Blodgett, Model DFG100 Xcel
Gas Full Size Convection Oven Performance Test

Application of ASTM Standard
Test Method F 1496-99

FSTC Report 5011.07.27

Food Service Technology Center
December 2007

Prepared by:

Victor Kong
Fisher-Nickel, Inc.

Contributors:

David Zabrowski
Fisher-Nickel, Inc.

Prepared for:
Pacific Gas & Electric Company
Customer Energy Efficiency Programs
P.O. Box 770000
San Francisco, California 94177

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

Acknowledgments

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Specific appreciation is extended to Blodgett, Inc. for supplying the FSTC with an Xcel, Model DFG100 convection oven for controlled testing in the appliance laboratory.

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Blodgett DFG100 Xcel.

The purpose of this study is to examine the performance of the Blodgett, model DFG100 Xcel gas convection oven (Figure ES-1). The Blodgett DFG100 is a standard full-size, direct-fired gas convection oven with dual rated burners that allow for food preparation at 60,000 or 80,000 Btu/h. A two-speed fan, powered by a ¾-hp motor, circulates hot air throughout the cavity, and solid-state controls maintain oven temperatures selected by a simple dial control. The two-speed fan allows for variable cooking conditions as well as quicker cool down times.

FSTC engineers tested the full-size gas convection oven under the tight specifications of the American Society for Testing and Materials' (ASTM) standard test method.[1] Convection oven performance is characterized by preheat time and energy consumption, idle energy consumption rate, cooking-energy efficiency, production capacity, cooking uniformity, and white sheet cake browning uniformity.

The Blodgett Xcel oven performed well throughout the application of ASTM test method 1496-99. The Xcel oven was able to preheat to 340°F in less than 12 minutes in its 60,000 Btu/h mode and in approximately nine minutes in the 80,000 Btu/h mode.

Cooking performance was determined by baking 100-count russet potatoes under three different loading scenarios (heavy—5 full-size sheet pans, medium—3 full-size sheet pans, and light—1 full-size sheet pan) for each input rate. The cook times for the three loading scenarios at 60,000 Btu/h were 50.6 minutes for the heavy-load test, 42.7 minutes for the medium-load test, and 39.1 minutes for the light-load test. At 80,000 Btu/h, the cook times were

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[1] American Society for Testing and Materials. 1999. *Standard Test Method for the Performance of Convection Ovens.* ASTM Designation F 1496-99, in *Annual Book of ASTM Standards,* West Conshohocken, PA.

48.1 minutes for the heavy-load test, 45.0 minutes for the medium-load test, and 44.2 minutes for the light-load test.

As specified by the ASTM test method, cooking-energy efficiency is a measure of how much of the energy that an appliance consumes is actually delivered to the food product during the cooking process. Cooking-energy efficiency is therefore defined by the following relationship:

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

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

Table ES-1. Summary of ASTM Convection Oven Performance Results.

Rated Energy Input Rate (Btu/h)	60,000	80,000
Measured Energy Input Rate (Btu/h)	60,020	78,680
Fan/Control Energy Rate (kW)	0.8	0.8
Preheat Time to 350°F (min)	11.8	9.1
Preheat Energy to 350°F (Btu)	11,810	11,880
Idle Energy Rate @ 350°F (Btu/h)	16,660	17,490
Pilot Energy Rate (Btu/h) [a]	0	0
Heavy-load Cooking-Energy Efficiency (%)	41.8 ± 0.3[b]	41.3 ± 0.4[b]
Medium-Load Cooking-Energy Efficiency (%)	34.5 ± 0.7[b]	34.3 ± 0.2[b]
Light-Load Cooking-Energy Efficiency (%)	18.1 ± 0.2[b]	17.9 ± 0.4[b]
Production Capacity [c] (lb/h)	86.2 ± 5.3[b]	90.4 ± 4.5[b]
Cooking Uniformity Average Rack Temperatures (°F):		
Rack #1 (Top)		177
Rack #2		151
Rack #3		161
Rack #4		157
Rack #5 (Bottom)		199
Maximum Temperature Difference		48

[a] This oven was equipped with automatic ignition.

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

[c] Based on the heavy-load cooking test with a 205°F endpoint.

Figure ES-2 illustrates the relationship between cooking-energy efficiency and production rate for this convection oven for the two cooking input rates (60,000 Btu/h, 80,000 Btu/h). Figures ES-3 illustrates the relationship between the convection oven's average energy consumption rate and the production rate. These graphs can be used as tools to estimate the daily energy consumption for the convection oven in a real-world operation. Average energy consumption rates while operating in the 60,000 Btu/h mode at 15, 30, and 60 pounds per hour are 16,340 Btu/h, 25,180 Btu/h, and 42,870 Btu/h, respectively. While in the 80,000 Btu/h mode, the consumption rates for the same production rates (15, 30, and 60 lb/h) are 15,910 Btu/h, 25,820Btu/h, and 45,660 Btu/h, respectively.

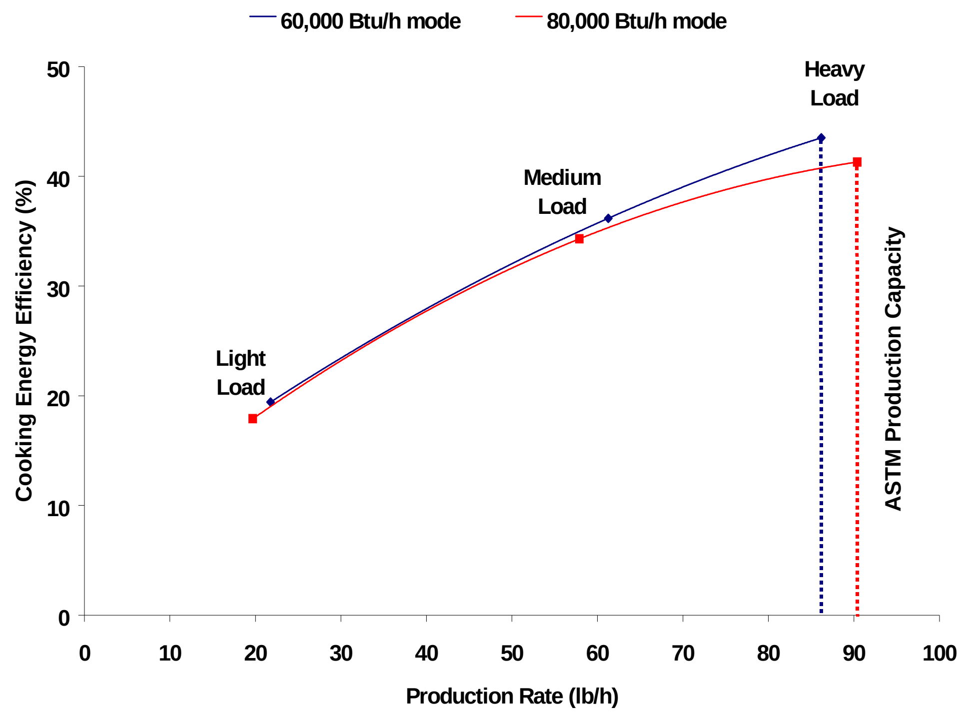


Figure ES-2.
Convection oven cooking-energy efficiencies.

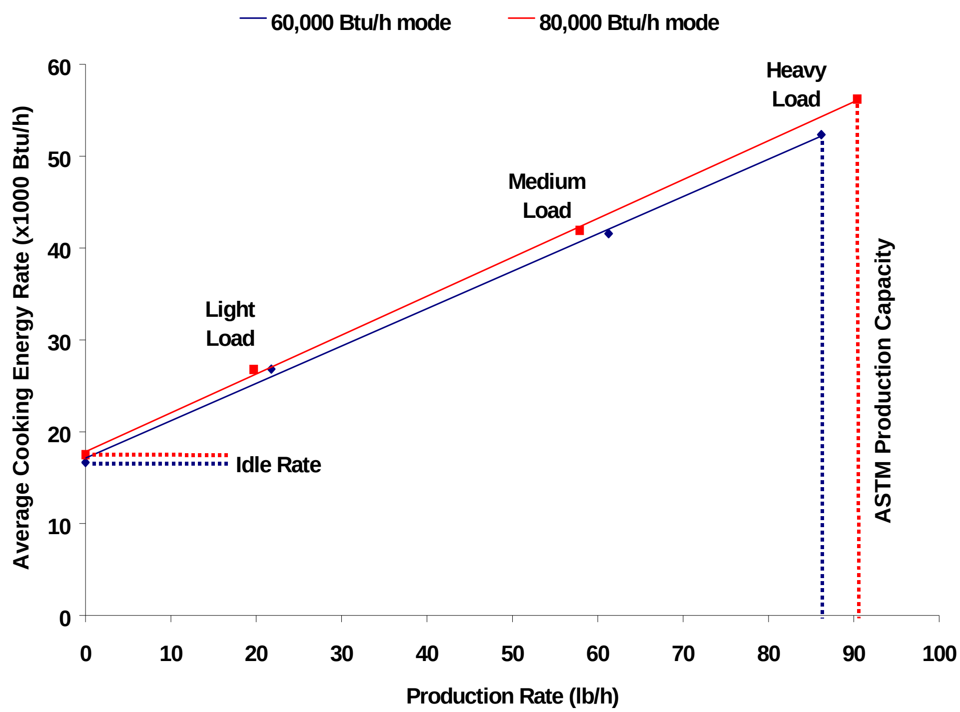


Figure ES-3. Convection oven cooking energy consumption profiles.

The cooking uniformity test, which was conducted in the 80,000 Btu/h mode, was meant to challenge the oven's uniform cooking ability with a difficult food product – frozen mac n' cheese. Four trays of mac n' cheese were placed on each of the five racks and cooked to an average temperature of 170°F. The Xcel oven was able to cook a heavy load of mac n' cheese with a maximum temperature difference of 48°F in less than 45 minutes with an efficiency of over 48 percent.

Another indication of the oven's cooking uniformity is the browning uniformity test in which five white sheet cakes are prepared in the oven and the final results, color and texture, are examined. The results of this test showed that the Xcel oven baked every batch of white sheet cakes with a nice golden brown color and even wrinkling within each cake.

Executive Summary

The Blodgett Xcel oven proved to be a solid performer throughout all phases of the ASTM test method. It would make an excellent addition to any cooking establishment.

1 Introduction

Background

Convection ovens are the most widely used appliances in the food service industry. Operators know that fresh-baked signature desserts, crusty breads, and familiar comfort foods, such as roasted meats and potatoes, are irresistible to their customers. In addition to traditional uses such as roasting and baking, these ovens can be used for nearly all types of food preparation, including foods typically prepared using other types of appliances.

With competition rising among equipment manufacturers, new designs that incorporate timesaving features via sophisticated control packages are being introduced. In 1993, the Food Service Technology Center (FSTC) developed a standard test method to quantify the performance of convection ovens. This test method was applicable to both full-size and half-size convection ovens and allowed manufacturers and end users to compare performance indices such as energy efficiency, cooking uniformity, and production capacity.

The draft test procedure was submitted to the American Society for Testing and Materials (ASTM), and February 1994 was accepted as a standard test method (Designation F 1496-93). Furthermore, this test method has undergone a recent revision in 1999 and now includes new standards in temperature endpoints. Pacific Gas and Electric Company's *Development and Application of a Uniform Testing Procedure for Convection Ovens* documents the developmental procedures and preliminary test results for four (two gas and two electric) convection ovens.[2] Other FSTC reports document results of applying the ASTM test method to different convection ovens.[3-9]

Blodgett's gas convection oven incorporates a two-speed, ¾-horsepower fan with a solid-state thermostat, and a zero-to-sixty minute timer. A speed selector switch allows the fan to run at high or low speed and with the doors open to cool the cooking cavity. In addition, Blodgett has incorporated dual-rated burners capable of producing 60,000 Btu/h or 80,000 Btu/h on demand. The individual cooking modes can be selected with a switch that adjusts the manifold pressure of the burners. In conjunction with the two-speed fan, the dual-rated burners allow for greater versatility and the ability to prepare a larger menu selection. The glossary in Appendix A is provided so that the reader has a quick reference to the terms used in this report, and Appendix B includes the full specification sheet for this oven.

Objectives

The objective of this report is to examine the operation and performance of the Blodgett DFG100 Xcel gas full-size convection oven 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 oven from room temperature to 340°F.
3. Characterize the oven's idle energy use with the thermostat set at a calibrated 350°F.
4. Document the cooking energy consumption and efficiency under three different scenarios: heavy (five pans of potatoes), medium (three pans of potatoes), and light (single pan of potatoes).
5. Determine the oven's production capacity when baking potatoes.
6. Document the oven's frozen-load cooking-energy efficiency, production capacity, and cooking uniformity using a representative food product such as macaroni and cheese.
7. Document the oven's browning uniformity using white sheet cakes.

Appliance Description

An array of atmospheric burners located beneath the floor of the oven cavity powers the thermostatically controlled convection oven. Heat is directly transferred to the oven cavity from combustion products as they travel up through spaces between the sidewalls and enter from the back of the oven cavity (Figure 1-1). A ¾-horsepower, two-speed (high or low speed) fan circulates air throughout the oven cavity. This oven was equipped with electronic ignition, thus eliminating the need for a standing pilot.

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

Figure 1-1.
DFG100 Xcel oven cavity.

Table 1-1. Appliance Specifications.

Manufacturer	Blodgett
Model	DFG100 Xcel
Generic Appliance Type	Full-size gas convection oven
Rated Input	Dual Rated 60,000/80,000 Btu/h
Dimensions	29" x 22$^1/_8$" x 20"
Oven Cavity Volume	12,832.5 cubic inches
Controls	Rated input selector, single thermostat adjustable from 150 to 550°F, 0 to 60 minute cook timer, and a two-speed fan.

2 Methods

Setup and Instrumentation

The convection oven was installed 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 convection oven and the edge of the hood. Figure 2-1 illustrates this setup. All test apparatus were installed in accordance with Section 9 of the ASTM test method.[1]

The convection oven was instrumented with several thermocouples to measure the temperature of the oven's walls and the temperature at the center of the cooking cavity. Natural gas consumption was measured with a positive displacement-type gas meter that generated a pulse for every 0.1 ft^3 consumed. Fan and control energy was measured with a Watt-hour transducer that generated a pulse for every 0.00001 watt-hours. The gas meter, transducer, and thermocouples were connected to an automated data acquisition unit that recorded data every 5 seconds. From this information, energy consumption and input rates were calculated and temperature profiles were generated.

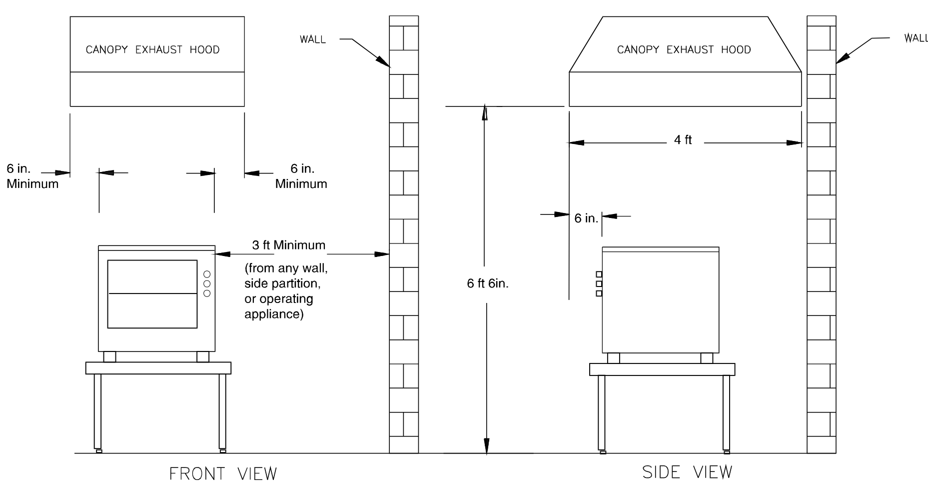


Figure 2-1. Appliance/hood configuration.

Measured Energy Input Rate

The energy input rate was determined by measuring the energy consumption during preheat from room temperature. The peak input recorded during this period was reported as the measured energy input rate. After stabilizing the oven cavity at room temperature (70 ± 5°F) overnight, the oven was turned on and preheated to 350°F. Elapsed time and energy consumption was recorded during this preheat period. However, for accuracy, preheat energy was recorded for the time the burners were on until the cavity temperature reached 340°F, as specified by the ASTM test method.[1] This is to ensure that there would be no disruption or premature reduction in burner rate during the preheat to the 350°F set point.

Cooking-Energy Efficiency Tests

The cooking-energy efficiency and production capacity tests consisted of baking 100-count russet potatoes on full-size sheet pans. The cooking-energy efficiency tests were conducted for three distinct loading scenarios: heavy (five sheet pans), medium (three sheet pans) and light (single sheet pan).

Each pan was filled with 30 potatoes that had a combined weight of approximately 14½ pounds. Three potatoes per pan were randomly selected and instrumented with thermocouples for monitoring temperature during the test. The potatoes were then baked from 70°F to an average temperature of 205°F. Each of the three cooking-energy efficiency tests were replicated a minimum of three times to ensure accuracy in the reported results. Production capacity was determined during the heavy-load test.

Energy imparted to the potatoes is the sum of the energy required to raise their temperatures from 70°F to the endpoint (sensible energy) and the energy required to vaporize a portion of the water contained in the potatoes (vaporization energy). The oven's cooking-energy efficiency for a given loading scenario is the amount of energy imparted to the potatoes, expressed as a percentage of the amount of energy consumed by the oven during the cooking process.

Methods

Cooking Uniformity Tests

The heavy-load cooking uniformity test was designed to reflect how evenly an oven cooks "stubborn" food products. The preheated oven was loaded with 20 quarter-size pans (four per rack) filled with a frozen food product, in this case macaroni and cheese. The temperature of each pan was individually monitored during the course of the test. When the entire quantity of macaroni and cheese trays reached an average temperature of 170°F, the test was complete. By recording the temperatures of the pans, the tester could show how uniformly the oven cooked the frozen food product, especially within each rack and in each corner.

Browning Uniformity Tests

The oven's browning uniformity was documented while baking white sheet cakes. For this test, the oven was loaded with five full-size sheet pans, each filled with 6 pounds of cake batter. The pans were loaded from the bottom up to minimize the disuniformity between racks. The cakes were considered done when a wood skewer could be inserted into the cakes and removed without any particles adhering to it.

Appendix C contains the ASTM results reporting sheets for this oven.

Operating Cost Model

The oven operating cost was calculated based on a combination of test data and assumptions about typical oven usage. This provides a standard method for estimating oven energy consumption based on ASTM performance test results. The examples contained in the operating cost model are for informational purposes only, and should not be considered an absolute.

The model assumed a typical twelve hour day, with two preheats. During the day 100 lb of food would be cooked; 50% of the food would be cooked under heavy-load conditions, 40% would be cooked under medium-load conditions, and 10% would be cooked under light-load conditions. The total daily energy usage was calculated based on the oven's energy consumption in each of these cooking scenarios. The cost model assumptions are listed in Table 2-1. Details of this calculation can be found in appendix E of this report.

Table 2-1: Cost Model Assumptions

Operating Time per Day	12 h
Number of Preheats per Day	2
Total Amount of Food Cooked per Day	100 lb
Percentage of Food Cooked Under Heavy-load Conditions	50 %
Percentage of Food Cooked Under Medium-load Conditions	40 %
Percentage of Food Cooked Under Light-load Conditions	10 %

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 convection oven was operating within its specified parameters. The measured energy input rates were 60,080 Btu/h and 78,680Btu/h (a difference of 0.1% and 1.7% from the nameplate ratings of 60,000 and 80,000 Btu/h, respectively).

Preheat and Idle Tests

Preheat Energy and Time

The oven was instrumented with thermocouples attached to the geometric center of the cooking cavity. For the preheat tests in the 60,000 Btu/h mode, the oven cavity reached 340°F in 11.8 minutes at an average preheat rate of 23°F per minute. While operating in the 80,000 Btu/h mode, the oven heated at an average preheat rate of 38°F per minute with a preheat time of 9.1 minutes. Figures 3-1 and 3-2 show the oven's energy consumption along with the cooking cavity temperature during these preheat tests.

Idle Energy Rate

The idle energy rate represents the energy required to maintain the set temperature, or the oven's stand-by losses. After the oven had stabilized at 350°F for at least one hour, researchers monitored oven energy consumption for an additional three hours. The idle energy rates during this period were 16,660 Btu/h in the 60,000 Btu/h mode, and 17,490 Btu/h in the 80,000 Btu/h mode, with an additional 800 watts of electricity for the fan and controls in both modes.

Test Results

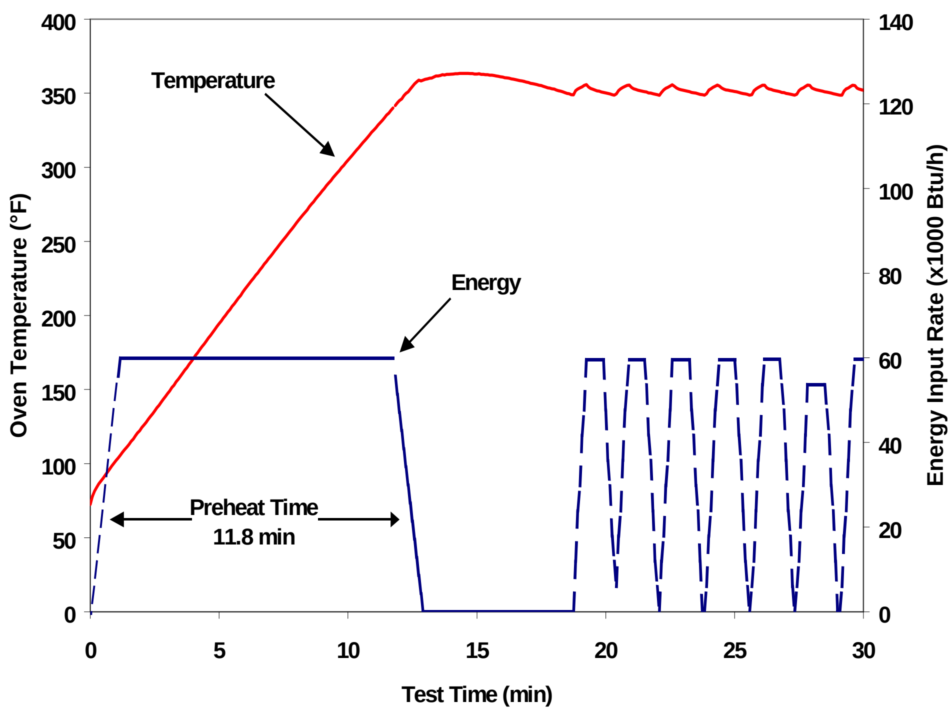


Figure 3-1.
Preheat characteristics at 60,000 Btu/h.

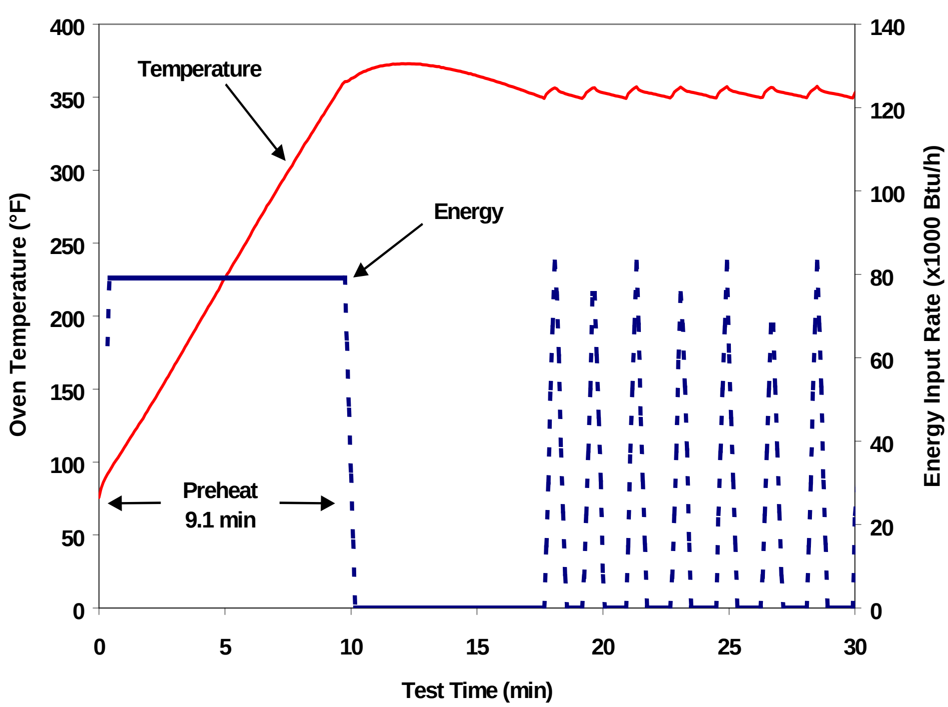


Figure 3-2.
Preheat characteristics at 80,000 Btu/h.

Results

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

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

Mode (Btu/h)	60,000	80,000
Rated Energy Input Rate (Btu/h)	60,000	80,000
Measured Energy Input Rate (Btu/h)	60,020	78,680
Fan/Control Energy Rate (kW)	0.8	0.8
Preheat		
Time to 340°F (min)	11.8	9.1
Energy (Btu)	11,810	11,880
Rate to 340°F (°F/min)	23	38
Idle Energy Rate @ 350°F (Btu/h)	16,660	17,490

Cooking-Energy Efficiency Tests

The convection oven was used to bake 100-count russet potatoes under three loading scenarios: full (five full-size pans), medium (three full-size pans), and light (single full-size pan). Each pan contained 30 potatoes, with a combined weight of approximately 14½ pounds.

The oven was tested at both the 60,000 and 80,000 Btu/h input ratings with the fan set to high speed. The cook time, potato temperature and convection oven energy consumption were monitored during these tests.

Heavy-load Tests

The heavy-load cooking tests were designed to reflect an oven's maximum performance. The oven was used to bake five full-size sheet pans of potatoes from 70°F to an average temperature of 205°F. Three potatoes per pan were randomly selected and instrumented with thermocouples for monitoring temperature. Figure 3-3 shows the average potato temperature during a typical heavy-load test.

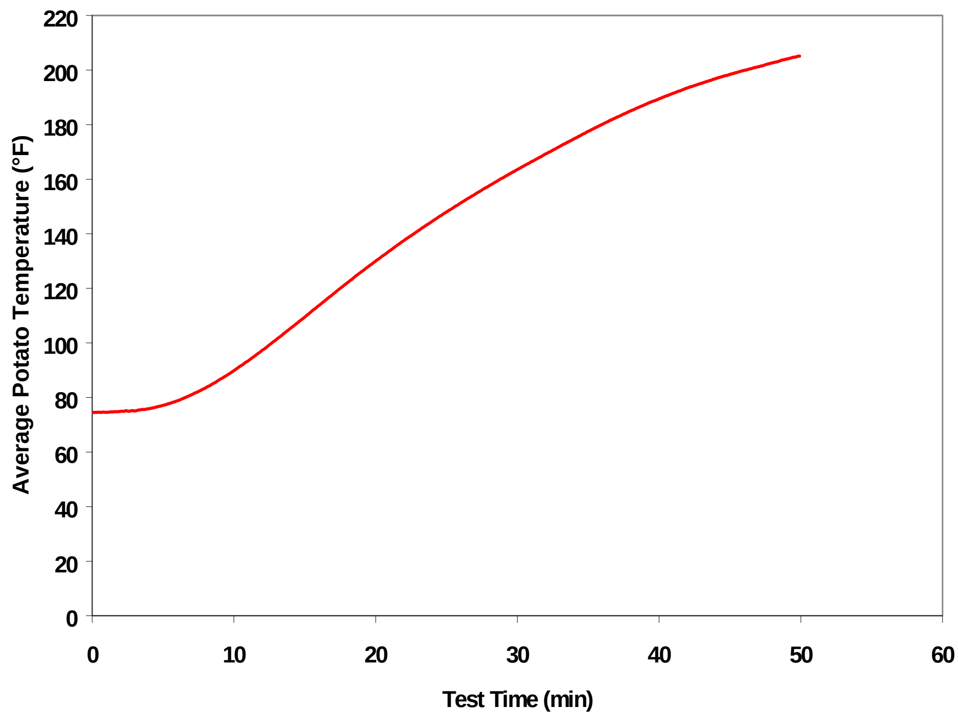


Figure 3-3.
Average potato temperature during a heavy-load test in 60,000 Btu/h mode.

Medium- and Light-Load Tests

Medium and light load tests determine the oven's performance under partial loading conditions. The medium-load tests were conducted with three full-size sheet pans of potatoes; the light-load tests were conducted with a single pan of potatoes. Since convection ovens may be used to bake less than a full load of product much of the time, these part-load efficiencies can be used to estimate convection oven performance in an actual operation.

Test Results

Cooking-energy efficiency results for the ASTM heavy-load tests at 60,000 Btu/h were 41.8%, 41.8%, and 42.0%, yielding an uncertainty of 0.3% in the test results. At 80,000 Btu/h, the ASTM heavy-load cooking efficiencies were 41.3%, 41.1%, and 41.3 %, yielding an uncertainty of 0.4% in the results. Tables 3-3 and 3-4 summarize the results of the ASTM cooking-energy efficiency and production capacity tests. Figure 3-4 illustrates the relationship between cooking-energy efficiency and production rate for this convection oven. Appendix D contains a synopsis of test data for each replicate of the cooking tests.

Figures 3-5 illustrates the relationship between the convection oven's average energy consumption rate and the production rate. These graphs can be used as a tool to estimate the daily energy consumption for the convection oven in a real-world operation.

Table 3-2. Cooking-Energy Efficiency and Production Capacity Test Results: 60,000 Btu/h Mode.

	Heavy-Load	Medium-Load	Light-Load
Endpoint (°F)	205	205	205
Cook Time (min)	50.6	42.7	39.1
Production Rate (lb/h)	86.2 ± 5.3	61.3 ± 2.7	22.3 ± 0.5
Energy to Food (Btu/lb)	250	235	235
Energy Consumption (Btu/lb)	597	681	1,302
Cooking Energy Rate (Btu/h)	52,380	41,560	26,820
Fan/Control Energy Rate (kW)	0.7	0.7	0.7
Cooking-Energy Efficiency (%)	41.8± 0.3	34.5 ± 0.7	18.1 ± 0.2

Table 3-3. Cooking-Energy Efficiency and Production Capacity Test Results: 80,000 Btu/h Mode.

	Heavy-Load	Medium-Load	Light-Load
Endpoint (°F)	205	205	205
Cook Time (min)	48.1	45.0	44.2
Production Rate (lb/h)	90.4 ± 4.5	57.9 ± 2.2	19.7 ± 1.1
Energy to Food (Btu/lb)	250	262	264
Energy Consumption (Btu/lb)	606	763	1,473
Cooking Energy Rate (Btu/h)	56,190	41,910	26,780
Fan/Control Energy Rate (kW)	0.7	0.7	0.7
Cooking-Energy Efficiency (%)	41.3 ± 0.4	34.3 ± 0.2	17.9 ± 0.4

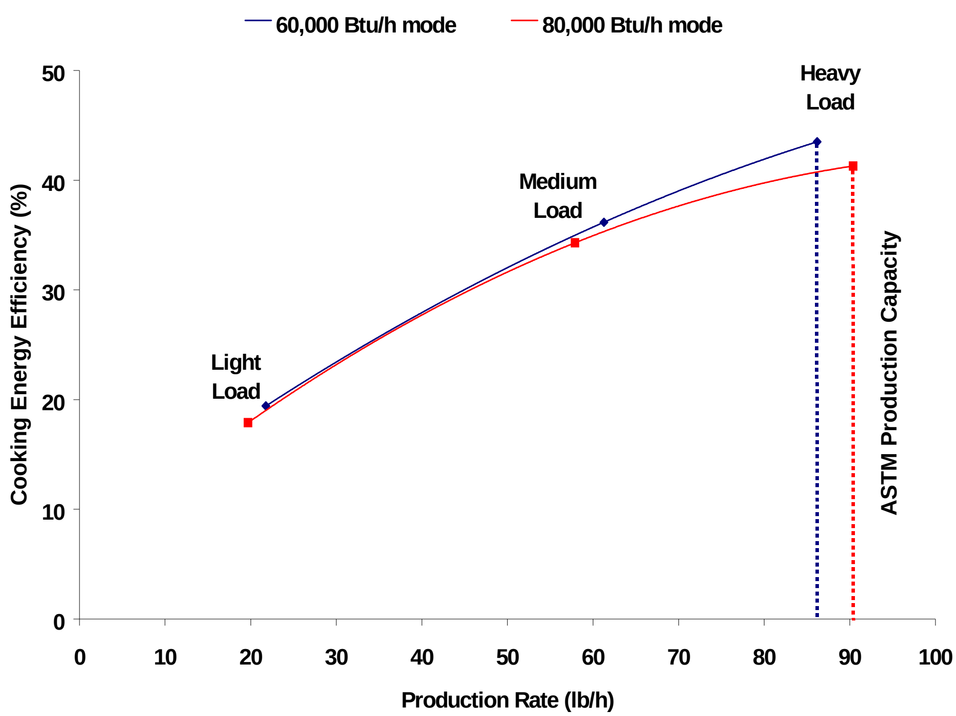


Figure 3-4.

Convection oven cooking-energy efficiencies.

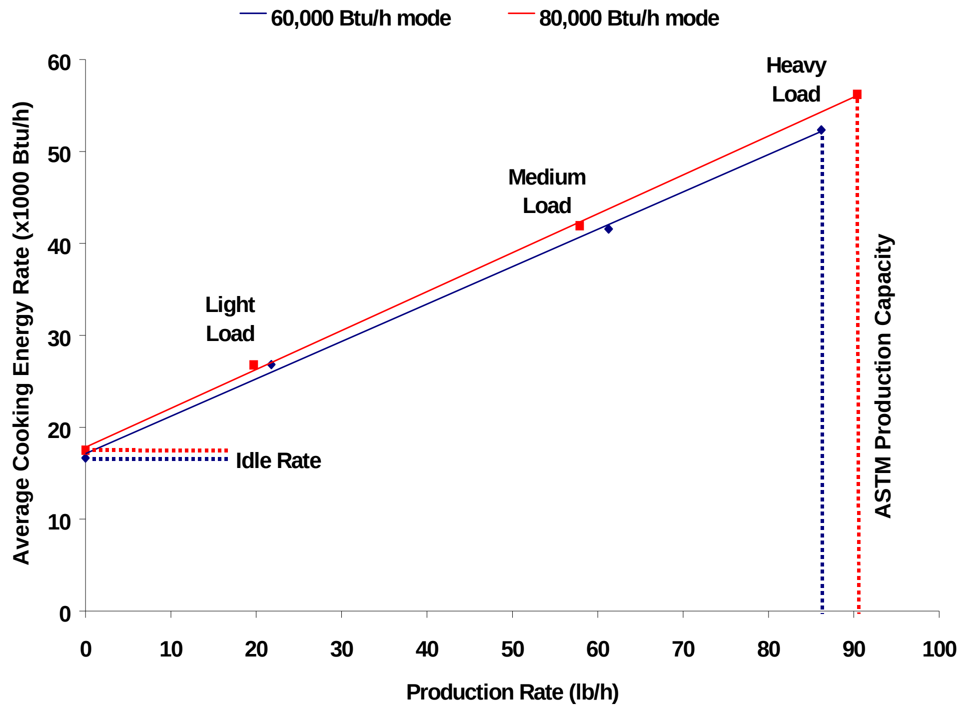


Figure 3-5.
Convection oven cooking energy consumption profiles.

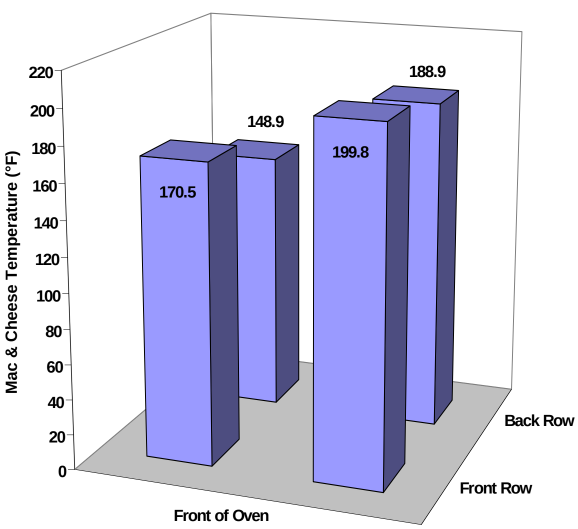
Note: Light-load = 1 pan/load; medium-load = 3 pans/load; heavy-load = 5 pans/load.

Cooking Uniformity

The frozen load tests were conducted at the 80,000 Btu/h input rating only. Individual tray temperatures were monitored to evaluate the oven's cooking uniformity and ability to sufficiently and adequately heat the macaroni and cheese frozen entrees. Each solid blue bar represents a single tray and its temperature (average of 3 replicates) at the moment when all 20 pans reached the ASTM specified average of 170°F. Table 3-4 lists the performance summary of the oven while cooking the frozen load. The oven rack temperature profiles are located next to their corresponding descriptions, labeled 1 through 5, and placed from the top of the oven to the bottom.

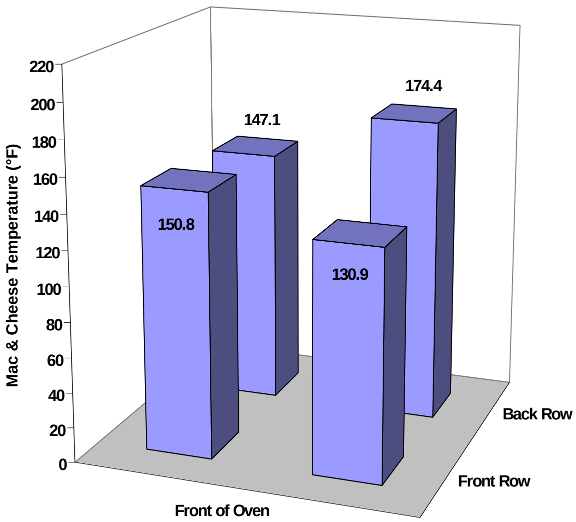
Table 3-4. Frozen (Macaroni & Cheese) Load Test Results: 80,000 Btu/h Mode.

Cook Time (min)				44.7
Frozen-Load Production Rate (lb/h)				124.5 ± 7.0
Energy to Food (Btu/lb)				282
Energy Consumption (Btu/lb)				586
Cooking Energy Rate (Btu/h)				72,890
Fan/Control Energy Rate (kW)				0.7
Frozen-Load Cooking-Energy Efficiency (%)				48.1± 2.4
Average Rack Temperatures (°F):	Run 1	Run 2	Run 3	AVG
Rack #1	189	166	178	177
Rack #2	154	149	150	151
Rack #3	159	162	161	161
Rack #4	156	172	143	157
Rack #5	194	194	209	199
Max Temp Difference				48

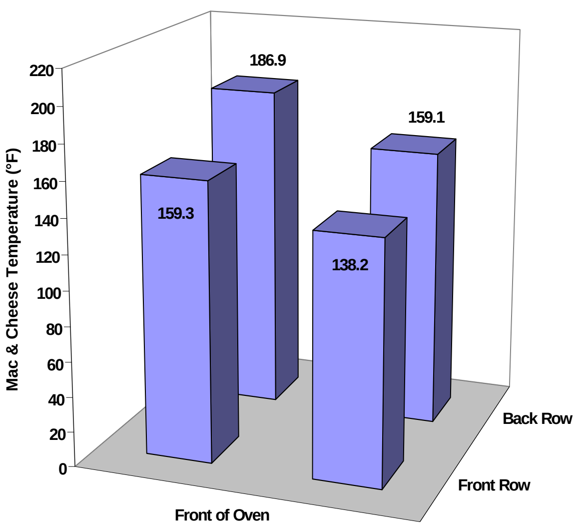


Rack 1. The top rack exhibited one of the highest average temperatures in the oven during the frozen-load tests, with an average rack temperature of 177°F. Among all the test runs, the left rear corner tray ended the coldest and the front right tray was consistently overcooked above 170°F.

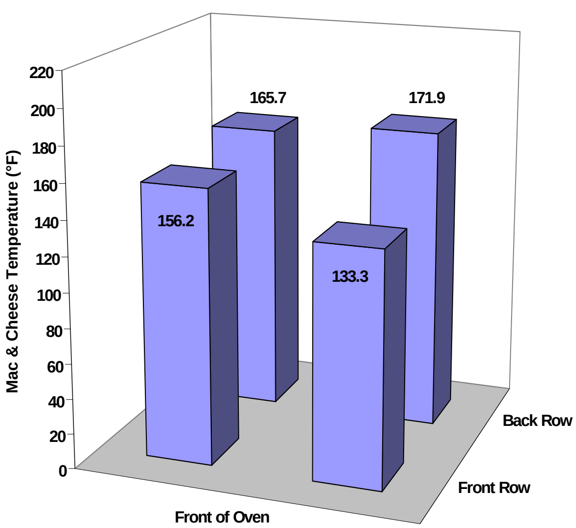
Results



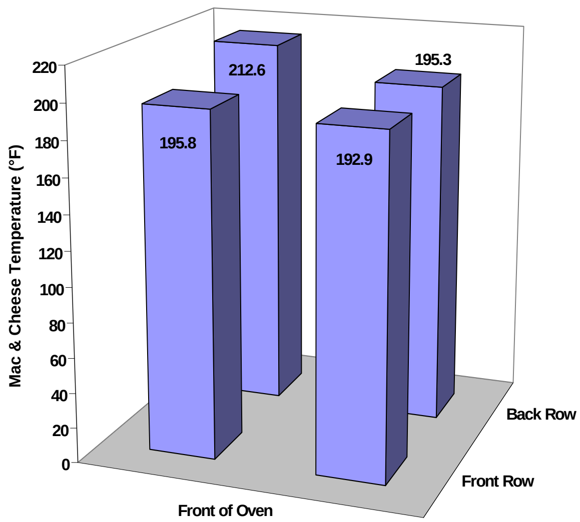
Rack 2. Contrary to the first rack, Rack 2 (upper middle rack) exhibited lower temperatures throughout the entire rack. The average temperature of Rack 2 never exceeded 155°F and the average of three replicates resulted in a temperature of 150.8°F. This rack was among the last to reach the ASTM endpoint.



Rack 3. The macaroni and cheese located on Rack 3 (center rack) resulted in an average rack temperature of 160.9. Two out of four trays never reached the ASTM endpoint, and the tray located in the left rear always surpassed 170°F. The entire rack never averaged past the ASTM either. Overall, this rack heated quicker than Rack 2 and achieved a higher average temperature each time.



Rack 4. Unlike Racks 2 and 3, this rack was able to reach 170°F at least on one occasion. The three test runs produced an average rack temperature of 156.8°F. Results show that the most uniform cooking can be achieved utilizing the central racks, especially since there was only a ten degree difference in average rack temperatures among Racks 2 through 4.



Rack 5. The bottom rack experienced the highest temperatures in the oven due to the fact that rack 5 is closest to the heat source at the bottom. This rack consistently reached temperatures averaging over 20 degrees past the ASTM endpoint (194°F, 194°F, 209°F). None of the trays on this rack were ever undercooked and at least two of the trays always ended the test with temperatures exceeding 200°F.

Browning Uniformity

White sheet cakes provide a visual indication of the temperature uniformity of an oven while baking. The cook time was experimentally determined so that the cakes were uniformly cooked while exhibiting the greatest possible differences in color. In any convection oven, one can expect variations in color and texture from rack to rack, especially in the bottom location, since this area of the oven is usually the hottest. Disuniformity can also result in surface texture variances and imperfections, which can sometimes be caused by a convection fan that draws enough air to distort the cake's surface.

Tests to determine the browning uniformity abilities of the oven were conducted under the 60,000 Btu/h, low-fan mode. As with the majority of ovens, individual sheet cakes were loaded from the top rack first to the bottom rack last to obtain the most uniform results. The final cook time that produced the most uniform batch of sheet cakes was determined to be 21 minutes. The results of the test are described below and visual representations of the browning are shown in Figures 3-6 through 3-10.

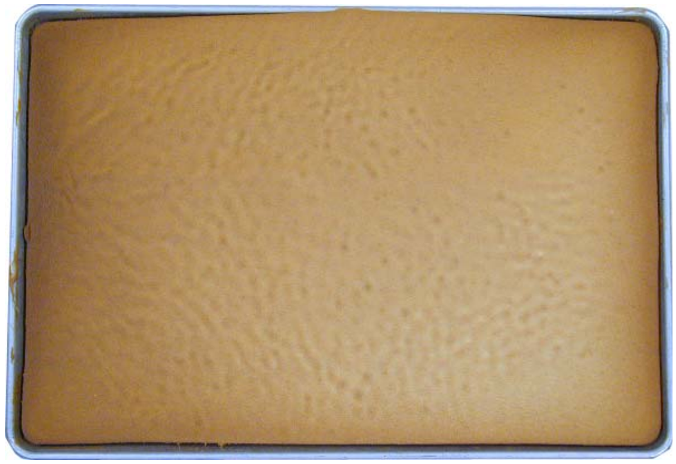


Figure 3-6.
Top sheet cake (rack #1).

Top rack. The surface of this cake had a nice, golden brown color and the texture appears smooth. There is no evidence of pulling or distortion by the fan. Surface imperfections on this cake are nonexistent, and the browning of this cake is the best of the batch.

Figure 3-7.
Upper middle sheet cake (rack #2).

Upper middle rack. This cake had a light section along the center of the cake and golden brown patches to either side. The light patch was also wider at the front of the cake than at the rear. Color and texture are consistent throughout most of the cake.

Figure 3-8.
Middle sheet cake (rack #3).

Middle rack. This cake exhibited a uniform golden color and even wrinkling over the entire surface. The browning of this cake was more uniform compared with the cake on rack #2.

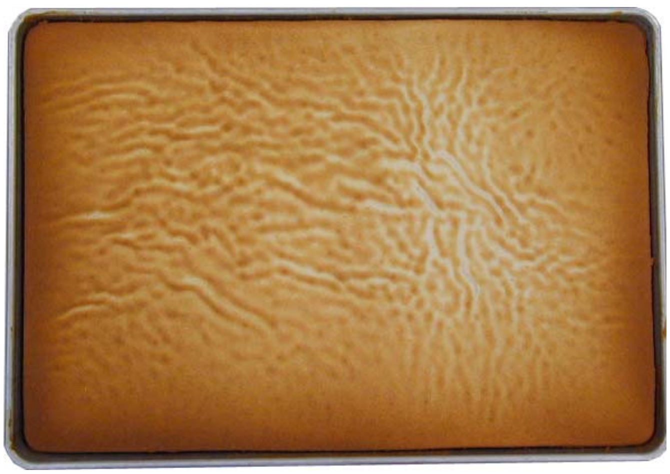


Figure 3-9.
Lower middle sheet cake (rack #4).

Lower middle rack. This cake also showed a nice, golden color along most of its surface and slightly darker edges to the sides and the front. Wrinkling was consistent with racks #2 and #3 and the color is nearly identical to the middle rack.

Figure 3-10. Bottom sheet cake (rack #5).

Bottom rack. Besides the remnants of air bubbles towards the rear, this cake had an overall uniform color, with a golden surface and edges that were not excessively darkened. Wrinkling was also consistent with the upper racks and there was no evidence of any uneven browning.

Energy Cost Model

With the results obtained from the application of the ASTM test method, the annual expenditures associated with its operation can be estimated. This guide can be used to project the operating cost of this oven based on the hours of operation, the amount of food cooked, etc. Consumers can use this tool, along with the performance results to compare this appliance with other models and manufacturers.

For this model, the oven was used to cook 100 pounds of food over a 12-hour day, with two preheats per day, 365 days a year. The assumptions found in Appendix F properly proportion a certain percentage of daily cooking time to heavy-load (fully loaded), medium-load (half-full), and light–load (single pan) conditions. The idle (standby) time for the oven was determined by taking the difference between the total daily “on” time (12 hours) and the time spent cooking and preheating. This approach produces a more accurate estimate of the operating costs for the oven. Table 3-6 summarizes the energy consumption and associated cost for the Blodgett Xcel oven under this scenario.

Table 3-5. Annual Cost Model.

	Gas (kBtu)[a]	Elec (Wh)
Daily Preheat Energy	23.6	300
Daily Idle Energy	163.3	5,880
Daily Cooking Energy	72.8	1,260
Total Daily Energy	259.7	7,440
Total Operating Cost ($/yr)[b]		$1,219

[a] 1 kBtu = 1,000 Btu
[b] Oven energy costs are based on $1.00/therm for gas and $0.10/kWh for electricity. (1 therm =100,000 Btu).

4 Conclusions

Blodgett's commitment to setting the standard for gas convection ovens is evident in the impressive results obtained through the application of ASTM standard test method F1496-99. The Blodgett, model DFG100 Xcel, full-size gas convection oven's performance was excellent under the rigorous conditions of the ASTM test method. Its 41.8% heavy-load efficiency is one of the best for any direct-fired gas oven tested to date at the FSTC, and it even out-produced ovens with a much larger rated input.[2-9]

With dual-rated burners that allow the operator to cook at 60,000 Btu/h or 80,000 Btu/h and a two-speed fan, the DFG100 Xcel provides a broad range of options for food preparation. When testing at the higher input rate (80,000 Btu/h), the Blodgett maintains its impressive cooking energy efficiencies and does so with shorter cook times. During the heavy-, medium-, and light-load potato tests, the monitored potatoes were sufficiently cooked in a minimal amount of time with little variation in temperature. Furthermore, the production capacity was increased by over four pounds per hour with the higher input rate with little or no change in cooking-energy efficiency. This shows the ovens ability to minimize heat loss at the higher input rate while still transferring its heat to the food product effectively. The result is an energy efficient oven in either mode, plus the added option of slow or fast cooking depending on food product and recipe.

As recommended by the manufacturer, the oven was placed in the higher input rate mode (80,000 Btu/h) when cooking frozen foods such as the frozen macaroni and cheese entrees. In the frozen load test, the DFG100 Xcel performed extremely well, both in terms of efficiency and uniformity. The DFG100 Xcel relies on direct-fired convection for cooking, and its production rate of 124.5 lb/h surpassed the best of the direct-fired ovens tested to date at the FSTC[6, 7]. It was also able to match some of the best direct-fired ovens' frozen load cooking energy efficiencies. As expected, the center racks (2-4) were the most even, and the top and bottom racks were the hottest.

A more qualitative evaluation of the cooking uniformity is the browning uniformity testing conducted with white sheet cake. The pictures included in this report show that the oven did a fine job of evenly distributing heat to all five sheet cakes. The surface color and texture were consistent from cake to cake and there was no evidence of overheating or uniformity issues, especially along the sides. Also, the draw of the fan was not an issue as the batter remained intact, and the cakes emerged level and smooth.

With the energy profiles provided in this report, the annual operating costs associated with this oven can be determined. The cost model in this report proportioned an entire day into percentages of heavy-, medium-, and light-load cooking. Together with the preheat and idle periods, a daily energy profile can be formulated, as shown in Appendix E using the oven in its 60,000 Btu/h mode. Under this scenario, the oven used a daily total of 259,000 Btu's (2.6 therms) of gas energy and 7,440 Wh of electrical energy. Therefore, the total, annual operating costs for the Blodgett Xcel DFG100 would be $1,219. With this cost model, end users and consumers can make informed decisions about purchasing their next convection oven.

Overall, the Blodgett performed well throughout the challenging ASTM tests. The DFG100 Xcel proved to be extremely versatile with its ability to switch input rates according to cooking requirements, and it did not sacrifice energy efficiency or production capacity for shorter cook times. The Blodgett DFG100 Xcel full size oven would be an excellent addition to any kitchen.

5 References

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5. Zabrowski, D., Cadotte, B., Cowen, D., 1999. *Montague, Model Vectaire HX63A Gas Full-Size Convection Oven Performance Test.* Food Service Technology Center Report 5011.99.79, December.
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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 kBtu/h)

The average rate of energy consumption during the cooking period.

Cooking Energy Efficiency (%)

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

Duty Cycle (%)
Load Factor

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

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

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

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

Heating Value (Btu/ft^3)
Heating Content

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

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

The rate of appliance energy consumption while it is holding or maintaining a stabilized operating condition or temperature 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 (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 product from the appliance until the cooking cavity is within 10°F of the thermostat set point and the appliance 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 Blodgett DFG100 Xcel gas convection oven.

BLODGETT®

DFG-100 XCEL

Full-Size Dual Flow Gas Convection Oven

Shown with optional casters and digital control

Project ______________________

Item No. ______________________

Quantity ______________________

DFG-100 XCEL

Standard depth baking compartment - accepts five 18" x 26" standard full-size baking pans in left-to-right positions.
All data is shown per oven section, unless otherwise indicated.
Refer to operator manual specification chart for listed model name.

OPTIONS AND ACCESSORIES

(AT ADDITIONAL CHARGE)

- **Control options:**
  - ❑ Solid state digital control with Cook & Hold and Pulse Plus™
  - ❑ Solid state digital control with Cook & Hold and Core Temperature Probe
  - ❑ Solid state digital control with Cook & Hold, Pulse Plus™, and Humidaire (available with stainless steel liner only)
  - ❑ Blodgett IQ2™ multi-stage programmable control
- **Legs/casters/stands:**
  - ❑ 6" (152mm) adjustable seismic legs
  - ❑ 6" (152mm) casters
  - ❑ 4-1/4" (108mm) low profile casters (double only)
  - ❑ 25" (635mm) stainless steel open stand with rack guides
- **Gas hose with quick disconnect and restraining device:**
  - ❑ 48" (1219mm) hose
  - ❑ 36" (914mm) hose
- ❑ Stainless steel oven liner
- ❑ Extra EZ slide oven racks
- ❑ Extra oven racks
- ❑ Gas manifold (for double sections)
- ❑ Prison package (includes security control panel and stainless steel back)
- ❑ Stainless steel solid back panel
- ❑ Security control panel

OPTIONS AND ACCESSORIES

(AT NO CHARGE)

- ❑ Solid stainless steel doors
- ❑ Draft hood

EXTERIOR CONSTRUCTION

- Welded full angle-iron frame
- Rigid mineral fiber insulation at top, back, sides and bottom
- Stainless steel front, top, and sides for easy cleaning
- Dual pane thermal glass windows encased in stainless steel door frames
- Porcelain door handle with simultaneous door operation
- Triple-mounted pressure lock door design with turnbuckle assembly
- Modular slide out front control panel for easy access

INTERIOR CONSTRUCTION

- Double-sided porcelainized baking compartment liner (14 gauge) with coved corners for easy cleaning
- Stainless and aluminized steel combustion chamber
- Dual inlet blower wheel
- Eleven rack positions with a minimum of 1-5/8" (41mm) spacing
- Bright halogen interior lights provide optimum visibility

OPERATION

- Dual Flow Gas system combines direct and indirect heat
- Electronic spark ignition control system
- Long life inshot burners
- Toggle switch to select either 60,000 BTU or 80,000 BTU input
- Manual gas service cut-off switch on front panel
- Solid state thermostat with temperature control range of 150°F (66°C) to 550°F (288°C)
- Two speed, 3/4 horsepower, convection motor with automatic thermal overload protection
- Control area cooling fan

STANDARD FEATURES

- Solid state manual control with separate dials to control thermostat and timer
- 25" (635mm) adjustable stainless steel legs (for single units)
- 6" (152mm) adjustable stainless steel legs (for double sections)
- Draft diverter
- Flue connector (for double & additional sections)
- Porcelainized crumb pans collects cooking residues for easy oven cleaning.
- One chrome plated EZ-Slide rack with ball bearing slides capable of gliding completely out of the oven cavity. Heavy duty design holds up to 50 lbs.
- Four chrome-plated racks
- Two year oven parts and one year labor warranty*
- Five year limited oven door warranty*

* *For all international markets, contact your local distributor.*

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BLODGETT OVEN COMPANY
www.blodgett.com
44 Lakeside Avenue, Burlington, VT 05401
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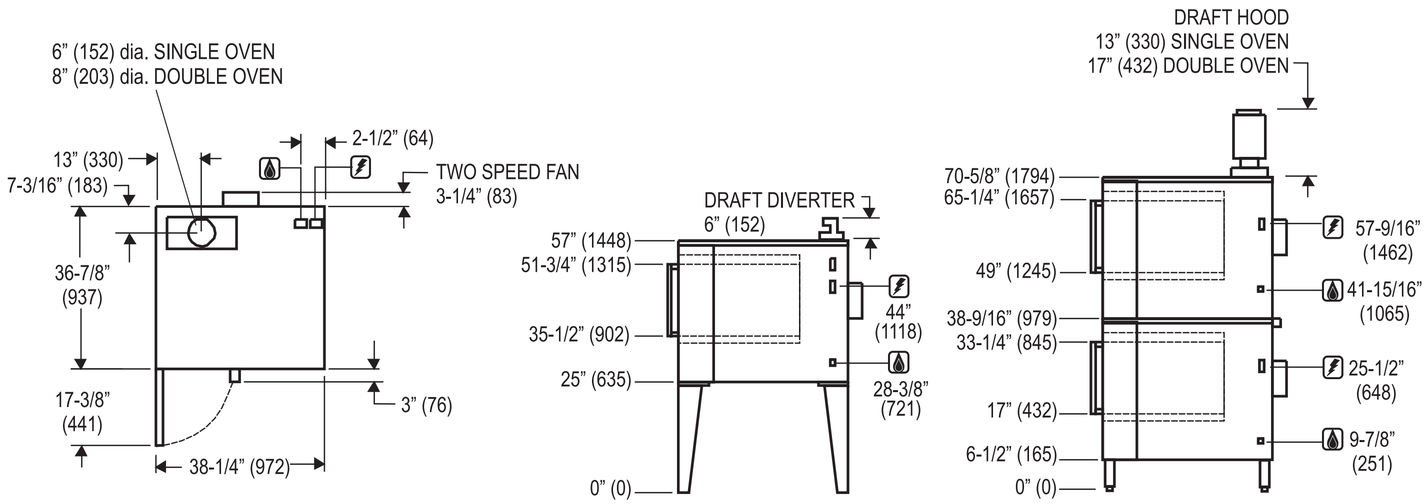
BLODGETT®

DFG-100 XCEL

APPROVAL/STAMP



TOP VIEW **SINGLE** **DOUBLE**

Dimensions are in inches (mm)

SHORT FORM SPECIFICATIONS

Provide Blodgett full-size convection oven model DFG-100 XCEL, (single/double) compartment with fully welded angle iron frame. Each compartment shall have double-sided, porcelainized or stainless steel liner. Liner to be coved top and bottom. Unit shall accept five l8" x 26" standard full-size bake pans. Stainless steel front, top and sides. Doors shall be triple mounted, stainless steel with dual pane thermal glass windows, with single porcelain handle and simultaneous operation. Unit shall be gas heated with electronic spark ignition and shall cook by means of a dual-flow system combining direct and indirect heat with a toggle switch to select either 60,000 or 80,000 BTUs. Air in baking chamber distributed by dual inlet blower wheel powered by a two-speed, 3/4 HP motor with thermal overload protection. Each chamber shall be fitted with bright halogen lamps, one chrome-plated EZ slide racks capable of holding 50 lbs, four standard chrome-plated removable racks and a two piece porcelain crumb pan. Control panel shall be recessed with Cook/Cool Down mode selector, solid state (manual/digital) infinite thermostat (150- 550°F), (66- 288°C) and 60-minute timer. Manual gas service cut-off switch on front panel. Two year oven parts and one year labor warranty and five year limited oven door warranty. Provide options and accessories as indicated.

DIMENSIONS:

Floor space 38-1/4" (972mm) W x 36-7/8" (937mm) D
Interior 29" (737mm) W x 20" (508mm) H x 24-1/4" (616mm) D
If oven is on casters add the following to all height dimensions
Single on casters 4-1/2" (114mm)
Double on casters 2-1/4" (57mm)
Product clearance
Oven back 0" from combustible and non-combustible construction
Oven sides 0" from combustible and non-combustible construction

MINIMUM ENTRY CLEARANCE:

Uncrated 32-1/16" (814mm)
Crated 37-1/2" (953mm)

SHIPPING INFORMATION:

Approx. Weight
Single 590 lbs. (268 kg)
Double 1095 lbs. (497 kg)
Crate sizes
37-1/2" (952mm) x 43-1/2" (1105mm) x 51-3/4" (1315mm)
(2 crates required for double)

GAS SUPPLY:

3/4" NPT
Manifold Pressure:
• Natural – 3.5" W.C • Propane – 10" W.C.
Inlet Pressure:
• Natural – 7.0" W.C. min. – 10.5" W.C. max.
• Propane – 11.0" W.C. min. – 13.0" W.C. max.

INPUT:

Single 80,000 BTU/hr (23.5 Kw)
Double 160,000 BTU/hr (47 Kw)

POWER SUPPLY:

115 VAC, 1 phase, 10 Amp, 60 Hz., 2-wire with ground, 3/4 H.P., 2 speed motor, 1725 and 1140 RPM
230, 220/240VAC, 1 phase, 3 Amp, 50 Hz., 2-wire with ground, 3/4 H.P., 2 speed motor, 1425 and 950 RPM
6' (1.8m) electric cord set furnished on 115 VAC ovens only.
Each unit requires a dedicated 15 amp. circuit.

NOTE: The company reserves the right to make substitutions of components without prior notice.

BLODGETT OVEN COMPANY
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44 Lakeside Avenue, Burlington, VT 05401 Toll Free: (800) 331-5842 • Phone: (802) 860-3700 • Fax: (802) 864-0183

C Results Reporting Sheets

Test Oven Description

Date:	February 2003
Manufacturer:	Blodgett
Model Number:	DFG100
Serial Number:	080808RI056Z
Fuel Type:	Natural gas
Size:	Full
Rated Input:	60,000 / 80,000 Btu/h
Oven Cavity Volume:	15,370 cubic inches
Controls:	Single thermostat adjustable from 200 to 500°F, 0 to 60 minute cook timer, and a two-speed fan.

Thermostat Accuracy

As-Received Condition:

Center of Oven Temperature:	350°F
Oven Temperature Control Setting:	350°F

As-Adjusted Condition:

Center of Oven Temperature:	350 ± 5°F
Oven Temperature Control Setting:	350°F

60,000 Btu/h-High Fan Mode Results

Energy Input Rate

Rated Input	**60,000** Btu/h
Gas Heating Value	1019.0 Btu/scf
Measured Energy Input Rate:	60,020 Btu/h
Percent Difference between Measured and Rated	< 1.0 %
Fan/Control Energy Rate:	0.8 kW

Pilot Energy Rate:	0 Btu/h*

*This oven was equipped with automatic ignition

Preheat Energy and Time

Gas Heating Value	1019.0Btu/scf
Starting Temperature	75°F
Preheat Energy Consumption	11,810 Btu
Preheat Fan/Control Energy	0.8 kW
Preheat Time	11.8 min
Average Preheat Rate	23°F/min

See Fig. 1 for a graphical representation of the preheat period.

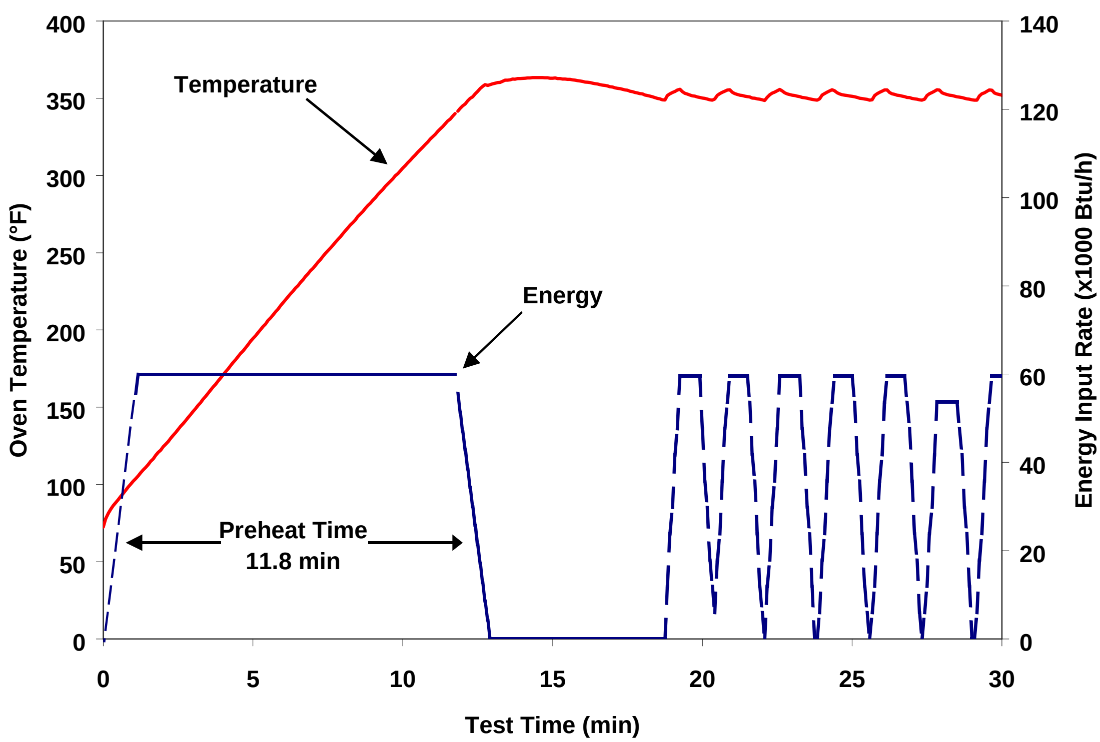

Fig. 1 Preheat and idle characteristics (60,000 Btu/h)

Results Reporting Sheets

Idle Energy Rate

Gas Heating Value	1019.0 Btu/scf
Center Oven Temperature	350°F
Idle Energy Rate	16,660 Btu/h
Fan/Control Energy Rate	0.6 kW

Cooking-Energy Efficiency

Heavy-Load:

Gas Heating Value	1019.9 Btu/scf
Cook Time	50.6 min
Production Capacity	86.2 ± 5.3 lb/h
Energy to Food	18,135 Btu
Energy to Oven*	43,340 Btu
Energy per Pound of Food Cooked*	597 Btu/lb
Cooking Energy Rate	52,380 ± 1290 Btu/h
Fan/Control Energy Rate	0.7 ± 0.01 kW
Cooking-Energy Efficiency*	41.8 ± 0.3 %

*Includes energy consumed by the fan and controls.

Medium-Load:

Gas Heating Value	1019.1 Btu/scf
Cook Time	42.7 min
Production Rate	61.3 ± 2.7 lb/h
Energy to Food	10,240 Btu
Energy to Oven*	29,680 Btu
Energy per Pound of Food Cooked*	681 Btu/lb
Cooking Energy Rate	41,560 ± 250 Btu/h
Fan/Control Energy Rate	0.7 ± 0.01 kW
Cooking-Energy Efficiency*	34.5 ± 0.7 %

*Includes energy consumed by the fan and controls.

Light-Load:

Gas Heating Value	1020.8 Btu/scf
Cook Time	39.1 min
Production Rate	18.1 ± 0.2 lb/h
Energy to Food	3,415 Btu
Energy to Oven*	18,920 Btu
Energy per Pound of Food Cooked*	1,302 Btu/lb
Cooking Energy Rate	26,820 ± 430 Btu/h
Fan/Control Energy Rate	0.7 ± 0.01 kW
Cooking-Energy Efficiency*	18.1 ± 0.2 %

*Includes energy consumed by the fan and controls.

80,000 Btu/h-High Fan Mode Results

Energy Input Rate

Rated Input	**80,000** Btu/h
Gas Heating Value	1,018.2 Btu/scf
Measured Energy Input Rate:	78,680 Btu/h
Percent Difference between Measured and Rated	1.7 %
Fan/Control Energy Rate:	0.8 kW
Pilot Energy Rate:	0 Btu/h*

*This oven was equipped with automatic ignition

Preheat Energy and Time

Gas Heating Value	1,018.2 Btu/scf
Starting Temperature	75°F
Preheat Energy Consumption	11,875 Btu
Preheat Fan/Control Energy	0.8 kW
Preheat Time	9.1min
Average Preheat Rate	38°F/min

See Fig. 2 for a graphical representation of the preheat period.

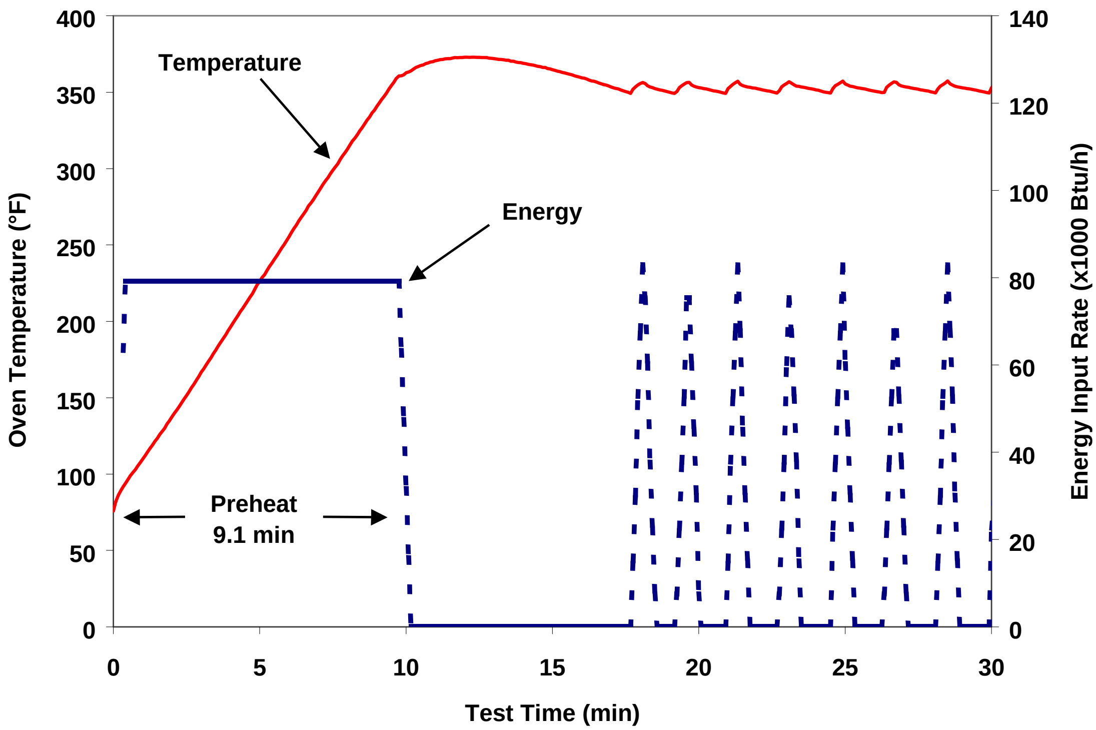

Fig. 2 Preheat and idle characteristics (80,000 Btu/h)

Idle Energy Rate

Gas Heating Value	1,018.2 Btu/scf
Center Oven Temperature	350°F
Idle Energy Rate	17,490 Btu/h
Fan/Control Energy Rate	0.6 kW

Cooking-Energy Efficiency

Heavy-Load:

Gas Heating Value	1,019.9 Btu/scf
Cook Time	48.1 min
Production Capacity	90.4 ± 4.5 lb/h
Energy to Food	18,130 Btu
Energy to Oven*	43,960 Btu

Energy per Pound of Food Cooked*	606 Btu/lb
Cooking Energy Rate	56,190 ± 1790 Btu/h
Fan/Control Energy Rate	0.7 ± 0.01 kW
Cooking-Energy Efficiency*	41.3 ± 0.4 %

*Includes energy consumed by the fan and controls.

Medium-Load:

Gas Heating Value	1,021.8 Btu/scf
Cook Time	45.0 min
Production Rate	57.9 ± 2.2 lb/h
Energy to Food	11,370 Btu
Energy to Oven*	33,120 Btu
Energy per Pound of Food Cooked*	763 Btu/lb
Cooking Energy Rate	41,910 ± 830 Btu/h
Fan/Control Energy Rate	0.7 ± 0.01 kW
Cooking-Energy Efficiency*	34.3 ± 0.2 %

*Includes energy consumed by the fan and controls.

Light-Load:

Gas Heating Value	1,013.0 Btu/scf
Cook Time	44.2 min
Production Rate	19.7 ± 1.1 lb/h
Energy to Food	3,824 Btu
Energy to Oven*	21,370 Btu
Energy per Pound of Food Cooked*	1,473 Btu/lb
Cooking Energy Rate	26,780 ± 1,560 Btu/h
Fan/Control Energy Rate	0.7 ± 0.01 kW
Cooking-Energy Efficiency*	17.9 ± 0.4 %

*Includes energy consumed by the fan and controls.

Cooking Uniformity (Mac & Cheese cooked in 80,000 Btu/hr–High Fan Mode**)**

Rack #	Average Temperature
1 (Top)	177°F
2	151°F
3	161°F
4	157°F
5 (Bottom)	199°F

Gas Heating Value	1025.3 Btu/scf
Cook Time	44.7 min
Production Rate	124.5 ± 7.0 lb/h
Energy to Food	26,140 Btu
Energy to Oven*	54,307 Btu
Energy per Pound of Food Cooked*	586 Btu/lb
Cooking Energy Rate	72,890 ± 3,250 Btu/h
Fan/Control Energy Rate	0.70 ± 0.03 kW
Cooking-Energy Efficiency*	48.1 ± 2.4 %

*Includes energy consumed by the fan and controls.

Browning Test

Top rack. The surface of this cake had a nice golden brown color and wrinkling was evenly distributed along the surface. The cake located on this rack was one of the first to reach doneness.

Upper middle rack. This cake had a light section along the center of the cake and golden brown patches to either side. The light patch was wider at the front of the cake than at the rear and the left rear is slightly darker than the rest of the cake.

Middle rack. This cake exhibited a nice, golden brown color and even wrinkling along the entire surface.

Lower middle rack. This cake showed a nice golden color along most of its surface and was nearly identical cake on the middle rack.

Bottom rack. This cake exhibited darker edges on the left and right, while the rest of the surface remained a golden brown color. Wrinkling was quite even and several remnants of air bubbles in the batter can be seen.

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
Potatoes	0.84
Macaroni & Cheese	0.70
Latent Heat (Btu/lb)	
Fusion, Water	144
Fusion, Fat	44
Vaporization, Water	970

Cooking-Energy Efficiency Data

Table D-2. Heavy-Load Test Data – 60,000 Btu/h mode.

	Rep #1	Rep #2	Rep #3
Measured Values			
Appliance Energy (Btu)	41,210	40,970	42,350
Fan/Control Energy (Wh)	530	525	550
Total Energy (Btu)	43,020	42,760	44,230
Cook Time (min)	49.8	49.9	52.0
Initial Weight (lb)	72,7	72.5	72.6
Final Weight (lb)	62.3	62.3	61.8
Initial Temperature (°F)	75	74	72
Final Temperature (°F)	205	205	205
Calculated Values			
Sensible (Btu)	7,932	7,975	8,137
Latent - Water Vaporization (Btu)	10,037	9,893	10,432
Total Energy to Food (Btu)	17,969	17,868	18,569
Energy to Food (Btu/lb)	247	246	256
Total Energy to Convection Oven	43,020	42,760	44,230
Energy to Convection Oven (Btu/lb)	592	590	610
Cooking-Energy Efficiency (%)	41.8	41.8	42.0
Cooking Energy Rate (Btu/h)	52,890	52,400	51,850
Fan Energy Rate (W)	710	700	700
Production Rate (lb/h)	87.7	87.2	83.7

Cooking-Energy Efficiency Data

Table D-3. Medium-Load Test Data – 60,000 Btu/h.

	Rep #1	Rep #2	Rep #3
Measured Values			
Appliance Energy (Btu)	27,760	28,609	28,127
Fan/Control Energy (Wh)	440	453	442
Total Energy (Btu)	29,250	30,155	29,634
Cook Time (min)	42.0	43.4	42.6
Initial Weight (lb)	43.6	43.5	43.6
Final Weight (lb)	38.1	37.6	37.9
Initial Temperature (°F)	76	75	76
Final Temperature (°F)	205	205	205
Calculated Values			
Sensible (Btu)	4,730	4,734	4,709
Latent - Water Vaporization (Btu)	5,288	5,753	5,517
Total Energy to Food (Btu)	10,018	10,487	10,226
Energy to Food (Btu/lb)	230	241	234
Total Energy to Convection Oven	29,250	30,155	29,634
Energy to Convection Oven (Btu/lb)	672	693	679
Cooking-Energy Efficiency (%)	34.3	34.8	34.5
Cooking Energy Rate (Btu/h)	41,640	41,445	41,584
Fan Energy Rate (W)	680	680	680
Production Rate (lb/h)	62.2	60.1	61.5

Cooking-Energy Efficiency Data

Table D-4. Light-Load Test Data – 60,000 Btu/h.

	Rep #1	Rep #2	Rep #3
Measured Values			
Appliance Energy (Btu)	17,270	17,620	17,490
Fan/Control Energy (Wh)	430	436	428
Total Energy (Btu)	18,734	19,103	18,930
Cook Time (min)	38.8	39.5	38.8
Initial Weight (lb)	14.5	14.6	14.6
Final Weight (lb)	12.6	12.7	12.7
Initial Temperature (°F)	77	72	74
Final Temperature (°F)	205	205	205
Calculated Values			
Sensible (Btu)	1,562	1,628	1,610
Latent - Water Vaporization (Btu)	1,803	1,839	1,804
Total Energy to Food (Btu)	3,365	3,467	3,414
Energy to Food (Btu/lb)	232	238	235
Total Energy to Convection Oven	18,734	19,103	18,930
Energy to Convection Oven (Btu/lb)	1,294	1,313	1,300
Cooking-Energy Efficiency (%)	18.0	18.2	18.0
Cooking Energy Rate (Btu/h)	26,688	26,760	27,020
Fan Energy Rate (W)	690	690	680
Production Rate (lb/h)	22.4	22.1	22.5

Cooking-Energy Efficiency Data

Table D-5. Cooking-Energy Efficiency and Production Capacity Statistics – 60,000 Btu/h.

	ASTM Cooking-Energy Efficiency			ASTM
	Heavy-Load	Medium-Load	Light-Load	Production Capacity
Replicate #1	41.8	34.3	18.0	87.7
Replicate #2	41.8	34.8	18.2	87.2
Replicate #3	42.0	34.5	18.0	83.7
Average	41.8	34.5	18.1	86.2
Standard Deviation	0.1	0.3	0.1	2.2
Absolute Uncertainty	0.3	0.7	0.2	5.3
Percent Uncertainty	0.7	1.9	1.3	6.2

Cooking-Energy Efficiency Data

Table D-6. Heavy-Load Test Data – 80,000 Btu/h.

	Rep #1	Rep #2	Rep #3
Measured Values			
Appliance Energy (Btu)	42,800	41,890	42,100
Fan/Control Energy (Wh)	500	484	504
Total Energy (Btu)	44,517	43,544	43,816
Cook Time (min)	49.0	47.1	48.3
Initial Weight (lb)	72.6	72.5	72.5
Final Weight (lb)	62.0	62.5	62.3
Initial Temperature (°F)	70.7	70.4	70.4
Final Temperature (°F)	205	205	205
Calculated Values			
Sensible (Btu)	8,197	8,136	8,214
Latent - Water Vaporization (Btu)	10,207	9,750	9,895
Total Energy to Food (Btu)	18,404	17,886	18,109
Energy to Food (Btu/lb)	254	247	250
Total Energy to Convection Oven	44,517	43,544	43,816
Energy to Convection Oven (Btu/lb)	614	600	604
Cooking-Energy Efficiency (%)	41.3	41.1	41.3
Cooking Energy Rate (Btu/h)	55,830	57,020	55,720
Fan Energy Rate (W)	680	685	690
Production Rate (lb/h)	88.8	92.4	90.1

Cooking-Energy Efficiency Data

Table D-7. Medium-Load Test Data – 80,000 Btu/h.

	Rep #1	Rep #2	Rep #3
Measured Values			
Appliance Energy (Btu)	31,230	31,440	31,590
Fan/Control Energy (Wh)	494	500	500
Total Energy (Btu)	32,920	33,144	33,300
Cook Time (min)	44.3	45.1	45.5
Initial Weight (lb)	43.5	43.3	43.4
Final Weight (lb)	36.8	36.5	36.6
Initial Temperature (°F)	74	74	74
Final Temperature (°F)	205	205	205
Calculated Values			
Sensible (Btu)	4,783	4,787	4,788
Latent - Water Vaporization (Btu)	6,553	6,578	6,617
Total Energy to Food (Btu)	11,336	11,365	11,405
Energy to Food (Btu/lb)	261	262	263
Total Energy to Convection Oven	32,920	33,144	33,300
Energy to Convection Oven (Btu/lb)	757	765	768
Cooking-Energy Efficiency (%)	34.4	34.3	34.3
Cooking Energy Rate (Btu/h)	42,290	41,790	41,660
Fan Energy Rate (W)	670	660	660
Production Rate (lb/h)	58.9	57.6	57.2

Table D-8. Light-Load Test Data – 80,000 Btu/h.

	Rep #1	Rep #2	Rep #3
Measured Values			
Appliance Energy (Btu)	19,730	19,940	19,525
Fan/Control Energy (Wh)	460	490	480
Total Energy (Btu)	21,310	21,610	21,180
Cook Time (min)	43.1	45.0	44.6
Initial Weight (lb)	14.5	14.5	14.5
Final Weight (lb)	12.2	12.2	12.2
Initial Temperature (°F)	73	73	71
Final Temperature (°F)	205	205	205
Calculated Values			
Sensible (Btu)	1,611	1,612	1,631
Latent - Water Vaporization (Btu)	2,213	2,214	2,192
Total Energy to Food (Btu)	3,824	3,826	3,823
Energy to Food (Btu/lb)	264	264	264
Total Energy to Convection Oven	21,310	21,610	21,180
Energy to Convection Oven (Btu/lb)	1,470	1,490	1,460
Cooking-Energy Efficiency (%)	17.9	17.7	18.1
Cooking Energy Rate (Btu/h)	27,480	26,580	26,270
Fan Energy Rate (W)	650	650	650
Production Rate (lb/h)	20.2	19.3	19.5

Cooking-Energy Efficiency Data

Table D-9. Cooking-Energy Efficiency and Production Capacity Statistics – 80,000 Btu/h.

	ASTM Cooking-Energy Efficiency			ASTM
	Heavy-Load	Medium-Load	Light-Load	Production Capacity
Replicate #1	41.3	34.4	17.9	88.8
Replicate #2	41.1	34.3	17.7	92.4
Replicate #3	41.3	34.3	18.1	90.1
Average	41.3	34.3	17.9	90.4
Standard Deviation	0.2	0.1	0.2	1.8
Absolute Uncertainty	0.4	0.2	0.4	4.5
Percent Uncertainty	0.9	0.7	2.4	5.0

E Energy Cost Model

Appliance test results are useful not only for benchmarking appliance performance, but also for estimating appliance energy consumption. The following procedure is a guideline for estimating convection oven energy consumption based on data obtained from applying the appropriate test method.

The intent of this Appendix is to present a standard method for estimating oven energy consumption based on ASTM performance test results. The examples contained herein are for information only and should not be considered an absolute. To obtain an accurate estimate of energy consumption for a particular operation, parameters specific to that operation should be used (e.g., operating time, and amount of food cooked under heavy-, medium-, and light-loads).

The appropriate oven performance parameters are obtained from section 11 in the test method.

The calculation will proceed as follows: First, determine the appliance operating time and total number of preheats. Then estimate the quantity of food cooked and establish the breakdown among heavy- (fully-loaded oven), medium- (half-loaded oven), and light- (single-pan) loads. For example, an oven operating for 12 hours a day with two preheats cooked 100 pounds of food: 50% of the food was cooked under heavy-load conditions, 40% was cooked under medium-load conditions, and 10% was cooked under light-load conditions. Calculate the energy due to cooking at heavy-, medium-, and light-load cooking rates, and then calculate the idle energy consumption. The total daily energy is the sum of these components plus the preheat energy. For simplicity, it is assumed that subsequent preheats require the same time and energy as the first preheat of the day.

Application of the test method to the Blodgett Xcel, Model DFG100 gas oven yielded the following results:

Table E.1: Blodgett Xcel Gas Oven Test Results (60,000 Btu/h input rate).

Preheat Time	11.8 min
Preheat Energy[a]	11,810 Btu + 150 Wh
Idle Energy Rate[a]	16,660 Btu/h + 600 W
Heavy-Load Cooking Energy Rate	52,380 Btu/h + 700 W
Medium-Load Cooking Energy Rate	41,560 Btu/h + 700 W
Light-Load Cooking Energy Rate	26,820 Btu/h + 700 W
Heavy-Load Production Capacity	86 lb/h
Medium-Load Production Capacity	61 lb/h
Light-Load Production Capacity	18 lb/h

[a]Includes electric energy consumed by the fan and controls.

Step *1*—The following appliance operation is assumed:

Table E.2: Oven Operation Assumptions.

Operating Time	12 h
Number of Preheats	2 preheats
Total Amount of Food Cooked	100 lb
Percentage of Food Cooked Under Heavy-Load Conditions	50% (x 100lb = 50 lb)
Percentage of Food Cooked Under Medium-Load Conditions	40% (x 100lb = 40 lb)
Percentage of Food Cooked Under Light-Load Conditions	10% (x 100lb = 10 lb)

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

The total time cooking heavy-loads is as follows:

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

$$t_h = \frac{50\% \times 100\ lb}{86\ lb/h},$$

$$t_h = 0.58\ h$$

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

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

$E_{gas,h} = 52{,}000 \text{ Btu/h} \times 0.58 \text{ h},$

$E_{gas,h} = 30{,}380 \text{ Btu}$

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

$E_{elec,h} = 700 \text{ W} \times 0.58 \text{ h},$

$E_{elec,h} = 410 \text{ Wh}$

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

The total time cooking medium-loads is as follows:

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

$$t_m = \frac{40\% \times 100 \text{ lb}}{61 \text{ lb/h}},$$

$$t_m = 0.66 \text{ h}$$

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

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

$E_{gas,m} = 41{,}560 \text{ Btu/h} \times 0.66 \text{ h},$

$E_{gas,m} = 27{,}430 \text{ Btu}$

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

$E_{elec,m} = 700 \text{ W} \times 0.66 \text{ h},$

$E_{elec,m} = 460 \text{ Wh}$

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

The total time cooking light-loads is as follows:

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

$$t_l = \frac{10\% \times 100 \text{ lb}}{18 \text{ lb/h}},$$

$$t_l = 0.56 \text{ h}$$

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

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

$E_{gas,l} = 26{,}820 \text{ Btu/h} \times 0.56 \text{ h}$

$E_{gas,l} = 15{,}020 \text{ Btu}$

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

$E_{elec,l} = 700 \text{ W} \times 0.56 \text{ h}$

$E_{elec,l} = 390 \text{ Wh}$

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

The total idle time is determined as follows:

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

$$t_i = 12.0\ h - 0.58\ h - 0.66\ h - 0.56\ h - \frac{2\ preheats \times 11.8\ min}{60\ min/h}$$

$$t_i = 9.8\ h$$

The idle energy consumption is then calculated as follows:

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

$$E_{gas,i} = 16{,}660\ Btu/h \times 9.8\ h$$

$$E_{gas,i} = 163{,}270\ Btu$$

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

$$E_{elec,i} = 600\ W \times 9.8\ h$$

$$E_{elec,i} = 5{,}880\ Wh$$

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

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

$$E_{gas,daily} = 30{,}380\ Btu + 27{,}430\ Btu + 15{,}020\ Btu + 163{,}270\ Btu + 2 \times 11{,}810\ Btu$$

$$E_{gas,daily} = 259{,}720\ Btu/day = 2.6\ therms/day$$

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

$$E_{elec,daily} = 410\ Wh + 460\ Wh + 390\ Wh + 5{,}880\ Wh + 2 \times 150\ Wh$$

$$E_{elec,daily} = 7{,}440\ Wh/day$$

Step 7—Calculate the average demand as follows:

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

$$q_{avg} = \frac{7{,}440\ Wh}{12.0\ h},$$

$$q_{avg} = 620\ W$$

Step *8*—The estimated yearly appliance energy cost may be determined as follows:

$$C_{gas,\,yearly} = r_{gas} \times \frac{E_{gas,\,daily}}{100{,}000\ \frac{Btu}{therm}} \times d_{op}$$

$$C_{\text{gas, yearly}} = \$1.00\ \frac{\$}{\text{therm}} \times \frac{259{,}720\ \frac{\text{Btu}}{\text{day}}}{100{,}000\ \frac{\text{Btu}}{\text{therm}}} \times 365\ \frac{\text{days}}{\text{yr}}$$

$$C_{\text{gas, yearly}} = \$948$$

$$C_{elec,\,yearly} = r_{elec} \times E_{elec,\,daily} \times d_{op}$$

$$C_{elec,\,yearly} = \$0.10\ \frac{\$}{kWh} \times \frac{7{,}440\ \frac{Wh}{day}}{1{,}000\ \frac{Wh}{kWh}} \times 365\ \frac{days}{yr}$$

$$C_{elec,\,yearly} = \$271$$