Thermal Engineering Corporation (TEC®)
Searmaster™ Model IR2003-S
Underfired Broiler Performance Test

Application of ASTM Standard
Test Method F 1695-96

FSTC Report 5011.03.04

Food Service Technology Center
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Specific appreciation is extended to TEC®, for supplying the Food Service Technology Center with the IR2003-S underfired broiler for controlled testing in the appliance laboratory.

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Executive Summary

The Thermal Engineering Corporation (TEC®) Searmaster™ model IR2003-S broiler is a gas fired, 3-foot underfired broiler with an energy input rate of 105,000 Btu/h. The IR2003-S broiler uses three infrared burners which are independently adjusted by manual control knobs. The burners are situated beneath stainless steel guards, called "emitter shields", which prevent grease from coming in direct contact with the burner, while also providing more even heat distribution. The IR 2003-S is constructed of stainless steel with a heavy cast iron cooking grid.

The Food Service Technology Center (FSTC) tested the IR2003-S broiler under the tightly controlled conditions of the American Society for Testing and Materials' (ASTM) Standard Test Method.[1] Broiler performance is characterized by preheat energy consumption and duration, temperature distribution, pilot energy rate, cooking energy rate and cooking energy efficiency.

The TEC® Searmaster™ broiler was set up and operated in accordance with the manufacturer's specifications. The broiler operated consistently and reliably in all phases of the testing process.

Cooking–energy efficiency and production capacity test results are obtained from the cooking of 1/3-lb pure beef hamburger patties under light– and heavy–load test scenarios. A summary of the test results is presented in Table ES-1.

Executive Summary

Table ES-1. Summary of performance: TEC® Searmaster™ Underfired Broiler, Model IR-2003S.

Energy Input and Preheat Tests	
Rated Energy Input Rate (Btu/h)	105,000
Measured Energy Input Rate (Btu/h)	110,000
Percentage Difference From Rated (%)	4.9
Preheat Time (min)	17.25
Preheat Energy (Btu)	32,000
Pilot Energy Rate (Btu/h)	500
Cooking Energy Rate (Btu/h)	64,600
Light–Load Cooking Energy Efficiency (%)	11.8 ± 0.4
Heavy–Load Cooking Energy Efficiency (%)	40.7 ± 1.1
Production Capacity (lb/h)	65.6 ± 0.3

The IR2003-S out-performed all other gas underfired broilers tested at the FSTC to date.[2] The 40.7% heavy–load cooking efficiency was achieved through a combination of the broiler's low (64,600 Btu/h) cooking energy rate and relatively short cook time of 6.25 minutes. Under a light–load cooking scenario, the cook time was even less- 5.5 minutes. The 11.8% cooking energy efficiency during the light-load test was also unparalelled to date at the FSTC.[2]

The infrared burners heated quickly from room temperature to bring the broiler to a ready-to-cook state in just over 17 minutes. This can be a dramatic energy saving feature, as many operations allow the broiler to preheat for anywhere from 30 to 60 minutes.[4,5]

During the temperature uniformity test, the broiler achieved a maximum broiling temperature of 811°F, and exhibited less fall off (215°F) than is typically associated with gas underfired charbroilers.[2] The broiler's more uniform heat distribution contributed to its short cook times and high production capacity of 65.6 lb/h.

Figure ES-1 shows the average broiling area temperatures, and Figure ES-2 shows the temperature distribution map for the Searmaster™ broiler with all controls set to maximum input. The maximum temperature difference across the broiling area was 215°F.

Figure ES-1. Average Broiler Temperatures.

610	602	586	615	589	599
787	717	755	801	753	769
779	791	789	801	778	777
619	647	683	684	685	666

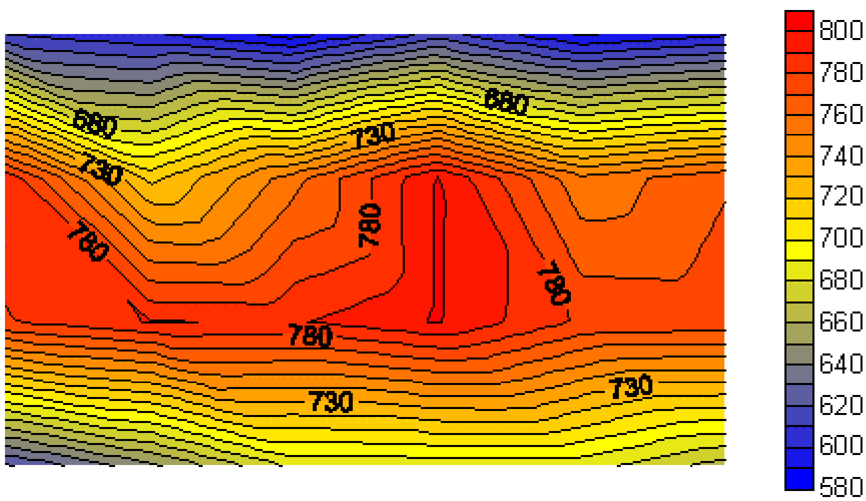

Figure ES-2. Temperature Distribution Map.

1 Introduction

Background

Underfired broilers are an integral part of countless food service operations, where they are the “workhorse” appliance of the kitchen. In addition to the ability to quickly cook a wide variety of beef or poultry products, broilers can also prepare more delicate dishes such as fish, shrimp and vegetables.

While initial capital cost is a determining factor in the selection of new food service equipment, appliances can also be evaluated with regards to long–term operational cost and performance as characterized by cooking energy efficiency, cooking energy rate, and production capacity.

With support from the Electric Power Research Institute (EPRI) and the Gas Technology Institute (GTI), The Food Service Technology Center (FSTC) developed a standard test method to evaluate the performance of gas and electric underfired broilers. This test procedure was submitted to the American Society for Testing and Materials (ASTM) F26 committee on Food service equipment and accepted as a standard test method (Designation F 1695-96) in 1996.[1] The FSTC report, *Development and Validation of a Standard Test Method for Underfired Broilers* documents the developmental procedures and test results from both gas and electric underfired broilers.[2] In addition to the data generated in the laboratory setting, the performance of several gas and electric underfired charbroilers have been documented by the FSTC in a cafeteria style production kitchen.[3-5]

Thermal Engineering Corporation (TEC®) has taken a new approach to underfired broiler design by incorporating infrared burners in their line of Searmaster™ broilers. The IR2003-S uses three high–intensity burners under stainless steel “emitter shields”, which help distribute the heat evenly and prevent grease from directly contacting the burners. TEC® claims faster preheat times, more even heat distribution and increased energy efficiency over conventional designs.

Objective

The objective of this report is to examine the operation and performance of the TEC® Searmaster™ broiler, model IR 2003-S, under the controlled conditions of the ASTM Standard Test Method. The scope of this testing is as follows:

1. Energy input rate is determined to confirm that the broiler is operating within 5% of the nameplate energy input rate.
2. Broiler temperature distribution is determined.
3. Preheat energy and time are determined.
4. Pilot energy rate is determined.
5. Cooking energy rate is determined.
6. Cooking–energy efficiency and production rate is determined during light– (6 patties) and heavy– (24 patties) load cooking tests using 1/3 lb hamburger patties as a food product.

Appliance Description

The TEC® Searmaster™ broiler, model IR 2003-S, is a 3 foot wide, gas fired, underfired broiler with an input rate of 105,000 Btu/h (Figure 1-1). The broiler measures 42-inches wide, 21 1/4-inches tall and 27 1/4-inches deep. Broiler construction is all stainless steel, with a cast iron cooking grid that measures 36-inches wide by 25-inches deep. Heat is supplied by three infrared burners, equally spaced across the broiler and situated beneath “emitter shields” which help to even the heat distribution across the cooking grid. Each burner is controlled by a separate knob–type temperature control, allowing separate temperature adjustment for each of the three sections of the broiler. The broiler also features a support to allow angling of the cooking grid, and a removable splash guard and heat shield to simplify cleaning.

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

Table 1-1. Appliance Specifications.

Manufacturer	Thermal Engineering Corporation (TEC)
Model	IR2003-S
Generic Appliance Type	Underfired Broiler
Rated Energy Input Rate	105,000 Btu/h
Technology	Infrared Burners
Construction	Stainless Steel Construction Cast Iron Cooking Grate
Controls	Knob-Type
Cooking Surface Area	864 in^2
Dimensions (w/o stand)	42" Wide × 21 1/4" Tall × 27 1/4" Deep

2 Methods

Setup and Instrumentation

The TEC® broiler was installed in accordance with the manufacturer's instructions and Section 9 of the ASTM standard test method.[1] The broiler was positioned on a stainless steel table under a 4-foot-deep canopy hood, with the lower edge of the hood 6 feet, 6 inches above the floor and with the front of the broiler 6 inches inside the vertical front edge of the hood. The exhaust ventilation system operated at a nominal rate of 400 cfm per linear foot of hood.

Gas consumption was monitored using a positive displacement meter which generated a pulse for every 0.1 ft^3 of gas used. Broiler temperatures during the energy input rate, temperature distribution, and cooking energy rate tests were monitored using 24 carbon steel disks, with each disk having a separate thermocouple wire attached to its center. The disks were 5 inches in diameter, ¼ inch thick, and the thermocouples were 24 gauge, type K with fiberglass insulation. The gas meter and thermocouples were connected to a computerized data acquisition unit that recorded data every 5 seconds. Figure 2-1 shows the IR 2003-S broiler in position under the exhaust hood, and instrumented with steel disks for the temperature distribution test.

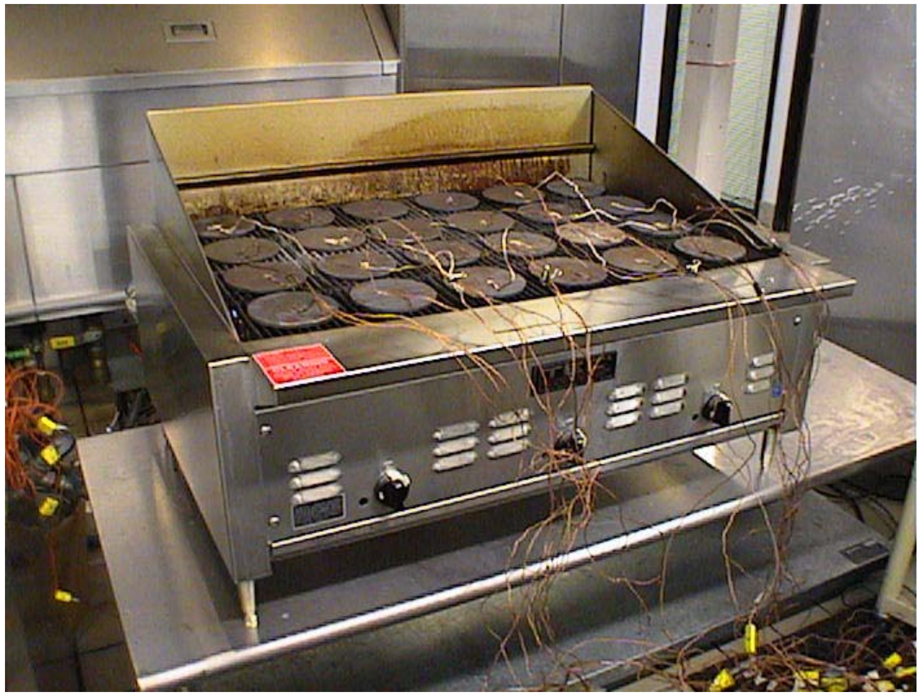

Figure 2-1.
The IR2003-S broiler instrumented with steel disks.

Energy Input Rate and Temperature Distribution

During the energy input rate and temperature distribution tests, the TEC® broiler was instrumented with 24 carbon steel disks evenly spaced across the grid surface. The energy input rate was determined by turning all 3 controls of the broiler to maximum input and measuring the energy consumption for a period of 15 minutes. The energy consumption and the time elapsed were used to calculate the maximum energy input rate. Temperature distribution was verified by allowing the broiler to operate at maximum input for a period of 1 hour and then monitoring the steel disk temperatures for an additional 1 hour period.

Preheat and Pilot Rate Tests

During the preheat and pilot rate tests, the TEC® broiler was instrumented with 3 steel disks, arranged with one disk centered on each linear foot of broiler grate. The preheat test measured the amount of energy the broiler consumed while heating from an ambient temperature of 75 ± 5°F, as when the broiler is first turned on in the day, to the time when the last section of cooking grate, as measured by the three disks, reached a temperature of at least 500°F. Testing began when the broiler was first turned on, and ended when the last of the 3 disks reached 500°F.

The pilot energy rate test recorded the energy consumption of the broiler's burner pilots for a period of 8 hours, with all controls set to the off position.

Cooking Energy Rate Test

For the cooking energy rate test, the broiler was re–instrumented with the 24 steel disks in the same manner as for the energy input rate and temperature distribution tests. The broiler was then operated for one hour with all controls set to maximum input. After this period, the controls were turned down until no disk registered a temperature above 600°F.

Once the control settings were determined, the broiler was stabilized for a period of 1 hour and then energy consumption was monitored for an additional 2 hours.

Cooking Tests

Light–Load Efficiency Tests

Light–load efficiency tests were used to calculate the cooking energy efficiency of the broiler under minimum loading conditions.

The cooking energy efficiency tests were performed with 1/3 lb, 20% fat, pure beef hamburger patties. The patties were machine prepared to a thickness of 5/8-inch and a diameter of 5-inches. The patties were placed on sheet pans, covered with plastic wrap and stabilized in a 40°F refrigerator for a period of at least 12 hours before testing.

Stabilization of the cooking grate was accomplished by operating the broiler for a period of 1 hour at the settings determined in the cooking energy rate test, and then cooking two loads of hamburger patties. For each stabilization load, six patties were removed from the refrigerator and loaded onto the broiler in an evenly spaced manner. The loading of the patties occurred during a period of no more than 30 seconds, and cook time was measured from the moment the first patty was placed on the broiler. Patties were cooked for 5.5 minutes– 3.3 minutes on the first side, and 2.2 minutes on the second.

After the cooking period, the patties were removed from the broiler and placed on a wire drip rack. The patties were dripped for 1 minute per side, then moved to a fresh sheet pan and weighed to verify the 35 ± 2% weight loss required by the test method. One minute after the removal of the first load, a second load was placed on the broiler and cooked in the same manner as the first.

One minute after the second stabilization load was removed, the cooking efficiency test was conducted using three additional loads of test patties. Test loads were cooked, dripped and weighed in the same manner as the stabilization loads.

Heavy–Load Efficiency and Production Capacity Tests

The heavy–load tests were used to calculate cooking energy efficiency and production capacity when the broiler was under maximum loading conditions.

Each individual load during the heavy–load cooking tests consisted of 24 hamburger patties. The heavy–load tests were conducted in the same manner as the light–load tests, with the only differences being the number of patties cooked, and the length of the cook time. Cook time for the heavy–load tests was 6.25 minutes– 3.75 minutes for the first side, and 2.5 minutes for the second.

Production capacity was determined by dividing the raw hamburger patty weight by the heavy–load total test time.

The ASTM results reporting sheets for the performance tests appear in Appendix C, and the cooking–energy efficiency data sheets appear in Appendix D of this report.

3 Results

Energy Input Rate and Temperature Distribution

Energy Input Rate

The energy input rate was measured and compared with the manufacturer's nameplate value to ensure the broiler was operating properly. The maximum energy input rate was 110,000 Btu/h, 4.9% higher than the nameplate rate of 105,000 Btu/h, but within the 5% tolerance of the ASTM standard.

Temperature Distribution

The temperature distribution test characterized the variation in temperature across the cooking grid. The maximum temperature realized was 801°F, and the minimum temperature was 586°F, for a maximum difference of 215°F. The average broiler temperatures are shown in Figure 3-1 and the temperature distribution map is shown in Figure 3-2.

610	602	586	615	589	599
787	717	755	801	753	769
779	791	789	801	778	777
619	647	683	684	685	666

Figure 3-1. Average Broiler Temperatures.

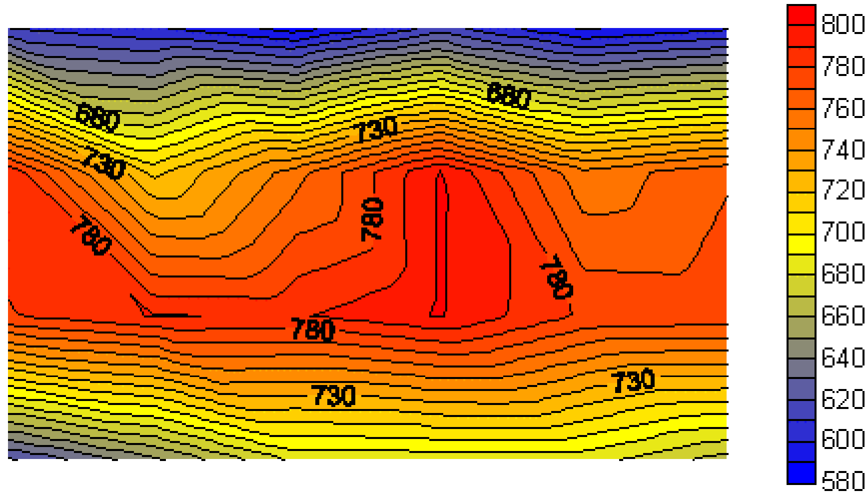

Figure 3-2. Temperature Distribution Map.

Preheat and Pilot Energy Rate Tests

Preheat Energy and Time

Time and energy were monitored from the time the broiler was first turned on. The preheat test ended when the last of the 3 broiler sections reached the specified temperature of 500°F. The TEC® broiler consumed 32,000 Btu over a period of 17.25 minutes during the preheat test.

Pilot Energy Rate

The gas consumption of the burner pilots was monitored for a period of 8 hours. The pilots consumed energy at a rate of 500 Btu/h, which is 0.5% of the broiler's measured input

Test Results

The broiler's preheat curve is shown in Figure 3-2. The measured energy input rate, preheat, and pilot energy rate test results are summarized in Table 3-1.

Results

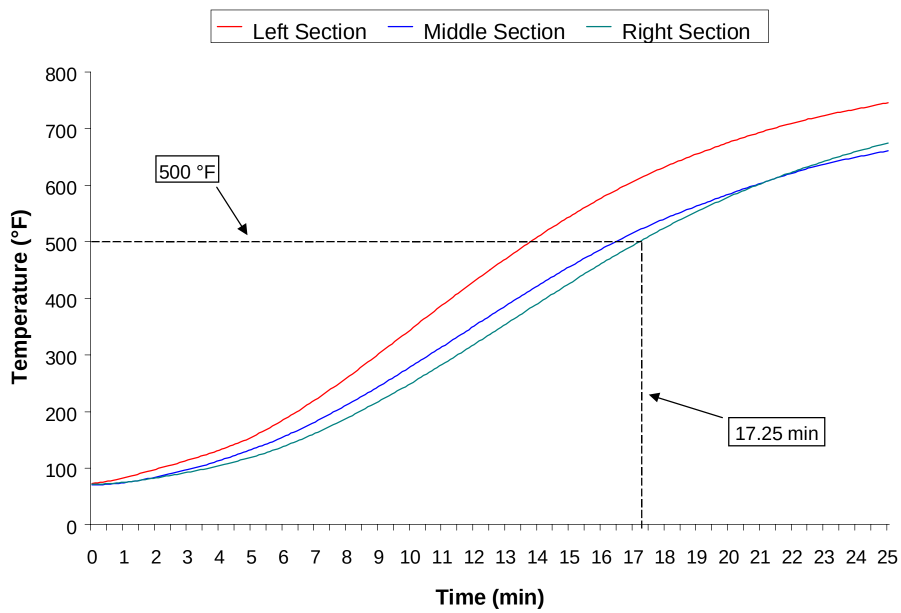

Figure 3-3.
Preheat Characteristics.

Table 3-1. Input, Preheat and Pilot Energy Test Results.

Rated Energy Input Rate (Btu/h)	105,000
Measured Energy Input Rate (Btu/h)	110,000
Percentage Difference From Rated (%)	4.9
Preheat Time (min)	17.25
Preheat Energy (Btu)	32,000
Pilot Energy Rate (Btu/h)	500
Percentage of Measured Energy Input Rate (%)	0.5

Cooking Tests

Light– and heavy– load hamburger patty cooking tests were applied to the TEC® broiler to determine cooking energy efficiency. During each test, time and energy data were recorded at five second intervals with the computerized data acquisition system.

Light–Load Energy Efficiency Tests

The light–load tests determined the energy efficiency of the TEC® broiler while cooking under minimum loading conditions (6 patties per load). The cook time for the hamburger patties was 5.5 minutes, and the broiler exhibited an 11.8% cooking––energy efficiency. Total test time was 19.5 minutes, and the production rate was 18.3 lb/h.

Heavy–Load Energy Efficiency and Production Capacity Tests

The heavy–load tests determined the energy efficiency of the TEC® broiler while cooking under maximum loading conditions (24 patties per load). The hamburger patties cooked in 6.25 minutes, with the broiler exhibiting an energy efficiency of 40.7%. Total test time was 21.75 minutes, and the production capacity was 65.6 lb/h.

Test Results

Cooking–energy efficiency is defined as the quantity of energy consumed by the hamburger patties expressed as a percentage of energy consumed by the broiler during the cooking test. The mathematical expression is:

$$\text{Cooking–Energy Efficiency \%} = \frac{E_{\textit{patties}}}{E_{\textit{broiler}}} \times 100\%$$

Energy imparted into the hamburger patties is calculated using the measured values of initial and final temperature, initial and final weight, the specific heat of the patties, and the heat of vaporization of water at 212°F. Energy consumed by the test broiler is calculated using the broiler's cooking–energy rate and the hamburger patty cook time, multiplied by three. Appendix D lists the physical properties and measured values of all the test variables for each test run. Using the detailed equations provided in Section 11 of the underfired broiler ASTM Standard Test Method, the cooking energy efficiencies can be readily calculated. Table 3-2 summarizes the cooking energy efficiency test results for the TEC® broiler.

Table 3-2. Cooking Energy Efficiency Test Results.

	Light	Heavy
Load Size (Hamburger Patties)	6	24
Cook Time (min)	5.5	6.25
Cooking Energy Rate (Btu/h)	64,600	64,600
Energy to Food (Btu/lb)	350	350
Cooking Energy Efficiency (%)	11.8 ± 0.4	40.7 ± 1.1
Production Capacity (lb/h)	18.3 ± 0.1	65.6 ± 0.3

4 Conclusions

Thermal Engineering Corporation has taken an innovative approach to underfired broiler design by incorporating infrared burners in their Searmaster™ line. The effort paid off nicely, as the IR2003-S out-performed all other gas underfired broilers tested at the FSTC to date.[2] The 40.7% heavy–load cooking efficiency was achieved through a combination of the broiler's low (64,600 Btu/h) cooking energy rate and relatively short cook time of 6.25 minutes. Under a light–load cooking scenario, the cook time was even less- 5.5 minutes. The 11.8% cooking energy efficiency during the light-load test was also unparalelled to date at the FSTC.[2]

During the temperature uniformity test, the broiler achieved a maximum broiling temperature of 811°F, and exhibited less fall off (215°F) than is typically associated with gas underfired charbroilers.[2] The broiler's more uniform heat distribution contributed to its short cook times and high production capacity of 65.6 lb/h.

The infrared burners heated quickly from room temperature to bring the broiler to a ready-to-cook state in just over 17 minutes. This can be a dramatic energy saving feature, as many operations allow the broiler to preheat for anywhere from 30 to 60 minutes.[4,5]

With it's excellent energy performance and solid overall design, the TEC® IR2003-S merits serious consideration by any food service operator in the market for a gas underfired broiler.

5 References

1. American Society for Testing and Materials, 1996. *Standard Test Method for the Performance of Underfired Broilers.* ASTM Designation F 1695-96. In *Annual Book of ASTM Standards,* West Conshohocken, PA.

2. Zabrowski, D., Nickel, J., Weller, T., Mogel, K., 1997. *Development and Validation of a Standard Test Method for Underfired Broilers.* Food Service Technology Center Report 5011.97.48, December.

3. Selden, M., 1992. *Appliance Performance in Production: "Hobart" Electric Char Broiler Model CB51*. 1992. Pacific Gas and Electric Company Department of Research and Development Report 008.1-92-4, December.

4. Geiger, T., 1993. *Wolf Commander Range-Match SUPER Char-Broiler: Appliance Performance in Production*. Pacific Gas and Electric Company Department of Research and Development Report 008.1-91-28, February.

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Appendixes

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 Btu/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 Btu/h)
Energy Consumption Rate
Energy Rate

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

Heating Value (Btu/ft^3)
Heating Content

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

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

The rate of appliance energy consumption while it is holding or maintaining a stabilized operating condition or temperature at a specified control setting.

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 (Btu/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 broiler 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)
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.

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 manufacturer's product literature for the TEC®

Searmaster™ underfired broiler, model IR2003-S.

C Results Reporting Sheets

Manufacturer Thermal Engineering Corporation (TEC®)

Model IR2003-S

Serial # B3-8774SNF9

Date: January, 2003

Test Reference Number (optional) N/A

Section 11.1 Test Underfired Broiler

Description of operational characteristics:

The broiler incorporates 3 infrared burners underneath stainless steel "emitter shields". Each burner is individually adjustable by a manual control knob.

Section 11.2 Apparatus

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

Deviations:

None.

Section 11.4 Energy Input Rate

Test Voltage (V)	N/A	
Gas Heating Value (Btu/ft^3)	1018.0	
Measured (Btu/h or kW)		110,000
Rated (Btu/h or kW)		105,000
Percent Difference between Measured and Rated (%)		4.9

Section 11.5 Temperature Distribution

610	602	586	615	589	599
787	717	755	801	753	769
779	791	789	801	778	777
619	647	683	684	685	666

FIG. X1.1 Average Broiling Area Temperatures

Maximum temperature difference across broiling area (°F (°C)): 215

Section 11.6 Preheat Energy and Time

Test Voltage (V) N/A

Gas Heating Value (Btu/ft^3) 1018.0

Starting Temperature (°F (°C)): 71.7

Energy Consumption (Btu or kWh) 32,000

Duration (min) 17.25

Preheat Rate (°F/min (°C/min)) 24.8

Section 11.7 Pilot Energy Rate (If Applicable)

Gas Heating Value (Btu/ ft^3) 1016.3

Pilot Energy Rate (Btu/h or kW) 500

Section 11.8 Cooking Energy Rate

Test Voltage (V) N/A

Gas Heating Value (Btu/ft^3) 1018.5

Cooking Energy Rate (Btu/h or kW) 64,600

Electric Energy Rate (kW, gas underfired broilers only) N/A

Section 11.9 Cooking Energy Efficiency

Heavy Load:

Test Voltage (V)	N/A	
Gas Heating Value (Btu/ft3))	1018.5	
Cooking Time (min)		6.25
Total Test Time (min)		21.75
Energy to Food (Btu/lb)		350
Energy per Pound of Food Cooked (Btu/lb or Wh/lb)		850
Cooking Energy Rate (Btu/h or kW)		64,600
Cooking Energy Efficiency (%)		40.7 ± 1.1
Production Capacity (lb/h)		65.6 ± 0.3

Light Load:

Test Voltage (V)	N/A	
Gas Heating Value (Btu/ft^3)	1019.2	
Cooking Time (min)		5.5
Total Test Time (min)		19.5
Energy to Food (Btu/lb)		350
Energy per Pound of Food Cooked (Btu/lb or Wh/lb)		2980
Cooking Energy Rate (Btu/h or kW)		64,600
Cooking Energy Efficiency (%)		11.8 ± 0.4
Production Rate (lb/h)		18.3 ± 0.1

D Cooking–Energy Efficiency Data

Table D-1. Physical Properties.

Specific Heat (Btu/lb °F)	
Hamburger Patty	0.72
Latent Heat (Btu/lb)	
Vaporization, Water	970

Table D-2. Light–Load Efficiency Test Data.

Measured Values	Repetition #1	Repetition #2	Repetition #3
Total Energy (Btu)	17,800	17,800	17,800
Cook Time (min)	5.5	5.5	5.5
Total Test Time (min)	19.5	19.5	19.5
Weight Loss (%)	33.8	33.6	34.1
Initial Weight (lb)	5.96	5.96	5.96
Final Weight (lb)	3.95	3.97	3.93
Initial Moisture Content (%)	60.8	60.8	60.8
Final Moisture Content (%)	51.7	52.4	51.4
Initial Temperature (°F)	40	40	40
Final Temperature (°F)	172.8	172.4	173.5
Calculated Values			
Initial Weight of Water (lb)	3.63	3.63	3.63
Final Weight of Water (lb)	2.04	2.07	2.02
Sensible to Patties (Btu)	570	570	570
Latent – Water Vaporization (Btu)	1540	1500	1560
Total Energy to Food (Btu)	2110	2070	2130
Energy to Food (Btu/lb)	350	350	360
Total Energy to Broiler (Btu)	17,800	17,800	17,800
Energy to Broiler (Btu/lb)	2980	2980	2980
Cooking–Energy Efficiency (%)	11.8	11.7	12.0
Production Rate (lb/h)	18.3	18.3	18.3
Cooking Energy Rate (Btu/h)	64,600	64,600	64,600

Cooking–Energy Efficiency Data

Table D-3. Heavy–Load Efficiency Test Data.

Measured Values	Repetition #1	Repetition #2	Repetition #3
Total Energy (Btu)	20,200	20,200	20,200
Cook Time (min)	6.25	6.25	6.25
Total Test Time (min)	21.75	21.75	21.75
Weight Loss (%)	34.8	35.4	34.7
Initial Weight (lb)	23.8	23.8	23.8
Final Weight (lb)	15.5	15.4	15.6
Initial Moisture Content (%)	60.8	60.8	60.8
Final Moisture Content (%)	53.2	55.1	54.3
Initial Temperature (°F)	40	40	40
Final Temperature (°F)	174.9	176.2	174.7
Calculated Values			
Initial Weight of Water (lb)	14.45	14.45	14.45
Final Weight of Water (lb)	8.25	8.45	8.46
Sensible to Patties (Btu)	2310	2330	2310
Latent – Water Vaporization (Btu)	6010	5820	5860
Total Energy to Food (Btu)	8320	8150	8170
Energy to Food (Btu/lb)	350	340	340
Total Energy to Broiler (Btu)	20,200	20,200	20,200
Energy to Broiler (Btu/lb)	850	850	850
Cooking–Energy Efficiency (%)	41.2	40.3	40.5
Production Capacity (lb/h)	65.5	65.5	65.8
Cooking Energy Rate (Btu/h)	64,600	64,600	64,600

Cooking–Energy Efficiency Data

Table D-4. Cooking–Energy Efficiency Statistics.

	Light Load	Heavy Load	Production Capacity
Replicate #1	11.8	41.2	65.5
Replicate #2	11.7	40.3	65.5
Replicate #3	12.0	40.5	65.8
Average	11.8	40.7	65.6
Standard Deviation	0.16	0.45	0.13
Absolute Uncertainty	0.39	1.13	0.32
Percent Uncertainty	3.3	2.8	0.5