Wells Gas Griddle Performance Test

Application of ASTM Standard
Test Method F 1275-99

FSTC Report 5011.03.05

Food Service Technology Center
January 2003

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

Acknowledgments

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Specific appreciation is extended to Wells Manufacturing, for supplying the Food Service Technology Center with a 3-foot gas griddle for controlled testing in the appliance laboratory.

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Executive Summary

Griddles are widely used throughout the hospitality industry to prepare a variety of menu items, from pancakes to hamburgers. As concern over food safety continues, griddle performance parameters such as temperature uniformity and productivity are becoming more important to the food service operator.

Wells' WG2436G griddle features an all stainless steel construction, snap action thermostats, and a 1-inch thick polished cooking surface. Food Service Technology Center (FSTC) engineers tested the 3-foot griddle under the tightly controlled conditions of the American Society for Testing and Materials' (ASTM) Standard Test Method for the Performance of Griddles.[1] Griddle performance is characterized by temperature uniformity, preheat time and energy consumption, idle energy consumption rate, cooking-energy efficiency, and production capacity.

Cooking-energy efficiency and production capacity were determined by cooking frozen hamburgers under three different loading scenarios (heavy—24 hamburgers, medium—12 hamburgers, and light—4 hamburgers). The cook time for each of the loading scenarios was 7.75 minutes. Production capacity includes the cooking time and the time required for the cooking surface to return to within 25°F of the thermostat set point. Production rate varies with the amount of food being cooked.

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:

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[1] American Society for Testing and Materials. 1999. *Standard Test Method for the Performance of Griddles.* ASTM Designation F 1275-99, in *Annual Book of ASTM Standards,* Philadelphia.

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

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

Table ES-1. Summary of Griddle Performance.

Rated Energy Input Rate (Btu/h)	75,000
Measured Energy Input Rate (Btu/h)	72,955
Temperature Uniformity (°F) [a]	± 24.9
Preheat Time to 375°F (min)	10.75
Preheat Energy to 375°F (Btu)	12,266
Idle Energy Rate @ 375°F (Btu/h)	16,378
Heavy-Load Cooking-Energy Efficiency (%)	39.5 ± 2.3
Medium-Load Cooking-Energy Efficiency (%)	33.4 ± 0.9
Light-Load Cooking-Energy Efficiency (%)	17.2 ± 1.1
Production Capacity[b] (lb/h)	33.0 ± 1.8
Cooking Surface Recovery Time[b] (min)	3.2

[a]Temperature uniformity reflects the absolute temperature variance across the cooking surface to within 3 inches from each edge.
[b]Based on the heavy-load cooking test with a minimum 30-second preparation time between loads.

Figure ES-1 illustrates the relationship between cooking-energy efficiency and production rate for this griddle. Griddle production rate is a function of both the hamburger patty cook time and the recovery time.

Figure ES-2 illustrates the relationship between the griddle'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 griddle in a real-world operation. Average energy consumption rates at 10, 20, and 30 pounds per hour are 23,140 Btu/h, 30,510 Btu/h, and 37,870 Btu/h, respectively. For an operation cooking an average of 15 pounds of food per hour over the course of the day (e.g., 200 pounds of food over a ten hour day), the average energy consumption for this griddle would be 30,510 Btu/h.

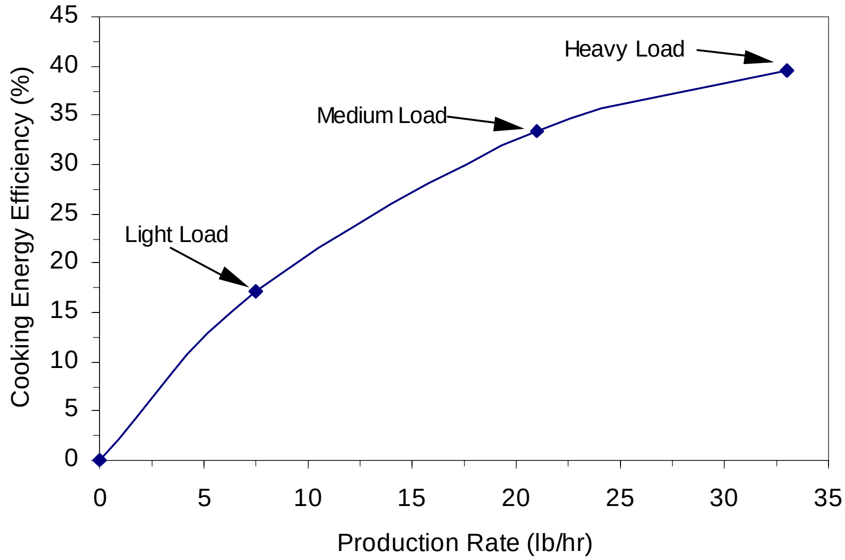

Figure ES-1.
Griddle part-load cooking-energy efficiency.

Note: Light-load = 4 hamburgers/load; medium-load = 12 hamburgers/load; heavy-load = 24 hamburgers/load

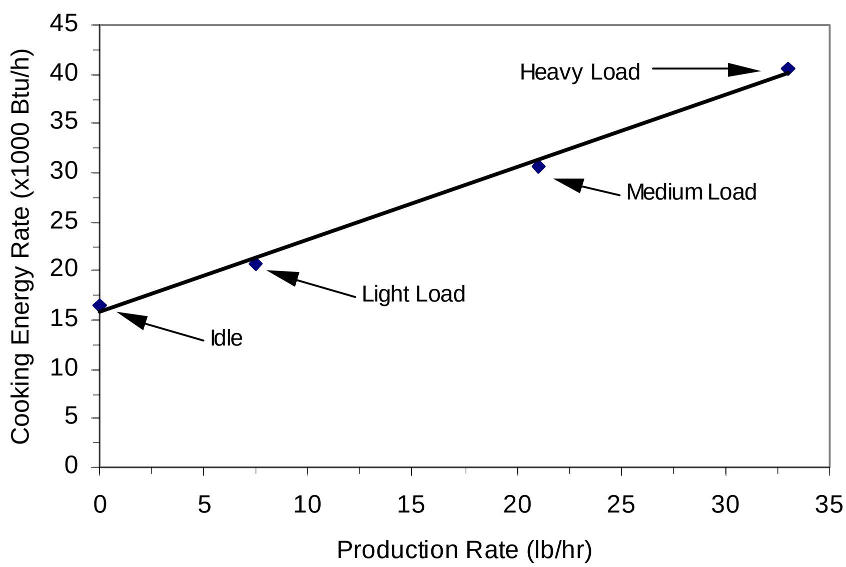

Figure ES-2.
Griddle cooking energy consumption profile.

Note: Light-load = 4 hamburgers/load; medium-load = 12 hamburgers/load; heavy-load = 24 hamburgers/load

Executive Summary

The Wells WG2436G gas griddle demonstrated an impressive 10.8 minute preheat to a set point of 375°F, the fastest tested to date at the Food Service Technology Center, and a competitive temperature uniformity across the cooking service with a maximum temperature difference of ± 24.9°F. The gas griddle exhibited a competitive cooking-energy efficiency (39.5%) under heavy-load testing, and its production capacity (33.0 lb/h per ASTM test method) was on par with other 3-foot griddles tested in its class. Food service operations typically cook in medium and light load scenarios. The Well's griddle demonstrated above par cooking-energy efficiencies (33.4% and 17.0%) and production rates (21.0 lb/h and 7.5 lb/h) during both medium and light-load testing. The compact size of the Well's WG2436G gas griddle, combined with its ability to perform like its larger brothers, is a bonus feature for a food service operator with limited kitchen space.

1 Introduction

Background

Griddles are used throughout the hospitality industry to prepare a variety of menu items such as pancakes and hamburgers. An operator shopping for a new griddle looks for energy usage, uniformity of cooking surface temperature, and amount of food that can be cooked in a given period of time.

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.

With support from the Electric Power Research Institute (EPRI), the Gas Technology Institute (GTI), and the National Restaurant Association, the Food Service Technology Center (FSTC) developed a uniform testing procedure to evaluate the performance of gas and electric griddles. This test procedure was submitted to the American Society for Testing and Materials (ASTM), and it was accepted as a standard test method (Designation F 1275-90) in January 1990.[1]

In keeping with ASTM's policy that a document be periodically reviewed, the FSTC re-evaluated the griddle test method and suggested various simplifications. The test method was subsequently updated in 1999 (*new* Designation F 1275-99). Other FSTC reports document results of applying the revised version of the ASTM test method and discuss the scope of these revisions.[2,3,4,5,6,7,8,9,10,11]

Wells WG2436G griddle features an all stainless steel construction and snap action thermostats with a 1-inch thick polished griddle-cooking surface. The

Introduction

WG2436G Wells gas griddle was tested according to the ASTM procedure, and this report documents the results.

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 the Wells gas griddle, model WG2436G, 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. Document the temperature uniformity of the cooking surface and the accuracy of the thermostats.
3. Determine the time and energy required to preheat the cooking surface from room temperature to 375°F.
4. Characterize the idle energy use with the thermostats set at a calibrated 375°F.
5. Document the cooking energy consumption and efficiency under three hamburger loading scenarios: heavy (24 patties), medium (12 patties), and light (4 patties).
6. Determine the production capacity and cooking surface temperature recovery time during the heavy-load test.

Appliance Description

Wells WG2436G gas griddle features snap action thermostats controlling three 30,000 Btu U shaped burners for every twelve inches of griddle surface. Cooking temperatures from 200°F to 450°F are adjusted using three thermostats located on the front panel. The cooking surface is 1-inch thick steel surrounded by stainless steel splashguards and back splash.

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

Table 1-1. Appliance Specifications.

Manufacturer	Wells Manufacturing, Inc.
Model	WG2436G
Generic Appliance Type	Counter Top Thermostatically Controlled Griddle
Rated Input	75,000 Btu
Dimensions	35.8" x 25.4" x 16.5"
Construction	1 inch-thick stainless steel
Controls	Individual snap action thermostats for each 1-foot cooking zone adjustable from 200 to 450°F.

2 Methods

Setup and Instrumentation

FSTC researchers installed the griddle 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 griddle and the edge of the hood. All test apparatus were installed in accordance with Section 9 of the ASTM test method.[1]

Researchers instrumented the griddle with thermocouples to measure cooking surface temperatures. For the temperature uniformity test, 35 thermocouples were welded to the cooking surface in a grid pattern (see Figure 2-1). Three thermocouples (one at the center of each linear foot of griddle plate—Figure 2-2) were used for the remainder of the tests.

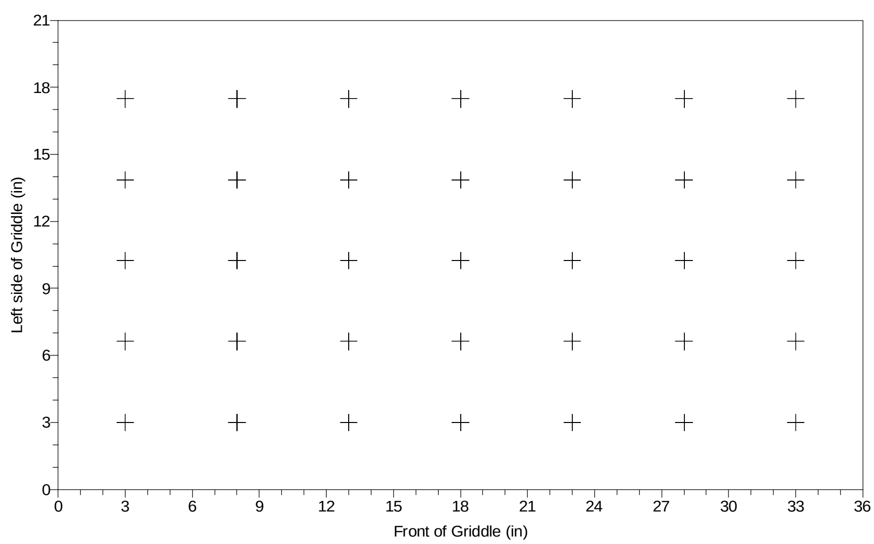

Figure 2-1.
Thermocouple grid for temperature uniformity test.

Natural gas consumption was measured using a positive displacement-type gas meter that generated a pulse every 0.1 ft³. The gas meter and the thermocouples were connected to an automated data acquisition unit that recorded data every 5 seconds. A chemical laboratory used a gas chromatograph to determine the gas heating value on each day of testing. All gas measurements were corrected to standard conditions.

Measured Energy Input Rate

Researchers determined the energy input rate by measuring the energy consumption during a preheat from room temperature. The maximum power draw during this period was reported as the measured energy input rate.

Cooking Tests

Researchers specified frozen, 20% fat, quarter-pound hamburger patties for all cooking tests. Each load of hamburgers was cooked to a 35% weight loss. The cooking tests involved “barreling” six loads of frozen hamburger patties; cooking surface temperature was used as a basis for recovery (see Figure 2-2). Each test was followed by a 1-hour wait period and was then repeated two more times. Researchers tested the griddle using 24 patties (heavy load), 12 patties (medium load), and 4 patties (light load).

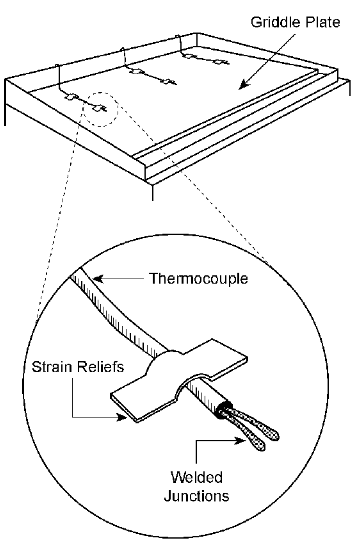

Figure 2-2. Thermocouple placement for testing.

Due to the logistics involved in removing one load of cooked hamburgers and placing another load onto the griddle, a minimum preparation time of 30 seconds (based on 10 seconds per linear foot) was incorporated into the cooking procedure. This ensures that the cooking tests are uniformly applied from laboratory to laboratory. Griddle recovery was then based on the cooking surface reaching a threshold temperature of 350°F (measured at the center of each linear foot of griddle plate). Reloading within 25°F of the 375°F thermostat set point does not significantly lower the average cooking surface over the cooking cycle, nor does it extend the cook time. The griddle was reloaded either after all three thermocouples reached the threshold temperature, or 30 seconds after removing the previous load from the griddle, whichever was longer.

Prior to the six-load test, one to two loads of hamburgers were cooked to stabilize the griddle response. Energy consumption, elapsed time, and the average weight loss of the hamburger patties were recorded during the final six loads of the cooking test. After removing the last load and allowing the griddle to recover, researchers terminated the test.

Cooking tests were run in the following sequence: three replicates of the heavy-load test, three replicates of the medium-load test, and three replicates of the light-load test. This procedure ensured that the reported cooking-energy efficiency and production capacity results had an uncertainty of less than ±10%. The results from each test run were averaged, and the absolute uncertainty was calculated based on the standard deviation of the results.

The ASTM results reporting sheets appear in Appendix C.

3 Results

Energy Input Rate

Prior to testing, the energy input rate was measured and compared with the manufacturer's nameplate value. This procedure ensured that the griddle was operating within its specified parameters. The measured energy input rate was 72,955 (a difference of 2.73% from the nameplate rating).

Temperature Uniformity

Thermocouples were welded to the cooking surface at the center of each linear foot to facilitate temperature calibration. The thermostat control was turned to a ~ 375°F setting. The thermocouples were then monitored after the griddle had stabilized at the set temperature for one hour. Researchers manually adjusted the control to maintain an average of 375 ± 5°F on the cooking surface at the center of each linear foot.

To characterize the temperature profile of the cooking surface at 375°F, researchers welded additional thermocouples to the cooking surface in a 35-point grid with approximately 5 inches between adjacent points. Griddle temperatures were monitored for one hour after the cooking surface had stabilized at a calibrated 375°F. Figure 3-1 illustrates the temperatures across the griddle cooking surface. The temperature uniformity profiles are represented Figure 3-2. The results from the temperature uniformity test are summarized in Table 3-1.

Results

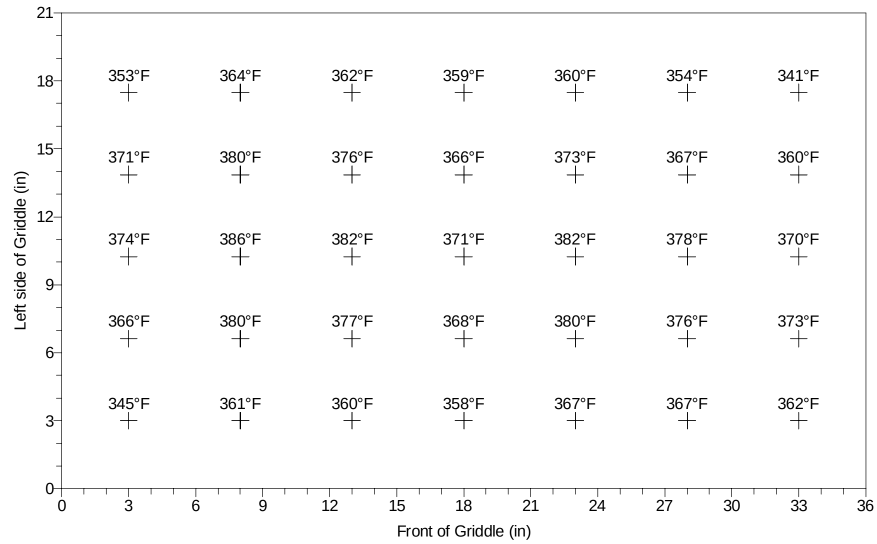

Figure 3-1.

Temperature sensing points on the griddle surface.

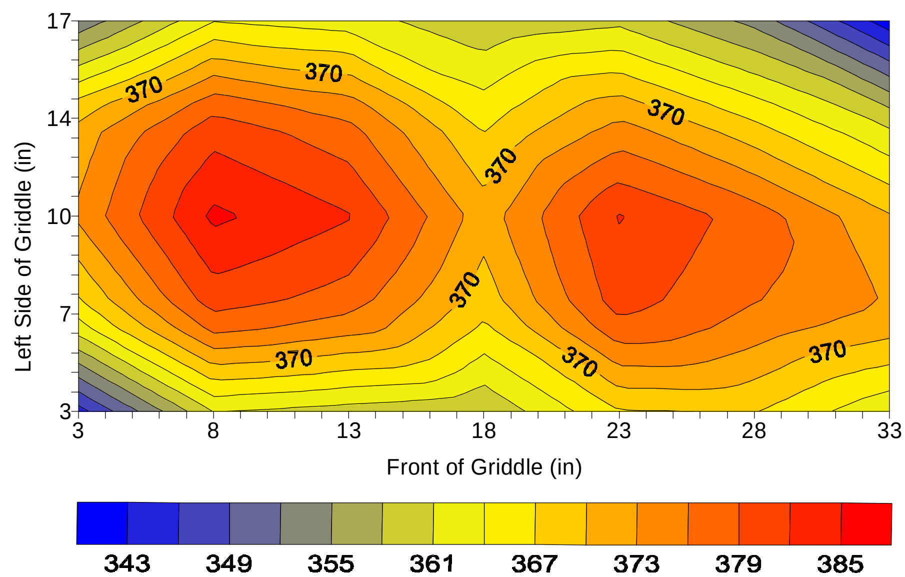

Figure 3-2.

Temperature map of the cooking surface.

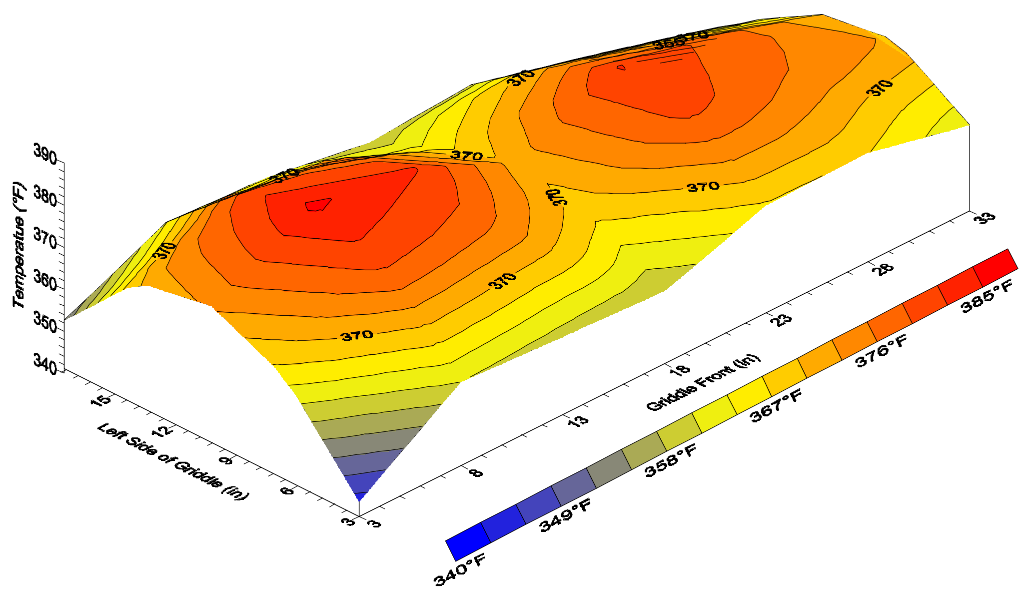

Table 3-1. Temperature Uniformity and Thermostat Accuracy.

Thermostat Setting[a] (°F)	375
Average Surface Temperature (°F)	374
Left Thermostat (°F)	374
Center Thermostat (°F)	375
Right Thermostat (°F)	376
Maximum Temperature Difference Across Plate (°F)	49.8
Standard Deviation of Surface Temperatures (°F)	12.3

[a]Thermostat accuracy is the thermostat setting required to maintain 375 ± 5°F on the cooking surface.

Preheat and Idle Tests

Preheat Energy and Time

Researchers removed the additional thermocouples, leaving only the points at the center of each linear foot. The cooking surface temperature was an average of 74°F at the outset of the preheat test. Researchers measured the energy consumption and time required to preheat the cooking surface to a calibrated 375°F. The griddle's preheat required 12,266 Btu and 10.75 minutes. Figure 3-3 shows the energy consumption rate in conjunction with the cooking surface temperature during the preheat test.

Idle Energy Rate

The griddle was allowed to stabilize at 375°F for one hour. Researchers then monitored the energy consumption over a 2-hour period. The idle energy rate during this period was 16,378 Btu/h.

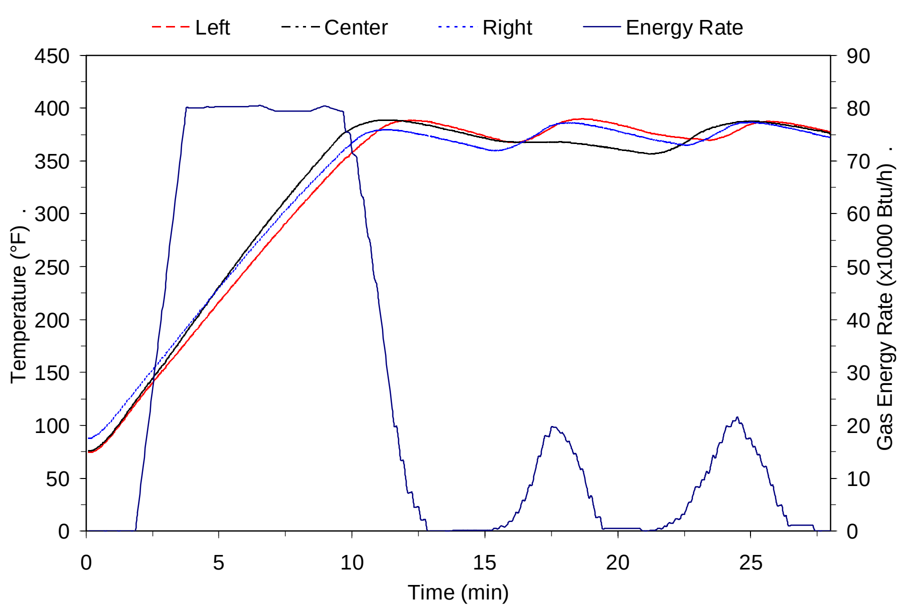

Figure 3-3.
Preheat characteristics.

Test Results

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

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

Rated Energy Input Rate (Btu/h)	75,000
Measured Energy Input Rate (Btu/h)	72,955
Percentage Difference (%)	2.73
Preheat	
Time to 375°F (min)	10.75
Energy (Btu)	12,226
Rate to 375°F (°F/min)	27.7
Idle Energy Rate @ 375°F (Btu/h)	16,378

Cooking Tests

The griddle was tested under three loading scenarios: heavy (24 hamburger patties), medium (12 hamburger patties), and light (4 hamburger patties). The hamburgers used for the cooking tests consisted of 20% fat and approximately 60% moisture, as specified by the ASTM procedure. Researchers monitored hamburger patty cook time and weight loss, cooking surface recovery time, and griddle energy consumption during these tests.

Heavy-Load Tests

The heavy-load cooking tests were designed to reflect a griddle's maximum performance. The griddle is used to cook six loads of 24 frozen hamburger patties—one load after the other, similar to a batch-cooking procedure. Figure 3-4 shows the average cooking surface temperature during a heavy-load test. One load was used to stabilize the griddle, and six loads were used to calculate cooking-energy efficiency and production capacity.

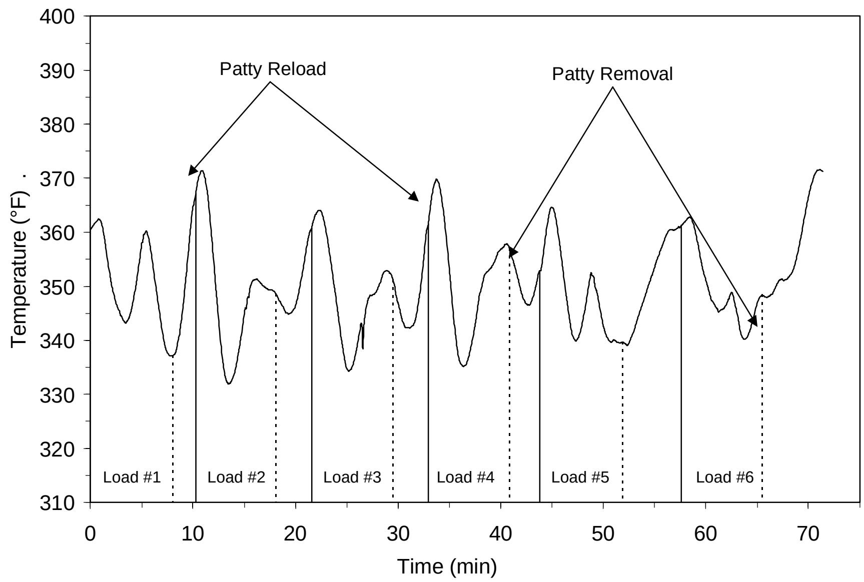

Figure 3-4.
Average cooking surface temperature during a heavy-load test.

Figure 3-5 illustrates the griddle's temperature response while a heavy load of frozen hamburger patties was cooked. Production capacity includes the time required for the cooking surface to recover to 350°F (recovery time); production rate varies with the amount of food being cooked at one time.

Medium- and Light-Load Tests

Medium- and light-load tests represent a more typical usage pattern for a griddle in cook-to-order applications. Since a griddle is seldom fully loaded in many food service establishments, these part-load efficiencies can be used to estimate griddle performance in an actual operation. Both the medium- and light-load tests were conducted on the left half of the cooking surface. Since the entire griddle was heated to 375°F, the energy consumed during these part-load tests includes radiant heat losses from the unused half of the griddle. Cooking-energy efficiencies at 21.0 (medium) and 7.5 (light) pounds per hour were 33.4% and 17.2%, respectively.

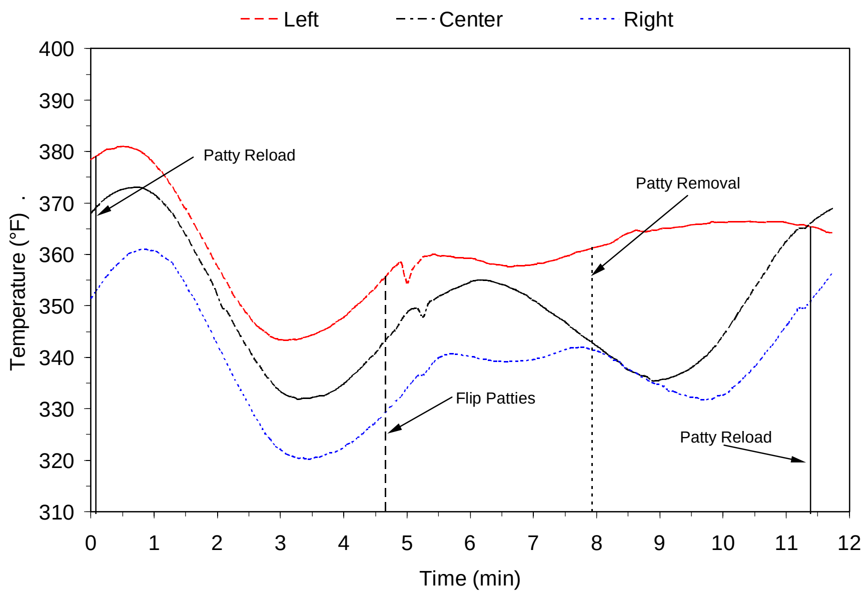

Figure 3-5. Griddle temperatures while cooking a heavy load.

Test Results

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

Cooking-energy efficiency results for the heavy-load tests were 40.4%, 38.6%, and 39.6%, yielding a maximum uncertainty of 5.7% in the test results. Table 3-3 summarizes the results of the ASTM cooking-energy efficiency and production capacity tests.

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

	Heavy Load	Medium Load	Light Load
Hamburger Patty Cook Time (min)	7.75	7.75	7.75
Average Recovery Time (min)	3.20	0.85	0.30
Production Rate (lb/h)	33.0 ± 1.8	21.0 ± 1.1	7.5 ± 0.0
Energy Consumption (Btu/lb)	1,232	1,458	2,789
Cooking Energy Rate (Btu/h)	40,692	30,628	20,864
Cooking-Energy Efficiency (%)	39.5 ± 2.3	33.4 ± 0.9	17.2 ± 1.1

Figure 3-6 illustrates the relationship between cooking-energy efficiency and production rate for this griddle. Griddle production rate is a function of both the hamburger patty cook time and the recovery time. Appendix D contains a synopsis of test data for each replicate of the cooking tests.

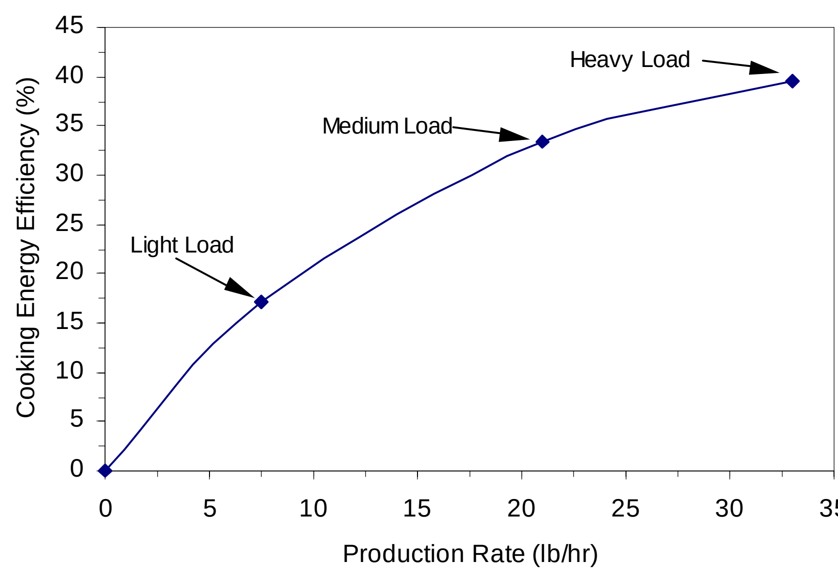

Figure 3-6.
Griddle part-load cooking-energy efficiency.

Note: Light-load = 4 hamburgers/load; medium-load = 12 hamburgers/load; heavy-load = 24 hamburgers/load

Figure 3-8 illustrates the relationship between the griddle'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 griddle in a real-world operation. Average energy consumption rates at 10, 20, and 30 pounds per hour are 23,140 Btu/h, 30,510 Btu/h, and 37,870 Btu/h, respectively. For an operation cooking an average of 20 pounds of food per hour over the course of the day (e.g., 200 pounds of food over a ten hour day), the average energy consumption rate for this griddle would be 30,510 Btu/h.

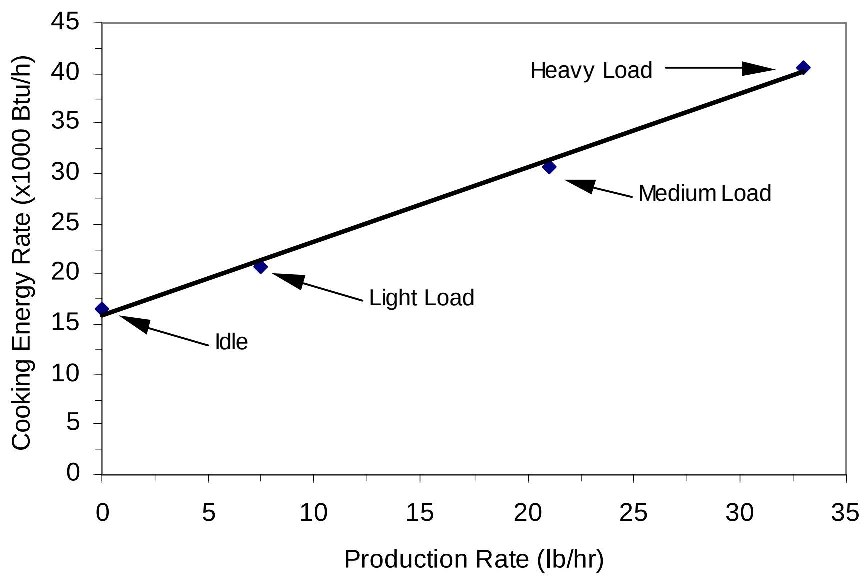

Figure 3-7.
Griddle cooking energy consumption profile.

Note: Light-load = 4 hamburgers/load; medium-load = 12 hamburgers/load; heavy-load = 24 hamburgers/load

4 Conclusions

The Wells WG2436G gas griddle was successfully tested in accordance with ASTM standard test method. The griddle demonstrated an impressive 10.8 minute preheat to a set point of 375°F and a competitive temperature uniformity across the cooking service with a maximum temperature difference of ± 24.9°F.

The WG2436G griddle featured a reduced cooking surface area of10 %. This reduction was noted in the depth front to back of the griddle-cooking surface. However, the griddle's smaller cooking surface area did not hinder its performance. Though the griddle-cooking surface was smaller than other 3-foot griddles, a heavy-load test of 24 patties was easily executable. The gas griddle exhibited a competitive cooking-energy efficiency (39.5%) under heavy-load testing, and its production capacity (33.0 lb/h per ASTM test method) was comparable to other 3-foot griddles tested in its class.[2,3,4,5,6,7,8,9,10,11]

Food service operations typically cook in medium and light load scenarios. The Wells griddle demonstrated excellent part-load cooking-energy efficiencies (33.4% and 17.0%) during the medium and light-load tests. The compact size of the Well's WG2436G gas griddle combined with its ability to perform like its larger brothers is a bonus feature for a food service operator with limited kitchen space.

5 References

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A Glossary

Cooking Energy (kWh or kBtu)

The total energy consumed by an appliance as it is used to cook a specified food product.

Cooking Energy Consumption Rate (kW or kBtu/h)

The average rate of energy consumption during the cooking period.

Cooking-Energy Efficiency (%)

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

Duty Cycle (%)
Load Factor

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

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

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

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

Heating Value (Btu/ft^3)
Heating Content

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

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

The rate of appliance energy consumption while it is “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.

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

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 "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 cooked food until the surface temperature is within 25°F of the thermostat set point and the griddle 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 Wells griddle.

Appliance Specifications.

Manufacturer	Wells
Model	WG2436G
Generic Appliance Type	Thermostatically Controlled Griddle
Rated Input	75,000 Btu
Dimensions	35.8” x 25.4” x 16.5”
Construction	1”-thick stainless steel
Controls	Individual snap action thermostats for each 1-foot cooking zone adjustable from 200 to 450°F.

C Results Reporting Sheets

Manufacturer: Wells
Model: WG2436G
Date: November 2001

Test Griddle

Description of operational characteristics: 1inch thick Polished finish steel plate with imbedded thermo-stat sensors. Three electronic thermostats control three 30,000 Btu/h burners U shaped. The griddle is equipped with electronic ignition to light the pilots. Stainless steel construction on the splash guards, grease trough and front panel.

Apparatus

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

Deviations: None.

Energy Input Rate

Heating Value	75,000 Btu/h
Measured	72,955 Btu/h
Percent Difference between Measured and Rated	2.73 %

Temperature Uniformity and Thermostat Accuracy

Thermostat settings required to maintain 375°F cooking surface temperature:

Thermostat #1	374 °F
Thermostat #2	375 °F
Thermostat #3	376 °F
Maximum Temperature Difference	45 °F

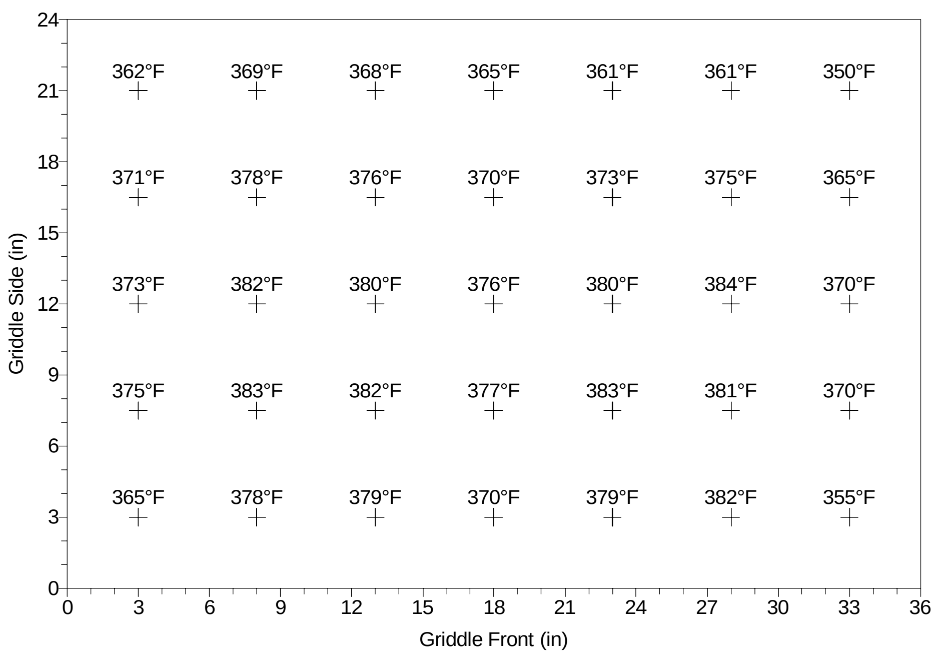

Figure C-1. Average cooking surface temperatures.

Preheat Energy and Time

Heating Value	1016.8 Btu/scf
Starting Temperature	73 °F
Energy Consumption	12,266 Btu
Duration	10.75 min
Preheat Rate	27.7 °F/min

Results Reporting Sheets

Idle Energy Rate

Heating Value	1016.9 Btu/scf
Idle Energy Rate @ 375°F	16,378 Btu/h

Cooking-energy efficiency and Cooking Energy Rate

Heavy Load:

Heating Value	1018.5 Btu/scf
Cooking Time	7.75 min
Average Cooking Surface Recovery Time	3.2 min
Production Capacity	33.0 ± 1.8 lb/h
Energy to Food	487 Btu/lb
Cooking Energy Rate	40,692 Btu/h
Energy per Pound of Food Cooked	1,232 Btu/lb
Cooking-Energy Efficiency	39.5 ± 2.3 %

Medium Load:

Heating Value	1017.8 Btu/scf
Cooking Time	7.75 min
Average Cooking Surface Recovery Time	0.85 min
Production Capacity	21.0 ± 1.1 lb/h
Energy to Food	487 Btu/lb
Cooking Energy Rate	30,628 Btu/h
Energy per Pound of Food Cooked	1,458 Btu/lb
Cooking-Energy Efficiency	33.4 ± 0.9 %

Light Load:

Heating Value	1021.8 Btu/scf
Cooking Time	7.75 min
Average Cooking Surface Recovery Time	0.30 min
Production Capacity	7.5 ± 0.0 lb/h
Energy to Food	479 Btu/lb
Cooking Energy Rate	20,864 Btu/h
Energy per Pound of Food Cooked	2,789 Btu/lb
Cooking-Energy Efficiency	17.2 ± 1.1 %

D Cooking-Energy Efficiency Data

Table D-1. Specific Heat and Latent Heat.

Specific Heat (Btu/lb, °F)	
Ice	0.50
Fat	0.40
Solids	0.20
Latent Heat (Btu/lb)	
Fusion, Water	144
Fusion, Fat	44
Vaporization, Water	970

Cooking-Energy Efficiency Data

Table D-2. Heavy-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	43,505	45,667	44,315
Cook Time (min)	7.75	7.75	7.75
Total Test Time (min)	65.7	67.0	64.1
Weight Loss (%)	34.8	36.1	35.3
Initial Weight (lb)	36.115	36.115	36.115
Final Weight (lb)	23.565	23.073	23.369
Initial Fat Content (%)	20.0	20.0	20.0
Initial Moisture Content (%)	60.0	60.0	60.0
Final Moisture Content (%)	49.6	50.7	50.3
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	165	165	165
Calculated Values			
Initial Weight of Water (lb)	21.669	21.669	21.669
Final Weight of Water (lb)	11.696	11.689	11.757
Weight of Fat (lb)	7.223	7.223	7.223
Weight of Solids (lb)	7.223	7.223	7.223
Sensible to Ice (Btu)	347	347	347
Sensible to Water (Btu)	2,882	2,882	2,882
Sensible to Fat (Btu)	477	477	477
Sensible to Solids (Btu)	238	238	238
Latent - Water Fusion (Btu)	3,120	3,120	3,120
Latent - Fat Fusion (Btu)	347	347	347
Latent - Water Vaporization (Btu)	10,158	10,197	9,128
Total Energy to Food (Btu)	17,569	17,608	17,539
Energy to Food (Btu/lb)	486	488	486
Total Energy to Griddle	43,505	45,668	44,315
Energy to Griddle (Btu/lb)	1,205	1,265	1,205
Cooking-Energy Efficiency (%)	40.4	38.6	39.6
Cooking Energy Rate (Btu/h)	39,735	40,884	41,454
Production Rate (lb/h)	33.0	32.3	33.8
Average Recovery Time (min)	3.2	3.4	2.9

Cooking-Energy Efficiency Data

Cooking-Energy Efficiency Data

Table D-3. Medium-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	26,333	26,333	26,333
Cook Time (min)	7.75	7.75	7.75
Total Test Time (min)	51.5	50.6	52.8
Weight Loss (%)	35.5	35.0	36.3
Initial Weight (lb)	18.058	18.058	18.058
Final Weight (lb)	11.641	11.746	11.498
Initial Fat Content (%)	20.0	20.0	20.0
Initial Moisture Content (%)	60.0	60.0	60.0
Final Moisture Content (%)	49.6	50.7	50.3
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	165	165	165
Calculated Values			
Initial Weight of Water (lb)	10.835	10.835	10.835
Final Weight of Water (lb)	5.778	5.951	5.785
Weight of Fat (lb)	3.612	3.612	3.612
Weight of Solids (lb)	3.612	3.612	3.612
Sensible to Ice (Btu)	173	173	173
Sensible to Water (Btu)	1,441	1,441	1,441
Sensible to Fat (Btu)	238	238	238
Sensible to Solids (Btu)	119	119	119
Latent - Water Fusion (Btu)	1,560	1,560	1,560
Latent - Fat Fusion (Btu)	173	173	173
Latent - Water Vaporization (Btu)	5,147	4,971	5,140
Total Energy to Food (Btu)	8,852	8,852	8,845
Energy to Food (Btu/lb)	490	480	490
Total Energy to Griddle	26,334	26,334	26,334
Energy to Griddle (Btu/lb)	1,458	1,458	1,458
Cooking-Energy Efficiency (%)	33.6	32.9	33.6
Cooking Energy Rate (Btu/h)	30,709	31,232	29,942
Production Rate (lb/h)	21.1	21.4	20.5
Average Recovery Time (min)	0.8	0.7	1.0

Cooking-Energy Efficiency Data

Cooking-Energy Efficiency Data

Table D-4. Light-Load Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu/h)	17,120	16,938	16,299
Cook Time (min)	7.75	7.75	7.75
Total Test Time (min)	48.3	48.2	48.4
Weight Loss (%)	33.7	33.7	33.8
Initial Weight (lb)	6.019	6.019	6.019
Final Weight (lb)	3.988	3.988	3.984
Initial Fat Content (%)	20.0	20.0	20.0
Initial Moisture Content (%)	60.0	60.0	60.0
Final Moisture Content (%)	49.6	50.7	50.3
Initial Temperature (°F)	0	0	0
Final Temperature (°F)	165	165	165
Calculated Values			
Initial Weight of Water (lb)	3.612	3.612	3.612
Final Weight of Water (lb)	1.979	2.020	2.004
Weight of Fat (lb)	1.204	1.204	1.204
Weight of Solids (lb)	1.204	1.204	1.204
Sensible to Ice (Btu)	58	58	58
Sensible to Water (Btu)	480	480	480
Sensible to Fat (Btu)	79	79	79
Sensible to Solids (Btu)	40	40	40
Latent - Water Fusion (Btu)	520	520	520
Latent - Fat Fusion (Btu)	58	58	58
Latent - Water Vaporization (Btu)	1,583	1,626	1,642
Total Energy to Food (Btu)	2,818	2,861	2,878
Energy to Food (Btu/lb)	468	475	478
Total Energy to Griddle	17,121	16,938	16,299
Energy to Griddle (Btu/lb)	2,844	2,814	2,844
Cooking-Energy Efficiency (%)	16.5	16.9	17.7
Cooking Energy Rate (Btu/h)	21,281	21,089	20,222
Production Rate (lb/h)	7.5	7.5	7.5
Average Recovery Time (min)	0.3	0.3	0.3

Cooking-Energy Efficiency Data

Table D-6. Cooking-Energy Efficiency and Production Capacity Statistics.

	Cooking-Energy Efficiency			Production Capacity
	Heavy-Load	Medium-Load	Light-Load	
Replicate #1	40.4	33.6	16.5	33.0
Replicate #2	38.6	32.9	16.9	32.3
Replicate #3	39.6	33.6	17.7	33.8
Average	39.5	33.6	17.0	39.5
Standard Deviation	0.92	0.38	0.60	0.73
Absolute Uncertainty	2.27	0.94	1.50	1.80
Percent Uncertainty	5.57	2.81	8.81	5.46