Counter Top Gas Fryer Performance Testing

FSTC Report # 5011.03.14

Food Service Technology Center
May 2003

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

Contributor:
Scott Miner
Fisher-Nickel, Inc.

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

Acknowledgments

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

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

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

Advantica Restaurant Group

Applebee's International Group

California Energy Commission (CEC)

California Restaurant Association

Carl Karcher Enterprises, Inc.

DJ Horton & Associates

Electric Power Research Institute (EPRI)

Enbridge Gas Distribution

EPA Energy Star

Gas Technology Institute (GTI)

Lawrence Berkeley National Laboratories

McDonald's Corporation

National Restaurant Association

Pacific Gas and Electric Company

Safeway, Inc.

Southern California Edison

Underwriters Laboratories (UL)

University of California at Berkeley

University of California at Riverside

US Department of Energy, FEMP

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

- Fisher-Nickel, inc. and the Food Service Technology Center (FSTC) do not endorse particular products or services from any specific manufacturer or service provider.
- The FSTC is *strongly* committed to testing food service equipment using the best available scientific techniques and instrumentation.
- The FSTC is neutral as to fuel and energy source. It does not, in any way, encourage or promote the use of any fuel or energy source nor does it endorse any of the equipment tested at the FSTC.
- FSTC test results are made available to the general public through technical research reports and publications and are protected under U.S. and international copyright laws.
- In the event that FSTC data are to be reported, quoted, or referred to in any way in publications, papers, brochures, advertising, or any other publicly available documents, the rules of copyright must be strictly followed, including written permission from Fisher-Nickel, inc. *in advance* and proper attribution to Fisher-Nickel, inc. and the Food Service Technology Center. In any such publication, sufficient text must be excerpted or quoted so as to give full and fair representation of findings as reported in the original documentation from FSTC.

Contents

List of Figures and Tables

Figures

Tables

Executive Summary

The Food Service Technology Center (FSTC) worked with a large restaurant chain in an effort to benchmark the performance of three gas counter top fryers. Fried foods have a major role in many restaurants' menus. In a cook-to-order style kitchen, energy efficiency, production capacity, safety and conveinence of operation are significant concerns when choosing a fryer.

FSTC engineers tested three countertop fryers under the tightly controlled conditions of the American Society for Testing and Materials' (ASTM) standard test method.[1] Fryer performance is characterized by preheat time and energy consumption, idle energy consumption rate, cooking-energy efficiency, and production capacity.

Cooking performance was determined by cooking frozen French fries under three different loading scenarios (heavy—3 pounds per load, medium—1½ pounds per load, and light—¾ pound per load). Heavy –load cook times were 3.17 minutes, 2.63 minutes and 2.92 minutes for Units A, B and C respectively. Production capacity includes the cooking time and the time required for the frying medium to recover to 340°F (recovery time).

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

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

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

Executive Summary

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

Table ES-1. Summary of Fryer Performance.

	Unit A	Unit B	Unit C
Rated Energy Input Rate (Btu/h)	60,000	90,000	80,000
Measured Energy Input Rate (Btu/h)	61,216	87,593	77,879
Preheat Time to 350°F (min)	10.6	6.61	11.2
Preheat Energy to 350°F (Btu)	10,778	9,816	11,911
Preheat Rate (°F/min)	27	42	25
Idle Energy Rate @ 325°F (Btu/h)	7,867	4,121	9,210
Cooking-Energy Efficiency:			
Heavy-Load (%)	41.1 ± 0.3 [a]	59.6 ± 1.9 [a]	46.1 ± 2.1 [a]
Medium-Load (%)	37.8 ± 2.5 [a]	56.6 ± 3.5 [a]	40.6 ± 3.6 [a]
Light-Load (%)	33.0 ± 1.9 [a]	44.5 ± 1.4 [a]	31.5 ± 2.2 [a]
Production Capacity (lb/h) [b]	43.6 ± 0.5 [a]	59.7 ± 4.3 [a]	58.4 ± 1.5 [a]

[a] This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.
[b] Based on the heavy-load cooking test.

Unit A's preheat to 350°F was approximately 10 minutes, while Unit B was ready to cook in just over 6 minutes. Unit C took slightly longer at just over 11 minutes to reach a cooking temperature of 350°F. Fryers spend a large portion of their on time idling, making idle rates an important factor in performance. Unit A posted an idle rate of 7,867 Btu/h, while Unit B and Unit C demonstrated idle rates of 4,121 Btu/h and 9,210 Btu/h respectively.

Cooking tests under heavy-load conditions proved all three counter top fryers could perform as well as floor model fryers. During heavy-load testing, Unit A produced 43.6 lbs/h of French fries while achieving a cooking-energy efficiency of 41%. Unit B exhibited 60% cooking-energy efficiency while producing an impressive 59.7 lbs/h of fries. Unit C was able to cook 58.4 lbs/h of French fries while demonstrating 46 % cooking-energy efficiency. All three units also performed well under partial-load testing conditions. Figure ES-1 illustrates the relationship between cooking-energy efficiency and production rate for the three counter top fryers.

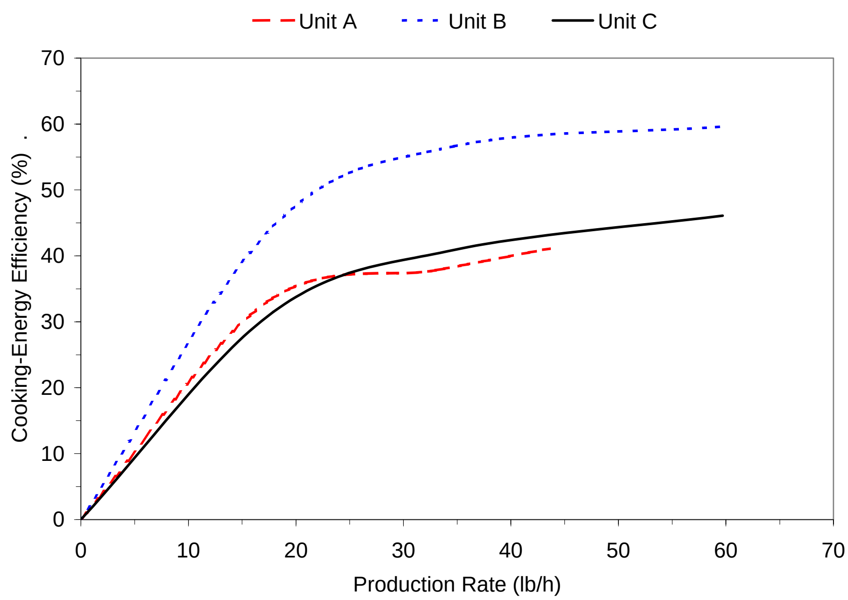

Figure ES-1.
Fryer part-load cooking-energy efficiency.

Figure ES-2 illustrates the relationship between the fryers' average energy consumption rates and the production rates. This graph can be used as a tool to estimate the daily energy consumption for a fryer in a real-world operation. Average energy consumption rates at 10, 30, and 50 pounds per hour for Unit B were 13,770 Btu/h, 31,090 Btu/h, and 48,420 Btu/h respectively. For an operation cooking an average of 15 pounds of food per hour over the course of the day (e.g., 150 lb of food over a ten hour day), the average daily energy consumption rate for this fryer would be 18,100 Btu/h.

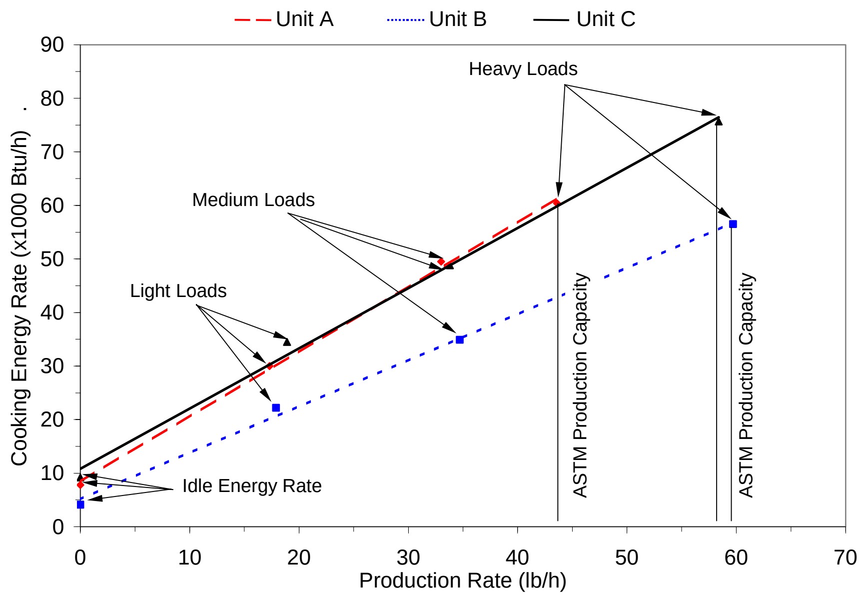

Figure ES-2. Fryer cooking energy consumption profile.

Note: Light-Load = ¾ pounds/load; Medium-Load = 1 ½ pounds/load; Heavy-Load = 3 pounds/load.

Counter top fryers offer small footprints and space savings for a restaurateur. All three counter top fryers were of a simple design: a stainless steel frypot, small cold zone (if present), solid-state thermostat, atmospheric burners and no cooking computers. Despite being smaller in size, all three fryers exhibited comparable performance to their larger floor standing counterparts. While offering a compact and versatile design, a food service operator can expect no performance losses due to the smaller footprint. [2]

The differences in performance translated to differences in estimated operating cost. Unit B with it's low idle rate and high cooking-energy efficiency proved to have the lowest operating cost with an annual estimated cost of $328 per year. Unit A was more expensive to operate per year by $173 with

[2] Conner, M. M., Young, R., Fisher, D.R. and Nickel, J., 1991. *Development and Application of a Uniform Testing Procedure for Fryers.* Pacific Gas and Electric Company Department of Research and Development Report 008.1.89.2, November.

it's higher idle rate and lower cooking energy efficiencies accounting for the higher operating costs. Unit C exhibited the highest idle rate of the three fryers, which placed its operating cost at $524 per year. Figure ES-3 breaks down the annual operating cost for the three fryers.

Unit B demonstrated impressive cooking performance during testing under the rigorous conditions of the ASTM test method. It's innovative heat exchanger proved very effective in transferring heat into the oil, enabling it to achieve a very fast preheat, low idle rate, high cooking-energy efficiency and production capacity.

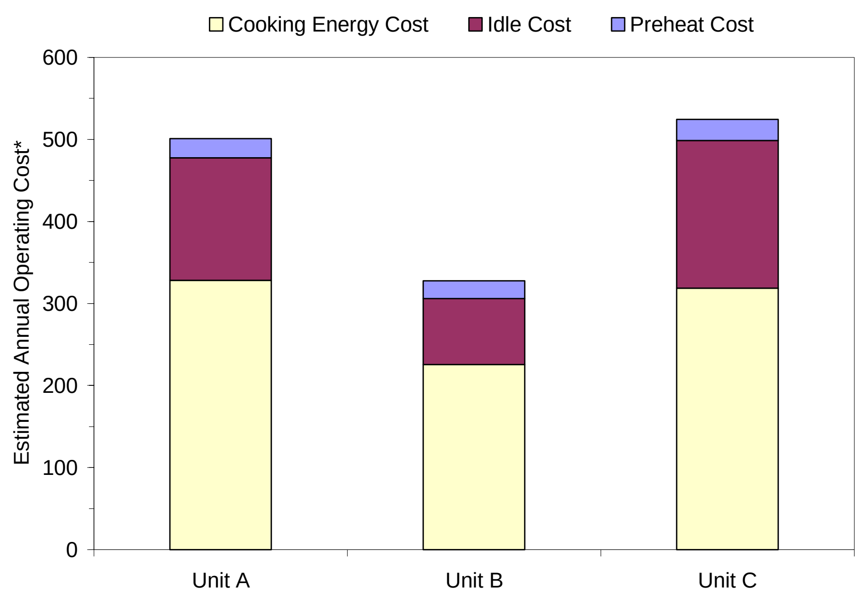

Figure ES-3.
Fryer operating cost.

* Fryer energy costs are based on $0.60/therm (1 therm = 100,000 Btu).

1 Introduction

Background

Dedicated to the advancement of the food service industry, the Food Service Technology Center (FSTC) has focused on the development of standard test methods for commercial food service equipment since 1987. The test methods, approved and ratified by the American Society for Testing and Materials (ASTM), allow benchmarking of equipment such that users can make meaningful comparisons among available equipment choices. End-use customers and commercial appliance manufacturers consider the FSTC to be the national leader in commercial food service equipment testing and standards, sparking alliances with several major chain customers to date.

This study was a part of a larger project with a major restaurant chain to benchmark the performance of the appliances typically used in their restaurants. The fryer is a workhorse in their cook-to-order style kitchens, which feature fried foods with many of their dishes. French fried potatoes are still the most common deep fried food, along with onion rings, chicken and fish. Recent advances in equipment design have produced fryers that operate more efficiently, quickly, safely and conveniently.

FSTC engineers worked with the restaurant chain and three fryer manufacturers to establish a performance benchmark for gas counter top fryers. The fryers were tested for energy efficiency, energy consumption, and cooking performance in accordance with the ASTM *Standard Test Method for the Performance of Open Deep Fat Fryers*.[1] Performance testing was conducted under tightly controlled laboratory conditions, using Simplot® brand ¼-inch blue ribbon product, par-cooked, frozen shoestring potatoes, the majority of which was donated to food kitchens in the area after the testing was completed.

Since the development of the ASTM test method for fryers in 1991, the FSTC has tested a wide range of gas and electric fryers and built a solid

Introduction

knowledge base on fryer performance.[2-14] A glossary is provided in Appendix A so that the reader has a quick reference to the terms used in this report.

Objectives

The objective of this report is to examine the operation and performance of three counter top gas fryers, under the controlled conditions of the ASTM standard test method. The scope of this testing is as follows:

1. Verify that the appliance is operating at the manufacturer's rated energy input.
2. Determine the time and energy required to preheat the appliance from room temperature to 350°F.
3. Characterize the idle energy use with the thermostat set at a calibrated 350°F.
4. Document the cooking energy consumption and efficiency under three French fry loading scenarios: heavy (3 pounds per load), medium (1½ pounds per load), and light (¾ pound per load).
5. Determine the production capacity and frying medium temperature recovery time during the heavy-load test.

Appliance Description

Three counter top gas fryers were tested in the course of this study. Typical designs contained heat exchanger systems with snap-action thermostats controlling atmospheric burners. The counter top fryers ranged in input from 60,000 Btu/h to 90,000 Btu/h. Unit A featured an underfired heating system, where the atmospheric burners were located in raised sections of the bottom of the frypot, while Units B and C use a front to back tube-fired system, which uses emersed tubes that transfer heat from the hot gases into the oil. All three fryers feature stainless steel frypots and mechanical snap-action thermostats. Figures 1-1 thru 1-3 show the heat exchanger systems for the three counter top fryers. Appliance specifications are listed in Table 1-1.

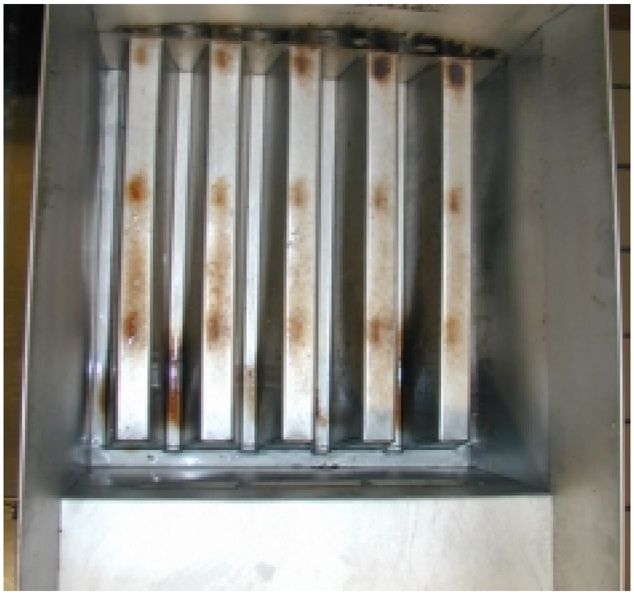

Figure 1-1.
Unit A heat transfer tubes.

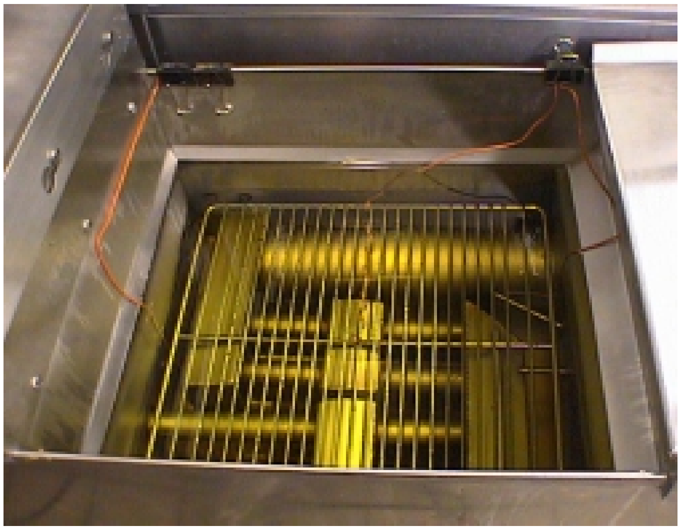

Figure 1-2.
Unit B heat transfer tubes.

Figure 1-3. Unit C heat transfer tubes.

Table 1-1. Appliance Specifications.

Fryer Unit A	
Rated Input	60,000 Btu/h
Generic Appliance Type	Open Deep Fat Fryer
Oil Capacity	35 lbs
Construction	Stainless Steel
Controls	Snap action thermostat with a temperature range of 200 to 400°F
Fryer Unit B	
Rated Input	90,000 Btu/h
Generic Appliance Type	Open Deep Fat Fryer
Oil Capacity	30 lbs
Construction	Stainless Steel
Controls	Snap action thermostat with a temperature range of 200 to 400°F

Appliance Specifications Continued.

Fryer Unit C

Rated Input	80,000 Btu/h
Generic Appliance Type	Open Deep Fat Fryer
Oil Capacity	38 lbs
Construction	Stainless Steel
Controls	Snap action thermostat with a temperature range of 200 to 400°F

2 Methods

Setup and Instrumentation

FSTC researchers installed the fryers on a stainless steel table over a tiled floor under a 4-foot-deep canopy hood that was 6 feet, 6 inches above the floor. The hood operated at a nominal exhaust rate of 300 cfm per linear foot of hood. There was at least 6 inches of clearance between the vertical plane of the fryers and the edge of the hood. All test apparatus were installed in accordance with Section 9 of the ASTM test method. See Figure 2-1.

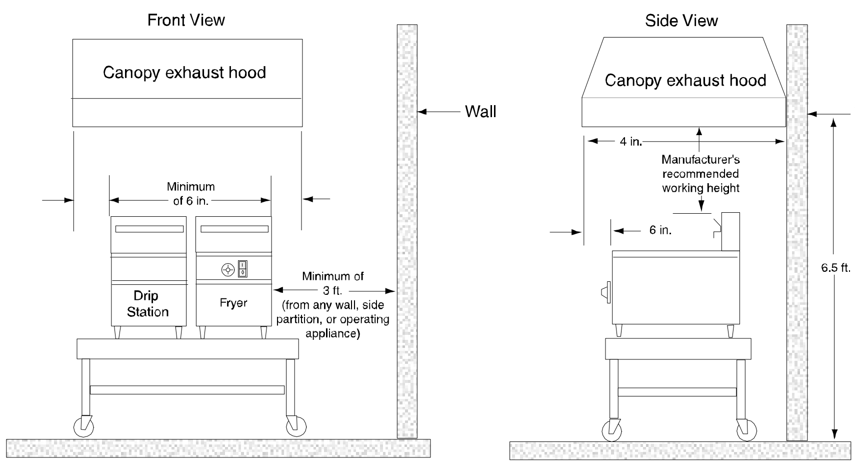

Figure 2-1. Equipment configuration.

Researchers instrumented the fryers with thermocouples to measure temperatures in the cold and the cooking zones and at the thermostat sensing bulb. Two thermocouples were placed in the cook zone, one in the geometric center of the frypot, approximately 1 inch above the fry basket support, and the other at the tip of the thermostat sensing bulb. 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.

Natural gas consumption was measured using a positive displacement-type gas meter that generated a pulse every 0.1 ft³. 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 Melfry Brand, partially hydrogenated, 100% pure vegetable oil for all tests except the energy input rate determination test. This test required the fryer to be filled with water to inhibit burner cycling during the test.

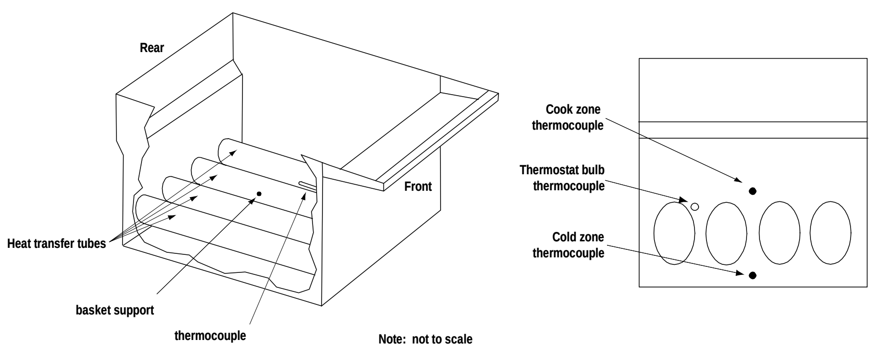

Figure 2-2. Thermocouple placement for testing.

Measured Energy Input Rate

Rated energy input rate is the maximum or peak rate at which a fryer consumes energy—as specified on the fryer's nameplate. Measured energy input rate is the maximum or peak rate of energy consumption, which is recorded during a period when the burners are operating (such as preheat). For the purpose of this test, the fryer was filled with water to the frypot's indicated fill-line. The controls were set to attain maximum output and the energy consumption was monitored for a period of 15 minutes after a full rolling boil was established. Researchers compared the measured energy input rate with the nameplate energy input rate to ensure that the fryer was operating properly.

Cooking Tests

Researchers specified Simplot® 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 fryers using 3-pound (heavy), 1 ½-pound (medium), and ¾-pound (light) French fry loads.

Due to the logistics involved in removing one load of cooked French fries and placing another load into the fryers, a minimum preparation time of 10 seconds was incorporated into the cooking procedure. This ensured that the cooking tests were uniformly applied from test to test. 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 fryers were 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 fryers to recover, researchers terminated the test. Total elapsed time, energy consumption, weight of cooked fries, and average weight loss of the French fries were recorded for the last five loads of the six-load test.

Methods

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 ± 10%. The results from each test run were averaged, and the absolute uncertainty was calculated based on the standard deviation of the results.

The ASTM results reporting sheets appear in Appendix B.

3 Results

Energy Input Rate

Energy input rate was measured prior to each day of testing to confirm that the fryer was operating properly. Table 3-1 shows the measured input rate along with each fryer's corresponding nameplate value.

Table 3-1. Energy Input Rate.

	Unit A	Unit B	Unit C
Rated (Btu/h)	60,000	90,000	80,000
Measured (Btu/h)	61,216	87,593	77,879
Difference (%)	2.03	2.67	2.65

Preheat and Idle Tests

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

Preheat Energy and Time

Researchers filled the fryers with new oil, which was then heated to 350°F at least once prior to any testing. The preheat tests were conducted at the beginning of a test day, after the oil had stabilized at room temperature overnight. Figures 3-1 thru 3-3 show the preheat characteristics for each of the three counter top fryers.

Results

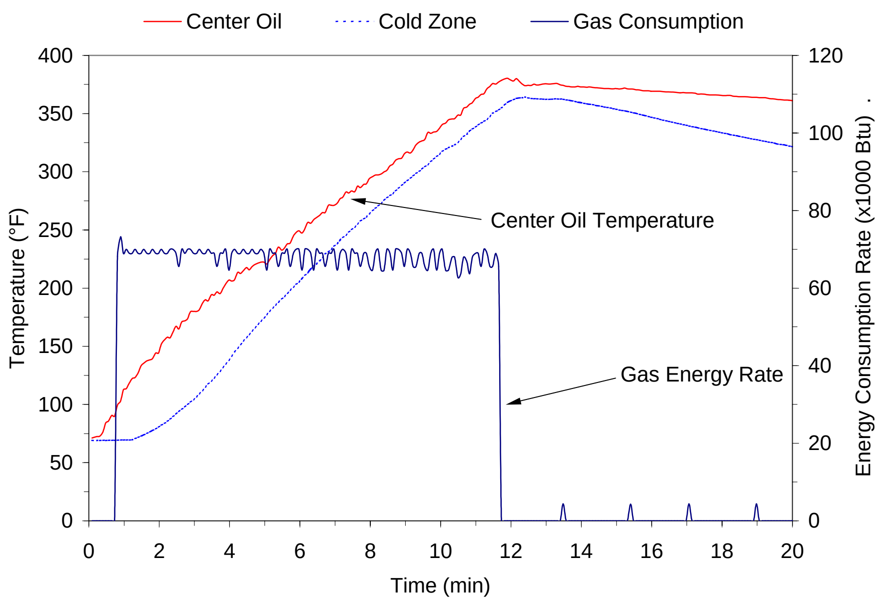

Figure 3-1. Unit A preheat characteristics.

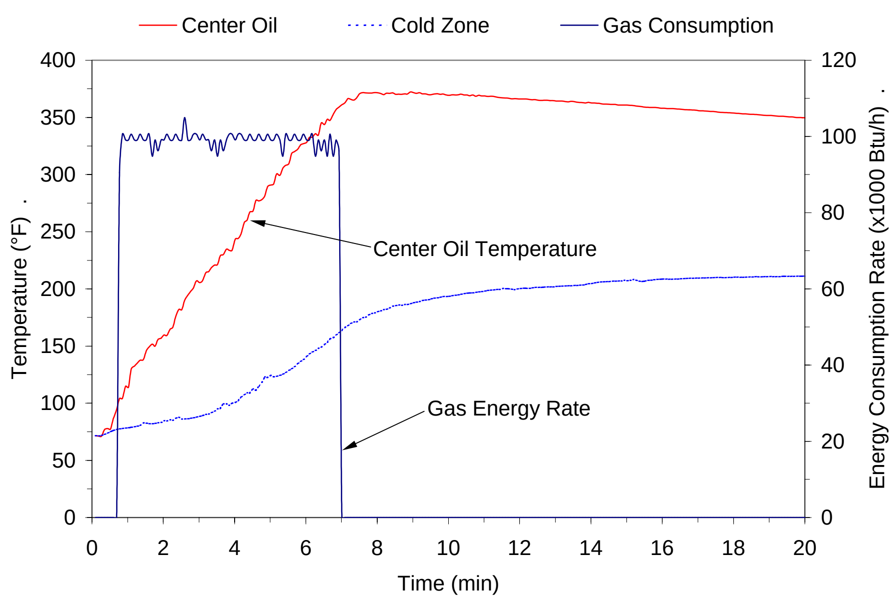

Figure 3-2. Unit B preheat characteristics.

Results

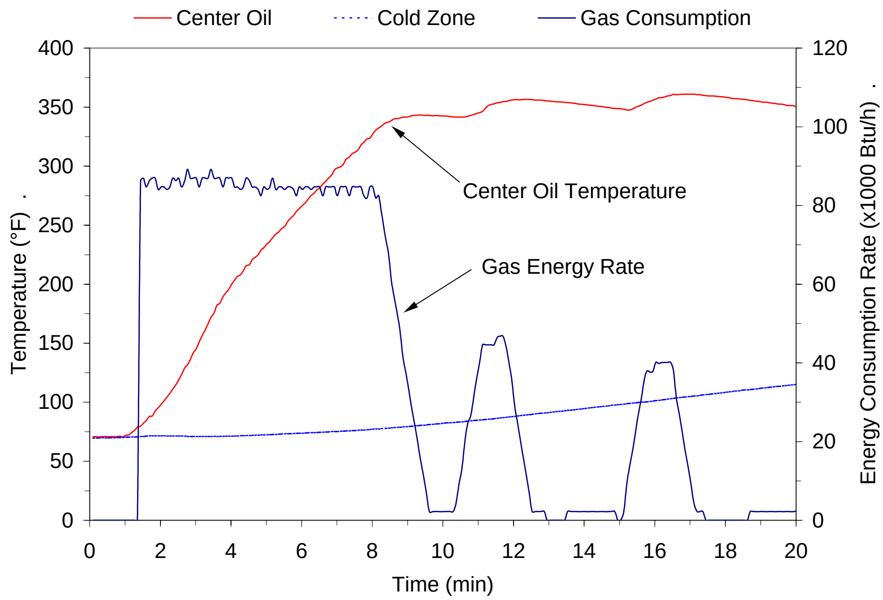

Figure 3-3. Unit C preheat characteristics.

Preheat melt cycles which prevent the scorching of solid shortening were not incorporated in these counter top fryers; preheat represents full power from the time the fryer is turned on until it reached the temperature set point. Unit A preheated in 10.6 minutes using 10,778 Btu, while Unit B quickly reached set point in 6.61 minutes while using 9,816 Btu. Unit C used 11,911 Btu and was ready to cook in 11.2 minutes.

Idle Energy Rate

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

Results

Test Results

The preheat, and idle test results are summarized in Table 3-2.

Table 3-2. Preheat and Idle Test Results.

	Unit A	Unit B	Unit C
Preheat			
Duration (min)	10.6	6.61	11.2
Energy (Btu)	10,778	9,816	11,911
Rate (°F/min)	27	42	25
Idle			
Energy Rate (Btu/h)	7,867	4,121	9,210
Idle Duty Cycle (%)	12.8	4.7	11.5

Cooking Tests

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

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

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

Heavy-Load Tests

The heavy-load cooking tests were designed to reflect a fryer's maximum performance. The fryers were used to cook six 3-pound loads of frozen French fries—one load after the other in rapid succession, similar to a batch-cooking procedure. The first load was used to stabilize the fryer, and the remaining five loads were used to calculate cooking-energy efficiency and production capacity. During the testing, energy, time and oil temperatures were measured and logged on a computer at 5-second intervals. Temperature and weight loss were recorded for use in the energy calculations. Table 3-3 summarizes the frying medium temperature characteristics during the heavy-load cooking tests. Figures 3-4 thru 3-6 show the average frying medium temperatures for each fryer during the heavy-load tests.

Table 3-3. Heavy-Load Frying Medium Temperature Characteristics.

	Unit A	Unit B	Unit C
Temperature (°F)			
Average	303	329	324
Minimum	297	300	306
Maximum	344	353	353

During testing under heavy-load conditions Unit B demonstrated the highest production capacity, 59.7 lbs/h., and 59.6% cooking-energy efficiency. Unit C produced slightly less food, 58.4 lbs/h, and exhibited 46.1% cooking-energy efficiency. Unit A exhibited the lowest efficiency, 41.1%, and produced 43.6 lbs/h of French fries.

Results

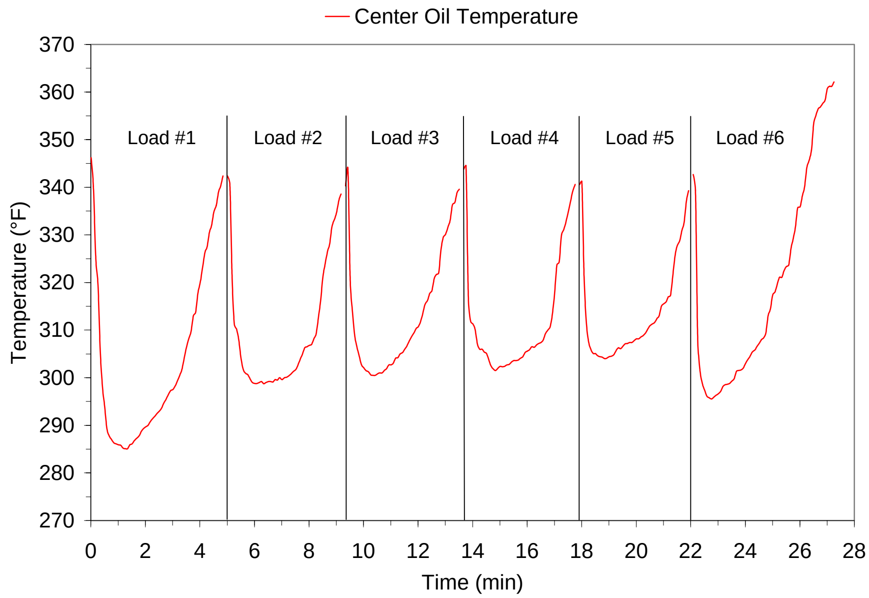

Figure 3-4. Unit A frying medium temperature during a heavy-load test.

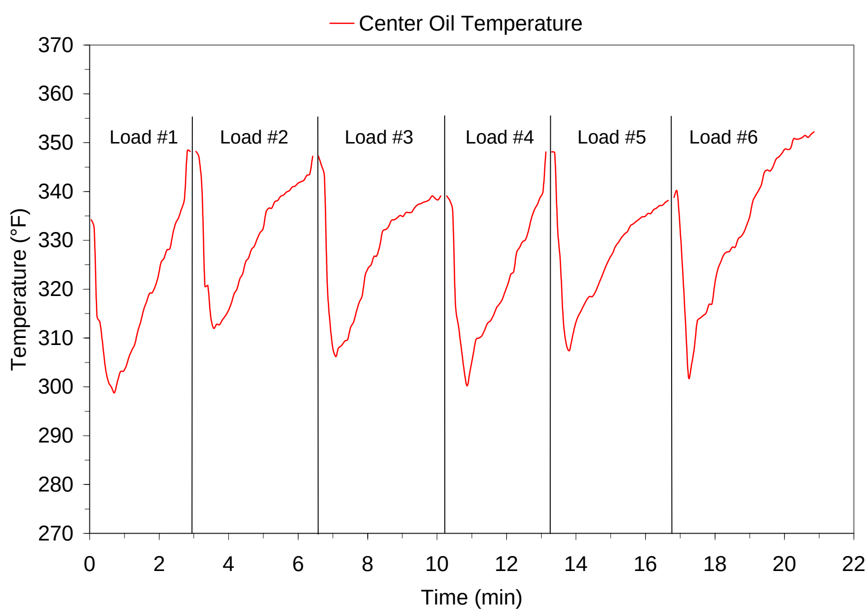

Figure 3-5. Unit B frying medium temperature during a heavy-load test.

Results

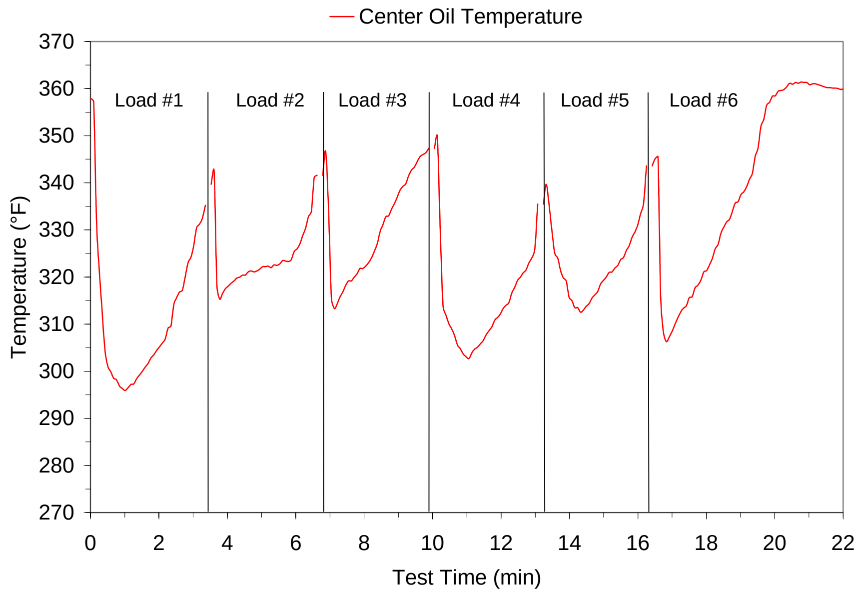

Figure 3-6.
Unit C frying medium temperature during a heavy-load test.

Figure 3-7 compares the temperature response for the three fryers while cooking a single 3-pound load of frozen French fries. Fryer B and Fryer C began to recover during the cooking cycle, reaching within 20°F of the set point by the end of the cooking cycle.

Unit C had consistently recovered to 340°F by the time the 3-pound load of French fries was removed from the fryer. Units A and B required an average of 58 seconds and 23 seconds, respectively, to recover to 340°F after the removal of fries. Recovery time is measured from when the fries are removed from the fry pot until the frying medium reaches a temperature of 340°F, at which point the fryer is considered recovered and ready to cook another load of fries. The heavy-load cooking test results are summarized in Table 3-4.

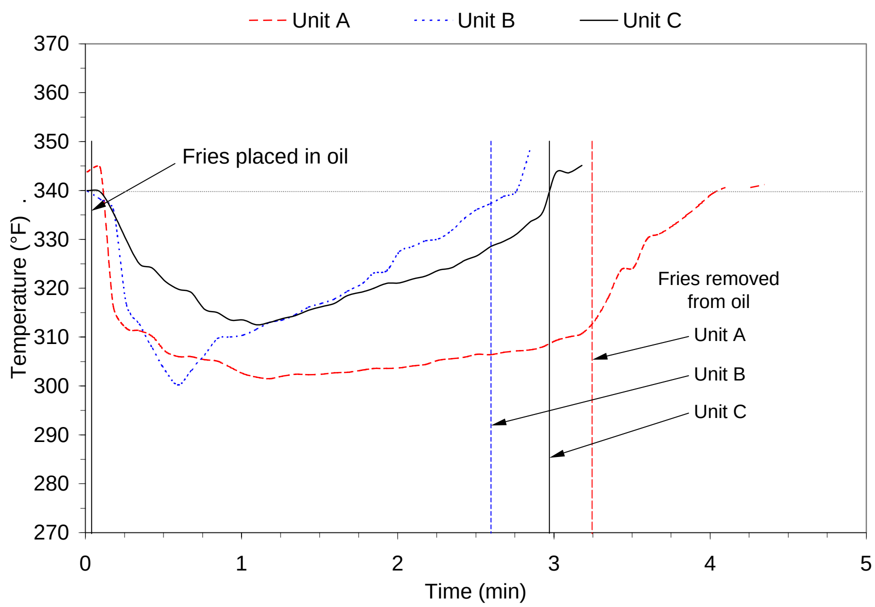

***Figure 3-7.
Fryer cooking cycle temperature signatures.***

Table 3-4. Heavy-Load Cooking Test Results.

	Unit A	Unit B	Unit C
Load Size (lbs)	3.0	3.0	3.0
French Fry Cook Time (min)	3.17	2.63	2.92
Average Recovery Time (sec)	58	23	10
Production Capacity (lb/h) [a]	43.6 ± 0.5 [b]	59.7 ± 4.3 [b]	58.4 ± 1.5 [b]
Energy to Food (Btu/lb)	569	564	597
Cooking Energy Rate (Bu/h)	60,400	56,536	75,710
Cooking-Energy Efficiency (%)	41.1 ± 0.3 [b]	59.6 ± 1.9 [b]	46.1 ± 2.1 [b]

[a] Based on the heavy-load cooking test.

[b] This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.

Medium- and Light-Load Tests

Medium- and light-load tests represent a more typical usage pattern for a fryer in cook-to-order applications. Since a fryer is often used to cook single basket loads in many food service establishments, these part-load efficiencies can be used to estimate the fryer's performance in an actual operation. Table 3-5 summarizes the medium- and light-load test results for the three fryers.

Table 3-5. Medium- and Light-Load Cooking Test Results.

	Unit A	Unit B	Unit C
Medium-Load:			
Load Size (lbs)	1.5	1.5	1.5
French Fry Cook Time (min)	2.54	2.40	2.44
Average Recovery Time (sec)	11	11	13
Production Rate (lb/h)	33.0 ± 0.7 [a]	34.7 ± 1.3 [a]	33.8 ± 1.5 [a]
Energy to Food (Btu/lb)	569	572	1,441
Cooking Energy Rate (Btu/h)	49,647	34,908	48,784
Cooking-Energy Efficiency (%)	37.8 ± 2.5 [a]	56.6 ± 3.5 [a]	40.9 ± 3.6 [a]
Light-Load:			
Load Size (lbs)	.75	.75	.75
French Fry Cook Time (min)	2.42	2.33	2.18
Average Recovery Time (sec)	11	11	12
Production Rate (lb/h)	17.3 ± 0.1 [a]	17.9 ± 0.1 [a]	18.9 ± 1.0 [a]
Energy to Food (Btu/lb)	574	556	1,834
Cooking Energy Rate (Bu/h)	29,983	22,321	34,694
Cooking-Energy Efficiency (%)	33.0 ± 1.9 [a]	44.5 ± 1.4 [a]	31.5 ± 2.2 [a]

[a] This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.

Results

Both the medium- and light-load tests were conducted using a single fry basket. The medium-load tests used 1½ pounds of fries per load with Unit B achieving the highest cooking-energy efficiency of 56.6% at a production rate of 34.7 lbs/h. Unit A and Unit C exhibited somewhat lower cooking-energy efficiencies of 37.8% and 40.9%, respectively.

Light-load tests used a ¾-pounds/load of fries. Unit B posted the highest light-load cooking-energy efficiency of 45% at 17.9 lbs of fries per hour. Unit A achieved a cooking-energy efficiency of 33% at a similar production rate of 17.3 lbs/h, while Unit C exhibited a cooking-energy efficiency of 32% at 18.9 lbs/h.

Results Discussion

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

Cooking-energy efficiencies for Unit A were 41.2%, 40.9%, and 41.1%, yielding an absolute uncertainty of 0.3%. Unit B demonstrated a slightly wider range in cooking-energy efficiency, with results of 58.5%, 60.3%, 58.5%, and 60.9%, yielding an absolute uncertainty of 1.9%. The cooking-energy efficiencies for Unit C were 45.7%, 47.0%, and 45.4%, yielding an absolute uncertainty of 2.1%.

Figure ES-2 illustrates the relationship between cooking-energy efficiency and production rate for the three counter top fryers. Fryer production rate is a function of both the French fry cook time and the frying medium recovery time. Appendix C contains a synopsis of test data for each replicate of the cooking test for each fryer.

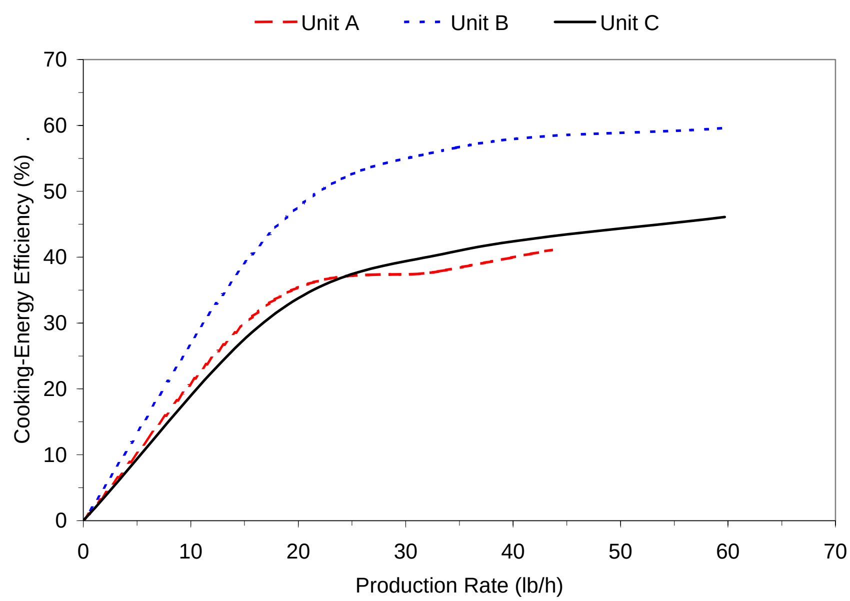

Figure 3-8.
Fryer part-load cooking-energy efficiency.

Figure ES-3 illustrates the relationship between the fryers average energy consumption rates and the production rates. This graph can be used as a tool to estimate the daily energy consumption for a fryer in a real-world operation. Average energy consumption rates at 10, 30, and 50 pounds per hour for Unit B were 13,770 Btu/h, 31,090 Btu/h, and 48,420 Btu/h respectively. For an operation cooking an average of 15 pounds of food per hour over the course of the day (e.g., 150 lb of food over a ten hour day), the average daily energy consumption rate for this fryer would be 18,100 Btu/h. Average energy consumption rates at 10, 30 and 50 pounds per hour are listed for each fry in Table 3-6.

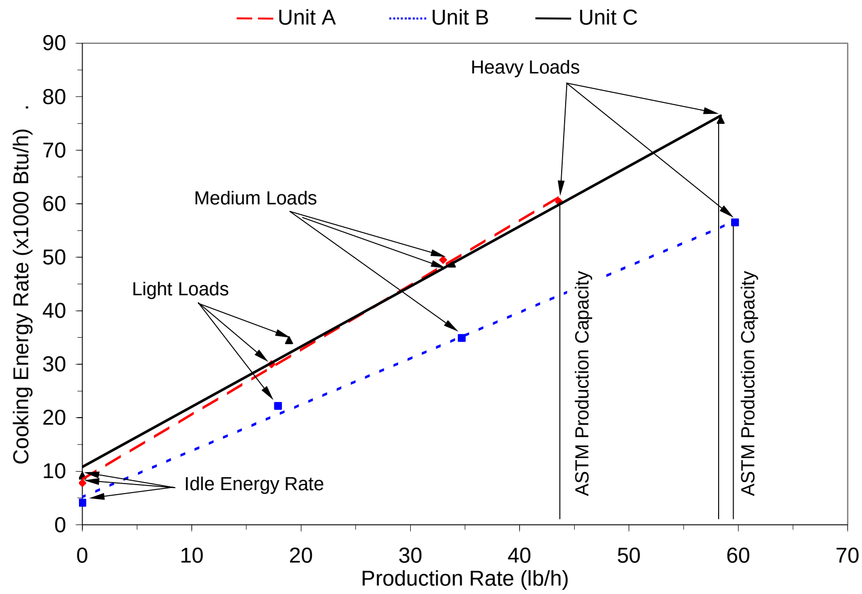

Figure 3-9. Fryer cooking energy consumption profile.

Note: Light-Load = ¾ pounds/load; Medium-Load = 1 ½ pounds/load; Heavy-Load = 3 pounds/load.

Table 3-6. Energy Consumption Estimations.

Production Rate	Unit A	Unit B	Unit C
10 lbs/h	20,550 Btu/h	13,770 Btu/h	22,070 Btu/h
30 lbs/h	44,850 Btu/h	31,090 Btu/h	44,550 Btu/h
50 lbs/h	69,160 Btu/h	48,420 Btu/h	67,030 Btu/h

Energy Cost Model

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

The idle (standby) time for each of the fryers was determined by taking the difference between the total daily on–time (12 hours) and the time spent cooking and preheating. Since the average cook times and preheat times were different for each fryer, the idle times varied somewhat. This approach produces a more accurate estimate of the operating costs for the fryers. Table 3-7 summarizes the daily energy consumption and associated annual energy cost for the three fryers under this scenario.

Table 3-7. Estimated Fryer Energy Consumption and Cost.

	Unit A	**Unit B**	**Unit C**
Preheat Energy (kBtu/year)	3,940	3,580	4,350
Idle Energy (kBtu/year)	24,760	13,550	30,020
Cooking Energy (kBtu/year)	54,680	37,350	53,040
Annual Energy (kBtu/year) [a]	**83,380**	**54,480**	**87,410**
Annual Cost ($/year) [b]	**500**	**327**	**524**

[a] 1 kBtu = 1,000 Btu
[b] Fryer energy costs are based on $0.60/therm (1 therm = 100,000 Btu).

Unit A and C would essentially cost the same to operate in a restaurant, based on the combination of preheat, idle, and cooking energy. Unit B exhibited the lowest estimated annual operating cost. Idle rates and cooking energy contributed to the higher annual operating costs of Units A and C. Preheat energy had only a minimal impact on the operating costs due to its short duration.

4 Conclusions

The latest generation of counter top gas fryers offer a food service operator space saving frying capabilities, while equaling the performance of their floor model cousins. This fryer bench test highlights performance benefits due to differences in design strategy. All three fryers were of a basic design: a stainless steel frypot, small cold zone (if present), solid-state thermostat, and atmospheric burners. A primary difference between counter top fryers and floor-model fryers is a smaller cold zone. The cold zone is intended to have a relatively low temperature, so the crumbs will not carbonize and create the breakdown products that limit oil life. Researchers noticed that without frequent filtration and removal of the debris, the build up of crumbs so close to the burners could cause the oil to “boil over” or foam up and spill over the sides of the frypot. So much heat was retained by the mass of debris that shutting off the burners did not stop the oil from spilling over. Once started, the “boil over” would continue until most of the oil had spilled to the floor.

Unit B posted the fastest preheat to 350°F at 6.6 minutes and a very low idle rate of 4,121 Btu/h, while Unit A achieved preheat at 10.6 minutes with a higher idle rate of 7,867 Btu/h. Unit C took slightly longer to preheat and was ready to cook in 11.2 minutes. Unit C also posted the highest idle rate of 9,210 Btu/h. Monitoring the usage of fryers in commercial kitchens has demonstrated that fryers spend a significant proportion of their on time in idle mode and that the rate of idle energy consumption has a significant impact on total energy consumption.

Unit B employs a unique heat transfer tube (originally developed for their floor model), which maximizes heat transfer into the oil to a greater degree than either Unit A or C. The innovative heat exchanger enabled Unit B to achieve a very fast preheat, low idle rate and high cooking-energy efficiency in comparison to the other two counter top units.

The differences in performance translated to differences in estimated operating cost. Unit B, with it's low idle rate and high cooking-energy efficiency, proved to have the lowest operating cost with an annual estimated cost of $327 per year. Unit A was more expensive to operate at $500 per year with it's higher idle rate and lower cooking energy efficiencies accounting for the higher operating costs. Unit C exhibited the highest idle rate of the three fryers, which placed its operating cost at $524 per year.

5 References

1. American Society for Testing and Materials, 1999. *Standard Test Method for the Performance of Open, Deep Fat Fryers.* ASTM Designation F 1361-99. In Annual Book of ASTM Standards, West Conshohocken, PA.

2. Conner, M. M., Young, R., Fisher, D.R. and Nickel, J., 1991. *Development and Application of a Uniform Testing Procedure for Fryers*. Pacific Gas and Electric Company Department of Research and Development Report 008.1.89.2, November.

3. Holliday, J., Conner, M., 1993. *Frymaster® Model H-17CSC Electric Fryer Performance Test: Application of ASTM Standard Test Method F 1361-91.* Food Service Technology Center Report 5017.93.2, November.

4. Zabrowski, D., Nickel, J., Holliday, J., 1994. *TekmaStar Model FD-212 Electric Fryer Performance Test: Application of ASTM Standard Test Method F 1361-91.* Food Service Technology Center Report 5011.94.2, June.

5. Zabrowski, D., Nickel, J., Knapp, S., 1995. *Keating Model 14 IFM Gas Fryer Performance Test.* Food Service Technology Center Report 5011.95.32, December.

6. Knapp, S., Zabrowski, D., 1996. *Pitco Frialator® Model E14B Electric Fryer Performance Test.* Food Service Technology Center Report 5011.95.12, March.

7. Knapp, S., Zabrowski, D., 1996. *Pitco Frialator® Model RPB14 Technofry 1™ Gas Fryer: Application of ASTM Standard Test Method F1361-95.* Food Service Technology Center Report 5011.94.11, April.

8. Knapp, S., 1998. *Watlow® Model Firebar 1000 and 1600 Prototype Element Performance Test.* Food Service Technology Center Report 5011.98.60, July.

9. Zabrowski, D., Bell, T., 1999. *Ultrafryer, Model PAR 3-14 Gas Fryer Performance Test.* Food Service Technology Center Report 5011.99.78, September.

10. Cowen, D., Zabrowski, D., 2000. *Vulcan 14-inch Fryer Performance Test: Application of ASTM Standard Test Method F1361-99.* Food Service Technology Center Report 5011.00.87, December.

References

11. Cowen, D., Zabrowski, D. 2000. *Vulcan High Capacity Fryer Performance Test: Application of ASTM Standard Test Method F1361-99*. Food Service Technology Center Report 5011.00.88, December.

12. Cowen, D., Zabrowski, D., Miner, S., 2002. *Pitco AG14 Fryer Performance Tests: Application of ASTM Standard Test Method F1361-99.* Food Service Technology Center Report 5011.02.07, September.

13. Cowen, D., Zabrowski, D., Miner, S., 2002. *Pitco SGH50 Fryer Performance Tests: Application of ASTM Standard Test Method F1361-99.* Food Service Technology Center Report 5011.02.08, September.

14. Cowen, D., Zabrowski, D., Miner, S., 2001. *Anets Fryer Performance Tests.* Food Service Technology Center Report 5011.01.03, December.

A Glossary

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

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

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

Duty Cycle (%)
Load Factor

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

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

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

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

Heating Value (Btu/ft^3)
Heating Content

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

Idle Energy Rate (kW or Btu/h)
Idle Energy Input Rate
Idle Rate

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

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

Idle Duty Cycle (%)
Idle Energy Factor

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

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

Measured Input Rate (kW or Btu/h)
Measured Energy Input Rate
Measured Peak Energy Input Rate

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

Glossary

Pilot Energy Rate (kBtu/h)
Pilot Energy Consumption Rate

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

Preheat Energy (kWh or Btu)
Preheat Energy Consumption

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

Preheat Rate (°F/min)

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

Preheat Time (minute)
Preheat Period

The time required for an appliance to warm from the ambient room temperature (75 ± 5°F) to a specified (and calibrated) operating temperature or thermostat set point.

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

Production Rate (lb/h)
Productivity

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

Rated Energy Input Rate
(kW, W or Btu/h, Btu/h)
Input Rating (ANSI definition)
Nameplate Energy Input Rate
Rated Input

The maximum or peak rate at which an appliance consumes energy as rated by the manufacturer and specified on the nameplate.

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

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

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

B Results Reporting Sheets

Test Fryers

Description of operational characteristics: All three fryers featured stainless steel frypots with a small if present cold zone. Gas atomspheric burners were used by each fryer. Unit A had five atmospheric gas burners each rated at 12,000 Btu/h, while Unit B used a single 90,000 Btu/h forced induced gas atmospheric burner with the hot gases routed through an advanced heat exchanger. Unit C employed three atmospheric burners each rated at 26,500 Btu/h routed through three heat transfer tubes from front to back.

Apparatus

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

Deviations: None.

Energy Input Rate

	Unit A	Unit B	Unit C
Gas Heating Value (Btu/scf)	1013	1014	1019
Name Plate (Btu/h)	60,000	90,000	80,000
Measured (Btu/h)	61,216	87,593	77,879
Percentage Difference (%)	2.03	2.67	2.65

Thermostat Calibration

	Unit A	Unit B	Unit C
Thermostat Setting (°F)	350	350	350
Oil Temperature (°F)	350	351	350

Results Reporting Sheets

Preheat Energy and Time

	Unit A	Unit B	Unit C
Gas Heating Value (Btu/scf)	1014	1014	1018
Starting Temperature (°F)	71	72	71
Energy Consumption (Btu)	10,778	9,816	11,911
Duration (min)	10.6	6.61	11.2
Preheat Rate (°F/min)	27	42	25

Idle Energy Rate

	Unit A	Unit B	Unit C
Gas Heating Value (Btu/scf)	1014	1014	1018
Idle Energy Rate @ 325 °F (Btu/h)	7,867	4,121	9,210
Idle Duty Cycle %	12.8	4.7	11.5

Heavy-Load Cooking-Energy Efficiency and Cooking Energy Rate

	Unit A	Unit B	Unit C
Gas Heating Value (Btu/scf)	1018	1018	1018
Load Size (lbs)	3.0	3.0	3.0
Cook Time (min)	3.17	2.63	2.92
Recovery Time (sec)	58	23	10
Production Capacity (lb/h)	43.6 ± 0.5	59.7 ± 4.3	58.4 ± 1.5
Energy to Food (Btu/lb)	569	564	597
Cooking Energy Rate (Btu/h)	60,400	56,536	75,710
Energy to Fryer (Btu/lb) [a]	1,386	947	1,296
Cooking-Energy Efficiency (%)	41.1 ± 0.3	59.6 ± 1.9	46.1 ± 2.1

[a] Energy consumped per pound of raw food cooked.

Results Reporting Sheets

Medium-Load Cooking-Energy Efficiency and Cooking Energy Rate

	Unit A	Unit B	Unit C
Gas Heating Value (Btu/scf)	1014	1014	1020
Load Size (lbs)	1.5	1.5	1.5
Cook Time (min)	2.54	2.40	2.44
Recovery Time (sec)	11	11	13
Production Rate (lb/h)	33.0 ± 0.7	34.7 ± 1.3	33.8 ± 1.5
Energy to Food (Btu/lb)	569	569	590
Cooking Energy Rate (Btu/h)	49,647	34,908	48,784
Energy to Fryer (Btu/lb) [a]	1,505	1,007	1,441
Cooking-Energy Efficiency (%)	37.8 ± 2.5	56.6 ± 3.5	40.9 ± 3.6

[a] Energy consumped per pound of raw food cooked.

Light-Load Cooking-Energy Efficiency and Cooking Energy Rate

	Unit A	Unit B	Unit C
Gas Heating Value (Btu/scf)	1013	1014	1018
Load Size (pieces)	.75	.75	.75
Cook Time (min)	2.42	2.33	2.18
Recovery Time (sec)	11	11	12
Production Rate (lb/h)	17.3 ± 0.1	17.9 ± 0.1	18.9 ± 1.0
Energy to Food (Btu/lb)	574	556	578
Cooking Energy Rate (Btu/h)	29,983	22,231	34,694
Energy to Fryer (Btu/lb) [a]	1,737	1,249	1,834
Cooking-Energy Efficiency (%)	33.0 ± 1.9	44.5 ± 1.4	31.5 ± 2.2

[a] Energy consumed per pound of raw food cooked.

C Cooking-Energy Efficiency Data

Table D-1. Specific Heat and Latent Heat.

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

Cooking-Energy Efficiency Data

Table D-2. Unit A Heavy-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	20,897	20,821	20,646
Cook Time (min)	**3.17**	**3.17**	**3.17**
Total Test Time (min)	20.7	20.7	20.6
Weight Loss (%)	29.08	29.25	29.08
Initial Weight (lb)	15.000	15.000	15.000
Final Weight (lb)	10.638	10.613	10.638
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	43.6	44.4	44.7
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Water Loss (lb)	5.137	5.059	5.014
Calculated Values			
Initial Weight of Water (lb)	9.780	9.780	9.780
Final Weight of Water (lb)	4.638	4.712	4.755
Sensible (Btu)	2,210	2,210	2,210
Latent - Heat of Fusion (Btu)	1,407	1,407	1,407
Latent - Heat of Vaporization (Btu)	4,983	4,907	4,864
Total Energy to Food (Btu)	8,600	8,525	8,481
Energy to Food (Btu/lb)	**573**	**568**	**565**
Total Energy to Fryer (Btu)	20,897	20,821	20,646
Energy to Fryer (Btu/lb)	**1,393**	**1,388**	**1,376**
Cooking-Energy Efficiency (%)	**41.2**	**40.9**	**41.1**
Cooking Energy Rate (Btu/h)	**60,543**	**60,378**	**60,279**
Production Rate (lb/h)	**43.5**	**43.5**	**43.8**
Average Recovery Time (sec)	**0.97**	**0.97**	**0.94**

Cooking-Energy Efficiency Data

Table D-3. Unit A Medium-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	11,549	11,169	11,152
Cook Time (min)	**2.50**	**2.56**	**2.55**
Total Test Time (min)	13.5	13.7	13.7
Weight Loss (%)	29.41	29.74	30.17
Initial Weight (lb)	7.500	7.500	7.500
Final Weight (lb)	5.295	5.269	5.238
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	45.1	44.7	44.2
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Water Loss (lb)	2.498	2.529	2.573
Calculated Values			
Initial Weight of Water (lb)	4.890	4.890	4.890
Final Weight of Water (lb)	2.388	2.355	2.315
Sensible (Btu)	1,105	1,105	1,105
Latent - Heat of Fusion (Btu)	704	704	704
Latent - Heat of Vaporization (Btu)	2,423	2,453	2,495
Total Energy to Food (Btu)	4,231	4,231	4,304
Energy to Food (Btu/lb)	**564**	**568**	**574**
Total Energy to Fryer (Btu)	11,549	11,169	11,152
Energy to Fryer (Btu/lb)	**1,540**	**1,489**	**1,487**
Cooking-Energy Efficiency (%)	**36.6**	**38.2**	**38.6**
Cooking Energy Rate (Btu/h)	**51,254**	**48,772**	**48,913**
Production Rate (lb/h)	**33.3**	**32.8**	**32.9**
Average Recovery Time (sec)	**0.20**	**0.19**	**0.19**

Cooking-Energy Efficiency Data

Table D-4. Unit A Light-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	6,616	6,562	6,366
Cook Time (min)	**2.42**	**2.42**	**2.42**
Total Test Time (min)	13.0	13.1	13.0
Weight Loss (%)	29.34	29.15	29.65
Initial Weight (lb)	3.750	3.750	3.750
Final Weight (lb)	2.650	2.657	2.638
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	44.0	43.4	43.7
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Water Loss (lb)	1.276	1.291	1.291
Calculated Values			
Initial Weight of Water (lb)	2.445	2.445	2.445
Final Weight of Water (lb)	1.166	1.153	1.153
Sensible (Btu)	553	553	553
Latent - Heat of Fusion (Btu)	352	352	352
Latent - Heat of Vaporization (Btu)	1,238	1,253	1,253
Total Energy to Food (Btu)	2,143	2,157	2,157
Energy to Food (Btu/lb)	**571**	**575**	**575**
Total Energy to Fryer (Btu)	6,616	6,562	6,366
Energy to Fryer (Btu/lb)	**1,764**	**1,750**	**1,698**
Cooking-Energy Efficiency (%)	**32.4**	**32.9**	**33.9**
Cooking Energy Rate (Btu/h)	**30,441**	**30,169**	**29,339**
Production Rate (lb/h)	**17.3**	**17.2**	**17.3**
Average Recovery Time (sec)	**0.19**	**0.19**	**0.18**

Cooking-Energy Efficiency Data

Table D-5. Unit B Heavy-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3	Repetition #4
Measured Values				
Total Energy (Btu)	14,489	14,102	14,392	13,813
Cook Time (min)	**2.51**	**2.66**	**2.67**	**2.67**
Total Test Time (min)	14.7	14.4	16.0	15.3
Weight Loss (%)	28.92	29.86	29.71	29.51
Initial Weight (lb)	15.000	15.000	15.000	15.000
Final Weight (lb)	10.663	10.521	10.543	10.573
Initial Moisture Content (%)	65.2	65.2	65.2	65.2
Final Moisture Content (%)	44.6	45.0	45.7	45.7
Initial Temperature (°F)	0	0	0	0
Final Temperature (°F)	212	212	212	212
Water Loss (lb)	5.016	5.038	4.957	4.943
Calculated Values				
Initial Weight of Water (lb)	9.780	9.780	9.780	9.780
Final Weight of Water (lb)	4.756	4.734	4.818	4.832
Sensible (Btu)	2,210	2,210	2,210	2,210
Latent - Heat of Fusion (Btu)	1,407	1,407	1,407	1,407
Latent - Heat of Vaporization (Btu)	4,866	4,887	4,808	4,795
Total Energy to Food (Btu)	8,483	8,505	8,426	8,412
Energy to Food (Btu/lb)	**566**	**567**	**562**	**561**
Total Energy to Fryer (Btu)	14,489	14,102	14,392	13,813
Energy to Fryer (Btu/lb)	**966**	**940**	**959**	**921**
Cooking-Energy Efficiency (%)	**58.5**	**60.3**	**58.5**	**60.9**
Cooking Energy Rate (Btu/h)	**59,299**	**58,637**	**54,004**	**54,203**
Production Rate (lb/h)	**61.4**	**62.4**	**56.3**	**58.9**
Average Recovery Time (sec)	**0.43**	**0.23**	**0.53**	**0.39**

Cooking-Energy Efficiency Data

Table D-6. Unit B Medium-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3	Repetition #4
Measured Values				
Total Energy (Btu)	7,737	7,111	7,727	7,631
Cook Time (min)	**2.42**	**2.33**	**2.41**	**2.44**
Total Test Time (min)	13.0	12.6	13.0	13.3
Weight Loss (%)	30.29	29.52	29.66	29.46
Initial Weight (lb)	7.500	7.500	7.500	7.500
Final Weight (lb)	5.228	5.286	5.276	5.290
Initial Moisture Content (%)	65.2	65.2	65.2	65.2
Final Moisture Content (%)	45.3	44.8	44.1	44.1
Initial Temperature (°F)	0	0	0	0
Final Temperature (°F)	212	212	212	212
Water Loss (lb)	2.517	2.518	2.561	2.555
Calculated Values				
Initial Weight of Water (lb)	4.890	4.890	4.890	4.890
Final Weight of Water (lb)	2.368	2.368	2.327	2.333
Sensible (Btu)	1,105	1,105	1,105	1,105
Latent - Heat of Fusion (Btu)	704	704	704	704
Latent - Heat of Vaporization (Btu)	2,442	2,442	2,485	2,478
Total Energy to Food (Btu)	4,250	4,251	4,293	4,287
Energy to Food (Btu/lb)	**567**	**567**	**572**	**572**
Total Energy to Fryer (Btu)	7,737	7,111	7,727	7,631
Energy to Fryer (Btu/lb)	**1,032**	**948**	**1,030**	**1,017**
Cooking-Energy Efficiency (%)	**54.9**	**59.8**	**55.6**	**56.2**
Cooking Energy Rate (Btu/h)	**35,766**	**33,887**	**35,583**	**34,398**
Production Rate (lb/h)	**34.7**	**35.7**	**34.5**	**33.8**
Average Recovery Time (sec)	**0.17**	**0.19**	**0.19**	**0.22**

Cooking-Energy Efficiency Data

Table D-7. Unit B Light-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	4,662	4,749	4,641
Cook Time (min)	**2.33**	**2.33**	**2.33**
Total Test Time (min)	12.6	12.6	12.6
Weight Loss (%)	29.56	29.15	29.64
Initial Weight (lb)	3.750	3.750	3.750
Final Weight (lb)	2.642	2.657	2.639
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	46.4	46.2	46.4
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	2120
Water Loss (lb)	1.216	1.215	1.218
Calculated Values			
Initial Weight of Water (lb)	2.445	2.445	2.445
Final Weight of Water (lb)	1.226	1.228	1.225
Sensible (Btu)	553	553	553
Latent - Heat of Fusion (Btu)	352	352	352
Latent - Heat of Vaporization (Btu)	1,180	1,178	1,182
Total Energy to Food (Btu)	2,084	2,083	2,086
Energy to Food (Btu/lb)	**556**	**555**	**556**
Total Energy to Fryer (Btu)	4,662	4,749	4,641
Energy to Fryer (Btu/lb)	**1,243**	**1,266**	**1,237**
Cooking-Energy Efficiency (%)	**44.7**	**43.9**	**45.0**
Cooking Energy Rate (Btu/h)	**22,164**	**22,667**	**22,133**
Production Rate (lb/h)	**17.8**	**17.9**	**17.9**
Average Recovery Time (sec)	**0.19**	**0.18**	**0.19**

Cooking-Energy Efficiency Data

Table D-8. Unit C Heavy-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	19,814	19,277	19,246
Cook Time (min)	**2.92**	**2.88**	**2.94**
Total Test Time (min)	15.6	15.3	15.4
Weight Loss (%)	30.91	29.74	29.60
Initial Weight (lb)	15.000	15.000	15.000
Final Weight (lb)	10.363	10.539	10.560
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	40.2	39.4	42.6
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Water Loss (lb)	5.612	5.618	5.280
Calculated Values			
Initial Weight of Water (lb)	9.780	9.780	9.780
Final Weight of Water (lb)	4.166	4.152	4.499
Sensible (Btu)	2,210	2,210	2,210
Latent - Heat of Fusion (Btu)	1,407	1,407	1,407
Latent - Heat of Vaporization (Btu)	5,444	5,450	5,121
Total Energy to Food (Btu)	9,061	9,067	8,739
Energy to Food (Btu/lb)	**604**	**604**	**583**
Total Energy to Fryer (Btu)	19,814	19,277	19,246
Energy to Fryer (Btu/lb)	**1,321**	**1,285**	**1,283**
Cooking-Energy Efficiency (%)	**45.7**	**47.0**	**45.4**
Cooking Energy Rate (Btu/h)	**76,257**	**75,695**	**75,178**
Production Rate (lb/h)	**57.7**	**58.9**	**58.6**
Average Recovery Time (sec)	**0.20**	**0.17**	**0.13**

Cooking-Energy Efficiency Data

Table D-9. Unit C Medium-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	10,719	10,828	10,882
Cook Time (min)	**2.38**	**2.45**	**2.50**
Total Test Time (min)	13.3	13.1	13.5
Weight Loss (%)	29.53	29.93	23.06
Initial Weight (lb)	7.500	7.500	7.500
Final Weight (lb)	5.285	5.256	5.771
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	40.1	40.2	40.7
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Water Loss (lb)	2.769	2.775	2.540
Calculated Values			
Initial Weight of Water (lb)	4.890	4.890	4.890
Final Weight of Water (lb)	2.119	2.113	2.349
Sensible (Btu)	1,105	1,105	1,105
Latent - Heat of Fusion (Btu)	704	704	704
Latent - Heat of Vaporization (Btu)	2,686	2,691	2,464
Total Energy to Food (Btu)	4,494	4,500	4,272
Energy to Food (Btu/lb)	**599**	**600**	**570**
Total Energy to Fryer (Btu)	10,719	10,828	10,882
Energy to Fryer (Btu/lb)	**1,429**	**1,444**	**1,451**
Cooking-Energy Efficiency (%)	**41.9**	**41.6**	**39.3**
Cooking Energy Rate (Btu/h)	**48,428**	**49,672**	**48,221**
Production Rate (lb/h)	**33.9**	**34.4**	**33.2**
Average Recovery Time (sec)	**0.28**	**0.17**	**0.21**

Cooking-Energy Efficiency Data

Table D-10. Unit C Light-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	6,590	6,998	7,041
Cook Time (min)	**2.12**	**2.22**	**2.20**
Total Test Time (min)	11.6	12.1	12.0
Weight Loss (%)	29.33	29.65	30.61
Initial Weight (lb)	3.750	3.750	3.750
Final Weight (lb)	2.650	2.638	2.602
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	44.4	42.1	44.3
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Water Loss (lb)	1.267	1.334	1.292
Calculated Values			
Initial Weight of Water (lb)	2.445	2.445	2.445
Final Weight of Water (lb)	1.177	1.111	1.153
Sensible (Btu)	553	553	553
Latent - Heat of Fusion (Btu)	352	352	352
Latent - Heat of Vaporization (Btu)	1,229	1,294	1,253
Total Energy to Food (Btu)	2,133	2,198	2,157
Energy to Food (Btu/lb)	**569**	**586**	**575**
Total Energy to Fryer (Btu)	6,590	6,998	7,041
Energy to Fryer (Btu/lb)	**1,757**	**1,866**	**1,878**
Cooking-Energy Efficiency (%)	**32.4**	**31.4**	**30.6**
Cooking Energy Rate (Btu/h)	**34,058**	**34,700**	**35,325**
Production Rate (lb/h)	**19.4**	**18.6**	**18.8**
Average Recovery Time (sec)	**0.20**	**0.20**	**0.19**

Cooking-Energy Efficiency Data

Table D-17. Unit A Cooking-Energy Efficiency and Production Capacity Statistics.

	Cooking-Energy Efficiency			Production Capacity
	Heavy-Load	**Medium-Load**	**Light-Load**	
Replicate #1	41.2	36.6	32.4	43.5
Replicate #2	40.9	38.2	32.9	43.5
Replicate #3	41.1	38.6	33.9	43.8
Average	**41.1**	**37.8**	**33.0**	**43.6**
Standard Deviation	0.1	1.0	0.8	0.2
Absolute Uncertainty	0.3	2.5	1.9	0.5
Percent Uncertainty	0.6	6.7	5.7	1.0

Table D-18. Unit B Cooking-Energy Efficiency and Production Capacity Statistics.

	Cooking-Energy Efficiency			Production Capacity
	Heavy-Load	**Medium-Load**	**Light-Load**	
Replicate #1	58.5	54.9	44.7	61.4
Replicate #2	60.3	59.8	43.9	62.4
Replicate #3	58.5	55.6	45.0	56.3
Replicate #4	60.9	56.2	—	58.9
Average	**59.6**	**56.6**	**44.5**	**59.7**
Standard Deviation	1.2	2.2	0.6	2.7
Absolute Uncertainty	1.9	3.5	1.4	4.3
Percent Uncertainty	3.2	6.1	3.2	7.3

Cooking-Energy Efficiency Data

Table D-19. Unit C Cooking-Energy Efficiency and Production Capacity Statistics.

	Cooking-Energy Efficiency			Production Capacity
	Heavy-Load	**Medium-Load**	**Light-Load**	
Replicate #1	45.7	41.9	32.4	57.7
Replicate #2	47.0	41.6	31.4	58.9
Replicate #3	45.4	39.3	30.6	58.6
Average	**46.1**	**40.9**	**31.5**	**58.4**
Standard Deviation	0.9	1.4	0.9	0.6
Absolute Uncertainty	2.1	2.2	2.2	1.5
Percent Uncertainty	4.6	8.8	6.8	2.6