Vulcan 14-inch Fryer
Performance Testing

Application of ASTM Standard
Test Method F 1361-99

FSTC Report 5011.00.87

Food Service Technology Center
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Executive Summary

The four Vulcan fryers tested are powered by atmospheric burners, each rated at 30,000 Btu/h. The TK35 and GRD35 contain three burners, for a total input of 90,000 Btu/h, while the TK45 and GRD45 fryers use four burners, for a total input of 120,000 Btu/h. The TK series fryers are controlled by a mechanical thermostat, and the GRD series fryers use a solid state thermostat and control package with an integrated melt cycle for solid shortening. Figure ES-1 illustrates Vulcan TK and GRD series fryers tested at the FSTC. The melt cycle has a manual override that allows for a shorter preheat when using a liquid shortening.

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

Cooking performance was determined by cooking frozen French fries under two different loading scenarios (heavy—3 pounds per load, and light—¾ pound per load). The heavy-load cook times for the TK 35 and TK 45 series fryers were 2.75 and 2.42 minutes respectively, while the GRD 35 and GRD 45 series fryers cooked 3-pounds of fries in 2.65 and 2.30 minutes respectively. Production capacity includes the cooking time and the time required for the frying medium to recover to 340°F (recovery time).

Cooking energy efficiency is a measure of how much of the energy that an appliance consumes is actually delivered to the food product during the

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

cooking process. Cooking energy efficiency is therefore defined by the following relationship:

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

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

Figure ES-1.
Vulcan TK and GRD series Gas fryers.

TK Series ***GRD Series***

Executive Summary

Table ES-1. Summary of Fryer Performance.

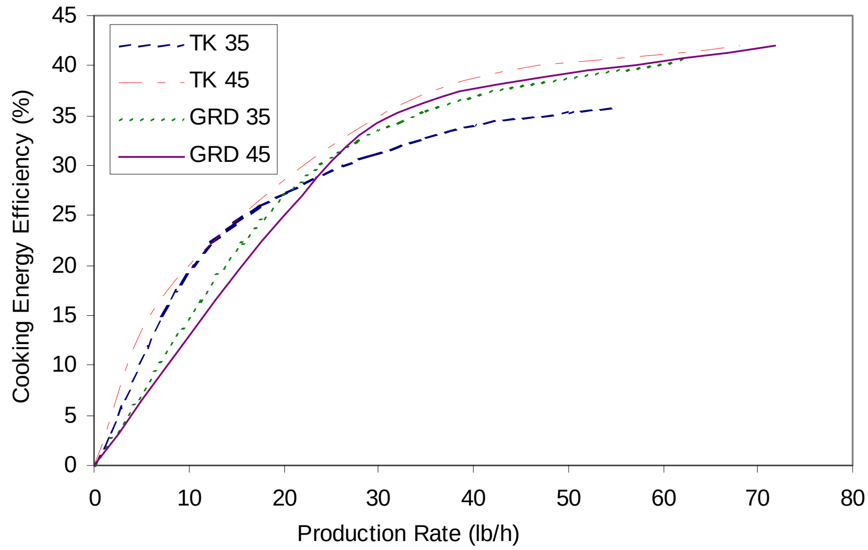
	TK 35	*GRD 35*	*TK 45*	*GRD 45*
Rated Energy Input Rate (Btu/h)	90,000	90,000	120,000	120,000
Measured Energy Input Rate (Btu/h)	93,540	88,490	117,130	119,620
Preheat Time to 350°F (min)	10.7	9.41	9.0	8.3
Preheat Energy to 350°F (Btu)	17,140	13,790	17,550	15,430
Idle Energy Rate @ 350°F (Btu/h)	13,180	12,830	12,380	14,250
Cooking Energy Efficiency				
Heavy-Load (%)[a]	35.8 ± 1.5	40.7 ± 1.2	42.0 ± 2.1	42.0 ± 1.4
Light-Load (%)[a]	22.2 ± 0.7	24.7 ± 1.4	18.5 ± 1.4	24.8 ± 1.1
Production Capacity (lb/h)[b]	55.0 ± 2.5	62.8 ± 0.5	68.0 ± 3.0	71.8 ± 4.5
Average Frying Medium Recovery Time(min)[b]	0.52	0.22	0.24	0.20

[a]This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.
[b]Based on the heavy-load cooking test with a minimum 10-second preparation time between loads.

Vulcan's GRD series fryers exhibited higher production capacities and faster recovery times. In addition all four fryers had similar idle energy rates with the slightly shorter preheat times for the GRD series fryers. The solid state thermostats of the GRD series fryers produce higher cooking energy efficiencies under partial load testing.

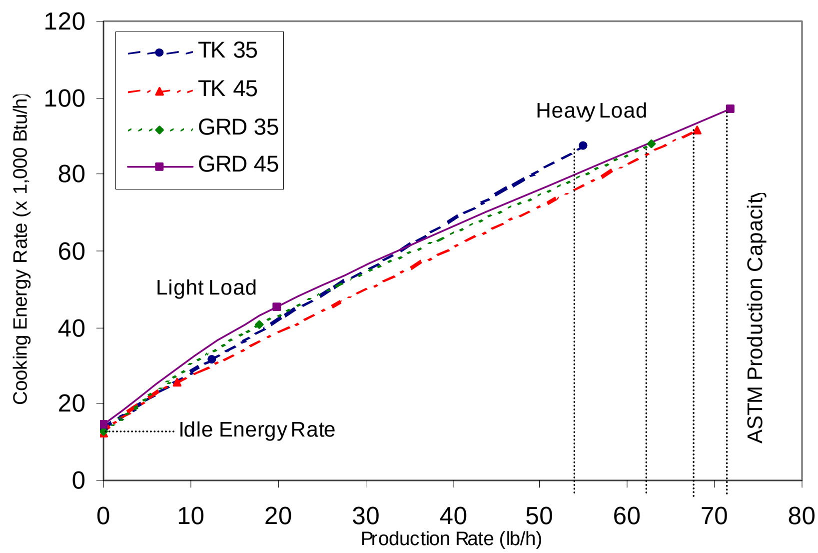
Figure ES-2 illustrates the relationship between cooking energy efficiency and production rate for the four fryers. Figure ES-3 illustrates the relationship between the fryer's average energy consumption rates and the production rates. This graph can be used as a tool to estimate the daily energy consumption for the fryer in a real-world operation. Average energy consumption rates at 10, 30, and 50 pounds per hour for the TK 35 are 27,310 Btu/h, 54,230 Btu/h, and 81,150 Btu/h respectively. Table ES-2 summarizes the estimated energy consumption at 10,30, and 50 lb/h for all four fryers.

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



Note: Light-load = ¾ pounds ; heavy-load = 3 pounds/load.

Figure ES-3.
Fryer cooking energy consumption profile.



Note: Light-load = ¾ pounds /load; heavy-load = 3 pounds.

Table ES-2. Energy Consumption Estimations.

Production Rate	TK 35	GRD 35	TK 45	GRD 45
10 lbs/h	27,310 Btu/h	29,030 Btu/h	25,550 Btu/h	30,890 Btu/h
30 lbs/h	54,230 Btu/h	56,560 Btu/h	48,370 Btu/h	58,900 Btu/h
50 lbs/h	81,150 Btu/h	77,610 Btu/h	71,180 Btu/h	80,590 Btu/h

Vulcan's GRD series fryers demonstrated higher cooking energy efficiencies over the TK series fryers due to the use of a solid state thermostat control. The solid state thermostat provided a tighter frying medium cooking temperature during operation, allowing for a decrease in recovery times and an overall increase in production capacities. In fact, the production capacity for the GRD 35 was 14% greater than the TK 35 (62.8 lb/h vs. 55.0 lb/h); the GRD 45 fryer's production capacity was 6% higher than the TK 45 fryer (71.8 lb/h vs. 68.0 lb/h).

The solid state thermostats utilized on the GRD series fryers offers increased cooking energy efficiency and production capacity over their TK series counterparts which offer cost saving mechanical thermostats. With the addition of slightly lower preheat energy consumption and comparable idle energy rates, the GRD series fryers are well worth the investment.

1 Introduction

Background

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

With today's food service operators becoming more sophisticated in their choice of equipment, the demand for objective performance data has increased. Since Pacific Gas and Electric Company is a dual-fuel utility, the food service industry felt that it would produce unbiased data for gas and electric appliances. Pacific Gas and Electric Company would benefit by passing this performance data on to its customers, helping them to select energy efficient equipment. With support from the Electric Power Research Institute (EPRI), the Gas Research Institute (GRI), and the National Restaurant Association, Pacific Gas and Electric Company has been involved in developing test methods for commercial cooking equipment for over ten years at its Food Service Technology Center (FSTC) in San Ramon, California.

In 1991, FSTC researchers developed a uniform test procedure to evaluate the performance of gas and electric fryers. This test method was submitted to the American Society for Testing and Materials' (ASTM) committee F26 on Food Service Equipment, and in January 1992, it was accepted as a standard test method (Designation F 1361-99).[1] Pacific Gas and Electric Company's *Development and Application of a Uniform Testing Procedure for Open, Deep-fat Fryers* documents the developmental procedures and test results of several gas and electric fryers.[2] Other Pacific Gas and Electric Company reports document results of applying the ASTM test method to different fryers.[3,4,5,6,7]

Introduction

Vulcan-Hart is considered one of the leading manufacturers of food service equipment, offering a wide variety of gas fryers. Through the use of "high thermal-efficiency, tube fired heating system" they offer a food service operator quality food production and cost savings. Vulcan approached the FSTC to test their full line of gas fryers under the tightly controlled conditions of the modified ASTM test method. Fryer performance is characterized by preheat time and energy consumption, idle energy consumption rate, pilot energy consumption rate, cooking energy efficiency and production capacity.

This report presents the results of applying the ASTM test method to four Vulcan gas fryers. 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 Vulcan's line of 14-inch gas fryers, under the controlled conditions of the ASTM standard test method. The scope of this testing is as follows:

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

Appliance Description

Vulcan offers two power ratings for its 14-inch gas fryers. The TK 35 and GRD 35 fryers have 90,000 Btu/h of available input from three 30,000 Btu/h burners. The TK 45 and GRD 45 fryers add an extra burner to provide 120,000 Btu/h of input. The flue gasses are routed from the front of the fryer through heat transfer tubes to the back of the frypot (see Figure 1-1).

All four fryers, as tested, were constructed of stainless steel front and painted steel sides. The frypots were made from 14-gauge cold rolled steel. Optional stainless steel frypots are also available. The TK-series fryer is controlled by a mechanical thermostat, with a high-limit shut off. The GRD-series fryers incorporate a solid state thermostat and control package with a solid shortening melt cycle and a high-limit shot off.

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

Figure 1-1. Vulcan heat transfer tubes.

90,000 Btu Fryers

120,000 Btu Fryers

Table 1-1. Appliance Specifications.

Model: Vulcan TK 35

Rated Input	90,000 Btu/h
Oil Capacity	50 lb
Frying Area	15” x 15”
Construction	Stainless steel front and top, painted sides and cold rolled steel fry tank
Controls	Mechanical thermostat
Generic Appliance Type	Open Deep Fat Fryer

Model: Vulcan GRD 35

Rated Input	90,000 Btu/h
Oil Capacity	50 lb
Frying Area	15” x 15”
Construction	Stainless steel front and top, painted sides and cold rolled steel fry tank
Controls	Solid state thermostat with melt cycle
Generic Appliance Type	Open Deep Fat Fryer

Model: Vulcan TK 45

Rated Input	120,000 Btu/h
Oil Capacity	50 lb
Frying Area	15” x 15”
Construction	Stainless steel front and top, painted sides and cold rolled steel fry tank
Controls	Solid state thermostat with melt cycle
Generic Appliance Type	Open Deep Fat Fryer

Model: Vulcan GRD 45

Rated Input	120,000 Btu/h
Oil Capacity	50 lb
Frying Area	15” x 15”
Construction	Stainless steel front and top, painted sides and cold rolled steel fry tank
Controls	Solid state thermostat with melt cycle
Generic Appliance Type	Open Deep Fat Fryer

2 Methods

Setup and Instrumentation

FSTC researchers installed the fryers 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 were installed in accordance with Section 9 of the ASTM test method.[1] See Figure 2-1.

Researchers instrumented the fryer with thermocouples to measure temperatures in the cold and the cooking zones and at the thermostat bulb. Additionally, four thermocouples were welded onto the heat transfer tubes, one in each of the four quadrants of the frypot, and a single thermocouple monitored flue temperature. 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

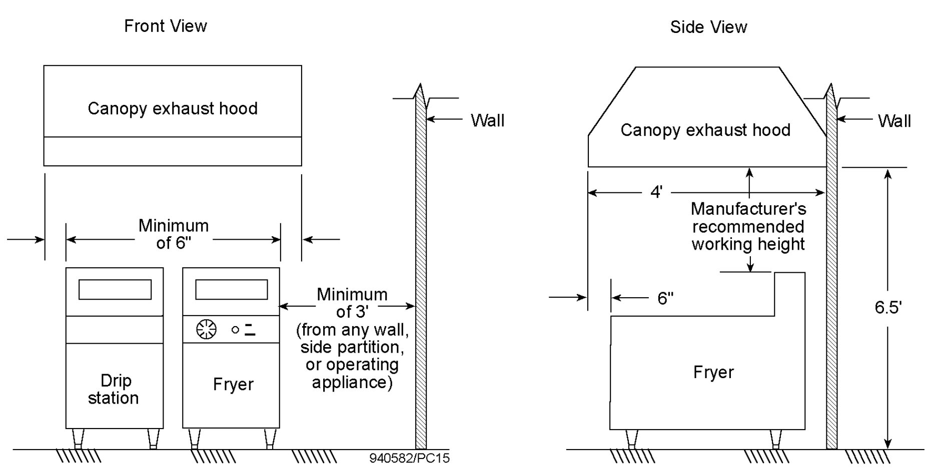


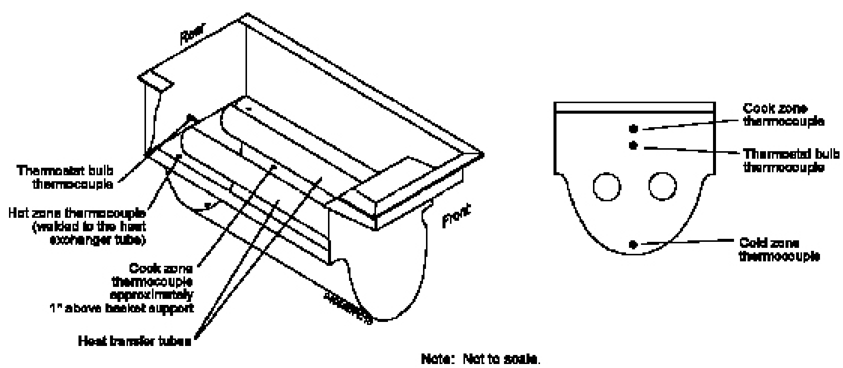
Figure 2-1. Equipment configuration.

was measured toward the rear of the frypot, 1/8-inch from the bottom of the pot. See Figure 2-2.

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

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

Figure 2-2. Thermocouple placement for testing.



Measured Energy Input Rate

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

Cooking Tests

Researchers specified Simplot® brand ¼-inch blue ribbon product, par-cooked, frozen shoestring potatoes for all cooking tests. Each load of French fries was cooked to a 30% weight loss. The cooking tests involved "barreling" six loads of frozen French fries, using fry medium temperature as a basis for recovery. Each test was followed by a 10-minute wait period and was then repeated two more times. Researchers tested the fryer using 3-pound (heavy), and ¾-pound (light) French fry loads.

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

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

Cooking tests were run in the following sequence: three replicates of the heavy-load test, 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 each fryer was operating within its specified parameters. The measured energy input rates for the four fryers are listed in Table 3-1.

Table 3-1. Energy Input Rates.

	TK 35	GRD 35	TK 45	GRD 45
Name Plate (Btu/h)	90,000	90,000	120,000	120,000
Measured (Btu/h)	93,540	88,490	117,130	119,620
Percentage Difference (%)	3.93	1.68	2.39	0.32

Preheat and Idle Tests

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

Preheat Energy and Time

Researchers filled the 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. The TK 35 and GRD 35 fryers were ready to cook in about 11 minutes. The higher input TK 45 and GRD 45 fryers were preheated in approximately 9 minutes. The addition of the solid state controls in the GRD-series fryers reduced the preheat energy requirements by 13% by minimizing temperature overshoot. Figure 3-1 thru Figure 3-4 show the preheat characteristics for the four fryers.

Idle Energy Rate

Once the frying medium reached 350°F, the fryer was allowed to stabilize for half an hour. Time and energy consumption was monitored for an additional two-hour period as each fryer maintained the oil at 350°F. The idle energy rate during this period for the TK 35 fryer was 13,180 Btu/h and the TK 45 was 12,380 Btu/h. The GRD 35 fryer had an idle rate of 12,830 Btu/h, while the GRD 45's idle rate was 14,520.

Figure 3-1. TK 35 preheat characteristics.

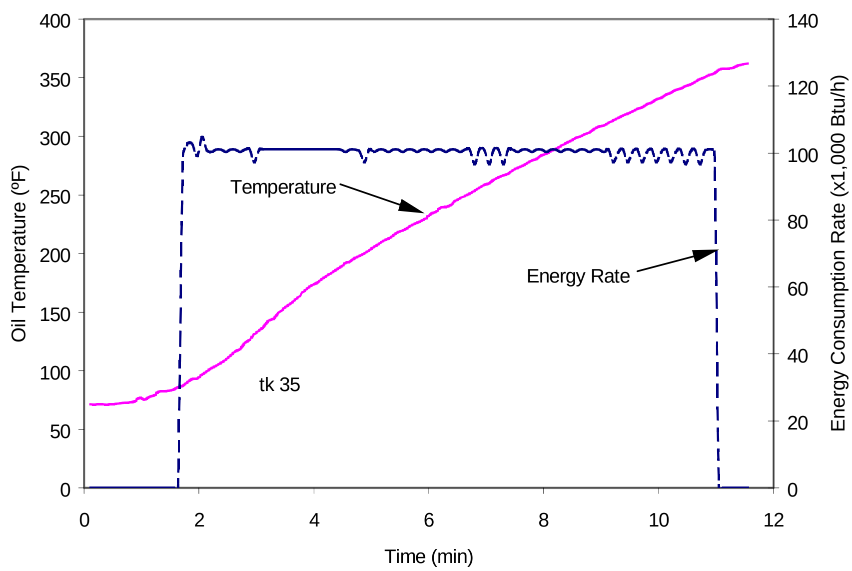


Figure 3-2.
GRD 35 preheat characteristics.

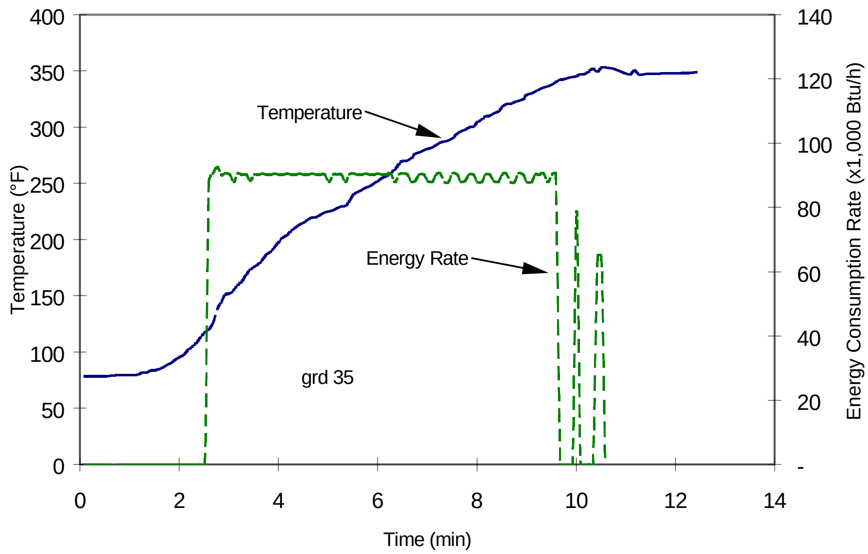


Figure 3-3.
TK 45 preheat characteristics.

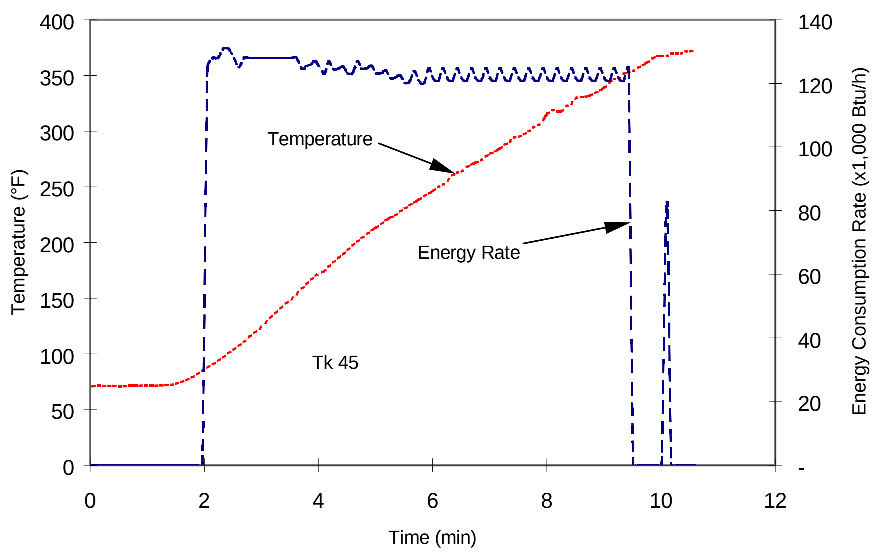
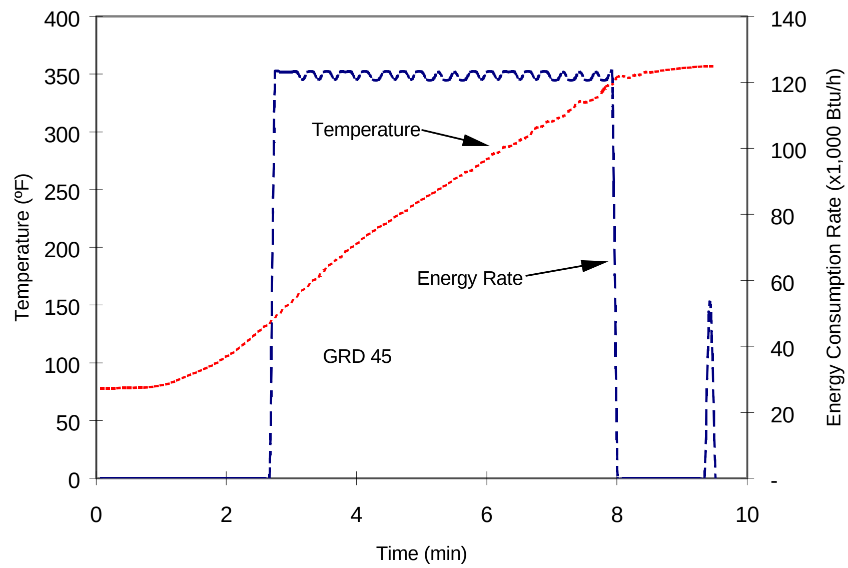


Figure 3-4.
GRD 45 preheat characteristics.



Test Results

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

Table 3-2. Input, Preheat, and Idle Test Results.

	TK 35	***GRD 35***	***TK 45***	***GRD 45***
Rated Energy Input Rate (Btu/h)	90,000	90,000	120,000	120,000
Measured Energy Input Rate (Btu/h)	93,539	88,490	117,130	119,620
Preheat				
Time to 350°F (min)	10.7	10.4	9.0	8.3
Energy (Btu)	17,140	13,790	17,552	15,426
Rate to 350°F (°F/min)	25.9	26.1	31.0	32.8
Idle Energy Rate @ 350°F (Btu/h)	13,180	12,829	12,384	14,522

Results

Cooking Tests

The fryers were tested under two loading scenarios: heavy (3 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. Figures 3-5 thru 3-9 show the average temperature of the frying mediums during the heavy-load tests. 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 temperatures during the heavy-load test were 325°F for the TK 35, 335°F for the TK 45, 331°F for the GRD 35, and 335°F for the GRD 45.

Figure 3-5.
Frying medium temperature during a heavy-load test for the TK 35 fryer.

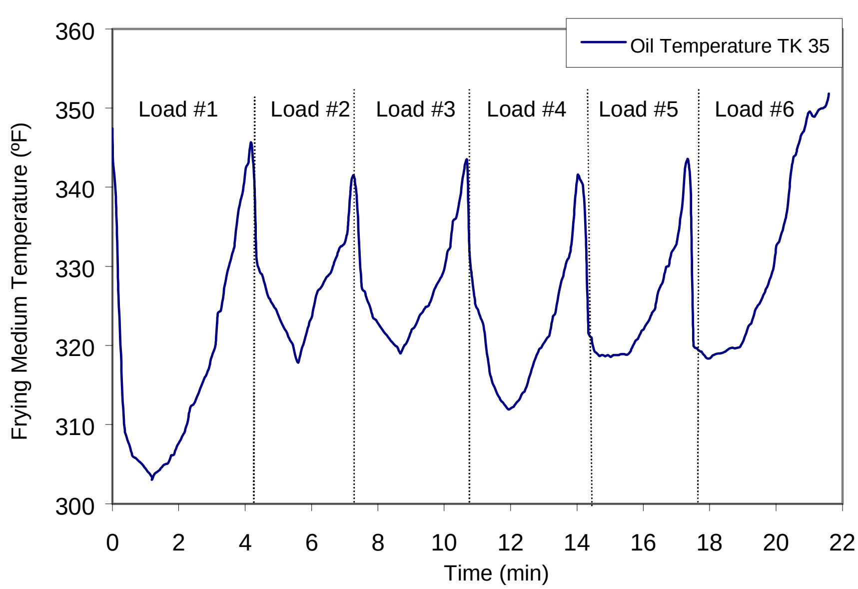


Figure 3-6.

Frying medium temperature during a heavy-load test for the GRD 35 fryer.

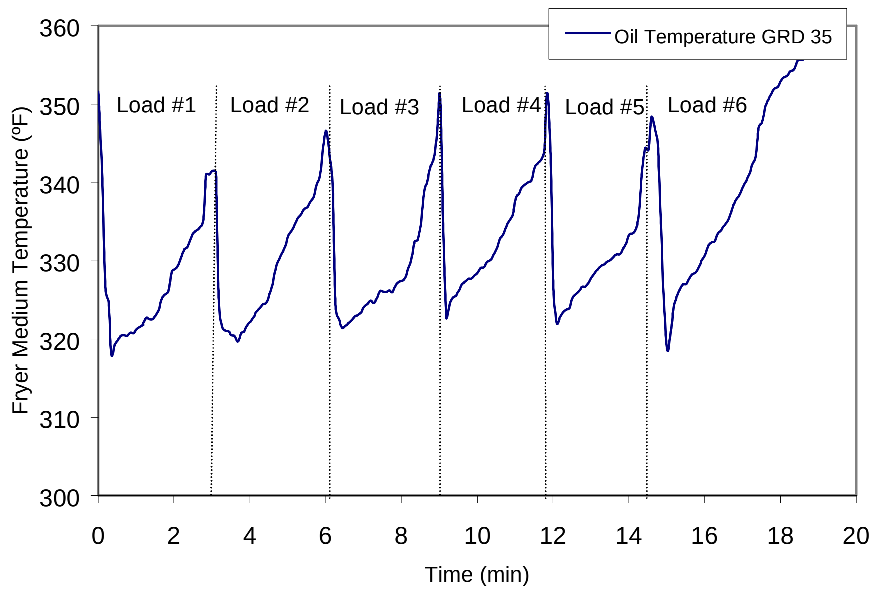


Figure 3-7.

Frying medium temperature during a heavy-load test for them TK 45 fryer.

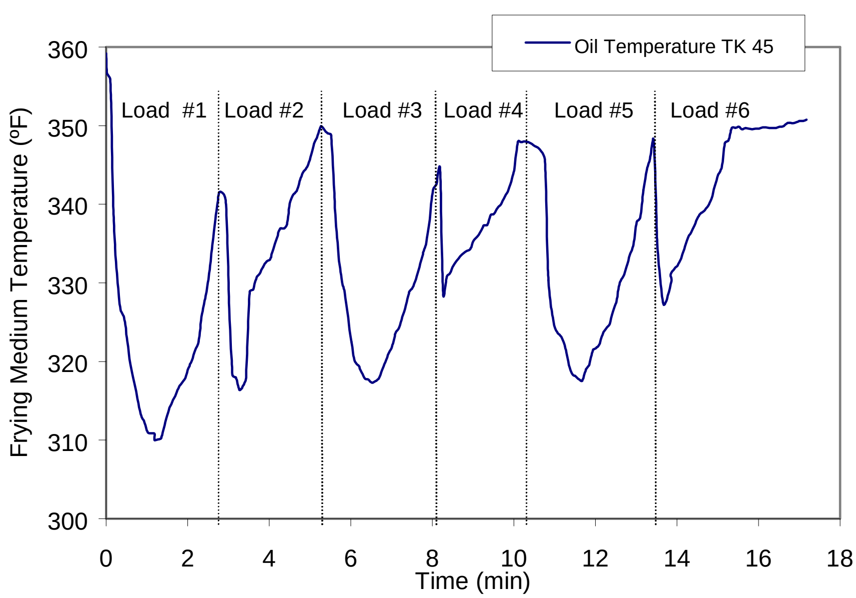
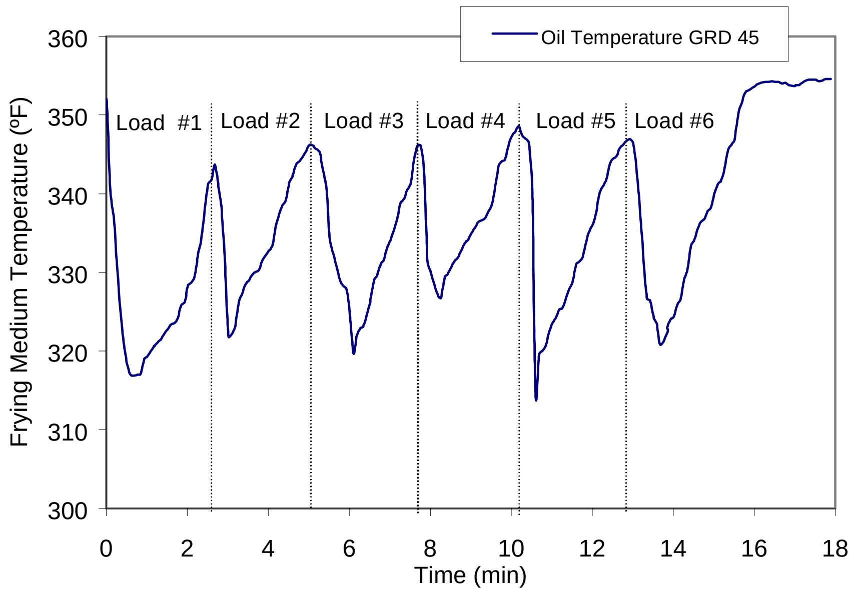


Figure 3-8.
Frying medium temperature during a heavy-load test for them GRD 45 fryer.



The heavy load cook time for the TK 35 fryer was 2.75 minutes with a recovery time of 0.52 minutes. The TK 45 fryer had a cook time of 2.42 minutes and an average recovery time of 0.24 minutes. The GRD 35 fryer cooked 3-pounds of fries in 2.65 minutes and required 0.22 minutes to recover to 340 °F, while the GRD 45 fryer had the shortest heavy-load cook time at 2.30 minutes and a 0.20 minute recovery time. Figure 3-9 compares the temperature response of the four fryers 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).

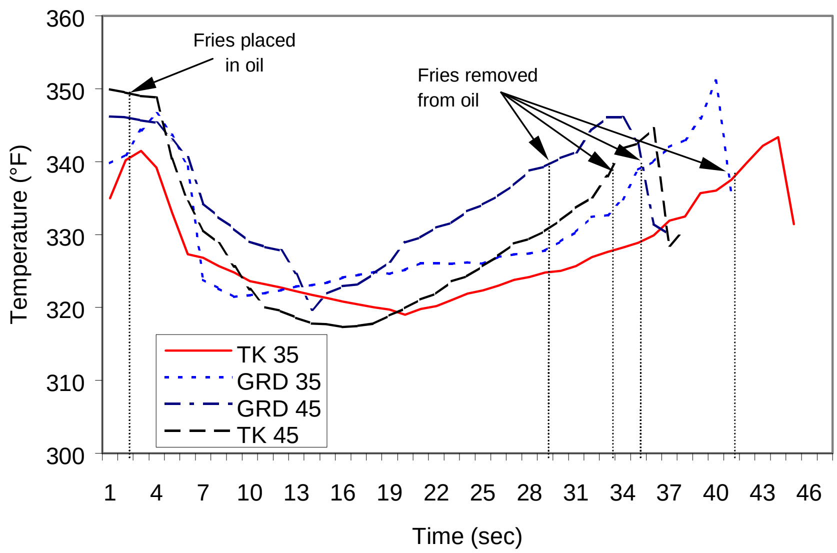


Figure 3-9. Fryer cooking cycle temperature signature.

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 for the TK 35 fryer were 35.1%, 36.1%, 36.2%, yielding a maximum uncertainty of 1.5%. The GRD 35 fryer had cooking energy efficiency results of 41.1%, 40.1%, 40.9%, yielding a maximum uncertainty of 1.2%. The TK 45 fryer exhibited 41.1%, 41.9%, 42.9% cooking energy efficiency, yielding a maximum uncertainty of 2.1 % in the test results. The GRD 45 fryer had cooking energy efficiencies of 42.1%, 41.5%, 42.5, resulting in a maximum uncertainty of 1.4%. Table 3-3 and Table 3-4 summarizes the results of the heavy and light-load tests.

Table 3-3. Heavy Load Test Results.

	TK 35	***GRD 35***	***TK45***	***GRD45***
Load Size (lb)	3.00	3.00	3.00	3.00
French Fry Cook Time (min)	2.75	2.65	2.42	2.30
Average Recovery Time (min)	0.52	0.22	0.24	0.20
Production Rate (lb/h)	55.0 ± 2.5	62.8 ± 0.5	67.6 ± 3.0	71.8 ± 4.5
Energy Consumption (Btu/lb)	571	569	567	569
Cooking Energy Rate (Btu/h)	87,680	87,760	91,460	97,190
Cooking Energy Efficiency (%)	35.8 ± 1.5	40.7 ± 1.2	42.0 ± 2.1	42.0 ± 1.4

Figure 3-10 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.

Table 3-4. Light Load Test Results.

	TK 35	***GRD 35***	***TK 45***	***GRD 45***
Load Size (pounds)	¾	¾	¾	¾
French Fry Cook Time (min)	2.32	2.33	2.28	2.08
Average Recovery Time (min)	1.27	0.18	3.01	0.18
Production Rate (lb/h)	12.5 ± 0.3	17.9 ± 0.2	8.5 ± 1.2	19.9 ± 0.1
Energy Consumption (Btu/lb)	559	559	561	567
Cooking Energy Rate (Btu/h)	31,545	40,675	24,980	45,560
Cooking Energy Efficiency (%)	22.2 ± 0.7	24.7 ± 1.4	18.5 ± 1.4	24.8 ± 1.1

Figure 3-10.

Fryer part-load cooking energy efficiency.

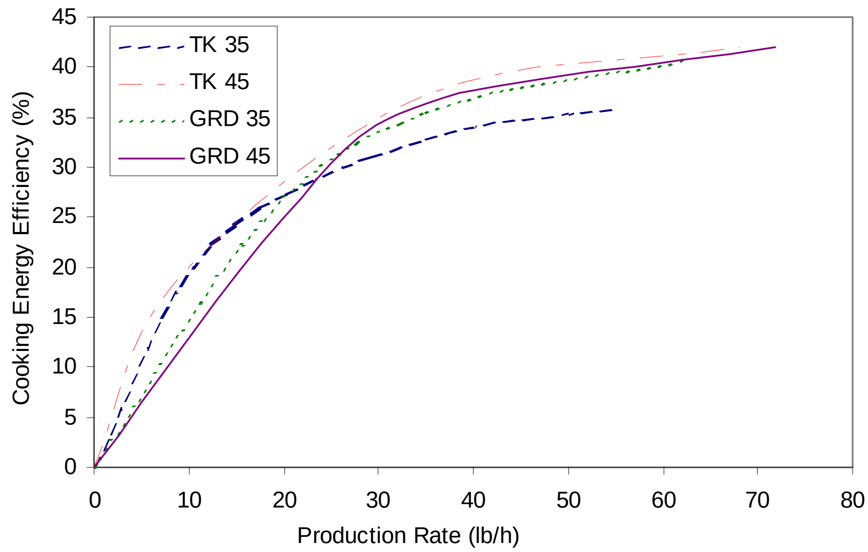
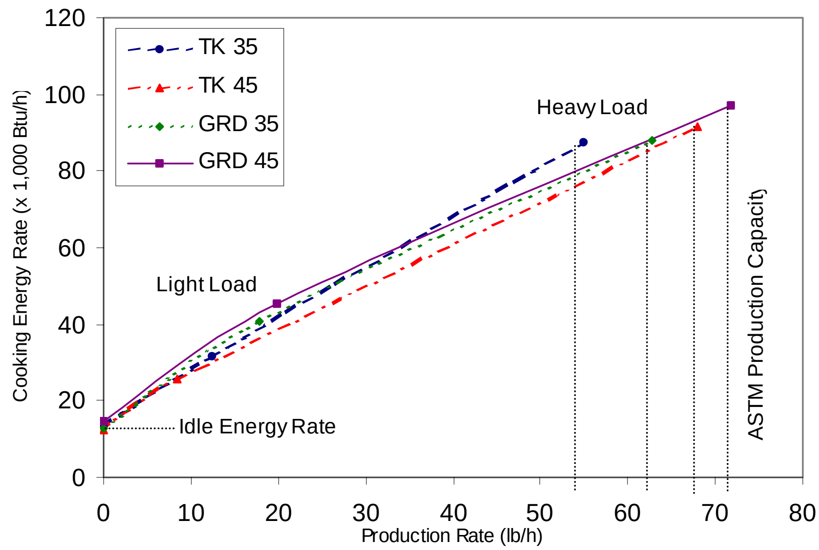


Figure 3-11 illustrates the relationship between the fryer's average energy consumption rate and the production rate. This graph can be used as a tool to estimate the daily energy consumption for the fryer in a real-world operation. Average energy consumption rates at 10, 30, and 50 pounds per hour are for the TK 35 fryer 27,310 Btu/h, 54,230 Btu/h, and 81,150 Btu/h, respectively. Table 3-5 represents the estimated energy daily consumption for all four fryers.

Figure 3-11.
Fryer cooking energy consumption profile.



Note: Light-load = ¾ pounds /load; heavy-load = 3 pounds/load.

Table 3-5. Energy Consumption Estimations.

Production Rate	***TK 35***	***GRD 35***	***TK 45***	***GRD 45***
10 lbs/h	27,310 Btu/h	29,030 Btu/h	25,550 Btu/h	30,890 Btu/h
30 lbs/h	54,230 Btu/h	56,560 Btu/h	48,370 Btu/h	58,900 Btu/h
50 lbs/h	81,150 Btu/h	77,610 Btu/h	71,180 Btu/h	80,590 Btu/h

4 Conclusions

The GRD series fryers with their solid state thermostats, demonstrated an increase in cooking energy efficiency over the TK series fryers. The solid state thermostat provides a tighter frying medium cooking temperature during operation, allowing for a decrease in recovery time and an increase in production capacity. Not only does the solid state thermostat improve performance under heavy load conditions, its real benefit is during partial-loading which is a more typical operating state in most applications. With the tighter temperature bandwidth of the solid state thermostat, the GRD series fryer demonstrated drastically reduced recovery times especially during the light-load tests, contributing to much as 34% increase in cooking energy efficiency.

This increase in energy efficiency is not at the cost of cooking performance. In fact, the production capacity was 14% greater for the GRD 35 over the TK 35 (62.8 vs. 55.0) and 6% greater for the GRD 45 over the TK 45 (71.8 vs. 68.0). The solid state thermostats used less energy than the mechanical thermostat during preheat, due to a reduction in temperature overshoot. During idle conditions the solid state thermostat did not adversely affect the idle rates of the GRD fryers in comparison to the TK fryers.

The additional input of the TK 45 and GRD 45 fryers allowed for a 3% increase in production without sacrificing energy efficiency. The extra heat transfer tube in the 120,000 Btu/h fryer increases the surface area for heat transfer into the frying medium. The 120,000 Btu/h fryers showed comparable standby losses during idle conditions relative to the 90,000 Btu/h fryers. Under heavy load conditions the additional input for the TK 45 fryer increased the cooking performance over the TK 35. The addition of the solid state thermostat levels the performance playing field between the GRD 35 and GRD 45 fryers with almost identical recovery times.

Conclusions

The solid state thermostats utilized on the GRD series fryers offer increased cooking energy efficiency and production capacity over their TK series counterparts which offer cost saving mechanical thermostats. With the addition of slightly lower preheat energy consumption and comparable idle energy rates, the GRD series fryers are well worth the investment.

5 Appendixes

1. Pacific Gas and Electric Company. 1991. *Development and Application of a Uniform Testing Procedure for Open, Deep Fat Fryers.* Report 008.1-90.22 prepared for Research and Development. San Ramon, California: Pacific Gas and Electric Company.

2. Food Service Technology Center. 1993. *Frymaster® Model H-17CSC Electric Fryer Performance Test.* Report 5017.93.2 prepared for Products and Services Department. San Francisco: Pacific Gas and Electric Company.

3. Food Service Technology Center. 1994. *TekmaStar Model FD-212 Electric Fryer Performance Test.* Report 5011.94.2 prepared for Products and Services Department. San Francisco: Pacific Gas and Electric Company

4. Food Service Technology Center. 1995. *Keating Model 14 IFM Gas Fryer Performance Test.* Report 5011.95.32 prepared for Products and Services Department. San Francisco: Pacific Gas and Electric Company.

5. Food Service Technology Center. 1996. *Pitco Frialator® Model RPB14 Technofry 1™ Gas Fryer: Application of ASTM Standard Test Method F1361-95.* Report 5011.94.11 for Products and Services Department. San Francisco: Pacific Gas and Electric Company.

6. Food Service Technology Center. 1996. *Pitco Frialator® Model E14B Electric Fryer Performance Test.* Report 5011.95.12 prepared for Products and Services Department. San Francisco: Pacific Gas and Electric Company.

7. Food Service Technology Center. 1999. *Ultrafryer, Model PAR 3-14 Gas Fryer Performance Test.* Report 5011.99.78 prepared for Customer Energy Management. San Francisco. Pacific Gas and Electric Company.

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.

Glossary

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

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

Idle Temperature (°F, Setting)

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

Idle Duty Cycle (%)
Idle Energy Factor

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

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

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

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

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 "preheat" from the ambient room temperature (75 ± 5°F) to a specified (and calibrated) operating temperature or thermostat set point.

Production Capacity (lb/h)

The maximum production rate of an appliance while cooking a specified food product in accordance with the heavy-load cooking test.

Production Rate (lb/h)
Productivity

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

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

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

Recovery Time (minute, second)

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

Test Method

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

B Appliance Specifications

Appendix B includes the product literature for the Vulcan fryers.

C Results Reporting Sheets

Manufacturer: Vulcan

Models: TK 35, GRD 35, TK 45, and GRD 45

Date: November 2000

Section 11.1 Test Fryers and Burners

Description of operational characteristics: The TK 35 and GRD 35 fryers are powered by three atmoshperic burners, each rate at 30,000 Btu/h. The TK 35 fryer is controlled by a mechanical thermostat, while the GRD 35 fryer has a solid state thermostat and a control package. The GRD 35 fryer also inlcudes a melt cycle for solid shortening, with a manual override that allows for a shorter preheat when using liquid shortening. The TK 45 and GRD 45 fryers have the same characteristics as the respective 35 series fryers expect the 45 series fryers incorporate one more 30,000 Btu/h burner. Making a total of four atmossheric burners.

Section 11.2 Apparatus

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

Deviations: None.

Results Reporting Sheets

Section 11.4. Energy Input Rate.

	TK 35	GRD 35	TK 45	GRD 45
Gas Heating Value (Btu/scf)	1019	1018	1015	1015
Name Plate (Btu/h)	90,000	90,000	120,000	120,000
Measured (Btu/h)	93,540	88,490	117,130	119,620
Percentage Difference (%)	3.93	1.68	2.39	0.32

Section 11.5 Thermostat Calibration

	TK 35	GRD 35	TK 45	GRD 45
Thermostat Setting (°F)	350	350	350	350
Oil Temperature (°F)	350	350	351	350

Section 11.6 Preheat Energy and Time

	TK 35	GRD 35	TK 45	GRD 45
Gas Heating Value (Btu/scf)	1020	1015	1016	1015
Starting Temperature (°F)	72	79	71	78
Energy Consumption (Btu)	17,140	13,790	17,550	15,430
Duration (min)	10.7	9.4	9.0	8.3
Preheat Rate (°F/min)	25.9	28.8	31.0	32.8

Results Reporting Sheets

Section 11.7 Idle Energy Rate

	TK 35	GRD 35	TK 45	GRD 45
Gas Heating Value (Btu/scf)	1020	1015	1016	1015
Idle Energy Rate @ 350 °F (Btu/h)	13,180	12,830	12.380	14,520

Section 11.8 Heavy Load Cooking Energy Efficiency and Cooking Energy Rate

	TK 35	GRD 35	TK45	GRD45
Gas Heating Value (Btu/scf)	1016	1019	1016	1013
Load Size (lb)	3.00	3.00	3.00	3.00
French Fry Cook Time (min)	2.75	2.65	2.42	2.30
Average Recovery Time (min)	0.52	0.22	0.24	0.20
Production Rate (lb/h)	55.0 ± 2.5	62.8 ± 0.5	67.6 ± 3.0	71.8 ± 4.5
Energy Consumption (Btu/lb)	571	569	567	569
Cooking Energy Rate (Btu/h)	87,680	87,760	91,460	97,190
Energy per Pound of Food Cooked (Btu/lb)	1,594	1,398	1,352	1,354
Cooking Energy Efficiency (%)	35.8 ± 1.5	40.7 ± 1.2	42.0 ± 2.1	42.0 ± 1.4

Results Reporting Sheets

Section 11.9 Light Load Cooking Energy Efficiency and Cooking Energy Rate

	TK 35	GRD 35	TK 45	GRD 45
Gas Heating Value (Btu/scf)	1020	1020	1020	1020
Load Size (pounds)	¾	¾	¾	¾
French Fry Cook Time (min)	2.32	2.33	2.28	2.08
Average Recovery Time (min)	1.27	0.18	3.01	0.18
Production Rate (lb/h)	12.5 ± 0.3	17.9 ± 0.2	8.5 ± 1.2	19.9 ± 0.1
Energy Consumption (Btu/lb)	559	559	561	567
Cooking Energy Rate (Btu/h)	31,545	40,675	24,980	45,560
Energy per Pound of Food Cooked (Btu/lb)	2,515	2,268	3,035	2,288
Cooking Energy Efficiency (%)	22.2 ± 0.7	24.7 ± 1.4	18.5 ± 1.4	24.8 ± 1.1

D Cooking Energy Efficiency Data

Table D-1. Specific Heat and Latent Heat.

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

Cooking Energy Efficiency Data

Table D-2. TK 35 Heavy-Load Fry Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	24,337	23,840	23,598
Cook Time (min)	**2.75**	**2.75**	**2.75**
Total Test Time (min)	16.7	16.2	16.2
Weight Loss (%)	29.91	29.89	29.79
Initial Weight (lb)	15.000	15.000	15.000
Final Weight (lb)	10.514	10.516	10.532
Initial Fat Content (%)	6.1	6.1	6.1
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	44.6	44.0	44.5
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	9.773	9.773	9.773
Final Weight of Water (lb)	4.694	4.625	4.685
Sensible (Btu)	2,210	2,210	2,210
Latent - Heat of Fusion (Btu)	1,407	1,407	1,407
Latent - Heat of Vaporization (Btu)	4,927	4,994	4,936
Total Energy to Food (Btu)	8,544	8,611	8,553
Energy to Food (Btu/lb)	**570**	**574**	**570**
Total Energy to Fryer	24,337	23,840	23,598
Energy to Fryer (Btu/lb)	**1,622**	**1,589**	**1,573**
Cooking Energy Efficiency (%)	**35.1**	**36.1**	**36.2**
Cooking Energy Rate (Btu/h)	**87,333**	**88,514**	**87,185**
Production Rate (lb/h)	**53.8**	**55.7**	**55.4**
Average Recovery Time (sec)	**0.59**	**0.48**	**0.50**

Cooking Energy Efficiency Data

Table D-3. TK 35 Light-Load Fry Test Data.

	Repetition #1	Repetition #2	Repetition #3	Repetition #4
Measured Values				
Total Energy (Btu)	9,380	9.283	9.674	9,381
Cook Time (min)	**2.32**	**2.32**	**2.32**	**2.32**
Total Test Time (min)	18.1	17.3	18.4	17.9
Weight Loss (%)	29.29	29.31	29.57	29.49
Initial Weight (lb)	3.750	3.750	3.750	3.750
Final Weight (lb)	2.652	2.651	2.641	2.644
Initial Fat Content (%)	6.1	6.1	6.1	6.1
Initial Moisture Content (%)	64.3	64.3	64.3	64.3
Final Moisture Content (%)	44.2	44.3	44.8	44.8
Initial Temperature (°F)	0	0	0	0
Final Temperature (°F)	212	212	212	212
Calculated Values				
Initial Weight of Water (lb)	2.411	2.411	2.411	2.411
Final Weight of Water (lb)	1.171	1.174	1.182	1.184
Sensible (Btu)	553	553	553	553
Latent - Heat of Fusion (Btu)	347	347	347	347
Latent - Heat of Vaporization (Btu)	1,203	1,200	1,192	1,191
Total Energy to Food (Btu)	2,103	2,099	2,092	2,096
Energy to Food (Btu/lb)	**561**	**560**	**558**	**557**
Total Energy to Fryer	9,380	9,283	9,674	9,381
Energy to Fryer (Btu/lb)	**2,501**	**2,475**	**2,580**	**2,502**
Cooking Energy Efficiency (%)	**22.4**	**22.6**	**21.6**	**22.3**
Cooking Energy Rate (Btu/h)	**31,043**	**32,195**	**31,547**	**31,393**
Production Rate (lb/h)	**12.4**	**13.0**	**12.2**	**12.5**
Average Recovery Time (sec)	**1.31**	**1.14**	**1.36**	**1.27**

Cooking Energy Efficiency Data

Table D-4. GRD 35 Heavy Load Fry Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	20,943	21,196	20,771
Cook Time (min)	**2.65**	**2.65**	**2.65**
Total Test Time (min)	14.3	14.4	14.4
Weight Loss (%)	30.11	30.04	29.81
Initial Weight (lb)	15.000	15.000	15.000
Final Weight (lb)	10.483	10.494	10.529
Initial Fat Content (%)	6.1	6.1	6.1
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	44.2	45.1	45.1
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	9.773	9.773	9.773
Final Weight of Water (lb)	4.636	4.736	4.751
Sensible (Btu)	2,210	2,210	2,210
Latent - Heat of Fusion (Btu)	1,407	1,407	1,407
Latent - Heat of Vaporization (Btu)	4,984	4,886	4,872
Total Energy to Food (Btu)	8,601	8,503	8,489
Energy to Food (Btu/lb)	**573**	**567**	**566**
Total Energy to Fryer	20,943	21,196	20,771
Energy to Fryer (Btu/lb)	**1,396**	**1,413**	**1,385**
Cooking Energy Efficiency (%)	**41.1**	**40.1**	**40.9**
Cooking Energy Rate (Btu/h)	**87,933**	**88,625**	**86,728**
Production Rate (lb/h)	**63.0**	**62.7**	**62.6**
Average Recovery Time (sec)	**0.21**	**0.22**	**0.22**

Cooking Energy Efficiency Data

Table D-5. GRD 35 Light Load Fry Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	8,368	8,663	8,486
Cook Time (min)	**2.33**	**2.33**	**2.33**
Total Test Time (min)	12.5	12.5	12.6
Weight Loss (%)	30.79	30.69	30.80
Initial Weight (lb)	3.750	3.750	3.750
Final Weight (lb)	2.596	2.599	2.595
Initial Fat Content (%)	6.1	6.1	6.1
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	46.1	46.9	47.4
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	2.443	2.443	2.443
Final Weight of Water (lb)	1.196	1.218	1.230
Sensible (Btu)	553	553	553
Latent - Heat of Fusion (Btu)	352	352	352
Latent - Heat of Vaporization (Btu)	1,210	1,189	1,177
Total Energy to Food (Btu)	2,114	2,093	2,081
Energy to Food (Btu/lb)	**564**	**558**	**555**
Total Energy to Fryer	8,368	8,663	8,486
Energy to Fryer (Btu/lb)	**2,231**	**2,310**	**2,263**
Cooking Energy Efficiency (%)	**25.3**	**24.2**	**24.5**
Cooking Energy Rate (Btu/h)	**40,068**	**41,549**	**40,409**
Production Rate (lb/h)	**18.0**	**18.0**	**17.9**
Average Recovery Time (sec)	**0.18**	**0.17**	**0.19**

Cooking Energy Efficiency Data

Table D-6. TK 45 Heavy Load Fry Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	20,382	20.284	20,187
Cook Time (min)	**2.38**	**2.42**	**2.47**
Total Test Time (min)	13.1	13.4	13.5
Weight Loss (%)	29.47	29.60	30.07
Initial Weight (lb)	15.000	15.000	15.000
Final Weight (lb)	10.580	10.560	10.490
Initial Fat Content (%)	6.1	6.1	6.1
Initial Moisture Content (%)	64.3	64.3	64.3
Final Moisture Content (%)	44.5	44.5	44.5
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	9.644	9.644	9.644
Final Weight of Water (lb)	4.711	4.599	4.437
Sensible (Btu)	2,210	2,210	2,210
Latent - Heat of Fusion (Btu)	1,389	1,389	1,389
Latent - Heat of Vaporization (Btu)	4,786	4,894	5,052
Total Energy to Food (Btu)	8,385	8,493	8,651
Energy to Food (Btu/lb)	**559**	**566**	**577**
Total Energy to Fryer	20,382	20,284	20,187
Energy to Fryer (Btu/lb)	**1,359**	**1,352**	**1,346**
Cooking Energy Efficiency (%)	**41.1**	**41.9**	**42.9**
Cooking Energy Rate (Btu/h)	**93,709**	**91,096**	**89,585**
Production Rate (lb/h)	**69.0**	**67.4**	**66.6**
Average Recovery Time (sec)	**0.23**	**0.26**	**0.23**

Cooking Energy Efficiency Data

Table D-7. TK 45 Light-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3	Repetition #4
Measured Values				
Total Energy (Btu)	10,744	11,919	11,140	11,726
Cook Time (min)	**2.30**	**2.28**	**2.28**	**2.28**
Total Test Time (min)	23.6	28.2	25.9	28.2
Weight Loss (%)	30.19	30.19	30.27	30.47
Initial Weight (lb)	3.750	3.750	3.750	3.750
Final Weight (lb)	2.618	2.618	2.615	2.608
Initial Fat Content (%)	6.1	6.1	6.1	6.1
Initial Moisture Content (%)	64.3	64.3	64.3	64.3
Final Moisture Content (%)	44.6	44.6	44.9	44.9
Initial Temperature (°F)	0	0	0	0
Final Temperature (°F)	212	212	212	212
Calculated Values				
Initial Weight of Water (lb)	2.411	2.411	2.411	2.411
Final Weight of Water (lb)	1.167	1.167	1.174	1.171
Sensible (Btu)	553	553	553	553
Latent - Heat of Fusion (Btu)	347	347	347	347
Latent - Heat of Vaporization (Btu)	1,207	1,206	1,200	1,203
Total Energy to Food (Btu)	2,106	2,106	2,099	2,103
Energy to Food (Btu/lb)	**562**	**562**	**560**	**561**
Total Energy to Fryer	10,744	11,919	11,140	11,726
Energy to Fryer (Btu/lb)	**2,865**	**3,178**	**2,971**	**3,127**
Cooking Energy Efficiency (%)	**19.6**	**17.7**	**18.8**	**17.9**
Cooking Energy Rate (Btu/h)	**27,270**	**25,360**	**25,837**	**24,982**
Production Rate (lb/h)	**9.5**	**8.0**	**8.7**	**8.0**
Average Recovery Time (sec)	**2.43**	**3.36**	**2.89**	**3.35**

Cooking Energy Efficiency Data

Table D-8. GRD 45 Heavy Load Fry Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	20,146	20,538	20,232
Cook Time (min)	**2.25**	**2.33**	**2.33**
Total Test Time (min)	12.3	12.7	12.6
Weight Loss (%)	29.00	29.85	30.25
Initial Weight (lb)	15.000	15.000	15.000
Final Weight (lb)	10.650	10.523	10.463
Initial Fat Content (%)	6.1	6.1	6.1
Initial Moisture Content (%)	65.2	65.2	65.2
Final Moisture Content (%)	44.8	44.9	44.2
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	9.773	9.773	9.773
Final Weight of Water (lb)	4.768	4.726	4.629
Sensible (Btu)	2,210	2,210	2,210
Latent - Heat of Fusion (Btu)	1,407	1,407	1,407
Latent - Heat of Vaporization (Btu)	4,856	4,896	4,990
Total Energy to Food (Btu)	8,473	8,514	8,607
Energy to Food (Btu/lb)	**565**	**568**	**574**
Total Energy to Fryer	20,146	20,538	20,232
Energy to Fryer (Btu/lb)	**1,343**	**1,369**	**1,349**
Cooking Energy Efficiency (%)	**42.1**	**41.5**	**42.5**
Cooking Energy Rate (Btu/h)	**98,433**	**97,106**	**96,039**
Production Rate (lb/h)	**73.3**	**70.9**	**71.2**
Average Recovery Time (sec)	**0.21**	**0.21**	**0.20**

Cooking Energy Efficiency Data

Table D-9. GRD 45 Light Load Fry Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	8,319	8,715	8,706
Cook Time (min)	**2.08**	**2.08**	**2.08**
Total Test Time (min)	11.3	11.3	11.3
Weight Loss (%)	29.67	29.47	29.84
Initial Weight (lb)	3.750	3.750	3.750
Final Weight (lb)	2.638	2.645	2.631
Initial Fat Content (%)	6.1	6.1	6.1
Initial Moisture Content (%)	64.3	64.3	64.3
Final Moisture Content (%)	44.5	43.5	42.3
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	212	212	212
Calculated Values			
Initial Weight of Water (lb)	2.411	2.411	2.411
Final Weight of Water (lb)	1.174	1.152	1.113
Sensible (Btu)	553	553	553
Latent - Heat of Fusion (Btu)	347	347	347
Latent - Heat of Vaporization (Btu)	1,200	1,222	1,259
Total Energy to Food (Btu)	2,099	2,121	2,159
Energy to Food (Btu/lb)	**560**	**566**	**576**
Total Energy to Fryer	8,319	8,715	8,706
Energy to Fryer (Btu/lb)	**2,218**	**2,324**	**2,322**
Cooking Energy Efficiency (%)	**25.2**	**24.3**	**24.8**
Cooking Energy Rate (Btu/h)	**44,094**	**46,395**	**46,184**
Production Rate (lb/h)	**19.9**	**20.0**	**19.9**
Average Recovery Time (sec)	**0.18**	**0.17**	**0.18**

Cooking Energy Efficiency Data

Table D-10. TK 35 Cooking Energy Efficiency and Production Capacity Statistics.

	Cooking Energy Efficiency		Production Capacity
	Heavy Load	Light Load	
Replicate #1	35.1	22.4	53.8
Replicate #2	36.1	22.6	55.7
Replicate #3	36.2	21.6	55.4
Replicate #4	—	22.3	—
Average	**35.8**	**22.2**	**55.0**
Standard Deviation	0.6	0.4	1.0
Absolute Uncertainty	1.5	0.7	2.5
Percent Uncertainty	4.3	3.1	4.5

Table D-11. GRD 35 Cooking Energy Efficiency and Production Capacity Statistics.

	Cooking Energy Efficiency		Production Capacity
	Heavy Load	Light Load	
Replicate #1	41.1	25.3	63.0
Replicate #2	40.1	24.2	62.7
Replicate #3	40.9	24.5	62.6
Replicate #4	—	—	—
Average	**40.7**	**24.7**	**62.8**
Standard Deviation	0.5	0.6	0.2
Absolute Uncertainty	1.2	1.4	0.5
Percent Uncertainty	3.1	5.7	0.7

Cooking Energy Efficiency Data

Table D-12. TK 45 Cooking Energy Efficiency and Production Capacity Statistics.

	Cooking Energy Efficiency		**Production Capacity**
	Heavy Load	**Light Load**	
Replicate #1	41.1	19.6	69.0
Replicate #2	41.9	17.7	67.4
Replicate #3	42.9	18.8	66.6
Replicate #4	—	17.9	—
Average	**42.0**	**18.5**	**67.6**
Standard Deviation	0.9	0.9	1.2
Absolute Uncertainty	2.1	1.4	3.0
Percent Uncertainty	5.1	7.6	4.5

Table D-13. GRD 45 Cooking Energy Efficiency and Production Capacity Statistics.

	Cooking Energy Efficiency		**Production Capacity**
	Heavy Load	**Light Load**	
Replicate #1	42.1	25.2	73.3
Replicate #2	41.5	24.3	70.9
Replicate #3	42.5	24.8	71.2
Replicate #4	—	—	—
Average	**42.0**	**24.8**	**71.8**
Standard Deviation	0.5	0.4	1.3
Absolute Uncertainty	1.4	1.1	3.2
Percent Uncertainty	3.2	4.5	4.5