Pitco Frialator® Model RPB14 Technofry 1 ™ Gas Fryer:

Application of ASTM Standard Test Method F 1361-95

Report 5011.94.11

Food Service Technology Center

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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.

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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 subsequently 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 RPB14 Technofry 1™ gas 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 RPB14 Technofry 1™ gas fryer incorporates metal fiber infrared power burners into its design. The flue gases are recirculated around the sides of the frypot for increased energy performance. In addition to solid-state temperature controls and an all-stainless-steel frypot, each fryer features Pitco's exclusive hot surface ignition for increased 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 RPB14 Technofry 1 Gas Fryer

Rated Energy Input Rate (kBtu/h)	80.0
Measured Energy Input Rate (kBtu/h)	81.5
Preheat to 350°F	
Time (min)	10.5
Energy Consumption (kBtu)	13.8
Rate to 350°F (°F/min)	25.6
Idle Energy Rate @ 350°F (kBtu/h)	5.6
Cooking Energy Efficiency (%)	
Heavy Load	48.7
Medium Load	45.1
Light Load	39.9
Production Capacity (lb/h) [a]	62.3
Frying Medium Recovery Time (sec)[a]	19.0

[a] Based on heavy-load test.

[1] American Society for Testing and Materials. 1992. *Standard Test Methods for the Performance of Open, Deep-fat Fryers.* ASTM Designation F1361-95. In *Annual Book of ASTM Standards*. Philadelphia.

Fryer cooking performance was determined by cooking three different loads—a heavy load (3 pounds), a medium load ($1\frac{1}{2}$ pounds), and a light load ($\frac{3}{4}$ pound)—using $\frac{1}{4}$-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 35 seconds for the heavy-load test, 2 minutes 15 seconds for the medium-load test, and 2 minutes 10 seconds for the light-load test. Cooking energy efficiency was defined as the following relationship:

$$Cooking\ Energy\ Efficiency = \frac{Energy\ to\ Food}{Energy\ to\ Fryer}$$

The ASTM standard test method uses barreling with the requirement, "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."[1] The term "barrel" loading 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 total restaurants fryer energy usage. Partial-load efficiency rapidly increases with a corresponding increase in the production rate, and leveling at around 15 pounds per hour. Figure ES-1 graphically summarizes the fryer's cooking energy efficiency at different production rates.

The Pitco Frialator model RPB14 gas fryer performed well, especially under light–load cooking scenarios (40% vs. 33% for an average of three standard gas fryers).[2] This fryer's part-load cooking efficiency was enhanced by its low idle (standby) losses, which is advantageous because most fryers are operated under light-load conditions many hours during the day.

The average energy consumption rate while cooking loads of french fries is illustrated in Figure ES-2. Figure ES-2 can be used to calculate energy consumption for various daily production rates. As an example, at 10, 30, and 50 pounds per hour, average energy consumption rates are 18 kBtu/h, 38 kBtu/h, and 58 kBtu/h, respectively.

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[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.

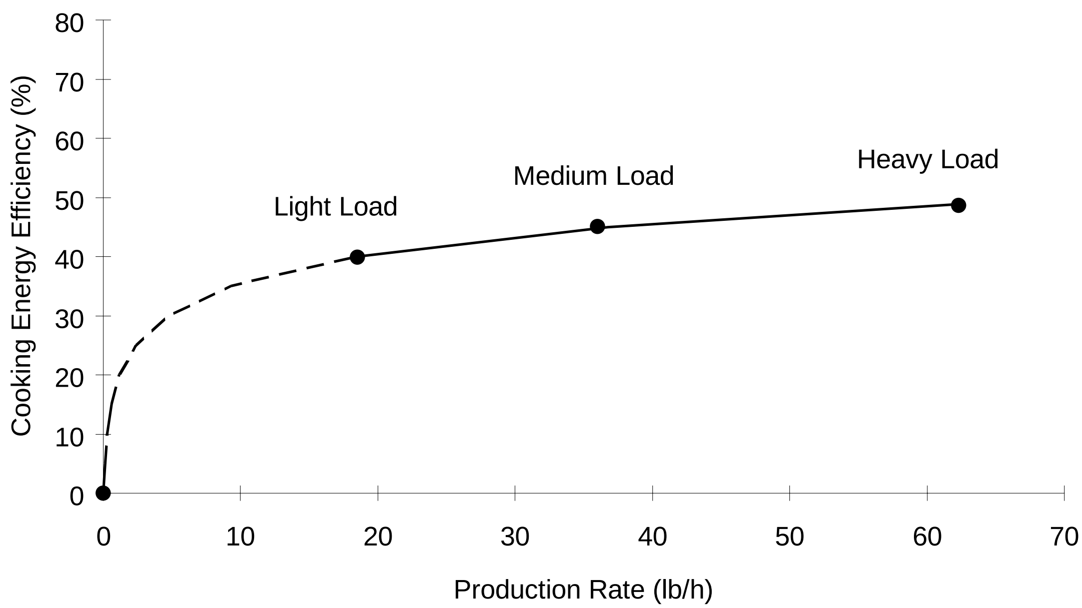

Figure ES-1. Fryer cooking energy efficiency.

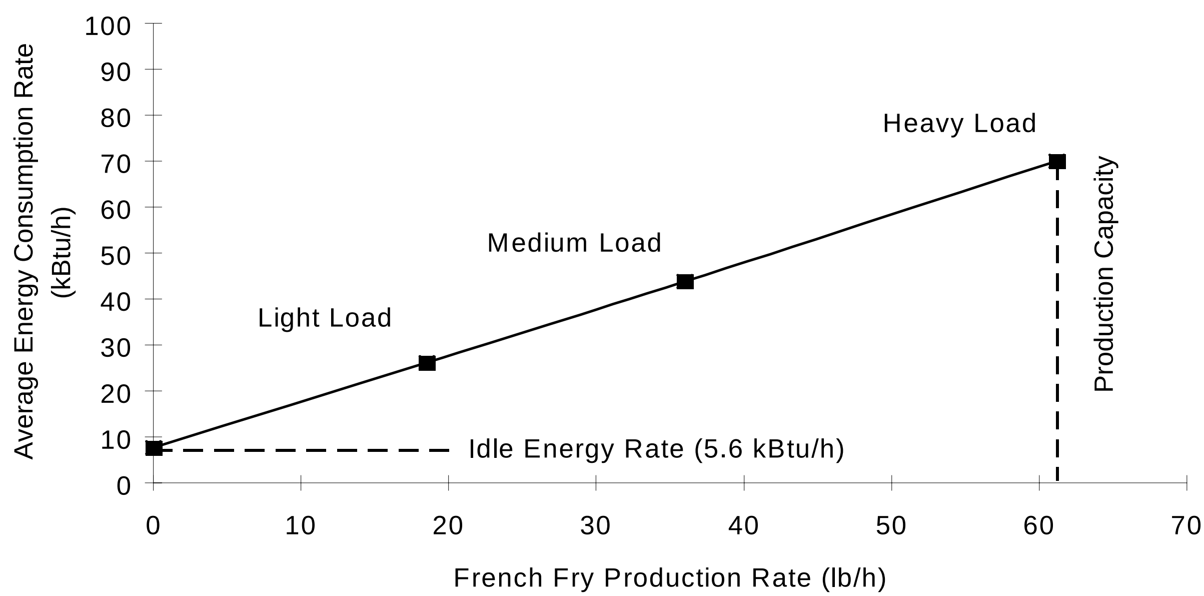

Figure ES-2. Average energy consumption rate during typical heavy-, medium-, and light-load cooking tests.

The fryer produced a competitive 62 pounds of french fries per hour under heavy-load conditions, and had a fast recovery time (19 seconds) without sacrificing efficiency. It performed well during energy consumption tests, recording one of the lowest idle energy rates (5.6 kBtu/h) compared to the average idle energy rate (7.7 kBtu/h) of gas fryers tested by the FSTC.[2]

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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 allows 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 of Testing and Materials (ASTM) and in January 1992 it was accepted as a standard test method (Designation F1361-91).[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 document the results of applying the ASTM standard test method to fryers.[2,3]

Food Service Technology Center (FSTC) researchers continued development of the standard test method to enhance its applicability. A revised test method for fryers was recently published by ASTM (1995). The enhanced test method has proven to be more accurate and reliable than the previous version and is available through ASTM as Designation F1361-95.

This report documents the application of the ASTM *Standard Test Method for the Performance of Open, Deep-fat Fryers* (Designation F1361-95) to the Pitco Frialator® RPB14 Technofry 1™ gas fryer. Forth-coming 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 in Appendix B, cooking energy efficiency and production capacity variables in Appendix C and uncertainty calculations in Appendix D.

OBJECTIVES

This report examines the performance of the Pitco Frialator *Technofry 1* gas fryer under the 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 $\frac{1}{4}''$ frozen shoestring potatoes.
5. Determine the production capacity and frying medium recovery time when cooking $\frac{1}{4}''$ frozen shoestring potatoes during the heavy-load test.

APPLIANCE DESCRIPTION AND OPERATION

The Pitco Frialator Model RPB14 features the manufacturer's new *Technofry 1* high efficiency design. The fryer's burner uses a fan to circulate a fuel-air mixture through a metal fiber honeycomb. The mixture burns on the outside of the honeycomb, causing it to glow red and emit infrared radiation to the surrounding tube walls. The baffled tubes provide a large surface area to transfer heat to the frying medium. Burned gases are then recirculated around the outside of the fry vat prior to exhausting to the atmosphere. Appliance specifications are listed in Table 1.1, the manufacturer's literature is in Appendix B.

Table 1-1

Appliance Specifications

Manufacturer:	Pitco Frialator
Model Number:	RPB14
Rated Energy Input:	80,000 Btu/h
Frying Medium Capacity:	50 lb
Frying Area:	13-5/8″ x 14″
Heat Transfer Tubes:	Radiant baffled tubes (2)
Type of Frypot:	Stainless steel
Temperature Controls:	Solid state
Ignition Type	Hot surface ignition
Heating Cycles:	Melt and non-melt

Section 2

METHODS

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 clearance 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] Gas consumption was measured using a calibrated gas meter with a 0.01-cubic-foot resolution. Temperature was measured with K-type immersion 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 measured temperatures on the heat transfer tubes, the cold zone, the cooking zone, and at the thermostat bulb. Four thermocouples were tack-welded onto the heat transfer tubes, 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 burners are on. For the purpose of this test, the fryer was filled with water to the frypot's indication line, and the manifold pressure was adjusted to the manufacturer's specifications. The controls were set for maximum input, and the fryer was operated for a 15 minutes. After the 15-minutes period, researchers monitor the time required to for the fryer to consume 5 ft^3 of gas. This energy rate to consume the 5 ft^3 of gas is then compared to the "nameplate" energy input rate to ensure that the fryer was operating properly.

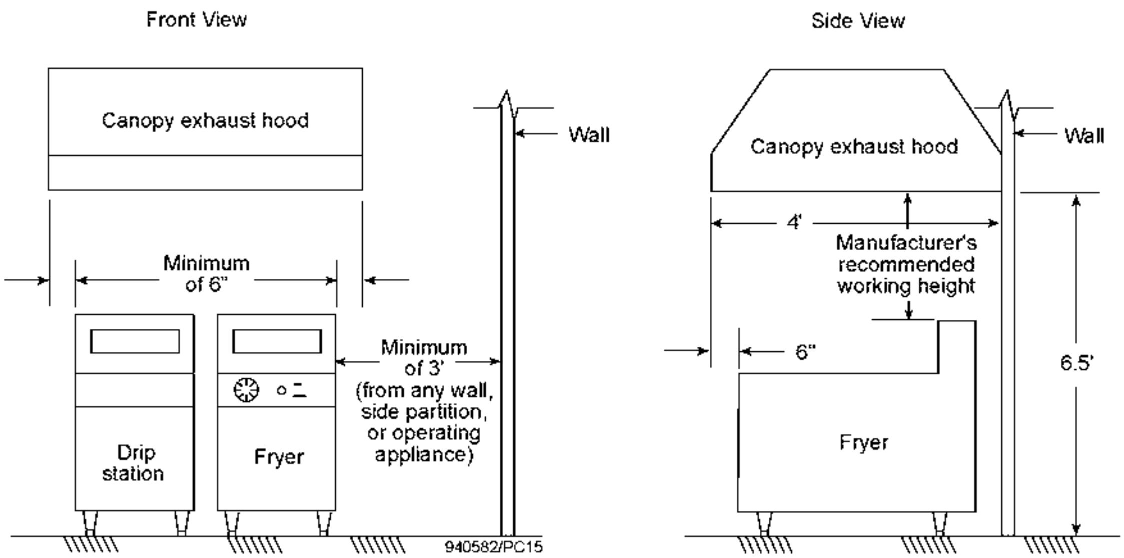

Figure 2-1. Equipment configuration.

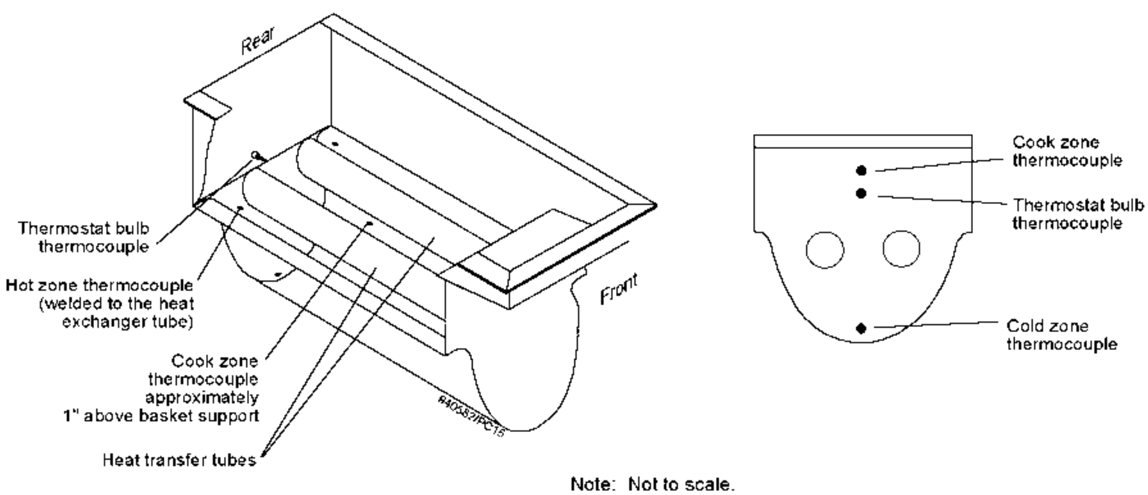

Figure 2-2. Frypot configuration and corresponding thermocouple placement.

WATER-BOIL EFFICIENCY DETERMINATION

The water-boil test is customarily 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. Accordingly, water-boil efficiency was not determined for this fryer.

FRENCH FRY COOKING-ENERGY EFFICIENCY AND PRODUCTION CAPACITY TESTS

Researchers specified $\frac{1}{4}$-inch blue ribbon, par-cooked, frozen shoestring potatoes for all cooking tests. The french fries were 6 $\pm$ 1% fat and 66 $\pm$ 2% moisture by weight.[1] Each load was cooked to 30 $\pm$ 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 $\frac{1}{2}$-pound (medium), and $\frac{3}{4}$-pound (light) french fry loads. Cooking-time determination tests were done to establish a cook time for the fryer. The cook-time determination is an iteration process, that may take several tests to yield average 30 $\pm$ 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 to 340°F, 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 $\pm$ 10%. The results from each test run were averaged, and the absolute uncertainty was calculated based on the standard deviation of the results.

Section 3

RESULTS

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 80,000 Btu/h. The measured energy input rate was 81,500 Btu/h (a difference of 1.8%).

PREHEAT AND IDLE ENERGY CONSUMPTION

The frying medium used for all tests was partially hydrogenated, 100% pure vegetable oil. For the preheat and idle tests, the intake manifold was set to 3.0 inch H_2O column and the gas used had a heating value of 1,034.3 Btu/ft^3.

Preheat Energy Consumption

The frying medium's average temperature was 81.5°F at the start of the preheat test. Energy consumption and time to heat the frying medium to 350°F was monitored. The fryer preheat required 13.8 kBtu and 10.5 minutes. Figure 3-1 shows fryer energy consumption and cook zone temperature during the preheat and idle test period.

Idle Energy Consumption

The frying medium was 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 5,600 Btu/h.

Test Results

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

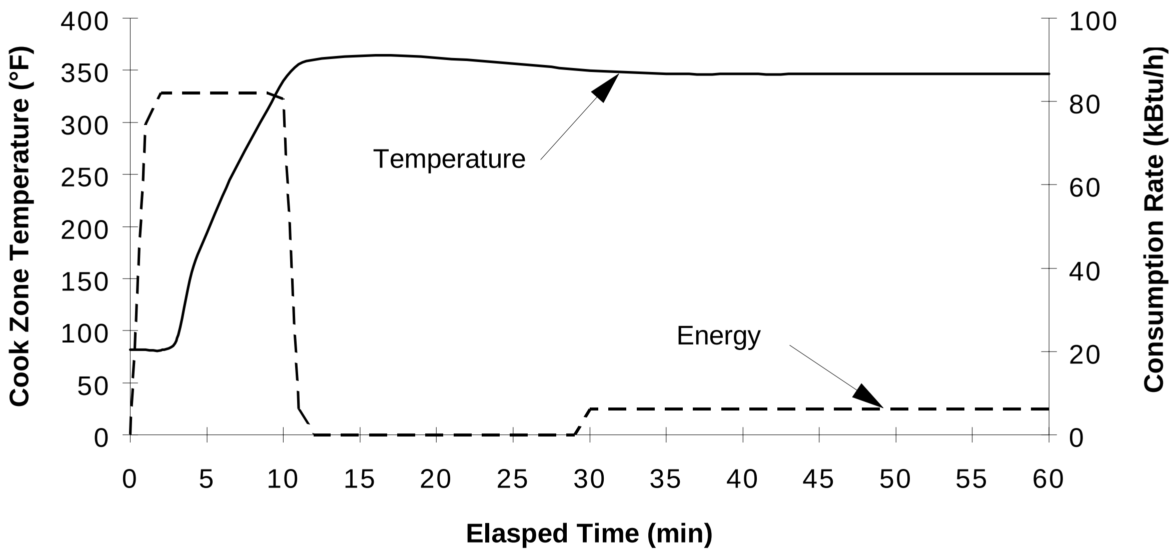

Figure 3-1. Energy consumption and cook zone temperature during the preheat and idle test.

Table 3-1

Input, Preheat, and Idle Test Results

Rated Energy Input Rate (kBtu/h)	80.0
Measured Energy Input Rate (kBtu/h)	81.5
Preheat:	
Time to 350°F (min)	10.5
Energy Consumption (kBtu)	13.8
Rate to 350°F (°F/min)	25.6
Idle Energy Consumption Rate @ 350°F (kBtu/h)	5.6
Idle Duty Cycle (%)	6.7

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 calculation 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 3-2

Cooking Energy Efficiencies and Production Capacity Test Results

	Heavy Load	Medium Load	Light Load
Cook Time (min)	2.58	2.25	2.20
Recovery Time (sec)	19	15	14
Production Rate (lb/h)	62.3 ± 2.4	36.0 ± 0.4	18.5 ± 0.7
Average Cooking Energy Consumption Rate (kBtu/h)	71.3	43.8	25.9
Energy to Fryer (Btu/lb)	1144	1217	1411
Energy to Food (Btu/lb)	557	549	563
Cooking Energy Efficiency (%)	48.7 ± 1.3	45.1 ± 2.4	39.9 ± 2.9

Cooking energy efficiency is defined as the energy to the french fries, expressed as a percentage of the energy to the fryer. Researchers determined the energy imparted to the french fries by calculating the heat absorbed by each component of the fries (fat, solid, and water), including the latent heat of vaporization required to evaporate moisture contained in the fries. The reported test results are an average of three replicated test runs. Cooking energy efficiency results were 48.7%, 45.1%, 39.9% for heavy-, medium-, and light-loads, respectively (see Appendix C for details).

Figure 3-2 depicts the temperature profiles of the heat transfer tubes and the cook zone during typical heavy-, medium-, and light-load cooking tests. The heavy-load cook zone temperature profiles have a more pronounced fluctuation: because the fryer is under greater loading demand, the heat transfer tube temperature profile has higher peaks as the fryer works harder to maintain cooking temperature.

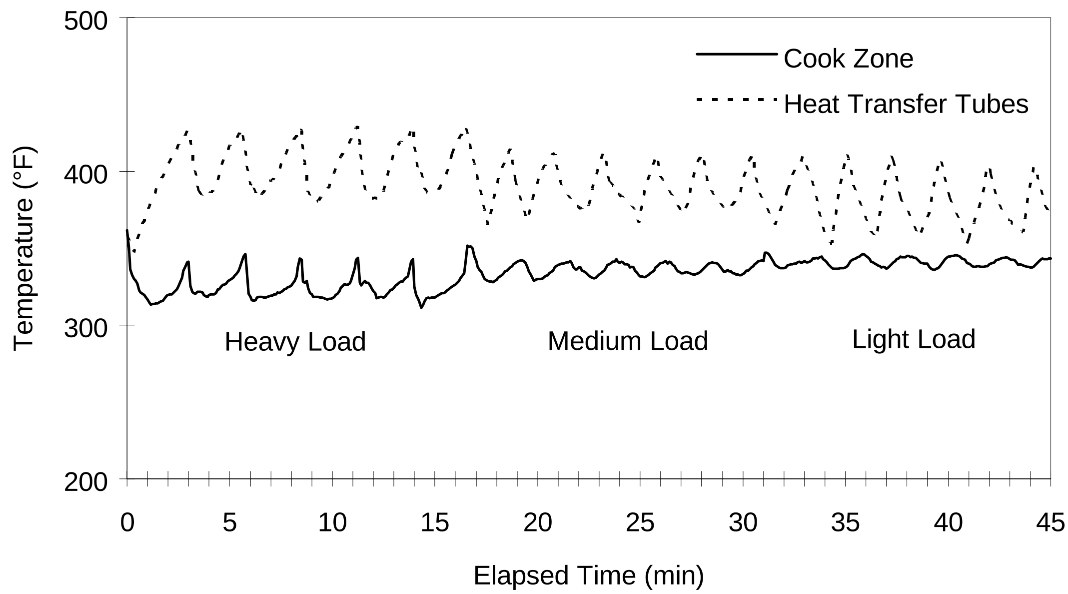

Figure 3-2. Temperature profile of heat transfer tubes and cook zone during cooking tests.

Figure 3-3 shows the cook zone temperature during a heavy-load test. This cook zone temperature "signature" is important to end users when evaluating the fryer; that is, can the fryer handle loads without drastically dropping its temperature and affecting the product quality? Figure 3-4 presents a magnified view of the fryer's cooking temperature signature for a heavy-load (3 pounds) of french fries. The average cook zone temperature over a typical cooking cycle was 324°F.

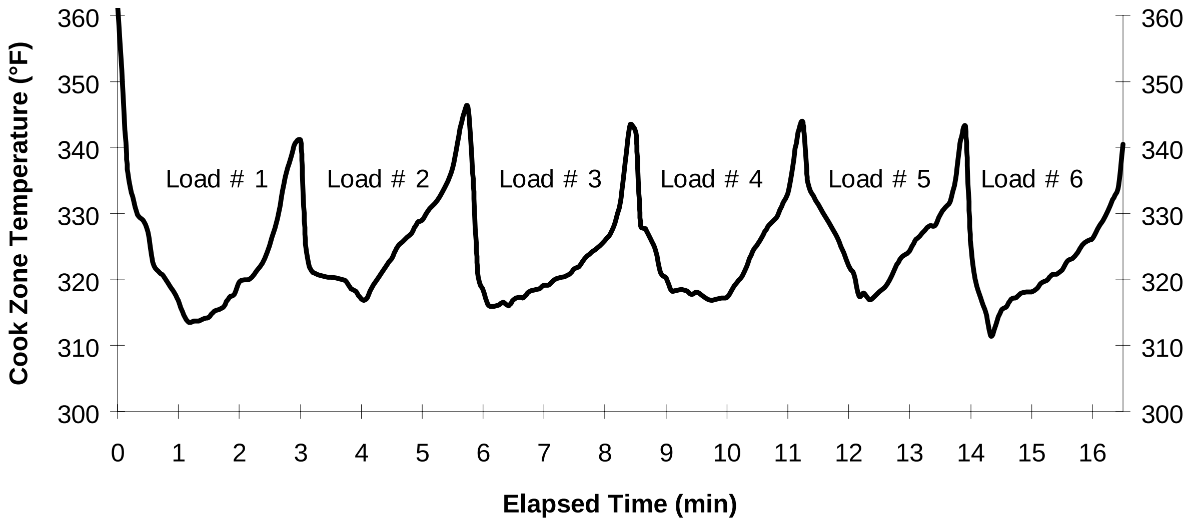

Figure 3-3. Temperature profile for a typical heavy-load cooking test showing cook zone temperature recovery.

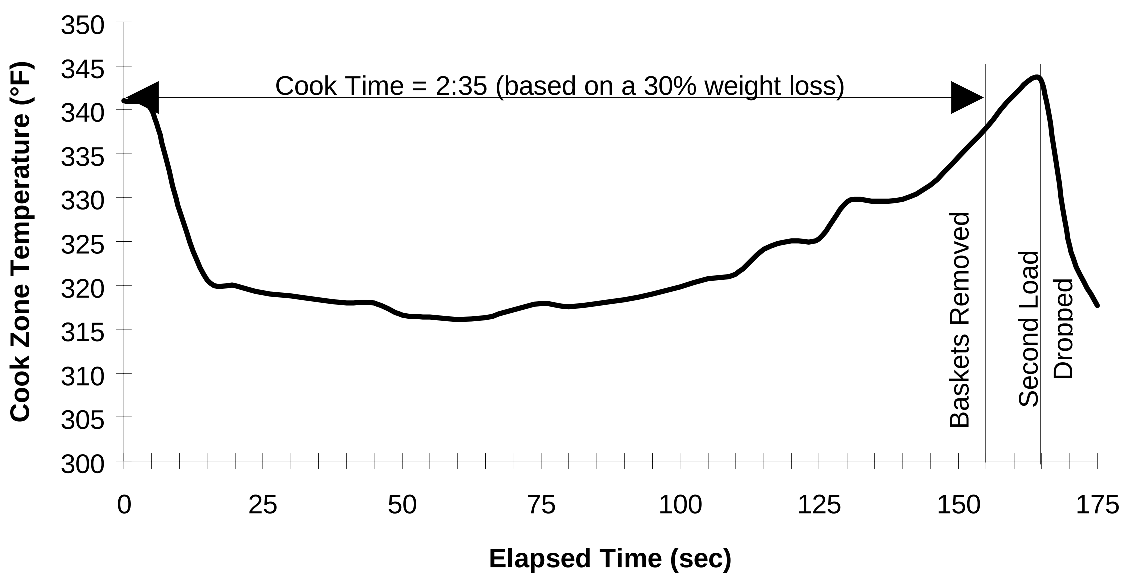

Figure 3-4. Cook zone temperature recovery for a typical heavy-load (3-pound).

Figure 3-5 illustrates the average energy consumption rate during light-, medium-, and heavy-load french fry cooking. The idle energy rate (5,600 Btu/h) is also presented for reference. This graph can be used as a tool to estimate the daily energy consumption for the fryer. The average energy consumption rates at 10, 30, and 50 pounds per hour, are 18, 38, and 58 kBtu/h, respectively.

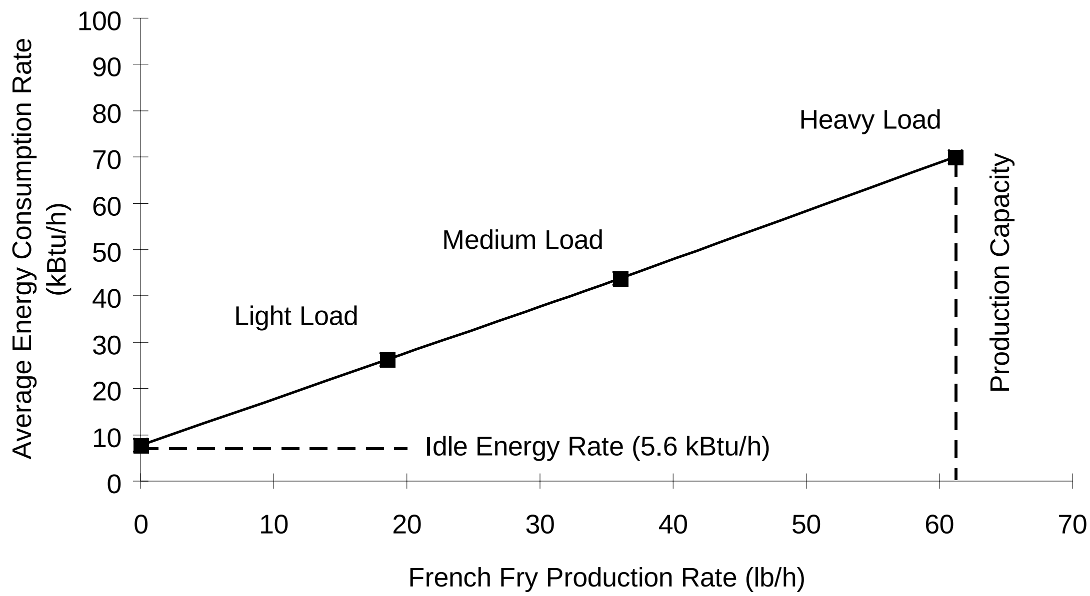

Figure 3-5. Cooking energy consumption rate during cooking tests.

Figure 3-6 summarizes the fryer's cooking energy efficiency at different production rates. Part-load efficiency rapidly increases with a corresponding increase in production rate, and begins to levels out around 15 pounds per hour.

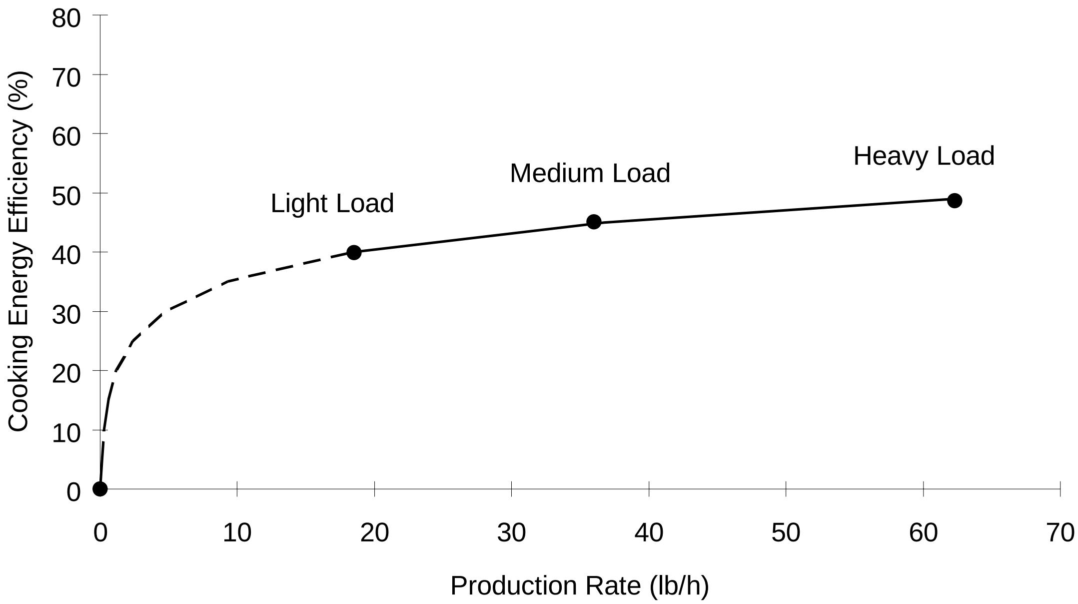

Figure 3-6. Fryer part-load cooking energy efficiency.

Section 4

CONCLUSIONS AND RECOMENDATIONS

The Pitco Frialator model RPB14 gas fryer performed competitively with other fryers tested at PG&E's Food Service Technology Center. The fryer exhibited competitive cooking energy efficiencies for heavy- (49%), medium- (45%), and light-load (40%) scenarios, while maintaining a 62 pound-per-hour production capacity (3 pound loads). Its efficiencies are a marked improvement over atmospheric burner fryers.[2]

During cooking events, the fryer maintained a relatively high average cook zone temperature (324°F) under heavy-load conditions with a 340°F reload. Of all gas fryers tested by the FSTC, it had one of the fastest recovery times (19 seconds) for heavy-load conditions. Also, the standby losses were 12% less than previously tested gas infrared fryer,[2] contributing to a high light-load cooking energy efficiency. This fryer's part-load cooking efficiency was enhanced by its low idle (standby) losses, which is advantageous because fryers are typically operated at an average of 10 to 30 pounds per hour over the course of the day.

The fryer's powered infrared burners allowed a 10.5 minute preheat time, while consuming 13.8 kBtu. Additionally, the fryer exhibited low idle losses. Its idle energy rate (5.6 kBtu/h) was considerably lower than other fryers tested.[2]

Test results indicate that this fryer will perform well in actual production. The fryer performed well under ASTM cooking tests, recording a high part-load cooking efficiency. Its productivity is sufficiently high to handle peak periods while consuming a low amount of energy. 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. 1995. *American Society of Testing and Materials Standard Test Method 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. Food Service Technology Center. 1995. *Application of ASTM Standard Test Method F1361-95: Keating Fryer Model 14 IFM*. Report 5011.95.32. Consumer Energy Management 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
Cooking 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.

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)
Energy Consumption Rate
Energy Rate

The peak rate at which an appliance will consume energy, typically reflected during preheat.

Hot Zone

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

Idle Energy Consumption (kWh or kBtu)
Idle Energy Use

The amount of energy consumed by an appliance operating under an idle condition over the duration of an idle period.

Idle Energy Rate (kW or kBtu/h)
Idle Energy Input Rate
Idle Energy Consumption Rate
Idle Rate

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

Idle Duty Cycle (%)
Idle Energy Factor
Idle Load Factor

The idle energy consumption rate expressed as a percentage of the measured energy input rate.

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

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)
Measured Input
Measured Peak Energy Input Rate
Peak Rate of Energy Input

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").

Open Deep-Fat Fryer

An appliance, including a cooking vessel, in which oils are placed to such a depth that the food cooked is essentially supported by displacement of the cooking fluid within a perforated container immersed in the cooking fluid rather than by the bottom of the vessel.

Pilot Energy Rate (kBtu/h)

Average Pilot Energy Rate
Average Pilot Energy Use Rate
Pilot Energy Consumption Rate

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).

Preheat Energy (kWh or kBtu)
Preheat Energy Consumption

The amount of energy consumed by an appliance while preheating the cook zone form room temperature to the thermostat set point.

Preheat Rate

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

Preheat Time (minute, hour)
Preheat Period

The time required for an appliance to "preheat" from the ambient room temperature to the thermostat set point.

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)
Input Rating (ANSI definition)
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.

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*

August 24, 1994

Cooking Energy Efficiency	**48.1%**
Production Rate	**61.5 lb/h**
Average Recovery Time	**0.35 min**
Average Energy Consumption Rate	**71.3 kBtu/h**

Measured Values

Energy	
Total Gas Volume (ft^3)	17.30
Fries	
Cook Time (min)	**2.58**
Total Test Time (min)	14.63
Weight Loss (%)	30.3
Total Fry Weight (lb)	15.0
Initial Fat (%)	6.4
Initial Moisture (%)	64.9
Final Moisture (%)	46.4
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)	17,376
Energy to Fryer (Btu/lb)	**1,158**
Fries	
Final Weight of Water (lb)	4.9
Weight of Water Vaporized (lb)	4.9
Weight of Fat (lb)	1.0
Weight of Solids (lb)	4.3
Final Fry Weight (lb)	10.5
Initial Weight of Water (lb)	9.7
Sensible to Ice (Btu)	156
Sensible to Water (Btu)	1,752
Sensible to Fat (Btu)	81
Sensible to Solids (Btu)	183
Latent - Water Fusion (Btu)	1,402
Latent - Fat Fusion (Btu)	42
Latent - Water Vaporization (Btu)	4,734
Total Energy to Food (Btu)	8,350
Energy to Food (Btu/lb)	**557**

Gas Values	
Gas Pressure (in H_2O)	8.0
Gas Temperature (°F)	77.0
Barometer (psi)	14.477
Heating Value (Btu/ft^3)	1,034.7

*3 lb basket of frozen shoestring potatoes

HEAVY-LOAD TEST #2*
August 24, 1994

Cooking Energy Efficiency	**49.1%**
Production Rate	**62.0 lb/h**
Average Recovery Time	**0.32 min**
Average Energy Consumption Rate	**70.4 kBtu/h**

Measured Values

Energy	
Total Gas Volume (ft^3)	17.00
Fries	
Cook Time (min)	**2.58**
Total Test Time (min)	14.52
Weight Loss (%)	30.49
Total Fry Weight (lb)	15.0
Initial Fat (%)	6.4
Initial Moisture (%)	64.9
Final Moisture (%)	46.4
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)	17,047
Energy to Fryer (Btu/lb)	**1,136**
Fries	
Final Weight of Water (lb)	4.8
Weight of Water Vaporized (lb)	4.9
Weight of Fat (lb)	1.0
Weight of Solids (lb)	4.3
Final Fry Weight (lb)	10.4
Initial Weight of Water (lb)	9.7
Sensible to Ice (Btu)	156
Sensible to Water (Btu)	1,752
Sensible to Fat (Btu)	81
Sensible to Solids (Btu)	183
Latent - Water Fusion (Btu)	1,402
Latent - Fat Fusion (Btu)	42
Latent - Water Vaporization (Btu)	4,746
Total Energy to Food (Btu)	8,362
Energy to Food (Btu/lb)	**557**

Gas Values	
Gas Pressure (in H_2O)	7.8
Gas Temperature (°F)	77.4
Barometer (psi)	14.472
Heating Value (Btu/ft^3)	1,034.7

*3 lb basket of frozen shoestring potatoes

HEAVY-LOAD TEST #3*

August 24, 1994

Cooking Energy Efficiency	**48.9%**
Production Rate	**63.4 lb/h**
Average Recovery Time	**0.26 min**
Average Energy Consumption Rate	**72.1 kBtu/h**

Measured Values

Energy	
Total Gas Volume (ft^3)	16.9
Fries	
Cook Time (min)	**2.58**
Total Test Time (min)	14.2
Weight Loss (%)	30.36
Total Fry Weight (lb)	15.0
Initial Fat (%)	6.4
Initial Moisture (%)	64.9
Final Moisture (%)	46.6
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)	17,071
Energy to Fryer (Btu/lb)	**1,138**
Fries	
Final Weight of Water (lb)	4.9
Weight of Water Vaporized (lb)	4.9
Weight of Fat (lb)	1.0
Weight of Solids (lb)	4.3
Final Fry Weight (lb)	10.4
Initial Weight of Water (lb)	9.7
Sensible to Ice (Btu)	156
Sensible to Water (Btu)	1,752
Sensible to Fat (Btu)	81
Sensible to Solids (Btu)	183
Latent - Water Fusion (Btu)	1,402
Latent - Fat Fusion (Btu)	42
Latent - Water Vaporization (Btu)	4,725
Total Energy to Food (Btu)	8,341
Energy to Food (Btu/lb)	**556**

Gas Values	
Gas Pressure (in H_2O)	8.0
Gas Temperature (°F)	73.8
Barometer (psi)	14.473
Heating Value (Btu/ft^3)	1,034.7

*3 lb basket of frozen shoestring potatoes

MEDIUM-LOAD TEST #1*

July 20, 1994

Cooking Energy Efficiency	**46.2%**
Production Rate	**36.2 lb/h**
Average Recovery Time	**0.24 min**
Average Energy Consumption Rate	**43.4 kBtu/h**

Measured Values

Energy	
Total Gas Volume (ft^3)	9.0
Fries	
Cook Time (min)	**2.25**
Total Test Time (min)	12.43
Weight Loss (%)	30.5
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.4
Initial Moisture (%)	64.9
Final Moisture (%)	46.9
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)	8,996
Energy to Fryer (Btu/lb)	**1,199**
Fries	
Final Weight of Water (lb)	2.4
Weight of Water Vaporized (lb)	2.4
Weight of Fat (lb)	0.5
Weight of Solids (lb)	2.2
Final Fry Weight (lb)	5.2
Initial Weight of Water (lb)	4.9
Sensible to Ice (Btu)	78
Sensible to Water (Btu)	876
Sensible to Fat (Btu)	41
Sensible to Solids (Btu)	91
Latent - Water Fusion (Btu)	701
Latent - Fat Fusion (Btu)	21
Latent - Water Vaporization (Btu)	2,350
Total Energy to Food (Btu)	4,158
Energy to Food (Btu/lb)	**554**

Gas Values	
Gas Pressure (in H_2O)	8.0
Gas Temperature (°F)	78.0
Barometer (psi)	14.465
Heating Value (Btu/ft^3)	1,032.5

*1.5 lb basket of frozen shoestring potatoes

MEDIUM-LOAD TEST #2*
July 20, 1994

Cooking Energy Efficiency	**44.3%**
Production Rate	**35.9 lb/h**
Average Recovery Time	**0.26 min**
Average Energy Consumption Rate	**44.9 kBtu/h**

Measured Values

Energy	
Total Gas Volume (ft^3)	9.40

Fries	
Cook Time (min)	**2.25**
Total Test Time (min)	12.55
Weight Loss (%)	30.7
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.4
Initial Moisture (%)	64.9
Final Moisture (%)	47.0
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)	9,396
Energy to Fryer (Btu/lb)	**1,253**

Fries	
Final Weight of Water (lb)	2.4
Weight of Water Vaporized (lb)	2.4
Weight of Fat (lb)	0.5
Weight of Solids (lb)	2.2
Final Fry Weight (lb)	5.2
Initial Weight of Water (lb)	4.9
Sensible to Ice (Btu)	78
Sensible to Water (Btu)	876
Sensible to Fat (Btu)	41
Sensible to Solids (Btu)	91
Latent - Water Fusion (Btu)	701
Latent - Fat Fusion (Btu)	21
Latent - Water Vaporization (Btu)	2,352
Total Energy to Food (Btu)	4,160
Energy to Food (Btu/lb)	**555**

Gas Values	
Gas Pressure (in H_2O)	8.0
Gas Temperature (°F)	78.0
Barometer (psi)	14.465
Heating Value (Btu/ft^3)	1,032.5

*1.5 lb basket of frozen shoestring potatoes

MEDIUM-LOAD TEST #3*

July 20, 1994

Cooking Energy Efficiency	**44.9%**
Production Rate	**35.9 lb/h**
Average Recovery Time	**0.26 min**
Average Energy Consumption Rate	**43.0 kBtu/h**

Measured Values

Energy	
Total Gas Volume (ft^3)	9.00
Fries	
Cook Time (min)	**2.25**
Total Test Time (min)	12.55
Weight Loss (%)	29.2
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.4
Initial Moisture (%)	64.9
Final Moisture (%)	48.4
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)	8,988
Energy to Fryer (Btu/lb)	**1,198**
Fries	
Final Weight of Water (lb)	2.6
Weight of Water Vaporized (lb)	2.3
Weight of Fat (lb)	0.5
Weight of Solids (lb)	2.2
Final Fry Weight (lb)	5.3
Initial Weight of Water (lb)	4.9
Sensible to Ice (Btu)	78
Sensible to Water (Btu)	876
Sensible to Fat (Btu)	41
Sensible to Solids (Btu)	91
Latent - Water Fusion (Btu)	701
Latent - Fat Fusion (Btu)	21
Latent - Water Vaporization (Btu)	2,229
Total Energy to Food (Btu)	4,037
Energy to Food (Btu/lb)	**538**

Gas Values	
Gas Pressure (in H_2O)	8.0
Gas Temperature (°F)	78.0
Barometer (psi)	14.463
Heating Value (Btu/ft^3)	1,032.5

*1.5 lb basket of frozen shoestring potatoes

LIGHT-LOAD TEST #1*

July 20, 1994

Cooking Energy Efficiency	**40.7%**
Production Rate	**18.7 lb/h**
Average Recovery Time	**0.23 min**
Average Energy Consumption Rate	**25.2 kBtu/h**

Measured Values

Energy	
Total Gas Volume (ft^3)	5.20
Fries	
Cook Time (min)	**2.17**
Total Test Time (min)	12.02
Weight Loss (%)	29.3
Total Fry Weight (lb)	3.75
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)	5,186
Energy to Fryer (Btu/lb)	**1,383**
Fries	
Final Weight of Water (lb)	1.3
Weight of Water Vaporized (lb)	1.2
Weight of Fat (lb)	0.2
Weight of Solids (lb)	1.0
Final Fry Weight (lb)	2.7
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)	1,192
Total Energy to Food (Btu)	2,113
Energy to Food (Btu/lb)	**564**

Gas Values	
Gas Pressure (in H_2O)	8.0
Gas Temperature (°F)	78.9
Barometer (psi)	14.456
Heating Value (Btu/ft^3)	1,032.5

*.75 lb basket of frozen shoestring potatoes

LIGHT-LOAD TEST #2*
July 20, 1994

Cooking Energy Efficiency	**38.6%**
Production Rate	**18.7 lb/h**
Average Recovery Time	**0.23 min**
Average Energy Consumption Rate	**27.4 kBtu/h**

Measured Values

Energy	
Total Gas Volume (ft^3)	5.50
Fries	
Cook Time (min)	**2.18**
Total Test Time (min)	12.03
Weight Loss (%)	29.4
Total Fry Weight (lb)	3.75
Initial Fat (%)	6.1
Initial Moisture (%)	66.5
Final Moisture (%)	47.5
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)	5,492
Energy to Fryer (Btu/lb)	**1,465**
Fries	
Final Weight of Water (lb)	1.3
Weight of Water Vaporized (lb)	1.2
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)	1,199
Total Energy to Food (Btu)	2,120
Energy to Food (Btu/lb)	**565**

Gas Values	
Gas Pressure (in H_2O)	8.0
Gas Temperature (°F)	78.2
Barometer (psi)	14.456
Heating Value (Btu/ft^3)	1,032.5

*.75 lb basket of frozen shoestring potatoes

LIGHT-LOAD TEST #3*

July 20, 1994

Cooking Energy Efficiency	**40.5%**
Production Rate	**18.2 lb/h**
Average Recovery Time	**0.23 min**
Average Energy Consumption Rate	**25.2 kBtu/h**

Measured Values

Energy	
Total Gas Volume (ft^3)	5.20
Fries	
Cook Time (min)	**2.25**
Total Test Time (min)	12.38
Weight Loss (%)	29.8
Total Fry Weight (lb)	3.75
Initial Fat (%)	6.1
Initial Moisture (%)	66.5
Final Moisture (%)	48.5
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)	5,194
Energy to Fryer (Btu/lb)	**1,385**
Fries	
Final Weight of Water (lb)	1.3
Weight of Water Vaporized (lb)	1.2
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)	1,180
Total Energy to Food (Btu)	2,101
Energy to Food (Btu/lb)	**560**

Gas Values	
Gas Pressure (in H_2O)	8.0
Gas Temperature (°F)	78.0
Barometer (psi)	14.455
Heating Value (Btu/ft^3)	1,032.5

*.75 lb basket of frozen shoestring potatoes

Appendix D

UNCERTAINTY CALCULATIONS

UNCERTAINTY RESULTS

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. The following tables D.1-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 (kBtu/hr)**
Scenario #1	61.5	48.1	71.3
Scenario #2	62.0	49.1	70.4
Scenario #3	63.4	48.9	72.1
Average of Runs	62.3	48.7	71.3
Standard Deviation	1.0	0.5	0.8
Absolute Uncertainty	2.4	1.3	2.3
Percent Uncertainty (%)	3.9	2.7	2.9

Table D-2

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

	Production Rate (lb/h)	**Cooking Energy Efficiency (%)**	**Cooking Energy Rate (kBtu/hr)**
Scenario #1	36.2	46.2	43.4
Scenario #2	35.9	44.3	44.9
Scenario #3	35.9	44.9	43.0
Average of Runs	36.0	45.1	43.8
Standard Deviation	0.2	1.0	1.0
Absolute Uncertainty	0.4	2.4	2.5
Percent Uncertainty (%)	1.2	5.3	5.8

Table D-1

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

	Production Rate (lb/h)	**Cooking Energy Efficiency (%)**	**Cooking Energy Rate (kBtu/hr)**
Scenario #1	18.7	40.7	25.2
Scenario #2	18.7	38.6	27.4
Scenario #3	18.2	40.5	25.2
Average of Runs	18.5	39.9	26.2
Standard Deviation	0.3	1.2	1.1
Absolute Uncertainty	0.7	2.9	2.8
Percent Uncertainty (%)	3.9	7.2	10.7