

# **Henny Penny OFE-321 22.0 kW Electric Fryer Performance Tests**

Application of ASTM Standard  
Test Method F 1361-99

FSTC Report 5011.05.14

**Food Service Technology Center  
November 2005**

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

## Acknowledgments

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Specific appreciation is extended to Henny Penny for supplying the FSTC with an electric fryer, Model OFE-321 for controlled testing in the appliance laboratory.

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## Executive Summary

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Henny Penny's OFE-321 electric fryer is heated by tubular elements that wrap around the bottom perimeter of the fry vat with a total input rating of 22.0 kW. A programmable cooking computer controls the input to the fryer and provides for a more consistent product. Figure ES-1 illustrates the OFE-321 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.<sup>1</sup> Fryer performance is characterized by preheat time and energy consumption, idle energy consumption rate, cooking-energy efficiency, and production capacity.

Cooking performance was determined by cooking frozen French fries under three different loading scenarios (heavy—3 pounds per load, medium—1½ pounds per load, and light—¾ pound per load). The OFE-321's heavy-load cook time was 2.40 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:

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

---

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

## Executive Summary

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



*Figure ES-1.*  
*Henny Penny OFE-321 Fryer.*

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

|  |            |
|--|------------|
| Rated Energy Input Rate (kW)                           | 22.0       |
| Measured Energy Input Rate (kW)                        | 23.0       |
| Preheat Time to 350°F (min)                            | 8.45       |
| Preheat Energy to 350°F (kWh)                          | 2.58       |
| Idle Energy Rate @ 350°F (kW)                          | 0.75       |
| Heavy-Load Cooking-Energy Efficiency (%) <sup>a</sup>  | 83.2 ± 5.3 |
| Medium-Load Cooking-Energy Efficiency (%) <sup>a</sup> | 77.2 ± 2.0 |
| Light-Load Cooking-Energy Efficiency (%) <sup>a</sup>  | 62.8 ± 4.8 |
| Production Capacity (lb/h) <sup>a</sup>                | 69.2 ± 0.0 |
| Average Frying Recovery Time (sec) <sup>b</sup>        | 12.0       |

<sup>a</sup> This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.

<sup>b</sup> Based on the heavy-load cooking test with a minimum 10-second preparation time between loads.

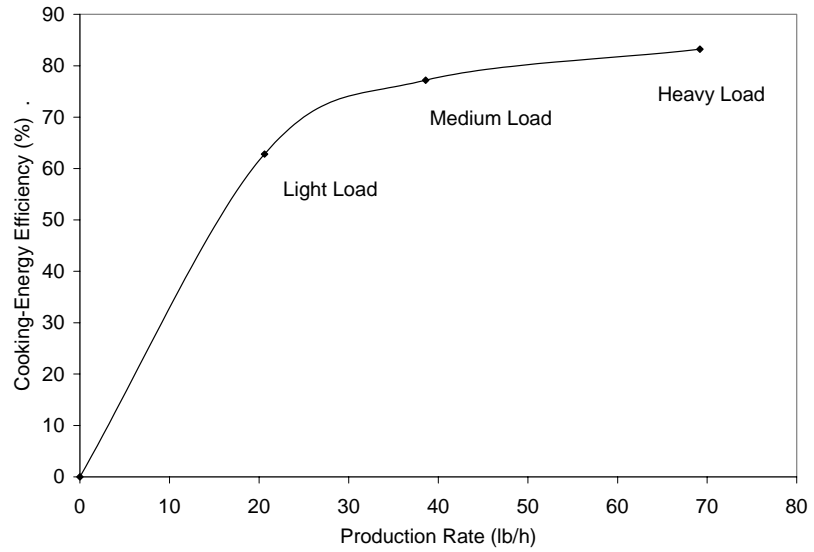
Henny Penny's OFE-321 electric fryer uses tubular low watt-density elements to transfer heat into the frying medium. The elements surround the bottom perimeter of the fry vat. During testing of the OFE-321, the horse power from an input of 22.0 kW produced a very fast heavy-load time of frozen French fries in an impressive 2.4 minutes, and demonstrated a competitive cooking-energy efficiency of 83.2% and a production capacity 69.2 lbs/h.

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 OFE-321 fryer are 2.9 kW, 6.6 kW, and 10.3 kW respectively. For an operation cooking an average of 15 pounds of food per hour over the course of the

# Executive Summary

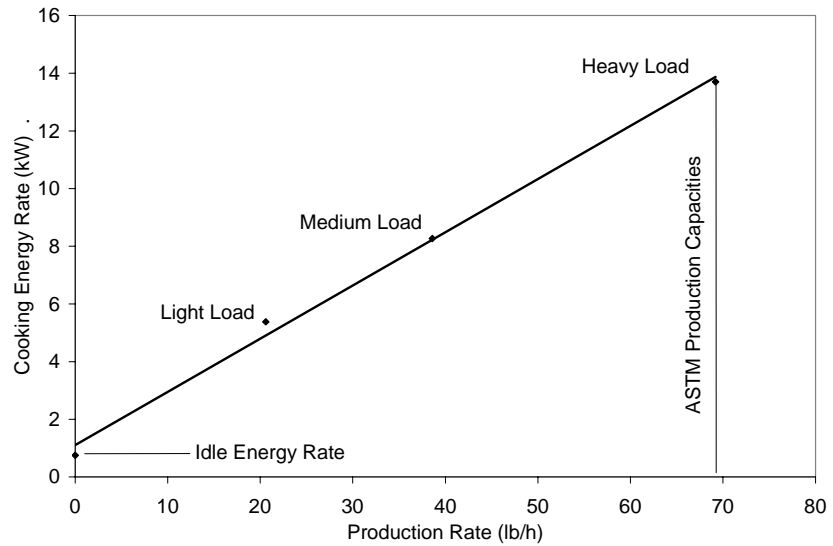
day (e.g., 150 lb of food over a ten hour day), the probable demand contribution for the OFE-321 fryer would be 3.9 kW.

**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.

**Figure ES-3.**  
*Fryer cooking energy consumption profile.*



Note: Light-load = ¾ pounds/load; Medium-load = 1½ pounds/load; Heavy-load = 3 pounds/load.

# Executive Summary

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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.

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

|  |               |
|--|---------------|
| Preheat Energy (kWh/day)                 | 2.58          |
| Idle Energy (kWh/day)                    | 6.99          |
| Cooking Energy (kWh/day)                 | 21.6          |
| <b>Annual Energy (kWh/year)</b>          | <b>11,388</b> |
| <b>Annual Cost (\$/year)<sup>a</sup></b> | <b>1,139</b>  |

<sup>a</sup> Fryer energy costs are based on \$0.10/kWh

Henny Penny's OFE-321 fryer established itself as a leading energy efficient electric fryer. The low watt-density tubular 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 high volume.

# 1 Introduction

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## 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. 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.

Since the development of the ASTM test method for fryers in 1991<sup>1,2</sup>, the FSTC has tested a wide range of gas and electric fryers.<sup>3-17</sup>

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

# Introduction

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Henny Penny's OFE-321 electric fryer features low watt-density tubular elements submerged in the frying oil with a stainless steel insulated frypot and 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 to the Henny Penny OFE-321 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-321, 14-inch electric fryer at an input rating of 22.0 kW, under the controlled conditions of the ASTM standard test method. The scope of this testing is as follows:

1. Verify that the appliance is operating at the manufacturer's rated energy input.
2. Determine the time and energy required to preheat the appliance from room temperature to 350°F.
3. Characterize the idle energy use with the thermostat set at a calibrated 350°F.
4. Document the cooking energy consumption and efficiency under three French fry loading scenarios: heavy (3 pounds per load), medium (1 ½ 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

Henny Penny's OFE-321, 14-inch electric fryer has a power rating of 22.0 kW. The fry pot is insulated with a stainless steel construction and contains submerged low watt-density tubular elements that circle the bottom of the fry vat perimeter (see Figure 1-1). A cooking computer allows for individualized programming for multiple food products.

# Introduction

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



*Figure 1-1.  
Henny Penny OFE-321  
frypot.*

*Table 1-1. Appliance Specifications.*

|                        |                               |
|------------------------|-------------------------------|
| Manufacturer           | Henny Penny                   |
| Model                  | OFE-321                       |
| Generic Appliance Type | Open Deep Fat Fryer           |
| Rated Input            | 22.0 kW                       |
| Frying Area            | 13 ½" x 16" x 16"             |
| Oil Capacity           | 65 lb                         |
| Controls               | Programmable cooking computer |
| Construction           | Stainless Steel               |

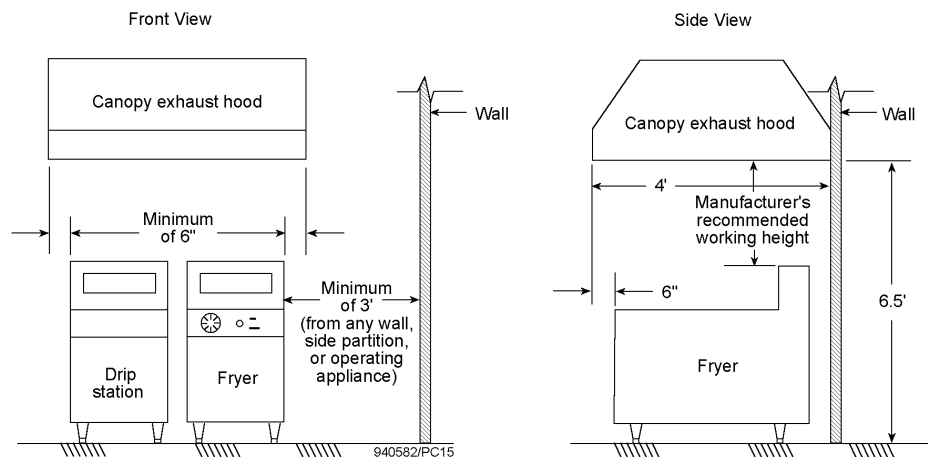
## 2 Methods

### 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.<sup>1</sup> 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

*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).

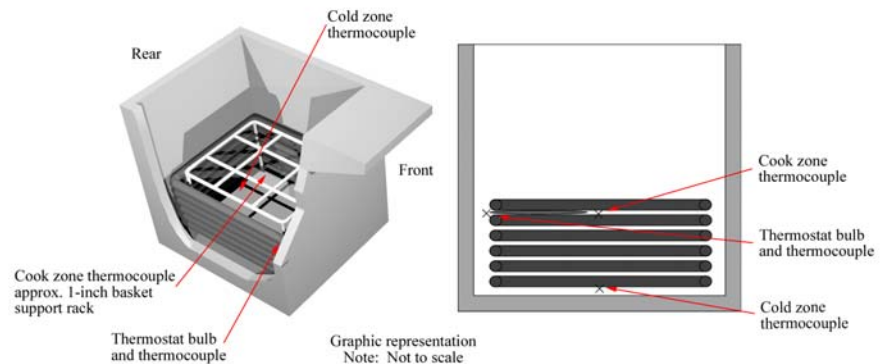
# Methods

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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

## Methods

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with the nameplate energy input rate to ensure that the fryer was operating properly.

### Cooking Tests

Researchers specified Simplot<sup>®</sup> brand ¼-inch blue ribbon product, par-cooked, frozen shoestring potatoes for all cooking tests. Each load of French fries was cooked to a 30% weight loss. The cooking tests involved “barreling” six loads of frozen French fries, using fry medium temperature as a basis for recovery. Each test was followed by a 10-minute wait period and was then repeated two more times. Researchers tested the fryer using 3-pound (heavy), 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.

## Methods

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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  $\pm 10\%$ . 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

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### 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 23.0 kW (a difference of 4.4% 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 350°F, or the appliance's stand-by losses.

#### **Preheat Energy and Time**

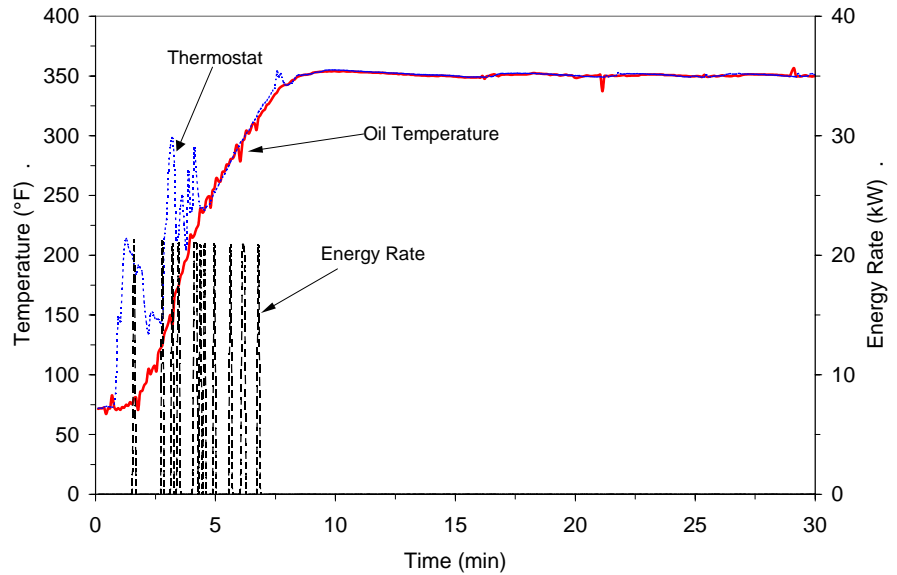
Researchers filled the fryer with new oil, which was then heated to 350°F at least once prior to any testing. The preheat tests were conducted at the beginning of a test day, after the oil had stabilized at room temperature overnight. For the preheat test only, the thermocouple location for the center oil temperature was raised 1-inch to represent the calibration point for the fryer's control package. Henny Penny'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 in the ASTM test procedure. Henny Penny's OFE-321 fryer was ready to cook in 8.45 minutes. Figure 3-1 shows the fryer's 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

# Results

two-hour period as each fryer maintained the oil at 350°F. The idle energy rate during this period was 0.75 kW.



**Figure 3-1.**  
*Henny Penny OFE-321  
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) | 23.0 |
| Percentage Difference (%)       | 4.35 |
| Preheat                         |      |
| Time to 350°F (min)             | 8.45 |
| Preheat Energy (kWh)            | 2.58 |
| Preheat Rate to 350°F (°F/min)  | 32.9 |
| Idle                            |      |
| Total Idle Energy Rate (kW)     | 0.75 |

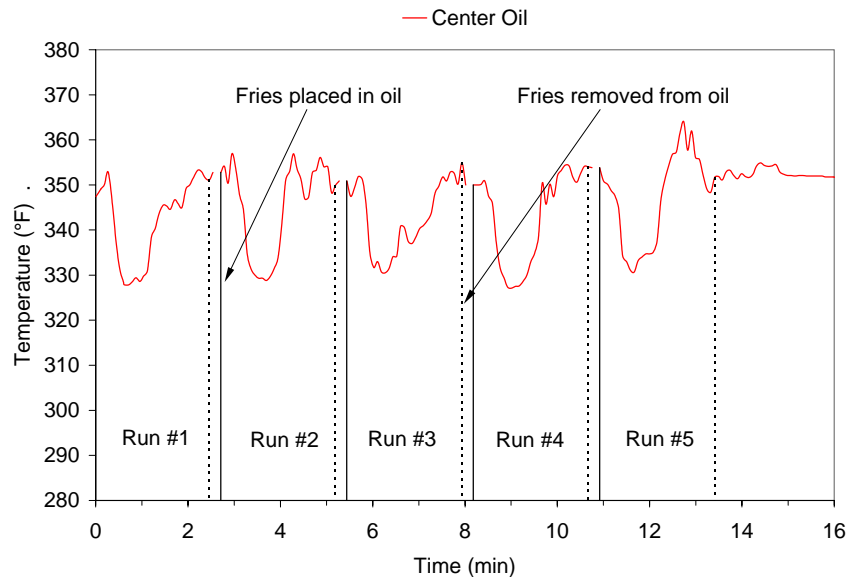
# Results

## Cooking Tests

The fryers were tested under three loading scenarios: heavy (3 pounds of fries per load), medium (1 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

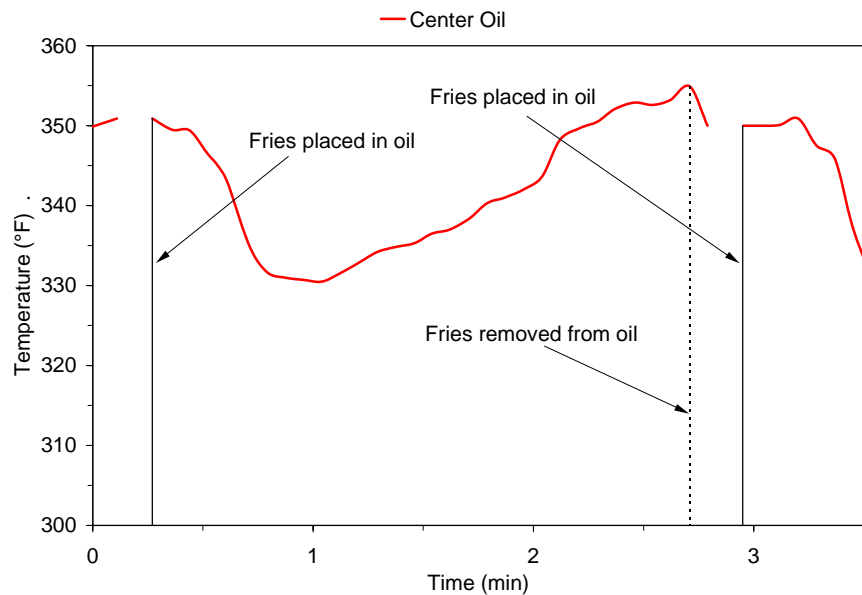
The heavy-load cooking tests were designed to reflect a fryer's maximum performance. The fryers were used to cook six 3-pound loads of frozen French fries—one load after the other in rapid succession, similar to a batch-cooking procedure. Figure 3-2 shows the average temperature of the frying medium at the center of the cook zone during the heavy-load tests.



*Figure 3-2.*  
*Frying medium*  
*temperature during a*  
*heavy-load test for the*  
*OFE-321 fryer.*

# Results

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 and cold zone temperatures during the heavy-load test were 347°F and 333°F, respectively. The heavy-load cook time for the fryer was 2.40 minutes with an average recovery time of 12.0 seconds. Figure 3-3 illustrates the temperature response of the Henny Penny 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.*

## 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.

# Results

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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 the light load tests used ¾ pounds of fries per load. Cooking-energy efficiencies at 38.6 (medium) and 20.6 (light) pounds per hour were 77.2% and 62.8%, 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 80.9%, 85.1% and 83.5%, yielding a maximum uncertainty of 5.3%. Table 3-2 summarizes the results of the ASTM cooking-energy efficiency and production capacity tests.

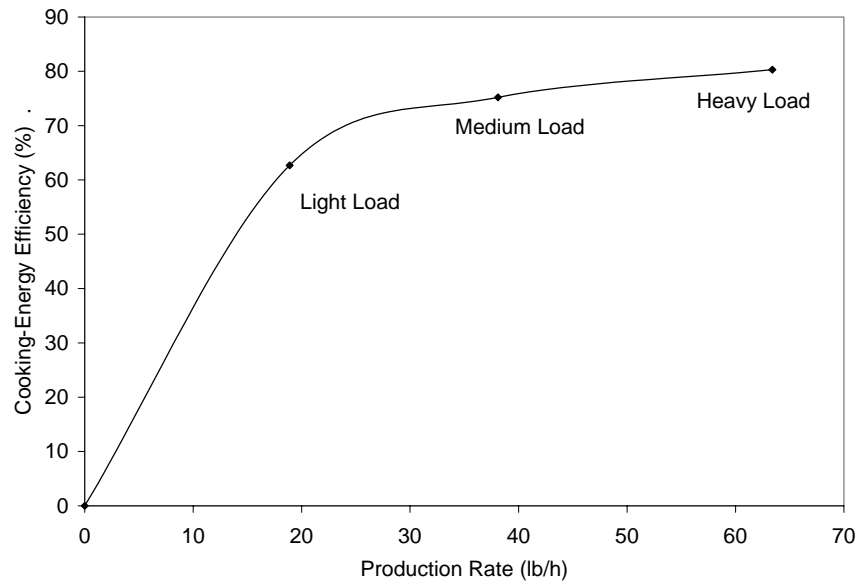
*Table 3-2. Cooking-Energy Efficiency and Production Capacity Test Results.*

|  | Heavy-Load | Medium-Load | Light-Load |
|--|------------|-------------|------------|
| Load Size (lb)                             | 3.0        | 1 ½         | ¾          |
| French Fry Cook Time (min)                 | 2.40       | 2.27        | 2.00       |
| Average Recovery Time (sec)                | 12.0       | 10.2        | 11.4       |
| Production Rate (lb/h) <sup>a</sup>        | 69.2 ± 0.0 | 38.6 ± 1.2  | 20.6 ± 0.2 |
| Energy to Food (Btu/lb)                    | 563        | 564         | 559        |
| Electric Cooking Energy Rate (kW)          | 13.72      | 8.27        | 5.38       |
| Energy per Pound of Food Cooked (Btu/lb)   | 676        | 731         | 892        |
| Cooking-Energy Efficiency (%) <sup>a</sup> | 83.2 ± 5.3 | 77.2 ± 2.0  | 62.8 ± 4.8 |

<sup>a</sup> This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.

# Results

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 = ¼ pounds/load; Medium-load = 1½ pounds/load; Heavy-load = 3 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 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 buildings peak demand is equal to the appliance's average energy consumption rate during a typical day.<sup>18</sup> Average energy consumption rates at 10, 30, and 50 pounds per hour were 2.9 kW, 6.6 kW, and 10.3 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 3.8 kW.

# Results

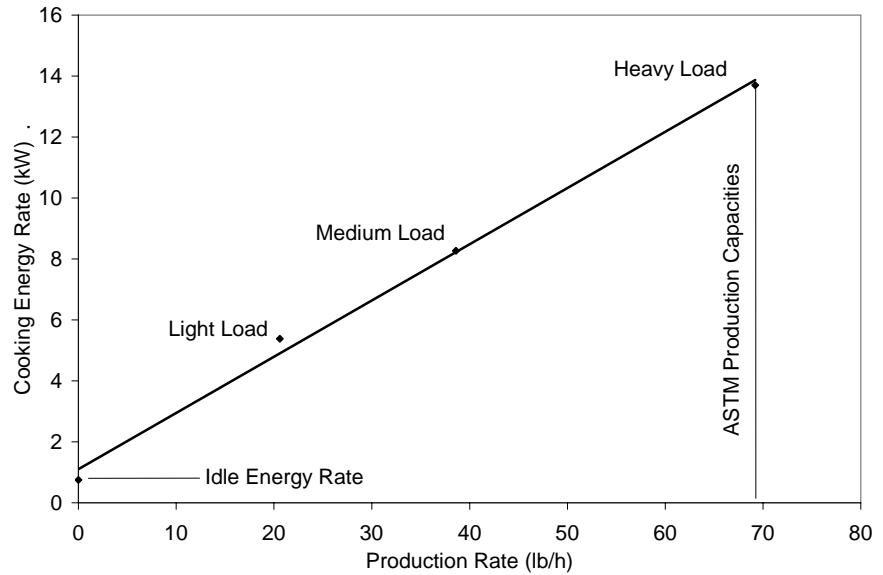


Figure 3-5.  
Fryer cooking energy consumption profile.

Note: Light-load = ¼ pounds/load; Medium-load = 1½ pounds/load; Heavy-load = 3 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.

# Results

---

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

|  |               |
|--|---------------|
| Preheat Energy (kWh/day)                 | 2.58          |
| Idle Energy (kWh/day)                    | 6.99          |
| Cooking Energy (kWh/day)                 | 21.6          |
| <b>Annual Energy (kWh/year)</b>          | <b>11,388</b> |
| <b>Annual Cost (\$/year)<sup>a</sup></b> | <b>1,139</b>  |

<sup>a</sup> Fryer energy costs are based on \$0.10/kWh

## 4 Conclusions

---

Henny Penny's OFE-321 fryer performed very well under heavy-load testing in comparison to other electric fryers tested at the Food Service Technology Center (FSTC).<sup>3,17</sup> During testing, the OFE-321 fryer produced 69.2 pounds of French fries per hour, while demonstrating an excellent cooking-energy efficiency of 83.2%. A single heavy-load test (3-pounds) of French fries was completed in a very rapid time of 2.40 minutes. The fryer was ready to cook another load of French fries after only 12.0 seconds. The rapid cook time and recovery allowed this fryer to achieve high production capacity and high cooking-energy efficiency.

The OFE-321 fryer employs low watt-density tubular elements surrounding the bottom perimeter of the fry vat. This design is similar to electric pressure and kettle fryers, which locate the elements around the perimeter of the fry vat to allow for more product to be held in the cooking baskets. In comparison, traditional 14-inch fryers locate the elements directly below the fry baskets.

The OFE-321 featured an insulated frypot giving a low idle energy rate of 0.75 kW. Studies have shown that fryers spend a good portion of the day in a ready-to-cook standby (idle) mode.<sup>3</sup> To a restaurateur, this low idle rate means a reduction in operating cost. This low idle rate also translated to a competitive part-load performance. The OFE-321 fryer posted comparable efficiencies to other top performing electric fryers with a medium-load efficiency of 77.2% and a light-load efficiency of 62.7%. 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

---

The estimated operational cost of the OFE-321 electric fryer is \$1,139 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.

Henny Penny's OFE-321 fryer established itself as a leading energy efficient electric fryer. The low watt-density tubular style elements, surrounded by an insulated fry vat, transfer heat into the frying medium easily and effectively, allowing the fryer to have lower stand by losses. Quick response times and rapid oil temperature recovery during cooking provide a food service operator with a workhorse fryer that can handle high volume.

## 5 References

---

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# A Glossary

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## 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<sup>3</sup>) 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 ( $75 \pm 5^\circ\text{F}$ ) 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  $10^\circ\text{F}$  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-321 fryer.

*Table B-1. Appliance Specifications.*

---

|                        |                               |
|------------------------|-------------------------------|
| Manufacturer           | Henny Penny                   |
| Model                  | OFE-321                       |
| Generic Appliance Type | Open Deep Fat Fryer           |
| Rated Input            | 22.0 kW                       |
| Frying Area            | 13 ½" x 16" x 16"             |
| Oil Capacity           | 65 lb                         |
| Controls               | Programmable cooking computer |
| Construction           | Stainless Steel               |

---

# Open Fryers

OFE-321 Single well, electric

OFE-322 Two-well, electric

OFE-323 Three-well, electric

OFG-321 Single well, gas

OFG-322 Two-well, gas

OFG-323 Three-well, gas

*These compact, high volume open fryers are designed for greater efficiency, faster cycle recovery time and simpler programmable operation.*

## Description

Henny Penny open fryers offer up to three large-capacity wells in a slim footprint with easy-to-use programmable controls, optimal energy efficiency and durable, round-the-clock operation. All models include built-in filtration.

## Configuration

- Choose from one, two or three-well models.
- Available in electric or gas.
- Also available with electro-mechanical controls.
- Auto Lift models available—see separate Data Sheet.
- Special two-well fryer with built-in dump station available. (See separate Data Sheet for details.)
- Connector kits available separately for connecting any combination of one, two or three-well units (all electric or all gas).

## 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.



OFE-323 three-well electric

- Load compensation feature.
- Cook cycle completion signal.
- Stainless steel rectangular fry pots promote more even cooking.
- Easy basket set and release
- Specially designed cold zone prevents scorching.
- One convenient, built-in filtering system serves up to three wells.
  - Switch activated.
  - Unique pivoting return spout refills wells.
  - Drain pan stores conveniently under fryer.
- Doors swing open for easy access.

## Accessories shipped with unit:

- (1) Set of cleaning brushes
- (5) PHT filter envelopes
- (4) Heavy-duty casters, two locking
- (2) Half-baskets with handles OR (1) full basket with handle per well. Please specify when ordering.
- (1) Basket support per well
- (1) Installation and operating manual

## Accessories available separately:

- Filter pan dolly
- Shortening shuttle
- Fry well covers

**Henny Penny Corporation**  
PO Box 60  
Eaton OH 45320 USA

+1 937 456.8400  
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**Toll free in USA**  
800 417.8417  
800 417.8434 Fax

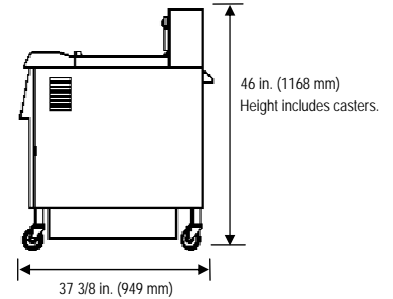
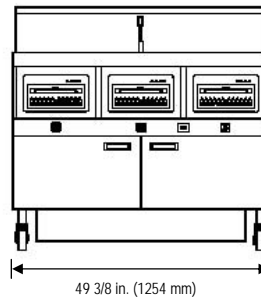
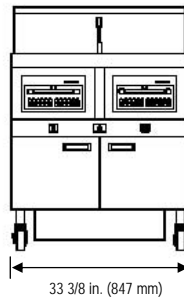
[www.hennypenny.com](http://www.hennypenny.com)

# OFE/OFG 321, 322, 323 Specifications

OFE/OFG-321

OFE/OFG-322

OFE/OFG-323



**Dimensions**

**Clearances**

N/A

**Floor Space**

**Capacity**

Product Shortening

**Fryer Throughput**

OFE  
OFG

**Heating Format**

Electric immersion  
Natural or liquid petroleum gas

**Single well**

4.3 sq. ft. (.4 m<sup>2</sup>)  
15 lbs. (6.8 kg)  
65 lbs. (29.5 kg)  
Fries/hr: 63 lbs. (28.6 kg)  
Fries/hr: 72 lbs. (32.7 kg)  
14.4 kw  
(2) burner  
(1) ½ in. connection  
85,000 BTU/hr (25 kW)

**Two well**

7.9 sq. ft. (.73 m<sup>2</sup>)  
30 lbs. (13.6 kg)  
130 lbs. (59 kg)  
Fries/hr: 126 lbs. (57.2 kg)  
Fries/hr: 144 lbs. (65.4 kg)  
28.8 kw  
(4) burners  
(1) ¾ in. connection  
170,000 BTU/hr (50 kW)

**Three well**

11.8 sq. ft. (1.1 m<sup>2</sup>)  
45 lbs. (20.4 kg)  
195 lbs. (88.5 kg)  
Fries/hr: 189 lbs. (85.8 kg)  
Fries/hr: 216 lbs. (98.1 kg)  
43.2 kw  
(6) burners  
(1) 1 in. connection  
255,000 BTU/hr (75 kW)

**Shipping Weight**

OFE  
OFG

**Shipping Cube Dimensions**

L x W x H

40 x 25 x 52¼ in  
(102 x 59 x 134 cm)

40 x 39 x 54¼ in  
(102 x 99 x 138 cm)

55 x 39 x 54¼ in  
(140 x 99 x 138 cm)

**Listings**

OFE  
OFG

UL, UL Sanitation, CUL, CE  
UL Sanitation, CSA, CE

UL, UL Sanitation, CUL, CE  
UL Sanitation, CSA, CE

UL, UL Sanitation, CUL, CE  
UL Sanitation, CSA, CE

**Electrical**

|                 | Volts   | Phase | Cycle/Hz | Watts per well | Amps per well | Wire |  |
|-----------------|---------|-------|----------|----------------|---------------|------|--|
| Electric models | 208     | 3     | 60       | 14400 or 22000 | 39.9 or 62.0  | 3+G  | Power cord and plug need to be installed on site by a qualified electrician. |
|                 | 220-240 | 3     | 50/60    | 14400          | 37.2          | 3+G  |  |
|                 | 240     | 3     | 60       | 14400 or 22000 | 37.2 or 53.0  | 2+G  |  |
|                 | 380-415 | 3     | 50/60    | 14400          | 21.7          | 3NG  |  |
| Gas models      | 480     | 3     | 60       | 14400 or 22000 | 17.5 or 27.0  | 3+G  |  |
|                 | 120     | 1     | 60       | N/A            | 12            | 2+G  |  |
|                 | 230     | 1     | 50       | N/A            | 2.5           | 1NG  |  |
|                 | 220-240 | 1     | 50       | N/A            | 12            | 2+G  |  |

Specifications subject to change without notice.  
For up-to-date product information, please visit  
[www.hennypenny.com](http://www.hennypenny.com).

**Order from:**

Manufactured by:

**Henny Penny Corporation**  
PO Box 60  
Eaton OH 45320 USA

## C Results Reporting Sheets

---

Manufacturer: Henny Penny  
Models: OFE-321  
Date: November 2004

### *Test Fryer and Elements*

Description of operational characteristics: Henny Penny's OFE-321 electric fryer is rated at 22.0 kW. The OFE-321 fryer features tubular low watt-density elements submerged in the frying oil around the bottom perimeter of the insulated fry vat. 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 (KW)  | 22.0 |
| Measured (KW)                                     | 23.0 |
| Percent Difference between Measured and Rated (%) | 4.35 |

---

### *Thermostat Calibration*

---

|                         |     |
|-------------------------|-----|
| Thermostat Setting (°F) | 343 |
| Oil Temperature (°F)    | 350 |

---

# Results Reporting Sheets

---

## *Preheat Energy and Time*

---

|                                   |      |
|-----------------------------------|------|
| Starting Temperature (°F)         | 72.9 |
| Electric Energy Consumption (kWh) | 2.58 |
| Duration (min)                    | 8.45 |
| Preheat Rate (°F/min)             | 32.9 |

---

## *Idle Energy Rate*

---

|                                     |      |
|-------------------------------------|------|
| Total Idle Energy Rate @ 350°F (kW) | 0.75 |
|-------------------------------------|------|

---

## *Heavy-Load Cooking-Energy Efficiency and Cooking Energy Rate*

---

|  |            |
|--|------------|
| Load Size (lb)                             | 3.0        |
| French Fry Cook Time (min)                 | 2.40       |
| Average Recovery Time (sec)                | 12.0       |
| Production Capacity (lb/h) <sup>a</sup>    | 69.2 ± 0.0 |
| Energy to Food (Btu/lb)                    | 563        |
| Cooking Energy Rate (kW)                   | 13.72      |
| Energy per Pound of Food Cooked (Btu/lb)   | 676        |
| Cooking-Energy Efficiency (%) <sup>a</sup> | 83.2 ± 5.3 |

---

<sup>a</sup> This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.

## *Medium-Load Cooking-Energy Efficiency and Cooking Energy Rate*

---

|  |            |
|--|------------|
| Load Size (lb)                             | 1 ½        |
| French Fry Cook Time (min)                 | 2.17       |
| Average Recovery Time (sec)                | 10.2       |
| Production Rate (lb/h) <sup>a</sup>        | 38.6 ± 1.2 |
| Energy to Food (Btu/lb)                    | 564        |
| Cooking Energy Rate (kW)                   | 8.27       |
| Energy per Pound of Food Cooked (Btu/lb)   | 731        |
| Cooking-Energy Efficiency (%) <sup>a</sup> | 77.2 ± 2.0 |

---

<sup>a</sup> This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.

# Results Reporting Sheets

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## *Light-Load Cooking-Energy Efficiency and Cooking Energy Rate*

---

|  |                |
|--|----------------|
| Load Size (lb)                             | $\frac{3}{4}$  |
| French Fry Cook Time (min)                 | 2.00           |
| Average Recovery Time (sec)                | 11.4           |
| Production Rate (lb/h) <sup>a</sup>        | $20.6 \pm 0.2$ |
| Energy to Food (Btu/lb)                    | 559            |
| Cooking Energy Rate (kW)                   | 5.38           |
| Energy per Pound of Food Cooked (Btu/lb)   | 892            |
| Cooking-Energy Efficiency (%) <sup>a</sup> | $62.8 \pm 4.8$ |

---

<sup>a</sup> 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*

---

|                                   |       |
|-----------------------------------|-------|
| <b>Specific Heat (Btu/lb, °F)</b> |       |
| Ice                               | 0.500 |
| Fat                               | 0.400 |
| Solids                            | 0.200 |
| Frozen French Fries               | 0.695 |
| <b>Latent Heat (Btu/lb)</b>       |       |
| 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 |
|--------------------------------------|---------------|---------------|---------------|
| <b>Measured Values</b>               |               |               |               |
| Test Voltage (V)                     | 208           | 208           | 208           |
| Energy Consumption (kWh)             | 3.02          | 2.98          | 2.92          |
| Total Energy (Btu)                   | 10,307        | 10,171        | 9,966         |
| <b>Cook Time (min)</b>               | <b>2.40</b>   | <b>2.40</b>   | <b>2.40</b>   |
| Total Test Time (min)                | 13.0          | 13.0          | 13.0          |
| Weight Loss (%)                      | 29.90         | 30.90         | 30.20         |
| Initial Weight (lb)                  | 15.000        | 15.000        | 15.000        |
| Final Weight (lb)                    | 10.518        | 10.366        | 10.468        |
| Initial Moisture Content (%)         | 67.1          | 67.1          | 67.1          |
| Final Moisture Content (%)           | 49.8          | 47.4          | 50.2          |
| Initial Temperature (°F)             | 0             | 0             | 0             |
| Final Temperature (°F)               | 212           | 212           | 212           |
| <b>Calculated Values</b>             |               |               |               |
| Initial Weight of Water (lb)         | 10.065        | 10.065        | 10.065        |
| Final Weight of Water (lb)           | 5.238         | 4.913         | 5.255         |
| Sensible (Btu)                       | 2,210         | 2,210         | 2,210         |
| Latent – Heat of Fusion (Btu)        | 1,449         | 1,449         | 1,449         |
| Latent – Heat of Vaporization (Btu)  | 4,682         | 4,997         | 4,666         |
| Total Energy to Food (Btu)           | 8,341         | 8,656         | 8,325         |
| <b>Energy to Food (Btu/lb)</b>       | <b>556</b>    | <b>577</b>    | <b>555</b>    |
| Total Energy to Fryer (Btu)          | 10,307        | 10,171        | 9,966         |
| <b>Energy to Fryer (Btu/lb)</b>      | <b>687</b>    | <b>678</b>    | <b>664</b>    |
| <b>Cooking-Energy Efficiency (%)</b> | <b>80.9</b>   | <b>85.1</b>   | <b>83.5</b>   |
| Electric Energy Rate (kW)            | 13.9          | 13.8          | 13.5          |
| Production Rate (lb/h)               | 69.2          | 69.2          | 69.2          |
| Average Recovery Time (sec)          | 12.0          | 12.0          | 12.0          |

## Cooking-Energy Efficiency Data

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

|                                      | Repetition #1 | Repetition #2 | Repetition #3 |
|--------------------------------------|---------------|---------------|---------------|
| <b>Measured Values</b>               |               |               |               |
| Test Voltage (V)                     | 208           | 208           | 208           |
| Energy Consumption (kWh)             | 1.60          | 1.60          | 1.62          |
| Total Energy (Btu)                   | 5,461         | 5,461         | 5,529         |
| <b>Cook Time (min)</b>               | <b>2.10</b>   | <b>2.20</b>   | <b>2.20</b>   |
| Total Test Time (min)                | 11.5          | 11.7          | 11.8          |
| Weight Loss (%)                      | 30.10         | 30.60         | 30.40         |
| Initial Weight (lb)                  | 7.500         | 7.500         | 7.500         |
| Final Weight (lb)                    | 5.246         | 5.204         | 5.220         |
| Initial Moisture Content (%)         | 66.8          | 66.8          | 66.8          |
| Final Moisture Content (%)           | 48.8          | 47.9          | 48.5          |
| Initial Temperature (°F)             | 0             | 0             | 0             |
| Final Temperature (°F)               | 212           | 212           | 212           |
| <b>Calculated Values</b>             |               |               |               |
| Initial Weight of Water (lb)         | 5.010         | 5.010         | 5.010         |
| Final Weight of Water (lb)           | 2.560         | 2.493         | 2.532         |
| Sensible (Btu)                       | 1,105         | 1,105         | 1,105         |
| Latent – Heat of Fusion (Btu)        | 721           | 721           | 721           |
| Latent – Heat of Vaporization (Btu)  | 2,377         | 2,441         | 2,404         |
| Total Energy to Food (Btu)           | 4,203         | 4,267         | 4,230         |
| <b>Energy to Food (Btu/lb)</b>       | <b>560</b>    | <b>569</b>    | <b>564</b>    |
| Total Energy to Fryer (Btu)          | 5,461         | 5,461         | 5,529         |
| <b>Energy to Fryer (Btu/lb)</b>      | <b>728</b>    | <b>769</b>    | <b>737</b>    |
| <b>Cooking-Energy Efficiency (%)</b> | <b>77.0</b>   | <b>78.1</b>   | <b>76.5</b>   |
| Electric Energy Rate (kW)            | 8.35          | 8.21          | 8.24          |
| Production Rate (lb/h)               | 36.0          | 39.1          | 39.1          |
| Average Recovery Time (sec)          | 12.0          | 10.0          | 10.0          |

## Cooking-Energy Efficiency Data

*Table D-4. Light Load Fry Test Data*

|                                      | Repetition #1 | Repetition #2 | Repetition #3 |
|--------------------------------------|---------------|---------------|---------------|
| <b>Measured Values</b>               |               |               |               |
| Test Voltage (V)                     | 208           | 208           | 208           |
| Energy Consumption (kWh)             | 0.94          | 1.02          | 0.98          |
| Total Energy (Btu)                   | 3,208         | 3,481         | 3,345         |
| <b>Cook Time (min)</b>               | <b>2.00</b>   | <b>2.00</b>   | <b>2.00</b>   |
| Total Test Time (min)                | 11.0          | 10.9          | 10.9          |
| Weight Loss (%)                      | 29.30         | 30.20         | 29.50         |
| Initial Weight (lb)                  | 3.750         | 3.750         | 3.750         |
| Final Weight (lb)                    | 2.653         | 2.617         | 2.642         |
| Initial Moisture Content (%)         | 66.8          | 66.8          | 66.8          |
| Final Moisture Content (%)           | 49.0          | 48.0          | 49.2          |
| Initial Temperature (°F)             | 0             | 0             | 0             |
| Final Temperature (°F)               | 212           | 212           | 212           |
| <b>Calculated Values</b>             |               |               |               |
| Initial Weight of Water (lb)         | 2.505         | 2.505         | 2.505         |
| Final Weight of Water (lb)           | 1.300         | 1.256         | 1.300         |
| Sensible (Btu)                       | 553           | 553           | 553           |
| Latent – Heat of Fusion (Btu)        | 361           | 361           | 361           |
| Latent – Heat of Vaporization (Btu)  | 1,169         | 1,212         | 1,169         |
| Total Energy to Food (Btu)           | 2,083         | 2,126         | 2,083         |
| <b>Energy to Food (Btu/lb)</b>       | <b>555</b>    | <b>567</b>    | <b>555</b>    |
| Total Energy to Fryer (Btu)          | 3,208         | 3,481         | 3,345         |
| <b>Energy to Fryer (Btu/lb)</b>      | <b>855</b>    | <b>928</b>    | <b>892</b>    |
| <b>Cooking-Energy Efficiency (%)</b> | <b>64.9</b>   | <b>61.1</b>   | <b>62.3</b>   |
| Electric Energy Rate (kW)            | 5.13          | 5.61          | 5.39          |
| Production Rate (lb/h)               | 20.5          | 20.6          | 20.6          |
| Average Recovery Time (sec)          | 12.0          | 10.8          | 10.8          |

## Cooking-Energy Efficiency Data

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

|                      | Cooking-Energy Efficiency (%) <sup>a</sup> |             |             | Production Capacity  |
|----------------------|--|-------------|-------------|----------------------|
|                      | Heavy-Load                                 | Medium-Load | Light-Load  | (lbs/h) <sup>a</sup> |
| Replicate #1         | 83.2                                       | 77.0        | 64.9        | 69.2                 |
| Replicate #2         | 85.1                                       | 78.1        | 61.1        | 69.2                 |
| Replicate #3         | 83.5                                       | 76.5        | 62.3        | 69.2                 |
| <b>Average</b>       | <b>83.2</b>                                | <b>77.2</b> | <b>62.8</b> |                      |
| Standard Deviation   | 2.12                                       | 0.82        | 1.94        | 0.00                 |
| Absolute Uncertainty | 5.26                                       | 2.03        | 4.81        | 0.00                 |
| Percent Uncertainty  | 6.32                                       | 2.63        | 7.66        | 0.00                 |

<sup>a</sup> This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.

# E Energy Cost Model

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## 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), medium- (one 1½-lb basket), 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: 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

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**Table E-1: Electric Fryer Performance Parameters.**

| Test                            | Result    |
|---------------------------------|-----------|
| Preheat Time                    | 8.45 min  |
| Preheat Energy                  | 2.58 kWh  |
| Idle Energy Rate                | 0.75 kW   |
| Heavy-Load Cooking Energy Rate  | 13.72 kW  |
| Medium-Load Cooking Energy Rate | 8.27 kW   |
| Light-Load Cooking Energy Rate  | 5.38 kW   |
| Production Capacity             | 69.2 lb/h |
| Medium-Load Production Rate     | 38.6 lb/h |
| Light-Load Production Rate      | 20.6 lb/h |

**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  | 36% (× 100 lb = 36 lb) |
| Percentage of Food Cooked Under Medium-Load Conditions | 48% (× 100 lb = 48 lb) |
| Percentage of Food Cooked Under Light-Load Conditions  | 16% (× 100 lb = 16 lb) |

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

The total time cooking heavy-loads is as follows:

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

$$t_h = \frac{36\% \times 100 \text{ lb}}{69.2 \text{ lb/h}},$$

$$t_h = 0.52 \text{ h}$$

# Energy Cost Model

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

$$\begin{aligned}E_{elec,h} &= q_{elec,h} \times t_h \\E_{elec,h} &= 13.72 \text{ kW} \times 0.52 \text{ h}, \\E_{elec,h} &= 7.13 \text{ kWh}\end{aligned}$$

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

The total time cooking medium-loads is as follows:

$$\begin{aligned}t_m &= \frac{\% m \times W}{PR_m}, \\t_m &= \frac{48\% \times 100 \text{ lb}}{38.6 \text{ lb/h}}, \\t_m &= 1.24 \text{ h}\end{aligned}$$

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

$$\begin{aligned}E_{elec,m} &= q_{elec,m} \times t_m \\E_{elec,m} &= 8.27 \text{ kW} \times 1.24 \text{ h}, \\E_{elec,m} &= 10.3 \text{ kWh}\end{aligned}$$

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

The total time cooking light-loads is as follows:

$$\begin{aligned}t_l &= \frac{\% l \times W}{PR_l}, \\t_l &= \frac{16\% \times 100 \text{ lb}}{20.6 \text{ lb/h}}, \\t_l &= 0.78 \text{ h}\end{aligned}$$

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

$$\begin{aligned}E_{elec,l} &= q_{elec,l} \times t_l \\E_{elec,l} &= 5.38 \text{ kW} \times 0.78 \text{ h} \\E_{elec,l} &= 4.20 \text{ kWh}\end{aligned}$$

# Energy Cost Model

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

The total idle time is determined as follows:

$$t_i = t_{on} - t_h - t_m - t_l - \frac{n_p \times t_p}{60},$$
$$t_i = 12.0 \text{ h} - 0.52 \text{ h} - 1.24 \text{ h} - 0.78 \text{ h} - \frac{1 \text{ preheat} \times 8.45 \text{ min}}{60 \text{ min/h}}$$
$$t_i = 9.32 \text{ h}$$

The idle energy consumption is then calculated as follows:

$$E_{elec,i} = q_{elec,i} \times t_i,$$
$$E_{elec,i} = 0.75 \text{ kW} \times 9.32 \text{ h}$$
$$E_{elec,i} = 6.99 \text{ kWh}$$

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

$$E_{elec,daily} = E_{elec,h} + E_{elec,m} + E_{elec,l} + E_{elec,i} + n_p \times E_{elec,p}$$
$$E_{elec,daily} = 7.13 \text{ kWh} + 10.3 \text{ kWh} + 4.20 \text{ kWh} + 6.99 \text{ kWh} + 1 \times 2.58 \text{ kWh}$$
$$E_{elec,daily} = 31.2 \text{ kWh/day}$$

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

$$q_{avg} = \frac{E_{elec,daily}}{t_{on}},$$
$$q_{avg} = \frac{31.2 \text{ kWh}}{12.0 \text{ h}},$$
$$q_{avg} = 2.60 \text{ kW}$$

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

$$Cost_{annual} = E_{elec,daily} \times R_{elec} \times Days$$
$$Cost_{annual} = 31.2 \text{ kWh/day} \times 0.10 \text{ \$/kWh} \times 365 \text{ days/year}$$
$$Cost_{annual} = 1,139 \text{ \$/year}$$