Henny Penny OFE-341 22.0 kW
Electric Fryer Performance Tests

Application of ASTM Standard
Test Method F 1361-99

FSTC Report 5011.05.17

Food Service Technology Center
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Specific appreciation is extended to Henny Penny for supplying the FSTC with an electric fryer, Model OFE-341 for controlled testing in the appliance laboratory.

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Henny Penny OFE-341 Fryer.

Henny Penny's OFE-341 large-vat electric fryer features low watt density ribbon elements, stainless steel construction, and a programmable cooking computer that controls the input to the fryer and provides for a more consistent product. Figure ES-1 illustrates the OFE-341 fryer, as tested at the Food Service Technology Center (FSTC).

FSTC engineers tested the fryer under the tightly controlled conditions of the American Society for Testing and Materials' (ASTM) standard test method.[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 breaded 8-piece cut 2 ¾ pound frying chicken under three load scenarios: heavy—48 pieces per load, medium—24 pieces per load, and light—8 pieces per load. The OFE-341's heavy-load cook time was 15.4 minutes. Production capacity includes the cooking time and the time required for the frying medium to recover to 320°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:

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

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[1] American Society for Testing and Materials. 2000. *Standard Test Method for the Performance of Large Open, Deep Fat Fryers.* ASTM Designation F 2144-01, 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.

Rated Energy Input Rate (kW)	22.0
Measured Energy Input Rate (kW)	21.1
Preheat Time to 325°F (min)	9.93
Preheat Energy to 325°F (kWh)	2.10
Idle Energy Rate @ 325°F (kW)	1.08
Heavy-Load Cooking-Energy Efficiency (%)[a]	73.0 ± 2.4
Medium-Load Cooking-Energy Efficiency (%)[a]	72.8 ± 3.6
Light-Load Cooking-Energy Efficiency (%)[a]	51.0 ± 3.9
Production Capacity (lb/h)[a]	68.9 ± 4.3

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

The fryer’s 22.0 kW input provided the necessary horsepower to produce a very competitive heavy-load (48 pieces) cooking-energy efficiency of 73.0% and a production capacity of 68.9 lbs/h. During testing, the OFE-341 was able to cook the heavy-load of chicken in a very fast 15.4 minutes.

Figure ES-2 illustrates the relationship between cooking-energy efficiency and production rate for the fryer.

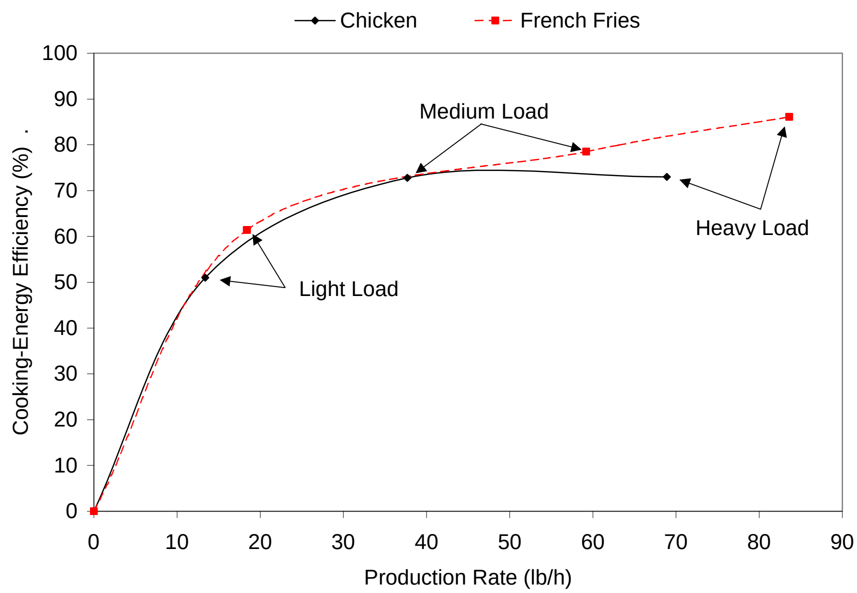

Figure ES-2.
Fryer part-load cooking-energy efficiency.

Note: Light-load = 8 pieces/load; Medium-load = 24 pieces/load; Heavy-load = 48 pieces/load.

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 OFE-341 fryer are 2.3 kW, 4.9 kW, and 7.5 kW respectively. For an operation cooking an average of 15 pounds of food per hour over the course of the day (e.g., 150 lb of food over a ten hour day), the probable demand contribution for the OFE-341 fryer would be 3.0 kW.

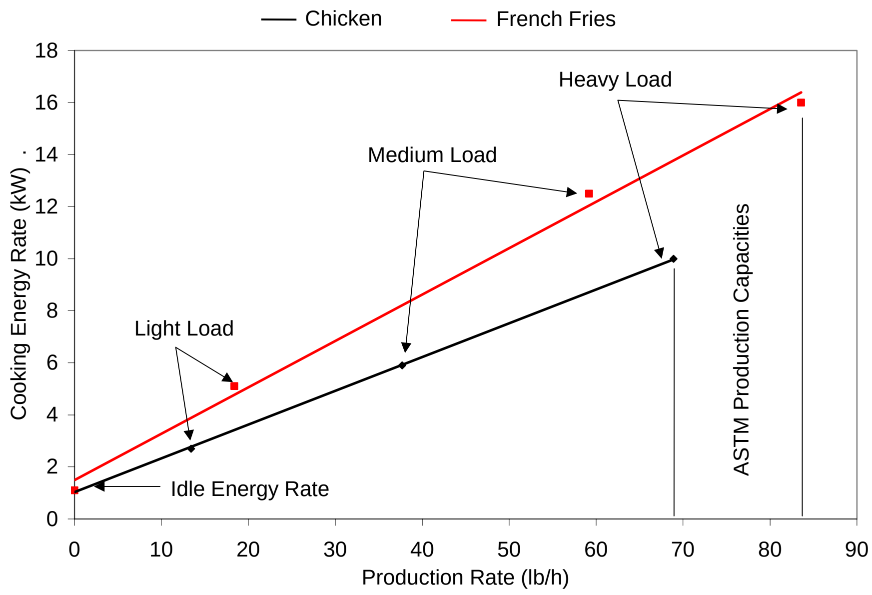

Figure ES-3.
Fryer cooking energy consumption profile.

Note: Light-load = 8 pieces/load; Medium-load = 24 pieces/load; Heavy-load = 48 pieces/load.

The classic open deep fat fryer design allows this large vat fryer to be used in a traditional fashion. FSTC researchers conducted additional French fry tests on the Henny Penny fryer. Based on the size of the fry vat, the heavy-load was changed from 3 to 5 pounds. The fryer exhibited an impressive production capacity of 83.6 lbs/hr of frozen French fries, with a cooking-energy efficiency of 86.1%.

Table ES-3. French Fry Heavy-Load Test Results

Load Size (lbs)	5.0
Production Capacity (lb/h)[a]	83.6 ± 3.3
Energy per Pound of Food Cooked (Btu/lb)	651
Electric Cooking Energy Rate (kW)	16.0
Cooking-Energy Efficiency (%)[a]	86.1 ± 0.9

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

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 150 pounds of chicken over a 12-hour day, with one preheat per day, 365 days per year.

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

Preheat Energy (kWh/day)	2.10
Idle Energy (kWh/day)	7.94
Cooking Energy (kWh/day)	23.9
Annual Energy (kWh/year)	12,374
Annual Cost ($/year)[a]	1,237

[a] Fryer energy costs are based on $0.10/kWh

Henny Penny's OFE-341 fryer established itself as a versatile open deep fat electric fryer. Its large vat size provides a restaurateur with the option of cooking large quantities of breaded product such as fried chicken or traditional French fries. The low watt-density ribbon style elements transfer heat into the frying medium easily and effectively. Quick response times and rapid oil temperature recovery during cooking provide a food service operator with a workhorse fryer that can handle seriously high volume.

1 Introduction

Background

Fried foods continue to be popular on the restaurant scene. Fryers of a larger vat size and input typically are used for cooking foods such as chicken and fish. Recent advances in equipment design have produced fryers that operate more efficiently, quickly, safely and conveniently.

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

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

FSTC researchers modified ASTM (F 1964-99) Standard Test Method for the Performance of Pressure and Kettle Fryers[1] to apply to large open vat, deep fat fryers, which was accepted as a Standard Test Method for Performance of Large Open Vat Fryers (Designation F 2144-01).[2]

Introduction

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

Henny Penny's OFE-341 electric fryer features low watt-density ribbon elements submerged in the frying oil with a stainless steel frypot, backsplash, 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[1] to the Henny Penny OFE-341 electric 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 Henny Penny's OFE-341, 18-inch electric fryer at an input rating of 22.0 kW, under the controlled conditions of the ASTM standard test method.[1] 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 325°F.
3. Characterize the idle energy use with the thermostat set at a calibrated 325°F.
4. Document the cooking energy consumption and efficiency under three fry loading scenarios: heavy (48 piece load), medium (24 piece load) and light (8 piece per load).
5. Determine the production capacity during the heavy-load test.
6. Document the cooking energy consumption and efficiency under three French fry loading scenarios at 350°F: heavy (5 pounds per load), medium (2 ½ pounds per load), and light (¾ pound per load).
7. Determine the production capacity and frying medium temperature recovery time during the heavy-load test.

8. Estimate the annual operating cost for the fryer using a standard cost model.

Appliance Description

Henny Penny's OFE-341, 18-inch electric fryer has a power rating of 22.0 kW. The fry pot is of a stainless steel construction and contains submerged low watt-density ribbon elements that provide a cooking platform within the fry vat (see Figure 1-1). The elements can lift up to allow for easy cleaning of the fry vat. A cooking computer allows for individualized programming for multiple food products. An integrated melt cycle prevents solid frying medium from scorching during preheat.

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

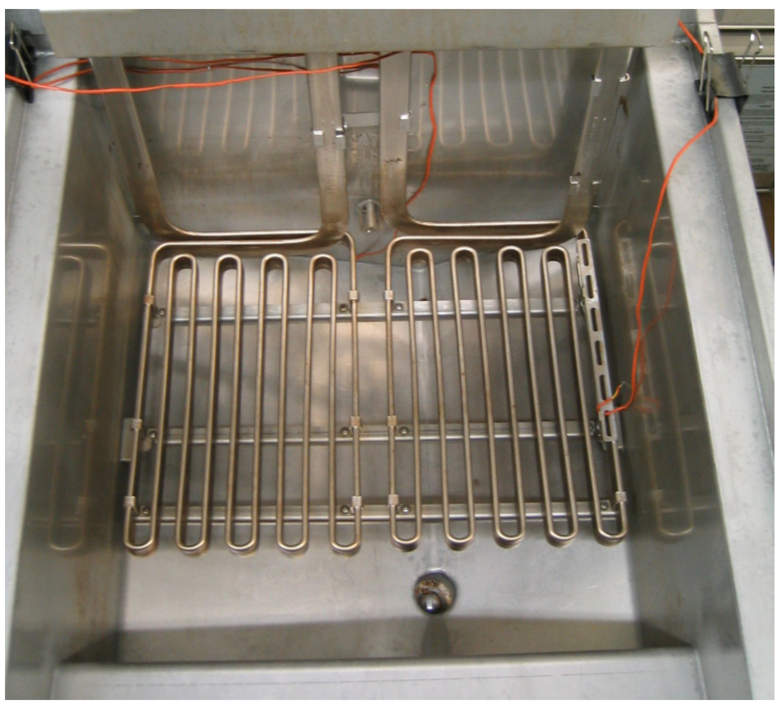

Figure 1-1.
Henny Penny OFE-341 frypot.

Table 1-1. Appliance Specifications.

Manufacturer	Henny Penny
Model	OFE-341
Generic Appliance Type	Open Deep Fat Fryer
Rated Input	22.0 kW
Frying Area	18” x 18” x 15”
Oil Capacity	80 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.[2] See Figure 2-1.

Researchers instrumented the fryer with thermocouples to measure temperatures in the cold and the cooking zones and at the thermostat bulb. Two thermocouples were placed in the cook zone, one in the geometric center of the frypot, approximately 1 inch above the fry basket support, and the other at the tip of the thermostat bulb. The cold zone thermocouple was supported from above, independent of the frypot surface, so that the temperature of the cold zone reflected the frying medium temperature, not the frypot's surface temperature. The cold zone temperature was measured toward the rear of the frypot, 1/8-inch from the bottom of the pot (See Figure 2-2).

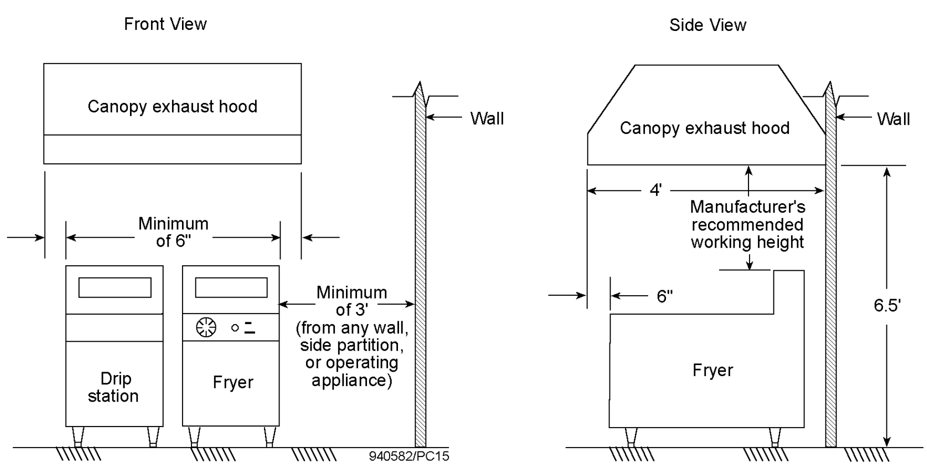

Figure 2-1.
Equipment configuration.

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

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

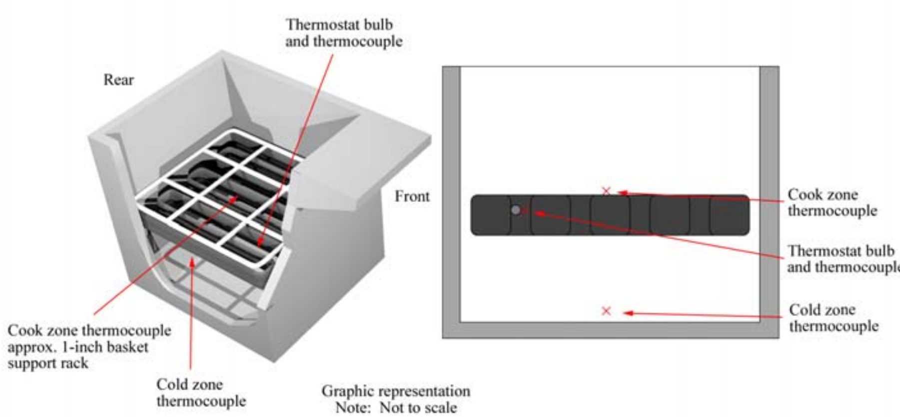

Figure 2-2. Thermocouple placement for testing.

Measured Energy Input Rate

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

Chicken Tests

The fryer was tested with 8-piece cut, 2 ¾-pound, individually quick frozen frying chicken which had been thawed, breaded, and stabilized in a refrigerator at 38 °F. Researchers tested the fryers using nominal heavy, medium and light-loads of chicken (Table 2-1). Each load comprised an equal number of breasts, wings, legs, and thighs. The chicken was cooked to an average weight loss of 27 ± 2%. This ensured fully-cooked chicken with no redness in the center.

Table 2-1. Chicken Load Size.

Heavy-Load (pieces)	48
Medium-Load (pieces)	24
Light-Load (pieces)	8

During the testing, energy, time and oil temperature were recorded at 5-secound intervals. Chicken temperature and weight loss were measured and recorded for use in energy calculations.

Due to logistics in removing one load of cooked chicken and placing another load into the fryer, a minimum preparation time of 10 minutes 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 320°F (measured at the center of the cook zone).

The chicken 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.

French Fry Tests

For additional performance information on the fryer, researchers applied the French fry test from the ASTM Test Method for Open Deep Fat Fryers (F1361-99)[3]. Since the frypot could accommodate a larger load than specified in the test method, the heavy-load size was increased from three to five pounds of frozen French fries. Medium-loads were also increased in size to half the weight of the heavy-load, two and one-half pounds.

Simplot® brand ¼-inch blue ribbon product, par-cooked, frozen shoestring potatoes were used for the French fry tests. Each load of French fries was cooked to a 30% weight loss. The 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 5-pound (heavy), 2 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 does not significantly lower the average oil temperature over the cooking cycle, nor does it extend the cook time. The fryer was reloaded either after the cook zone thermocouple reached the threshold temperature or 10 seconds after removing the previous load from the fryer, whichever was longer.

The first load of each six-load cooking test was designated as a stabilization load and was not counted when calculating the elapsed time and energy used.

Energy monitoring and elapsed time of the test were determined after the second load contacted the frying medium. After removing the last load and allowing the fryer to recover, researchers terminated the test. Total elapsed time, energy consumption, weight of fries cooked, and average weight loss of the French fries were recorded for the last five loads of the six-load test.

The French fry tests were run in the following sequence: three replicates of the heavy-load test followed by 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 C.

3 Results

Energy Input Rate

Prior to testing, the energy input rate was measured and compared with the manufacturer's nameplate value. This procedure ensured that the fryer was operating within its specified parameters. The measured energy input rate was 21.1 kW (a difference of 4.1% 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 325°F, or the appliance's stand-by losses.

Preheat Energy and Time

Researchers filled the fryer with new oil, which was then heated to 325°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. Henny Penny's cooking computer has an integrated melt cycle to prevent scorching of solid shortening. Henny Penny's OFE-341 fryer was ready to cook in 9.93 minutes. Figure 3-1 shows the fryer's preheat characteristics.

Idle Energy Rate

Once the frying medium reached 325°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 325°F. The idle energy rate during this period was 1.08 kW.

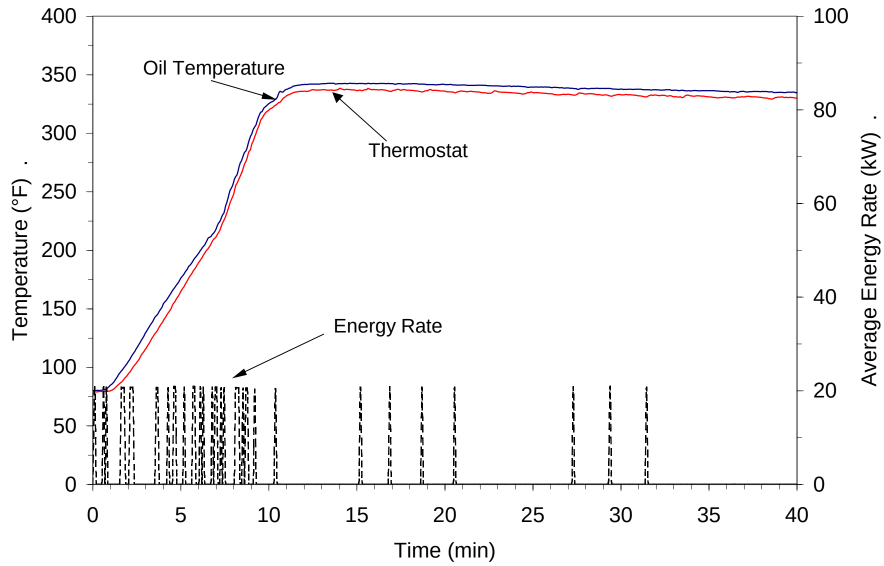

Figure 3-1.
Henny Penny OFE-341 preheat characteristics.

Test Results

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

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

Rated Energy Input Rate (kW)	22.0
Measured Energy Input Rate (kW)	21.1
Percentage Difference (%)	4.09
Preheat	
Time to 325°F (min)	9.93
Preheat Energy (kWh)	2.10
Preheat Rate to 325°F (°F/min)	24.8
Idle Energy Rate (kW)	1.08

Results

Chicken Tests

The fryer was tested using 8-piece cut, 2 ¾-pound chickens that had been thawed, breaded, and stabilized at 38°F to 40°F. For heavy-load tests, the OFE-341 fryer was used to cook 48 pieces per load (12 of each type of piece–breast, wings, legs and thighs). Medium-loads comprised one half the number of pieces used in the heavy load tests. Light-load tests used 8 pieces per load for all three fryers. Researchers monitored chicken cooking time and weight loss, frying medium temperature, 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 three or more heavy loads of chicken–one load after another in rapid succession, simulating a peak cooking period. Cooking-energy efficiency and production capacity were determined from these tests. The characteristic temperature curve, or temperature signature, during a single heavy-load indicates how well the fryer maintained the oil temperature during a cooking event. This curve is also an indicator of product quality as the chicken pieces begin to absorb more oil at lower cooking temperatures. Figure 3-2 shows the temperature signature during a heavy-load test.

The heavy-load cook time for the Henny Penny fryer was 15.4 minutes. Production capacity includes the cook time and a 30 second reload time.

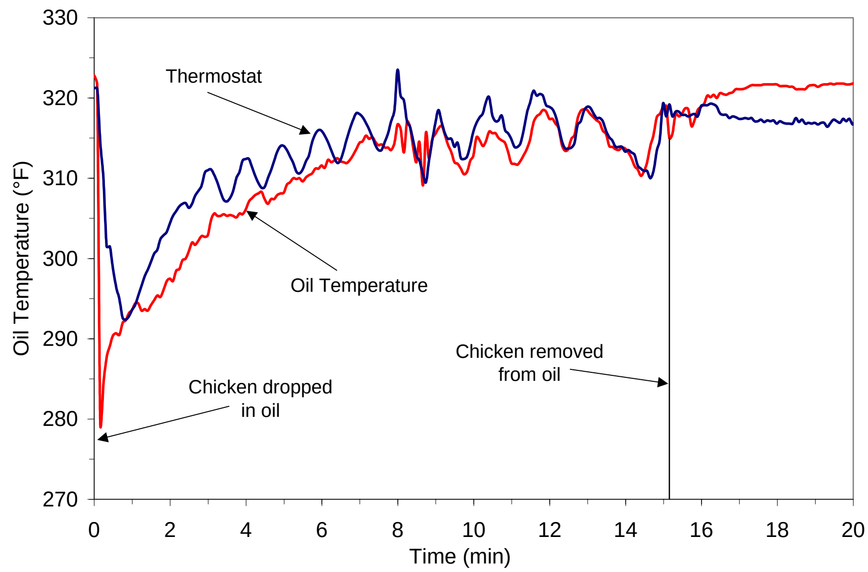

Figure 3-2. Chicken cook cycle tempeature signature.

Medium- and Light Load Tests

Medium and light load tests represent the fryer's performance under non-peak conditions. Since a fryer is often used to cook single-basket loads during slow periods, these part-load efficiencies can be used to estimate a fryer's performance in an actual operation.

Both the medium and light-load tests were conducted using a single fry basket. The fryer, during medium- and light-load testing, demonstrated cooking-energy efficiencies of 72.8 % and 51.0%, while producing 37.7 lbs/h and 13.4 lb/h respectively.

Test Results

Energy imparted to the chicken was calculated by separating the various components of the chicken (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 chicken, expressed as a percentage of the amount of energy consumed by the fryer during the cooking process.

Heavy-load cooking-energy efficiency results were 71.8%, 73.5%, 76.4% and 70.4%, yielding a maximum uncertainty of 4.1%. Table 3-2 summarizes the results of the ASTM cooking-energy efficiency and production capacity tests for chicken.

Table 3-2. Chicken Cooking Test Results.

	Heavy-Load	Medium-Load	Light-Load
Load Size (pieces)	48	24	8
Cook Time (min)	15.4	14.8	13.6
Production Rate (lb/h)[a]	68.9 ± 4.3	37.7 ± 3.8	13.4 ± 0.5
Energy to Food (Btu/lb)	360	390	346
Energy Consumption (kWh)	2.56	1.46	0.60
Electric Cooking Energy Rate (kW)	9.96	5.90	2.67
Energy per Pound of Food Cooked (Btu/lb)	494	537	681
Cooking-Energy Efficiency (%)[a]	73.0 ± 2.4	72.8 ± 3.6	51.0 ± 3.9

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

French Fry Tests

The fryers were tested under three loading scenarios: heavy (5 pounds of fries per load), medium (2 ½ pounds of fries per load) and light (¾ pound of fries per load). The fries used for the cooking tests consisted of approximately 6% fat and 66% moisture, as specified by the ASTM procedure. Researchers monitored French fry cook time and weight loss, frying medium recovery time, and fryer energy consumption during these tests.

Heavy-Load Tests

The heavy-load cooking tests were designed to reflect a fryer's maximum performance. The fryers were used to cook six 5-pound loads of frozen French fries—one load after the other in rapid succession, similar to a batch-cooking procedure. Figures 3-3 shows the average temperature of the frying medium during the heavy-load tests.

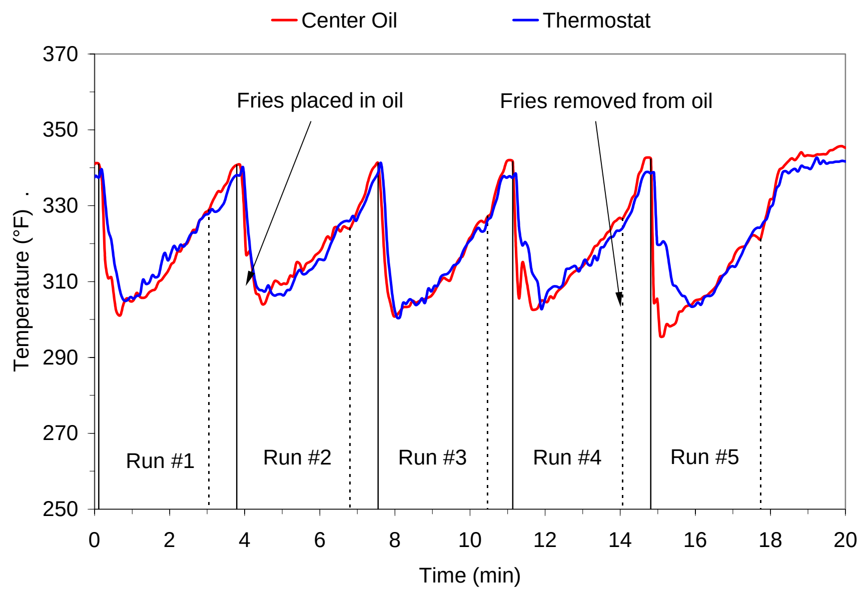

Figure 3-3. Frying medium temperarture during a heavy-load test for the OFE-341 fryer.

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 heavy-load cook time for the fryer was 2.80 minutes with an average recovery time of 47.4 seconds. Figure 3-4 illustrates the temperature response of the Henny Penny fryer while cooking a 5-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).

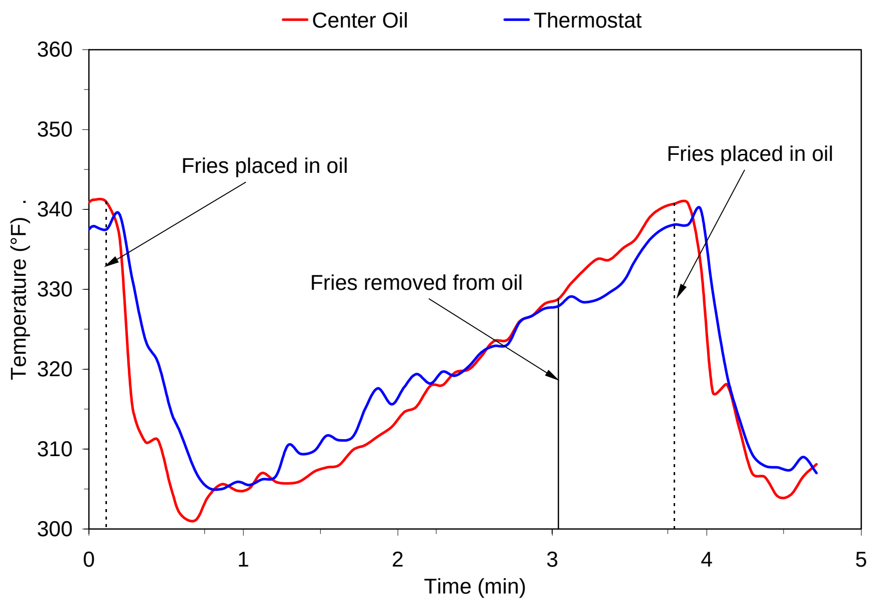

Figure 3-4.
Fryer cooking cycle temperature signature.

Medium- and Light-Load Tests

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

Both the medium- and light-load tests were conducted using a single fry basket. The medium-load tests used 2½ pounds of fries per load and the light load tests used ¾ pounds of fries per load. Cooking-energy efficiencies during testing were 78.5% for medium- and 61.4% for light-loads while producing 59.2 lbs/h and 18.4 lbs/h of cooked French fries, respectively.

Test Results

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

Heavy-load cooking-energy efficiency results were 86.5%, 85.9% and 85.9%, yielding a maximum uncertainty of 0.9%. Table 3-3 summarizes the results of the ASTM cooking-energy efficiency and production capacity tests for French fries.

Table 3-3. French Fry Cooking Test Results.

	Heavy-Load	Medium-Load	Light-Load
Load Size (lb)	5.0	2 ½	¾
French Fry Cook Time (min)	2.80	2.30	2.30
Average Recovery Time (sec)	47.4	13.8	8.4
Production Rate (lb/h)[a]	83.6 ± 3.3	59.2 ± 1.3	18.4 ± 0.0
Energy to Food (Btu/lb)	560	563	553
Energy Consumption (kWh)	4.77	2.63	1.03
Electric Cooking Energy Rate (kW)	16.0	12.5	5.1
Energy per Pound of Food Cooked (Btu/lb)	651	717	934
Cooking-Energy Efficiency (%)[a]	86.1 ± 0.9	78.5 ± 0.9	60.1 ± 5.9

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

Figure 3-5 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 chicken and French fry cooking tests.

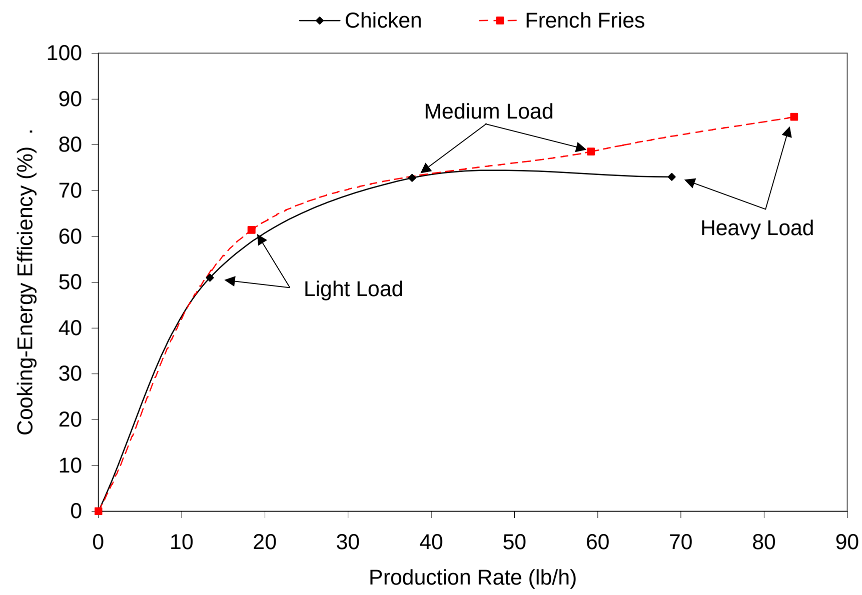

Figure 3-5.
Fryer part-load cooking-energy efficiency.

Note: Light-load = 8 pieces/load; Medium-load = 24 pieces/load; Heavy-load = 48 pieces/load.

Figure 3-6 illustrates the relationship between the fryer's average energy consumption rate and the production rate. This graph can be used as a tool to estimate the daily energy consumption and probable demand for the fryer in a real-world operation. End-use monitoring studies have shown that an electric appliance's probable contribution to the building's peak demand is equal to the appliance's average energy consumption rate during a typical day.[5] Average energy consumption rates at 10, 30, and 50 pounds per hour were 2.3 kW, 4.9 kW, and 7.5 kW, respectively. For an operation cooking an average of 15 pounds of food per hour over the course of the day (e.g., 150 lb of food over a ten hour day), the probable demand contribution for this fryer would be 3.0 kW.

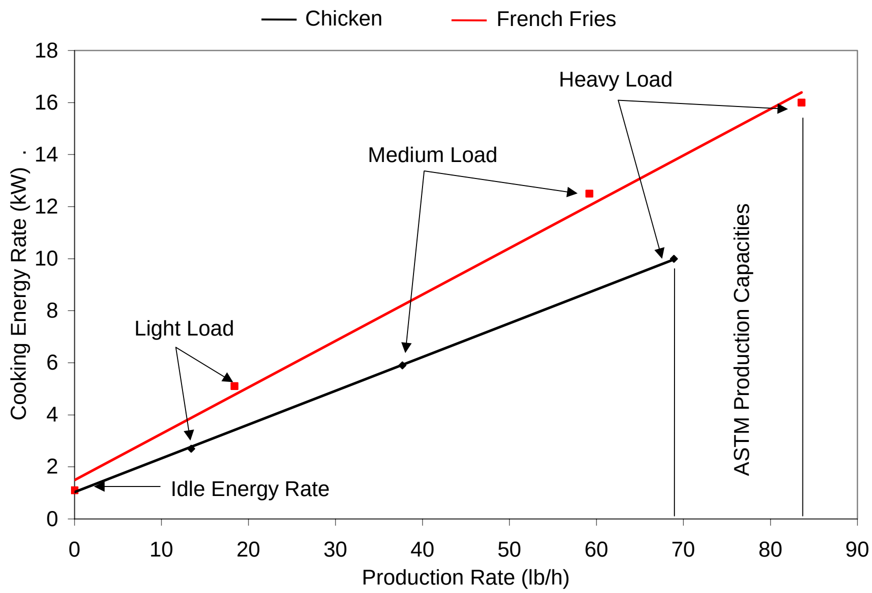

Figure 3-6.
Fryer cooking energy consumption profile.

Note: Light-load = 8 pieces/load; Medium-load = 24 pieces/load; Heavy-load = 48 pieces/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 150 pounds of chicken 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. Estimated Fryer Energy Consumption and Cost.

Preheat Energy (kWh/day)	2.1
Idle Energy (kWh/day)	7.94
Cooking Energy (kWh/day)	23.9
Annual Energy (kWh/year)	12,374
Annual Cost ($/year)[a]	1,237

[a] Fryer energy costs are based on $0.10/kWh

4 Conclusions

Henny Penny's OF-341 large-vat electric fryer exhibited strong performance while cooking both breaded chicken product and traditional French fries. During the heavy-load tests, the fryer produced 69 lbs/h while demonstrating a cooking-energy efficiency of 73%. Similarly, during the French fry tests, the fryer produced 84 lbs/h while achieving an 86% cooking-energy efficiency.

While the OFE-341 fryer really showed its prowess with heavy-loads, it posted solid medium- and light-load efficiencies as well. During the chicken tests, the medium-load efficiency was nearly as high as for the heavy-load tests (72.8% vs 73.0%), and the light-load efficiency was a respectable 57%.

During non-cooking periods, the fryer required only 1.08 kW to maintain a ready-to-cook state (325°F oil temperature). Since fryers typically spend a good portion of the day in a ready-to-cook state, this translates to lower operating costs.

The estimated operational cost of the OFE-341 large vat electric fryer is $1,237 per year. The model assumes the fryer is used to cook 150 lbs of chicken 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 (standby) state.

Granted, the Henny Penny OFE-341 fryer has a high input for conventional pressure fryers and kettle fryers, but this large vat open deep fat fryer offers versatility without sacrificing performance. This fryer is well suited for institutions requiring high volume production.

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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 5°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 Henny Penny OFE-341 fryer.

Table B-1. Appliance Specifications.

Manufacturer	Henny Penny
Model	OFE-341
Generic Appliance Type	Open Deep Fat Fryer
Rated Input	22.0 kW
Frying Area	18” x 18” x 15”
Oil Capacity	80 lb
Controls	Programmable cooking computer
Construction	Stainless Steel

Open Fryers

High-volume

OFE-341 Single well, electric
OFE-342 Two well, electric
OFG-341 Single well, gas
OFG-342 Two well, gas

These high volume open fryers feature a larger fry well with higher efficiency and faster cycle recovery than any fryer of its size or type. Greater surface area produces more consistent frying results with items that float when cooking.

Description

The 340 series open fryers from Henny Penny are high volume open fryers designed to offer a maximum frying surface area within a reasonable footprint.

Controls are fully programmable. Auto Lift feature automatically lowers load to begin cycle and raises load to drain at end.

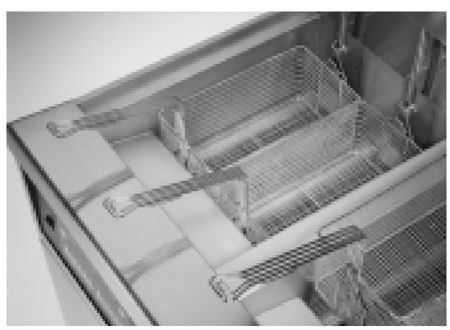
Electric elements are fully immersed. Induced-draft technology enables over 60% efficiency in gas units.

Configuration

- Choose from one or two-well models.
- Available in electric or gas.
- Also available without Auto Lift feature.
- Connector kits available separately for connecting any combination of one or two-well units (all electric or all gas).
- Itegrated dump station available on two well unit.

Main Features

- Electronic controls for each well feature:
  - 12 programmable cook cycles.
  - Digital time and temperature display.
  - Dual timers to time half baskets separately.
  - Idle and melt modes.
  - Load compensation feature.
  - Cook cycle completion signal.
- Large rectangular well offers greater surface area and promotes more even cooking.
- Specially designed “beach” accommodates shortening displacement when lowering the basket.
- Convenient built-in, single switch filtering system serves up to two wells.
- Doors swing open for easy access.



Above: OFG-342 two-well with Auto Lift
Left: Large well with specially designed “beach.”

Auto Lift Features

- Separate switch for Auto Lift and Pause/Resume.
- Each well can be programmed to operate half baskets independently or together at the touch of a button.
- Quiet, low-voltage motor and drive built into cabinet—no extra clearance needed.
- Easy basket set and release.

Accessories shipped with unit:

(1) Set of cleaning brushes
(10) Filter envelopes
(4) Heavy-duty casters, two locking.
(2) Half-baskets with handles OR (1) full basket per well. (3) third-size baskets are available, but can only be used on units without Auto Lift. Please specify when ordering.
(1) Basket support per well.
(1) Installation, operating and service manual.

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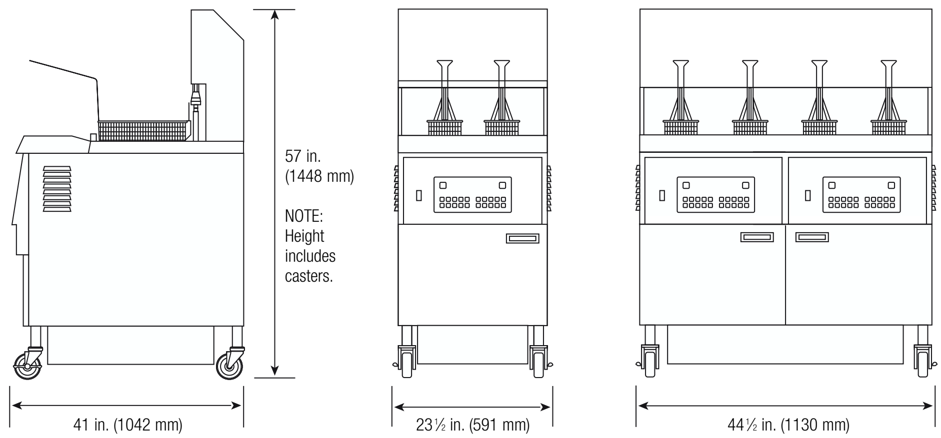
HENNY PENNY
Global Foodservice Solutions

OFE/OFG 341, 342 Specifications



Dimensions

Clearances 4 in. side, 4 in. back (gas units)

		Single well	Two well
Floor space		6.6 sq. ft. (.62 m^2)	12.7 sq. ft. (1.17 m^2)
Capacity	Product	18 lbs. (8.2 kg)	36 lbs. (16.4 kg)
	Shortening OFE	80 lbs. (36 kg)	160 lbs. (73 kg)
	Shortening OFG	90 lbs. (41 kg)	180 lbs. (82 kg)
Heating format	Electric	Electric immersion 22 kw	Electric immersion 44 kw
	Gas	Natural or propane gas. (3) burners (1) 1/2 in. connection 120,000 BTU/hr (35 kw)	Natural or propane gas. (6) burners (1) 3/4 in. connection 240,000 BTU/hr (70 kw)
Shipping weight	OFE	348 lbs. (158 kg) approximate	700 lbs. (318 kg) approximate
	OFG	341 lbs. (155 kg) approximate	665 lbs. (300 kg) approximate
Listings	OFE	UL, UL Sanitation, CUL, CE	UL, UL Sanitation, CUL, CE
	OFG	CSA, UL Sanitation, CE	CSA, UL Sanitation, CE

Electrical

Model	Voltage	Phase	Cycle/Hz	KW	Amps
Electric Units	208 240	3 3	50/60 50/60	22 per well 22 per well	61 per well 53 per well
Gas Units	120 230	1 1	50 or 60 50 or 60	35 per well 70 per well	12 per well 6 per well
All international voltages available.					
*Power cord and plug need to be installed on site by a qualified electrician.					

Specifications subject to change without notice.
For up to date product information please visit
hennypenny.com

Order from:

Manufactured by:

Henny Penny Corporation
P.O. Box 60
Eaton, OH 45320

C Results Reporting Sheets

Manufacturer: Henny Penny

Models: OFE-341

Date: November 2004

Test Fryer and Elements

Description of operational characteristics: Henny Penny's OFE-341 electric fryer is rated at 22.0 kW. The OFE-341 fryer features low watt-density ribbon elements submerged in the frying oil. A cooking computer controls the elements with features such as a melt cycle and multiple programmable cook times.

Apparatus

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

Deviations: None.

Energy Input Rate

Rated (Btu/h)	22.0
Measured (Btu/h)	21.1
Percent Difference between Measured and Rated (%)	4.09

Thermostat Calibration

Thermostat Setting (°F)	325
Oil Temperature (°F)	325

Results Reporting Sheets

Preheat Energy and Time

Starting Temperature (°F)	79.0
Electric Energy Consumption (kWh)	2.10
Duration (min)	9.93
Preheat Rate (°F/min)	24.8

Idle Energy Rate

Total Idle Energy Rate @ 325°F (kW)	1.08

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

Load Size (pieces)	48
Cook Time (min)	15.4
Production Capacity (lb/h) [a]	68.9 ± 4.3
Energy to Food (Btu/lb)	360
Energy Consumption (kWh)	2.56
Electric Cooking Energy Rate (kW)	9.96
Energy per Pound of Food Cooked (Btu/lb)	494
Cooking-Energy Efficiency (%)[a]	73.0 ± 2.4

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

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

Load Size (lb)	24
French Fry Cook Time (min)	14.8
Production Rate (lb/h) [a]	37.7 ± 3.8
Energy to Food (Btu/lb)	390
Energy Consumption (kWh)	1.46
Electric Cooking Energy Rate (kW)	5.90
Energy per Pound of Food Cooked (Btu/lb)	537
Cooking-Energy Efficiency (%)[a]	72.8 ± 3.6

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

Results Reporting Sheets

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

Load Size (lb)	8
French Fry Cook Time (min)	13.6
Production Rate (lb/h) [a]	13.4 ± 0.5
Energy to Food (Btu/lb)	346
Energy Consumption (kWh)	0.60
Cooking Energy Rate (kW)	2.67
Energy per Pound of Food Cooked (Btu/lb)	681
Cooking-Energy Efficiency (%)[a]	51.0 ± 3.9

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

Heavy-Load French Fry Cooking-Energy Efficiency and Cooking Energy Rate

Load Size (lb)	5.0
French Fry Cook Time (min)	2.80
Average Recovery Time (sec)	47.4
Production Capacity (lb/h) [a]	83.6 ± 3.3
Energy to Food (Btu/lb)	560
Energy Consumption (kWh)	4.77
Electric Cooking Energy Rate (kW)	16.0
Energy per Pound of Food Cooked (Btu/lb)	651
Cooking-Energy Efficiency (%)[a]	86.1 ± 0.9

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

Results Reporting Sheets

Medium-Load French Fry Cooking-Energy Efficiency and Cooking Energy Rate

Load Size (lb)	2 ½
French Fry Cook Time (min)	2.30
Average Recovery Time (sec)	13.8
Production Rate (lb/h) [a]	59.2 ± 1.3
Energy to Food (Btu/lb)	563
Energy Consumption (kWh)	2.63
Electric Cooking Energy Rate (kW)	12.5
Energy per Pound of Food Cooked (Btu/lb)	717
Cooking-Energy Efficiency (%)[a]	78.5 ± 0.9

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

Light-Load French Fry Cooking-Energy Efficiency and Cooking Energy Rate

Load Size (lb)	¾
French Fry Cook Time (min)	2.30
Average Recovery Time (sec)	8.4
Production Rate (lb/h) [a]	18.4 ± 0.0
Energy to Food (Btu/lb)	553
Energy Consumption (kWh)	1.03
Electric Cooking Energy Rate (kW)	5.1
Energy per Pound of Food Cooked (Btu/lb)	934
Cooking-Energy Efficiency (%)[a]	60.1 ± 5.9

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

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
Chicken	0.688
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 Chicken Test Data.

	Repetition #1	Repetition #2	Repetition #3	Repetition #4
Measured Values				
Test Voltage (V)	208	208	208	208
Energy Consumption (kWh)	2.72	2.66	2.32	2.48
Total Energy (Btu)	9,283	9,079	7,918	8,464
Total Test Time (min)	15.9	16.2	15.4	15.3
Weight Loss (%)	28.53	29.48	25.52	25.56
Initial Weight (lb)	17.914	17.785	17.444	17.257
Final Weight (lb)	12.803	12.542	12.992	12.845
Initial Moisture Content (%)	66.8	66.8	66.8	66.8
Final Moisture Content (%)	55.3	55.7	56.6	56.8
Initial Temperature (°F)	37	38	39	38
Final Temperature (°F)	192	194	193	194
Water Loss (lb)	4.90	4.90	4.31	4.24
Calculated Values				
Initial Weight of Water (lb)	11.967	11.880	11.653	11.528
Final Weight of Water (lb)	7.080	6.986	7.353	7.296
Sensible (Btu)	1,904	1,905	1,854	1,854
Latent – Heat of Vaporization (Btu)	4,750	4,749	4,182	4,110
Total Energy to Food (Btu)	6,655	6,654	6,036	5,964
Energy to Food (Btu/lb)	372	374	346	346
Total Energy to Fryer (Btu)	9,283	9,079	7,918	8,464
Energy to Fryer (Btu/lb)	518	510	454	490
Cooking-Energy Efficiency (%)	71.7	73.3	76.2	70.5
Electric Energy Rate (kW)	10.3	9.9	9.06	9.73
Production Rate (lb/h)	67.5	66.1	68.1	67.7

Cooking-Energy Efficiency Data

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

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Test Voltage (V)	208	208	208
Energy Consumption (kWh)	1.52	1.54	1.34
Total Energy (Btu)	5,188	5,256	4,573
Total Test Time (min)	16.7	15.3	12.9
Weight Loss (%)	30.84	31.69	24.45
Initial Weight (lb)	9.417	9.409	9.508
Final Weight (lb)	6.513	6.427	7.183
Initial Moisture Content (%)	66.8	66.8	66.8
Final Moisture Content (%)	48.8	52.0	57.5
Initial Temperature (°F)	37	38	39
Final Temperature (°F)	195	197	192
Water Loss (lb)	3.11	2.95	2.22
Calculated Values			
Initial Weight of Water (lb)	6.290	6.285	6.351
Final Weight of Water (lb)	3.178	3.342	5.467
Sensible (Btu)	1,019	1,027	1,002
Latent – Heat of Vaporization (Btu)	3,021	2,859	2,156
Total Energy to Food (Btu)	4,040	3,885	3,158
Energy to Food (Btu/lb)	429	413	332
Total Energy to Fryer (Btu)	5,188	5,256	4,573
Energy to Fryer (Btu/lb)	551	559	481
Cooking-Energy Efficiency (%)	77.9	73.9	69.0
Electric Energy Rate (kW)	5.47	6.06	6.22
Production Rate (lb/h)	33.9	37.0	44.2

Cooking-Energy Efficiency Data

Table D-4. Medium-Load Chicken Test Data continued.

	Repetition #4	Repetition #5	Repetition #6
Measured Values			
Test Voltage (V)	208	208	208
Energy Consumption (kWh)	1.30	1.66	1.38
Total Energy (Btu)	4,437	5,666	4,710
Total Test Time (min)	13.8	15.8	14.6
Weight Loss (%)	24.81	32.66	28.20
Initial Weight (lb)	8.981	9.259	9.010
Final Weight (lb)	6.753	6.235	6.469
Initial Moisture Content (%)	66.8	66.8	66.8
Final Moisture Content (%)	53.0	51.0	54.0
Initial Temperature (°F)	39	38	38
Final Temperature (°F)	193	192	194
Water Loss (lb)	2.22	3.01	2.53
Calculated Values			
Initial Weight of Water (lb)	5.999	6.185	6.019
Final Weight of Water (lb)	3.579	3.180	3.493
Sensible (Btu)	952	978	968
Latent – Heat of Vaporization (Btu)	2,348	2,921	2,452
Total Energy to Food (Btu)	3,301	3,899	3,420
Energy to Food (Btu/lb)	368	421	380
Total Energy to Fryer (Btu)	4,437	5,666	4,710
Energy to Fryer (Btu/lb)	494	612	523
Cooking-Energy Efficiency (%)	74.4	68.8	72.6
Electric Energy Rate (kW)	5.66	6.31	5.66
Production Rate (lb/h)	39.1	35.2	37.0

Cooking-Energy Efficiency Data

Table D-5. Light-Load Chicken Test Data

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Test Voltage (V)	208	208	208
Energy Consumption (kWh)	0.58	0.58	0.62
Total Energy (Btu)	1,980	1,980	2,116
Total Test Time (min)	13.6	13.6	13.1
Weight Loss (%)	21.92	28.85	26.74
Initial Weight (lb)	3.078	2.951	3.032
Final Weight (lb)	2.403	2.100	2.221
Initial Moisture Content (%)	66.8	66.8	66.8
Final Moisture Content (%)	55.6	55.6	57.2
Initial Temperature (°F)	37	39	38
Final Temperature (°F)	190	190	186
Water Loss (lb)	0.72	0.80	0.76
Calculated Values			
Initial Weight of Water (lb)	2.056	1.971	2.025
Final Weight of Water (lb)	1.336	1.168	1.270
Sensible (Btu)	324	309	306
Latent – Heat of Vaporization (Btu)	699	780	733
Total Energy to Food (Btu)	1,023	1,089	1,039
Energy to Food (Btu/lb)	332	369	343
Total Energy to Fryer (Btu)	1,980	1,980	2,116
Energy to Fryer (Btu/lb)	643	671	698
Cooking-Energy Efficiency (%)	51.7	55.0	49.1
Electric Energy Rate (kW)	2.56	2.56	2.85
Production Rate (lb/h)	13.6	13.0	13.9

Table D-6. Light-Load Chicken Test Data continued.

	Repetition #4	Repetition #5
Measured Values		
Test Voltage (V)	208	208
Energy Consumption (kWh)	0.60	0.64
Total Energy (Btu)	2,048	2,184
Total Test Time (min)	13.9	13.7
Weight Loss (%)	23.51	25.93
Initial Weight (lb)	3.122	2.973
Final Weight (lb)	2.388	2.202
Initial Moisture Content (%)	66.8	66.8
Final Moisture Content (%)	55.8	57.2
Initial Temperature (°F)	39	38
Final Temperature (°F)	192	191
Water Loss (lb)	0.76	0.73
Calculated Values		
Initial Weight of Water (lb)	2.085	1.986
Final Weight of Water (lb)	1.331	1.260
Sensible (Btu)	329	312
Latent – Heat of Vaporization (Btu)	733	705
Total Energy to Food (Btu)	1,062	1,017
Energy to Food (Btu/lb)	340	342
Total Energy to Fryer (Btu)	2,048	2,184
Energy to Fryer (Btu/lb)	656	735
Cooking-Energy Efficiency (%)	51.8	46.6
Electric Energy Rate (kW)	2.60	2.81
Production Rate (lb/h)	13.5	13.0

Cooking-Energy Efficiency Data

Table D-7. Heavy-Load Fry Test Data

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Test Voltage (V)	208	208	208
Energy Consumption (kWh)	4.76	4.80	4.74
Total Energy (Btu)	16,246	16,382	16,178
Cook Time (min)	2.80	2.80	2.80
Total Test Time (min)	18.1	17.6	18.1
Weight Loss (%)	29.90	29.80	29.60
Initial Weight (lb)	25.000	25.000	25.000
Final Weight (lb)	17.535	17.542	17.612
Initial Moisture Content (%)	67.1	67.1	67.1
Final Moisture Content (%)	48.9	48.8	49.6
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	16.775	16.775	16,775
Final Weight of Water (lb)	8.575	8.561	8.736
Sensible (Btu)	3,684	3,684	3,684
Latent – Heat of Fusion (Btu)	2,416	2,416	2,416
Latent – Heat of Vaporization (Btu)	7,954	7,969	7,798
Total Energy to Food (Btu)	14,054	14,069	13,898
Energy to Food (Btu/lb)	562	563	556
Total Energy to Fryer (Btu)	16,246	16,382	16,178
Energy to Fryer (Btu/lb)	650	655	647
Cooking-Energy Efficiency (%)	86.5	85.9	85.9
Electric Energy Rate (kW)	15.8	16.4	15.7
Production Rate (lb/h)	82.9	85.2	82.9
Average Recovery Time (sec)	49.2	43.2	49.2

Cooking-Energy Efficiency Data

Table D-8. Medium-Load Fry Test Data

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Test Voltage (V)	208	208	208
Energy Consumption (kWh)	2.62	2.64	2.62
Total Energy (Btu)	8,942	9,010	8,942
Cook Time (min)	2.30	2.30	2.30
Total Test Time (min)	12.6	12.8	12.6
Weight Loss (%)	30.00	30.20	29.80
Initial Weight (lb)	12.500	12.500	12.500
Final Weight (lb)	8.756	8.722	8.775
Initial Moisture Content (%)	67.1	67.1	67.1
Final Moisture Content (%)	48.7	48.4	49.4
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	8.388	8.388	8.388
Final Weight of Water (lb)	4.264	4.221	4.335
Sensible (Btu)	1,842	1,842	1,842
Latent – Heat of Fusion (Btu)	1,208	1,208	1,208
Latent – Heat of Vaporization (Btu)	4,000	4,042	3,931
Total Energy to Food (Btu)	7,050	7,092	6,981
Energy to Food (Btu/lb)	564	567	558
Total Energy to Fryer (Btu)	8,942	9,010	8,942
Energy to Fryer (Btu/lb)	715	721	715
Cooking-Energy Efficiency (%)	78.8	78.7	78.1
Electric Energy Rate (kW)	12.5	12.4	12.5
Production Rate (lb/h)	59.5	58.6	59.5
Average Recovery Time (sec)	13.2	15.6	13.2

Table D-9. Light-Load Fry Test Data

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Test Voltage (V)	208	208	208
Energy Consumption (kWh)	1.02	1.06	1.00
Total Energy (Btu)	3,481	3,618	3,413
Cook Time (min)	2.30	2.30	2.30
Total Test Time (min)	12.2	12.2	12.2
Weight Loss (%)	29.70	29.80	30.10
Initial Weight (lb)	3.750	3.750	3.750
Final Weight (lb)	2.638	2.632	2.620
Initial Moisture Content (%)	67.1	67.1	67.1
Final Moisture Content (%)	49.7	49.3	48.0
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	2.516	2.516	2.516
Final Weight of Water (lb)	1.311	1.298	1.258
Sensible (Btu)	553	553	553
Latent – Heat of Fusion (Btu)	362	362	362
Latent – Heat of Vaporization (Btu)	1,169	1,181	1,220
Total Energy to Food (Btu)	2,084	2,096	2,135
Energy to Food (Btu/lb)	556	559	569
Total Energy to Fryer (Btu)	3,481	3,618	3,413
Energy to Fryer (Btu/lb)	928	965	910
Cooking-Energy Efficiency (%)	59.9	57.9	62.6
Electric Energy Rate (kW)	5.02	5.21	4.92
Production Rate (lb/h)	18.4	18.4	18.4
Average Recovery Time (sec)	10.0	10.0	10.0

Table D-10. Chicken Cooking-Energy Efficiency and Production Capacity Statistics

	Cooking-Energy Efficiency (%)[a]			Production Capacity
	Heavy-Load	Medium-Load	Light-Load	(lb/h)[a]
Replicate #1	71.7	77.9	51.9	67.6
Replicate #2	73.3	73.9	55.1	66.1
Replicate #3	76.2	69.0	49.2	68.0
Replicate #4	70.5	74.4	51.9	68.0
Replicate #5	--	68.8	46.7	67.7
Replicate #6	--	72.6	--	--
Average	73.0	72.8	51.0	67.4
Standard Deviation	2.58	3.45	3.17	0.85
Absolute Uncertainty	4.10	3.62	3.93	1.35
Percent Uncertainty	5.61	4.98	7.71	2.00

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

Table D-11. French Fry Cooking-Energy Efficiency and Production Capacity Statistics

	Cooking-Energy Efficiency (%)[a]			Production Capacity
	Heavy-Load	Medium-Load	Light-Load	(lb/h)[a]
Replicate #1	86.5	78.8	59.9	82.9
Replicate #2	85.9	78.7	57.9	85.2
Replicate #3	85.9	78.1	62.6	82.9
Average	86.1	78.5	60.1	83.7
Standard Deviation	0.35	0.38	2.36	1.33
Absolute Uncertainty	0.87	0.94	5.85	3.30
Percent Uncertainty	1.01	1.20	9.73	3.94

[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-load conditions).

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- (48 pieces), medium- (24 pieces), and light- (8 pieces) loads. For example, a fryer operating for 12 hours a day with one preheat cooked 150 pounds of food: 36% of the food was cooked under heavy-load conditions, 48% was cooked under medium-load conditions, and 16% was cooked under light-load conditions. Calculate the energy due to cooking at heavy-, medium-, and light-load cooking rates, and then calculate the idle energy consumption. The total daily energy is the sum of these components plus the preheat energy. For simplicity, it is assumed that subsequent preheats require the same time and energy as the first preheat of the day.

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

Energy Cost Model

Table E-1: Electric Fryer Performance Parameters.

Test	Result
Preheat Time (min)	9.93
Preheat Energy (kWh)	2.10
Idle Energy Rate (kW)	1.08
Heavy-Load Cooking Energy Rate (kW)	9.96
Medium-Load Cooking Energy Rate (kW)	5.90
Light-Load Cooking Energy Rate (kW)	2.67
Production Capacity (lb/h)	68.9
Medium-Load Production Rate (lb/h)	37.7
Light-Load Production Rate (lb/h)	13.4

***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	150 lb
Percentage of Food Cooked Under Heavy-Load Conditions	36% (× 150 lb = 54 lb)
Percentage of Food Cooked Under Medium-Load Conditions	48% (× 150 lb = 72 lb)
Percentage of Food Cooked Under Light-Load Conditions	16% (× 150 lb = 24 lb)

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

The total time cooking heavy-loads is as follows:

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

$$t_h = \frac{36\% \times 150\ lb}{68.9\ lb/h},$$

$$t_h = 0.78\ h$$

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

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

$$E_{elec,h} = 9.96\ kW \times 0.78\ h,$$

$$E_{elec,h} = 7.77\ kWh$$

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

The total time cooking medium-loads is as follows:

$$t_m = \frac{\%_m \times W}{PR_m},$$

$$t_m = \frac{48\% \times 150\ lb}{37.7\ lb/h},$$

$$t_m = 1.91\ h$$

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

$$E_{elec,m} = q_{elec,m} \times t_m,$$

$$E_{elec,m} = 5.90\ kW \times 1.91\ h,$$

$$E_{elec,m} = 11.3\ kWh$$

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

The total time cooking light-loads is as follows:

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

$$t_l = \frac{16\% \times 150\ lb}{13.4\ lb/h},$$

$$t_l = 1.79\ h$$

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

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

$$E_{elec,l} = 2.67\ kW \times 1.79\ h$$

$$E_{elec,l} = 4.78\ kWh$$

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

The total idle time is determined as follows:

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

$$t_i = 12.0\ h - 0.78\ h - 1.91\ h - 1.79\ h - \frac{1\ preheat \times 9.93\ min}{60\ min/h}$$

$$t_i = 7.35\ h$$

The idle energy consumption is then calculated as follows:

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

$$E_{elec,i} = 1.08\ kW \times 7.35\ h$$

$$E_{elec,i} = 7.94\ kWh$$

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

$$E_{elec,daily} = E_{elec,h} + E_{elec,m} + E_{elec,l} + E_{elec,i} + n_p \times E_{elec,p},$$

$$E_{elec,daily} = 7.77\ kWh + 11.3\ kWh + 4.78\ kWh + 7.94\ kWh + 1 \times 2.10\ kWh$$

$$E_{elec,daily} = 33.9\ kWh/day$$

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

$$q_{avg} = \frac{E_{elec,\ daily}}{t_{on}},$$

$$q_{avg} = \frac{33.9\ kWh}{12.0\ h},$$

$$q_{avg} = 2.83\ kW$$

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

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

$$Cost_{snnual} = 33.9\ kWh/day \times 0.10\ \$/kWh \times 365\ days/year$$

$$Cost_{annual} = 1{,}237\ \$/year$$