

**Montague, Model Vectaire HX63A
Gas Full-Size Convection Oven Performance Test**

Application of ASTM Standard
Test Method F 1496-93

FSTC Report 5011.99.79

**Food Service Technology Center
Final Report, December 1999**

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The information in this report is based on data generated at Pacific Gas and Electric Company's Food Service Technology Center.

Acknowledgments

Pacific Gas and Electric Company's Food Service Technology Center is supported by the National Advisory Group, which includes

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Gas Research Institute (GRI)

National Restaurant Association

California Restaurant Association (CRA)

International Facility Management Association (IFMA)

California Energy Commission (CEC)

Underwriters Laboratories (UL)

Gas Appliance Manufacturers Association (GAMA)

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Specific appreciation is extended to Montague, for supplying the Food Service Technology Center with a gas full-size convection oven for controlled testing in the appliance laboratory.

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This program is funded by California utility customers and administered by Pacific Gas and Electric Company under the auspices of the California Public Utilities Commission.

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Executive Summary

Montague redesigned their Vectaire gas convection oven (Figure ES-1), incorporating an advanced heat exchanger and lowering the rated input from 70,000 Btu/h to 63,000 Btu/h. Hot air is circulated throughout the cooking cavity by a two-speed, ½-horsepower fan and the oven temperature is controlled with a solid-state thermostat. The controls include a cool-down setting, which allows the fan to run at high speed with the doors open to cool the cooking cavity.



Figure ES-1.
*Montague Vectaire
gas convection oven.*

Food Service Technology Center (FSTC) engineers tested the full-size gas convection oven under the tightly controlled conditions 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.

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). The cook times for the three loading scenarios were 61.5 minutes for the full-load test, 53.9 minutes for the medium-load test, and 52.4 minutes for the light-load test.

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:

¹ American Society for Testing and Materials. 1993. *Standard Test Method for the Performance of Convection Ovens*. ASTM Designation F 1496-93, in *Annual Book of ASTM Standards*, Philadelphia.

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

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)	63,000
Measured Energy Input Rate (Btu/h)	66,040
Fan/Control Energy Rate (kW)	0.41
Preheat Time to 350°F (min) ^a	12.8
Preheat Energy to 350°F (Btu) ^a	13,569
Idle Energy Rate @ 350°F (Btu/h) ^a	12,890
Pilot Energy Rate (Btu/h) ^a	0
Full-Load Cooking Energy Efficiency (%)	43.9 ± 1.4 ^b
Medium-Load Cooking Energy Efficiency (%)	37.1 ± 0.7 ^b
Light-Load Cooking Energy Efficiency (%)	19.6 ± 1.1 ^b
Production Capacity ^c (lb/h)	71.4 ± 1.5 ^b
Cooking Uniformity Average Rack Temperatures (°F):	
Rack #1 (Top)	161
Rack #2	145
Rack #3	156
Rack #4	145
Rack #5 (Bottom)	158
Maximum Temperature Difference	16

^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 full-load cooking test with a 210°F endpoint.

The full-load potato test was re-evaluated using a 205°F endpoint as opposed to the ASTM-specified 210°F endpoint. At 205°F, the starch conversion had progressed sufficiently to consider the potatoes acceptable, and the cooking energy efficiencies and cooking energy rates for the two full-load tests were

Executive Summary

nearly identical. Thus, the higher endpoint was not necessary to ensure accurate energy measurements. Furthermore, dropping the endpoint from 210°F to 205°F reduced the cook time by 10.3 minutes and increased the reported production capacity by 18% (from 71.4 lb/h to 84.4 lb/h). It is recommended that future revisions of the ASTM test method consider reducing the endpoint from 210°F to 205°F.

Under the difficult conditions of the frozen-load test, the oven delivered 48.9% of its energy to the frozen macaroni and cheese and produced 87.4 pounds per hour. In addition to providing cooking uniformity information, using a real food product instead of a simulated food product (ice-loads) provided realistic production rates and cooking energy efficiencies.

Figure ES-1 illustrates the relationship between cooking energy efficiency and production rate for this convection oven. Figure ES-2 illustrates the relationship between the convection oven's average energy consumption rate and the production rate. This graph can be used as a tool to estimate the daily energy consumption for the convection oven in a real-world operation. Average energy consumption rates at 15, 30, and 60 pounds per hour are 21,370 Btu/h, 28,660 Btu/h, and 40,390 Btu/h, respectively.

The Montague, model Vectaire HX63A, full-size gas convection oven performed well under the rigorous conditions of the ASTM test method. Its 43.9% full-load cooking energy efficiency is the highest for any gas oven tested at the Food Service Technology Center to date, nearly 38% higher than the previously tested model.² Improved airflow in this newly redesigned oven is evidenced by its cooking uniformity. The ice-load tests showed a 16°F maximum difference between the hottest and coolest racks, whereas 30°F to 40°F differences are much more common. This Montague oven's low, 12,890 Btu/h, idle rate contributes to its high part-load cooking

² Food Service Technology Center. 1995. *Montague Model SE70AH Gas Convection Oven Application of ASTM Standard Test Method F1496-93*. Report 5011.95.25 prepared for Customer Energy Management Department. San Francisco: Pacific Gas and Electric Company.

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Figure ES-1.
Convection oven part-load cooking energy efficiency.

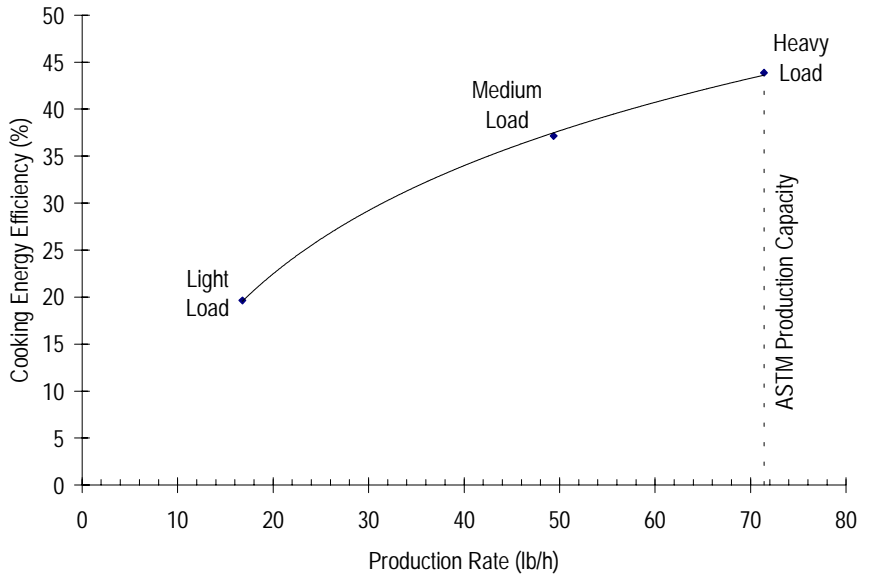
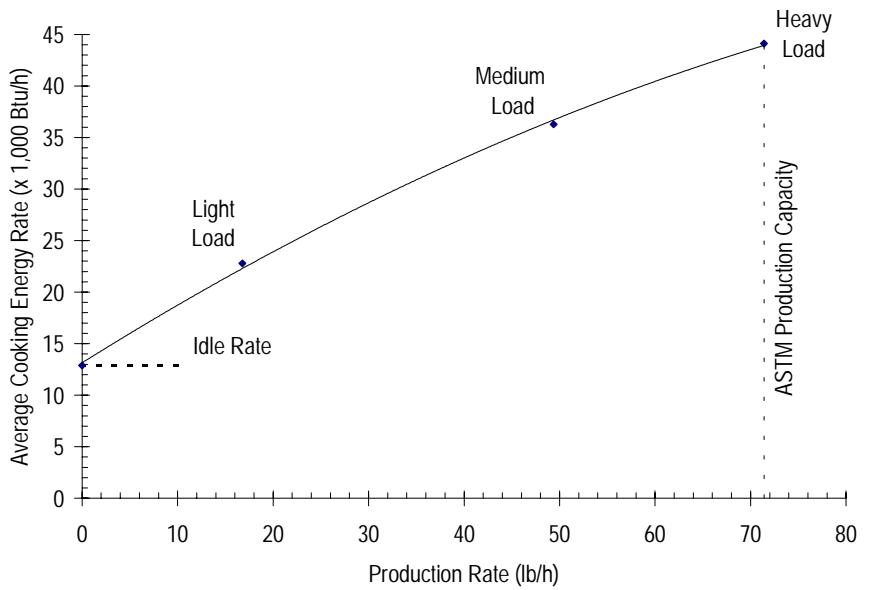


Figure ES-2.
Convection oven cooking energy consumption profile.



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

Executive Summary

energy efficiency, making the oven a solid energy performer for any type of operation. Evaluation of this convection oven in the real-world setting of the Production-Test Kitchen was recommended and implemented.

1 Introduction

Background

Convection ovens are the most widely used appliance 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.

Montague's new convection oven incorporates a two-speed fan with a solid-state thermostat, and a zero to 60-minute timer.

With competition heating up among equipment manufacturers, new designs incorporating timesaving features via sophisticated control packages are being introduced. In 1993, Pacific Gas and Electric Company's 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).¹ 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 Pacific Gas and Electric Company reports document results of applying the ASTM test method to different convection ovens.^{3,4}

Montague's new Vectaire convection oven incorporates a two-speed, ½-horsepower fan with a solid-state thermostat, and a zero-to-sixty minute timer. The controls include a cool-down setting, which allows the fan to run at high speed with the doors open to cool the cooking cavity. The glossary in

Introduction

Appendix A is provided so that the reader has a quick reference to the terms used in this report.

Objectives

The objective of this report is to examine the operation and performance of the Montague Vectaire gas full-size convection oven, model HX63A, 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 350°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. Characterize the oven's cooking uniformity using three different frozen test products.
7. Document the oven's frozen-load cooking energy efficiency and production capacity using a representative food product.
8. Document the oven's browning uniformity using white sheet cakes.

Appliance Description

An atmospheric burner located under the floor of the oven cavity powers the thermostatically controlled convection oven. Heat is transferred to the oven cavity from combustion products as they circulate up through spaces between the sidewalls of the oven cavity (Figure 1-1) and the outside skin of the oven. A ½-horsepower, 2-speed (full or half speed) fan circulates air throughout the oven cavity. This oven was equipped with electronic ignition, thus eliminating the need for a standing pilot.

Introduction

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

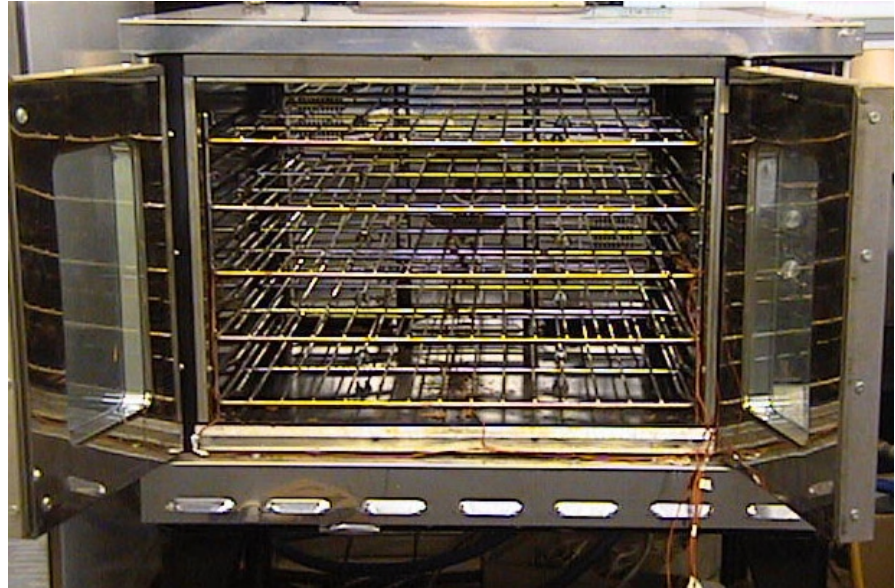


Figure 1-1.
Vectaire oven cavity.

Table 1-1. Appliance Specifications.

Manufacturer	Montague
Model	Vectaire HX63A
Generic Appliance Type	Full-size convection oven
Rated Input	63,000 Btu/h
Dimensions	24" x 35½" x 15¼"
Oven Cavity Volume	15,221 cubic inches
Controls	Single thermostat adjustable from 200 to 500°F, 0 to 60 minute cook timer, and a two-speed fan.

2 Methods

Setup and Instrumentation

FSTC researchers installed the convection oven 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

Researchers instrumented the convection oven 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 ft³ consumed. Fan and control energy was measured with a Watt-hour transducer

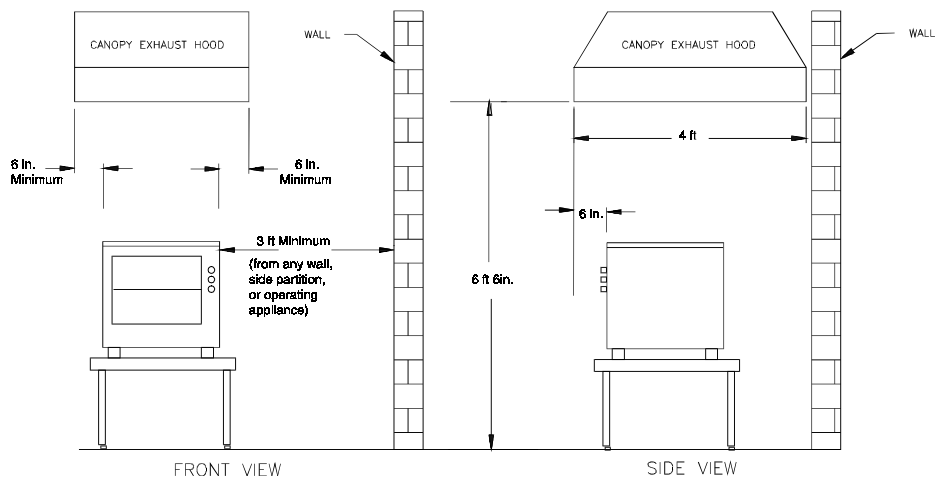


Figure 2-1.
Appliance/hood
configuration.

Methods

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. Energy consumption and input rates were calculated and temperature profiles were generated from this information.

Measured Energy Input Rate

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

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: full (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 210°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 full-load test.

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 a frozen food product, such as macaroni & cheese, lasagna or ice. The temperature of each pan was individually monitored during the course of the test. When the first rack of four pans reached an average temperature of 160°F, the test was complete. By recording the temperatures of the remaining pans, the tester could then show how uniformly the oven cooked the frozen food product.

Methods

The ASTM test procedure calls for the pans to be filled with six pounds of ice to simulate a stubborn food product. Ice had the advantages of being consistent, repeatable, and inexpensive, while exhibiting the temperature differences that would occur between racks when baking frozen foods.²

Although ice was a desirable test product due to its low cost and repeatability, it tended to overstate the oven's productivity under heavy, frozen-load conditions, and did not provide realistic energy consumption data. Researchers therefore repeated the cooking uniformity test with a variety of food products including macaroni & cheese, potatoes gratin, and pork & beans to identify a more representative food product.

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.

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 rate was 66,040 Btu/h (a difference of 4.8% from the nameplate rating).

Preheat and Idle Tests

Preheat Energy and Time

The oven was instrumented with thermocouples attached to the center of each of the oven's walls and located at the geometric center of the cooking cavity. After stabilizing the oven cavity at room temperature ($70 \pm 5^\circ\text{F}$) overnight, the oven was turned on and preheated to 350°F . Elapsed time and energy consumption was recorded during this preheat period. Figure 3-1 shows the oven's energy consumption along with the cooking cavity temperature during this preheat test.

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 rate during this period was 12,900 Btu/h, with an additional 410 watts of electricity for the fan and controls.

Test Results

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

Results

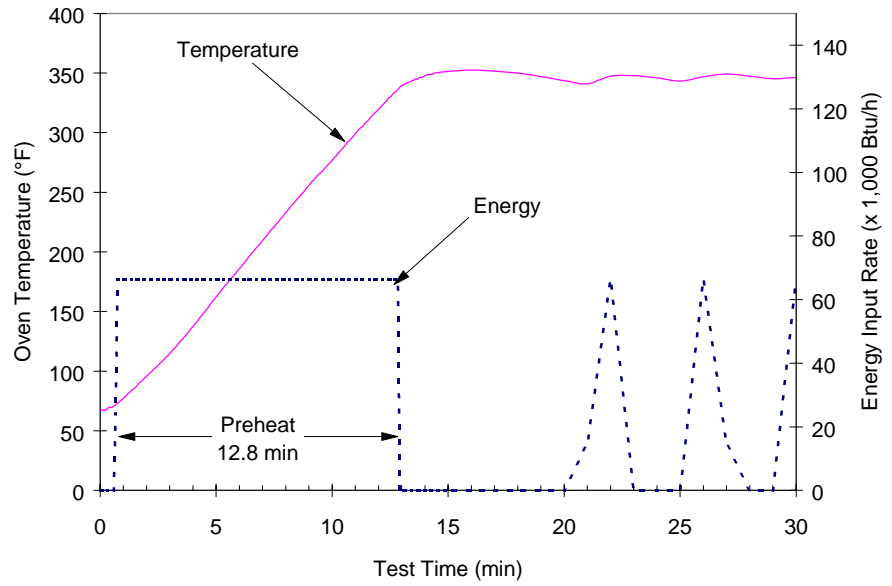


Figure 3-1.
Preheat characteristics.

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

Rated Energy Input Rate (Btu/h)	63,000
Measured Energy Input Rate (Btu/h)	66,040
Fan/Control Energy Rate (kW)	0.41
Preheat	
Time to 350°F (min)	12.8
Energy (Btu/h)	13,569
Rate to 350°F (°F/min)	21
Idle Energy Rate @ 350°F (Btu/h)	12,890

Results

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. Researchers monitored cook time, potato temperature and convection oven energy consumption during these tests.

Full-Load Tests

The full-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 210°F. Three potatoes per pan were randomly selected and instrumented with thermocouples for monitoring temperature. Figure 3-2 shows the average potato temperature during a typical full-load test.

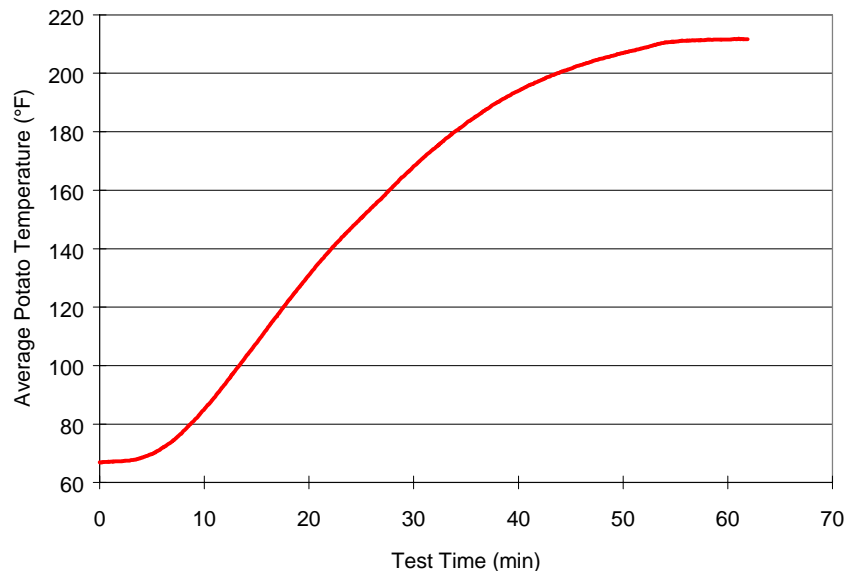


Figure 3-2.
Average potato temperature during a full-load test.

Results

Since 210°F is close to the boiling point for water, the temperature curve tends to flatten out as it approaches the specified endpoint. At this point, the potatoes begin to absorb the available heat much more slowly, which may somewhat overstate the required cook time.

A 205°F endpoint was considered as an alternative to the specified 210°F endpoint since 205°F was still on the steep portion of the temperature curve. The full-load tests were then repeated using 205°F as the endpoint. At this temperature, the starch conversion had progressed sufficiently to consider the potatoes acceptable. The heavy-load test results for both endpoints are summarized in Table 3-2.

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.

Table 3-2. Full-Load Test Results.

	ASTM-Specified Endpoint	205°F Endpoint
Endpoint (°F)	210	205
Cook Time (min)	61.51	51.17
Production Rate (lb/h)	71.4 ± 1.5	84.4 ± 4.6
Energy to Food (Btu/lb)	271	236
Energy Consumption (Btu/lb)	618	545
Cooking Energy Rate (Btu/h)	44,110 ± 490	45,000 ± 1,530
Fan/Control Energy Rate (kW)	0.29 ± 0.01	0.30 ± 0.00
Cooking Energy Efficiency (%)	43.9 ± 1.4	43.2 ± 0.7

Results

The cooking energy efficiencies and cooking energy rates for the two full-load tests were nearly identical, indicating that the higher endpoint is not necessary for accurate energy measurements. Furthermore, dropping the endpoint from 210°F to 205°F reduced the cook time by 10.3 minutes and increased the reported production capacity by 18%.

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 a convection oven 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 full-load tests were 43.2%, 43.6%, and 44.9%, yielding an uncertainty of 3.3% in the test results. Table 3-3 summarizes the results of the ASTM cooking energy efficiency and production capacity tests. Figure 3-3 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.

Figure 3-4 illustrates the relationship between the convection oven's average energy consumption rate and the production rate. This graph can be used as a tool to estimate the daily energy consumption for the convection oven in a real-world operation. Average energy consumption rates at 15, 30, and 60 pounds per hour are 21,370 Btu/h, 28,660 Btu/h, and 40,390 Btu/h, respectively.

Results

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

	Heavy Load	Medium Load	Light Load
Endpoint (°F)	210	210	210
Cook Time (min)	61.51	53.92	52.42
Production Rate (lb/h)	71.4 ± 1.5	49.4	16.8
Energy to Food (Btu/lb)	271	273	267
Energy Consumption (Btu/lb)	618	735	1,368
Cooking Energy Rate (Btu/h)	44,110	36,280	22,790
Fan/Control Energy Rate (kW)	0.29	0.33	0.34
Cooking Energy Efficiency (%)	43.9 ± 1.4	37.1 ± 0.7	19.6 ± 1.1

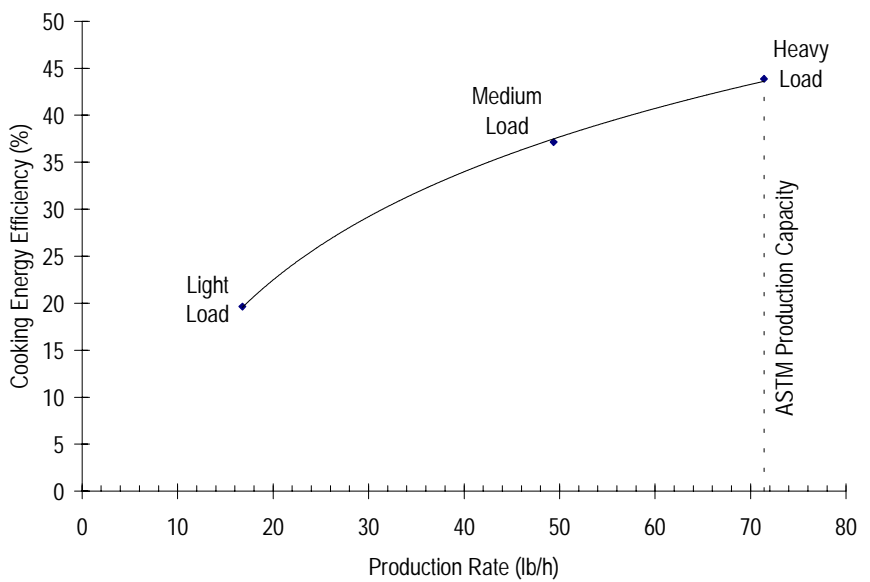


Figure 3-3.
Convection oven part-load cooking energy efficiency.

Results

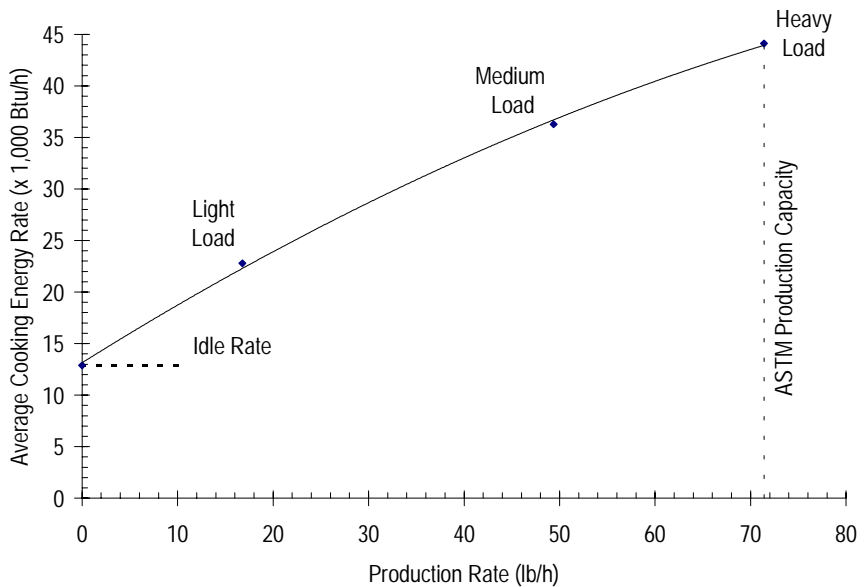


Figure 3-4.
Convection oven cooking energy consumption profile.

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

Cooking Uniformity

The cooking uniformity test was designed to characterize the oven’s performance when baking a dense, frozen food product, such as lasagna or macaroni and cheese. The oven was loaded with 20 pans of frozen product and the test was finished when the first rack (of four pans) hit an average temperature of 160°F. By recording the temperatures of the remaining pans, the tester could then show how uniformly the oven baked the pans of frozen food.

Researchers tested the oven with frozen macaroni & cheese, potatoes gratin, and pork & beans, in addition to the ASTM-specified ice-loads (Figure 3-5). Of the three food products tested, macaroni & cheese proved to be the best test product. It was consistent, moderately priced, and fairly representative of other types of frozen foods cooked in ovens. The macaroni & cheese also exhibited greater differences in temperature from rack-to-rack than the other products tested, indicating that it was a heavier load on the oven.

Results

Figure 3-5. Products for the cooking uniformity tests: ice pans, macaroni and cheese, potatoes gratin, and pork and beans.



The potatoes gratin was hard to obtain and difficult to work with since it was fairly inconsistent—a thermocouple inserted into the frozen mass could easily be located in a layer of potato, a layer of sauce, or a layer of cheese. The pork & beans tended to exaggerate the oven’s productivity much like the ice-loads, probably due to its high water content. It also understated any temperature differences from rack to rack compared with other food products. Table 3-4 compares the cooking uniformity test results for the four products.

Table 3-4. Oven Cooking Uniformity.

	Ice-Load	Mac & Cheese	Potatoes Gratin	Pork & Beans
Rack #1 (Top)	161°F	155°F	151°F	154°F
Rack #2	145°F	145°F	155°F	156°F
Rack #3	156°F	135°F	151°F	160°F
Rack #4	145°F	134°F	138°F	152°F
Rack #5 (Bottom)	158°F	160°F	160°F	148°F
Maximum Temperature Difference	16°F	26°F	22°F	12°F

Results

In addition to providing cooking uniformity information, using a real food product as opposed to simulated food product (ice-loads) provided realistic production rates and cooking energy efficiencies. Table 3-5 summarizes the frozen-load test results.

Table 3-5. Frozen (Macaroni & Cheese) Load Test Results.

Cook Time (min)	64.8
Production Rate (lb/h)	87.4
Energy to Food (Btu/lb)	254
Energy Consumption (Btu/lb)	507
Cooking Energy Rate (Btu/h)	48,000
Fan/Control Energy Rate (kW)	0.32
Cooking Energy Efficiency (%)	48.9

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. The results of the test are described below and visual representations of the browning are shown in Figures 3-6 through 3-10.

Results

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



Top rack. The surface of this cake varied from golden to medium brown, with a light spot in the front. Small cracks were grouped along the right-hand side, near a dark patch.

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 wider at the rear of the cake than at the front.

Results

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



Middle rack. This cake was a nice golden brown with light spots in the left front corner and along the center. The left rear corner was slightly darker than the rest of the cake.

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



Lower middle rack. This cake was somewhat lighter overall than the rest of the cakes, especially along the front. The rear corners were dark brown.

Results



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

Bottom rack. The cake was more golden in color than the previous rack especially on the lateral sides of the cake. There is a light area in the front of the cake, which graduates to a darker shade towards the rear.

4 Conclusions

Its 43.9% full-load cooking energy efficiency is the highest for any gas oven tested.

The Montague Vectaire, model HX63A, full-size gas convection oven performed well under the rigorous conditions of the ASTM test method. Its 43.9% full-load cooking energy efficiency is the highest for any gas oven tested at the Food Service Technology Center to date, nearly 38% higher than the previously tested model.⁴ In addition, the oven exhibited a quick preheat (under 13 minutes to 350°F) and low standby losses.

Improved airflow in this newly redesigned oven is evidenced by its cooking uniformity. The ice-load tests showed a 16°F maximum difference between the hottest and coolest racks, whereas 30°F to 40°F differences are much more common. This enhanced uniformity was supported by the excellent browning during the white sheet cake test.^{2,3,4}

Frozen macaroni and cheese proved to be a more difficult to bake than the ice-loads, thus exaggerating the difference between the hottest and coolest racks. Under the difficult conditions of this frozen-load test, the oven delivered 48.9% of its energy to the macaroni and cheese and produced 87.4 lb/h. In addition to providing cooking uniformity information, using a real food product as opposed to simulated food product (ice-loads) provided realistic production rates and cooking energy efficiencies for this type of usage.

The full-load potato test was re-evaluated using a 205°F endpoint as opposed to the ASTM-specified 210°F endpoint. At 205°F, the starch conversion had progressed sufficiently to consider the potatoes acceptable, and the cooking energy efficiencies and cooking energy rates for the two full-load tests were nearly identical. Thus, the higher endpoint was not necessary to ensure accurate energy consumption data. Furthermore, dropping the endpoint from 210°F to 205°F reduced the cook time by 10.3 minutes and increased the reported production capacity by 18%. It is recommended that future revi-

Conclusions

sions of the ASTM test method consider reducing the endpoint from 210°F to 205°F.

This Montague oven's low, 12,890 Btu/h, idle rate contributed to its high part-load cooking energy efficiency, making the oven a solid energy performer for any type of operation. Evaluation of this convection oven in the real-world setting of the Production-Test Kitchen was recommended and implemented.

5 References

1. American Society for Testing and Materials. 1993. *Standard Test Method for the Performance of Convection ovens*. ASTM Designation F 1496-93, in *Annual Book of ASTM Standards*, Philadelphia.
2. Pacific Gas and Electric Company. 1994. *Development and Application of a Uniform Testing Procedure for Convection Ovens*. Report 008.1-94-12 prepared for Research and Development. San Ramon, California: Pacific Gas and Electric Company.
3. Food Service Technology Center. 1995. *Montague Model SEK15AH Electric Convection Oven Application of ASTM Standard Test Method F1496-93*. Report 5011.95.24 prepared for Customer Energy Management Department. San Francisco: Pacific Gas and Electric Company.
4. Food Service Technology Center. 1995. *Montague Model SE70AH Gas Convection Oven Application of ASTM Standard Test Method F1496-93*. Report 5011.95.25 prepared for Customer Energy Management Department. San Francisco: Pacific Gas and Electric Company.

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/ft³)

Heating Content

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

Glossary

Idle Energy Rate (kW or Btu/h)

Idle Energy Input Rate
Idle Rate

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

Idle Temperature (°F, Setting)

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

Idle Duty Cycle (%)

Idle Energy Factor

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

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

Measured Input Rate (kW or Btu/h)

Measured Energy Input Rate
Measured Peak Energy Input Rate

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

Pilot Energy Rate (kBtu/h)

Pilot Energy Consumption Rate

The rate of energy consumption by the standing or constant pilot while the appliance is not being operated (i.e., when the thermostats or control knobs have been turned off by the food service operator).

Preheat Energy (kWh or Btu)

Preheat Energy Consumption

The total amount of energy consumed by an appliance during the preheat period.

Glossary

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 ($75 \pm 5^\circ\text{F}$) to a specified (and calibrated) operating temperature or thermostat set point.

Production Capacity (lb/h)

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

Production Rate (lb/h)

Productivity

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

Rated Energy Input Rate (kW, W or Btu/h, Btu/h)

Input Rating (ANSI definition)

Nameplate Energy Input Rate

Rated Input

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

Recovery Time (minute, second)

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

Test Method

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

B Appliance Specifications

Appendix B includes the product literature for the Montague Vectaire convection oven.

MONTAGUE

VECTAIRE HX



Gas Convection Ovens HX-63 Series

GENERAL

Single, indirect fired "muffled" oven, 38-1/4" wide x 41-1/4" deep x 57-1/2" high (97.2 x 104.8 x 146.1 cm) overall, including standard gusset-style adjustable legs. 27" wide x 27" deep x 20-1/2" high (68.6 x 68.6 x 52.1 cm) interior accommodates 18" x 26" (45.7 x 66.1 cm) pans lengthwise or widthwise. Burner with heat exchanger boosts the oven heating efficiency for improved cooking performance. Electronic controls for greater baking consistency. Used for general purpose baking and roasting.

MODELS:

HX-63A - Standard Electronic Controls and Electric Timer
HX-63AH - Cook-n-Hold Electronic Controls and Digital Timer

STANDARD FEATURES

- Porcelainized 16 gauge steel interior.
- Removable 9-position bright nickel rack guides.
- Five 26" x 27" (66.1 x 68.6 cm) bright nickel racks with rack stop and non-tip feature.
- High efficiency Euro design burners, S/S.
- Sealed heat exchanger, S/S.
- Burner pilot with reliable spark ignition system.
- Double layers of 2" (5.1 cm) thick insulation.
- Door style is split-type, vertical opening, side mounted. Each door has a double pane thermal viewing window. A single handle opens both doors. Durable S/S door gaskets.

CONTROLS, with universal symbols:

- Standard - Solid State Thermostat, 200°F (93°C) to 500°F (260°C) with "Burner/On" indicator light. One-hour electric countdown timer and alarm.

OPTIONAL, (*extra cost):

- *Cook-n-Hold - Solid State Thermostat, 150°F (66°C) to 500°F (260°C) with "Burner/On" indicator light. 24-hour digital countdown timer and electronic alarm. Preprogrammed HOLD feature permits slow Roast-n-Hold operations.

LEGS

- Gusset-style legs, standard. Black finish.

OPTIONAL, (*extra cost):

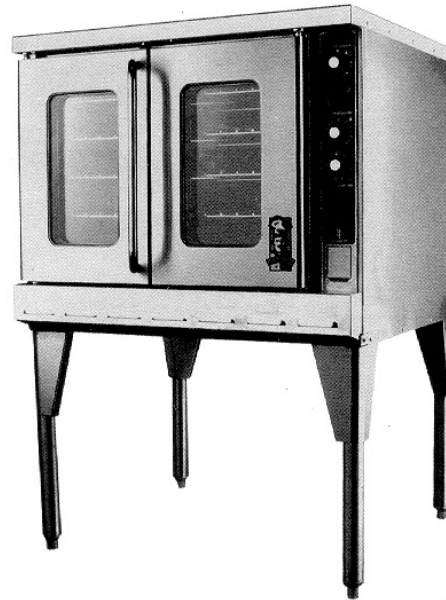
- *Enclosed base (cabinet style) w/6" (15.2 cm) legs. Black finish.
 - *S/S Front *S/S left side *S/S right side
 - *S/S back *S/S bottom shelfDoors for enclosed base: *S/S *Black
- 9-position removable rack guides for enclosed base.
- *Modular Stand (open base) w/4" (10.2 cm) frame. S/S front and lower shelf. 19-1/2" (49.5 cm) S/S legs.
 - Sides and Back will match oven.
 - *9-position removable rack guides for Modular Stand.

FINISH

Satin stainless steel front, sides and top. Aluminized steel back and flue extensions. Black gusset-style legs.

OPTIONAL, (*extra cost):

- Oven: *S/S back.
- Flue Deflector: S/S
- Legs: *S/S Gusset-style legs.



HX-63A
with Tri-Therm™ Heating System

MOTOR

Split phase, air cooled, two-speed 1725/1140 RPM, 1/2 Hp with thermal overload protection. Sealed, self-lubricating ball bearing requires no lubrication for the life of the bearing. Motor is serviceable from the front through the oven chamber.

ELECTRICAL, (*extra cost):

- 120V, 1Ph, 60Hz, 7.2 amps. 6' (182.8 cm) grounded supply cord.
- 208-240V, 1Ph, 60Hz, 2.9 amps, (3 wire).
- *208-240V, 3Ph, 60Hz available. Consult factory.

OPTIONS, (*extra cost):

- *CASTERS - Set of 4
 - Gusset-style Legs: 5" (12.7 cm) stem casters.
 - Enclosed Base: 5" (12.7 cm) plate casters.
 - Modular Stand: 3-1/2" (8.9 cm) stem casters.
- *DOWN DRAFT DIVERTER, (in-lieu-of std. flue deflector).
 - *S/S *Black
- *DRIP TRAY, S/S. - (To be placed on oven rack).
- FLEX CONNECTOR KIT, per deck - hose, disconnect and restraining device: 3' x 1/2" (91.4 cm x 1.3 cm).
- *HEAT SHIELD KIT - **refer min. clearances on back.
- OVEN INTERIORS:
 - *Full stainless steel oven lining, (ASC).
 - *PANCAKE MOTOR, 3/4 Hp. Two-speed 1725/1140 RPM. Note: Reduces OA oven depth to 39-1/2" (100.3 cm).
 - *120V, 1Ph, 60Hz, 11.6 amps 6' grounded supply cord.
 - *208-240V, 1Ph, 60 Hz, 5.9 amps (3 wire).
- *RACKS, EXTRA:
 - *Standard *Extra Heavy (for roasting).
- RACK GUIDES, 11-position.
- *SECURITY OPTIONS, (prisons, etc). Consult factory.
 - SOLID DOORS - (in-lieu-of windows).

THE MONTAGUE CO.
March 1997



11

FOOD SERVICE EQUIPMENT
convection ovens

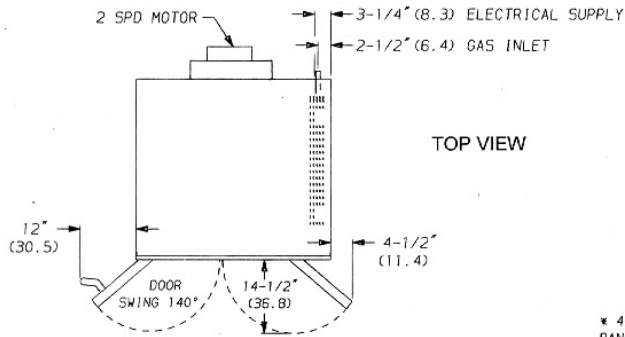


Vectaire 1

MONTAGUE HX-63 Series

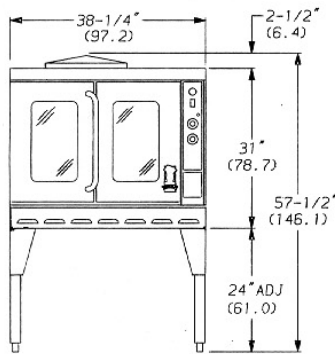
Gas Vectaire Convection Ovens

Dimensions in parenthesis are centimeters.

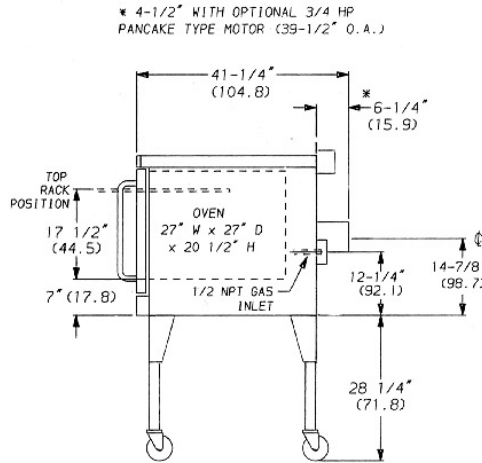


TOP VIEW

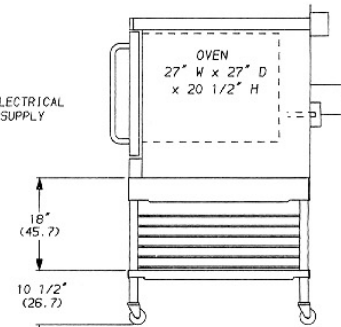
RACK SPACING	
# Racks/Oven Section	Clearance
5	3-3/8" (8.6)
9	1-1/2" (3.8)



FRONT VIEW - Shown with standard gusset-style legs.



SIDE VIEW - Shown with standard gusset-style legs and 5" (12.7 cm) casters.



SIDE VIEW - Horizontal Doors. Shown w/optional modular stand with lower shelf, rack guides and 3-1/2" (8.9 cm) casters.

IMPORTANT

Commercial oven(s) must be installed in accordance with local codes or, in the absence of local codes, with the National Fuel Gas Code ANSI Z223.1, National Gas Installation Code CAN/CGA-B149.1 or B149.2. Compliance with codes is the responsibility of the Owner and Installer.

Adequate Ventilation System required. Must be installed in accordance with local codes.

AGA and CGA Design Certified: In accordance with ANSI Z83.12/CGA 1.10-M. Gas Foodservice Equipment - Ovens. NOTE: These appliances are intended for commercial use by professionally trained personnel. *NOT Intended For Household Use.*

TYPE OF GAS	Natural	Propane
Manifold Pressure	3.5" WC	10.0" WC
Model	# burners	BTU/HR
All HX-63	1	63,000

GAS INLET SIZE (for all models):

One 1/2" (1.3 cm) NPT at right rear. Pressure regulator included in combination gas valve - no additional exterior regulator required.

NOTE: Specify type of gas Natural Propane
Specify elevation if installing above 2000 feet.

ENTRY CLEARANCE: 31-1/2" (80 cm) uncrated

APPROX. CU. FT./CU. METER:

	SHP WGT: (Class 70)
Oven, w/ Gusset-style legs	34/0.96 500 Lbs. 227 kg.
Enclosed base:	21/0.59 90 Lbs. 41 kg.
Modular stand and shelf	21/0.59 78 Lbs. 35 kg.

Minimum Clearances:	Combustible Construction	Noncombustible Construction
Back Wall:	7" (17.8 cm)	7" (17.8 cm)
Left & Right Side:	6" (15.2 cm)	**0"

With 24" (61 cm) legs: suitable for installation on combustible floors.

**HX Vectaire spacing to adjacent equipment: 6" (15.2 cm) minimum clearance on right side between similar ovens or other cooking equipment. Optional heat shield kits are available to reduce the clearance between similar ovens to 1" (2.5 cm) and between other equipment to 2" (5 cm). Consult factory.

Montague's continuing commitment to quality/product improvement can cause specification and design changes without prior notice.



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Printed in U.S.A.

Vectaire 2
26645-0 3/97

C Results Reporting Sheets

Section 11.1 Test Oven Description

Date: June 1998
Manufacturer: Montague
Model Number: HX63A
Serial Number: C8-D43396A
Fuel Type: natural gas
Size: full
Rated Input: 63,000 Btu/h
Oven Cavity Volume: 15,221 cubic inches
Controls: Single thermostat adjustable from 200 to 500°F, 0 to 60 minute cook timer, and a two-speed fan.

Section 11.2 Thermostat Accuracy

As-Received Condition:

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

As-Adjusted Condition:

Center of Oven Temperature: $350 \pm 5^\circ\text{F}$
Oven Temperature Control Setting: 350°F

Section 11.3 Energy Input Rate

Rated Input 63,000 Btu/h
Gas Heating Value 1031.7 Btu/scf
Measured Energy Input Rate: 66,040 Btu/h
Percent Difference between Measured and Rated 4.8%
Fan/Control Energy Rate: 0.41 kW

Results Reporting Sheets

Pilot Energy Rate: 0 Btu/h*

*This oven was equipped with automatic ignition

Section 11.4 Preheat Energy and Time

Gas Heating Value	1031.7 Btu/scf
Starting Temperature	68°F
Preheat Energy Consumption	13,569 Btu
Preheat Fan/Control Energy	0.17 kW
Preheat Time	12.8 min
Average Preheat Rate	21°F/min

See Fig. 3 for a graphical representation of the preheat period.

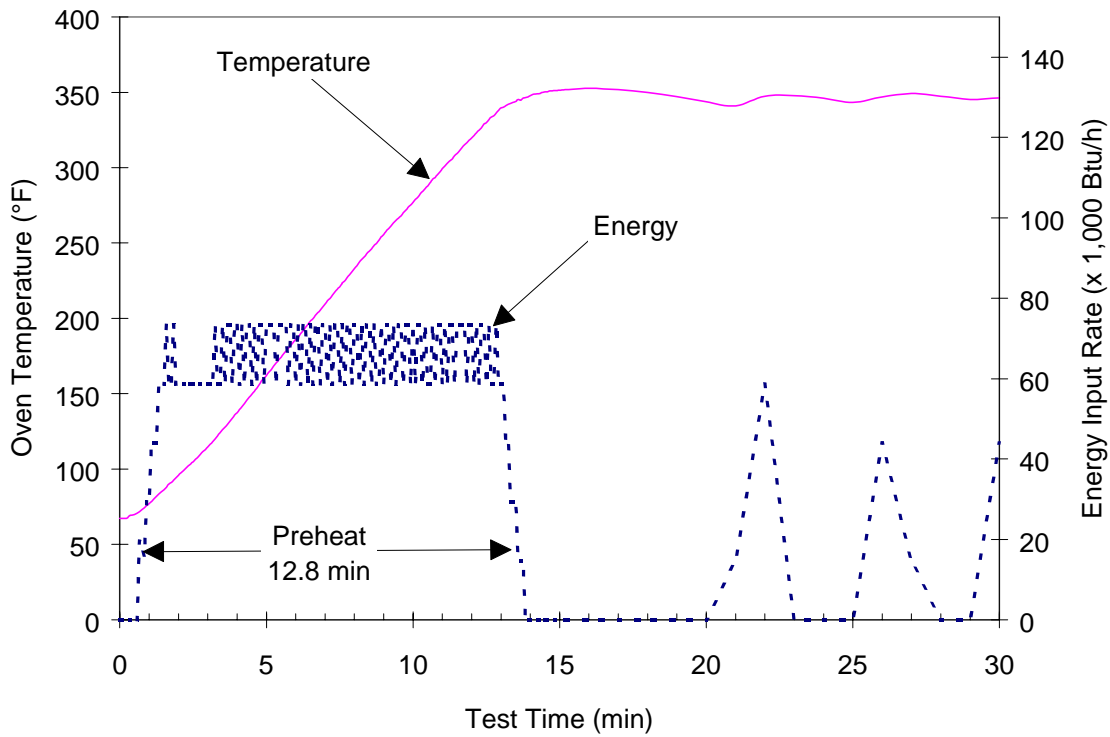


Fig. 3 Preheat and idle characteristics

Results Reporting Sheets

Section 11.5 Idle Energy Rate

Gas Heating Value	1031.7 Btu/scf
Center Oven Temperature	353°F
Idle Energy Rate	12,890 Btu/h
Fan/Control Energy Rate	0.29 kW

Section 11.6 Cooking Energy Efficiency

Full Load:

Gas Heating Value	1023.9 Btu/scf
Cook Time	62.67 min
Production Capacity	71.0 ± 6.5 lb/h
Energy to Food	19,808 Btu
Energy to Oven*	45,901 Btu
Energy per Pound of Food Cooked*	619 Btu/lb
Cooking Energy Rate	43,960 ± 1,330 Btu/h
Fan/Control Energy Rate	0.29 ± 0.03 kW
Cooking Energy Efficiency*	43.2 ± 1.0 %

*Includes energy consumed by the fan and controls.

Medium Load:

Gas Heating Value	1023.1 Btu/scf
Cook Time	53.92 min
Production Rate	49.4 ± 2.7 lb/h
Energy to Food	12,111 Btu
Energy to Oven*	32,607 Btu
Energy per Pound of Food Cooked*	735 Btu/lb

Results Reporting Sheets

Cooking Energy Rate	37,420 ± 560 Btu/h
Fan/Control Energy Rate	0.33 ± 0.02 kW
Cooking Energy Efficiency*	37.1 ± 0.7 %

*Includes energy consumed by the fan and controls.

Light Load:

Gas Heating Value	1020.9 Btu/scf
Cook Time	52.70 min
Production Rate	16.8 ± 1.8 lb/h
Energy to Food	3,905 Btu
Energy to Oven*	19,944 Btu
Energy per Pound of Food Cooked*	1,351 Btu/lb
Cooking Energy Rate	22,730 ± 2,690 Btu/h
Fan/Control Energy Rate	0.34 ± 0.04 kW
Cooking Energy Efficiency*	19.6 ± 2.1 %

*Includes energy consumed by the fan and controls.

Section 11.7 Cooking Uniformity

Rack #	Average Temperature
1 (Top)	161°F
2	145°F
3	156°F
4	145°F
5 (Bottom)	158°F

Results Reporting Sheets

Section 11.8 Browning Test



Top rack. The surface of this cake varied from golden to medium brown, with a light spot in the front. Small cracks were grouped along the right-hand side, near a dark patch.



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 rear of the cake than at the front.



Middle rack. This cake was a nice golden brown with light spots in the left front corner and along the center. The left rear corner was slightly darker than the rest of the cake.



Lower middle rack. This cake was somewhat lighter overall than the rest of the cakes, especially along the front. The rear corners were dark brown.



Bottom rack. The cake was more golden in color than the previous rack especially on the lateral sides of the cake. There is a light area in the front of the cake, which graduates to a darker shade towards the rear.

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. Full-Load Test Data—210°F Endpoint.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Appliance Energy (Btu)	44,505	43,872	44,206
Fan/Control Energy (Wh)	300	300	300
Total Energy (Btu)	45,529	44,896	45,230
Cook Time (min)	62.00	60.62	61.92
Initial Weight (lb)	74.243	73.917	71.415
Final Weight (lb)	63.066	62.619	59.307
Initial Temperature (°F)	68.7	71.5	67.4
Final Temperature (°F)	210	210	210
Calculated Values			
Sensible (Btu)	8,806	8,600	8,555
Latent - Water Vaporization (Btu)	10,842	10,959	11,745
Total Energy to Food (Btu)	19,648	19,559	20,300
Energy to Food (Btu/lb)	265	265	284
Total Energy to Convection Oven	45,529	44,896	45,230
Energy to Convection Oven (Btu/lb)	613	607	633
Cooking Energy Efficiency (%)	43.2	43.6	44.9
Cooking Energy Rate (Btu/h)	44,061	44,437	43,829
Fan Energy Rate (W)	290	297	291
Production Rate (lb/h)	71.8	73.2	69.2

Cooking Energy Efficiency Data

Table D-3. Full-Load Test Data—205°F Endpoint.

	Rep #1	Rep #2	Rep #3	Rep #4
Measured Values				
Appliance Energy (Btu)	38,012	37,522	38,745	39,126
Fan/Control Energy (Wh)	257	243	260	265
Total Energy (Btu)	38,890	38,350	39,634	40,028
Cook Time (min)	51.5	48.5	52.0	52.7
Initial Weight (lb)	72.72	71.44	71.70	71.94
Final Weight (lb)	63.88	62.84	62.51	62.07
Initial Temperature (°F)	69	70	70	74
Final Temperature (°F)	205	205	205	205
Calculated Values				
Sensible (Btu)	8,297	8,095	8,104	7,939
Latent - Water Vaporization (Btu)	8,582	8,341	8,914	9,573
Total Energy to Food (Btu)	16,879	16,436	17,018	17,513
Energy to Food (Btu/lb)	232	230	237	243
Total Energy to Convection Oven	38,890	38,350	39,634	40,028
Energy to Convection Oven (Btu/lb)	535	537	553	556
Cooking Energy Efficiency (%)	43.4	42.9	42.9	43.8
Cooking Energy Rate (Btu/h)	44,286	46,418	44,706	44,574
Fan Energy Rate (W)	300	300	301	301
Production Rate (lb/h)	84.7	88.4	82.7	82.0

Cooking Energy Efficiency Data

Table D-4. Medium-Load Test Data—210°F Endpoint.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Appliance Energy (Btu)	32,244	30,547	31,958
Fan/Control Energy (Wh)	300	300	300
Total Energy (Btu)	33,268	31,571	32,982
Cook Time (min)	54.62	52.36	54.79
Initial Weight (lb)	44.454	44.167	44.437
Final Weight (lb)	37.147	37.289	37.115
Initial Temperature (°F)	70	71	74
Final Temperature (°F)	210	210	210
Calculated Values			
Sensible (Btu)	5,236	5,158	5,077
Latent - Water Vaporization (Btu)	7,087	6,672	7,102
Total Energy to Food (Btu)	12,323	11,829	12,180
Energy to Food (Btu/lb)	277	268	274
Total Energy to Convection Oven	33,268	31,571	32,982
Energy to Convection Oven (Btu/lb)	748	715	742
Cooking Energy Efficiency (%)	37.0	37.5	36.9
Cooking Energy Rate (Btu/h)	36,544	36,177	36,118
Fan Energy Rate (W)	330	344	329
Production Rate (lb/h)	48.8	50.6	48.7

Cooking Energy Efficiency Data

Table D-5. Light-Load Test Data—210°F Endpoint.

	Rep #1	Rep #2	Rep #3	Rep #4
Measured Values				
Appliance Energy (Btu)	19,071	18,416	19,272	18,719
Fan/Control Energy (Wh)	300	300	300	300
Total Energy (Btu)	20,095	19,440	20,296	19,743
Cook Time (min)	55.17	52.06	50.86	51.58
Initial Weight (lb)	14.734	14.800	14.768	14.303
Final Weight (lb)	12.263	12.789	12.395	12.025
Initial Temperature (°F)	73	74	75	66
Final Temperature (°F)	210	210	210	210
Calculated Values				
Sensible (Btu)	1,702	1,689	1,673	1,716
Latent - Water Vaporization (Btu)	2,397	1,951	2,302	2,210
Total Energy to Food (Btu)	4,100	3,639	3,975	3,926
Energy to Food (Btu/lb)	278	246	269	274
Total Energy to Convection Oven	20,095	19,440	20,296	20,296
Energy to Convection Oven (Btu/lb)	1,364	1,313	1,374	1,419
Cooking Energy Efficiency (%)	20.4	18.7	19.6	19.9
Cooking Energy Rate (Btu/h)	21,854	22,405	23,944	22,965
Fan Energy Rate (W)	326	346	354	349
Production Rate (lb/h)	16.0	17.1	17.4	16.6

Cooking Energy Efficiency Data

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

	ASTM Cooking Energy Efficiency			ASTM Production Capacity
	Heavy Load	Medium Load	Light Load	
Replicate #1	43.2	37.0	20.4	71.8
Replicate #2	43.6	37.5	18.7	73.2
Replicate #3	44.9	36.9	19.6	69.2
Replicate #4	—	—	19.9	—
Average	43.9	37.1	19.6	71.4
Standard Deviation	0.90	0.29	0.70	0.93
Absolute Uncertainty	1.43	0.71	1.12	1.48
Percent Uncertainty	3.27	1.90	5.70	2.07