62 pounds of french fries per hour under heavy-load conditions, and had a fast recovery time (14 seconds).

The fryer's proportional thermostat control strategy is to "soft land" the frying medium temperature at it's desired cooking temperature. The purpose of this control strategy is to protect the frying medium from being overheated. To achieve this temperature control, the fryer's thermostat cycles the heating elements on and off until the cooking temperature is attained. The effect on the fryer's cooking performance is to slightly reduce the productivity and lengthen the recovery time during heavy-load cooking conditions.

FSTC Manager ______________________

Donald R. Fisher

Senior Program Manager ______________________

Peter W. Turnbull

Section 1

INTRODUCTION

BACKGROUND

Food service operators have become more sophisticated when choosing commercial fryers, preferring energy-efficient fryers that meet their production capacity requirements. Most fryer studies focus on either gas or electric equipment and do not compare performances between fryers of different energy sources. Because PG&E is a dual-fuel utility, the food service industry felt that PG&E would conduct unbiased testing and comparison of gas and electric fryers and therefore asked the company to develop uniform test procedures. Data gathered in the application of these tests allow PG&E to educate end users about energy-efficient commercial cooking equipment.

With support from the Gas Research Institute (GRI), the Electric Power Research Institute (EPRI), and the National Restaurant Association, PG&E developed a uniform testing procedure (UTP) to evaluate the performance of gas and electric fryers. This test method was submitted to the American Society for Testing and Materials (ASTM) and in January 1992 was accepted as a standard test method (Designation F 1361-91).[1] PG&E's *Development and Application of a Uniform Testing Procedure for Open, Deep-fat Fryers* documents procedure development and test results for several gas and electric fryers.[2] Numerous PG&E reports documents the results of applying the ASTM standard test method to fryers.

Food Service Technology Center (FSTC) researchers continued development of the standard test method to enhance its applicability. A revised test method for fryers has proven to be more accurate and reliable than the previous version. It is available through ASTM as Designation F1361-95.

This report documents application of ASTM *Standard Test Methods for the Performance of Open Deep-fat Fryers* (Designation F1361-95) to the Pitco Frialator® E14B electric fryer. Forthcoming will be a report of fryer performance in the production-test kitchen, PG&E's corporate style-cafeteria operation. A glossary is provided in Appendix A, manufacturer's specifications are in Appendix B, cooking energy efficiency and production capacity variables are in Appendix C, and uncertainty calculations are in Appendix D.

OBJECTIVES

This report examines the performance of the Pitco Frialator model E14B electric fryer under the tightly controlled conditions of the ASTM test method. The scope of this testing is as follows:

1. Verify that the fryer operates at the manufacturer’s rated energy input.
2. Document the time and energy required to preheat the frying medium from room temperature to 350°F.
3. Determine the energy consumption rate while the fryer is idling at 350°F.
4. Determine the cooking energy efficiency under heavy-, medium-, and light-load cooking conditions using ¼-inch frozen shoestring potatoes.
5. Determine the production capacity and frying medium recovery time when cooking ¼-inch frozen shoestring potatoes during the heavy-load test.

APPLIANCE DESCRIPTION AND OPERATION

The Pitco Frialator model E14B features tubular heating elements with solid-state electronic temperature controls. The heating elements are mounted on a hinge that allows the elements to swing away for easier cleaning of the frypot. For safety purposes the heating elements de-energize when raised. The fryer is equipped with a high limit temperature control that cuts off power to all heating elements if shortening temperature exceeds 435°F (224°C). Appliance specifications are listed in Table 1-1 and manufacture’s literature is in Appendix B.

Table 1-1

Appliance Specifications

Manufacturer:	Pitco Frialator
Model Number:	E14B
Rated Energy Input:	21.0 kW
Frying Medium Capacity:	42 lb
Frying Area:	14″ x 14″
High Temperature Limit Switch:	Max. temp. 435°F (224°C)
Temperature Controls:	Solid-state electronic
Heat Transfer:	Tubular, immersion electric elements
Type of Frypot:	Stainless steel
Heating Cycles:	Melt and non-melt
Accessories:	Two fry baskets

Section 2

METHOD

TEST SETUP/INSTRUMENTATION

The fryer was installed on a tiled floor under a 4-foot-deep canopy hood that was 6 feet 6 inches above the floor. The hood operated at a nominal exhaust rate of 300 cfm per linear foot of hood. There was at least 6 inches of clearances between the vertical plane of the fryer and the edge of the hood (see Figure 2-1). All test apparatus were installed in accordance with Section 8 of the *ASTM Standard Test Method for the Performance of Open, Deep-fat Fryers*.[1] A voltage regulator maintained a constant 208 V to the appliance for each test. Temperature was measured with K-type immersible thermocouple probes. All data were logged using a Fluke Helios data logger and recorded on a personal computer, using software developed by FSTC engineers.

Thermocouples measure temperatures on the heating element zone, the cold zones, the cooking zone, and at the thermostat bulb. Four thermocouples were tack-welded onto heating elements, one in each of the four quadrants of the frypot. Two thermocouples were placed in the cook zone, one in the geometric center of the frypot, approximately 1 inch above the fry basket support, and the other at the tip of the thermostat bulb. The cold zone thermocouple was supported from above, independent of the frypot surface, so that the temperature of the cold zone reflected the frying medium temperature and not the frypot's surface temperature (see Figure 2-2).

ENERGY INPUT RATE

Rated energy input rate is the maximum or peak rate at which the appliance consumes energy as specified on the nameplate. Measured energy input rate is the maximum or peak rate of energy consumption, which is recorded during the appliance's preheat when all elements are on. For the purpose of this test, the fryer was filled with water to the frypot's indication line, and a voltage regulator was used to maintain a constant supply "nameplate" voltage. The controls were set so that the elements were at maximum output, and energy consumption was monitored for a period of 15 minutes. After the 15-minute period, researchers compared the nameplate energy input rate to the tested input rate to ensure that the fryer was operating properly.

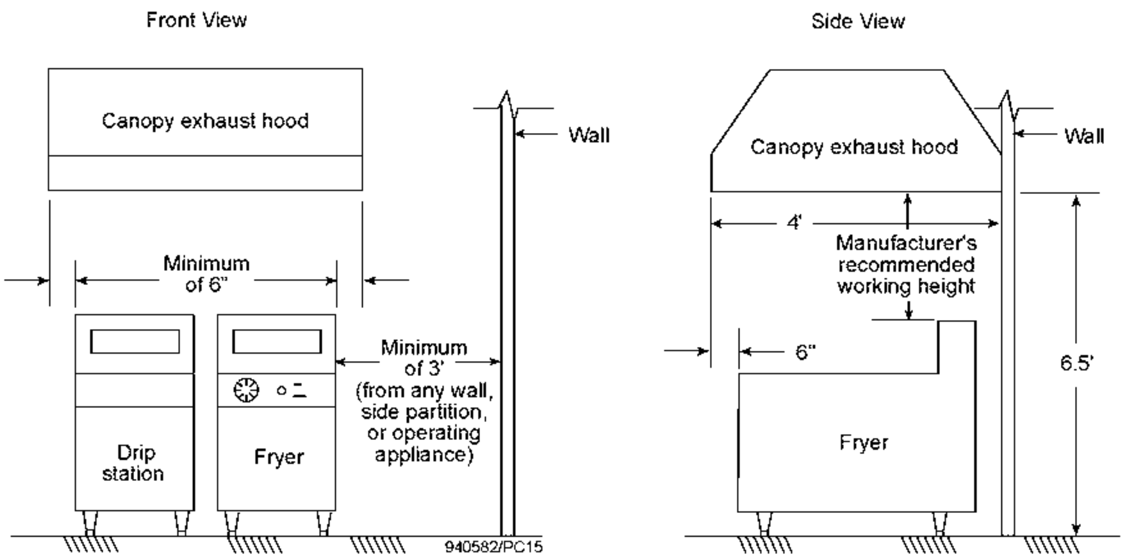

Figure 2-1. Equipment configuration.

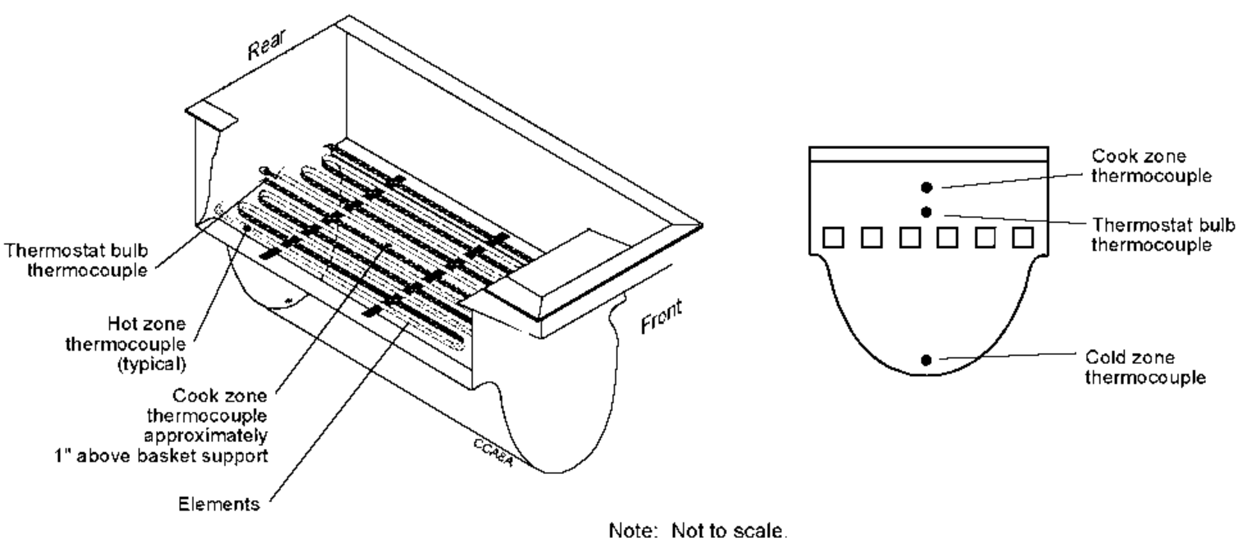

Figure 2-2. Frypot configuration and corresponding thermocouple placement.

WATER-BOIL EFFICIENCY

The water-boil test is used during product development as a quick indicator of heat transfer efficiency. However, experience demonstrates that a fryer's performance during the water-boil test is not indicative of the actual performance during cooking. For this reason, the revised version of the ASTM standard test method lists the water boil test as an optional procedure.

For this report, a water boil test was performed. The fryer was place on a platform scale and tared. Researchers filled the fryer with water to the fill line of the fryer and recorded the weight. Then five pounds of additional water were added. After the fryer had stabilized by boiling off the additional five pounds of water, the energy consumption and water boil-off were monitored.

FRENCH FRY COOKING ENERGY EFFICIENCY AND PRODUCTION CAPACITY TESTS

Researchers specified ¼-inch blue ribbon, par-cooked, frozen shoestring potatoes for all cooking tests. The french fries were 6 ± 1% fat and 66 ± 2% moisture by weight.[1] Each load was cooked to 30 ± 1% weight loss. The cooking test procedure involved "barreling" six loads of frozen french fries, using the fryer's cook zone temperature as an indication of recovery. Researchers tested the fryer using 3-pound (heavy), 1 ½-pound (medium), and ¾-pound (light) french fry loads. Cooking time determination tests established a cook time for the fryer. The cook time determination is an iterative process that may take several tests to yield average 30 ± 1% fry weight loss during cooking.

Due to the logistics involved in removing cooked fries and placing a new load into the fryer, a minimum preparation time of 10 seconds was introduced into the cooking procedure. This ensures that the cooking tests are uniformly applied from laboratory to laboratory. Fryer recovery was then based on the frying medium's reaching a threshold temperature of 340°F (measured at the center of the cook zone). Reloading within 10°F of the 350°F thermostat set point does not significantly lower the average oil temperature over the cooking cycle, nor does it extend the cook time. The fryer was reloaded either after the cook zone thermocouple reached the threshold temperature or 10 seconds after removing the previous load from the fryer, whichever was longer.

The first load of each six-load cooking test was designated a stabilization load: Energy monitoring and elapsed test time were calculated after the *second* load was placed in the frying medium. After removing the last load and allowing the fryer to recover, researchers terminated the test. Total elapsed time, energy consumption, weight of fries cooked, and average weight loss of the french fries were recorded for loads two through six.

Cooking tests were run sequentially—three replicates of the heavy-load test, three replicates of the medium-load test, and three replicates of the light-load test—to ensure that the reported cooking energy efficiency and production capacity results had an uncertainty of less than ± 10%. Results of each test run were averaged, and absolute uncertainty was calculated based on the standard deviation of the results.

Section 3

RESULTS

ENERGY INPUT RATE AND WATER-BOIL TESTS

Energy Input Rate

The energy input rate was measured and compared with the manufacturer's nameplate value prior to testing. This provided a check to ensure that the fryer was operating properly. The fryer's rated energy input rate is 21.0 kW. The measured energy rate was 21.2 kW (a difference of 1.0%).

Water-Boil Efficiency

The optional water-boil test was applied for this fryer. The test was run three times back to back on the same day. The average barometric pressure was 14.493 psia. After the fryer had stabilized by boiling off the additional 5 pounds of water, the fryer boiled off water at an average rate 68 pounds per hour. The fryer's calculated water-boil efficiency was 90.0%.

PREHEAT AND IDLE ENERGY CONSUMPTION

Preheat and idle energy tests are conducted to estimate time and energy consumption demands on appliances. Non-cooking energy performance tests of the E14B fryer were conducted in accordance with the ASTM standard test method F 1361-95. The frying medium used in all tests was partially hydrogenated, 100% pure vegetable oil.

Preheat Energy Consumption

The frying medium's average temperature was 75.3°F at the start of the preheat test. The time to heat the frying medium to 350°F was 4.9 minutes. The total energy consumed during preheat was 1.6 kWh. Figure 3-1 shows fryer energy consumption and cook zone temperature during the preheat period. Figure 3-2 shows fryer temperature profile of heating, cook and cold zones during the preheat and idle test periods.

Idle Energy Consumption

The fryer was preheated and allowed to stabilize at 350°F for 1 hour. Researchers monitored the fryer's energy consumption over a 2-hour period. The energy rate during this period was 1.02 kW.

Test Results

Input, preheat, and idle test results are summarized in Table 3-1.

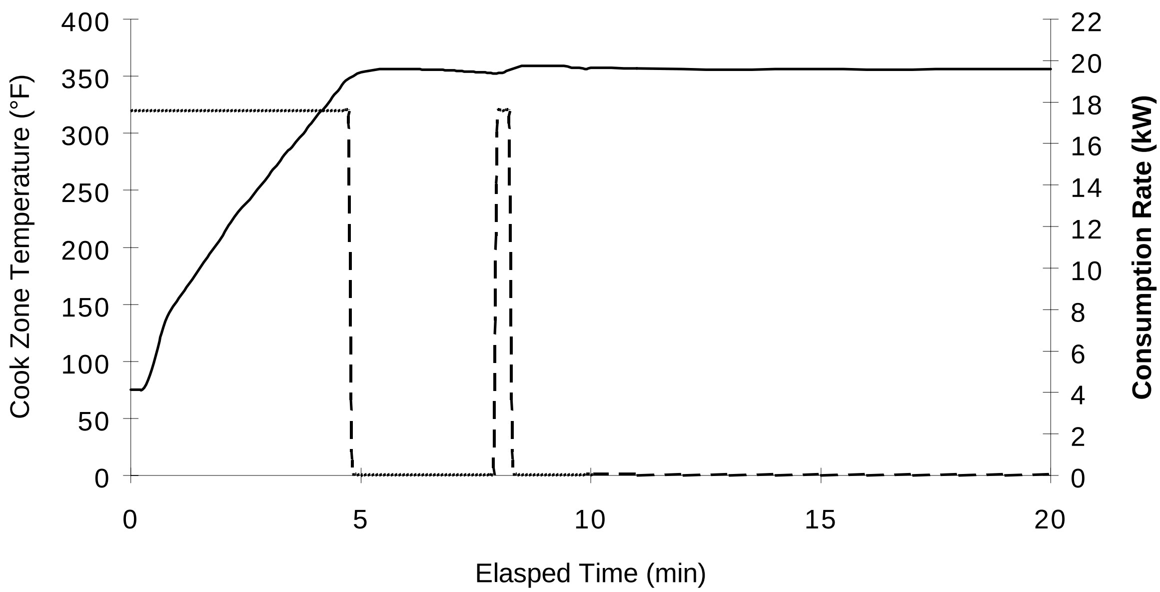

Figure 3-1. Energy consumption and cook zone temperature during preheat.

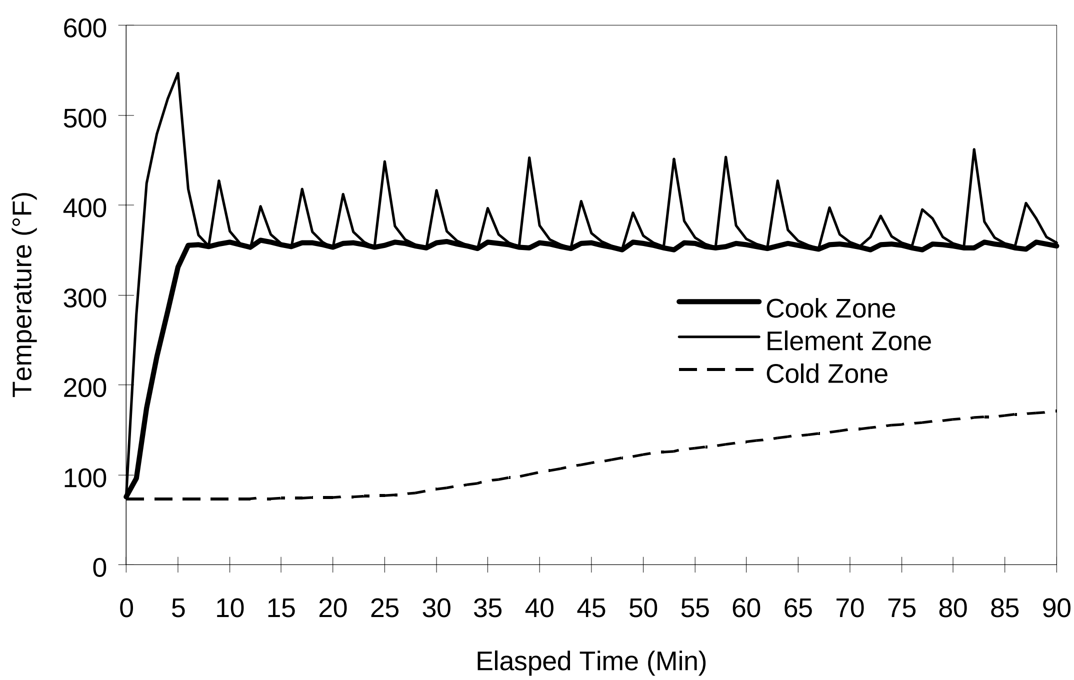

Figure 3-2. Temperature profile of heating, cook, and cold zones during a preheat and idle test.

Table 3-1

Input, Preheat, and Idle Test Results

Rated Energy Input Rate (kW)	21.0
Measured Energy Input Rate (kW)	21.2
Water-Boil Efficiency	90.0
Preheat:	
Time @ 350°F (min)	4.9
Energy Consumption (kWh)	1.6
Rate to 350°F (°F/min)	56
Preheat (melt cycle on.):	
Time @ 350°F (min)	9.3
Energy Consumption (kWh)	1.7
Rate to 350°F (°F/min)	30
Idle Energy Consumption Rate @ 350°F (kW)	1.02
Idle Duty cycle (%)	4.8

COOKING PERFORMANCE TESTS

The fryer was tested under three different loading scenarios: heavy (3 pounds), medium (1 ½ pounds) and light (¾ pound). Researchers recorded cook time, cooking energy consumption, recovery time, and french fry weight loss during testing. Table 3-2 presents the results of applying ASTM standard test method F1361-95 (*Section 10.10 Cooking-Energy Efficiency and Production Capacity for Heavy, Medium, and Light-load Fry Tests*) to the fryer. Appendix D includes the uncertainty calculations for production rate, cooking energy efficiency and cooking energy rate for french fry cooking loads.

Table 3-2

Cooking Energy Efficiencies and Production Capacity Test Results

	Heavy Load	Medium Load	Light Load
Cook Time (min)	2.67	2.52	2.52
Recovery Time (sec)	14	13	13
Production Rate (lb/h)	62.0 ± 1.3	33.9 ± 1.6	16.5 ± 0.6
Average Cooking Energy Consumption Rate (kW)	12.6	7.3	4.2
Energy to Fryer (Btu/lb)	693	759	865
Energy to Food (Btu/lb)	574	581	590
Cooking Energy Efficiency (%)	83.0 ± 4.9	76.6 ± 3.8	68.3 ± 4.3

Cooking energy efficiency is defined as the energy to the french fries, expressed as a percentage of the energy to the fryer. Researchers determine the energy imparted to the french fries by calculating the heat absorbed by each component of the french fries (fat, solid, and water), including the latent heat of vaporization required to evaporate the moisture contained in the fries. The reported test results are an average of three replicated test runs. Cooking energy efficiencies were 83.0%, 76.6%, 68.3% for heavy-, medium-, and light-loads, respectively.

To determine how well the fryer is cooking, one can look at the temperature profile of the frying medium: Too low of a temperature drop and the french fries absorb too much oil. Figure 3-3 illustrates the fluctuating frying medium temperature during a heavy-load french fry cooking test. If the cooking medium is able to quickly return to 340°F during each heavy load, the fryer will also be able to recover during medium- and light-load tests.

Figure 3-4 illustrates the differences in temperature during between the thermostat probe and the cook zone temperature. Figure 3-5 presents a magnified view of the cook zone temperature's reaction (sometimes called the fryer's cooking temperature signature) when a heavy load of fries is lowered into the 350°F frying medium. Figure 3-5 illustrates the fryer's proportional thermostat control. The thermostat reduces energy to the heating elements when the frying medium temperature is close to it's thermostat cooking temperature.

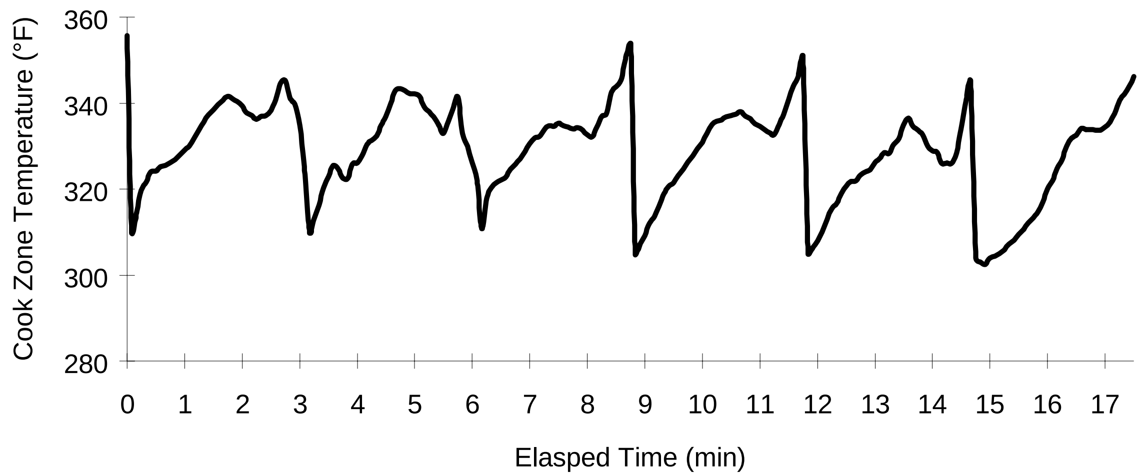

Figure 3-3. Temperature profile for a typical heavy-load cooking test showing cook zone temperature recovery.

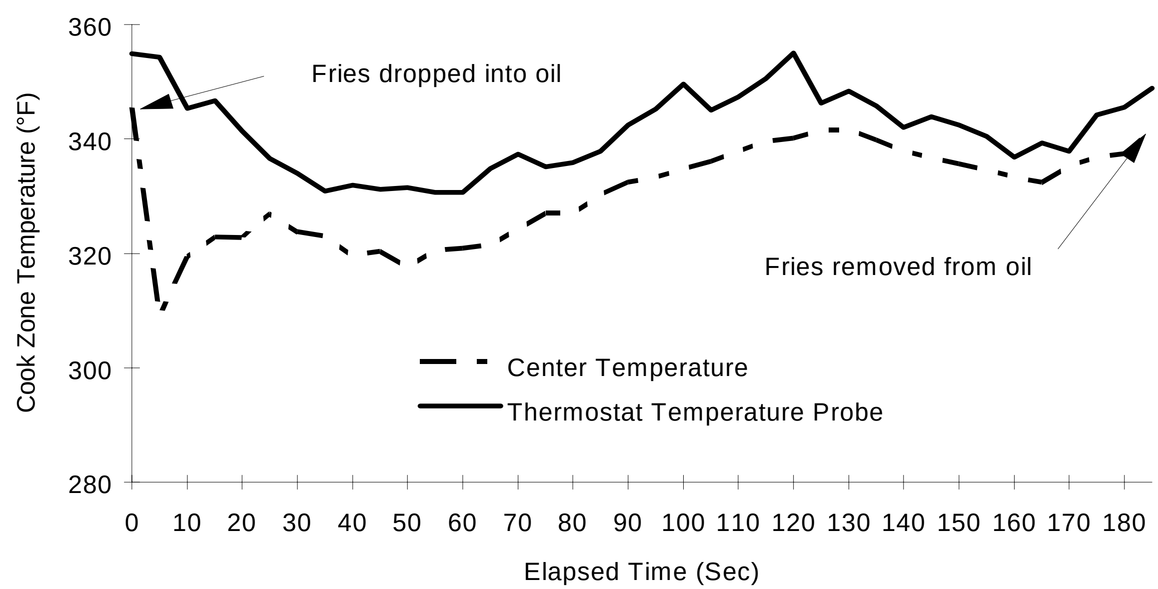

Figure 3-4. Thermostat probe and cook zone temperatures for a typical heavy load.

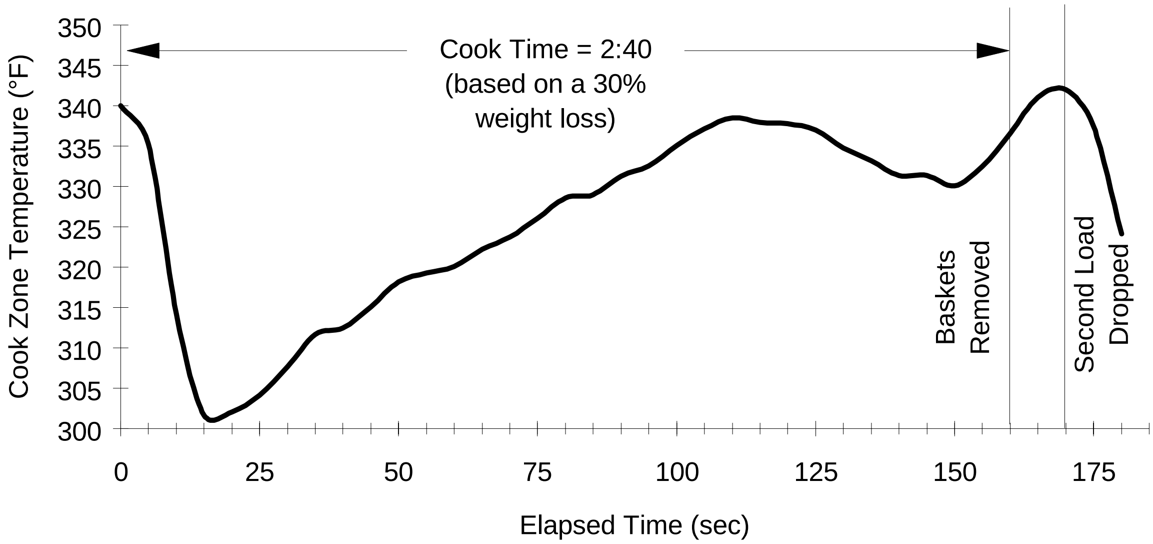

Figure 3-5. Cook zone temperature recovery for a typical heavy load.

Figure 3-6 represents the cooking energy consumption rate during a typical heavy-, medium-, and light-load cooking test. Figure 3-6 can be used to calculate energy consumption for different production rates. For example, at 10, 30, and 50 pounds per hour, average energy consumption rates are 3.0 kW, 6.8 kW, and 10.3 kW, respectively.

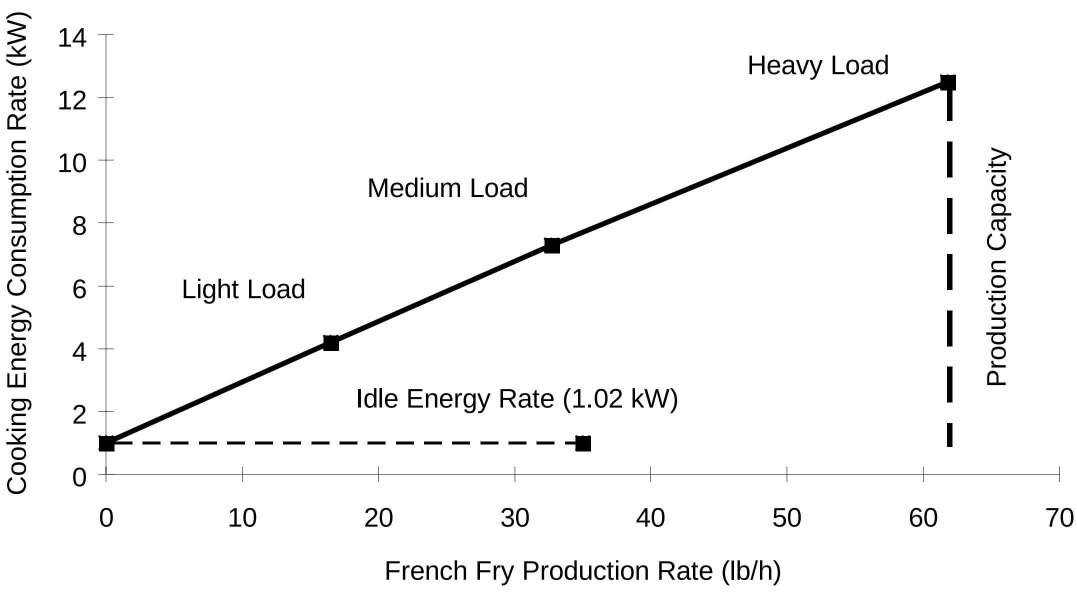

Figure 3-6. Cooking energy consumption rate during a typical heavy-, medium-, and light-load cooking test.

Part load refers to any production rate less than a fryer's production capacity. Most restaurants cook smaller batches of french fries during non-peak periods. That is why part-load energy consumption is a valuable piece of the restaurant's total fryer energy usage. Figure 3-7 graphically summarizes the fryer's cooking energy efficiency at different production rates. Part load efficiency rapidly increases with a corresponding increase in the production rate and starts leveling at around 15 pounds per hour.

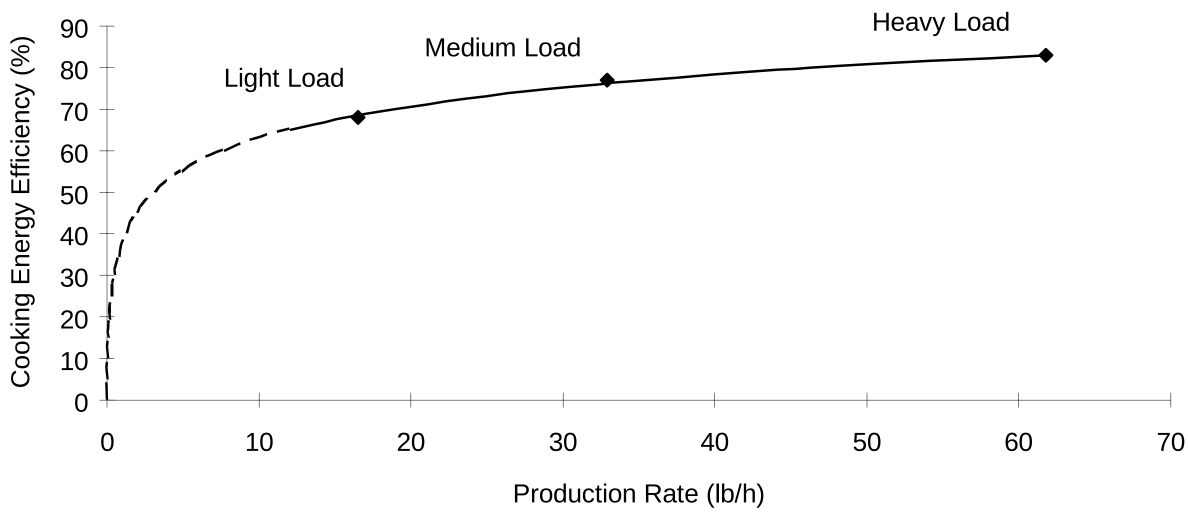

Figure 3-7. Fryer cooking energy efficiency.

Section 4

CONCLUSIONS AND RECOMMENDATIONS

The Pitco Frialator model E14B electric fryer performed competitively with other fryers tested at PG&E's Food Service Technology Center. The fryer achieved good cooking energy efficiencies for heavy- (83%), medium- (77%), and light-load (68%) cooking tests. These values for cooking efficiencies were among the highest of fryers tested by the FSTC.[2,3,4] The fryer exhibited a slightly lower production capacity then other electric fryers tested (62 pounds per hour vs. 68 pounds per hour for other fryers).[2,3,4]

The fryer was responsive during cooking events, maintaining a relatively high average cook zone temperature (typical load 328°F) under heavy-load conditions with a 340°F reload. Had a fast recovery time for heavy-load conditions (14 seconds).[2]

The fryer's proportional thermostat control reduces energy input to the heating elements when the frying medium temperature is close to the thermostat set point temperature. The premise for this proportional control strategy is to carefully control the frying medium temperature to avoid overheating the frying medium. The benefit to the user is that the fryer has a control strategy to help avoid overheating. The effect of the proportional thermostat controls on the fryer's cooking performance is to slightly reduce productivity and slightly lengthen the recovery time during heavy-load cooking conditions.

The appliance recorded one of the quickest elapsed times and lowest energy consumption for a preheat test. During the preheat test, the fryer took 4.9 minutes and used 1.6 kWh of energy to bring the frying medium (pourable, partially hydrogenated vegetable oil) from room temperature to 350°F. The next best fryer had a preheat time of 6.1 minutes and 1.7 kWh of energy use.[2]

Test results indicate that this fryer will perform well in actual production. The fryer performed well under ASTM cooking tests, recording among the highest cooking energy efficiencies. Evaluation of this fryer in the real-world setting of the production-test kitchen was recommended and implemented.

Section 5

REFERENCES

1. American Society for Testing and Materials. 1992. *American Society for Testing and Materials Standard Test Methods for the Performance of Open Deep-fat Fryers*. ASTM Designation F1361-95. Philadelphia: American Society for Testing and Materials.

2. Pacific Gas and Electric Company. 1991. *Development and Application of a Uniform Testing Procedure for Open, Deep-fat Fryers.* Report 008.1-90.22 prepared for Research and Development. San Ramon, California: Pacific Gas and Electric Company.

3. Pacific Gas and Electric Company. 1993. *Application of ASTM Standard Test Method F1361-91: Frymaster Fryer Model H-17CSC.* Report 5017.93.2 prepared for Products and Services Department. San Francisco, California: Pacific Gas and Electric Company.

4. Pacific Gas and Electric Company. 1994. *Application of ASTM Standard Test Method F1361-91: TekmaStar Fryer Model FD-212.* Report 5011.94.2 prepared for Products and Services Department. San Francisco, California: Pacific Gas and Electric Company.

Appendix A

GLOSSARY

GLOSSARY

Cold Zone—The volume in the fryer below the heating element(s) or heat exchanger surface designed to remain cooler than the fry zone and hot zone.

Cook Zone—The volume of oil in the fryer where the fries are cooked. Typically, the entire volume from the heating element(s) of a heat exchanger surface to the surface of the frying medium. Also referred to as *Cooking Zone.*

Cooking Energy *(kWh or kBtu)*—The total energy consumed by an appliance as it is used to cook a specified food product.

Cooking Energy Consumption Rate *(kW or kBtu/h)*—The average rate of energy consumption during the cooking period.

Cooking Energy Efficiency—The quantity of energy input to the food products; expressed as a percentage of the quantity of energy input to the appliance during the heavy-, medium-, and light-load tests.

Energy Input Rate *(kW or kBtu/h)*—The peak rate at which an appliance will consume energy, typically reflected during preheat. Also referred to as *Energy Consumption Rate* and *Energy Rate*.

Hot Zone—The area surrounding the heating element(s) or heat exchanger surface.

Idle Energy Consumption *(kWh or kBtu)*—The amount of energy consumed by an appliance operating under an idle condition over the duration of an idle period. Also referred to as *Idle Energy Use.*

Idle Energy Rate *(kW or kBtu/h)*—The rate of appliance energy consumption while it is "idling" or "holding" at a stabilized operating condition or temperature. Also referred to as *Idle Energy Input Rate* or *Idle Energy Consumption Rate* or *Idle Rate.*

Idle Duty Cycle *(%)*—The idle energy consumption rate expressed as a percentage of the measured energy input rate. Also referred to as *Idle Energy Factor* or *Idle Load Factor*.

$$\text{Idle Energy Factor} = \frac{\text{Idle Energy Consumption Rate}}{\text{Measured Energy Input Rate}} \times 100$$

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.

Measured Energy Input Rate *(kW, W or kBtu/h, Btu/h)*—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"). Also referred to as *Measured Input* or *Measured Peak Energy Input Rate* or *Peak Rate of Energy Input.*

Open Deep-Fat Fryer—An appliance, including a cooking vessel, that holds oils to such a depth that the food cooked is essentially supported by the cooking fluid rather than by the vessel itself.

Pilot Energy Rate *(kBtu/h)*— The rate of energy consumption by the standing or constant pilot while the appliance is not being operated (i.e., when the thermostats or control knobs have been turned off by the food service operator). Also referred to as *Average Pilot Energy Rate* or *Average Pilot Energy Use Rate* or *Pilot Energy Consumption Rate.*

Preheat Energy *(kWh or kBtu)*—The amount of energy consumed by an appliance while preheating the cook zone form room temperature to the thermostat set point. Also refered to as *Preheat Energy Consumption.*

Preheat Rate—The rate at which the cook zone heats during a preheat.

Preheat Time *(minute, hour)*—The time required for an appliance to "preheat" from the ambient room temperature to the thermostat set point. Also referred to as *Preheat Period.*

Production Capacity—The maximum production rate (lb/h) of an appliance while cooking a specified food product in accordance with the heavy-load cooking test.

Rated Energy Input Rate *(kW, W or kBtu/h, Btu/h)*—The maximum or peak rate at which an appliance consumes energy as rated by the manufacturer and specified on the nameplate. Also referred to as *Input Rating* (ANSI definition) or *Nameplate Energy Input Rate* or *Rated Input.*

Recovery Time—The average time from the removal of the fry baskets from the fryer until the frying medium is within 10°F of the thermostat set point and the fryer is ready to be reloaded.

Test Method—A definitive procedure for the identification, measurement, and evaluation of one or more qualities, characteristics, or properties of a material, product, system, or service that produces a test result.

Water-Boil Efficiency (%)—The quantity of energy required to boil water; expressed as a percentage of the quantity of energy input to the appliance during the boil-off test period.

APPENDIX B

MANUFACTURER'S PRODUCT SPECIFICATIONS

Appendix C

COOKING ENERGY EFFICIENCY AND PRODUCTION CAPACITY VARIABLES

HEAVY-LOAD TEST #1*

June 30, 1994

Cooking Energy Efficiency	**84.2%**
Production Rate	**61.6 lb/h**
Average Recovery Time	**0.26 min**
Average Energy Consumption Rate	**12.6 kW**

Measured Values

Energy	
Total Energy (kWh)	3.08
Fries	
Cook Time (min)	**2.67**
Total Test Time (min)	14.62
Weight Loss (%)	30.5
Total Fry Weight (lb)	15.0
Initial Fat (%)	6.1
Initial Moisture (%)	66.5
Final Moisture (%)	44.6
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212

Assumed Values

Fries	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization Water (Btu/lb)	970

Calculated Values

Energy	
Total Energy to Fryer (Btu)	10,512
Energy to Fryer (Btu/lb)	**701**
Fries	
Final Weight of Water (lb)	4.6
Weight of Water Vaporized (lb)	5.3
Weight of Fat (lb)	0.9
Weight of Solids (lb)	4.1
Final Fry Weight (lb)	10.4
Initial Weight of Water (lb)	10.0
Sensible to Ice (Btu)	160
Sensible to Water (Btu)	1,796
Sensible to Fat (Btu)	78
Sensible to Solids (Btu)	174
Latent - Water Fusion (Btu)	1,436
Latent - Fat Fusion (Btu)	40
Latent - Water Vaporization (Btu)	5,166
Total Energy to Food (Btu)	8,849
Energy to Food (Btu/lb)	**590**

*3-lb basket of frozen shoestring potatoes

HEAVY-LOAD TEST #2*
June 30, 1994

Cooking Energy Efficiency	**84.0%**
Production Rate	**61.9 lb/h**
Average Recovery Time	**0.24 min**
Average Energy Consumption Rate	**12.2 kW**

Measured Values

Energy	
Total Energy (kWh)	2.97
Fries	
Cook Time (min)	**2.67**
Total Test Time (min)	14.55
Weight Loss (%)	29.2
Total Fry Weight (lb)	15.0
Initial Fat (%)	6.1
Initial Moisture (%)	66.6
Final Moisture (%)	47.2
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212

Assumed Values

Fries	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970

Calculated Values

Energy	
Total Energy to Fryer (Btu)	10,137
Energy to Fryer (Btu/lb)	**676**
Fries	
Final Weight of Water (lb)	5.0
Weight of Water Vaporized (lb)	5.0
Weight of Fat (lb)	0.9
Weight of Solids (lb)	4.1
Final Fry Weight (lb)	10.6
Initial Weight of Water (lb)	10.0
Sensible to Ice (Btu)	160
Sensible to Water (Btu)	1,798
Sensible to Fat (Btu)	78
Sensible to Solids (Btu)	174
Latent - Water Fusion (Btu)	1,439
Latent - Fat Fusion (Btu)	40
Latent - Water Vaporization (Btu)	4,828
Total Energy to Food (Btu)	8,516
Energy to Food (Btu/lb)	**568**

*3-lb basket of frozen shoestring potatoes

HEAVY-LOAD TEST #3*

June 30, 1994

Cooking Energy Efficiency	**80.7%**
Production Rate	**61.8 lb/h**
Average Recovery Time	**0.25 min**
Average Energy Consumption Rate	**12.7 kW**

Measured Values

Energy	
Total Energy (kWh)	3.08
Fries	
Cook Time (min)	**2.67**
Total Test Time (min)	14.6
Weight Loss (%)	29.0
Total Fry Weight (lb)	15.0
Initial Fat (%)	6.1
Initial Moisture (%)	66.5
Final Moisture (%)	47.2
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212

Assumed Values

Fries	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat(Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970

Calculated Values

Energy	
Total Energy to Fryer (Btu)	10,512
Energy to Fryer (Btu/lb)	**701**
Fries	
Final Weight of Water (lb)	5.0
Weight of Water Vaporized (lb)	4.9
Weight of Fat (lb)	0.9
Weight of Solids (lb)	4.1
Final Fry Weight (lb)	10.7
Initial Weight of Water (lb)	10.0
Sensible to Ice (Btu)	160
Sensible to Water (Btu)	1,796
Sensible to Fat (Btu)	78
Sensible to Solids (Btu)	174
Latent - Water Fusion (Btu)	1,436
Latent - Fat Fusion (Btu)	40
Latent - Water Vaporization (Btu)	4,795
Total Energy to Food (Btu)	8,479
Energy to Food (Btu/lb)	**565**

*3-lb basket of frozen shoestring potatoes

MEDIUM-LOAD TEST #1*

July 7, 1994

Cooking Energy Efficiency	**75.5%**
Production Rate	**32.2 lb/h**
Average Recovery Time	**0.24 min**
Average Energy Consumption Rate	**7.3 kW**

Measured Values

Energy	
Total Energy (kWh)	1.71
Fries	
Cook Time (min)	**2.55**
Total Test Time (min)	13.97
Weight Loss (%)	30.5
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.1
Initial Moisture (%)	66.5
Final Moisture (%)	44.9
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212

Assumed Values

Fries	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization Water (Btu/lb)	970

Calculated Values

Energy	
Total Energy to Fryer (Btu)	5,836
Energy to Fryer (Btu/lb)	**778**
Fries	
Final Weight of Water (lb)	2.3
Weight of Water Vaporized (lb)	2.6
Weight of Fat (lb)	0.5
Weight of Solids (lb)	2.1
Final Fry Weight (lb)	5.2
Initial Weight of Water (lb)	5.0
Sensible to Ice (Btu)	80
Sensible to Water (Btu)	898
Sensible to Fat (Btu)	39
Sensible to Solids (Btu)	87
Latent - Water Fusion (Btu)	718
Latent - Fat Fusion (Btu)	20
Latent - Water Vaporization (Btu)	2,566
Total Energy to Food (Btu)	4,408
Energy to Food (Btu/lb)	**588**

*1.5-lb basket of frozen shoestring potatoes

MEDIUM-LOAD TEST #2*
July 7, 1994

Cooking Energy Efficiency	**78.4%**
Production Rate	**33.3 lb/h**
Average Recovery Time	**0.20 min**
Average Energy Consumption Rate	**7.1 kBtu/h**

Measured Values

Energy	
Total Energy (kWh)	1.59
Fries	
Cook Time (min)	**2.50**
Total Test Time (min)	13.52
Weight Loss (%)	30.2
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.1
Initial Moisture (%)	66.5
Final Moisture (%)	47.7
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212

Assumed Values

Fries	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970

Calculated Values

Energy	
Total Energy to Fryer (Btu)	5,427
Energy to Fryer (Btu/lb)	**724**
Fries	
Final Weight of Water (lb)	2.5
Weight of Water Vaporized (lb)	2.5
Weight of Fat (lb)	0.5
Weight of Solids (lb)	2.1
Final Fry Weight (lb)	5.2
Initial Weight of Water (lb)	5.0
Sensible to Ice (Btu)	80
Sensible to Water (Btu)	898
Sensible to Fat (Btu)	39
Sensible to Solids (Btu)	87
Latent - Water Fusion (Btu)	718
Latent - Fat Fusion (Btu)	20
Latent - Water Vaporization (Btu)	2,415
Total Energy to Food (Btu)	4,257
Energy to Food (Btu/lb)	**568**

*1.5-lb basket of frozen shoestring potatoes

MEDIUM-LOAD TEST #3*

July 7, 1994

Cooking Energy Efficiency	**76.0%**
Production Rate	**33.3 lb/h**
Average Recovery Time	**0.21 min**
Average Energy Consumption Rate	**7.5 kW**

Measured Values

Energy	
Total Energy (kWh)	1.70
Fries	
Cook Time (min)	**2.50**
Total Test Time (min)	13.53
Weight Loss (%)	30.7
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.1
Initial Moisture (%)	66.5
Final Moisture (%)	45.0
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212

Assumed Values

Fries	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat(Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970

Calculated Values

Energy	
Total Energy to Fryer (Btu)	5,802
Energy to Fryer (Btu/lb)	**774**
Fries	
Final Weight of Water (lb)	2.3
Weight of Water Vaporized (lb)	2.6
Weight of Fat (lb)	0.5
Weight of Solids (lb)	2.1
Final Fry Weight (lb)	5.2
Initial Weight of Water (lb)	5.0
Sensible to Ice (Btu)	80
Sensible to Water (Btu)	898
Sensible to Fat (Btu)	39
Sensible to Solids (Btu)	87
Latent - Water Fusion (Btu)	718
Latent - Fat Fusion (Btu)	20
Latent - Water Vaporization (Btu)	2,569
Total Energy to Food (Btu)	4,411
Energy to Food (Btu/lb)	**588**

*1.5-lb basket of frozen shoestring potatoes

LIGHT-LOAD TEST #1*

June 30, 1994

Cooking Energy Efficiency	**66.8%**
Production Rate	**16.2 lb/h**
Average Recovery Time	**0.21 min**
Average Energy Consumption Rate	**4.2 kW**

Measured Values

Energy	
Total Energy (kWh)	0.98
Fries	
Cook Time (min)	**2.57**
Total Test Time (min)	13.88
Weight Loss (%)	33.1
Total Fry Weight (lb)	3.75
Initial Fat (%)	6.1
Initial Moisture (%)	66.5
Final Moisture (%)	45.5
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212

Assumed Values

Fries	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization Water (Btu/lb)	970

Calculated Values

Energy	
Total Energy to Fryer (Btu)	3,345
Energy to Fryer (Btu/lb)	**892**
Fries	
Final Weight of Water (lb)	1.1
Weight of Water Vaporized (lb)	1.4
Weight of Fat (lb)	0.2
Weight of Solids (lb)	1.0
Final Fry Weight (lb)	2.5
Initial Weight of Water (lb)	2.5
Sensible to Ice (Btu)	40
Sensible to Water (Btu)	449
Sensible to Fat (Btu)	19
Sensible to Solids (Btu)	44
Latent - Water Fusion (Btu)	359
Latent - Fat Fusion (Btu)	10
Latent - Water Vaporization (Btu)	1,312
Total Energy to Food (Btu)	2,233
Energy to Food (Btu/lb)	**595**

*.75-lb basket of frozen shoestring potatoes

LIGHT-LOAD TEST #2*
June 30, 1994

Cooking Energy Efficiency	**67.9%**
Production Rate	**16.6 lb/h**
Average Recovery Time	**0.21 min**
Average Energy Consumption Rate	**4.2 kW**

Measured Values

Energy	
Total Energy (kWh)	0.95
Fries	
Cook Time (min)	**2.50**
Total Test Time (min)	13.53
Weight Loss (%)	31.4
Total Fry Weight (lb)	3.75
Initial Fat (%)	6.1
Initial Moisture (%)	66.5
Final Moisture (%)	45.6
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212

Assumed Values

Fries	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970

Calculated Values

Energy	
Total Energy to Fryer (Btu)	3,242
Energy to Fryer (Btu/lb)	**865**
Fries	
Final Weight of Water (lb)	1.2
Weight of Water Vaporized (lb)	1.3
Weight of Fat (lb)	0.2
Weight of Solids (lb)	1.0
Final Fry Weight (lb)	2.6
Initial Weight of Water (lb)	2.5
Sensible to Ice (Btu)	40
Sensible to Water (Btu)	449
Sensible to Fat (Btu)	19
Sensible to Solids (Btu)	44
Latent - Water Fusion (Btu)	359
Latent - Fat Fusion (Btu)	10
Latent - Water Vaporization (Btu)	1,281
Total Energy to Food (Btu)	2,202
Energy to Food (Btu/lb)	**587**

*.75-lb basket of frozen shoestring potatoes

LIGHT-LOAD TEST #3*

June 30, 1994

Cooking Energy Efficiency	**70.2%**
Production Rate	**16.6 lb/h**
Average Recovery Time	**0.21 min**
Average Energy Consumption Rate	**4.1 kW**

Measured Values

Energy	
Total Energy (kWh)	0.92
Fries	
Cook Time (min)	**2.50**
Total Test Time (min)	13.55
Weight Loss (%)	31.5
Total Fry Weight (lb)	3.75
Initial Fat (%)	6.1
Initial Moisture (%)	66.5
Final Moisture (%)	45.6
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212

Assumed Values

Fries	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat(Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970

Calculated Values

Energy	
Total Energy to Fryer (Btu)	3,140
Energy to Fryer (Btu/lb)	**837**
Fries	
Final Weight of Water (lb)	1.2
Weight of Water Vaporized (lb)	1.3
Weight of Fat (lb)	0.2
Weight of Solids (lb)	1.0
Final Fry Weight (lb)	2.6
Initial Weight of Water (lb)	2.5
Sensible to Ice (Btu)	40
Sensible to Water (Btu)	449
Sensible to Fat (Btu)	19
Sensible to Solids (Btu)	44
Latent - Water Fusion (Btu)	359
Latent - Fat Fusion (Btu)	10
Latent - Water Vaporization (Btu)	1,282
Total Energy to Food (Btu)	2,203
Energy to Food (Btu/lb)	**588**

*.75-lb basket of frozen shoestring potatoes

Appendix D

UNCERTAINTY CALCULATIONS

UNCERTAINTY CALCULATIONS

The ASTM *Standard Test Method for the Performance of Open, Deep-fat Fryers* (Designation F 1361-95) provides a mandatory annex for the statistical treatment of data *(A1. Procedure For Determining The Uncertainty In Reported Test Results)*. The standard test method requires that the uncertainty of the production capacity and cooking energy efficiency results be no greater than ± 10% before any part of the test results be reported. Calculating the uncertainty determines if the results are within the allowable tolerance and also how many test runs are required to satisfy this precision. Tables D-1, D-2, and D-3 summarize the uncertainty calculations for production rate, cooking energy efficiency, and cooking energy rate for heavy (3 pounds), medium (1 ½ pounds), and light (¾ pound) french fry cooking loads.

Table D-1

Production Rate, Cooking Energy Efficiency, Cooking Energy Rate for Heavy Load

	Production Rate (lb/h)	Cooking Energy Efficiency (%)	Cooking Energy Rate (kW)
Scenario #1	61.6	84.2	12.6
Scenario #2	62.6	84.0	12.4
Scenario #3	61.8	80.7	12.7
Average of Runs	62.0	83.0	12.6
Standard Deviation	0.7	2.0	0.2
Absolute Uncertainty	1.3	4.87	0.4
Percent Uncertainty (%)	2.1	5.9	3.1

Table D-2

Production Rate, Cooking Energy Efficiency, Cooking Energy Rate for Medium Load

	Production Rate (lb/h)	Cooking Energy Efficiency (%)	Cooking Energy Rate (kW)
Scenario #1	32.2	75.5	7.34
Scenario #2	33.3	78.4	7.06
Scenario #3	33.3	76.0	7.54
Average of Runs	32.9	76.6	7.31
Standard Deviation	0.6	1.6	0.2
Absolute Uncertainty	1.6	3.8	0.6
Percent Uncertainty (%)	4.8	5.0	8.2

Table D-1

Production Rate, Cooking Energy Efficiency, Cooking Energy Rate for Light Load

	Production Rate (lb/h)	Cooking Energy Efficiency (%)	Cooking Energy Rate (kW)
Scenario #1	16.2	40.7	4.24
Scenario #2	16.6	38.6	4.21
Scenario #3	16.6	40.5	4.07
Average of Runs	16.5	39.9	4.17
Standard Deviation	0.3	1.2	0.9
Absolute Uncertainty	.6	2.9	.2
Percent Uncertainty (%)	3.5	7.2	5.2