



**Keating Model 14 IFM  
Gas Fryer Performance Test**

**Application of ASTM Standard Test Method F 1361-95**

Report 5011.95.32

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## **POLICY ON THE USE OF FOOD SERVICE TECHNOLOGY CENTER (FSTC) TEST RESULTS AND OTHER RELATED INFORMATION**

- 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 both PG&E technical research reports and publications provided by the Kitchen Monitor subscription service. All of these documents are protected under U.S. and international copyright laws.
- In the event that FSTC data are to be reported, quoted, or referred to in any way in publications, papers, brochures, advertising, or any other publicly available documents, the rules of copyright must be strictly followed, including written permission from PG&E in advance and proper attribution to PG&E and the 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.

## PREFACE

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

The appliance testing program at the FSTC was originally undertaken to respond to the many requests for information about the performance of cooking appliances that PG&E receives from the 25,000 food service customers in its service territory. Since its beginning in 1986, the project has grown into a full-scale research program, combining the sophisticated instrumentation and controlled environment of a laboratory with the real-life conditions of a production kitchen. The FSTC comprises two distinct, but complementary, research components.

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

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

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

This report documents the application of ASTM F 1361-95, *Standard Test Method for the Performance of Open, Deep-fat Fryers*, to a Keating model 14 IFM gas infrared fryer. To supplement laboratory testing, this fryer was subsequently installed in the Production-Test Kitchen, and an in-kitchen performance report will also be published by the FSTC.

## **ACKNOWLEDGMENTS**

The establishment of a Food Service Technology Center reflects PG&E'S commitment to the hospitality industry. The goal of the research project is to provide PG&E's food service customers with information to help them evaluate technically innovative cooking appliances and make informed equipment purchases regarding advanced technologies and energy sources. The project was the result of many people and departments working together within PG&E and the overwhelming support of the commercial equipment manufacturers who loan the cooking appliances for testing. Specific appreciation is extended to Keating of Chicago, Inc., for supplying PG&E with the model 14 IFM gas fryer for controlled testing in the appliance laboratory and subsequent installation in the Production-Test Kitchen.

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

## EXECUTIVE SUMMARY

The Keating 14 IFM gas infrared fryer incorporates the latest technology, including powered infrared burners, frypot insulation, a patent pending heat reclamation tube, automatic basket lifts, electronic timers with Instant-On™, and stainless steel construction.

The fryer was laboratory tested 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. A summary of the test results is presented in Table ES-1.

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

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Rated Energy Input Rate	79,000 Btu/h
Measured Energy Input Rate	81,800 Btu/h
Preheat Time to 350°F	7.0 min
Preheat Energy to 350°F	9,730 Btu
Idle Energy Rate @ 350°F	4,700 Btu/h
Heavy-Load Cooking Efficiency	57.4%
Medium-Load Cooking Efficiency	52.8%
Light-Load Cooking Efficiency	44.2%
Production Capacity <sup>a</sup>	56 lb/h
Frying Medium Recovery Time <sup>a</sup>	26 sec

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<sup>a</sup>Based on the heavy-load cooking test without the use of Instant-On and a minimum 10-second preparation time between loads.

The fryer features Instant-On, a mechanism that immediately cycles the burners on—independent of the thermostat—when the cook timers are activated. This allows the fryer to anticipate a load of french fries just before it enters the frying medium. To evaluate its effectiveness, heavy-load tests were conducted with and without Instant-On. During the special test runs, the fryer was allowed to recover to 340°F; the timers were then started just prior to placing the loaded baskets into the frying medium. Table ES-2 presents test results.

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<sup>1</sup> American Society for Testing and Materials. 1992. *Standard Test Methods for the Performance of Open, Deep-fat Fryers*. ASTM Designation F 1361-95, In *Annual Book of ASTM Standards*, Philadelphia.

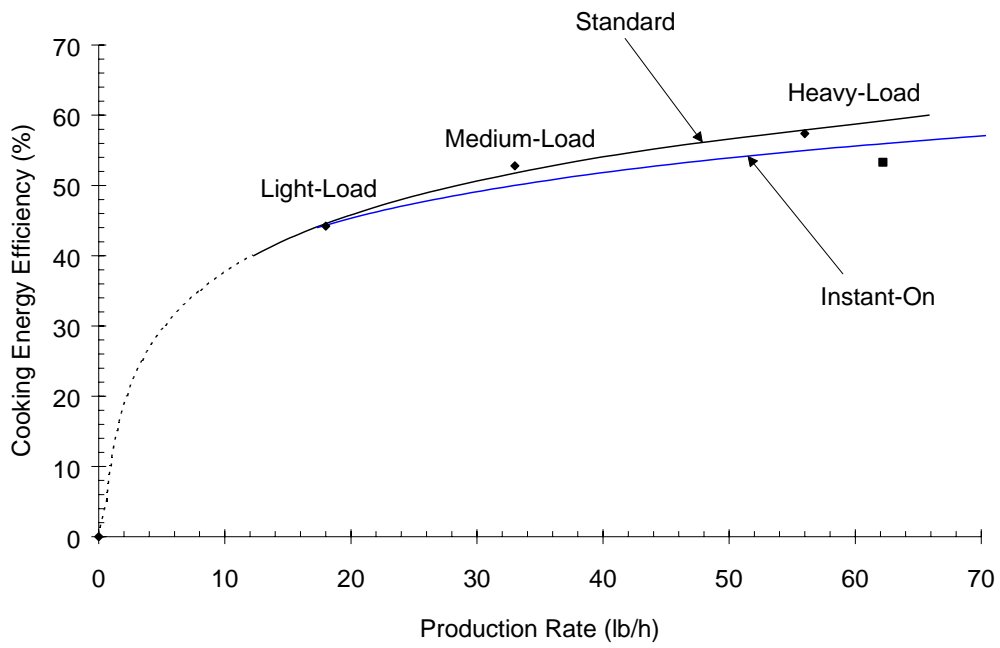
**Table ES-2**  
**Heavy-Load Cooking Test Results**

Condition	Instant-On	Standard
French Fry Cook Time (min)	2.58	2.75
Frying Medium Recovery Time (sec)	19	26
Productivity (lb/h)	62	57
Energy to Food (Btu/lb)	591	594
Energy to Fryer (Btu/lb)	1,110	1,036
Cooking Energy Efficiency (%)	53.3	57.4

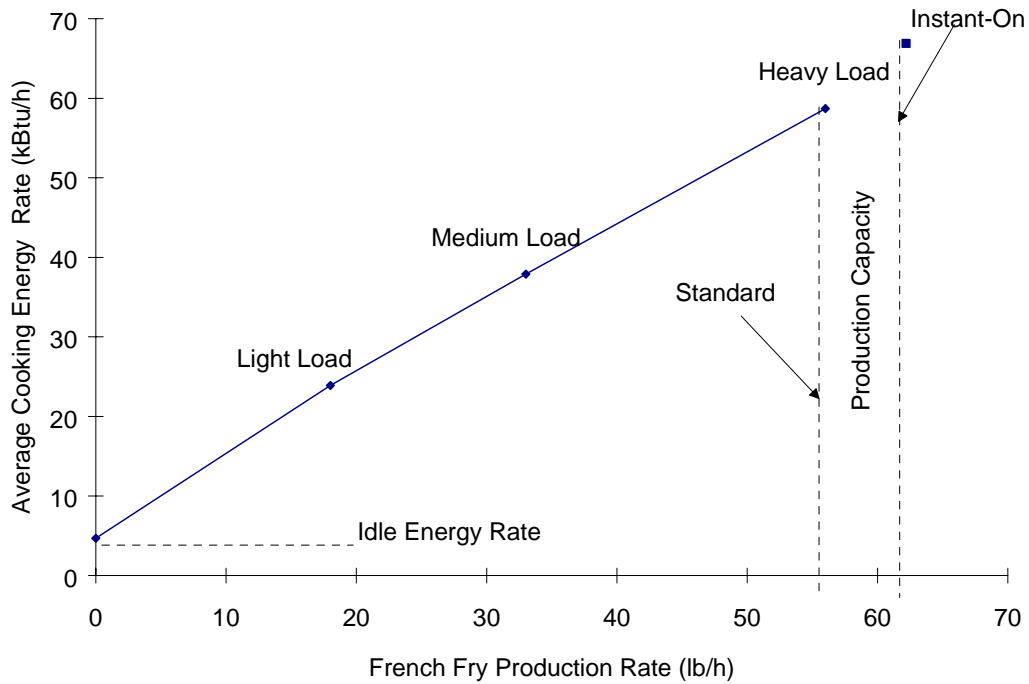
Fryer cooking performance was determined by cooking three different loads (heavy—3 pounds, medium—1½ pounds, and light—¾ pounds) of ¼-inch, par-cooked, frozen shoestring potatoes in partially hydrogenated vegetable oil. The cook times for the three loading scenarios were 2¼ minutes for the light-load test, 2½ minutes for the medium-load test, and 2¾ minutes for the heavy-load test. Cooking energy efficiency is defined by the following relationship:

Figure ES-1 summarizes fryer cooking energy efficiency for different production rates. Fryer production rate is a function of both the french fry cook time and the frying medium recovery time. Part-load efficiency rapidly drops off at production rates lower than 10 pounds per hour.

Figure ES-2 illustrates the relationship between fryer energy consumption and production rate. This information can be used as a tool to estimate daily energy consumption for the fryer. Average energy consumption rates at 10, 30, and 50 pounds per hour are 15,400 Btu/hour, 35,000 Btu/hour, and 53,100 Btu/hour, respectively.



**Figure ES-1. Fryer part-load cooking energy efficiency.**



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

The Keating fryer exhibited the highest cooking energy efficiency of any gas fryer tested to date at the Food Service Technology Center (57% vs. 50% for heavy-load efficiency).<sup>2</sup> For peak periods, productivity may be increased by as much as 9% (from 57 to 62 pounds per hour), with only a nominal increase in fryer energy consumption (from 1,036 to 1,110 Btu per pound of french fries), by utilizing the fryer's Instant-On feature. By anticipating the load, this feature raised the average frying medium temperature by 10°F over a typical cooking cycle, thereby reducing both the actual cook time required and the frying medium recovery time.

Test results indicate that this fryer will perform well in production. Its productivity is high enough to handle peak periods while consuming a low amount of energy due to the low idle losses and high part-load cooking efficiency.

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<sup>2</sup> Pacific Gas and Electric Company. 1989. *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.

## INTRODUCTION

### BACKGROUND

With support from the Electric Power Research Institute (EPRI), the Gas Research Institute (GRI), and the National Restaurant Association, PG&E's Food Service Technology Center (FSTC) developed a uniform testing procedure (UTP) to evaluate the performance of gas and electric fryers. This test method was submitted to the American Society for Testing and Materials (ASTM), and in January 1992, it was accepted as a standard test method (Designation F 1361-95).<sup>1</sup> PG&E's *Development and Application of a Uniform Testing Procedure for Open, Deep-fat Fryers* documents the developmental procedures and test results of several gas and electric fryers.<sup>2</sup> Numerous other PG&E reports document results of applying the ASTM test method.<sup>3,4</sup>

The FSTC has been exploring possible areas for improvement to the ASTM method. Through sensitivity testing and comparison of the results from one test to another, FSTC researchers developed a set of revisions that will be incorporated into the next version of the ASTM standard test method. For example, FSTC researchers have found that water-boil efficiency does not necessarily correlate to cooking efficiency.<sup>4</sup> Based on these findings and the growing importance of cooking energy efficiency as an indicator of appliance performance, the FSTC National Advisory Group recommended that the water-boil test be removed from the next version of the ASTM test method.

The revised test method was applied to the Keating gas infrared fryer, and this report documents the results. A forthcoming report will present performance data for this fryer as it was used in the Production-Test Kitchen (PTK). The glossary in Appendix A is provided so that the reader has a quick reference for the terms used in this report.

### OBJECTIVES

This report examines the operation and performance of the Keating gas infrared fryer, model 14 IFM, under the controlled conditions of the revised ASTM standard test method. The scope of this testing is as follows:

- Verify that the appliance is operating at the manufacturer's rated energy input.
- Determine the energy efficiency when boiling water.

- Determine the time and energy required to preheat the frying medium from room temperature to 350°F.
- Characterize the idle energy use with the thermostat set at a calibrated 350°F.
- Document the cooking energy consumption and efficiency under three french fry loading scenarios: heavy (3-pound load), medium (1½-pound load), and light (¾-pound load).
- Determine the production capacity and frying medium recovery time during the heavy load test.

## APPLIANCE DESCRIPTION AND OPERATION

The Keating gas infrared fryer incorporates the latest technology, including powered infrared burners, frypot insulation, a patent pending heat reclamation tube, automatic basket lifts, electronic timers with Instant-On™, and stainless steel construction. Appliance specifications are listed in Table 1-1 and the manufacturer's literature is in Appendix B.

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

Manufacturer	Keating of Chicago, Inc.
Model	14 IFM
Generic Appliance Type	Open, deep-fat fryer
Rated Energy Input	79,000 Btu/h
Frying Medium Capacity	44 lb
Frying Area	13-3/4" x 15-3/4"
Construction	Polished stainless steel
Controls	Single thermostat plus two cooking timers with automatic basket lifts and Instant-On™
Accessories	Pair of chrome-plated mesh fry baskets, chrome-plated grid screen, sample of Keating Klenzer and Sea Powder

The thermostatically controlled fryer is powered by two powered infrared burners, each rated at 39,500 Btu/hour. Gas mixes with air as it enters the venturi, and the mixture is forced through a fine ceramic mesh cloth. This mixture ignites on the outside surface of the ceramic, causing it to glow red. The glowing ceramic emits infrared radiation that is collected by the tube walls, which transmit heat to the

frying medium. A third heat transfer tube in the center of the frypot acts as a recycle baffle for the flue gases.

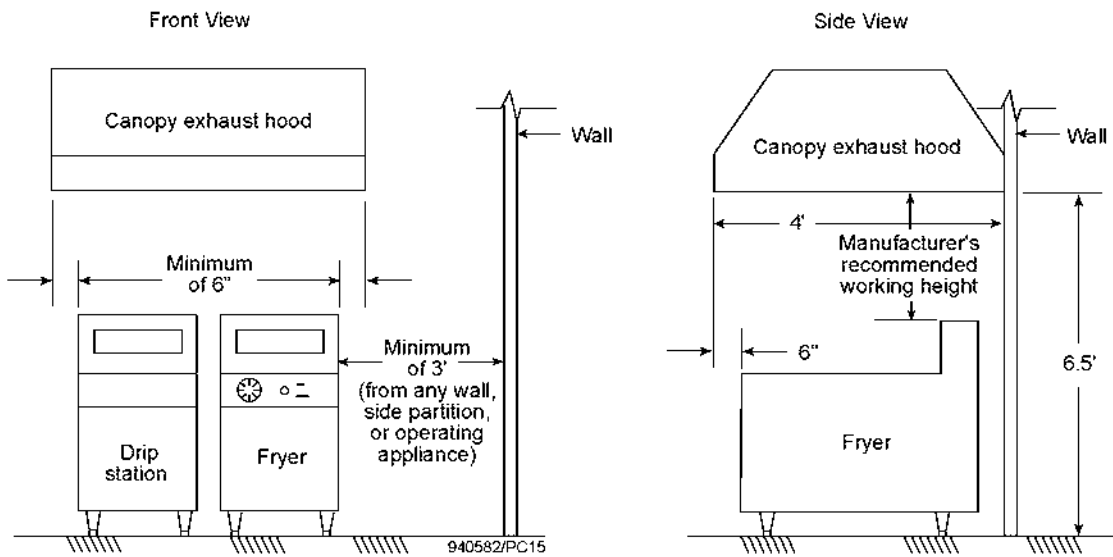
Keating's patent pending Instant-On improves fryer response time by anticipating loading. Designed to be used with the automatic basket lifts, Instant-On bypasses the thermostat and cycles the burners on when the cook timers are activated. The frying medium begins to heat just before the load hits, thereby reducing the total temperature drop.

Section 2

**METHODS**

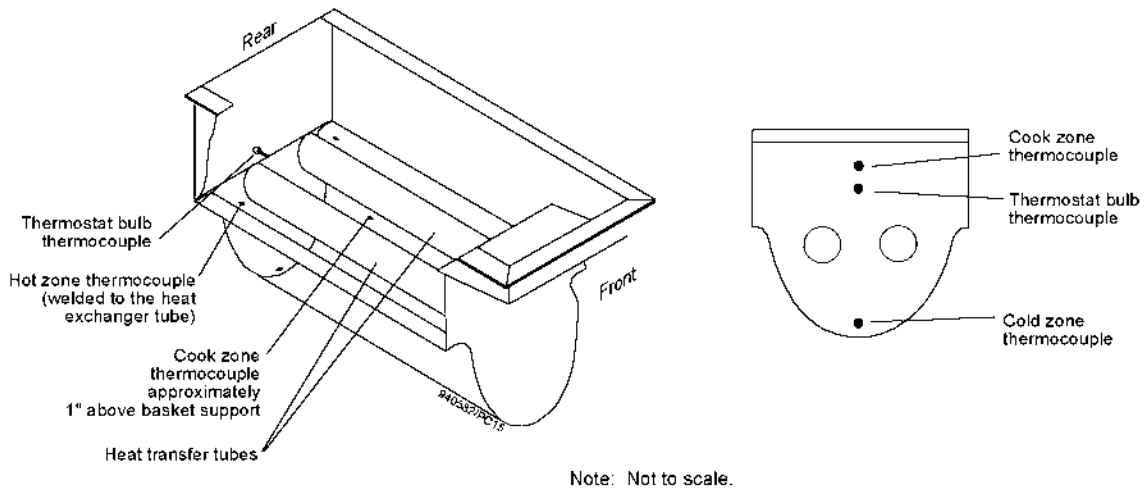
**TEST SETUP/INSTRUMENTATION**

FSTC researchers installed the fryer on a tiled floor under a 4-foot-deep canopy hood that was 6 feet 6 inches above the floor. The hood operated at a nominal exhaust rate of 300 cfm per linear foot of hood. There was at least 6 inches of clearance between the vertical plane of the fryer and the edge of the hood. See Figure 2-1. All test apparatus were installed in accordance with Section 8 of the ASTM test method.<sup>1</sup>



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

Researchers instrumented the fryer with thermocouples to measure temperatures in the cold and the cooking zones and at the thermostat bulb. Additionally, four thermocouples were welded onto the heat transfer tubes, one in each of the four quadrants of the frypot. Two thermocouples were placed in the cook zone, one in the geometric center of the frypot, approximately 1 inch above the fry basket support, and the other at the tip of the thermostat bulb. The cold zone thermocouple was supported from above, independent of the frypot surface, so that the temperature of the cold zone reflected the frying medium temperature, not the frypot's surface 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.



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

Natural gas consumption was measured using a positive displacement-type gas meter that generated a pulse every 0.1 ft<sup>3</sup>. The gas meter and the thermocouples were connected to an automated data acquisition unit that recorded data every 5 seconds. A chemical laboratory used a gas chromatograph to determine the gas heating value on each day of testing. All gas measurements were corrected to standard conditions.

The fryer was filled with Margate Brand, partially hydrogenated, 100% pure vegetable oil for all tests except the water-boil and energy input rate determination tests. These tests required distilled water in accordance with the ASTM test method.

### **MEASURED ENERGY INPUT RATE**

Researchers determined the energy input rate by measuring the energy consumption during a 10-minute interval while the fryer was boiling water after a full rolling boil had been established.

### **COOKING TIME DETERMINATION, COOKING ENERGY EFFICIENCY, AND PRODUCTION CAPACITY**

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 “barreling” 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), 1½-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 does not significantly lower the average oil temperature over the cooking cycle, nor does it extend the cook time. The fryer was reloaded either after the cook zone thermocouple reached the threshold temperature or 10 seconds after removing the previous load from the fryer, whichever was longer.

The first load of each six-load cooking test was designated a stabilization load and was not counted when calculating the elapsed time and energy used. 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 weight loss of the french fries were recorded for the last five loads of the six-load test.

Cooking tests were run in the following sequence: three replicates of the heavy-load test, three replicates of the medium-load test, and three replicates of the light-load test. 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.

## **RESULTS**

### **ENERGY INPUT RATE AND WATER-BOIL TESTS**

#### **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 properly. The initial test showed the fryer to be operating at 10.1% above the nameplate rating of 79,000 Btu/hour (87,000 Btu/hour). Researchers reduced the gas input pressure to 2.6 in. w.g. and optimized combustion. The energy input rate at 2.6 in. w.g. was 81,800 Btu/hour (a difference of 3.5% from the nameplate rating).

#### **Water-Boil Efficiency**

The fryer was installed on a pit scale under a vapor hood. Researchers then filled the vat to the fill line with water. After the fryer was stabilized by boiling 5 pounds of water, researchers recorded time and energy consumption. The fryer was allowed to continue until the water level reached 1 inch above the heat transfer tubes. Researchers repeated this procedure three times on the same day. The barometric pressure during these tests was 15.54 psia. The fryer boiled off water at an average rate of 52 pounds per hour, and the calculated water-boil efficiency was 62%.

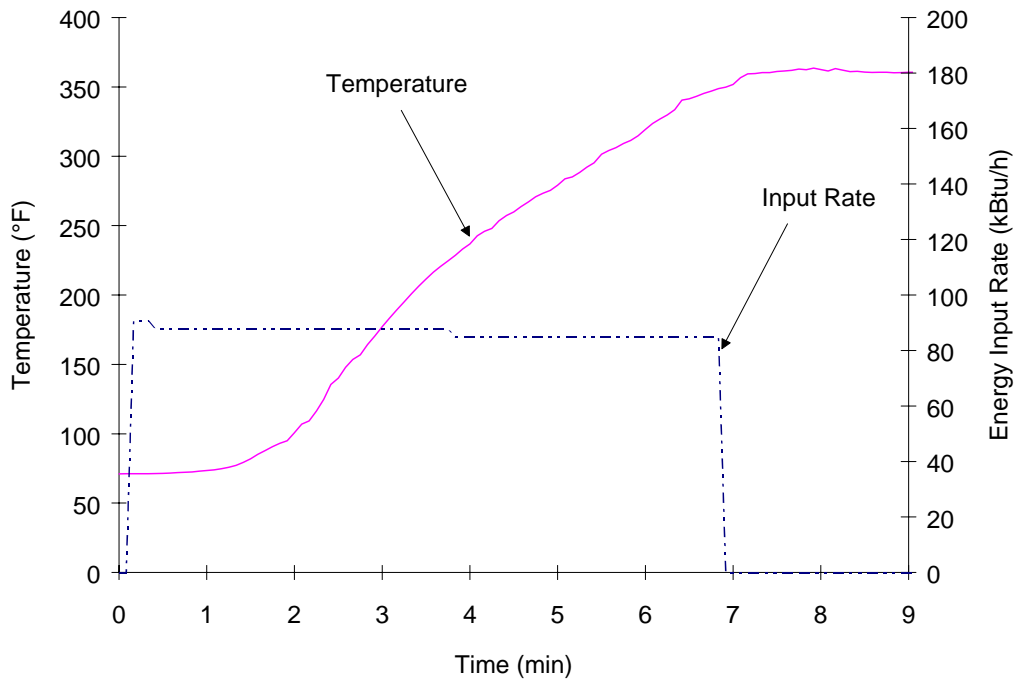
### **PREHEAT AND IDLE ENERGY CONSUMPTION**

#### **Preheat Energy Consumption**

Researchers moved the fryer under a grease and vapor hood and filled it to the indicated fill line with liquid vegetable shortening. The frying medium was approximately 72°F at the outset of the preheat. Energy consumption and time were measured to preheat the fryer to a calibrated 350°F. The fryer preheat required 9,730 Btu and 7.0 minutes. Figure 3-1 shows the energy consumption rate in conjunction with the cook zone temperature during preheat.

#### **Idle Energy Consumption**

The frying medium was allowed to stabilize at 350°F for 30 minutes. Researchers then monitored the energy over a 2-hour idle period. The idle energy rate during this period was 4,700 Btu/hour.



**Figure 3-1. Preheat characteristics.**

### Test Results

Preheat and idle test results are summarized in Table 3-1.

**Table 3-1  
Preheat and Idle Test Results**

Preheat	
Time to 350°F	7.0 min
Energy	9,730 Btu
Rate to 350°F	40°F/min
Idle Energy Rate @ 350°F	4,700 Btu/h
Idle Duty Cycle	5.7%

## **COOKING PERFORMANCE TESTS**

The fryer was tested under three loading scenarios: heavy (3 pounds), medium (1½ pounds), and light (¾ pound). Researchers monitored french fry cook time and weight loss, fry medium recovery time, and fryer energy consumption during these tests.

### **Heavy-Load Tests**

The fryer features Instant-On, a mechanism that immediately cycles the burners on—independent of the thermostat—when the cook timers are activated. This allows the fryer to anticipate a load of french fries just before it enters the frying medium. To evaluate its effectiveness, heavy-load tests were conducted with and without Instant-On. During the special test runs, the fryer was allowed to recover to 340°F; the timers were then started just prior to placing the loaded baskets into the frying medium. Figure 3-2 shows the frying medium temperatures while “barreling” the 3-pound loads of frozen french fries. The average cook zone temperature during the six-load test was 322°F, with a minimum temperature of 306°F. The average cold zone temperature during the six-load test was 312°F.

Figure 3-3 shows the frying medium temperature during a “standard” heavy-load test (conducted without the cook timers). Without Instant-On, the cook zone fell to an average temperature of 315°F, causing a 10-second increase in cook time. The decrease in fryer productivity is offset by a lower average energy consumption during cooking (67,000 Btu/hour vs. 59,000 Btu/hour with Instant-On). The heat exchanger surfaces ranged from 341°F to 456°F during the heavy-load cook test.

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

Table 3-2 summarizes the results of these two series of tests. In addition to reducing the cook time for 3-pound loads of frozen french fries, Instant-On reduced the average frying medium recovery time by 7 seconds. Figure 3-4 compares the fryer temperature signatures for cooking a 3-pound load of frozen french fries with and without Instant-On.

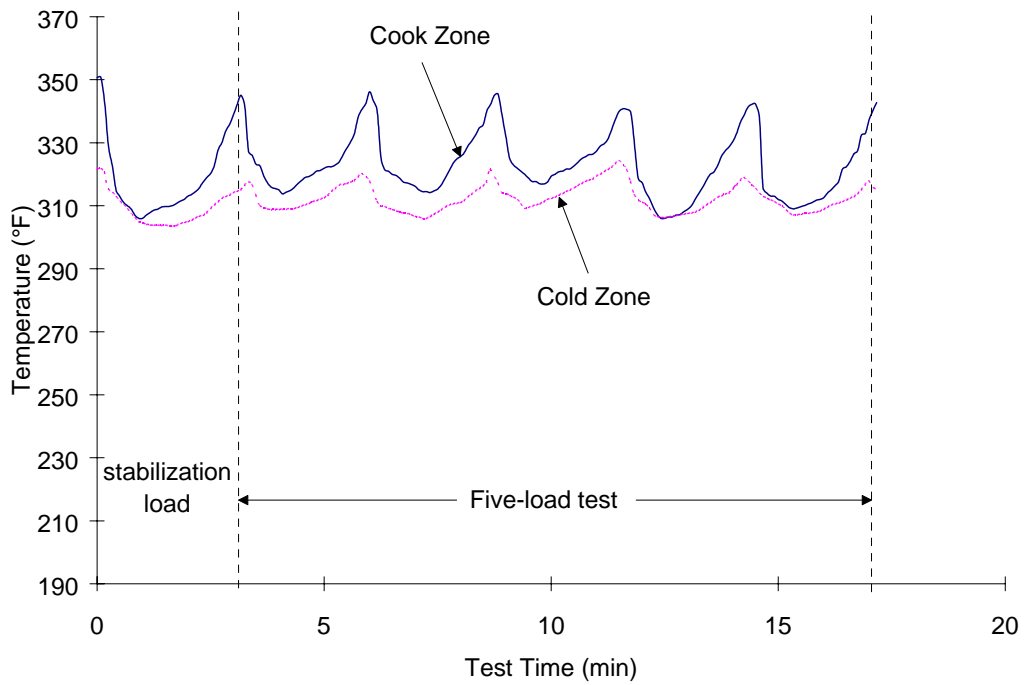


Figure 3-2. Frying medium temperatures during a heavy-load test using Instant-On.

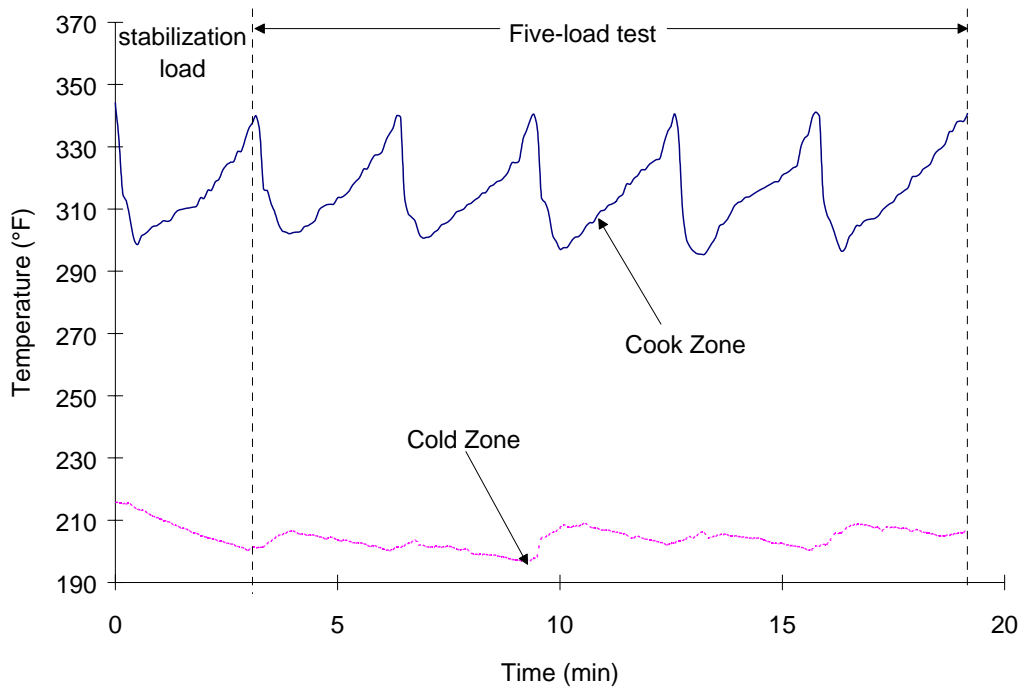
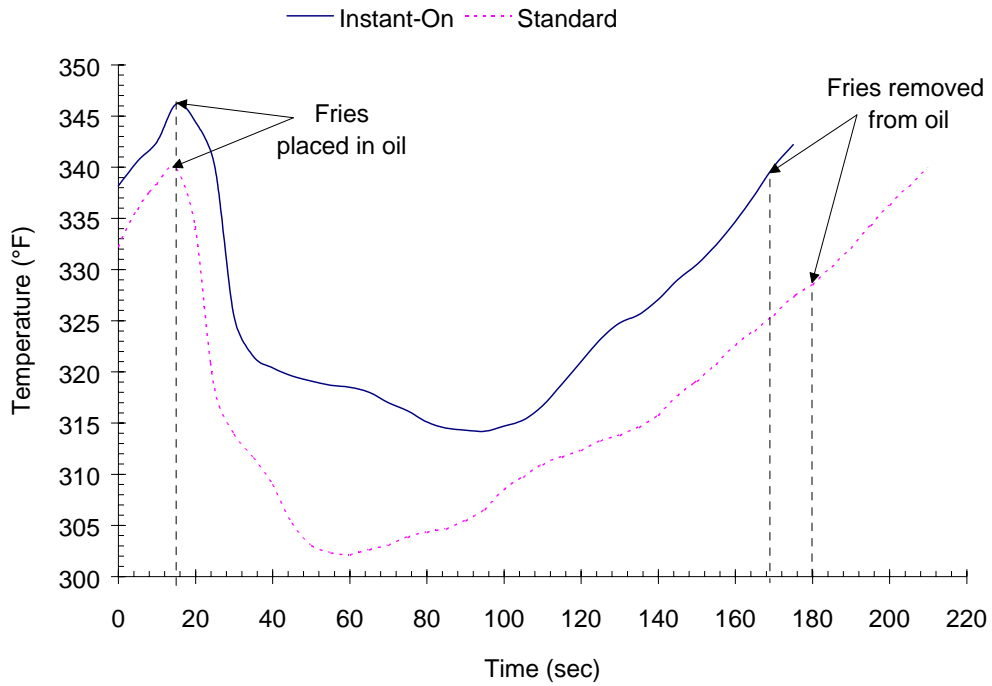


Figure 3-3. Frying medium temperatures during a standard heavy-load test.

**Table 3-2**  
**Heavy-Load Cooking Test Results**

<b>Condition</b>	<b>Instant-On</b>	<b>Standard</b>
French Fry Cook Time (min)	2.58	2.75
Frying Medium Recovery Time (sec)	19	26
Productivity (lb/h)	62	57
Energy to Food (Btu/lb)	591	594
Energy to Fryer (Btu/lb)	1,110	1,036
Cooking Energy Efficiency (%)	53.3	57.4



**Figure 3-4. Fryer cooking cycle temperature signatures with and without Instant-On.**

### Medium- and Light-Load Tests

The remainder of the cooking tests were conducted without the cook timers or Instant-On. Part-load tests were conducted with one basket per load. The medium- and light-load tests were run 10 minutes apart on the same day. The fryer exhibited instant recovery during all part-load cooking tests. Cooking energy efficiencies at 18 and 33 pounds per hour were 44.2% and 52.8%, respectively.

### Test Results

Cooking energy efficiency results for the standard heavy-load tests were 57.3%, 57.3%, and 57.4%, giving a maximum uncertainty of 0.2% in the test results. Table 3-3 presents the results of the cooking energy and production capacity tests. Figure 3-5 illustrates fryer cooking energy efficiency for different production rates. Fryer production rate is a function of both the french fry cook time and the frying medium recovery time. Part-load efficiency rapidly drops off at production rates lower than 10 pounds per hour. Appendix C contains a synopsis of test data from each replicate of the cooking tests.

Figure 3-6 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 daily energy consumption for the fryer. Average energy consumption rates at 10, 30, and 50 pounds per hour are 15,400 Btu/hour, 35,000 Btu/hour, and 53,100 Btu/hour, respectively.

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

Test Condition	Heavy Load	Medium Load	Light Load
French Fry Cook Time (min)	2.75	2.5	2.25
Average Recovery Time (min)	0.43	≤ 0.17	≤ 0.17
Production Rate (lb/h)	56	33	18
Energy Consumption (Btu/lb)	1,110	1,137	1,346
Average Input Rate (Btu/h)	58,700	37,900	23,900
Efficiency (%)	57.4	52.8	44.2

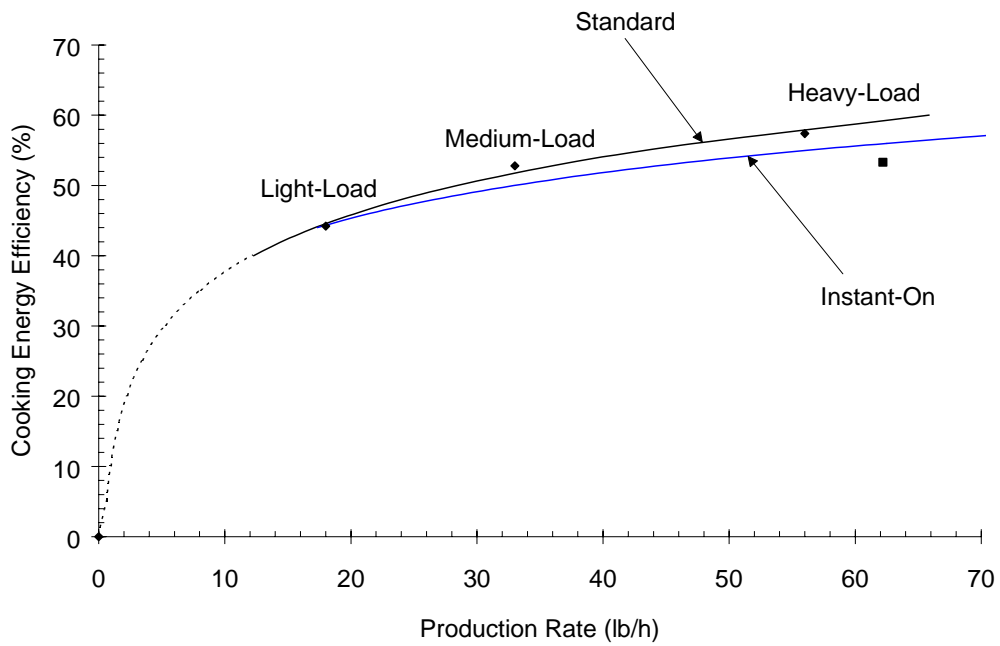


Figure 3-5. Fryer part-load cooking energy efficiency.

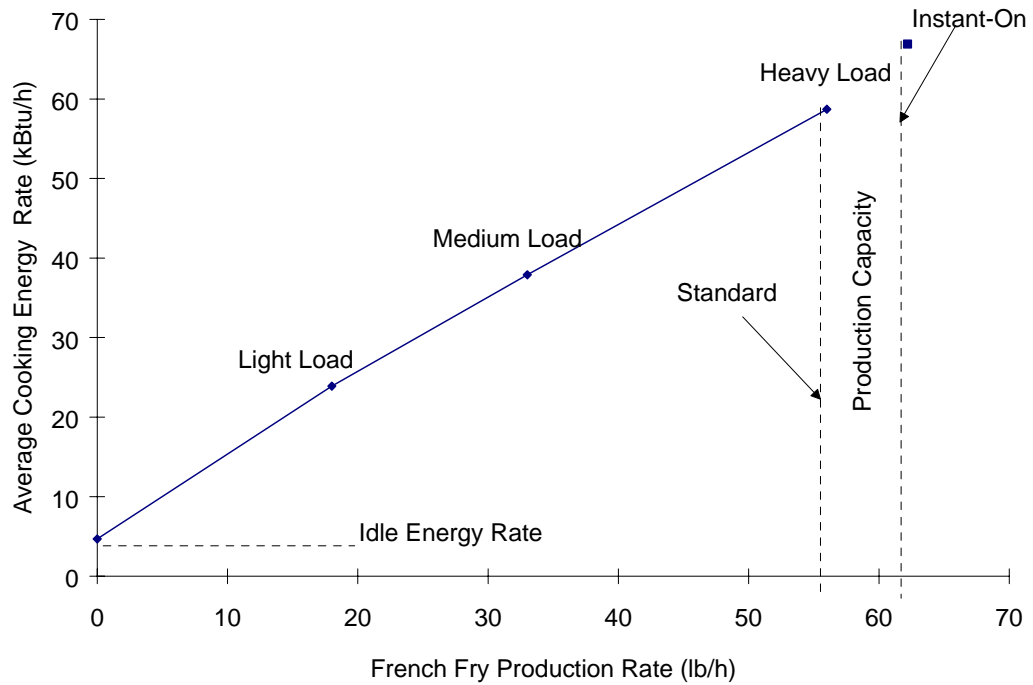


Figure 3-6. Cooking energy consumption rate during a typical heavy-, medium-, and light-load cooking test.

## Section 4

### CONCLUSIONS

The Keating model 14 IFM gas infrared fryer exhibited remarkable performance when tested under the controlled conditions of the *revised* ASTM standard test method for fryers. The addition of a third heat transfer tube to circulate hot flue gases through the frypot increased the heavy-load cooking energy efficiency by 14% (57% vs. 50% for another infrared fryer<sup>2</sup>) over the already efficient infrared fryer design. Idle losses on this fryer are 32% less than previously tested gas infrared fryers, and the 7.0-minute preheat time is the shortest preheat time recorded for any gas fryer tested at the Food Service Technology Center (typical preheat is 10 minutes).<sup>2</sup>

Even though this Keating fryer achieved a somewhat lower water-boil efficiency than other previously tested fryers, the cooking energy efficiency was the highest recorded for any gas fryer tested to date at the Food Service Technology Center. The fryer's performance during the water-boil test was not considered a good indication of the actual performance during cooking. This observation has also been documented for an electric fryer and supports the position to remove the water-boil test from the ASTM test method.<sup>4</sup>

Productivity may be increased by as much as 9% (from 57 to 62 pounds per hour), with only a nominal increase in fryer energy consumption (from 1,036 to 1,110 Btu per pound of french fries) by utilizing the fryer's Instant-On feature. By anticipating the load, this feature raised the average frying medium temperature by 10°F over a cooking cycle, thereby reducing both the actual cook time required and the frying medium recovery time.

Test results indicate that this fryer will perform well in production. Its productivity is high enough to handle peak periods while consuming a low amount of energy due to the low idle losses and high part-load cooking efficiency. Evaluation of this fryer in the real-world setting of the Production-Test Kitchen was recommended and implemented.

## Section 5

### REFERENCES

1. American Society for Testing and Materials. 1992. *Standard Test Methods for the Performance of Open, Deep-fat Fryers*. ASTM Designation F 1361-95, In *Annual Book of ASTM Standards*, Philadelphia.
2. Pacific Gas and Electric Company. 1989. *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.
3. Pacific Gas and Electric Company. 1993. *Application of ASTM Standard Test Method F 1361-95: Frymaster Fryer Model H-17CSC*. Report 5017.93.2 prepared for Products and Services Department, San Francisco.
4. Pacific Gas and Electric Company. 1994. *Application of ASTM Standard Test Method F 1361-95: TekmaStar Fryer Model FD-212*. Report 5011.94.2 prepared for Products and Services Department, San Francisco.

Appendix A  
**GLOSSARY**

## GLOSSARY

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

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

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

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

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

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

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

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

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

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

$$\text{Idle Energy Factor} = \quad \quad \quad \times 100$$

**Idle Temperature** (*°F, Setting*)—The temperature of the cooking cavity/surface (selected by the appliance operator or specified for a controlled test) that is maintained by the appliance under an idle condition.

**Measured Energy Input Rate** (*kW, W or kBtu/h, Btu/h*)—The maximum or peak rate at which an appliance consumes energy, measured during appliance preheat or while conducting a water-boil test (i.e., the period of operation when all burners or elements are “on”). Also referred to as *Measured Input* or *Measured Peak Energy Input Rate* or *Peak Rate of Energy Input*.

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

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

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

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

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

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

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

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

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

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

Appendix B

**MANUFACTURER'S PRODUCT SPECIFICATIONS**

Appendix C

**COOKING ENERGY EFFICIENCY AND  
PRODUCTION CAPACITY VARIABLES**

# LIGHT-LOAD TEST #1\*

May 27, 1994

<b>Cooking Energy Efficiency</b>	<b>45.4%</b>
<b>Production Rate</b>	<b>17.7 lb/h</b>
<b>Average Recovery Time</b>	<b>0.21 min</b>
<b>Average Energy Consumption Rate</b>	<b>23,700 Btu/h</b>

Measured Values	Calculated Values
<b>Energy</b>	
Total Gas (ft <sup>3</sup> )	5.0
	Total Energy to Fryer (Btu) 5,015
	<b>Energy to Fryer (Btu/lb) 1,337</b>
<b>Fries</b>	
<b>Cook Time (min)</b>	<b>2.33</b>
Total Test Time (min)	12.68
Weight Loss (%)	30.9
Total Fry Weight (lb)	3.75
Initial Fat (%)	6.1
Initial Moisture (%)	68.0
Final Moisture (%)	45.2
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212
<b>Assumed Values</b>	
<b>Fries</b>	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970
<b>Gas</b>	
Standard Pressure (psi)	14.73
Standard Temperature (°F)	60
<b>Gas Parameters</b>	
Higher Heating Value (Btu/ft <sup>3</sup> )	1024
Gas Pressure (in. H <sub>2</sub> O)	8.0
Gas Temperature (°F)	71
Barometric Pressure (psi)	14.456
Pressure Correction Factor	1.001
Temperature Correction Factor	0.979

\*3/4-lb basket of frozen shoestring potatoes

## LIGHT-LOAD TEST #2\*

May 27, 1994

<b>Cooking Energy Efficiency</b>	<b>43.6%</b>
<b>Production Rate</b>	<b>17.7 lb/h</b>
<b>Average Recovery Time</b>	<b>0.21 min</b>
<b>Average Energy Consumption Rate</b>	<b>24,200 Btu/h</b>

Measured Values	Calculated Values
<b>Energy</b>	
Total Gas (ft <sup>3</sup> )	5.1
	Total Energy to Fryer (Btu) 5,115
	<b>Energy to Fryer (Btu/lb) 1,364</b>
<b>Fries</b>	
<b>Cook Time (min)</b>	<b>2.33</b>
Total Test Time (min)	12.68
Weight Loss (%)	29.8
Total Fry Weight (lb)	3.75
Initial Fat (%)	6.1
Initial Moisture (%)	68.0
Final Moisture (%)	46.2
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212
<b>Assumed Values</b>	
<b>Fries</b>	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970
<b>Gas</b>	
Standard Pressure (psi)	14.73
Standard Temperature (°F)	60
<b>Gas Parameters</b>	
Higher Heating Value (Btu/ft <sup>3</sup> )	1024
Gas Pressure (in. H <sub>2</sub> O)	8.0
Gas Temperature (°F)	71
Barometric Pressure (psi)	14.456
Pressure Correction Factor	1.001
Temperature Correction Factor	0.979

\*3/4-lb basket of frozen shoestring potatoes

## LIGHT-LOAD TEST #3\*

May 27, 1994

<b>Cooking Energy Efficiency</b>	<b>43.6%</b>
<b>Production Rate</b>	<b>17.9 lb/h</b>
<b>Average Recovery Time</b>	<b>0.19 min</b>
<b>Average Energy Consumption Rate</b>	<b>23,900 Btu/h</b>

Measured Values	Calculated Values
<b>Energy</b>	
Total Gas (ft <sup>3</sup> )	5.0
	Total Energy to Fryer (Btu) 5,015
	<b>Energy to Fryer (Btu/lb) 1,337</b>
<b>Fries</b>	
<b>Cook Time (min)</b>	<b>2.33</b>
Total Test Time (min)	12.60
Weight Loss (%)	29.7
Total Fry Weight (lb)	3.75
Initial Fat (%)	6.1
Initial Moisture (%)	68.0
Final Moisture (%)	47.8
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212
<b>Assumed Values</b>	
<b>Fries</b>	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970
<b>Gas</b>	
Standard Pressure (psi)	14.73
Standard Temperature (°F)	60
<b>Gas Parameters</b>	
Higher Heating Value (Btu/ft <sup>3</sup> )	1024
Gas Pressure (in. H <sub>2</sub> O)	8.0
Gas Temperature (°F)	71
Barometric Pressure (psi)	14.456
Pressure Correction Factor	1.001
Temperature Correction Factor	0.979

\*3/4-lb basket of frozen shoestring potatoes

## MEDIUM-LOAD TEST #1\*

May 27, 1994

<b>Cooking Energy Efficiency</b>	<b>53.1%</b>
<b>Production Rate</b>	<b>33.4 lb/h</b>
<b>Average Recovery Time</b>	<b>0.20 min</b>
<b>Average Energy Consumption Rate</b>	<b>37,900 Btu/h</b>

Measured Values	Calculated Values
<b>Energy</b>	
Total Gas (ft <sup>3</sup> )	8.5
	Total Energy to Fryer (Btu) 8,526
	<b>Energy to Fryer (Btu/lb) 1,137</b>
<b>Fries</b>	
<b>Cook Time (min)</b>	<b>2.50</b>
Total Test Time (min)	13.48
Weight Loss (%)	30.9
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.1
Initial Moisture (%)	68.0
Final Moisture (%)	45.6
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212
<b>Assumed Values</b>	
<b>Fries</b>	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970
<b>Gas</b>	
Standard Pressure (psi)	14.73
Standard Temperature (°F)	60
<b>Gas Parameters</b>	
Higher Heating Value (Btu/ft <sup>3</sup> )	1024
Gas Pressure (in. H <sub>2</sub> O)	8.0
Gas Temperature (°F)	71
Barometric Pressure (psi)	14.456
Pressure Correction Factor	1.001
Temperature Correction Factor	0.979

\*1-½ lb basket of frozen shoestring potatoes

## MEDIUM-LOAD TEST #2\*

May 27, 1994

<b>Cooking Energy Efficiency</b>	<b>52.0%</b>
<b>Production Rate</b>	<b>33.7 lb/h</b>
<b>Average Recovery Time</b>	<b>0.17 min</b>
<b>Average Energy Consumption Rate</b>	<b>38,800 Btu/h</b>

Measured Values	Calculated Values
<b>Energy</b>	
Total Gas (ft <sup>3</sup> )	8.6
	<b>8,626</b>
	<b>1,150</b>
<b>Fries</b>	
<b>Cook Time (min)</b>	<b>2.50</b>
Total Test Time (min)	13.35
Weight Loss (%)	30.7
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.1
Initial Moisture (%)	68.0
Final Moisture (%)	46.4
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212
<b>Assumed Values</b>	
<b>Fries</b>	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970
<b>Gas</b>	
Standard Pressure (psi)	14.73
Standard Temperature (°F)	60
<b>Gas Parameters</b>	
Higher Heating Value (Btu/ft <sup>3</sup> )	1024
Gas Pressure (in. H <sub>2</sub> O)	8.0
Gas Temperature (°F)	71
Barometric Pressure (psi)	14.456
Pressure Correction Factor	1.001
Temperature Correction Factor	0.979

\*1-½ lb basket of frozen shoestring potatoes

## MEDIUM-LOAD TEST #3\*

May 27, 1994

<b>Cooking Energy Efficiency</b>	<b>53.4%</b>
<b>Production Rate</b>	<b>32.8 lb/h</b>
<b>Average Recovery Time</b>	<b>0.24 min</b>
<b>Average Energy Consumption Rate</b>	<b>36,900 Btu/h</b>

Measured Values	Calculated Values
<b>Energy</b>	
Total Gas (ft <sup>3</sup> )	8.4
	Total Energy to Fryer (Btu) 8,425
	<b>Energy to Fryer (Btu/lb) 1,123</b>
<b>Fries</b>	
<b>Cook Time (min)</b>	<b>2.50</b>
Total Test Time (min)	13.70
Weight Loss (%)	30.6
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.1
Initial Moisture (%)	68.0
Final Moisture (%)	46.0
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212
<b>Assumed Values</b>	
<b>Fries</b>	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970
<b>Gas</b>	
Standard Pressure (psi)	14.73
Standard Temperature (°F)	60
<b>Gas Parameters</b>	
Higher Heating Value (Btu/ft <sup>3</sup> )	1024
Gas Pressure (in. H <sub>2</sub> O)	8.0
Gas Temperature (°F)	71
Barometric Pressure (psi)	14.456
Pressure Correction Factor	1.001
Temperature Correction Factor	0.979

\*1-½ lb basket of frozen shoestring potatoes

# HEAVY-LOAD TEST #1\*

May 27, 1994

<b>Cooking Energy Efficiency</b>	<b>57.3%</b>
<b>Production Rate</b>	<b>56.5 lb/h</b>
<b>Average Recovery Time</b>	<b>0.44 min</b>
<b>Average Energy Consumption Rate</b>	<b>58,500 Btu/h</b>

Measured Values	Calculated Values
<b>Energy</b>	
Total Gas (ft <sup>3</sup> )	15.5
	<b>Energy</b>
	Total Energy to Fryer (Btu)
	15,547
	<b>Energy to Fryer (Btu/lb)</b>
	<b>1,036</b>
<b>Fries</b>	
<b>Cook Time (min)</b>	<b>2.75</b>
Total Test Time (min)	15.93
Weight Loss (%)	29.6
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.1
Initial Moisture (%)	68.0
Final Moisture (%)	46.2
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212
<b>Assumed Values</b>	
<b>Fries</b>	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970
<b>Gas</b>	
Standard Pressure (psi)	14.73
Standard Temperature (°F)	60
<b>Gas Parameters</b>	
Higher Heating Value (Btu/ft <sup>3</sup> )	1024
Gas Pressure (in. H <sub>2</sub> O)	8.0
Gas Temperature (°F)	71
Barometric Pressure (psi)	14.456
Pressure Correction Factor	1.001
Temperature Correction Factor	0.979

\*3-lb basket of frozen shoestring potatoes

## HEAVY-LOAD TEST #2\*

May 27, 1994

<b>Cooking Energy Efficiency</b>	<b>57.3%</b>
<b>Production Rate</b>	<b>56.4 lb/h</b>
<b>Average Recovery Time</b>	<b>0.44 min</b>
<b>Average Energy Consumption Rate</b>	<b>58,500 Btu/h</b>

Measured Values	Calculated Values
<b>Energy</b>	
Total Gas (ft <sup>3</sup> )	15.5
	Total Energy to Fryer (Btu) 15,547
	<b>Energy to Fryer (Btu/lb) 1,036</b>
<b>Fries</b>	
<b>Cook Time (min)</b>	<b>2.75</b>
Total Test Time (min)	15.95
Weight Loss (%)	29.6
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.1
Initial Moisture (%)	68.0
Final Moisture (%)	46.2
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212
<b>Assumed Values</b>	
<b>Fries</b>	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970
<b>Gas</b>	
Standard Pressure (psi)	14.73
Standard Temperature (°F)	60
<b>Gas Parameters</b>	
Higher Heating Value (Btu/ft <sup>3</sup> )	1024
Gas Pressure (in. H <sub>2</sub> O)	8.0
Gas Temperature (°F)	71
Barometric Pressure (psi)	14.456
Pressure Correction Factor	1.001
Temperature Correction Factor	0.979

\*3-lb basket of frozen shoestring potatoes

## HEAVY-LOAD TEST #3\*

May 27, 1994

<b>Cooking Energy Efficiency</b>	<b>57.4%</b>
<b>Production Rate</b>	<b>57.0 lb/h</b>
<b>Average Recovery Time</b>	<b>0.41 min</b>
<b>Average Energy Consumption Rate</b>	<b>59,100 Btu/h</b>

Measured Values	Calculated Values
<b>Energy</b>	
Total Gas (ft <sup>3</sup> )	15.5
	Total Energy to Fryer (Btu) 15,547
	<b>Energy to Fryer (Btu/lb) 1,036</b>
<b>Fries</b>	
<b>Cook Time (min)</b>	<b>2.75</b>
Total Test Time (min)	15.78
Weight Loss (%)	29.8
Total Fry Weight (lb)	7.5
Initial Fat (%)	6.1
Initial Moisture (%)	68.0
Final Moisture (%)	46.2
Initial Fry Temperature (°F)	0
Final Fry Temperature (°F)	212
<b>Assumed Values</b>	
<b>Fries</b>	
Specific Heat of Ice (Btu/lb, °F)	0.50
Specific Heat of Fat (Btu/lb, °F)	0.40
Specific Heat of Solids (Btu/lb, °F)	0.20
Latent Heat of Fusion, Water (Btu/lb)	144
Latent Heat of Fusion, Fat (Btu/lb)	44
Latent Heat of Vaporization, Water (Btu/lb)	970
<b>Gas</b>	
Standard Pressure (psi)	14.73
Standard Temperature (°F)	60
<b>Gas Parameters</b>	
Higher Heating Value (Btu/ft <sup>3</sup> )	1024
Gas Pressure (in. H <sub>2</sub> O)	8.0
Gas Temperature (°F)	71
Barometric Pressure (psi)	14.456
Pressure Correction Factor	1.001
Temperature Correction Factor	0.979

\*3-lb basket of frozen shoestring potatoes