

**Pitco SEH50 Electric Fryer  
Performance Tests**

Application of ASTM Standard  
Test Method F 1361-99

FSTC Report 5011.03.20

**Food Service Technology Center  
June 2003**

Prepared by:  
**David Cowen**  
**David Zabrowski**  
Fisher-Nickel, Inc.

Contributors:  
**Scott Minor**  
Fisher-Nickel Inc.

© 2003 by Fisher-Nickel, inc. All rights reserved.

The information in this report is based on data generated at the Food Service Technology Center.

## Acknowledgments

California consumers are not obligated to purchase any full service or other service not funded by this program. This program is funded by California utility ratepayers under the auspices of the California Public Utilities Commission.

Los consumidores en California no estan obligados a comprar servicios completos o adicionales que no esten cubiertos bajo este programa. Este programa esta financiado por los usuarios de servicios publicos en California bajo la jurisdiccion de la Comision de Servicios Publicos de California.

A National Advisory Group provides guidance to the Food Service Technology Center Project. Members include:

Advantica Restaurant Group  
Applebee's International Group  
California Energy Commission (CEC)  
California Restaurant Association  
Carl Karcher Enterprises, Inc.  
DJ Horton & Associates  
Electric Power Research Institute (EPRI)  
Enbridge Gas Distribution  
EPA Energy Star  
Gas Technology Institute (GTI)  
Lawrence Berkeley National Laboratories  
McDonald's Corporation  
National Restaurant Association  
Pacific Gas and Electric Company  
Safeway, Inc.  
Southern California Edison  
Underwriters Laboratories (UL)  
University of California at Berkeley  
University of California at Riverside  
US Department of Energy, FEMP

Specific appreciation is extended to Pitco, for supplying the Food Service Technology Center with an electric fryer for controlled testing in the appliance laboratory.

## Policy on the Use of Food Service Technology Center Test Results and Other Related Information

- Fisher-Nickel, inc. and the Food Service Technology Center (FSTC) do not endorse particular products or services from any specific manufacturer or service provider.
- The 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 technical research reports and publications and 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 Fisher-Nickel, inc. *in advance* and proper attribution to Fisher-Nickel, inc. and the Food Service Technology Center. 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 documentation from FSTC.

## Legal Notice

This report was prepared as a result of work sponsored by the California Public Utilities Commission (Commission). It does not necessarily represent the views of the Commission, its employees, or the State of California. The Commission, the State of California, its employees, contractors, and subcontractors make no warranty, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the use of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the Commission nor has the Commission passed upon the accuracy or adequacy of the information in this report.

# Contents

---

	<b>Page</b>
<b>Executive Summary</b> .....	iii
<b>1 Introduction</b> .....	1-1
Background .....	1-1
Objectives .....	1-2
Appliance Description .....	1-3
<b>2 Methods</b> .....	2-1
Setup and Instrumentation .....	2-1
Measured Energy Input Rate .....	2-2
Cooking Tests .....	2-3
<b>3 Results</b> .....	3-1
Energy Input Rate .....	3-1
Preheat and Idle Tests .....	3-1
Cooking Tests .....	3-3
Energy Cost Model.....	3-7
<b>4 Conclusions</b> .....	4-1
<b>5 References</b> .....	5-1
<b>Appendix A: Glossary</b>	
<b>Appendix B: Appliance Specifications</b>	
<b>Appendix C: Results Reporting Sheets</b>	
<b>Appendix D: Cooking-Energy Efficiency Data</b>	

## List of Figures and Tables

---

### Figures

		<b>Page</b>
1-1	Pitco SEH50 Frypot .....	1-3
2-1	Equipment configuration .....	2-1
2-2	Thermocouple placement for testing .....	2-2
3-1	Pitco SEH50 Preheat characteristics .....	3-2
3-2	Frying medium temperature during a heavy-load test ..... for the SEH50 fryer	3-3
3-3	Fryer cooking cycle temperature signature .....	3-4
3-4	Fryer part-load cooking energy efficiency .....	3-6
3-5	Fryer cooking energy consumption profile .....	3-7

### Tables

		<b>Page</b>
1-1	Appliance Specifications .....	1-3
3-1	Input, Preheat, and Idle Test Results .....	3-2
3-2	Cooking Energy Efficiency and Production Capacity Test ... Results .....	3-5
3-3	Energy Fryer Energy Consumption and Cost .....	3-7

## Executive Summary

---

Pitco's new SEH50 electric fryer is heated by two low watt-density tubular style electric elements with a total input rating of 14.0 kW. A programmable cooking computer controls the input to the fryer and provides for a more consistent product. Figure ES-1 illustrates the SEH50 fryer, as tested at the Food Service Technology Center (FSTC).

FSTC engineers tested the fryer under the tightly controlled conditions of the American Society for Testing and Materials' (ASTM) standard test method.<sup>1</sup> Fryer performance is characterized by preheat time and energy consumption, idle energy consumption rate, cooking energy efficiency, and production capacity.

Cooking performance was determined by cooking frozen French fries under three different loading scenarios (heavy—3 pounds per load, medium—1½ pounds per load, and light—¾ pound per load). The SEH50's heavy-load cook time was 2.32 minutes. Production capacity includes the cooking time and the time required for the frying medium to recover to 340°F (recovery time).

Cooking-energy efficiency is a measure of how much of the energy that an appliance consumes is actually delivered to the food product during the cooking process. Cooking energy efficiency is therefore defined by the following relationship:

$$\text{Cooking - Energy Efficiency} = \frac{\text{Energy to Food}}{\text{Energy to Appliance}}$$

---

<sup>1</sup> American Society for Testing and Materials. 2000. *Standard Test Method for the Performance of Open, Deep Fat Fryers*. ASTM Designation F 1361-99, in *Annual Book of ASTM Standards*, West Conshohocken, PA.

# Executive Summary

A summary of the test results is presented in Table ES-1.



*Pitco SEH50 Fryer.*

**Table ES-1. Summary of Fryer Performance.**

Rated Energy Input Rate (kW)	14.0
Measured Energy Input Rate (kW)	13.9
Preheat Time to 350°F (min)	11.9
Preheat Energy to 350°F (kWh)	2.30
Idle Energy Rate @ 350°F (kW)	0.93
Heavy-Load Cooking-Energy Efficiency (%)	82.1 ± 6.3
Medium-Load Cooking-Energy Efficiency (%)	80.3 ± 5.1
Light-Load Cooking-Energy Efficiency (%)	74.6 ± 6.1
Production Capacity (lb/h) <sup>a</sup>	69.0 ± 2.2
Average Frying Medium Recovery Time (sec) <sup>b</sup>	17.4

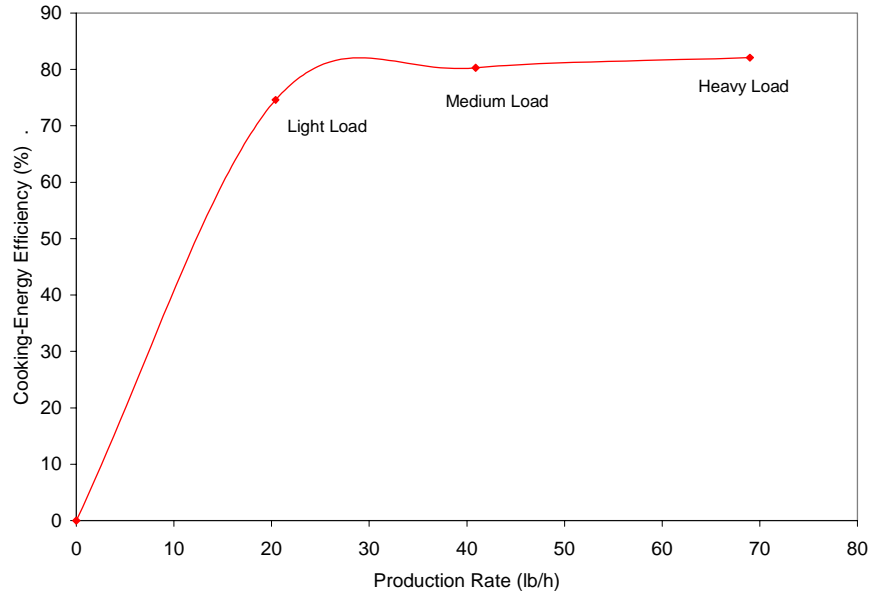
<sup>a</sup> This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.

<sup>b</sup> Based on the heavy-load cooking test with a minimum 10-second preparation time between loads.

Figure ES-2 illustrates the relationship between cooking-energy efficiency and production rate for the fryer. Figure ES-3 illustrates the relationship between the fryer's average energy consumption rate and the production rate. This graph can be used as a tool to estimate the daily energy consumption and probable demand contribution for the fryer in a real-world operation. Average energy consumption rates at 10, 30, and 50 pounds per hour for the SEH50 fryer are 2.76 kW, 6.54 kW, and 10.31 kW respectively. For an operation cooking an average of 15 pounds of food per hour over the course of the day (e.g., 150 lb of food over a ten hour day), the probable demand contribution for the SEH50 fryer would be 3.70 kW.

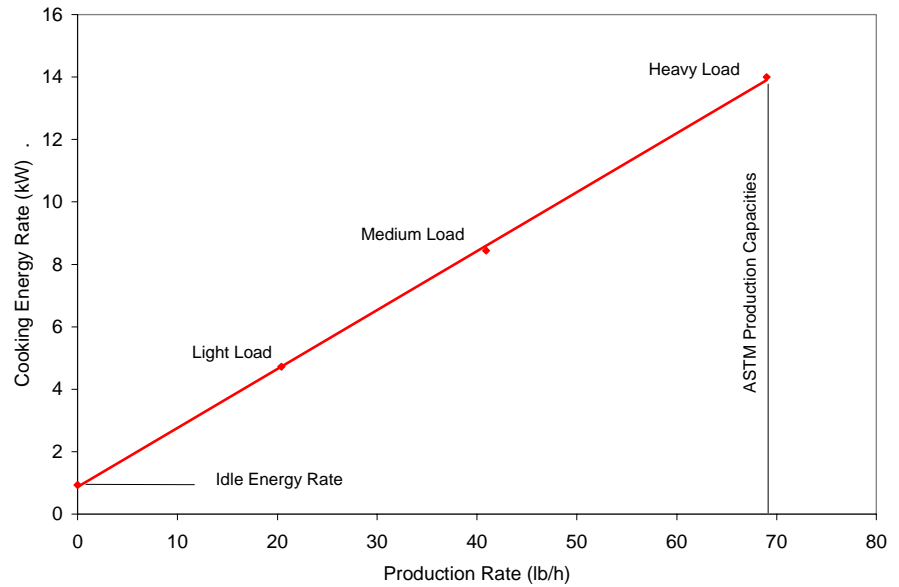
# Executive Summary

**Figure ES-2.**  
*Fryer part-load cooking-energy efficiency.*



Note: Light-load = ¼ pounds/load; Medium-load = 1½ pounds/load; Heavy-load = 3 pounds/load.

**Figure ES-3.**  
*Fryer cooking energy consumption profile.*



Note: Light-load = ¼ pounds/load; Medium-load = 1½ pounds/load; Heavy-load = 3 pounds/load.

---

### **The SEH50 fryer posted comparable cooking-energy efficiencies to other top performing electric fryers**

---

Pitco's newly designed SEH50 electric fryer incorporates low watt-density tubular style electric elements. The SEH50 fryer demonstrated excellent cooking-energy efficiencies and production capacities. With improved heat transfer efficiency in the frying medium, the SEH50 was able to cook a heavy-load (3 pounds) of French fries in a very quick 2.32 minutes with a cooking-energy efficiency of 82.1% and a production capacity of 69.0 lbs/h.

Pitco's SEH50 fryer idles at a low rate of 0.93 kW and this competitive idle rate translated to excellent part-load performance. The fryer posted a medium-load cooking-energy efficiency of 80.3% and a light-load efficiency of 74.6%. Since most food service establishments operate at an average of 15 pounds per hour over a typical day, these performance figures are more representative of real world application.

The estimated operational cost of the SEH50 electric fryer is \$1,500 per year. The model assumes the fryer is used to cook 100lbs of French fries over a 12-hour day, 365 days a year. The model also assumes 1 preheat each day with the remaining on-time being an idle (standby) state.

The SEH50 fryer's high productivity and an energy efficient design makes it a good match for any operation relying on electricity as it's primary energy source.

# 1 Introduction

---

## Background

Fried foods continue to be popular on the restaurant scene. French fried potatoes are still the most common deep fried food, along with onion rings, chicken and fish. Recent advances in equipment design have produced fryers that operate more efficiently, quickly, safely and conveniently.

Dedicated to the advancement of the food service industry, the Food Service Technology Center (FSTC) has focused on the development of standard test methods for commercial food service equipment since 1987. The primary component of the FSTC is a 10,000 square-foot appliance laboratory equipped with energy monitoring and data acquisition hardware, 60 linear feet of canopy exhaust hoods integrated with utility distribution systems, appliance setup and storage areas, and a state-of-the-art demonstration and training facility.

The test methods, approved and ratified by the American Society for Testing and Materials (ASTM), allow benchmarking of equipment such that users can make meaningful comparisons among available equipment choices. By collaborating with the Electric Power Research Institute (EPRI) and the Gas Technology Institute (GTI) through matching funding agreements, the test methods have remained unbiased to fuel choice. End-use customers and commercial appliance manufacturers consider the FSTC to be the national leader in commercial food service equipment testing and standards, sparking alliances with several major chain customers to date.

Since the development of the ASTM test method for fryers in 1991, the FSTC has tested a wide range of gas and electric fryers,<sup>3-20</sup> including Pitco's AE14 electric fryer.

# Introduction

---

Fryer performance is characterized by preheat time and energy consumption, idle energy consumption rate, pilot energy consumption rate, cooking-energy efficiency and production capacity.

Pitco's flagship electric fryer – the SEH50 – uses a new low-watt density tubular element design with a greater surface area than ribbon elements. The SEH50 14 kW electric fryer features a stainless steel frypot and backsplash, a programmable cooking computer, and an integrated melt cycle, which prevents solid frying medium from scorching during preheat.

This report presents the results of applying the ASTM test method to Pitco's SEH50 electrical fryer. The glossary in Appendix A is provided so that the reader has a quick reference to the terms used in this report.

## Objectives

The objective of this report is to examine the operation and performance of Pitco's SEH50, 14-inch electric fryer with an input rating of 14.0 kW, under the controlled conditions of the ASTM standard test method. The scope of this testing is as follows:

1. Verify that the appliance is operating at the manufacturer's rated energy input.
2. Determine the time and energy required to preheat the appliance from room temperature to 350°F.
3. Characterize the idle energy use with the thermostat set at a calibrated 350°F.
4. Document the cooking energy consumption and efficiency under three French fry loading scenarios: heavy (3 pounds per load), medium (1 ½ pounds per load), and light (¾ pound per load).
5. Determine the production capacity and frying medium temperature recovery time during the heavy-load test.

# Introduction

---

## Appliance Description

Pitco's SEH50, 14-inch electric fryer has a power rating of 14.0 kW. The stainless steel fry pot contains two sets of low watt-density tubular elements that coil through the frying medium in a front to back direction (see Figure 1-1). A cooking computer allows for individualized programs for various food products.

Appliance specifications are listed in Table 1-1, and the manufacturer's literature is in Appendix B.



*Figure 1-1.  
Pitco SEH50 frypot.*

***Table 1-1. Appliance Specifications.***

---

Manufacturer	Pitco
Model	SEH50
Generic Appliance Type	Open Deep Fat Fryer
Rated Input	14.0 kW
Frying Area	14" x 14"
Oil Capacity	50 lb
Controls	Programmable cooking computer
Construction	Stainless Steel

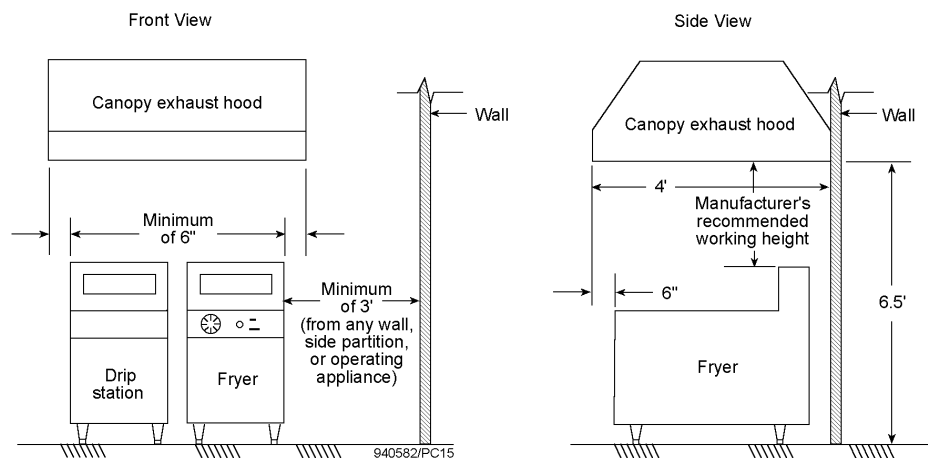
---

## 2 Methods

### Setup and Instrumentation

FSTC researchers installed the fryers 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 fryers and the edge of the hood. All test apparatus were installed in accordance with Section 9 of the ASTM test method.<sup>1</sup> See Figure 2-1.

Researchers instrumented the fryer with thermocouples to measure temperatures in the cold and the cooking zones and at the thermostat bulb. 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, not the frypot's surface



**Figure 2-1.**  
**Equipment configuration.**

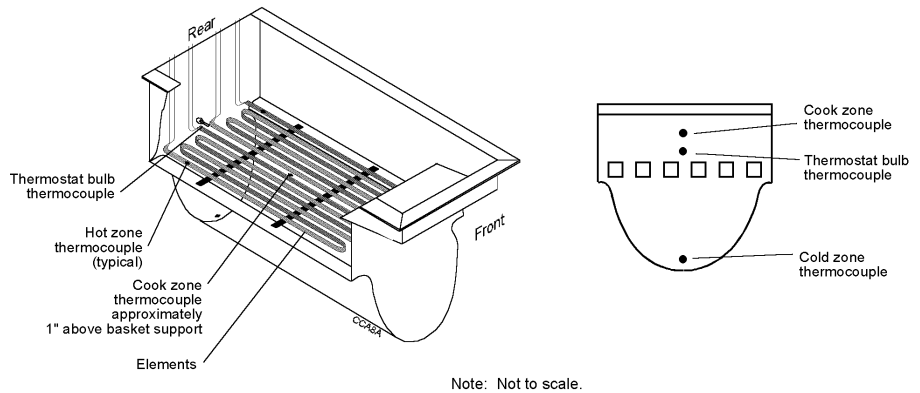
# Methods

temperature. The cold zone temperature was measured toward the rear of the frypot, 1/8-inch from the bottom of the pot. See Figure 2-2.

Power and energy were measured with a watt/watt-hour transducer that generated an analog signal for instantaneous power and a pulse for every 10 Wh. A voltage regulator, connected to the fryers, maintained a constant voltage for all tests. Control energy was monitored with a watt-hour transducer that generated a pulse for every 0.00001 watt-hours. The energy meters and thermocouples were connected to a data logger which recorded data every five seconds.

The fryer was filled with Melfry Brand, partially hydrogenated, 100% pure vegetable oil for all tests except the energy input rate determination test. This test required the fryer to be filled with water to inhibit burner cycling during the test.

**Figure 2-2.**  
*Thermocouple placement for testing.*



Graphic representation

## Measured Energy Input Rate

Rated energy input rate is the maximum or peak rate at which the fryer consumes energy—as specified on the fryer’s nameplate. Measured energy input rate is the maximum or peak rate of energy consumption, which is recorded during a period when the elements are energized (such as preheat). For the purpose of this test, the fryer was filled with water to the frypot’s indicated

## Methods

---

fill-line. The controls were set to attain maximum output and the energy consumption was monitored for a period of 15 minutes after a full rolling boil had been established. Researchers compared the measured energy input rate with the nameplate energy input rate to ensure that the fryer was operating properly.

### Cooking Tests

Researchers specified Simplot<sup>®</sup> brand ¼-inch blue ribbon product, par-cooked, frozen shoestring potatoes for all cooking tests. Each load of French fries was cooked to a 30% weight loss. The cooking tests involved “barrel-ing” six loads of frozen French fries, using fry medium temperature as a basis for recovery. Each test was followed by a 10-minute wait period and was then repeated two more times. Researchers tested the fryer using 3-pound (heavy), 1 ½-pound (medium), and ¾-pound (light) French fry loads.

Due to the logistics involved in removing one load of cooked French fries and placing another load into the fryer, a minimum preparation time of 10 seconds was incorporated 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 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 did 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 as a stabilization load and was not counted when calculating the elapsed time and energy consumed. Energy monitoring and elapsed time of the test were determined after the second load contacted 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

## Methods

---

weight loss of the French fries were recorded for the last five loads of the six-load test.

Each loading scenario (heavy, medium and light) was replicated a minimum of three times. This procedure ensured 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.

The ASTM results reporting sheets appear in Appendix C.

## 3 Results

---

### Energy Input Rate

Prior to testing, the energy input rate was measured and compared with the manufacturer's nameplate value. This procedure ensured that the fryer was operating within its specified parameters. The energy input rate was 13.9 kW (a difference of 0.7% from the nameplate rating).

### Preheat and Idle Tests

These tests show how the fryer uses energy when it is not cooking food. The preheat time allows an operator to know precisely how long it takes for the fryer to be ready to cook. The idle energy rate represents the energy required to maintain the set temperature, or the appliance's stand-by losses.

#### Preheat Energy and Time

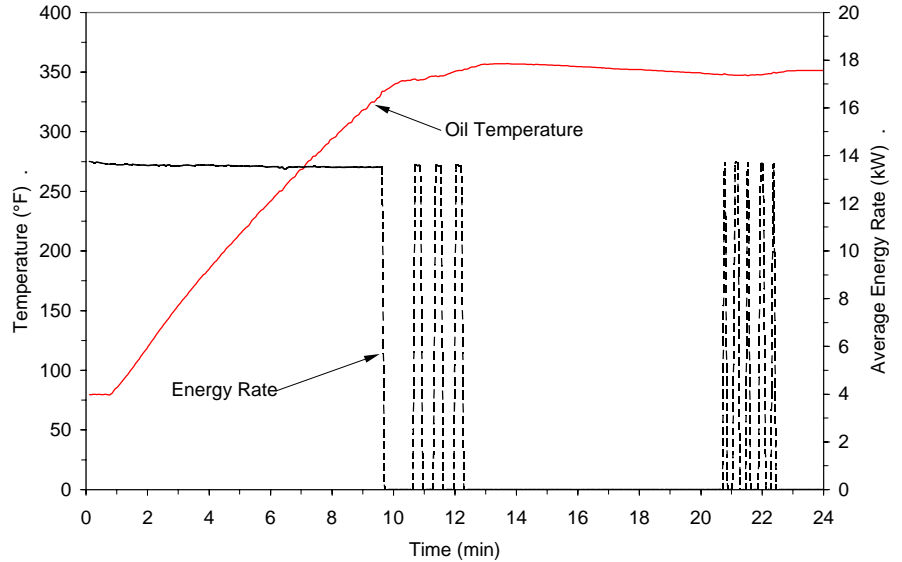
Researchers filled the fryer with new oil, which was then heated to 350°F at least once prior to any testing. The preheat tests were conducted at the beginning of a test day, after the oil had stabilized at room temperature overnight. Pitco's cooking computer has an integrated melt cycle to prevent scorching of solid shortening, but this feature was disabled to accommodate the shortening specified by the ASTM test procedure. Pitco's SEH50 fryer was ready to cook in 8.25 minutes. Figure 3-1 shows the fryer's preheat characteristics.

#### Idle Energy Rate

Once the frying medium reached 350°F, the fryer was allowed to stabilize for half an hour. Time and energy consumption was monitored for an additional two-hour period as each fryer maintained the oil at 350°F. The idle energy rate during this period was 0.93 kW.

# Results

**Figure 3-1.**  
*Pitco SEH50 preheat characteristics.*



## Test Results

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

**Table 3-1. Input, Preheat, and Idle Test Results.**

Rated Energy Input Rate (kW)	14.0
Measured Energy Input Rate (kW)	13.9
Percentage Difference (%)	0.7
Preheat	
Time to 350°F (min) <sup>a</sup>	11.9
Energy (kWh)	2.30
Preheat Rate to 350°F (°F/min)	22.8
Idle	
Element Energy Rate @ 350°F (kW)	0.92
Control Energy Rate (W)	14.6
Total Idle Energy Rate (kW)	0.93

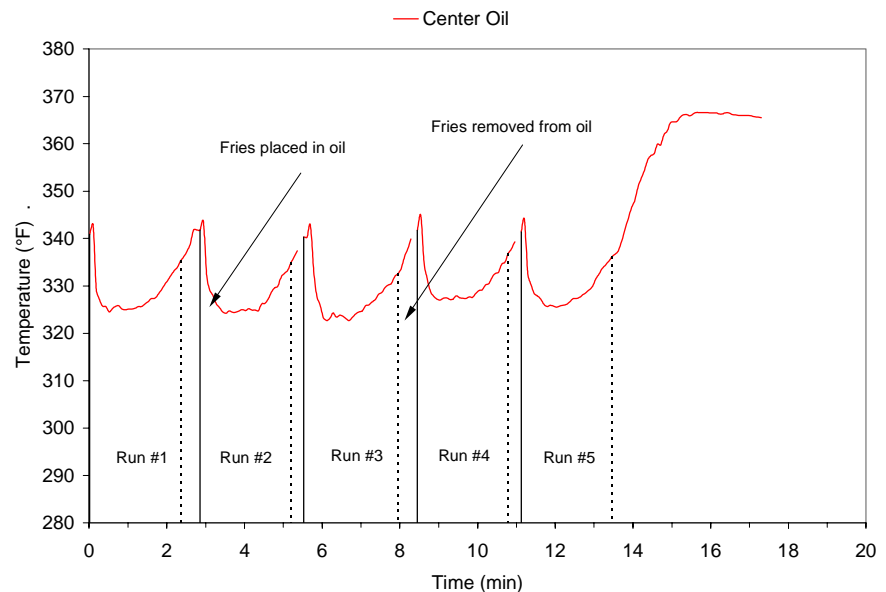
# Results

## Cooking Tests

The fryers were tested under three loading scenarios: heavy (3 pounds of fries per load), medium (1 ½ pounds of fries per load) and light (¾ pound of fries per load). The fries used for the cooking tests consisted of approximately 6% fat and 66% moisture, as specified by the ASTM procedure. Researchers monitored French fry cook time and weight loss, frying medium recovery time, and fryer energy consumption during these tests.

### Heavy-Load Tests

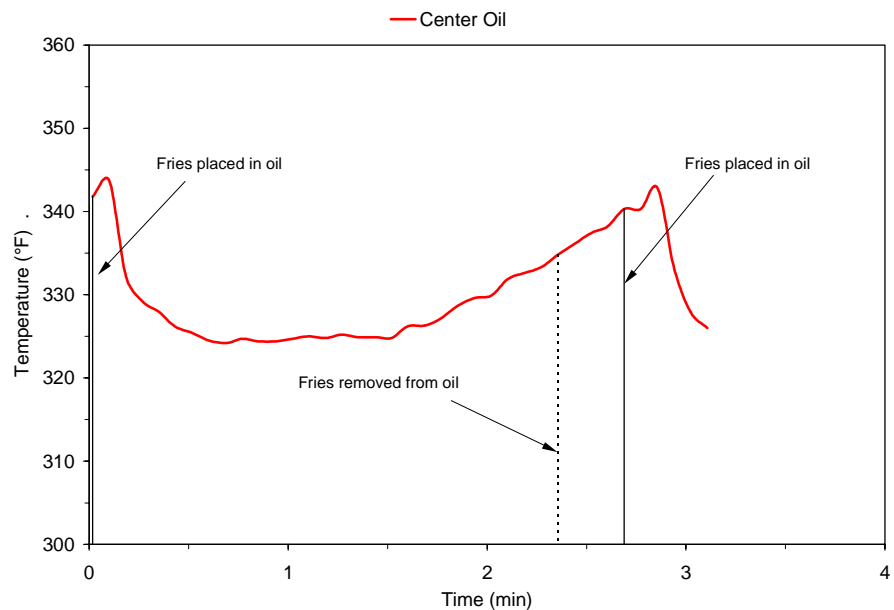
The heavy-load cooking tests were designed to reflect a fryer's maximum performance. The fryers were used to cook six 3-pound loads of frozen French fries—one load after the other in rapid succession, similar to a batch-cooking procedure. Figure 3-2 shows the average temperature of the frying medium and cold zone during the heavy-load tests.



**Figure 3-2.**  
*Frying medium temperature during a heavy load test for the SEH50 fryer.*

# Results

The first load was used to stabilize the fryer, and the remaining five loads were used to calculate cooking-energy efficiency and production capacity. The average frying medium and cold zone temperatures during the heavy-load test were 329°F and 317°F, respectively. The heavy load cook time for the fryer was 2.32 minutes with an average recovery time of 17.4 seconds. Figure 3-3 illustrates the temperature response of the SEH50 fryer while cooking a 3-pound load of frozen French fries. Production capacity includes the time required to remove the cooked fries and reload the fryer with a new batch of frozen fries (approximately 10 seconds per load).



**Figure 3-3.**  
*Fryer cooking cycle temperature signature.*

## Medium- and Light-Load Tests

Medium- and light-load tests represent a more typical usage pattern for a fryer in cook-to-order applications. Since a fryer is often used to cook single basket loads in many food service establishments, these part-load efficiencies can be used to estimate the fryer's performance in an actual operation.

# Results

---

Both the medium- and light-load tests were conducted using a single fry basket. The medium-load tests used 1½ pounds of fries per load and the light load tests used ¾ pounds of fries per load. Cooking-energy efficiencies at 40.9 (medium) and 20.4 (light) pounds per hour were 80.3% and 74.6%, respectively.

## Test Results

Energy imparted to the French fries was calculated by separating the various components of the fries (water, fat, and solids) and determining the amount of heat gained by each component (Appendix D). The fryer's cooking-energy efficiency for a given loading scenario is the amount of energy imparted to the fries, expressed as a percentage of the amount of energy consumed by the fryer during the cooking process.

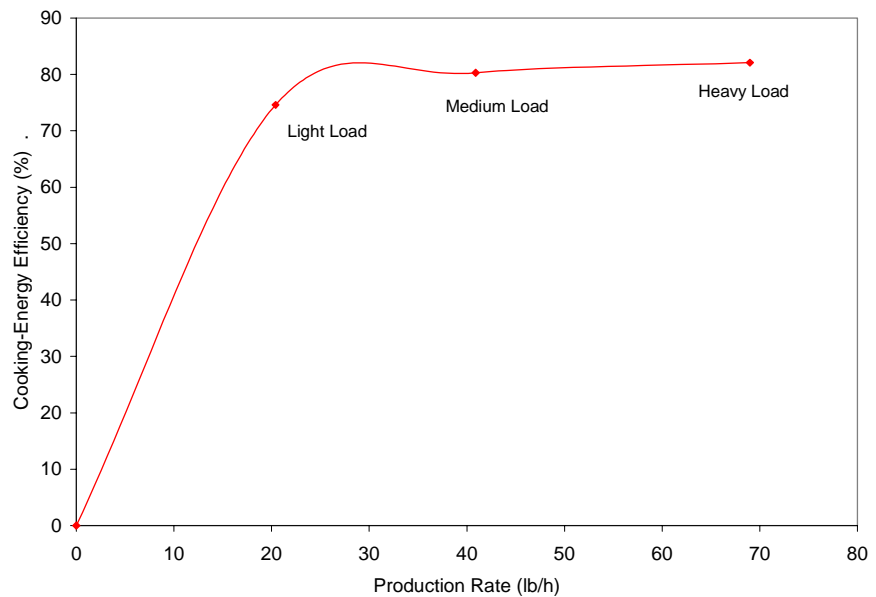
Heavy-load cooking-energy efficiency results were 80.3%, 81.0%, and 85.0%, yielding an uncertainty of 7.7%. Table 3-2 summarizes the results of the ASTM cooking-energy efficiency and production capacity tests.

*Table 3-2. Cooking-Energy Efficiency and Production Capacity Test Results.*

	Heavy-Load	Medium-Load	Light-Load
Load Size (lb)	3.0	1 ½	¾
French Fry Cook Time (min)	2.32	2.01	2.04
Average Recovery Time (sec)	17.4	11.4	10.2
Production Rate (lb/h)	69.0 ± 2.2	40.9 ± 1.2	20.4 ± 0.4
Energy Consumption (Btu/lb)	568	565	588
Electric Cooking Energy Rate (kW)	14.0	8.44	4.72
Control Energy Rate (W)	19.0	17.5	16.3
Energy per Pound of Food Cooked (Btu/lb)	693	705	790
Cooking-Energy Efficiency (%)	82.1 ± 6.3	80.3 ± 5.1	74.6 ± 6.1

# Results

Figure 3-4 illustrates the relationship between cooking-energy efficiency and production rate for this fryer. Fryer production rate is a function of both the French fry cook time and the frying medium recovery time. Appendix D contains a synopsis of test data for each replicate of the cooking tests.



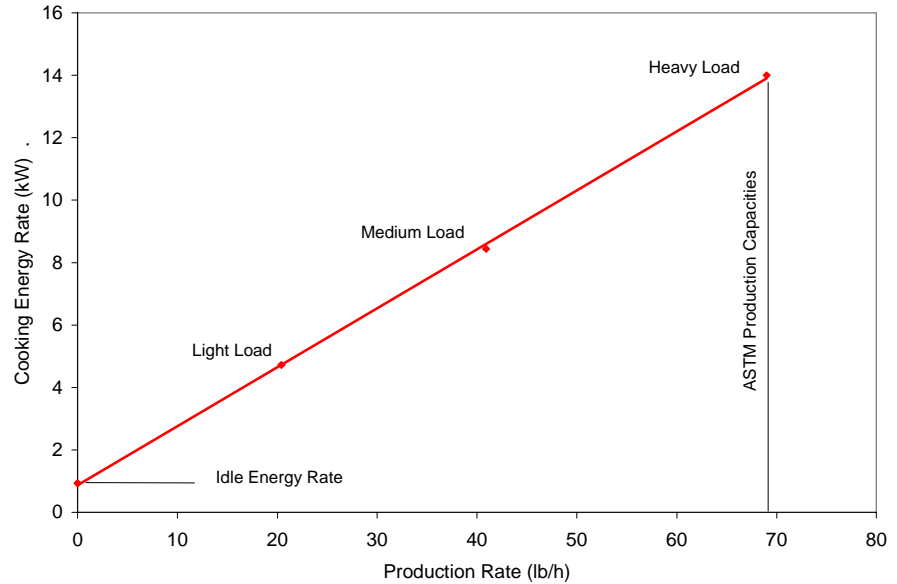
**Figure 3-4.**  
**Fryer part-load cooking-energy efficiency.**

Note: Light-load = ¾ pounds/load; Medium-load = 1½ pounds/load; Heavy-load = 3 pounds/load.

Figure 3-5 illustrates the relationship between the fryer’s average energy consumption rate and the production rate. This graph can be used as a tool to estimate the daily energy consumption and probable demand for the fryer in a real-world operation. End-use monitoring studies have shown that an electric appliance's probable contribution to the building's peak demand is equal to the appliance's average energy consumption rate during a typical day.<sup>3,4,5,6,7,9,10,11,20</sup> Average energy consumption rates at 10, 30, and 50 pounds per hour for the stock model were 2.76 kW, 6.54 kW, and 10.31 kW, respectively. For an operation cooking an average of 15 pounds of food per hour over the course of the day (e.g., 150 lb of food over a ten hour day), the probable demand contribution for this fryer would be 3.70 kW.

# Results

**Figure 3-5.**  
*Fryer cooking energy consumption profile.*



Note: Light-load = ¾ pounds/load; Medium-load = 1½ pounds/load; Heavy-load = 3 pounds/load.

## Energy Cost Model

The test results can be used to estimate the annual energy consumption for the fryer in a real-world operation. A simple cost model was developed to calculate the relationship between the various cost components (e.g., pre-heat, idle and cooking costs) and the annual operating cost, using the ASTM test data. For this model, the fryer was used to cook 100 pounds of fries over a 12-hour day, with one preheat per day, 365 days per year.

**Table 3-3. Estimated Fryer Energy Consumption and Cost.**

Preheat Energy (kWh/day)	2.3
Idle Energy (kWh/day)	7.4
Cooking Energy (kWh/day)	31.4
<b>Annual Energy (kWh/year)</b>	<b>15,000</b>
<b>Annual Cost (\$/year)<sup>a</sup></b>	<b>1,500</b>

<sup>a</sup> Fryer energy costs are based on \$0.10/kWh

## 4 Conclusions

---

---

### **The SEH50 fryer posted comparable cooking-energy efficiencies to other top performing electric fryers**

---

Pitco's newly designed SEH50 electric fryer incorporates electric low watt-density tubular style elements replacing the previous low watt-density ribbon elements of the AE14 fryer. The SEH50 fryer demonstrated improved performance over the excellent AE14 fryer. Cooking-energy efficiency was increased by 2% and production capacity saw an increase of approximately 7 lb/h. Improved heat transfer efficiency in the frying medium allowed the SEH50 to cook a heavy load (3 pounds) of French fries in a very quick 2.32 minutes with a recovery time of 17.4 seconds.

The SEH50 was ready to cook in 11.9 minutes using liquid shortening, and requiring only 2.30 kWh to raise the oil temperature to 350°F. While the SEH50's 0.93 kW idle rate was slightly higher than its predecessor (AE14), it was still among the lowest for electric fryers with a non-insulated frypot. This competitive idle rate translated to excellent part-load performance. The SEH50 fryer posted a medium-load cooking energy efficiency of 80.3% and a light-load of 74.6% the highest tested to date. Since most food service establishments operate at an average of 15 pounds per hour over a typical day, these performance figures are more representative of real world application.<sup>3,4,5,6,7,9,10,11,20</sup>

The estimated operational cost of the SEH50 electric fryer is \$1,500 per year. The model assumes the fryer is used to cook 100lbs of French fries over a 12-hour day, 365 days a year. The model also assumes 1 preheat each day with the remaining on-time being an idle (standby) state.

The SEH50 fryer's high productivity and energy efficient design, make it would be a good match for any operation using electric fryers.

## 5 References

---

1. American Society for Testing and Materials. 1995. *Standard Test Method for the Performance of Open, Deep Fat Fryers*. ASTM Designation F 1361-95, in *Annual Book of ASTM Standards*, West Conshohocken, PA.
2. Conner, M. M., Young, R., Fisher, D.R. and Nickel, J., 1991. *Development and Application of a Uniform Testing Procedure for Fryers*. Pacific Gas and Electric Company Department of Research and Development Report 008.1.89.2, November.
3. Pieretti, G., Blessent, J., Kaufman, D., Nickel, J., Fisher, D., 1990. *Cooking Appliance Performance Report - Pacific Gas and Electric Company Production-Test Kitchen*. Pacific Gas and Electric Company Department of Research and Development Report 008.1-90.8, May.
4. Nickel, J., 1991. *Frymaster® H-17 Electric Fryer Performance Report*. Pacific Gas and Electric Company Department of Research and Development Report 008.1-91.3, September.
5. Nickel, J., 1991. *Frymaster® H-14 Electric Fryer Performance Report*. Pacific Gas and Electric Company Department of Research and Development Report 008.1-91.4, September.
6. Nickel, J., 1991. *Pitco Frialator® Model E14 Electric Fryer Performance Report*. Pacific Gas and Electric Company Department of Research and Development Report 008.1-91.7, September.
7. Holliday, J., Conner, M., 1993. *Frymaster® Model H-17CSC Electric Fryer Performance Test: Application of ASTM Standard Test Method F 1361-91*. Food Service Technology Center Report 5017.93.2, November.
8. Knapp, S., Zabrowski, D., 1996. *Pitco Frialator® Model RPB14 Technofry I™ Gas Fryer: Application of ASTM Standard Test Method F1361-95*. Food Service Technology Center Report 5011.94.11, April.

## References

---

9. Nickel, J., Conner, M., Knapp, S., Zabrowski, D., 1995. *Pitco Model E14B-LQV Floor Model Electric Fryer In-Kitchen Appliance Performance*. Food Service Technology Center Report 5011.94.9, December.
10. Zabrowski, D., Nickel, J., Holliday, J., 1994. *TekmaStar Model FD-212 Electric Fryer Performance Test: Application of ASTM Standard Test Method F 1361-91*. Food Service Technology Center Report 5011.94.2, June.
11. Knapp, S., Zabrowski, D., 1996. *Pitco Frialator® Model E14B Electric Fryer Performance Test*. Food Service Technology Center Report 5011.95.12, March.
12. Zabrowski, D., Nickel, J., Knapp, S., 1995. *Keating Model 14 IFM Gas Fryer Performance Test*. Food Service Technology Center Report 5011.95.32, December.
13. Zabrowski, D., Bell, T., 1999. *Ultrafryer, Model PAR 3-14 Gas Fryer Performance Test*. Food Service Technology Center Report 5011.99.78, September.
14. Cowen, D., Zabrowski, D., 2000. *Vulcan 14-inch Fryer Performance Test: Application of ASTM Standard Test Method F1361-99*. Food Service Technology Center Report 5011.00.87, December.
15. Cowen, D., Zabrowski, D., 2000. *Vulcan High Capacity Fryer Performance Test: Application of ASTM Standard Test Method F1361-99*. Food Service Technology Center Report 5011.00.88, December.
16. Cowen, D., Zabrowski, D., Miner, S., 2001. *Anets Fryer Performance Tests*. Food Service Technology Center Report 5011.01.03, December.
17. Cowen, D., Zabrowski, D., Miner, S., 2002. *Pitco AG14 Fryer Performance Tests: Application of ASTM Standard Test Method F1361-99*. Food Service Technology Center Report 5011.02.07, September.
18. Cowen, D., Zabrowski, D., Miner, S., 2002. *Pitco SGH50 Fryer Performance Tests: Application of ASTM Standard Test Method F1361-99*. Food Service Technology Center Report 5011.02.08, September.

## References

---

19. Cowen, D., Zabrowski, D., 2003 *Counter Top Fryer Performance Testing: Application of ASTM Standard Test Method F1361-99*. Food Service Technology Center Report 5011.03.14, May.
20. Cowen, D., Zabrowski, D., Miner, S., 2003 *Pitco AE14 Electric Fryer Performance Test: Application of ASTM Standard Test Method F1361-99*. Food Service Technology Center Report 5011.03.19, May.

# A Glossary

---

## **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.

## **Duty Cycle** (%)

Load Factor

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

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

## **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.

## **Heating Value** (Btu/ft<sup>3</sup>)

Heating Content

The quantity of heat (energy) generated by the combustion of fuel. For natural gas, this quantity varies depending on the constituents of the gas.

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

Idle Energy Input Rate  
Idle Rate

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

## **Idle Temperature** (°F, Setting)

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

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

Idle Energy Factor

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

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

# Glossary

---

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

Measured Energy Input Rate

Measured Peak Energy Input Rate

The maximum or peak rate at which an appliance consumes energy, typically reflected during appliance preheat (i.e., the period of operation when all burners or elements are “on”).

## **Pilot Energy Rate (kBtu/h)**

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 Btu)**

Preheat Energy Consumption

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

## **Preheat Rate (°F/min)**

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

## **Preheat Time (minute)**

Preheat Period

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

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

The maximum production rate of an appliance while cooking a specified food product in accordance with the heavy-load cooking test.

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

Productivity

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

## **Rated Energy Input Rate**

(kW, W or Btu/h, Btu/h)

Input Rating (ANSI definition)

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 (minute, second)**

The average time from the removal of the fry baskets from the fryer until the frying medium is within  $10^\circ\text{F}$  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.

## **Typical Day**

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

## **B** Appliance Specifications

---

Appendix B includes the product literature for the Pitco SEH50 fryer.

## C Results Reporting Sheets

---

Manufacturer: Pitco  
Models: SEH50  
Date: May 2003

### *Test Fryers and Burners*

Description of operational characteristics: Pitco's SEH50 electric fryer is rated at 14.0 kW. The SEH50 fryer features two electric low watt-density elements submerged in the frying medium. A cooking computer controls the elements with features such as a melt cycle and multiple programmable cook times.

### *Apparatus*

√ Check if testing apparatus conformed to specifications in section 6.

Deviations: None.

---

### *Energy Input Rate*

---

Rated (Btu/h)	14.0
Measured (Btu/h)	13.9
Percent Difference between Measured and Rated (%)	0.7

---

### *Thermostat Calibration*

---

Thermostat Setting (°F)	352
Oil Temperature (°F)	350

---

# Results Reporting Sheets

---

## *Preheat Energy and Time*

---

Starting Temperature (°F)	79.0
Electric Energy Consumption (kWh)	2.30
Duration (min)	11.9
Preheat Rate (°F/min)	22.8

---

## *Idle Energy Rate*

---

Element Energy Rate (kW)	0.92
Control Energy Rate (W)	14.6
Total Idle Energy Rate @ 375°F (kW)	0.93

---

## *Heavy-Load Cooking-Energy Efficiency and Cooking Energy Rate*

---

Load Size (lb)	3.0
French Fry Cook Time (min)	2.32
Average Recovery Time (sec)	17.4
Production Capacity (lb/h)	69.0 ± 2.2
Energy to Food (Btu/lb)	568
Cooking Energy Rate (kW)	14.0
Control Energy Rate (W)	19.0
Energy per Pound of Food Cooked (Btu/lb)	693
Cooking-Energy Efficiency (%)	82.1 ± 6.3

---

# Results Reporting Sheets

---

## *Medium-Load Cooking-Energy Efficiency and Cooking Energy Rate*

---

Load Size (lb)	1.5
French Fry Cook Time (min)	2.01
Average Recovery Time (sec)	11.4
Production Rate (lb/h)	40.9 ± 1.2
Energy to Food (Btu/lb)	565
Cooking Energy Rate (kW)	8.44
Control Energy Rate (W)	17.5
Energy per Pound of Food Cooked (Btu/lb)	705
Cooking-Energy Efficiency (%)	80.3 ± 5.1

---

## *Light-Load Cooking-Energy Efficiency and Cooking Energy Rate*

---

Load Size (lb)	.75
French Fry Cook Time (min)	2.04
Average Recovery Time (sec)	10.2
Production Rate (lb/h)	20.4 ± 0.4
Energy to Food (Btu/lb)	588
Cooking Energy Rate (kW)	4.72
Control Energy Rate (W)	16.3
Energy per Pound of Food Cooked (Btu/lb)	790
Cooking-Energy Efficiency (%)	74.6 ± 6.1

---

## D Cooking-Energy Efficiency Data

---

*Table D-1. Specific Heat and Latent Heat*

---

<b>Specific Heat (Btu/lb, °F)</b>	
Ice	0.500
Fat	0.400
Solids	0.200
Frozen French Fries	0.695
<b>Latent Heat (Btu/lb)</b>	
Fusion, Water	144
Fusion, Fat	44
Vaporization, Water	970

---

## Cooking-Energy Efficiency Data

*Table D-2. Heavy-Load Fry Test Data*

	Repetition #1	Repetition #2	Repetition #3
<b>Measured Values</b>			
Test Voltage (V)	205	206	206
Element Energy Consumption (kWh)	3.10	3.08	2.94
Control Energy Consumption (Wh)	4.17	4.15	4.10
Total Energy (kWh)	3.10	3.08	2.94
<b>Cook Time (min)</b>	<b>2.32</b>	<b>2.32</b>	<b>2.32</b>
Total Test Time (min)	13.2	13.0	12.9
Weight Loss (%)	29.29	29.93	29.14
Initial Weight (lb)	15.000	15.000	15.000
Final Weight (lb)	10.606	10.510	10.629
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	44.6	44.9	44.2
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
<b>Calculated Values</b>			
Initial Weight of Water (lb)	9.780	9.780	9.780
Final Weight of Water (lb)	4.730	4.719	4.698
Sensible (Btu)	2,210	2,210	2,210
Latent – Heat of Fusion (Btu)	1,407	1,407	1,407
Latent – Heat of Vaporization (Btu)	4,889	4,905	4,927
Total Energy to Food (Btu)	8,506	8,522	8,545
<b>Energy to Food (Btu/lb)</b>	<b>567</b>	<b>568</b>	<b>570</b>
Total Energy to Fryer (Btu)	10,595	10,526	10,048
<b>Energy to Fryer (Btu/lb)</b>	<b>706</b>	<b>702</b>	<b>670</b>
<b>Cooking-Energy Efficiency (%)</b>	<b>80.3</b>	<b>81.0</b>	<b>85.0</b>
<b>Electric Energy Rate (kW)</b>	<b>14.1</b>	<b>14.2</b>	<b>13.7</b>
<b>Production Rate (lb/h)</b>	<b>68.0</b>	<b>69.2</b>	<b>69.7</b>
<b>Average Recovery Time (sec)</b>	<b>19.8</b>	<b>16.8</b>	<b>15.6</b>

## Cooking-Energy Efficiency Data

*Table D-3. Medium-Load Fry Test Data*

	Repetition #1	Repetition #2	Repetition #3	Repetition #4
<b>Measured Values</b>				
Test Voltage (V)	207	207	207	208
Element Energy Consumption (kWh)	1.50	1.50	1.56	1.62
Control Energy Consumption (Wh)	3.16	3.17	3.17	3.35
Total Energy (kWh)	1.50	1.50	1.56	1.62
<b>Cook Time (min)</b>	<b>2.00</b>	<b>2.00</b>	<b>2.00</b>	<b>2.02</b>
Total Test Time (min)	10.9	10.9	10.9	11.3
Weight Loss (%)	29.78	30.06	29.12	29.64
Initial Weight (lb)	7.500	7.500	7.500	7.500
Final Weight (lb)	5.267	5.246	5.316	5.277
Initial Moisture Content (%)	65.2	65.2	65.2	65.2
Final Moisture Content (%)	44.3	45.3	46.4	44.4
Initial Temperature (°F)	0	0	0	0
Final Temperature (°F)	212	212	212	212
<b>Calculated Values</b>				
Initial Weight of Water (lb)	4.890	4.890	4.890	4.890
Final Weight of Water (lb)	2.333	2.376	2.467	2.343
Sensible (Btu)	1,105	1,105	1,105	1,105
Latent – Heat of Fusion (Btu)	704	704	704	704
Latent – Heat of Vaporization (Btu)	2,476	2,434	2,348	2,467
Total Energy to Food (Btu)	4,285	4,242	4,156	4,276
<b>Energy to Food (Btu/lb)</b>	<b>571</b>	<b>566</b>	<b>554</b>	<b>570</b>
Total Energy to Fryer (Btu)	5,130	5,130	5,335	5,540
<b>Energy to Fryer (Btu/lb)</b>	<b>684</b>	<b>684</b>	<b>711</b>	<b>739</b>
<b>Cooking-Energy Efficiency (%)</b>	<b>83.5</b>	<b>82.7</b>	<b>77.9</b>	<b>77.2</b>
<b>Electric Energy Rate (kW)</b>	<b>8.27</b>	<b>8.27</b>	<b>8.61</b>	<b>8.61</b>
<b>Production Rate (lb/h)</b>	<b>41.2</b>	<b>41.3</b>	<b>41.3</b>	<b>39.8</b>
<b>Average Recovery Time (sec)</b>	<b>&lt; 10</b>	<b>&lt; 10</b>	<b>&lt; 10</b>	<b>&lt; 10</b>

## Cooking-Energy Efficiency Data

*Table D-4. Light Load Fry Test Data*

	Repetition #1	Repetition #2	Repetition #3	Repetition #3
<b>Measured Values</b>				
Test Voltage (V)	207	207	207	207
Element Energy Consumption (kWh)	0.90	0.84	0.90	0.82
Control Energy Consumption (Wh)	2.95	3.01	3.01	2.99
Total Energy (kWh)	0.90	0.84	0.90	0.82
<b>Cook Time (min)</b>	<b>2.00</b>	<b>2.05</b>	<b>2.05</b>	<b>2.05</b>
Total Test Time (min)	10.8	11.1	11.1	11.1
Weight Loss (%)	28.83	29.31	29.13	29.51
Initial Weight (lb)	3.750	3.750	3.750	3.750
Final Weight (lb)	2.669	2.651	2.658	2.644
Initial Moisture Content (%)	65.2	65.2	65.2	65.2
Final Moisture Content (%)	41.7	40.2	41.6	42.3
Initial Temperature (°F)	0	0	0	0
Final Temperature (°F)	212	212	212	212
<b>Calculated Values</b>				
Initial Weight of Water (lb)	2.445	2.445	2.445	2.445
Final Weight of Water (lb)	1.113	1.066	1.106	1.118
Sensible (Btu)	553	553	553	553
Latent – Heat of Fusion (Btu)	352	352	352	352
Latent – Heat of Vaporization (Btu)	1,289	1,336	1,297	1,285
Total Energy to Food (Btu)	2,194	2,240	2,201	2,190
<b>Energy to Food (Btu/lb)</b>	<b>585</b>	<b>597</b>	<b>587</b>	<b>584</b>
Total Energy to Fryer (Btu)	3,082	2,877	3,082	2,809
<b>Energy to Fryer (Btu/lb)</b>	<b>822</b>	<b>767</b>	<b>822</b>	<b>749</b>
<b>Cooking-Energy Efficiency (%)</b>	<b>71.2</b>	<b>77.9</b>	<b>71.4</b>	<b>77.99</b>
<b>Electric Energy Rate (kW)</b>	<b>5.02</b>	<b>4.55</b>	<b>4.89</b>	<b>4.44</b>
<b>Production Rate (lb/h)</b>	<b>20.8</b>	<b>20.2</b>	<b>20.3</b>	<b>20.3</b>
<b>Average Recovery Time (sec)</b>	<b>9.60</b>	<b>10.2</b>	<b>10.2</b>	<b>10.2</b>

## Cooking-Energy Efficiency Data

---

*Table D-5. Cooking Energy Efficiency and Production Capacity Statistics*

	Cooking Energy Efficiency			Production Capacity
	Heavy-Load	Medium-Load	Light-Load	
Replicate #1	80.3	83.5	71.2	68.0
Replicate #2	81.0	82.7	77.9	69.2
Replicate #3	85.0	77.9	71.4	69.7
Replicate #4	--	77.2	77.9	--
<b>Average</b>	<b>82.1</b>	<b>80.3</b>	<b>74.6</b>	<b>69.0</b>
Standard Deviation	2.54	3.23	3.81	0.87
Absolute Uncertainty	6.30	5.14	6.06	2.16
Percent Uncertainty	7.67	6.40	8.12	3.13

---

# E Energy Cost Model

---

## Procedure for Calculating the Energy Consumption of a Griddle Based on Reported Test Results

Appliance test results are useful not only for benchmarking appliance performance, but also for estimating appliance energy consumption. The following procedure is a guideline for estimating fryer energy consumption based on data obtained from applying the appropriate test method.

The intent of this Appendix is to present a standard method for estimating fryer energy consumption based on ASTM performance test results. The examples contained herein are for information only and should not be considered an absolute. To obtain an accurate estimate of energy consumption for a particular operation, parameters specific to that operation should be used (e.g., operating time, and amount of food cooked under heavy-, medium-, and light-loads).

The calculation will proceed as follows: First, determine the appliance operating time and total number of preheats. Then estimate the quantity of food cooked and establish the breakdown between heavy- (two 1½-lb baskets), medium- (one 1½-lb basket), and light- (one ¾-lb basket) loads. For example, a fryer operating for 12 hours a day with one preheat cooked 100 pounds of food: 36% of the food was cooked under heavy-load conditions, 48% was cooked under medium-load conditions, and 16% was cooked under light-load conditions. Calculate the energy due to cooking at heavy-, medium-, and light-load cooking rates, and then calculate the idle energy consumption. The total daily energy is the sum of these components plus the preheat energy. For simplicity, it is assumed that subsequent preheats require the same time and energy as the first preheat of the day.

The application of the test method to an electric fryer yielded the following results:

# Energy Cost Model

**Table E-1: Electric Fryer Performance Parameters.**

Test	Result
Preheat Time	11.9 min
Preheat Energy	2.30 kWh
Idle Energy Rate	0.93 kW
Heavy-Load Cooking Energy Rate	14.0 kW
Medium-Load Cooking Energy Rate	8.44 kW
Light-Load Cooking Energy Rate	4.72 kW
Production Capacity	69.0 lb/h
Medium-Load Production Rate	40.9 lb/h
Light-Load Production Rate	20.4 lb/h

**Step 1—The operation being modeled has the following parameters**

**Table E-2: Fryers Operation Assumptions.**

Operating Time	12 h
Number of Preheats	1 preheat
Total Amount of Food Cooked	100 lb
Percentage of Food Cooked Under Heavy-Load Conditions	36% (× 100 lb = 36 lb)
Percentage of Food Cooked Under Medium-Load Conditions	48% (× 100 lb = 48 lb)
Percentage of Food Cooked Under Light-Load Conditions	16% (× 100 lb = 16 lb)

**Step 2—Calculate the total heavy-load energy.**

The total time cooking heavy-loads is as follows:

$$t_h = \frac{\% h \times W}{PC},$$

$$t_h = \frac{36\% \times 100 \text{ lb}}{69.0 \text{ lb/h}},$$

$$t_h = 0.52 \text{ h}$$

## Energy Cost Model

---

The total heavy-load energy consumption is then calculated as follows:

$$\begin{aligned}E_{elec,h} &= q_{elec,h} \times t_h \\E_{elec,h} &= 14.0 \text{ kW} \times 0.52 \text{ h}, \\E_{elec,h} &= 7.28 \text{ kWh}\end{aligned}$$

### **Step 3—Calculate the total medium-load energy.**

The total time cooking medium-loads is as follows:

$$\begin{aligned}t_m &= \frac{\% m \times W}{PR_m}, \\t_m &= \frac{48\% \times 100 \text{ lb}}{40.9 \text{ lb/h}}, \\t_m &= 1.17 \text{ h}\end{aligned}$$

The total medium-load energy consumption is then calculated as follows:

$$\begin{aligned}E_{elec,m} &= q_{elec,m} \times t_m \\E_{elec,m} &= 8.44 \text{ kW} \times 1.17 \text{ h}, \\E_{elec,m} &= 9.88 \text{ kWh}\end{aligned}$$

### **Step 4—Calculate the total light-load energy.**

The total time cooking light-loads is as follows:

$$\begin{aligned}t_l &= \frac{\% l \times W}{PR_l}, \\t_l &= \frac{16\% \times 100 \text{ lb}}{20.4 \text{ lb/h}}, \\t_l &= 0.78 \text{ h}\end{aligned}$$

The total light-load energy consumption is then calculated as follows:

$$\begin{aligned}E_{elec,l} &= q_{elec,l} \times t_l \\E_{elec,l} &= 4.72 \text{ kW} \times 0.78 \text{ h} \\E_{elec,l} &= 3.68 \text{ kWh}\end{aligned}$$

# Energy Cost Model

---

## Step 5—Calculate the total idle time and energy consumption.

The total idle time is determined as follows:

$$t_i = t_{on} - t_h - t_m - t_l - \frac{n_p \times t_p}{60},$$
$$t_i = 12.0\text{ h} - 0.52\text{ h} - 1.17\text{ h} - 0.78\text{ h} - \frac{1\text{ preheat} \times 11.9\text{ min}}{60\text{ min/h}}$$
$$t_i = 9.33\text{ h}$$

The idle energy consumption is then calculated as follows:

$$E_{elec,i} = q_{elec,i} \times t_i,$$
$$E_{elec,i} = 0.93\text{ kW} \times 9.33\text{ h}$$
$$E_{elec,i} = 8.68\text{ kWh}$$

## Step 6—The total daily energy consumption is calculated as follows:

$$E_{elec,daily} = E_{elec,h} + E_{elec,m} + E_{elec,l} + E_{elec,i} + n_p \times E_{elec,p}$$
$$E_{elec,daily} = 7.28\text{ kWh} + 9.88\text{ kWh} + 3.68\text{ kWh} + 8.68\text{ kWh} + 1 \times 2.30\text{ kWh}$$
$$E_{elec,daily} = 31.82\text{ kWh/day}$$

## Step 7—Calculate the average demand as follows:

$$q_{avg} = \frac{E_{elec,daily}}{t_{on}},$$
$$q_{avg} = \frac{31.8\text{ kWh}}{12.0\text{ h}},$$
$$q_{avg} = 2.65\text{ kW}$$

## Step 7—The annual energy cost is calculated as follows:

$$Cost_{annual} = E_{elec,daily} \times R_{elec} \times Days$$
$$Cost_{annual} = 31.82\text{ kWh/day} \times 0.10\text{ \$/kWh} \times 365\text{ days/year}$$
$$Cost_{annual} = 1,161\text{ \$/year}$$