

**Watlow® Model Firebar 1000 and 1600
Prototype Element Performance Test**

In a standard fryer

In accordance with ASTM Standard

Test Method F 1361-95

FSTC Report 5011.98.60

**Food Service Technology Center Manager: Don Fisher
Final Report, July 1998**

Prepared by:

Shawn Knapp

Contributors:

David Zabrowski

Judy Nickel

Michael Schmitz

Prepared for:

**Pacific Gas and Electric Company
Consumer Energy Management
123 Mission Street, P.O. Box 770000
San Francisco, California 94177**

© 1998 by Pacific Gas and Electric Company. All rights reserved.



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

Acknowledgments

PG&E's Food Service Technology Center is supported by the National Advisory Group, which includes

Electric Power Research Institute (EPRI)

Gas Research Institute (GRI)

National Restaurant Association

California Restaurant Association (CRA)

International Facility Management Association (IFMA)

California Energy Commission (CEC)

Underwriters Laboratories (UL)

Gas Appliance Manufacturers Association (GAMA)

California Café Restaurant Corp.

Fresh Choice, Inc.

Darden Restaurants, Inc.

Specific appreciation is extended to Watlow Industries, for supplying the Food Service Technology Center with a the Firebar 1000 and two prototype Firebar 1600 electric fryer elements for controlled testing in the appliance laboratory.

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

- The Food Service Technology Center (FSTC) is *strongly* committed to testing food service equipment using the best available scientific techniques and instrumentation.
- The FSTC is neutral as to fuel and energy source. It does not, in any way, encourage or promote the use of any fuel or energy source nor does it endorse any of the equipment tested at the FSTC.
- FSTC test results are made available to the general public through both PG&E 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 PG&E *in advance* and proper attribution to PG&E 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 by Pacific Gas and Electric Company for exclusive use by its employees and agents. Neither Pacific Gas and Electric Company nor any of its employees:

- (1) makes any written or oral warranty, expressed or implied, including, but not limited to those concerning merchantability or fitness for a particular purpose;
- (2) assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, process, method, or policy contained herein; or
- (3) represents that its use would not infringe any privately owned rights, including, but not limited to, patents, trademarks, or copyrights.

Contents

	Page
Executive Summary	ii
1 Introduction	1-1
Background	1-1
Objectives	1-1
Fryer and Element Description	1-2
2 Methods	2-1
Test Setup and Instrumentation	2-1
Measure Energy Input Rate.....	2-2
French Fry Cooking Energy Efficiency and Production Capacity Tests.....	2-2
3 Results	3-1
Energy Input Rate	3-1
Preheat and Idle Energy Consumption	3-1
Cooking Performance Tests	3-2
4 Conclusions and Recommendations	4-1
5 References	5-1
Appendix A: Glossary	
Appendix B: Element Manufacturer’s Product Specifications	
Appendix C: Results Reporting Sheets	
Appendix D: Cooking Energy Efficiency Data	

List of Figures and Tables

Tables

	Page
ES-1 Summary of Watlow Electric Fryer Element Performance Results	iv
1-1 Fryer Specifications	1-3
1-2 Heating Element Specifications	1-3
3-1 Input, Preheat and Idle Test Results	3-2
3-2 Cooking Energy Efficiency and Production Capacity Test Results	3-4

Figures

	Page
ES-1 Cook zone temperature profiles for Watlow elements during a cooking test	vi
ES-2 Production capacity for heavy and extra-heavy load cooking test	viii
1-1 Watlow Firebar elements.....	1-2
2-1 Frypot configuration and corresponding thermocouple placement.....	2-2
3-1 Cooking zone temperature during preheat for each element.....	3-2
3-2 Watlow 1600 (24.7 kW) element temperature profile of cook zone and temperature recovery during a typical heavy-load cooking test	3-5
3-3 Watlow 1600 (24.7 kW) element cook zone temperature recovery for a typical heavy-load.....	3-6
3-4 Cooking zone temperature profiles for the Watlow elements during a cooking test	3-6
3-5 Element temperature profiles of hot zones during a heavy-load cooking test	3-8
3-6 Average hot zone temperatures during heavy-load and extra-heavy load cooking tests	3-8
3-7 Production capacity for heavy- and extra-heavy load cooking tests.....	3-9

Executive Summary

The Watlow Industries Firebar 1000 electric fryer element has long been considered an industry standard with its patented ribbon shape and low watt density design. In an attempt to raise the benchmark for electric fryers, Watlow created the prototype Firebar 1600. With a 1½-inch wide ribbon (compared to the 1-inch wide Firebar 1000) this new design has a greater surface area and the potential for lower watt density than its predecessor.

Two configurations of the Firebar 1600 were tested and compared to the original Firebar 1000: a 17 kW version (two hairpins) and a 24.7 kW version (three hairpins). A single fryer featuring an all-stainless steel frypot and solid state controls was used for the testing, thus keeping everything consistent. The tests were conducted 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.

New oil was used for each element configuration to ensure that oil age and possible contaminants would not skew the results. Production capacity is determined by cooking 3-pound loads of frozen French fries, one load after the other. The ASTM test requires a 10-second logistical preparation time between loads to allow the operator to remove the previous batch and prepare subsequent batches for cooking. To amplify any possible differences between

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

Executive Summary

the three element configurations, researchers conducted extra-heavy load tests using 4-pound loads of frozen french fries.

Table ES-1

Summary of Watlow Electric Fryer Elements Performance Results

Element Model	1000	1600	1600
Rated Energy Input Rate (kW) ^l	17.0	17.0	24.7
Tested Energy Input Rate (kW)	17.3	17.4	26.8
Preheat to 350°F			
Time (min)	6.4	5.5	4.2
Consumption (kWh)	1.8	1.5	1.7
Rate to 350°F (°F/min)	43	51	66
Idle Energy Consumption Rate @ 350°F (kW)	0.75	0.78	0.86
Heavy Load			
Cooking Energy Efficiency (%)	86.9	89.4	86.4
Production Capacity (lb/h) ^a	69.2	71.8	74.0
Recovery Time (sec) ^b	0	0	0
Cook Zone Temperature (°F)	331	328	337
Average Hot Zone Temperature (°F)	438	418	416
Extra-Heavy Load			
Cooking Energy Efficiency (%)	87.4	90.2	87.7
Production Capacity (lb/h) ^a	79.0	82.4	96.4
Recovery Time (sec) ^b	8	4	0
Cook Zone Temperature (°F)	332	323	330
Average Hot Zone Temperature (°F)	444	431	415

Executive Summary

^a Based on a minimum 10-second preparation time between loads.

^b Recovery time based on the elapse time from when french fry loads are removed from the fryer to when frying medium recovers back up to 340°F.

Fryer cooking performance was evaluated cooking two different loads—an extra-heavy load (4 pounds) and a heavy load (3 pounds)—using ¼-inch blue ribbon, par-cooked, frozen shoestring potatoes. All tests were conducted using Melfry partially hydrogenated soybean oil. The Firebar 1000 (17 kW) elements cook times were 2 minutes 45 seconds for the extra-heavy load test and 2 minutes 25 seconds for heavy-load test. The Firebar 1600 (17 kW) element cook times were 2 minutes 45 seconds for the extra-heavy load test and 2 minutes 25 seconds for heavy-load test. The Firebar 1600 (24.7 kW) element cook times were 2 minutes 20 seconds for the extra-heavy load test and 2 minutes 17 seconds for heavy-load test.

Under each of these loading scenarios, cooking energy efficiency was determined in accordance with the following relationship:

$$\text{CookingEnergyEfficiency} = \frac{\text{EnergytoFood}}{\text{EnergytoFryer}}$$

Although the FSTC has tested other high-efficient fryers that have been able to recover back to 340°F before the 10-second logistical reload period has expired, the Firebar 1600 (24.7 kW) element was the first element to consistently recover the frying medium to the 340°F reload temperature before the french fries were ready to be removed from the fryer. This fast frying medium recovery caused researchers to reconsider the mandatory 10-second logistical reload period. This new generation of high-efficiency electric fryers can recover more quickly and produce more product in less time. A 5-second logistical reload time may better reflect the benefit of a high-capacity fryer, while still reflecting a real-world time between removing one load and setting the next. As currently written, the ASTM F 1361-95 standard test method may not fully credit the Firebar 1600 element for its fast recovery.

Executive Summary

Figure ES-1 plots the cook zone temperature during a heavy-load test for the three elements. The plot illustrates the typical cook zone temperature “signature” as the fryer is used to cook a load of frozen french fries. Initially the temperature drops dramatically and the fryer thermostat responds by energizing the heating elements to raise the frying medium temperature. The Watlow 1600 (24.7 kW) element had the fastest temperature recovery and maintained the highest average cook zone temperature of the three elements. The Watlow 1600 (17 kW) element recorded the second fastest recovery, but its average cook zone temperature was slightly lower (3°F) than the other elements. The reason for the lower cook zone temperature was that the fryer’s thermostat controls sensed that the Watlow Firebar 1600 (17 kW) had returned the frying medium close to thermostatic set point and cycled off the elements. Cycling off the elements caused the average cook zone temperature to be slightly lower. The specification of a compatible thermostat to match the prototype element’s operating characteristics would improve the fryer performance and should increase the average cook zone temperature.

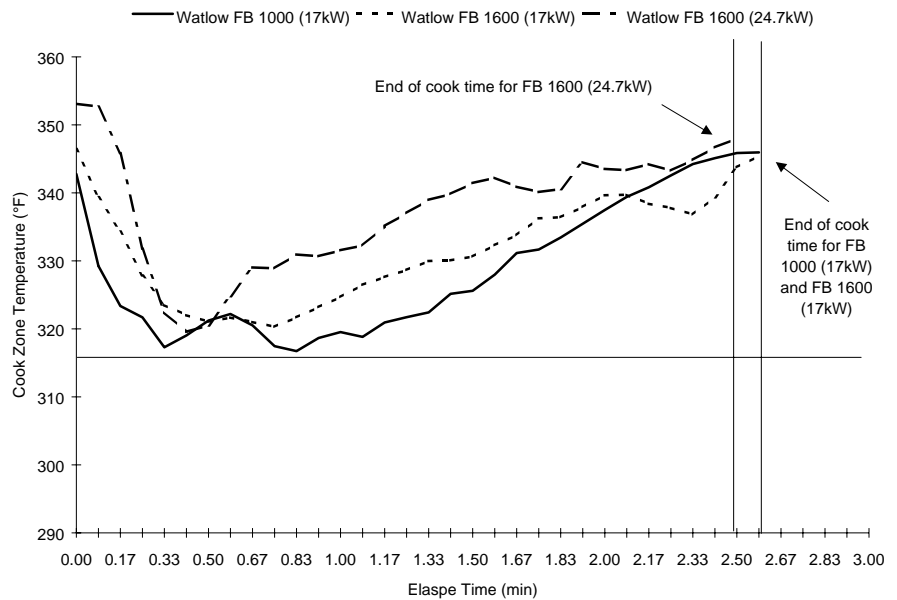


Figure ES-1. Cook zone temperature profiles for the Watlow elements during a cooking test.

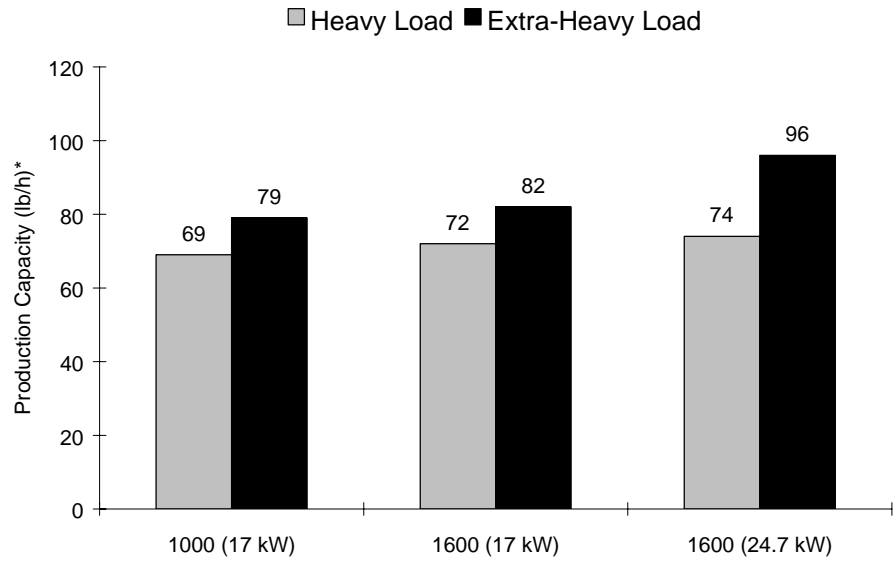
Executive Summary

Previous fryer tests have not shown significant advantages to increasing the energy input to the elements over today's industry standards of 14 kW and 17 kW. The prototype Watlow Firebar 1600 (24.7 kW) electric fryer element recorded the fastest preheat time and one of the lowest preheat energy consumption to heat the frying medium from room temperature to 350°F (1.7 kWh in 4.17 minutes vs. 1.6 kWh in 4.9 minutes for the next fastest fryer tested). The 1600 (17 kW) element recorded the second fastest preheat time of 5.5 minutes and a low energy use of 1.50 kWh. The 1600 (17 kW) element used nearly the same idle rate as the baseline model 1000 (17 kW) (0.75 kW vs. 0.78 kW), while the 1600 (24.7 kW) used slightly more energy at idle (0.86 kW).

The two prototype elements performed well during the cooking tests, recording the highest cooking efficiency ever tested by the FSTC. For example, the 1600 (17 kW) element demonstrated a heavy-load cooking energy efficiency of 89% (vs. 87% for the baseline element), produced 72 pounds of french fries per hour under heavy-load conditions, and had a fast recovery time. The 1600 (24.7 kW) element performed almost as well with 86% cooking energy efficiency for heavy-load testing and the fastest recovery. Figure ES-2 compares the production capacity of the three elements for heavy- and extra-heavy load cooking tests.

Executive Summary

Figure ES-2. Production capacity for heavy and extra-heavy load cooking tests.



*Based on a minimum 10-second preparation time between loads.

FSTC Manager

Donald R. Fisher

Senior Program Manager

Peter W. Turnbull

1 Introduction

Background

Watlow's new Firebar 1600 electric elements uses a flat wide surface to reduce the watt density to lower sheathe temperatures.

The Watlow Industries Firebar 1000 electric fryer element has long been considered an industry standard with its patented ribbon shape and low watt density design. In an attempt to raise the benchmark for electric fryers, Watlow created the prototype Firebar 1600. With a 1½-inch wide ribbon (compared to the 1-inch wide Firebar 1000) this new design has a greater surface area and the potential for lower watt density than its predecessor.

Two configurations of the Firebar 1600 were tested and compared to the original Firebar 1000: a 17 kW version (two hairpins) and a 24.7 kW version (three hairpins). A single fryer featuring an all-stainless steel frypot and solid state controls was used for the testing, thus keeping everything consistent.

The tests were conducted 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*.² 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 1-1.

Objective

This report compares and quantifies the performance differences of the Firebar 1000 (baseline) and the two Firebar 1600 (prototype) elements when tested in accordance with ASTM *Standard Test Methods for the Performance of Open Deep-fat Fryers* (Designation F1361-95) and to a modified version of this ASTM standard method of test. The scope of testing was as follows:

² American Society for Testing and Materials. 1992. *Standard Test Methods for the Performance of Open, Deep-fat Fryers*. ASTM Designation F 1361-95. Philadelphia: American Society for Testing and Materials.

1 Introduction

1. Verify that the fryer elements operate at the manufacturer's rated energy input.
2. Document the time and energy required to preheat the frying medium from 75°F (room temperature) to 350°F for each element.
3. Determine the energy consumption rate while the fryer is idling at 350°F for each element.
4. Determine the cooking energy efficiency under the ASTM heavy-load and the test-specific extra-heavy-load cooking conditions using $\frac{1}{4}$ -inch frozen shoestring potatoes for each element.
5. Determine the production capacity and frying medium recovery time when cooking $\frac{1}{4}$ -inch frozen shoestring potatoes during the heavy and extra-heavy load tests for each element.
6. Compare and quantify performance differences between the Firebar 1000 (baseline) and the two Firebar 1600 (prototypes) elements.

A glossary of terms used in the report is provided in Appendix A, manufacturer's specifications are in Appendix B, results reporting sheets in Appendix C, and cooking energy efficiency data are in Appendix D.

*Figure 1-1.
Watlow Firebar elements, positioned left to right is model 1000 (17 kW), 1600 (17 kW) and 1600 (24.7 kW).*



Fryer and Element Description

Watlow Industries model Firebar elements feature low-watt density, flat-surface heating elements. The elements are mounted on a hinge that allows

Introduction

the elements to swing away for easier cleaning of the frypot. For safety purposes, the heating elements de-energize when raised. Fryer specifications are listed in Table 1-1, the heating element specifications in Table 1-2 and manufacturer's literature is provided in Appendix B.

Table 1-1 Fryer Specifications

Frying Area:	14" x 15-1/2"
Temperature Controls:	Solid-state electronic
Frying Medium Capacity:	50 lb
Type of Frypot:	Stainless Steel
Heating Cycles:	Melt and non-melt
Controls:	Solid state thermostat and frying computer
Accessories:	Two fry baskets

Table 1-2 Heating Element Specifications

Manufacturer:	Wattlow	Wattlow	Wattlow
Model:	Firebar 1000	Firebar 1600	Firebar 1600
Rated Energy			
Input:	17.0 kW	17.0 kW	24.7 kW
Resistance Wires:	Nickel Chromium	Nickel Chromium	Nickel Chromium
Insulation:	MgO	MgO	MgO
Element Height:	1 inch	1-1/2 inch	1-1/2 inch
Heat Transfer	Flat Low-Watt	Flat Low-Watt	Flat Low-Watt
Surface:	Density	Density	Density

2 Methods

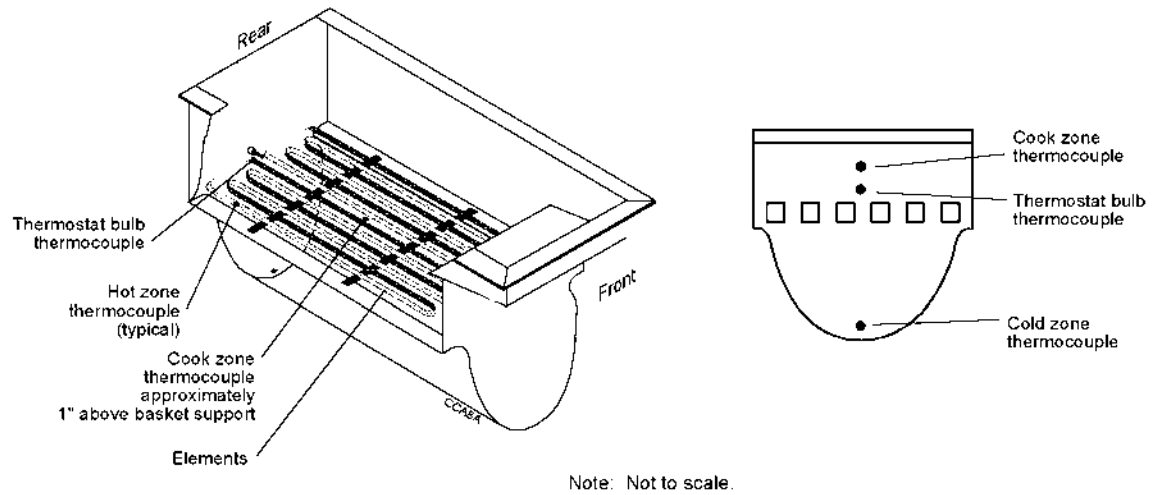
Setup and Instrumentation

The fryer was installed on a tiled floor under a 4-foot-deep canopy hood that was 6 feet 6 inches above the floor. The hood operated at a nominal exhaust rate of 300 cfm per linear foot of hood. There was at least 6 inches of clearances between the vertical plane of the fryer and the edge of the hood (see Figure 2-1). All test apparatus were installed in accordance with Section 8 of the *ASTM Standard Test Method for the Performance of Open, Deep-fat Fryers*.¹ A voltage regulator maintained a constant 206.5 V to the appliance for each test. Temperature was measured with K-type immersible thermocouple probes. All data were logged using a Fluke Helios data logger and recorded on a personal computer, using software developed by FSTC engineers.

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

One fryer was used to test all three elements. The fryer used for this testing featured an all-stainless steel frypot and solid-state controls. When one element was removed from the fryer and replaced with the next, the oil (frying medium) was drained. The next element was installed and the fryer was refilled with fresh oil. Using new oil for each element test ensured that the age of the oil and contamination from the used oil during each element test were exactly the same for each element and would not skew the results.

Figure 2-1.
Frypot configuration and corresponding thermocouple placement.



Measured Energy Input Rate

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

French Fry Cooking Energy Efficiency and Production Capacity Tests

As specified by the ASTM Standard Test Method for fryers, the $\frac{1}{4}$ -inch blue ribbon, par-cooked, frozen shoestring potatoes were used as the product in all cooking tests. The french fries were $6 \pm 1\%$ fat and $67 \pm 2\%$ moisture by weight.¹ Each load was cooked to a $30 \pm 1\%$ 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 elements using 3-pound (heavy) and 4-pound (extra-heavy) french fry loads. Cooking time determination tests established a cook time for each

Methods

element. Cook time determination is an iterative process that could take several tests to yield an average $30 \pm 1\%$ french fry weight loss during the cooking process.

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 ensured that the cooking tests were uniformly applied from laboratory to laboratory. Temperature recovery was 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 does not significantly lower the average oil temperature over the cooking cycle, nor does it extend the cook time. The fryer was then reloaded either after the cook zone thermocouple reached the threshold temperature (340°F) 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 the test was terminated. 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 and three replicates of the extra-heavy load test—to ensure that the reported cooking energy efficiency and production capacity results had an uncertainty of less than $\pm 10\%$. Results of each test run were averaged, and absolute uncertainty was calculated based on the standard deviation of the results. Researchers followed the ASTM F1361-95 standard test method completely except for one deviation. Only one cooked french fry sample was taken for each loading scenario (heavy and extra-heavy) to be analyzed for fat content. Normally a cooked french fry sample is taken from each 5-load test. Using only one sample only slightly increased the uncertainty of the calculated cooking energy efficiency results.

3 Results

Energy Input Rate

The energy input rate was measured and compared to the manufacturer's nameplate value prior to testing. This provided a check to ensure that the elements was operating properly. The Firebar 1000 and the two prototype Firebar 1600 elements rated energy input rates are 17.0, 17.0 and 24.7 kW, respectively. The measured energy rates were 17.3, 17.4 and 26.8 kW (a difference of 1.8%, 2.4% and 8.4%, respectively from their rated energy inputs) at a test voltage of 206.5 V.

Preheat and Idle Energy Consumption

Preheat and idle energy tests are conducted to estimate time and energy consumption demands on appliances. Non-cooking energy performance tests of the Firebar elements were conducted in accordance with the ASTM standard test method F 1361-95. Melfry partially hydrogenated, soybean oil was used in all tests.

The frying medium average temperature was 75°F at the start of each preheat test. The time to heat the frying medium to 350°F was 6.4, 5.5 and 4.2 minutes for the Firebar 1000, Firebar 1600 (17 kW) and Firebar 1600 (24.7) elements, respectively. The total energy consumed during preheat was 1.76, 1.50 and 1.70 kWh, respectively. Figure 3-1 shows cook zone temperature during the preheat period for each element configurations.

The fryer was preheated to 350°F and allowed to stabilize for 1 hour. Researchers monitored the fryer's energy consumption over a 2-hour period. The energy rate during this period was 0.75, 0.78, and 0.86 kW for the Watlow 1000 (17 kW), 1600 (17 kW) and 1600 (24.7 kW) elements, respectively. Input, preheat, and idle test results are summarized in Table 3-1.

Results

Table 3-1 Input, Preheat and Idle Test Results

Element Model	Firebar 1000	Firebar 1600	Firebar 1600
Rated Energy Input Rate (kW)	17.0	17.0	24.7
Tested Energy Input Rate (kW)	17.3	17.4	27
Test Voltage (V)	206.5	206.5	206.5
Preheat to 350°F			
Time (min)	6.4	5.5	4.17
Consumption (kWh)	1.8	1.5	1.7
Rate to 350°F (°F/min)	43	51	66
Idle Energy Consumption Rate @ 350°F (kW)	0.75	0.78	0.86
Idle Duty cycle (%)	4.3	4.5	3.2

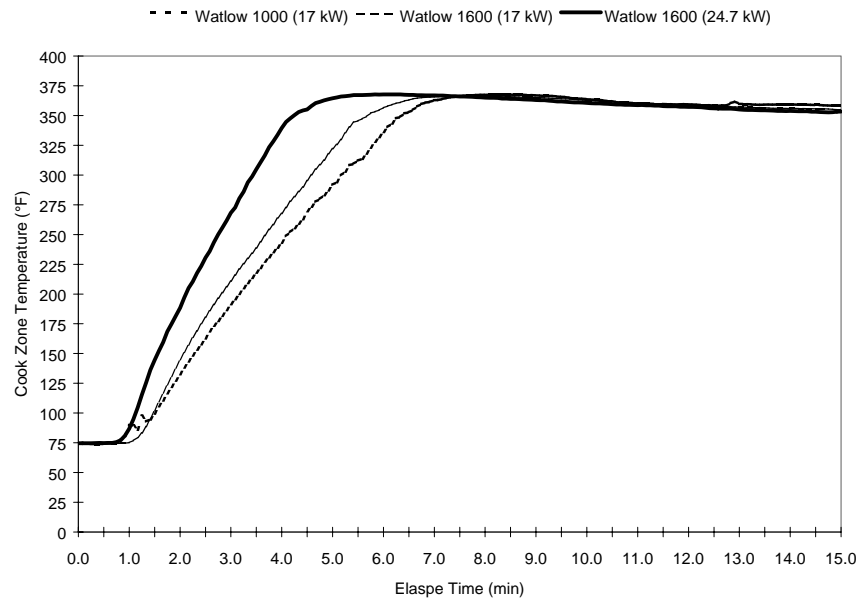


Figure 3-1 Cooking zone temperature during preheat for each element.

Cooking Performance Tests

The fryer was tested under two different loading scenarios: heavy (3 pounds) and extra-heavy (4 pounds) french fry loads. Researchers recorded cook

Results

time, cooking energy consumption, recovery time, and french fry weight loss during testing. Table 3-2 presents the results from 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 analysis for production capacity, cooking energy efficiency and cooking energy rate.

Cooking energy efficiency is defined as the energy absorbed by the french fries, expressed as a percentage of the energy consumed by the fryer. Researchers determined the french fry energy by calculating the heat absorbed by each component of the french fry (fat, solid, and water), including the latent heat of vaporization required to evaporate the moisture contained in the fries. The reported test results are an average of three test runs. Cooking energy efficiencies for the Firebar 1000 element were 86.9% and 87.4% for heavy and extra-heavy loads. Cooking energy efficiencies for the Firebar 1600 (17 kW) element were 89.4% and 90.2% for heavy- and extra-heavy loads, while cooking energy efficiencies for the Firebar 1600 (24.72 kW) element were 86.4% and 87.4% for heavy and extra-heavy loads.

To ascertain how well the fryer is cooking, one can look at the temperature profile of the frying medium; too low of a temperature drop, the french fries may begin to absorb too much oil. Figure 3-2 illustrates the fluctuating frying medium temperature during a heavy-load french fry cooking test for the Watlow 1600 (24.7 kW) element. If the cooking medium temperature is able to quickly return to 340°F or higher during each heavy and extra-heavy load, the fryer will also be able to recover quickly during medium- (1- 1/2 pounds per load) and light-load (3/4 pounds per load) cooking tests.

Each element was responsive during the cooking events, maintaining a relatively high average cook zone temperature of 331°F, 328°F and 337°F, for the Firebar 1000 (17 kW) element, the 1600 (17 kW) element and the 1600 (24.7 kW) element respectively under heavy-load conditions with a 340°F cook zone temperature at reload. Each of the elements had a fast recovery time under heavy-load conditions (less than 10 seconds).

Results

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

Element Model	Firebar 1000	Firebar 1600	Firebar 1600
Rated Energy Input Rate (kW) ^l	17.0	17.0	24.7
Heavy Load			
Cook Time (min)	2.41	2.40	2.28
Recovery Time (sec) ^b	0	0	0
Cooking Energy Efficiency (%)	86.9	89.4	86.4
Production Capacity (lb/h) ^a	69.2 ± 1.3	71.8 ± 1.0	74.0 ± 2.9
Average Cooking Energy Consumption			
Rate (kW)	13.6	14.1	14.7
Cook Zone Temperature (°F)	331	328	337
Average Hot Zone Temperature (°F)	438	418	416
Energy to Food (Btu/lb)	583	600	586
Energy to Fryer (Btu/lb)	671	671	678
Extra-Heavy Load			
Cook Time (min)	2.75	2.75	2.33
Recovery Time (sec) ^b	8	4	0
Cooking Energy Efficiency (%)	87.4	90.2	87.4
Production Capacity (lb/h) ^a	79.0 ± 1.1	82.4 ± 0.8	96.4 ± 0.9
Average Cooking Energy Consumption			
Rate (kW)	15.3	15.8	18.5
Cook Zone Temperature (°F)	332	323	330
Hot Zone Temperature (°F)	444	431	415
Energy to Food (Btu/lb)	580	589	574
Energy to Fryer (Btu/lb)	664	654	657

Results

^a Based on a minimum 10-second preparation time between loads.

^b Recovery time based on the elapse time from when french fry loads are removed from the fryer to when frying medium recovers back up to 340°F.

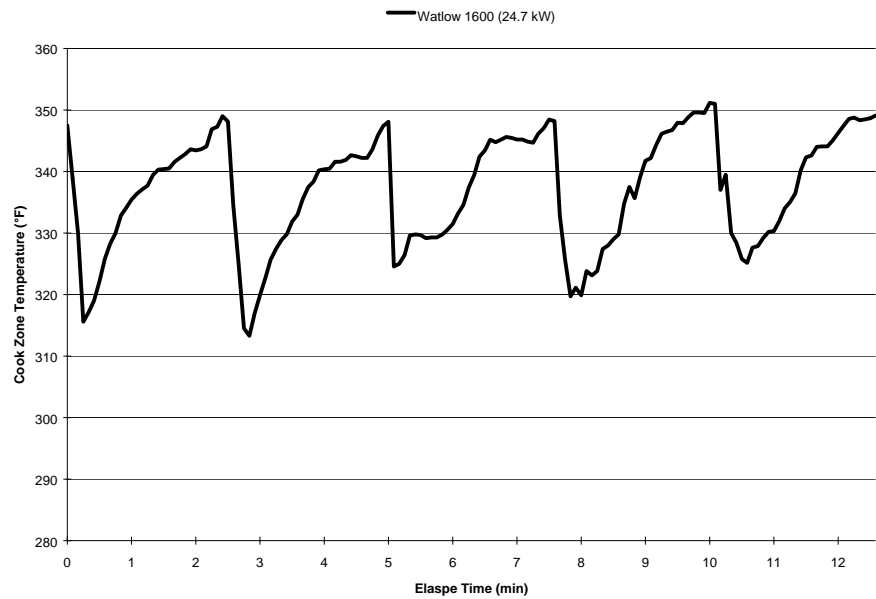


Figure 3-2. Watlow 1600 (24.7 kW) element temperature profile of cook zone and temperature recovery during a typical heavy-load cooking test.

Figure 3-3 presents a magnified view of the cook zone temperature's reaction (referred to as the fryer's cooking temperature signature) when a heavy load of fries was lowered into the 350°F frying medium.

Figure 3-4 illustrates the difference in cooking zone temperature recovery for the three elements. The cook zone temperatures for the two prototype elements do not drop as low as the baseline element and maintained a higher average oil temperature the during cooking tests.

Results

Figure 3-3. Watlow 1600 (24.7 kW) cook zone temperature recovery during a typical heavy-load cooking test.

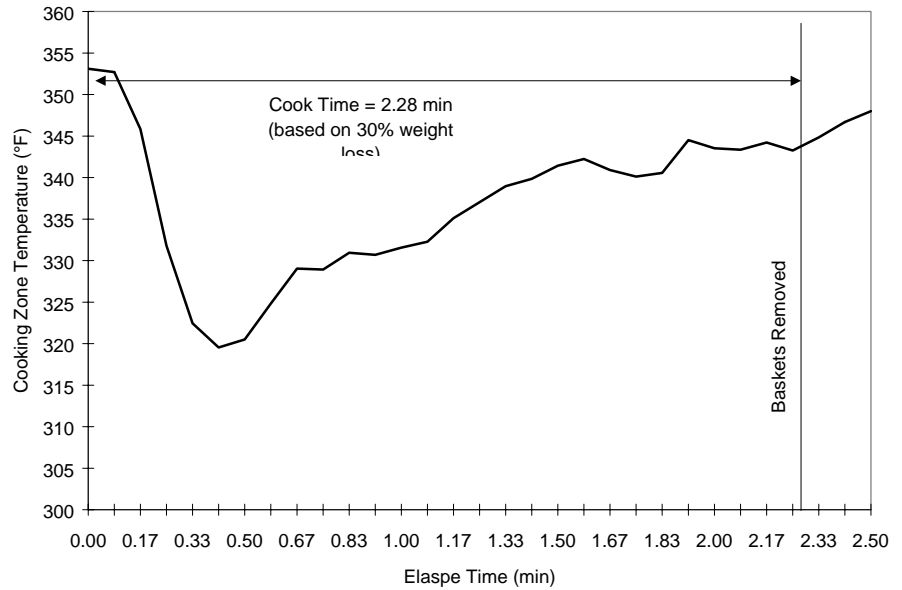
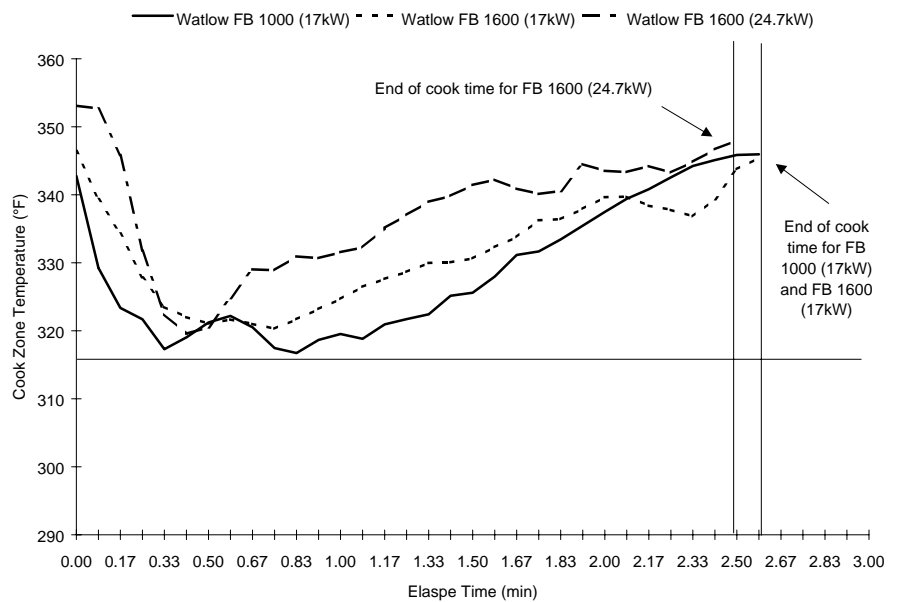


Figure 3-4. Cook zone temperature profiles for the Watlow elements during a cooking test.



Results

Each element was responsive during cooking events, maintaining a relatively high average cook zone temperature of 331°F, 328°F and 337°F, for 1000 (17 kW), 1600 (17 kW) and 1600 (24.7 kW) respectively under heavy-load conditions with a 340°F reload. Each element had a fast recovery time for heavy-load conditions (less than 10 seconds).

Thermocouples were attached to the top of the elements in the four corners of the cook zone. These four thermocouples make up the hot zone temperatures (i.e., element surface temperatures). The element manufacturer theorizes that its large flat surface elements have lower surface (sheath) temperatures, which will help extend oil life. Replacing of cooking oil is expensive, up to three times more than the energy cost to operate the fryer. Thus, increasing the useful life of the oil can significantly reduce overall fryer operation cost. Figure 3-5 illustrates hot-zone temperatures of the three elements during a heavy-load cooking test. During the test, the prototype Watlow 1600 (24.7 kW) element maintained the lowest average hot-zone temperature (416°F) while the 1600 (17 kW) followed closely (418°F) and the 1000 (17 kW) achieved much higher temperatures (438°F). Both prototype elements have increased surface area to reduce the watt density (w/in^2) and lower the sheath temperature. Figure 3-6 compares the average hot zone temperatures for the three elements during heavy-load and extra-heavy load cooking tests. Figure 3-7 compares the production capacity for the three elements during heavy-load and extra-heavy load cooking tests.

Results

Figure 3-5. Element temperature profile of hot zones during a heavy-load cooking test.

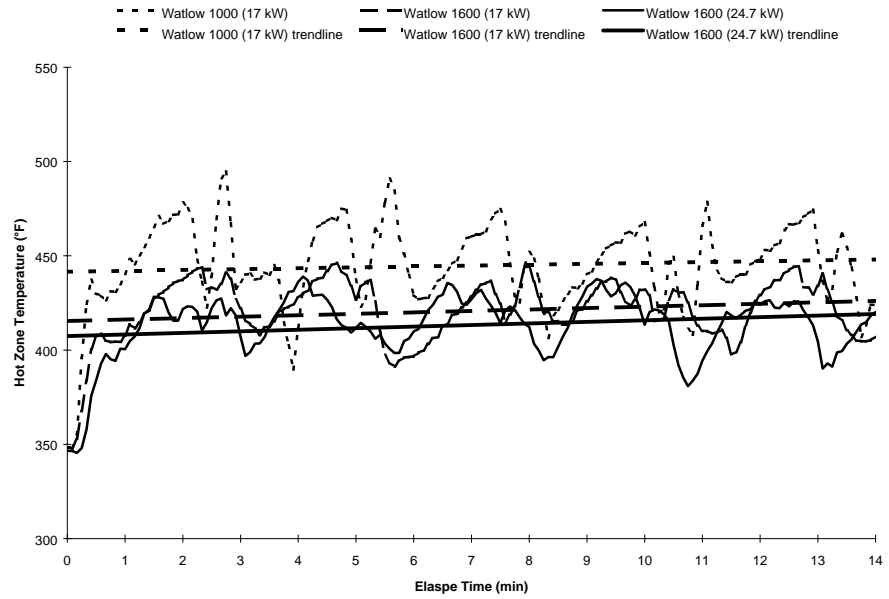
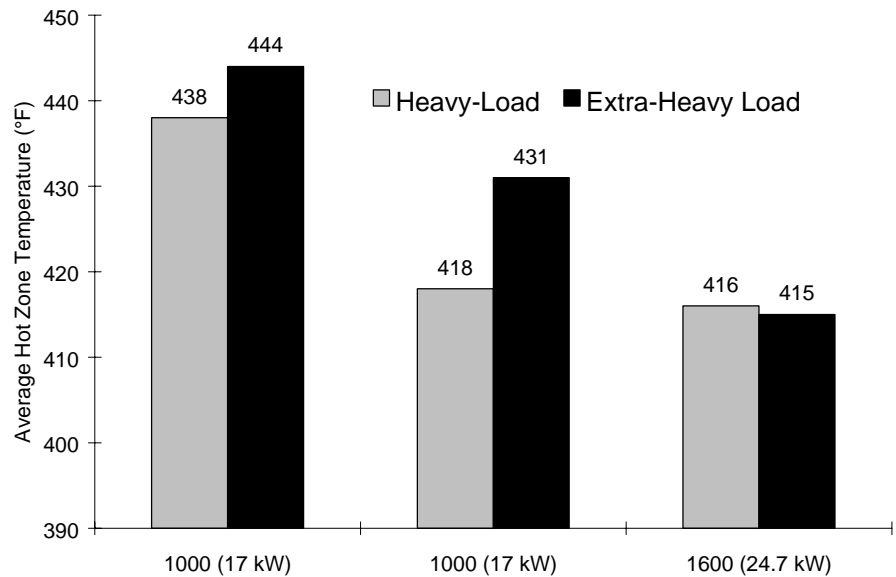


Figure 3-6. Average hot zone temperatures during heavy-load and extra-heavy load cooking tests.



Results

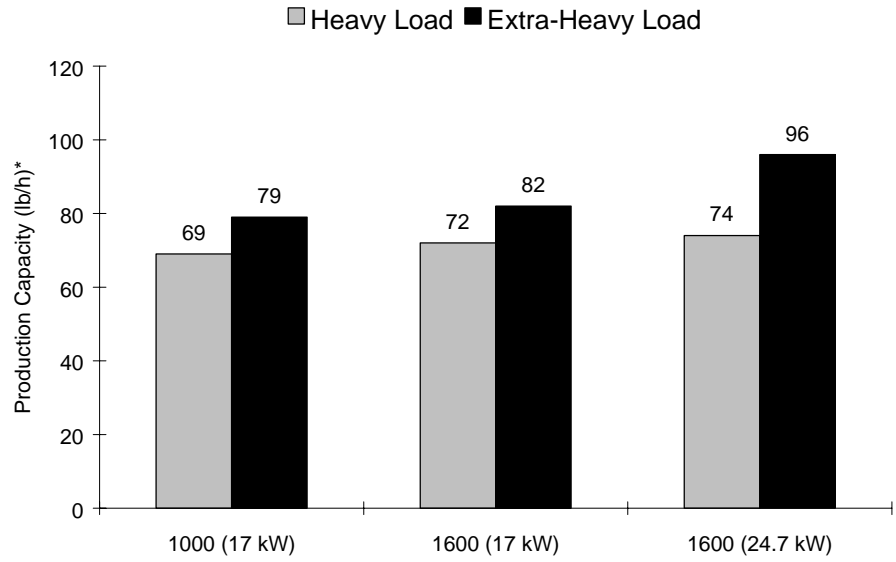


Figure 3-7. Production capacity for heavy-load and extra-heavy load cooking tests.

*Based on a minimum 10-second preparation time between loads.

4 Conclusions and Recommendations

The prototype elements outperformed the baseline Watlow Firebar 1000 electric element in several areas.

Watlow Industries requested an evaluation of two new prototype electric fryer elements against its own current top-of-the line element at PG&E's Food Service Technology Center (FSTC). The two prototypes employ a flat design with a large surface area to reduce the element watt density. The prototype elements outperformed the baseline Watlow Firebar 1000 electric element in several areas: The prototypes (17 kW and 24.7 kW) achieved higher cooking energy efficiencies for heavy-load (89.4% and 86.4% vs. 86.9% for the baseline element) and extra heavy-load tests (90.2% and 87.4% vs. 87.4 for the baseline element). These cooking efficiencies were the highest of any fryer tested by the FSTC.^{2,3,4} The 1600 (17 kW) element exhibited a slightly higher production capacity than other electric fryers tested (72 pounds per hour vs. 68 pounds per hour for other fryers),^{2,3,4} while the 1600 (24.7 kW) element exhibited the highest production capacity recorded to date (96 pounds per hour) under the extra-heavy load (4 pound) test.

Each element was responsive during cooking events, maintaining relatively high average cook zone temperatures of 331°F, 328°F and 337°F, for 1000 (17 kW), 1600 (17 kW) and 1600 (24.7 kW) respectively under heavy-load conditions with a 340°F reload. The 1600 (24.7 kW) element exhibited an average cook zone temperature that was 6°F above the 1000 (17 kW) element. All the elements had fast recovery times for heavy-load conditions (less than 10 seconds).

The FSTC has tested other high-efficiency fryers that have been able recovered back 340°F before the 10 second logistical reload period has expired. However, the Firebar 1600 (24.7 kW) element was the first element to consistently recover the frying medium to the 340°F reload temperature before

Conclusions and Recommendations

the french fries were ready to be removed from the fryer. This fast frying medium recovery caused the researchers to consider altering the 10 second logistical reload period, since it may be too long for the new generation of high efficiency fryers. Production capacity is based on cook time and recovery time as the fryer is “barrel” loaded. As currently written, the ASTM F 1361-95 standard test method may slightly penalize the Firebar 1600 element by not giving the element credit for the extremely fast recovery. The FSTC researchers will investigate reducing the 10 second logistical reload period to 5 seconds without impacting the repeatability of the test. If the logistical reload period can safely be reduced, the FSTC will work with the ASTM F 26 committee to revise the test method (F 1361-95).

The Watlow prototype 1600 (24.7 kW) element recorded the quickest preheat time for a fryer tested by the FSTC. The Watlow prototype 1600 (17 kW) recorded the lowest energy consumption for a preheat test (1.5 kWh). During the preheat test, the 1600 (24.7 kW) element took 4.17 minutes and used 1.7 kWh of energy to bring the frying medium (pourable, partially hydrogenated soybean oil) from 75°F (room temperature) to 350°F. During the preheat test, the 1600 (17 kW) element took 5.5 minutes and used a low 1.5 kWh of energy to bring the frying medium from room temperature to 350°F. The next best fryer tested by the FSTC had a preheat time of 4.9 minutes and 1.6 kWh of energy use.

Test results indicate that these fryer elements will perform well in an actual foodservice operation. The fryer elements performed well under ASTM cooking tests, recording among the highest cooking energy efficiencies. Evaluation of these fryer elements in the real-world setting of the FSTC’s production-test kitchen is recommended.

5 References

1. American Society for Testing and Materials. ASTM F 1361-95. *Standard Test Method for the Performance of Open Deep Fat Fryers*. In *Annual Book of ASTM Standards*. Philadelphia: American Society for Testing and Materials. This test method can be purchased from the American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, PA 19428-2959
2. Food Service Technology Center. 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. *Frymaster Fryer Model H-17CSC: Application of ASTM Standard Test Method*. Report 5017.93.2 prepared for Products and Services Department. San Francisco, California: Pacific Gas and Electric Company.
4. Food Service Technology Center. *TekmaStar Fryer Model FD-212: Application of ASTM Standard Test Method*. Report 5011.94.2 prepared for Products and Services Department. San Francisco, California: Pacific Gas and Electric Company.

Appendixes

A 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 Consumption (kWh or kBtu)

The total energy consumed by an appliance during the cooking period.

Cooking Energy Efficiency

The quantity of energy input to the food, expressed as a percentage of the quantity of energy input to the fryer during heavy- and extra-heavy load test.

Energy Input Rate (kW or kBtu/h)

Energy Consumption Rate

Energy Rate

The rate (Btu/h or kW) at which an appliance will consume energy.

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 Consumption Rate (kW or kBtu/h)

Idle Energy Rate

Idle Rate

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

Glossary

Idle Duty Cycle (%)

Idle Energy Factor

Idle Load Factor

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

$$IdleDutyCycle = \frac{IdleEnergyConsumptionRate}{MeasuredEnergyInputRate} * 100$$

Idle Temperature (°F, Setting)

The temperature of the cooking medium (oil) (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").

Pilot Energy Consumption (kBtu)

Pilot Energy Use

Standing or Constant Pilot Energy Consumption

Standing or Constant Pilot Energy Use

The rate of energy consumption by the standing or constant pilot(s) while the appliance is not being operated (i.e., when the thermostats or control knobs have been turned off).

Preheat Energy Consumption (kWh or kBtu)

Preheat Energy

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

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

Preheat Energy Rate

The rate of appliance energy consumption while it is "preheating" to a predetermined temperature.

Preheat Time (minute, hour)

Glossary

Preheat Period

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

Production Capacity

The production rate (lb/h) of the fryer as it is used to cook at full energy input rates.

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.

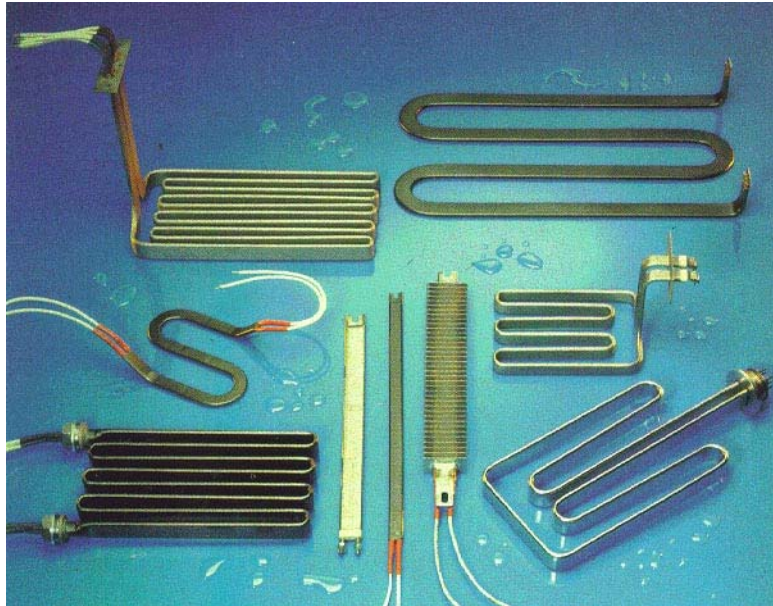
Test Method

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.

B Element Manufacturer's Product Specifications

Appendix B includes the product literature for the Watlow elements.

Element Manufacturer Product Specifications



Element Specifications.

Manufacturer	Watlow Industries
Model	Firebar 1000 (17 kW), Firebar 1600 (17 kW) pre-production and Firebar (24.7 kW) pre-production
Generic Appliance Type	Heating elements
Rated Input	17 kW, 17 kW and 24.7 kW
Dimensions	Flat bar height 1", 1- 1/2", 1- 1/2"
Construction	Flat wide heating elements with nickel chromium resistance wires and MgO insulation

C Results Reporting Sheets

Manufacturer: Watlow Industries
Model: Firebar 1000 (17 kW), Pre-production Firebar 1600 (17 kW) and
Pre-production Firebar 1600 (24.7 kW)
Date: June 1998

Section 11.1 Test Fryer and Test Elements

Description of operational characteristics: A single deep-fat fryer was used for all three electric elements.

The fryer used an all stainless steel frypot, a solid state thermostat and frying computer. The elements used

nickel-chromium resistance wires separated by MgO insulation all enclosed in an metal sheath.

Section 11.2 Apparatus

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

Deviations: None.

Section 11.3 Energy Input Rate

Element Model	1000 (17 kW)	1600 (17 kW)	1600 (24.7 kW)
Test Voltage	206.5 V	206.5 V	206.5 V
Measured	17.3 kW	17.4 kW	26.8 kW
Rate	17.0 kW	17.0 kW	24.7 kW
Percent Difference between Measured and Rated	1.8 %	2.4 %	8.4 %

Results Reporting Sheets

Section 11.5 Temperature Calibration

Dial Setting:	<u>350°F</u>
Average Cook Zone Temperature:	<u>350°F</u>

Section 11.6 Preheat Energy and Time

Element Model	<u>1000 (17 kW)</u>	<u>1600 (17 kW)</u>	<u>1600 (24.7 kW)</u>
Test Voltage	<u>206.5 V</u>	<u>206.5 V</u>	<u>206.5 V</u>
Starting Temperature	<u>75°F</u>	<u>75°F</u>	<u>75°F</u>
Energy Consumption	<u>1.8 kWh</u>	<u>1.5 kWh</u>	<u>1.7 kWh</u>
Time from 75°F (°C) to 350°F (177°C)	<u>6.4 min</u>	<u>5.5 min</u>	<u>4.2 min</u>
Preheat Rate	<u>43 °F/min</u>	<u>51 °F/min</u>	<u>66°F/min</u>

Section 11.7 Idle Energy Rate

Element Model	<u>1000 (17 kW)</u>	<u>1600 (17 kW)</u>	<u>1600 (24.7 kW)</u>
Test Voltage	<u>206.5 V</u>	<u>206.5 V</u>	<u>206.5 V</u>
Idle Energy Rate @ 350°F	<u>0.75 kW</u>	<u>0.78 kW</u>	<u>0.86 kW</u>

Section 11.9 Cooking Energy Efficiency and Cooking Energy Rate

Heavy Load:			
Element Model	<u>1000 (17 kW)</u>	<u>1600 (17 kW)</u>	<u>1600 (24.7 kW)</u>
Test Voltage	<u>206.5 V</u>	<u>206.5 V</u>	<u>206.5 V</u>
Cooking Time	<u>2.41 min</u>	<u>2.40 min</u>	<u>2.28 min</u>
Average Cook Zone Recovery Time	<u>0 sec</u>	<u>0 sec</u>	<u>0 sec</u>
Production Capacity	<u>69.2 ± 1.3 lb/h</u>	<u>71.8 ± 1.0 lb/h</u>	<u>74.0 ± 2.9 lb/h</u>
Energy to Fryer	<u>671 Btu/lb</u>	<u>671 Btu/lb</u>	<u>671 Btu/lb</u>
Cooking Energy Rate	<u>13.6 kW</u>	<u>14.1 kW</u>	<u>14.7 kW</u>
Energy to Food	<u>583 Btu/lb</u>	<u>600 Btu/lb</u>	<u>586 Btu/lb</u>
Cooking Energy Efficiency	<u>86.9 %</u>	<u>89.4 %</u>	<u>86.4 %</u>

Results Reporting Sheets

Extra-Heavy Load:*

Element Model	<u>1000 (17 kW)</u>	<u>1600 (17 kW)</u>	<u>1600 (24.7 kW)</u>
Test Voltage	<u>206.5 V</u>	<u>206.5 V</u>	<u>206.5 V</u>
Cooking Time	<u>2.75 min</u>	<u>2.75 min</u>	<u>2.33 min</u>
Average Cook Zone Recovery Time	<u>8 sec</u>	<u>4 sec</u>	<u>0 sec</u>
Production Capacity	<u>79.0 ± 1.1 lb/h</u>	<u>82.4 ± 0.8 lb/h</u>	<u>96.4 ± 0.9 lb/h</u>
Energy to Fryer	<u>664 Btu/lb</u>	<u>654 Btu/lb</u>	<u>574 Btu/lb</u>
Cooking Energy Rate	<u>15.3 kW</u>	<u>15.8 kW</u>	<u>18.5 kW</u>
Energy to Food	<u>580 Btu/lb</u>	<u>589 Btu/lb</u>	<u>574 Btu/lb</u>
Cooking Energy Efficiency	<u>87.4 %</u>	<u>90.2 %</u>	<u>87.4 %</u>

*Extra-Heavy load equals four pounds of frozen french fries. Extra-Heavy load is not a official ASTM load size.

D Cooking Energy Efficiency Data

Table D-1. Specific Heat and Latent Heat.

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

Cooking Energy Efficiency Data

Table D-2. Watlow 1000 (17 kW) Element Test Data.

	Heavy Load	Extra-Heavy Load
Measured Values		
Total Energy (kWh)	2.95	3.89
Cook Time (min)	2.41	2.75
Total Test Time (min)	13.0	15.2
Weight Loss (%)	29.9	29.9
5-Load Fry Test Weight (lb)	15.0	20.0
Weight per Load (lb)	3.0	4.0
Initial Fat Content (%)	5.4	5.4
Initial Moisture Content (%)	67.5	67.5
Final Moisture Content (%)	47.0	47.5
Initial Fry Temperature (°F)	0	0
Final Fry Temperature (°F)	212	212
Calculated Values		
Initial Weight of Water (lb)	10.1	13.5
Final Weight of Water (lb)	4.9	6.7
Weight of Fat (lb)	0.8	1.1
Weight of Solids (lb)	4.1	5.4
Sensible to Ice (Btu)	162	216
Sensible to Water (Btu)	1,823	2,431
Sensible to Fat (Btu)	69	92
Sensible to Solids (Btu)	172	230
Latent - Water Fusion (Btu)	1,459	1,945
Latent - Fat Fusion (Btu)	36	48
Latent - Water Vaporization (Btu)	5,030	6,637
Total Energy to Food (Btu)	8,750	11,598
Energy to Food (Btu/lb)	583	580
Total Energy to Fryer	10,068	13,277
Energy to Fryer (Btu/lb)	671	664
Cooking Energy Efficiency (%)	86.9	87.4
Cooking Energy Rate (kW)	13.6	15.3
Production Rate (lb/h)	69.2	79.0
Average Recovery Time (sec)	0	8

Cooking Energy Efficiency Data

Table D-3. Watlow 1600 (17 kW) Element Test Data.

	Heavy Load	Extra-Heavy Load
Measured Values		
Total Energy (kWh)	2.95	3.83
Cook Time (min)	2.40	2.75
Total Test Time (min)	12.53	14.56
Weight Loss (%)	29.8	29.8
5-Load Fry Test Weight (lb)	15.0	20.0
Weight per Load (lb)	3.0	4.0
Initial Fat Content (%)	5.4	5.4
Initial Moisture Content (%)	67.5	67.5
Final Moisture Content (%)	44.5	46.1
Initial Fry Temperature (°F)	0	0
Final Fry Temperature (°F)	212	212
Calculated Values		
Initial Weight of Water (lb)	10.1	13.5
Final Weight of Water (lb)	4.7	6.5
Weight of Fat (lb)	0.8	1.1
Weight of Solids (lb)	4.1	5.4
Sensible to Ice (Btu)	162	216
Sensible to Water (Btu)	1,823	2,431
Sensible to Fat (Btu)	69	92
Sensible to Solids (Btu)	172	230
Latent - Water Fusion (Btu)	1,459	1,945
Latent - Fat Fusion (Btu)	36	48
Latent - Water Vaporization (Btu)	5,283	6,824
Total Energy to Food (Btu)	9,004	11,785
Energy to Food (Btu/lb)	600	589
Total Energy to Fryer	10,068	13,072
Energy to Fryer (Btu/lb)	671	654
Cooking Energy Efficiency (%)	89.4	90.2
Cooking Energy Rate (kW)	14.1	15.8
Production Rate (lb/h)	71.8	82.4
Average Recovery Time (sec)	0	4

Cooking Energy Efficiency Data

Table D-4. Watlow 1600 (24.7 kW) Element Test Data.

	Heavy Load	Extra-Heavy Load
Measured Values		
Total Energy (kWh)	2.98	3.85
Cook Time (min)	2.28	2.33
Total Test Time (min)	12.17	12.44
Weight Loss (%)	30.1	29.7
5-Load Fry Test Weight (lb)	15.0	20.0
Weight per Load (lb)	3.0	4.0
Initial Fat Content (%)	5.4	5.4
Initial Moisture Content (%)	67.5	67.5
Final Moisture Content (%)	46.8	48.2
Initial Fry Temperature (°F)	0	0
Final Fry Temperature (°F)	212	212
Calculated Values		
Initial Weight of Water (lb)	10.1	13.5
Final Weight of Water (lb)	4.9	6.8
Weight of Fat (lb)	0.8	1.1
Weight of Solids (lb)	4.1	5.4
Sensible to Ice (Btu)	162	216
Sensible to Water (Btu)	1,823	2,431
Sensible to Fat (Btu)	69	92
Sensible to Solids (Btu)	172	230
Latent - Water Fusion (Btu)	1,459	1,945
Latent - Fat Fusion (Btu)	36	48
Latent - Water Vaporization (Btu)	5,063	6,522
Total Energy to Food (Btu)	8,783	11,482
Energy to Food (Btu/lb)	586	574
Total Energy to Fryer	10,171	13,140
Energy to Fryer (Btu/lb)	678	657
Cooking Energy Efficiency (%)	86.4	87.4
Cooking Energy Rate (kW)	14.7	18.5
Production Rate (lb/h)	74.0	96.4
Average Recovery Time (sec)	0	0