Paloma PF-12S Gas Fryer Performance Tests

Application of ASTM Standard
Test Method F 1361-05

FSTC Report 5011.07.06

Food Service Technology Center
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Prepared by:
David Cowen
David Zabrowski
Fisher-Nickel, Inc.

Contributors:
Scott Miner
Fisher-Nickel Inc.

Prepared for:
Pacific Gas & Electric Programs
P.O. Box 770000
San Francisco, California 94177

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Specific appreciation is extended to Paloma for supplying the FSTC with a gas fryer, Model PF-12S for controlled testing in the appliance laboratory.

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Executive Summary

Paloma's PF-12S gas fryer has an input rate of 70,000 Btu/h and features unique pulse combustion burners to transfer heat into the frying medium. A solid-state thermostat and cooking computer allows the operator to assign multiple cooking profiles for various food products. Figure ES-1 illustrates the PF-12S fryer, as tested at the Food Service Technology Center (FSTC).

Figure ES-1.
Paloma PF-12S Fryer.

FSTC engineers tested the fryer 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 four different loading scenarios (heavy—3 pounds per load, extra-heavy—4 pounds per load, medium—1½ pounds per load, and light—¾ pound per load). The PF-12S's heavy-load cook time was 2.19 minutes. Production capacity includes the cooking time and the time required for the frying medium to recover to 340°F (recovery time).

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

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

[1] American Society for Testing and Materials. 2005. *Standard Test Method for the Performance of Open, Deep Fat Fryers.* ASTM Designation F 1361-05, in *Annual Book of ASTM Standards,* West Conshohocken, PA.

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

Table ES-1. Summary of Fryer Performance.

Rated Energy Input Rate (Btu/h)	70,000
Measured Energy Input Rate (Btu/h)	72,155
Preheat Time to 350°F (min)	10.5
Preheat Energy to 350°F (Btu)	11,848
Idle Energy Rate @ 350°F (Btu/h)	3,420
Heavy-Load Cooking-Energy Efficiency (%)[a]	62.1 ± 1.1
Extra-Heavy Load Cooking-Energy Efficiency (%) [a]	66.4 ± 1.1
Medium-Load Cooking-Energy Efficiency (%)[a]	59.0 ± 4.4
Light-Load Cooking-Energy Efficiency (%)[a]	51.7 ± 2.9
Production Capacity (lb/h)[a]	72.4 ± 0.7
Average Frying Recovery Time (sec)[b]	18.0

[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 with a minimum 10-second preparation time between loads.

During heavy-load testing, Paloma's PF-12S gas fryer achieved a cooking-energy efficiency of 62.4%, while producing a 72.4 pounds of French fries per hour. The PF-12S required only 2.19 minutes to cook a single heavy-load test (3-pounds) of French fries, with the fryer recovered and ready-to-cook another load of French fries within 18 seconds.

Figure ES-2 illustrates the relationship between cooking-energy efficiency and production rate for the fryer. Figure ES-3 illustrates the relationship between the fryer's average energy consumption rate and the production rate. This graph can be used as a tool to estimate the daily energy consumption and probable demand contribution for the fryer in a real-world operation. Average energy consumption rates at 10, 30, and 50 pounds per hour for the PF-12S fryer are 13,000 Btu/h, 29,700 Btu/h, and 46,400 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 energy consumption rate for the PF-12S fryer would be 17,200 Btu/h.

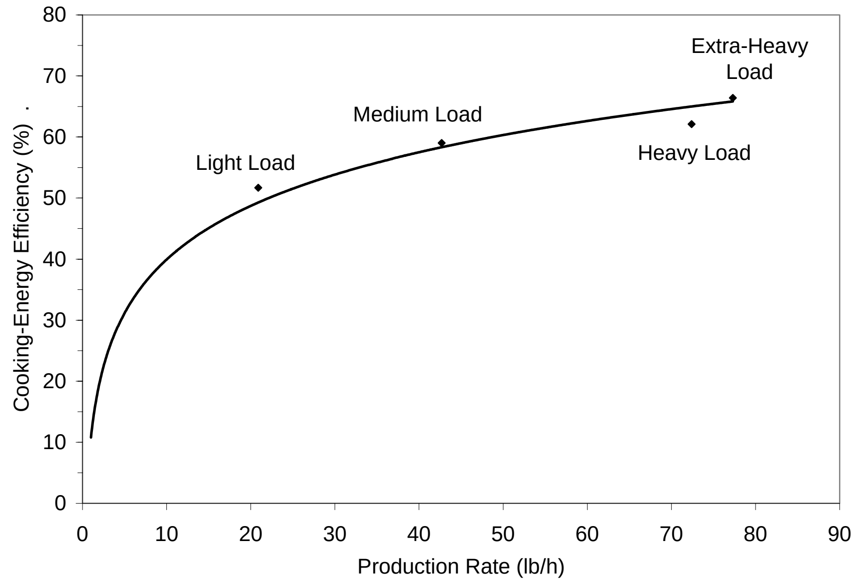

Figure ES-2.
Fryer part-load cooking-energy efficiency.

Note: Light-load = ¾ pounds/load; Medium-load = 1½ pounds/load; Heavy-load = 3 pounds/load, Extra-Heavy Load = 4 pounds/load.

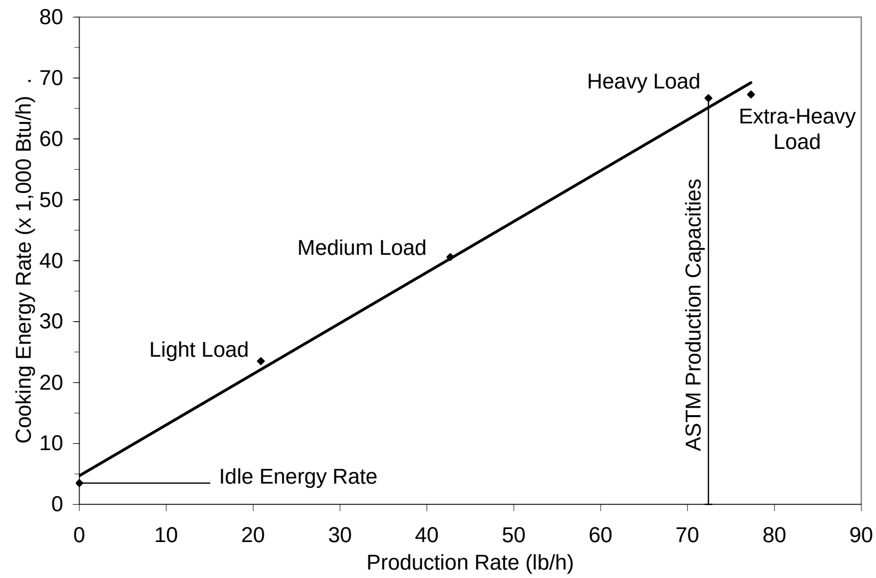

Figure ES-3.
Fryer cooking energy consumption profile.

Note: Light-load = ¾ pounds/load; Medium-load = 1½ pounds/load; Heavy-load = 3 pounds/load, Extra-Heavy Load = 4 pounds/load.

The ASTM test results can be used to estimate the annual energy consumption for the fryer in a real-world operation. A simple cost model was developed to calculate the relationship between the various cost components (e.g., preheat, idle and cooking costs) and the annual operating cost, using the ASTM test data. Table ES-2 summarizes the estimated annual energy consumption and associated cost based on the model.

Table ES-2. Estimated Fryer Energy Consumption and Cost.

Preheat Energy (kBtu/day)	11.9
Idle Energy (kBtu/day)	32.2
Cooking Energy (kBtu/day)	98.6
Annual Energy (kBtu/year)	52,044
Annual Cost ($/year)[a]	520

[a] Fryer energy costs are based on $1.00/therm = 100,000 Btu.

Executive Summary

The estimated operational cost of the PF-12S gas fryer is $520 per year. The model assumes the fryer is used to cook 100 pounds of French fries over a 12-hour day, 365 days a year. The model also assumes one preheat each day with the remaining on-time being in an idle (ready-to-cook) state.

Paloma's pulse combustion burner system provides short cook times and rapid oil temperature recovery during cooking. Food service operators will also appreciate the very low idle energy rate, giving a restaurateur a fryer that is both a workhorse and is low in cost to operate. With a heavy-load cooking-energy efficiency of 62.1% and a production rate of 72.4 lb/h Paloma's PF-12S pulse combustion gas fryer sits securely among the top performing gas fryers on the market.

1 Introduction

Background

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

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

The test methods, approved and ratified by the American Society for Testing and Materials (ASTM), allow benchmarking of equipment such that users can make meaningful comparisons among available equipment choices. Since the development of the ASTM test method for fryers in 1991[1,2], the FSTC has tested a wide range of gas and electric fryers.[3-23] 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.

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

Paloma's PF-12S features a stainless steal open frypot and backsplash design with pulse combustion heat exchanger tubes and a programmable cooking computer. An integrated melt cycle prevents solid frying medium from scorching during preheat.

This report presents the results of applying the ASTM test method to the Paloma PF-12S gas fryer. The glossary in Appendix A is provided so that the reader has a quick reference to the terms used in this report.

Objectives

The objective of this report is to examine the operation and performance of Paloma's PF-12S, 14-inch gas fryer at an input rating of 70,000 Btu/h 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 four French fry loading scenarios: heavy (3 pounds per load) extra-heavy (4 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.
6. Estimate the annual operating cost for the fryer using a standard cost model.

Appliance Description

Paloma's PF-12S, 14-inch gas fryer has an input rating of 70,000 Btu/h. The fry pot is of stainless steel construction with heat transferred into the frying medium through two looped pulse combustion heat exchangers located within the fry pot (see Figure 1-1). A cooking computer allows individualized programming for multiple food products.

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

Figure 1-1.
Paloma PF-12S frypot.

Table 1-1. Appliance Specifications.

Manufacturer	Paloma
Model	PF-12S
Generic Appliance Type	Open Deep Fat Fryer
Rated Input	70,000 Btu/h
Frying Area	14 5/8" x 14 13 5/8" x 17 1/2"
Oil Capacity	50 lb
Controls	Programmable cooking computer
Construction	Stainless Steel

2 Methods

Setup and 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 fryers and the edge of the hood. All test apparatus was installed in accordance with Section 9 of the ASTM test method.[1] See Figure 2-1.

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

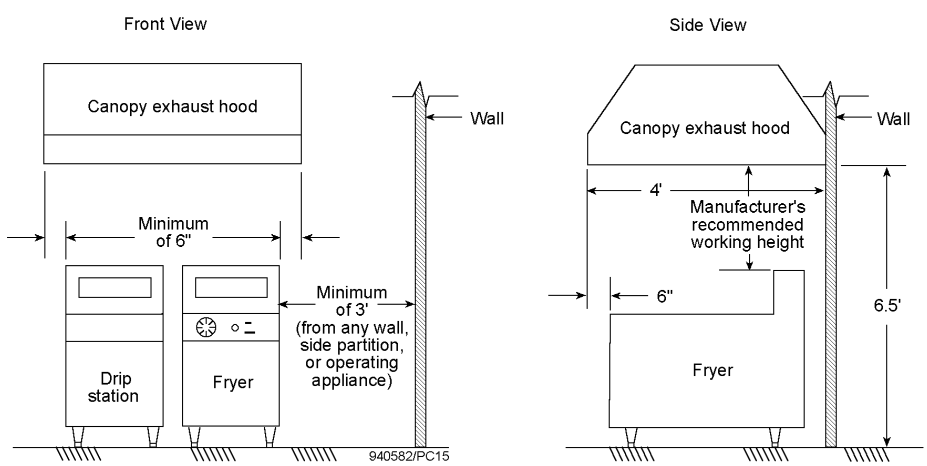

Figure 2-1.
Equipment configuration.

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).

Natural gas consumption was measured using a positive displacement-type gas meter that generated a pulse every 0.1 ft^3. The gas meter and the thermocouples were connected to an automated data acquisition unit that recorded data every 5 seconds. A Cutler-Hammer calorimeter was used 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.

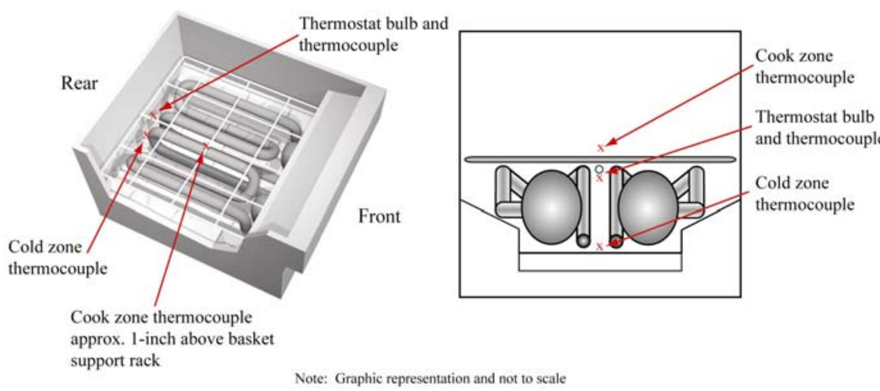

Figure 2-2. Thermocouple placement for testing.

Measured Energy Input Rate

Rated energy input rate is the maximum or peak rate at which the fryer consumes energy—as specified on the fryer's nameplate. Measured energy input rate is the maximum or peak rate of energy consumption, which is recorded during a period when the burners are firing (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 had been established. Researchers compared the measured energy input rate with the nameplate energy input rate to ensure that the fryer was operating properly.

Cooking Tests

Researchers specified ¼-inch, blue ribbon product, par-cooked, frozen shoe-string 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), 4-pound (extra-heavy), 1 ½-pound (medium), and ¾-pound (light) French fry loads.

Due to the logistics involved in removing one load of cooked French fries and placing another load into the fryer, a minimum preparation time of 10 seconds was incorporated into the cooking procedure. This ensures that the cooking tests are uniformly applied from laboratory to laboratory. Fryer recovery was then based on the frying medium reaching a threshold temperature of 340°F (measured at the center of the cook zone). Reloading within 10°F of the 350°F thermostat set point did not significantly lower the average oil temperature over the cooking cycle, nor did it extend the cook time. The fryer was reloaded either after the cook zone thermocouple reached the threshold temperature or 10 seconds after removing the previous load from the fryer, whichever was longer.

The first load of each six-load cooking test was designated as a stabilization load and was not counted when calculating the elapsed time and energy consumed. Energy monitoring and elapsed time of the test were determined after the second load contacted the frying medium. After removing the last load and allowing the fryer to recover, researchers terminated the test. Total elapsed time, energy consumption, weight of fries cooked, and average weight loss of the French fries were recorded for the last five loads of the six-load test.

Each loading scenario (heavy, medium and light) was replicated a minimum of three times. This procedure ensured that the reported cooking-energy efficiency and production capacity results had an uncertainty of less than ±10%. The results from each test run were averaged, and the absolute uncertainty was calculated based on the standard deviation of the results.

The ASTM results reporting sheets appear in Appendix C.

Energy Cost Model

Fryer operating cost was calculated based on a combination of test data and assumptions about typical fryer usage. This provides a standard method for estimating fryer energy consumption based on ASTM performance test results. The examples contained in the operating cost model are for informational purposes only, and should not be considered an absolute.

The model assumed a typical twelve-hour day, with the operation being broken down into three operating scenarios; preheat, idle and cooking. One preheat is assumed per day with the remainder being split between idle and cooking periods. During the day, 100 lbs. of food would be cooked; 70% under heavy-load (two 1.5 lb baskets) conditions with the remaining 30% under light-load (one 0.75 lb basket) conditions. The idle time was calculated as the total time of operation minus preheat and cooking times. The total daily energy usage was calculated based on the fryer's energy consumption in each of these operating scenarios. The cost model assumptions are listed in Table 2-1.

Details of this calculation can be found in Appendix E of this report.

3 Results

Energy Input Rate

Prior to testing, the energy input rate was measured and compared with the manufacturer's nameplate value. This procedure ensured that the fryer was operating within its specified parameters. The measured energy input rate was 72,155 Btu/h (a difference of 3.08% from the nameplate rating).

Preheat and Idle Tests

These tests show how the fryer uses energy when it is not cooking food. The preheat time allows an operator to know precisely how long it takes for the fryer to be ready to cook. The idle energy rate represents the energy required to maintain the set temperature of 350°F, or the appliance's stand-by losses.

Preheat Energy and Time

Researchers filled the fryer with new oil, which was then heated to 350°F at least once prior to any testing. The preheat tests were conducted at the beginning of a test day, after the oil had stabilized at room temperature overnight. Paloma's cooking computer has an integrated melt cycle to prevent scorching of solid shortening, but this feature was disabled to accommodate the liquid shortening specified by the ASTM test procedure. Paloma's PF-12S fryer was ready to cook in 10.5 minutes, while consuming 11,848 Btu during preheat. Figure 3-1 shows the fryer's preheat characteristics.

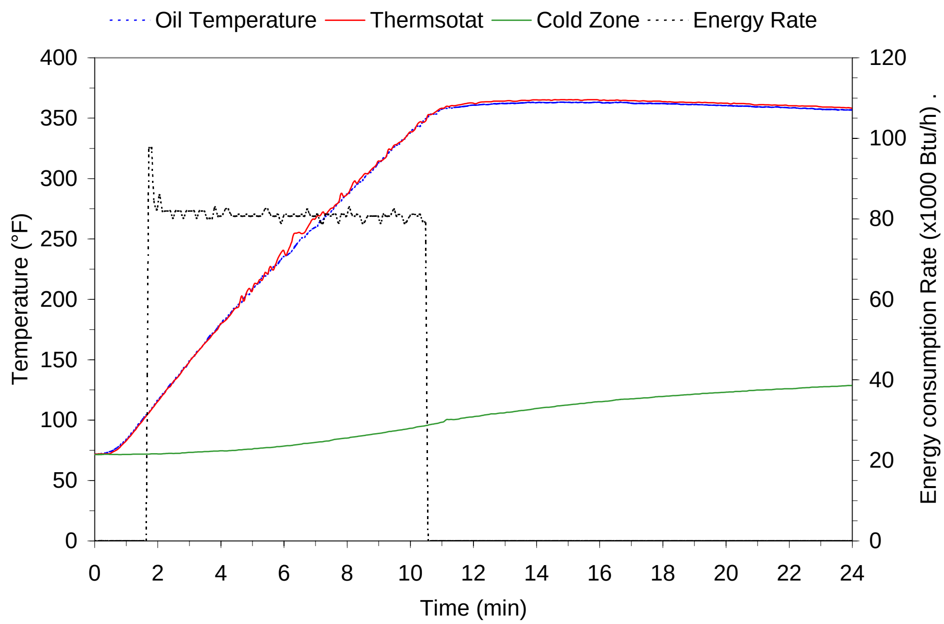

Figure 3-1.
Paloma PF-12S preheat characteristics.

Idle Energy Rate

Once the frying medium reached 350°F, the fryer was allowed to stabilize for half an hour. Time and energy consumption was monitored for an additional two-hour period as each fryer maintained the oil at 350°F. The idle energy rate during this period was 3,420 Btu/h.

Test Results

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

Results

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

Rated Energy Input Rate (Btu/h)	70,000
Measured Energy Input Rate (Btu/h)	72,155
Percentage Difference (%)	3.08
Preheat	
Time to 350°F (min)	10.5
Energy Consumption (Btu)	11,848
Control Energy (Wh)	7.40
Preheat Rate to 350°F (°F/min)	26.6
Idle	
Gas Energy Rate (Btu/h)	3,420
Control Energy Rate (W)	13.3

Cooking Tests

The fryer was tested under four loading scenarios: heavy (3 pounds of fries per load), extra-heavy (4pounds per load), medium (1½ pounds of fries per load) and light (¾ pound of fries per load). The fries used for the cooking tests consisted of approximately 6% fat and 70% moisture. Researchers monitored French fry cook time and weight loss, frying medium recovery time, and fryer energy consumption during these tests.

Heavy-Load Tests

The heavy-load cooking tests were designed to reflect a fryer's maximum performance. The fryer was 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. Figures 3-2 shows the average temperature of the frying medium at the center of the cook zone during the heavy-load tests.

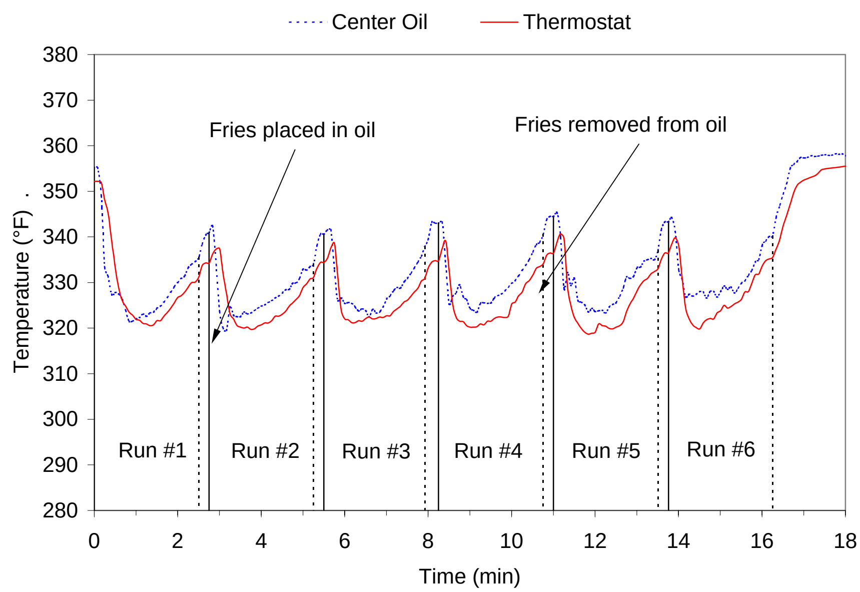

Figure 3-2.
Frying medium temperarture during a heavy-load test for the PF-12S fryer.

The first load was used to stabilize the fryer, and the remaining five loads were used to calculate cooking-energy efficiency and production capacity. The average frying medium temperature during the heavy-load tests was 328°F. The heavy-load cook time for the fryer was 2.19 minutes, and the fryer was recovered within the 10-second reload time. Figure 3-3 illustrates the temperature response of the Paloma fryer while cooking a 3-pound load of frozen French fries. Production capacity includes the time required to remove the cooked fries and reload the fryer with a new batch of frozen fries (approximately 10 seconds per load).

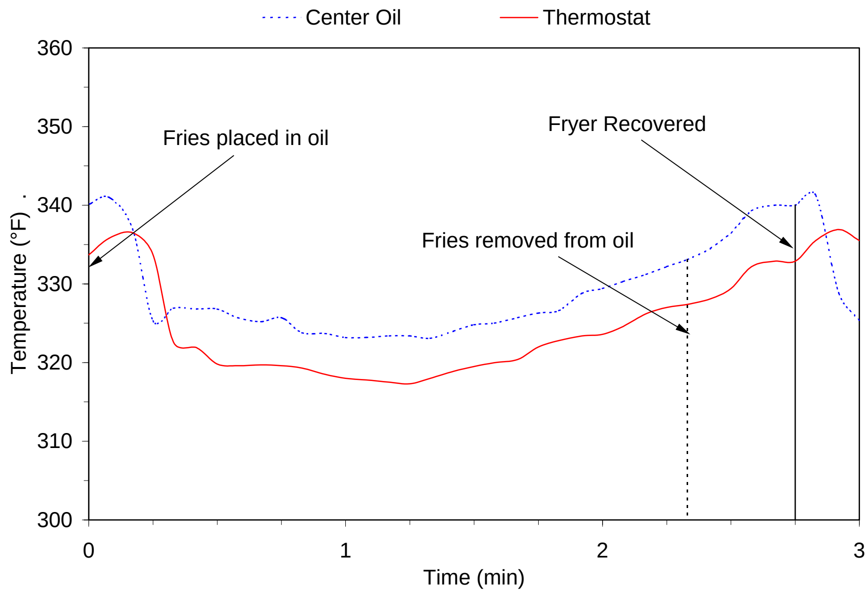

Figure 3-3.
Fryer cooking cycle temperature signature.

Due to the fryer's performance during heavy-load testing FSTC researchers decided to apply the optional 4-pound extra-heavy French fry load to the fryer. These extra-heavy load tests run in the same manner as the heavy-load tests, with one load for stabilization and five additional loads for determining fryer efficiency and productivity.

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.

Both the medium- and light-load tests were conducted using a single fry basket. The medium-load tests used 1½ pounds of fries per load and demonstrated a cooking-energy efficiency of 59.0%, while producing 42.7 pounds of cooked French fries per hour. The light load tests used ¾ pounds of fries per load and resulted in a cooking-energy efficiency of 51.7% at a production rate of 20.9 lb/h.

Test Results

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

Heavy-load cooking-energy efficiency results were 62.2%, 61.6% and 62.5%, yielding a maximum uncertainty of 1.1%. Researchers felt that based on the heavy-load test data that the Paloma fryer could handle the optional extra-heavy load (4-pound) test. Table 3-2 summarizes the results of the heavy-load and optional extra-heavy load cooking-energy efficiency and production capacity tests.

Table 3-2. Heavy- and Extra-Heavy Load Cooking-Energy Efficiency Results.

	Heavy Load	Extra Heavy Load
Load Size (lb)	3.0	4.0
French Fry Cook Time (min)	2.19	2.59
Average Recovery Time (sec)	18.0	31.2
Production Rate (lb/h) [a]	72.4 ± 0.7	77.3 ± 0.8
Energy to Food (Btu/lb)	573	579
Cooking Energy Rate (Btu/h)	66,703	67,284
Control Energy Rate (W)	40.7	40.0
Energy per Pound of Food Cooked (Btu/lb)	923	872
Cooking-Energy Efficiency (%)[a]	62.1 ± 1.1	66.4 ± 1.1

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

Table 3-3 summarizes the results of the medium- and light-load cooking tests.

Table 3-3. Medium- and Light-Load Cooking-Energy Efficiency Results.

	Medium-Load	Light-Load
Load Size (lb)	1 ½	¾
French Fry Cook Time (min)	1.93	1.99
Average Recovery Time (sec)	< 10	< 10
Production Rate (lb/h) [a]	42.7 ± 2.3	20.9 ± 0.3
Energy to Food (Btu/lb)	563	585
Cooking Energy Rate (Btu/h)	40,581	23,509
Control Energy Rate (W)	33.3	27.3
Energy per Pound of Food Cooked (Btu/lb)	954	1,133
Cooking-Energy Efficiency (%)[a]	59.0 ± 4.4	51.7 ± 2.9

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

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

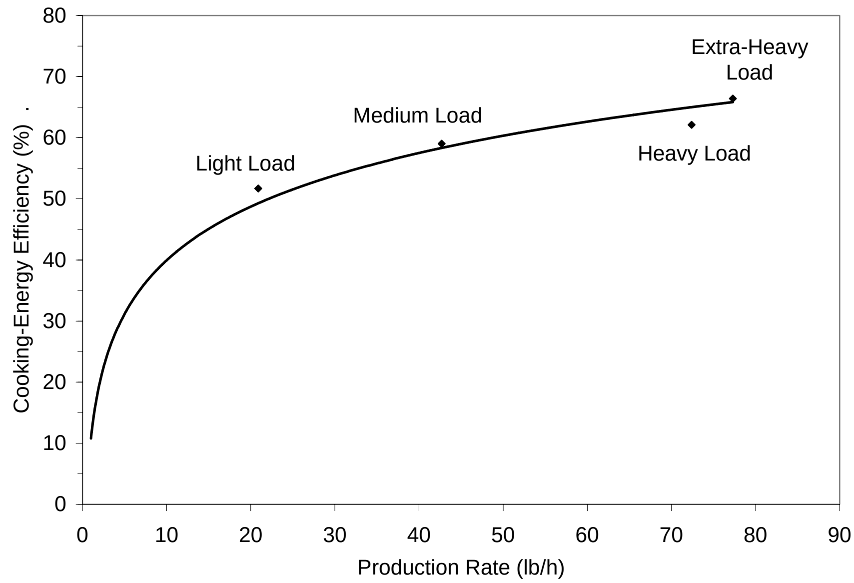

Figure 3-4.
Fryer part-load cooking-energy efficiency.

Note: Light-load = ¾ pounds/load; Medium-load = 1½ pounds/load; Heavy-load = 3 pounds/load, Extra-Heavy Load = 4 pounds/load.

Figure 3-5 illustrates the relationship between the fryer's average energy consumption rate and the production rate. This graph can be used as a tool to estimate the daily energy consumption for the fryer in a real-world operation. Average energy consumption rates at 10, 30, and 50 pounds per hour were 13,000 Btu/h, 29,700 Btu/h, and 46,400 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 energy consumption rate for this fryer would be 17,200 Btu/h.

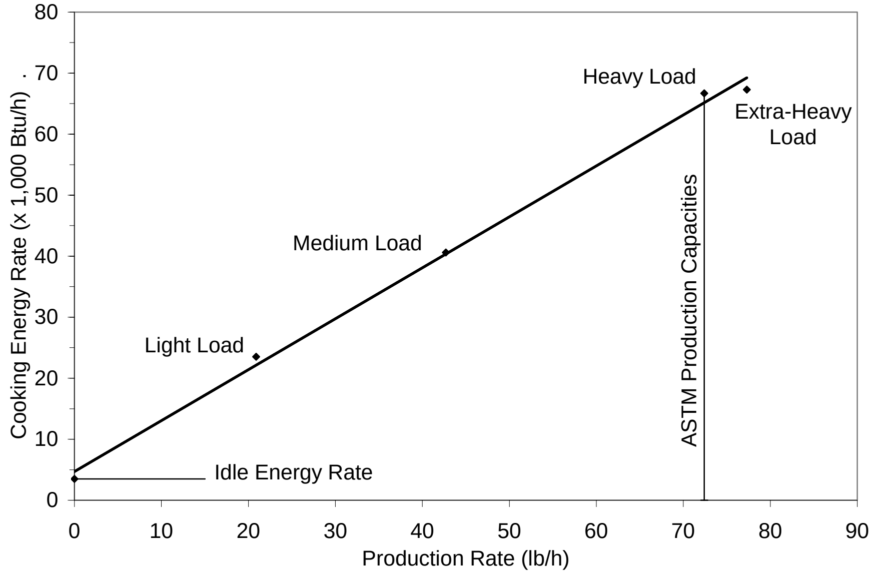

Figure 3-5.
Fryer cooking energy consumption profile.

Note: Light-load = ¾ pounds/load; Medium-load = 1½ pounds/load; Heavy-load = 3 pounds/load, Extra-Heavy Load = 4 pounds/load.

Energy Cost Model

The test results can be used to estimate the annual energy consumption for the fryer in a real-world operation. A simple cost model was developed to calculate the relationship between the various cost components (e.g., preheat, idle and cooking costs) and the annual operating cost, using the ASTM test data. For this model, the fryer was used to cook 100 pounds of fries over a 12-hour day, with one preheat per day, 365 days per year. The idle (ready-to-cook) time for the fryer was determined by taking the difference between the total daily on-time (12 hours) and the equivalent full-load cooking time. This approach produces a more accurate estimate of the operating cost for the fryer. Table 3-4 summarizes the estimated energy consumption and cost based on the model.

Table 3-4. Estimated Fryer Energy Consumption and Cost.

Preheat Energy (kBtu/day)	11.9
Idle Energy (kBtu/day)	32.2
Cooking Energy (kBtu/day)	98.6
Annual Energy (kBtu/year)	52,044
Annual Cost ($/year)[a]	520

[a] Fryer energy costs are based on $1.00/therm = 100,000 Btu.

4 Conclusions

Paloma's PF-12S gas pulse combustion fryer was successfully tested at the Food Service Technology Center. The fryer demonstrated high cooking-energy efficiencies, excellent production capacity and an impressively low idle energy rate. Paloma's PF-12S fryer features unique pulse combustion heat exchangers. Gas enters a combustion chamber at the front of the fry vat where it is ignited. The combustion gases enter a tube that travels through the fry vat where heat is transferred into the frying medium. This heat exchanger proved to be very affective. The fryer required only 10.5 minutes to reach a ready-to-cook (preheat) state of 350°F.

The PF-12S fryer performed very well under heavy-load testing in comparison to other gas fryers tested at the Food Service Technology Center (FSTC).[7-24] The fryer cooked a single heavy-load test (3-pounds) of French fries in a rapid 2.19 minutes, with the fryer recovered and ready to cook another load of French fries in 18 seconds. During heavy-load testing, the PF-12S fryer achieved an impressive respectable production capacity of 72.4 pounds of French fries per hour, while demonstrating a competitive cooking-energy efficiency of 62.1%.

Researchers felt that based on the heavy-load performance the fryer could handle even heavier loading. An optional series of extra-heavy (4-pound) load tests confirmed this with a 6.5% increase in efficiency and a 5.0 lb/h boost in production capacity.

During partial-load cooking the PF-12S fryer posted excellent results with a medium-load efficiency of 59.0% and a light-load efficiency of 51.7%. Since most food service establishments operate at an average of 15 pounds per hour over a typical day, these performance figures are more representative of real world application.

Conclusions

Studies have shown that fryers spend a good portion of the day in a ready-to-cook standby (idle) mode.[24] The PF-12S exhibited very low idle energy rate of 3,420 Btu/h, which could be contributed in part to the uniquely designed pulse combustion heat exchangers. To a restaurateur, this low idle rate means lower operating costs.

The estimated operational cost of the PF-12S gas fryer is $520 per year. The model assumes the fryer is used to cook 100 pounds of French fries over a 12-hour day, 365 days a year. The model also assumes one preheat each day, with the remaining on-time being an idle (ready-to-cook) state.

Paloma's PF-12S pulse combustion gas heat exchangers transfer heat into the frying medium easily and effectively, allowing the fryer to have lower standby losses. Quick response times and rapid oil temperature recovery during cooking provide a food service operator with a workhorse fryer that can handle high production volumes.

5 References

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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.

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

Glossary

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

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

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

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

Preheat Energy (kWh or Btu)
Preheat Energy Consumption

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

Preheat Rate (°F/min)

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

Preheat Time (minute)
Preheat Period

The time required for an appliance to warm from the ambient room temperature (75 ± 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 Appliance Specifications

Appendix B includes the product literature for the Paloma PF-12S fryer.

Table B-1. Appliance Specifications.

Manufacturer	Paloma
Model	PF-12S
Generic Appliance Type	Open Deep Fat Fryer
Rated Input	70,000 Btu/h
Frying Area	14 5/8" x 14 13 5/8" x 17 1/2"
Oil Capacity	50 lb
Controls	Programmable cooking computer
Construction	Stainless Steel

For more information,

Please visit our web site, **www.palomaglobal.com**

The Paloma Group is a privately held manufacturing company that began in 1911 as a pioneer in the gas appliance industry. Paloma craftsmanship is built on superior quality, advanced engineering and technical innovation. Today, Paloma is the leading and the largest producer of gas appliances and HVAC throughout the world.

The Paloma Group
World Headquarters

6-23 Momozono-cho, Mizuho-ku,
Nagoya 4678585, JAPAN
+81 52 824 5031 phone
+81 52 824 4366 fax
pa_gscm@paloma.co.jp
export4@paloma.co.jp

C Results Reporting Sheets

Manufacturer: Paloma

Models: PF-12S

Date: February 2007

Test Fryer and Burner.

Description of operational characteristics: The Paloma PF-12S gas fryer is rated at 70,000 Btu/h and features two pulse combustion heat transfer tubes, which are submerged in the frying medium and run from the front of the fryvat to the rear and back again, exiting at the fron of the frypot. The fryer is controlled by a solid state thermostat and a cooking computer which allows the operator to assign multiple cooking profiles for various food products.

Apparatus.

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

Deviations: The cook zone thermostat was raised from 1 inch above the fryer grate to 1½ inch above the fryer grate.

Energy Input Rate.

Name Plate (Btu/h)	70,000
Measured (Btu/h)	72,155
Percentage Difference (%)	3.08

Oil Capacity

Oil Capacity (lbs)	54.0

Results Reporting Sheets

Water Boil

Water Boil Efficiency (%) [a]	75.3 ± 0.4
Average Flue Temperature (°F) [b]	382

[a] This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.
[b] flue temperatures averaged from both left and right flue stacks.

Preheat Energy and Time.

Starting Temperature (°F)	71.9
Energy Consumption (Btu)	11,848
Control Energy (Wh)	7.40
Duration (min)	10.5
Preheat Rate (°F/min)	26.6

Idle Energy Rate.

Gas Energy Rate (Btu/h)	3,420
Control Energy Rate (W)	13.3

Heavy-Load Cooking-Energy Efficiency and Cooking Energy Rate.

Load Size (lb)	3.0
French Fry Cook Time (min)	2.19
Average Recovery Time (sec)	18.0
Production Rate (lb/h) [a]	72.4 ± 0.7
Energy to Food (Btu/lb)	573
Cooking Energy Rate (Btu/h)	66,703
Control Energy (W)	40.5
Energy per Pound of Food Cooked (Btu/lb)	923
Cooking Energy Efficiency (%)[a]	62.1 ± 1.1

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

Results Reporting Sheets

Medium-Load Cooking-Energy Efficiency and Cooking Energy Rate.

Load Size (lb)	1.5
French Fry Cook Time (min)	1.93
Average Recovery Time (sec)	< 10
Production Rate (lb/h) [a]	42.7 ± 2.3
Energy to Food (Btu/lb)	562
Cooking Energy Rate (Btu/h)	40,581
Control Energy (W)	33.3
Energy per Pound of Food Cooked (Btu/lb)	954
Cooking Energy Efficiency (%)[a]	59.0 ± 4.4

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

Light-Load Cooking-Energy Efficiency and Cooking Energy Rate.

Load Size (lb)	0.75
French Fry Cook Time (min)	1.99
Average Recovery Time (sec)	< 10
Production Rate (lb/h)	20.9 ± 0.3
Energy to Food (Btu/lb) [a]	585
Cooking Energy Rate (Btu/h)	23,509
Control Energy (W)	27.3
Energy per Pound of Food Cooked (Btu/lb)	1,133
Cooking Energy Efficiency (%)[a]	51.7 ± 2.9

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

Optional Extra-Heavy Load Cooking-Energy Efficiency and Cooking Energy Rate. [a]

Load Size (lb)	4.0
French Fry Cook Time (min)	2.59
Average Recovery Time (sec)	31.2
Production Rate (lb/h) [a]	77.3 ± 0.8
Energy to Food (Btu/lb)	579
Cooking Energy Rate (Btu/h)	67,284
Control Energy (W)	40.0
Energy per Pound of Food Cooked (Btu/lb)	872
Cooking Energy Efficiency (%) [a]	66.4 ± 1.1

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

Combustion Analysis

Apparatus and Procedure.

Description of analyzer and procedure: An Enerac Model 500 Micro-Emissions Analyzer was used for the combustion analysis on the Paloma PF-12S gas fryer. The analyzer probe was inserted approximately 1-inch into each exhaust stack; during the analysis the fryer was under continuous heavy-load cooking. The exhaust gases from the fryer were monitored for approximately 5 minutes per stack.

Combustion Analysis

	Left Exhaust Stack	Right Exhaust Stack
Efficiency of Exhaust Air (%)	81.4	80.6
Oxygen (%)	4.0	4.3
CO (PPM)	83	80
CO_2 (%)	9.4	9.3
Air Percentage in the Exhaust Air (%)	21	22
NO_x (PPM)	< 5	< 5
Exhaust Air Temperature (°F)	413	438

D 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. Heavy-Load Fry Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Electrical Energy Consumption (Wh)	8.48	8.40	8.50
Gas Energy Consumption (Btu)	13,918	13,808	13,719
Cook Time (min)	2.17	2.20	2.20
Total Test Time (min)	12.5	12.4	12.4
Weight Loss (%)	30.6	30.20	30.40
Initial Weight (lb)	15.000	15.000	15.000
Final Weight (lb)	10.412	10.470	10.444
Initial Moisture Content (%)	68.6	68.6	68.6
Final Moisture Content (%)	49.5	50.7	50.2
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	10.290	10.290	10.290
Final Weight of Water (lb)	5.154	5.308	5.243
Sensible (Btu)	2,210	2,210	2,210
Latent – Heat of Fusion (Btu)	1,482	1,482	1,482
Latent – Heat of Vaporization (Btu)	4,982	4,833	4,896
Total Energy to Food (Btu)	8,674	8,525	8,588
Energy to Food (Btu/lb)	578	568	573
Total Energy to Fryer (Btu)	13,947	13,837	13,747
Energy to Fryer (Btu/lb)	930	922	916
Cooking-Energy Efficiency (%)	62.2	61.6	62.5
Cooking Energy Rate (Btu/h)	66,913	66,813	67,382
Control Energy Rate (W)	40.8	40.7	40.2
Production Rate (lb/h)	72.1	72.6	72.6
Average Recovery Time (sec)	19.8	16.8	16.8

Cooking-Energy Efficiency Data

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

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Electrical Energy Consumption (Wh)	5.80	6.00	5.70
Gas Energy Consumption (Btu)	7,251	7,521	6,903
Cook Time (min)	1.98	1.92	1.90
Total Test Time (min)	10.8	10.4	10.4
Weight Loss (%)	30.70	30.00	29.30
Initial Weight (lb)	7.500	7.500	7.500
Final Weight (lb)	5.194	5.250	5.302
Initial Moisture Content (%)	68.6	68.6	68.6
Final Moisture Content (%)	51.6	51.8	50.8
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	5.145	5.145	5.145
Final Weight of Water (lb)	2.680	2.720	2.693
Sensible (Btu)	1,105	1,105	1,105
Latent – Heat of Fusion (Btu)	741	741	741
Latent – Heat of Vaporization (Btu)	2,391	2,353	2,378
Total Energy to Food (Btu)	4,237	4,199	4,224
Energy to Food (Btu/lb)	565	560	563
Total Energy to Fryer (Btu)	7,271	7,271	6,922
Energy to Fryer (Btu/lb)	969	969	923
Cooking-Energy Efficiency (%)	58.3	57.7	61.0
Cooking Energy Rate (Btu/h)	40,246	41,672	39,825
Control Energy Rate (W)	32.2	34.6	32.9
Production Rate (lb/h)	41.6	43.1	43.3
Average Recovery Time (sec)	< 10	< 10	< 10

Cooking-Energy Efficiency Data

Table D-4. Light Load Fry Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Electrical Energy Consumption (Wh)	4.97	4.90	4.80
Gas Energy Consumption (Btu)	4,315	4,114	4,265
Cook Time (min)	2.00	2.00	1.97
Total Test Time (min)	10.8	10.8	10.7
Weight Loss (%)	30.60	30.30	30.50
Initial Weight (lb)	3.750	3.750	3.750
Final Weight (lb)	2.604	2.612	2.607
Initial Moisture Content (%)	68.6	68.6	68.6
Final Moisture Content (%)	48.2	48.5	48.6
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	2.573	2.573	2.573
Final Weight of Water (lb)	1.255	1.267	1.267
Sensible (Btu)	553	553	553
Latent – Heat of Fusion (Btu)	371	371	371
Latent – Heat of Vaporization (Btu)	1,278	1,267	1,267
Total Energy to Food (Btu)	2,202	2,191	2,191
Energy to Food (Btu/lb)	587	584	584
Total Energy to Fryer (Btu)	4,332	4,131	4,281
Energy to Fryer (Btu/lb)	1,155	1,102	1,142
Cooking-Energy Efficiency (%)	50.8	53.0	51.2
Cooking Energy Rate (Btu/h)	23,906	22,771	23,849
Control Energy Rate (W)	27.6	27.2	26.9
Production Rate (lb/h)	20.8	20.8	21.0
Average Recovery Time (sec)	< 10	< 10	< 10

Cooking-Energy Efficiency Data

Table D-5. Optional Extra-Heavy Load Fry Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Electrical Energy Consumption (Wh)	10.4	10.4	10.3
Gas Energy Consumption (Btu)	17,382	17,432	17,432
Cook Time (min)	2.57	2.60	2.60
Total Test Time (min)	15.5	15.5	15.6
Weight Loss (%)	29.80	29.80	30.30
Initial Weight (lb)	20.000	20.000	20.000
Final Weight (lb)	14.046	14.047	13.939
Initial Moisture Content (%)	68.6	68.6	68.6
Final Moisture Content (%)	48.3	48.7	49.6
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	13.720	13.720	13.720
Final Weight of Water (lb)	6.784	6.841	6.914
Sensible (Btu)	2,947	2,947	2,947
Latent – Heat of Fusion (Btu)	1,976	1,976	1,976
Latent – Heat of Vaporization (Btu)	6,728	6,673	6,602
Total Energy to Food (Btu)	11,651	11,596	11,525
Energy to Food (Btu/lb)	583	580	576
Total Energy to Fryer (Btu)	17,417	17,467	17,467
Energy to Fryer (Btu/lb)	871	873	873
Cooking-Energy Efficiency (%)	66.9	66.4	66.0
Cooking Energy Rate (Btu/h)	67,329	67,479	67,046
Control Energy Rate (W)	40.2	40.3	39.6
Production Rate (lb/h)	77.5	77.4	76.9
Average Recovery Time (sec)	31.8	30.0	31.2

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

	Cooking-Energy Efficiency (%) [a]				Production Capacity
	Extra-Heavy Load	Heavy-Load	Medium-Load	Light-Load	(lbs/h) [a]
Replicate #1	66.9	62.2	58.3	50.8	72.1
Replicate #2	66.4	61.6	57.7	53.0	72.6
Replicate #3	66.0	62.5	61.0	51.2	72.6
Average	66.4	62.1	59.0	51.7	72.4
Standard Deviation	0.45	0.46	1.76	1.17	0.29
Absolute Uncertainty	1.12	1.14	4.36	2.90	0.72
Percent Uncertainty	1.69	1.84	7.39	5.61	0.99

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

E Energy Cost Model

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

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

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

The calculation will proceed as follows: First, determine the appliance operating time and total number of preheats. Then estimate the quantity of food cooked and establish the breakdown between heavy- (two 1½-lb baskets) and light- (one ¾-lb basket) loads. For example, a fryer operating for 12 hours a day with one preheat cooked 100 pounds of food: 70% of the food was cooked under heavy-load conditions and 30% was cooked under light-load conditions. Calculate the energy due to cooking at heavy- and light-load cooking rates, and then calculate the idle energy consumption. The total daily energy is the sum of these components plus the preheat energy. For simplicity, it is assumed that subsequent preheats require the same time and energy as the first preheat of the day.

The application of the test method to a gas fryer yielded the following results:

Table E-1: Gas Fryer Performance Parameters.

Test	Result
Preheat Time (min)	10.5
Preheat Energy (Btu)	11,848
Idle Energy Rate (Btu/h)	3,420
Heavy-Load Cooking Energy Rate (Btu/h)	66,703
Light-Load Cooking Energy Rate (Btu/h)	23,509
Production Capacity (lb/h)	72.4
Light-Load Production Rate (lb/h)	20.9

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

Table E-2: Fryers Operation Assumptions.

Operating Time	12 h
Number of Preheats	1 preheat
Total Amount of Food Cooked	100 lb
Percentage of Food Cooked Under Heavy-Load Conditions	70% (× 100 lb = 70 lb)
Percentage of Food Cooked Under Light-Load Conditions	30% (× 100 lb = 30 lb)

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

The total time cooking heavy-loads is as follows:

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

$$t_h = \frac{70\% \times 100\ lb}{72.4\ lb/h},$$

$$t_h = 0.97\ h$$

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

$$E_{gas,h} = q_{gas,h} \times t_h,$$

$$E_{gas,h} = 66{,}703 \text{ Btu/h} \times 0.97 \text{ h},$$

$$E_{gas,h} = 64{,}702 \text{ Btu}$$

***Step 3*—Calculate the total light-load energy.**

The total time cooking light-loads is as follows:

$$t_l = \frac{\%_l \times W}{PR_l},$$

$$t_l = \frac{30\% \times 100 \text{ lb}}{20.9 \text{ lb/h}},$$

$$t_l = 1.44 \text{ h}$$

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

$$E_{gas,l} = q_{gas,l} \times t_l,$$

$$E_{gas,l} = 23{,}509 \text{ Btu/h} \times 1.44 \text{ h}$$

$$E_{gas,l} = 33{,}853 \text{ Btu}$$

***Step 4*—Calculate the total idle time and energy consumption.**

The total idle time is determined as follows:

$$t_i = t_{on} - t_h - t_l - \frac{n_p \times t_p}{60},$$

$$t_i = 12.0 \text{ h} - 0.97 \text{ h} - 1.44 \text{ h} - \frac{1 \text{ preheat} \times 10.5 \text{ min}}{60 \text{ min/h}}$$

$$t_i = 9.41 \text{ h}$$

The idle energy consumption is then calculated as follows:

$$E_{gas,i} = q_{gas,i} \times t_i,$$

$$E_{gas,i} = 3{,}420 \text{ Btu/h} \times 9.41 \text{ h}$$

$$E_{gas,i} = 32{,}182 \text{ Btu}$$

***Step 5*—The total daily energy consumption is calculated as follows:**

$E_{gas,daily} = E_{gas,h} + E_{gas,l} + E_{gasc,i} + n_p \times E_{gas,p}$,

$E_{gas,daily}$ = 64,702 Btu + 33,853 Btu + 32,182 Btu +1 × 11,848 Btu

$E_{gas,daily}$ = 142,585 Btu/day = 1.426 therms/day

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

$Cost_{annual} = E_{gas,daily} \times R_{gas} \times Days$

$Cost_{snnual}$ = 1.426 therms/day × 1.00 \$/therm × 365 days/year

$Cost_{annual}$ = 520 \$/year