

**TurboChef® Technologies, Inc.
Model D Oven**

Product Evaluation

FSTC Report 5011.99.70

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The establishment of a Food Service Technology Center reflects Pacific Gas and Electric Company's commitment to the food service industry. The goal of the research project is to provide Pacific Gas and Electric Company's customers with information to help them evaluate technically innovative food service equipment and systems, and make informed equipment purchases regarding advanced technologies and energy sources. The project was the result of many people and departments working together within Pacific Gas and Electric Company and the overwhelming support of the commercial equipment manufacturers who supplied the cooking appliances for testing.

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Executive Summary

The engineers at TurboChef® Technologies, Inc. started with a clean sheet of paper when designing the TurboChef® oven. Their goal was to study the physical limitations of heat transfer to food during cooking and use this knowledge to create an oven that could cook food much faster than traditional cooking systems. They also believed that they could achieve this faster cooking without compromising the food quality. Early in the design process, the engineers realized that they would have to cook the food from both the inside and outside at the same time in order to meet their design goals. This led them to create a system that utilized both convection and microwave cooking.

To accomplish this, TurboChef® Technologies, Inc. developed a proprietary forced air, heat transfer system that is exclusive to the TurboChef® oven. This patented technology is combined with the use of microwaves and a sophisticated computer control system to produce a high performance hybrid oven that is both fast and user friendly.

The Food Service Technology Center (FSTC) tested the TurboChef® oven using modified American Society for Testing and Materials' (ASTM) test methods. Since the TurboChef® oven does not fall within a specific appliance category for which an ASTM standard test method exists, the test procedures were derived from existing ASTM standard test methods developed at the Food Service Technology Center^{1,2}. The specifics of each procedure are outlined in the Methods section and numerical results of the testing are included in the Results section.

The TurboChef® oven's performance is characterized by cooking energy efficiency, production capacity, and cooking energy rate. A summary of the test results is presented in Table ES-1, Figure ES-1 and Figure ES-2.

Executive Summary

Table ES-1. Summary of Performance: TurboChef® Oven, Model D.

Preheat and Idle

Rated Energy Input Rate (kW)	10.8
Measured Energy Input Rate (kW)	10.8
Preheat Time (min)	24.0
Preheat Energy (kWh)	2.48
Idle Energy Rate (kW)	0.98

Single Run Pizza Tests

Cook Time (min)	1.2
Cooking Energy Efficiency (%)	32.2 ± 0.4
Cooking Energy Rate (kW)	9.0

Barreling Run Pizza Test

Test Time (min)	9.1
Peak Cooking Energy Efficiency (%)	41.7
Cooking Energy Rate (kW)	7.0
Production Capacity (pizzas/h)	39.6
Production Capacity (lb/h)	57.1

Single Run Chicken Tests

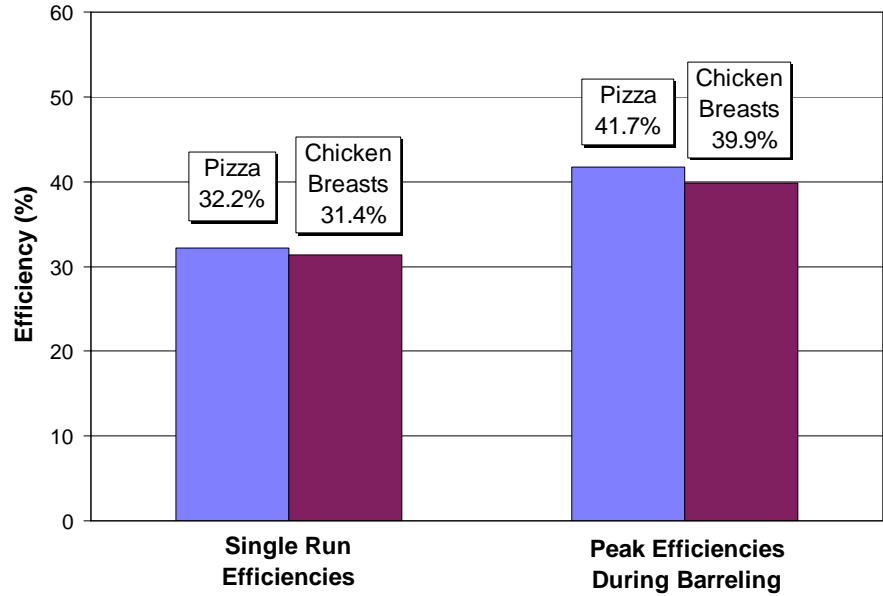
Cook Time (min)	1.6
Cooking Energy Efficiency (%)	31.4 ± 1.0
Cooking Energy Rate (kW)	10.6
Product Shrinkage (%)	22.0

Barreling Run Chicken Test

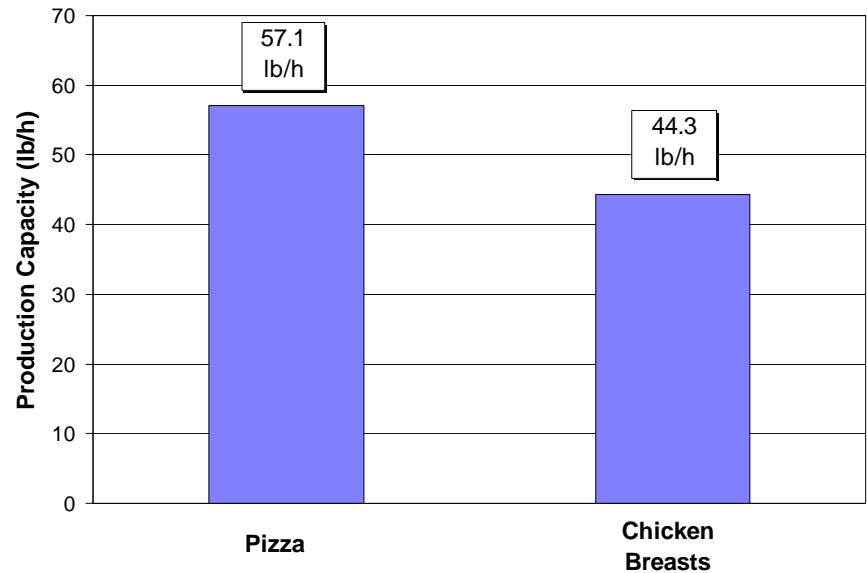
Test Time (min)	11.3
Peak Cooking Energy Efficiency (%)	39.9
Cooking Energy Rate (kW)	8.4
Product Shrinkage (%)	19.4
Production Capacity (lb/h)	44.3

Executive Summary

*Figure ES-1.
Cooking Energy
Efficiencies for Single
Run Tests and Peak
Cooking Energy Effi-
ciencies During Barrel-
ing Run Tests.*



*Figure ES-2.
Production Capacities
for Barreling Runs.*



Executive Summary

The TurboChef® oven's combination of forced hot air and microwave cooking allows it to cook food rapidly. The cook times were 73 seconds for test pizzas and 95 seconds for chicken breasts.


A comprehensive computer-control system monitors all operating functions for consistency and ease of use. The programmable memory can store up to 108 recipes.

The proprietary, integral, air filtering and catalytic grease scrubbing system allows the TurboChef® to operate without an exhaust hood and the 9 sq ft footprint gives the operator flexibility in placement of the oven.

The TurboChef® took 24.0 minutes to preheat, and idled at a rate of 0.98 kW. Single run cooking energy efficiencies were 32.2% for pizza and 31.4% for chicken breasts. During the barreling run tests, the oven reached cooking energy efficiencies as high as 41.7% for pizza, and 39.9% for chicken breasts.

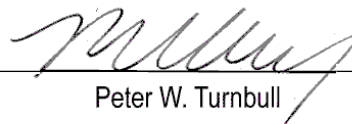
To provide a reference point, other small electric ovens, for example, deck, conveyor and ½ size convection, have heavy load cooking energy efficiencies ranging from 18 - 64% and idle at or near 1.4 kW.

FSTC Manager



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1 Introduction

Background

This rapid-cook oven heats food by combining forced hot air with microwave technology.

In today's fast paced world, food service customers are looking for high quality, cooked to order food that is available in convenient locations without a long wait. Food service operators are looking to fill the needs of these "on the go" customers using everything from food warmers to microwave ovens. TurboChef® Technologies, Inc. has uniquely approached the problem of quickly preparing fresh, made-to-order food by creating the TurboChef® oven. This rapid-cook oven heats food by combining forced hot air with microwave technology.

The philosophy behind the TurboChef® is to cook food as quickly as possible without sacrificing product quality. A proprietary heat transfer method was developed, and with the aid of sophisticated computerized control systems, TurboChef® Technologies, Inc. was able to incorporate cutting-edge technology while maintaining a simple user interface. Control flexibility was also designed in, so the oven is able to cook a variety of foods with simple program changes. Combined with the ability, in most instances, to be installed without an exhaust hood, the TurboChef® has the versatility to be used in many different types of food service situations.

The TurboChef® oven was tested using modified ASTM procedures, and this report documents the results. The glossary in Appendix A provides a quick reference to the terms used in this report.

Introduction

Objective

The objective of this report is to examine the operation and performance of the TurboChef® oven, Model D, under controlled conditions based on the ASTM Standard Test Methods^{1,2}. 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 cooking energy efficiency under four cooking scenarios: single run pizza, barreling run pizza, single run chicken, and barreling run chicken.
3. Determine the production capacity of the oven for each barreling run scenario.

Appliance Description

The TurboChef® Technologies, Inc. Model D oven is a stainless-steel, rapid-cook electric oven. Food is placed in the oven's cook chamber on a ceramic cook platter, where it is simultaneously cooked by forced hot air and microwaves. The programmable computer control allows separate adjustment of both hot air flow rate and microwave intensity level to permit maximum flexibility when developing cook settings. In addition, cook settings can be programmed in stages, called cook events, so, for example, a food product can be initially cooked with a high amount of microwaves, and then cooked with mostly hot air to preserve product quality. Up to four events can be programmed into a single cook setting, and up to 108 cook settings can be stored in the oven's memory. There is also a "Darker" key which will repeat 25% of the last cook event to allow more browning, or cooking a product to "well done".

The oven also uses a proprietary, integral, air filtering and catalytic grease scrubbing system, so in most instances it may be installed without an exhaust hood.

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

Introduction



Table 1-1. Appliance Specifications.

Manufacturer	TurboChef, Inc.
Model	D
Generic Appliance Type	Rapid-Cook Oven
Rated Input	10.8 kW at 208V, 13.0 kW at 240V
Technology	Hybrid Convection and Microwave
Construction	Stainless-steel
Controls	Programmable micro-processor controlled electronic keypad.
Dimensions	31.5" W X 40.0" H X 35.3" D

2 Methods

Set Up and Instrumentation

The oven was installed in accordance with the manufacturer's instructions. A ventilation hood was used with this appliance during testing in order to maintain the proper ambient temperature as specified by ASTM standards^{1,2}. The oven was placed under a 4-foot-deep canopy hood, with the lower edge of the hood 6 feet, 6 inches above the floor, and with the oven a minimum of 6 inches inside the vertical front edge of the hood. The exhaust ventilation operated at a nominal rate of 300 cfm per linear foot of hood. The researchers acknowledge that in most instances this appliance can be operated in a restaurant without a ventilation hood.

Power and energy were measured with a watt/watt-hour transducer that generated an analog signal for instantaneous power and a pulse for every 10 Wh. The transducer and thermocouple probes were connected to a computerized data acquisition unit that recorded data every 5 seconds. A voltage regulator was connected to the oven to maintain a constant voltage for all tests. Figure 2-1 shows the TurboChef® instrumented with the data acquisition system and voltage regulator.



*Figure 2-1.
The TurboChef® Oven
Instrumented for testing.*

Methods

Measured Energy Input Rate

The energy input rate is the maximum rate at which the oven will consume energy. The energy input rate was measured by placing a microwave-safe dish filled with water into the oven. A recipe was programmed so the oven would run for 3 minutes with 100% hot air and 100% microwaves. Time and energy consumption were monitored over the full length of the test. The maximum power draw during this period was reported as the measured energy input rate.

Preheat and Idle Rate Tests

When first switched on, the TurboChef® oven goes through a self-test procedure, and then proceeds to heat up to operating temperature. The preheat test recorded the time and energy required for the oven to reach its ready to cook state from a start at room temperature ($75 \pm 5^\circ\text{F}$). Recording began when the oven was first turned on and ended when the control display indicated that the oven was ready to cook.

After the oven was preheated, it was allowed to stabilize for one hour, and then idle energy consumption was monitored for a 2-hour period.

Pizza- Single Run Cooking Energy Efficiency Tests

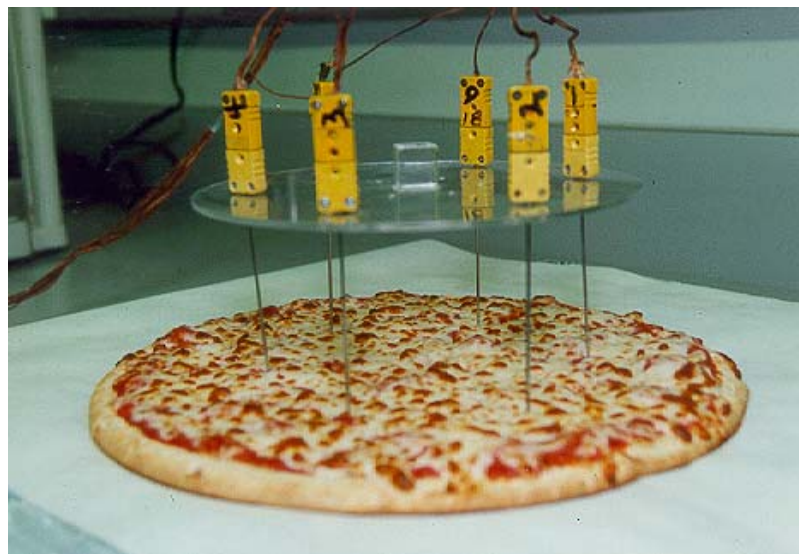
The ingredients used for the test pizzas, the preparation of the test pizzas, and the criteria for pizza doneness were identical to those described in Sections 7.1 - 7.4 of ASTM Designation F 1817-97, *Standard Test Method for the Performance of Conveyor Ovens*¹. Pizza crusts were 12-inch diameter, par-baked crusts weighing 0.9 ± 0.2 lb with a moisture content of $36 \pm 3\%$ by weight. Pizza sauce was a simple, tomato based sauce with a moisture content of $86 \pm 2\%$ by weight. Pizza cheese was part-skim, low moisture, shredded mozzarella cheese with a moisture content of $50 \pm 2\%$ by weight. All ingredients were verified for proper moisture content by gravimetric moisture analysis.

The pizzas were comprised of a pizza crust, pizza sauce and pizza cheese according to the following: 0.25 lb of pizza sauce spread uniformly on top of

Methods

a pizza crust to within 0.5 inch of the edge of the crust, and 0.375 lb of pizza cheese spread uniformly over the pizza sauce. The pizzas were then placed on sheet pans and covered with plastic wrap. The pizzas were stabilized in a refrigerator for a minimum of 18 hours before testing to ensure temperature uniformity of $39 \pm 1^\circ\text{F}$.

Pizza doneness, as outlined by ASTM standards¹, requires a final pizza temperature of $195 \pm 3^\circ\text{F}$. The final pizza temperature was measured by placing six hypodermic-style thermocouple probes on the surface of the pizza, located 3 inches from the center of the pizza and equidistant from each other, for a period of 60 seconds. The probes were allowed to penetrate the cheese and rest in the crust-sauce interface. The highest average temperature of the six probes during the 60 second period was the final pizza temperature. For consistency of the temperature readings, the probes were attached to a lightweight plastic disc which held the relative position of each probe constant from pizza to pizza. A picture of the thermocouple probe structure is shown in Figure 2-2



*Figure 2-2.
Thermocouple Probe
Structure.*

Methods

A recipe was determined to achieve both the desired final pizza temperature and the best food quality. The recipe was a 73 second, two event cook setting. The first event was 23 seconds of 75% hot air and 100% microwave, and the second event was 50 seconds of 90% hot air and 0% microwave.

After the recipe was determined, the single run pizza tests were conducted. A single pizza was weighed and then placed directly on the ceramic cook platter inside the cook chamber. No more than 1 minute was allowed to elapse from the time the pizza was removed from the refrigerator to the beginning of the cook cycle. After cooking, the pizza was removed from the oven and placed on a two inch thick square of polystyrene insulation that prevented heat loss into the table surface during temperature measurement. After the final temperature was determined, the pizza was weighed again so weight loss during cooking could be calculated. The test was performed three times, allowing 5 minutes between tests so the oven would be cooking in a “from-idle” state. Using three test runs ensured that the cooking energy efficiency could be reported with an uncertainty of less than $\pm 10\%$.

Pizza- Barreling Run and Production

A barreling run test is a cooking scenario where the oven is required to perform numerous cook cycles, one right after another. When one pizza is finished cooking, it is removed from the oven and another pizza is immediately loaded so the cooking cycle can be started again as quickly as possible.

The barreling run test was performed for two reasons: first, to provide the information necessary for calculating the oven’s production capacity. The second reason was to calculate cooking energy efficiency for each individual pizza as the barreling test progressed. This would determine if the oven gained any energy benefit from cooking loads repeatedly.

Methods

Chicken- Single Run Cooking Energy Efficiency Tests

The chicken breasts used, and the criteria for chicken doneness were the same as outlined in ASTM Designation F1639-95, *Standard Test Method for the Performance of Combination Ovens*². Chicken breasts were 5-oz, boneless, skinless, butterfly-cut, whole meat, chicken breasts. During test preparation, the raw chicken breasts were placed on a wire rack which sat on a sheet pan to catch any drippings. The breasts were arranged in a single layer and covered with plastic wrap. The wrapped chicken was stabilized in a refrigerator for a minimum of 24 hours before testing to ensure temperature uniformity of $37 \pm 2^\circ\text{F}$.

The number of chicken breasts used for each test run was determined by the size of the Pressware®, a pressed paperboard tray used for cooking items that would otherwise drip into the oven while cooking. The breasts were placed on the tray in a circular pattern which covered as much area of the tray as possible, without having any part of two adjacent breasts overlap. This resulted in six breasts being used for each run.

Chicken doneness, as outlined by ASTM standards², requires internal chicken temperature to reach at least 170°F . Since it is not possible to thermocouple the chicken breasts while they are in the oven, the temperature of the thickest part of each breast was measured with a hypodermic-style thermocouple probe after cooking. The breasts were monitored for 60 seconds, and the highest average temperature recorded during this time was the final chicken temperature.

The recipe required to achieve a final average chicken temperature of $170 \pm 3^\circ\text{F}$ was a single event of 95 seconds using 70% hot air and 100% microwave.

After recipe determination, three single run chicken tests were conducted. Six chicken breasts were arranged on the cooking tray and weighed, with the tray, before cooking. No more than 1 minute was allowed to elapse between removal from the refrigerator and the beginning of the cook cycle. Immediately after cooking the breasts were again weighed with the tray and the juices

Methods

from cooking. The breasts were then transferred to a wire drip rack, where they were probed for a period of 60 seconds to determine the final chicken temperature. Immediately following the temperature measurement, the breasts were weighed a final time, without the cooking tray or juices.

Chicken- Barreling Run and Production Capacity Test

A barreling test was also conducted using the chicken, with a new test run beginning immediately after removal of the previous run. This allowed the calculation of the cooking energy efficiencies for each run and the calculation of production capacity.

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

3 Results

Measured Energy Input Rate

The energy input rate was measured and compared with the manufacturer's rated value prior to any testing to ensure that the oven was operating properly. The maximum energy input rate was measured as 10.8 kW at 208 V. The manufacturer's specified maximum input at 208 V was also 10.8 kW.

Preheat and Idle Rate Tests

Preheat Energy and Time

The TurboChef® required a period of 24.0 minutes to preheat to operating temperature. The oven consumed 2.48 kWh during the test.

Idle Energy Rate

The oven was allowed to stabilize for one hour following the preheat test. Thereafter, the energy consumption was monitored over a 2-hour period. The idle energy rate was calculated to be 0.98 kW, which is 8.9% of the oven's rated input.

Cooking Tests

The oven was tested using pizza and chicken breasts, with both single run and barreling run test scenarios. The single run tests were performed in triplicate, while the barreling run tests were performed once. The order of testing was as follows: single run pizza tests, barreling pizza test, single run chicken tests, barreling chicken test. The energy consumption, elapsed cook time and ambient temperature were monitored for the duration of each cooking cycle at five second intervals. After each cooking cycle, final product temperature was determined using the technique described in the methods section for the particular food product.

Results

Single Run Pizza Tests

The TurboChef® oven cooked each pizza to an average final temperature of 193.6°F with a cook time of 1.2 minutes, while delivering 32.2% cooking energy efficiency at a cooking energy rate of 9.0 kW.

Pizza Barreling Run Test

The TurboChef® required 9.1 minutes to cook 6 consecutive pizzas to an average final temperature of 193.3°F. The cooking energy rate during the barreling run test steadily declined from 9.0 kW for the first pizza to 7.0 kW for the fifth and sixth pizzas. Therefore, the first pizza was cooked with a cooking energy efficiency of 31.9%, and the fifth and sixth pizzas were cooked with an average cooking energy efficiency of 41.0%. The production capacity for the barreling test was 39.6 pizzas/h, or 57.1 lb/h. Figure 3-1 shows the cooking energy rate and cooking energy efficiency of each load during the barreling run test.

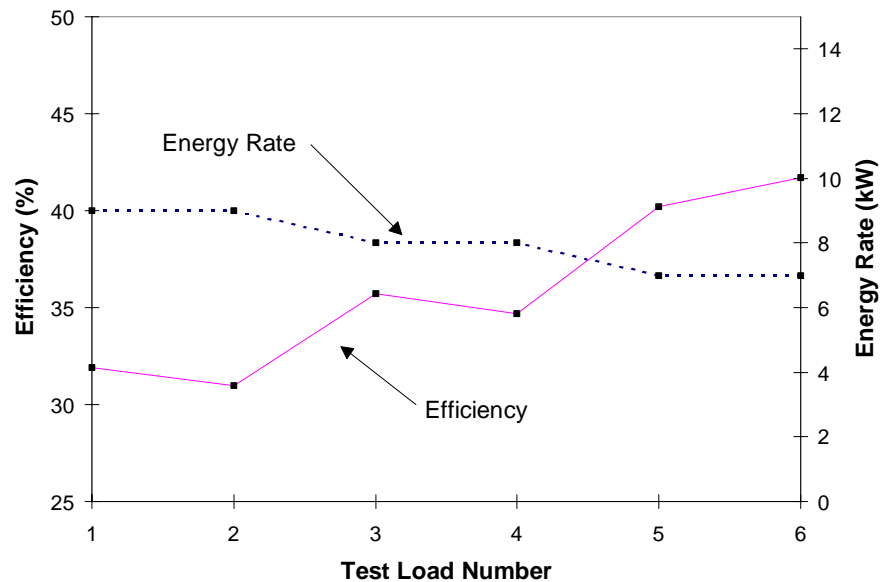


Figure 3-1.
Cooking Energy Rates
and Cooking Energy
Efficiencies for Pizza
Barreling Run Test

Results

Single Run Chicken Tests

The oven cooked the chicken breasts to a final average internal temperature of 170.7°F with a cook time of 1.6 minutes while delivering 31.4% cooking energy efficiency at a cooking energy rate of 10.6 kW.

Chicken Barreling Run Test

The TurboChef® required 11.3 minutes to cook 6 consecutive chicken breast loads to an average final temperature of 171.1°F. The cooking energy rate during the barreling test steadily declined from 10.6 kW for the first load to 8.4 kW for the fourth, fifth and sixth loads. Therefore, the first load was cooked with a cooking energy efficiency of 30.7%, and the fourth, fifth and sixth loads were cooked with an average cooking energy efficiency of 39.4%. The production capacity for the barreling test was 44.3 lb/h.

Figure 3-2 shows the cooking energy rate and cooking energy efficiency of each test load during the chicken barreling run test.

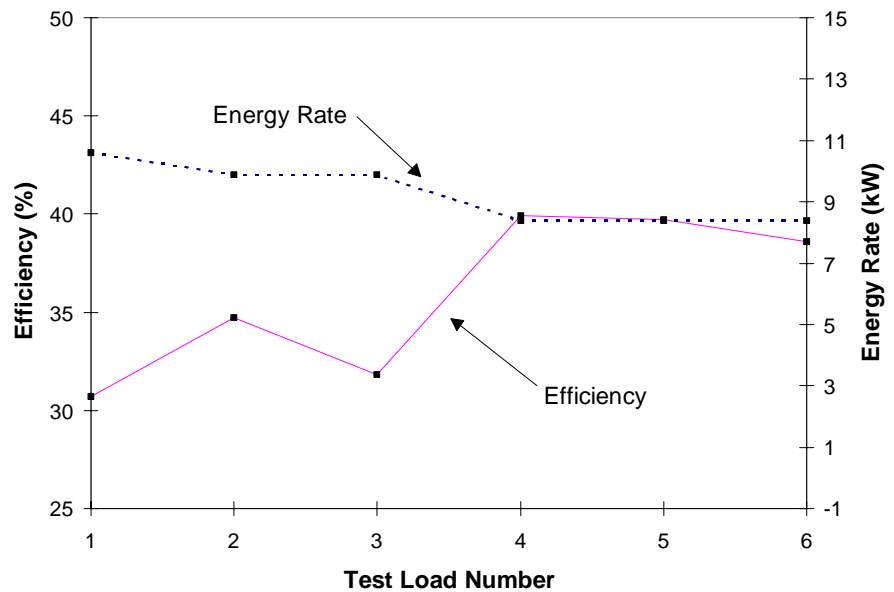


Figure 3-2.
Cooking Energy Rates
and Cooking Energy
Efficiencies for
Chicken Barreling Run
Test

Results

Test Results

Cooking energy efficiency is defined as the quantity of energy consumed by the food expressed as a percentage of energy consumed by the oven during the cooking event. The mathematical expression is therefore:

$$\text{Cooking Energy Efficiency (\%)} = \frac{E_{\text{food}}}{E_{\text{oven}}} \times 100\%$$

During pizza testing, energy is used for both heating the pizzas, and for evaporating some of the water present in the various ingredients. The energy consumed by the pizzas was calculated by determining the amount of heat gained by the pizzas while being heated from their initial temperature to their final temperature, and how much energy was necessary to evaporate the water which was lost during the cooking process. The energy consumption is expressed mathematically as:

$$E_{\text{pizza}} = E_{\text{(heat pizza)}} + E_{\text{(evaporate water)}}$$

Chicken energy consumption is also defined as the energy required to heat the chicken breasts from their initial temperature to their final temperature, and to evaporate the water lost during the cooking process:

$$E_{\text{chicken}} = E_{\text{(heat chicken breasts)}} + E_{\text{(evaporate water)}}$$

Using the detailed equations provided in Section 11 of each respective ASTM Standard Test Method, the cooking energy efficiencies can be readily calculated^{1,2}.

Tables 3-1 and 3-2 summarize the TurboChef® oven's performance for the two food products. Figures 3-3 and 3-4 illustrate these results in a graphical format.

Results

Table 3-1. Single Run Test Results- Cooking Energy Efficiency

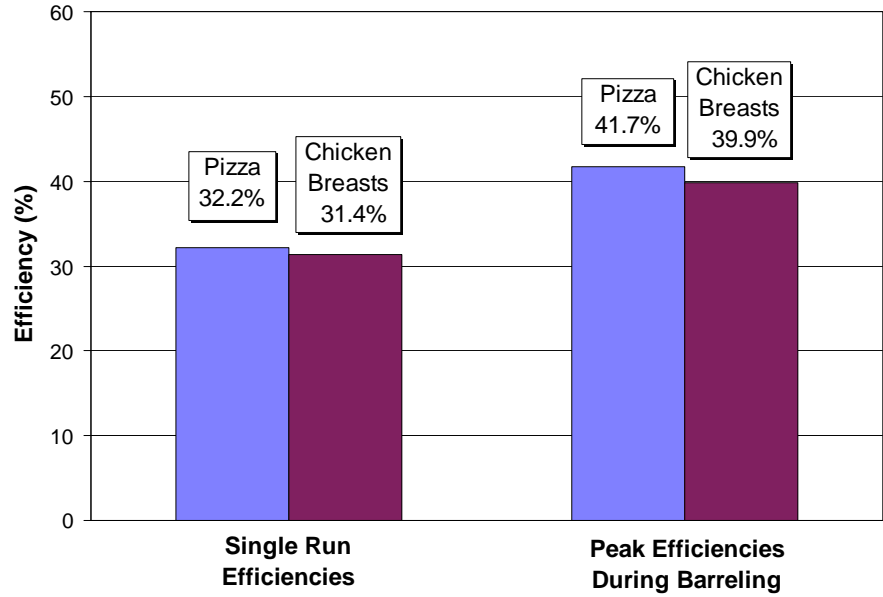
	Pizza	Chicken Breasts
Cook Time (min)	1.2	1.6
Cooking Energy Rate (kW)	9.0	10.6
Cooking Energy Efficiency (%)	32.2 ± 0.4	31.4 ± 1.0

Table 3-2. Barreling Run Test Results- Peak Cooking Energy Efficiency and Production Capacity

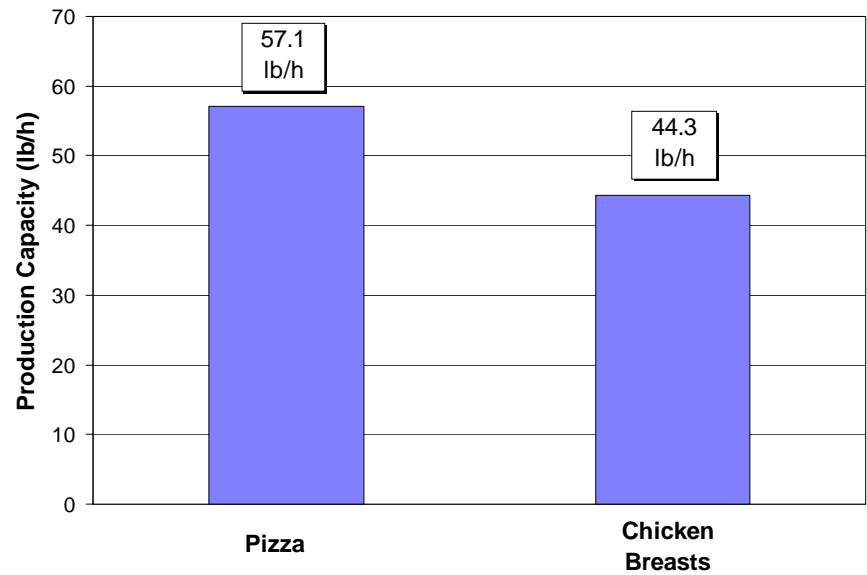
	Pizza	Chicken Breasts
Peak Cooking Energy Efficiency (%)	41.7	39.9
Cooking Energy Rate (kW)	7.0	8.4
Production Capacity (lb/h)	57.1	44.3
Production Capacity (pizzas/h)	39.6	-

Results

*Figure 3-3.
Cooking Energy Efficiencies for Single Runs and Peak Cooking Energy Efficiencies During Barreling Run Tests.*



*Figure 3-4.
Production Capacity Test Results*



4 Conclusions

With a combination of both hot air and microwave cooking processes, the TurboChef® was clearly developed with speed in mind.

With a combination of both hot-air and microwave cooking processes, the TurboChef® was clearly developed with speed in mind. Pizzas were cooked in only 73 seconds, and chicken breasts in just 95 seconds. Cooking energy efficiency for single run pizza testing was 32.2% while single run chicken testing showed a cooking energy efficiency of 31.4%. Barreling run tests produced a maximum cooking energy efficiency of 41.7% for pizza during the sixth consecutive load, and a maximum cooking energy efficiency of 39.9% for chicken during the fourth consecutive load. A preheat time of 24.0 minutes and an idle rate of 0.98 kW round out the TurboChef® oven's performance numbers.

To provide a reference point, other small electric ovens, for example, deck, conveyor and ½ size convection, have heavy load cooking energy efficiencies ranging from 18 - 64% and idle at or near 1.4 kW.

The TurboChef® was also easy to use. Once a recipe was programmed, pushing two buttons was all that was necessary to operate the oven. All timing and control issues were handled by the computerized operating system. With the ability to store 108 recipes, the TurboChef® is easily programmed to cook a variety of food products, and has the ability to adapt to changing menus.

The proprietary integrated air and grease scrubbing system make it possible, in most installations, to operate the TurboChef® oven without a separate exhaust hood. Combined with its relatively small footprint, the TurboChef® is flexible when it comes to physical placement, thereby minimizing its impact on the surrounding space.

With its quick speed, computer controlled operation, and extensive programmability, the TurboChef® oven is a viable alternative to traditional appliances in many different food service situations.

5 References

1. American Society for Testing and Materials. 1997. *Standard Test Method for the Performance of Conveyor Ovens*. ASTM Designation F 1817-97, in *Annual Book of ASTM Standards*, Philadelphia: American Society for Testing and Materials.
2. American Society for Testing and Materials. 1995. *Standard Test Method for the Performance of Combination Ovens*. ASTM Designation F 1639-95, in *Annual Book of ASTM Standards*, Philadelphia: American Society for Testing and Materials.

Appendixes

A Glossary

Barreling Run

Cooking test scenario where individual loads are cooked one after another, with loading and unloading performed as quickly as possible.

Combination Oven

An appliance that combines the function of hot air convection or saturated and superheated steam heating, or both, to perform steaming, baking, roasting, rethermalizing, and proofing of various food products. In general, the term combination oven is used to describe this type of equipment, which is self contained. The combination oven is also referred to as a combination oven/steamer.

Conveyor Oven

An appliance that carries the food product on a moving conveyor into and through a heated chamber. The chamber may be heated by gas or electric forced convection, radiants, or quartz tubes. Top and bottom heat may be independently controlled.

Cooking Energy Efficiency

Energy Efficiency

Quantity of energy imparted to the specified food product expressed as a percentage of energy consumed by the oven during the cooking event.

Cooking Energy Rate

Cooking Energy Consumption Rate

Average rate of energy consumption (Btu/h or kW) during the cooking energy efficiency test. Refers to all loading scenarios (heavy/light).

Energy Input Rate

Rate at which an oven consumes energy (Btu/h or kW).

Idle Energy Rate

Idle Rate

The oven's rate of energy consumption (kW or Btu/h), when empty, required to maintain its cavity temperature at the specified thermostat set point.

Maximum Energy Input Rate

Measured Energy Input

Measured Peak Energy Input Rate

Peak Rate of Energy Input

Peak rate at which an oven consumes energy (Btu/h or kW).

Oven Cavity

That portion of the oven in which food products are heated or cooked.

Pilot Energy Rate

Rate of energy consumption (Btu/h) by an oven's continuous pilot (if applicable).

Preheat Energy

Amount of energy consumed (Btu/h or kWh) by the oven while preheating its cavity from ambient temperature to the specified thermostat set point.

Preheat Time

Time (min.) required for the oven cavity to pre-heat from ambient temperature to the specified thermostat set point.

Glossary

Production Capacity

Maximum rate (lb(kg)/h) at which an oven can bring the specified food product to a specified "cooked" condition.

Production Rate

Rate (lb(kg)/h) at which an oven can bring the specified food product to a specified "cooked" condition.

Single Run

Cooking test scenario where only one test load is cooked.

Test Load

Amount of food placed in oven for cooking. (In the case of the TurboChef®, one pizza or six chicken breasts.)

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.

Uncertainty

Measure of systematic and precision errors in specified instrumentation or measure of repeatability of a reported test result.

B Appliance Specifications

Appendix B includes the product literature for the TurboChef® Model D oven.

Manufacturer's Product Literature

TurboChef's Rapid Cook Technology*

Traditional cooking systems employ a wide range of processes for transferring heat energy to food. These include: conduction (direct energy transfer from a hot surface, as in a grill); natural convection (energy transfer to and from naturally moving air, as in a typical home oven); forced convection (energy transfer to and from mechanically circulated air, as in a typical convection oven); air impingement (forced convection with rapidly moving air directed at the food); induction (heating by the generation of electromagnetic fields); microwave radiation (heating by the dissipation of microwave energy in food); and infra-red radiation (heating by light whose wavelength falls below that of the color red in the electromagnetic spectrum).

Newer cooking systems incorporate two or more of these conventional sources of energy. For example, some allow cooks to use both microwaves and air impingement. The Company believes that these systems generally do not provide tangible advantages to both commercial and residential kitchens because they typically operate each energy source independently, without facilitating their interaction.

In direct contrast, in its simplest form, the Company's unique, patented system couples hot air with microwave energy. Just as the inter-twining of two strings to form a rope gives the rope greater strength than the two strings could provide on their own, so does the close coupling of the two energy sources enable faster cooking at higher quality levels than is possible by each energy source operating independently. The air is forced down from the top of the oven and suctioned out through a return path. This creates a tight air wrap around food. The air wrap not only browns food more evenly, but also creates temperature and moisture gradients that enable precisely targeted microwaves to energize water molecules that cook the food. Microwave energy is introduced from a direction directly opposite that of the direction of the air flow, thus capturing the food between the two opposing energy gradients.

Two technological elements make possible the "coupling" described above. First, precise mechanical design enables a spatial coupling. The flowing air enshrouds the food in a fashion that is not achievable in traditional convection or impingement ovens. The microwave energy is directed precisely at those locations within the cooking cavity where it can contribute maximum value. In contrast, in most conventional microwave ovens, the energy resonates throughout the chamber. Second, a proprietary microprocessor system couples the hot air and microwaves temporally. It allows the cook/chef to define the precise airflow, microwave and, in some cases, temperature conditions required during different phases of the cooking process.

As a result, the *TurboChef* system cooks food extremely rapidly, enabling foods to retain their natural moisture and hence, their appearance, texture and flavor. Specific advantages over alternative cooking systems include:

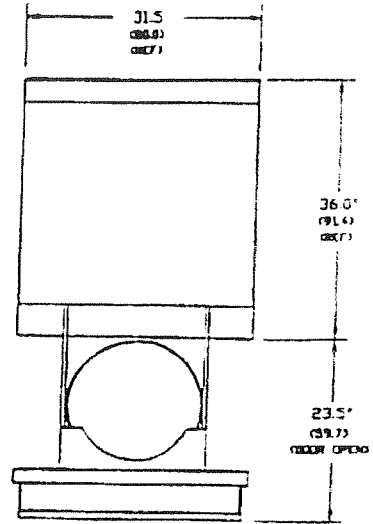
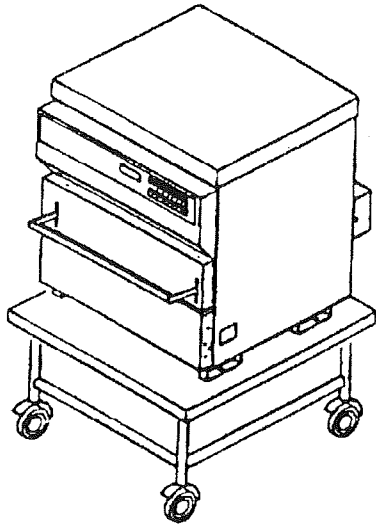
- *Speed* Single servings of most food items can be cooked in under 90 seconds.

Manufacturer's Product Literature

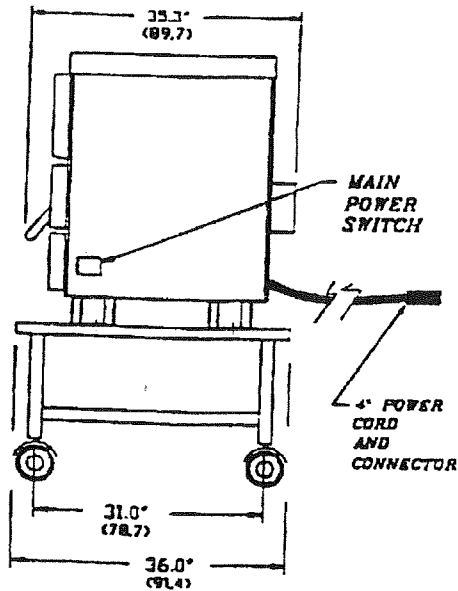
- *Quality* Foods retain much of their intrinsic moisture and as such, their tenderness. They can also be browned and/or crisped as desired.
- *Flexibility* A filtration and proprietary catalyst system strips the air in the oven of food particles and aromatic by-products of the cooking process. Thus, foods with very different flavors can be sequentially cooked without flavor transfer. Indeed, in some circumstances, different foods with similar cooking characteristics can be cooked simultaneously. Moreover, no external ventilation is required for most applications.
- *Consistency* Food cooks uniformly and evenly without the use of any special ingredient or formulation. Moreover, the microprocessor automatically adjusts cooking conditions to produce consistent quality even if the cooking process is unexpectedly interrupted.

*This information was supplied by the appliance manufacturer and represents the manufacturer's philosophy concerning the operation and performance of their appliance. Its inclusion in this report is for informational purposes only and does not represent an endorsement of the product claims by the Pacific Gas and Electric Company or the Food Service Technology Center.

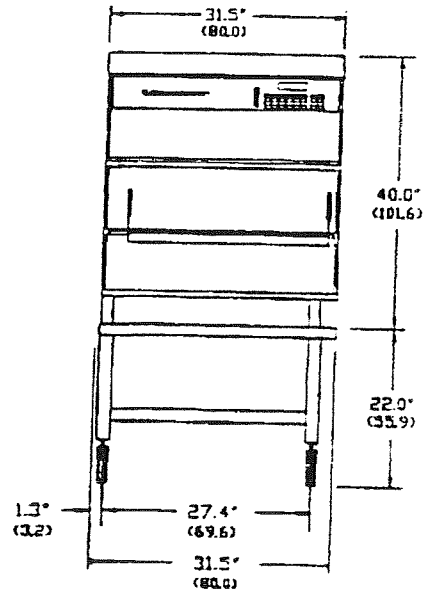
TURBOCHEF®



PLAN VIEW



RIGHT SIDE VIEW



FRONT VIEW

D2 PHYSICAL CHARACTERISTICS:

DIMENSIONS:

HEIGHT:	40.0"	(101.6)
WIDTH:	31.5"	(80.0)
DEPTH:	35.3"	(89.7)
WEIGHT:	540 lb.	(245 kg)

ACCESSORIES:

DESCRIPTION	ORDER NO.
D2 CART ASSEMBLY (INCLUDES BOTH TOP AND BOTTOM SHELF.)	7000668

D2 ELECTRICAL REQUIREMENTS:

DOMESTIC:	208-240 VAC, 3 PHASE, 60 HZ, 30-33 AMP 4 WIRE (INCLUDING GROUND) CONNECTOR TYPE: NEMA 15-50R
EUROPEAN:	400-415 VAC, 3 PHASE, 50 HZ, 18 AMP 5 WIRE (INCLUDING GROUND) CONNECTOR TYPE: IEC 309-32 AMP

C Results Reporting Sheets

Manufacturer TurboChef® Technologies, Inc.
Model D
Date: July, 98

Section 11.1 Test Oven

Description of operational characteristics: The oven uses a combination of forced hot air and microwaves to cook food. The oven uses a programmable computerized operating system and a touch pad user interface with program memory function.

Section 11.2 Apparatus

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

Deviations: None

Section 11.4 Energy Input Rate

Test Voltage	<u>208 V</u>
Gas Heating Value	<u>N/A</u>
Rated	<u>10.8 kW</u>
Measured	<u>10.8 kW</u>
Percent Difference between Measured and Rated	<u>0.0%</u>
Fan / Control Energy Rate (Gas Ovens Only)	<u>N/A</u>

Results Reporting Sheets

Section 11.5 Preheat Energy and Time

Test Voltage	<u>208V</u>
Gas Heating Value	<u>N/A</u>
Energy Consumption	<u>2.48 kWh</u>
Duration	<u>24.0 min</u>

Section 11.6 Idle Energy Rate

Test Voltage	<u>208V</u>
Gas Heating Value	<u>N/A</u>
Idle Energy Rate	<u>0.98 kW</u>

Section 11.7 Pilot Energy Rate

Gas Heating Value	<u>N/A</u>
Pilot Energy Rate	<u>N/A</u>

Section 11.8 Cooking Energy Efficiency and Cooking Energy Rate

Pizza Testing:

Test Voltage	<u>208 V</u>
Cook Time	<u>1.2 min</u>
Cooking Energy Efficiency	<u>32.2 ± 0.4 %</u>
Cooking Energy Rate	<u>9.0 kW</u>
Production Capacity	<u>39.6 Pizzas/h</u>

Chicken Testing:

Test Voltage	<u>208 V</u>
Cook Time	<u>1.6 min</u>
Cooking Energy Efficiency	<u>31.4 ± 1.0%</u>
Electric Cooking Energy Rate	<u>10.6 kW</u>
Product Shrinkage	<u>22.0%</u>
Production Capacity	<u>44.3 lb/h</u>

D Cooking Energy Efficiency Data

Table D-1. Physical Properties.

Specific Heat (Btu/lb °F)	
Pizza	0.593
Chicken	0.800
Latent Heat (Btu/lb)	
Vaporization, Water at 170°F	996

Table D-2. Pizza- Single Load Test Data.

Measured Values	Repetition #1	Repetition #2	Repetition #3
Total Energy (Wh)	180	180	180
Cook Time (min)	1.2	1.2	1.2
Initial Weight (lb)	1.463	1.463	1.431
Final Weight (lb)	1.397	1.397	1.361
Initial Temperature (°F)	40	40	40
Final Temperature (°F)	194.8	192.8	193.1
Calculated Values			
Sensible to Solids (Btu)	134	133	130
Latent - Water Vaporization (Btu)	64	64	68
Total Energy to Food (Btu)	198	197	198
Energy to Food (Btu/lb)	136	134	138
Total Energy to Oven (Btu)	614	614	614
Energy to Oven (Btu/lb)	420	420	429
Cooking Energy Efficiency (%)	32.3	32.0	32.2
Cooking Energy Rate (kW)	9.0	9.0	9.0

Cooking Energy Efficiency Data

Table D-3. Pizza Barreling Test Data.

Measured Values	Pizza #1	Pizza #2	Pizza #3
Total Energy (Wh)	180	180	160
Cook Time (min)	1.2	1.2	1.2
Initial Weight (lb)	1.438	1.436	1.443
Final Weight (lb)	1.372	1.375	1.378
Initial Temperature (°F)	40	40	40
Final Temperature (°F)	193.5	193.3	193.4
Calculated Values			
Sensible to Solids (Btu)	131	131	131
Latent - Water Vaporization (Btu)	65	60	64
Total Energy to Food (Btu)	196	190	195
Energy to Food (Btu/lb)	136	133	135
Total Energy to Oven (Btu)	614	614	546
Energy to Oven (Btu/lb)	427	428	378
Cooking Energy Efficiency (%)	31.9	31.0	35.7
Cooking Energy Rate (kW)	9.0	9.0	8.0
Production Capacity (pizzas/h)	39.6	39.6	39.6
Production Capacity (lb/h)	57.1	57.1	57.1

Cooking Energy Efficiency Data

Table D-3 (continued). Pizza Barreling Test Data.

Measured Values	Pizza #4	Pizza #5	Pizza #6
Electric Energy (Wh)	160	140	140
Cook Time (min)	1.2	1.2	1.2
Initial Weight (lb)	1.438	1.446	1.455
Final Weight (lb)	1.379	1.386	1.384
Initial Temperature (°F)	40	40	40
Final Temperature (°F)	194.2	195.2	190.3
Calculated Values			
Sensible to Solids (Btu)	131	133	130
Latent - Water Vaporization (Btu)	58	59	70
Total Energy to Food (Btu)	189	192	199
Energy to Food (Btu/lb)	132	133	137
Total Energy to Oven (Btu)	546	478	478
Energy to Oven (Btu/lb)	380	330	328
Cooking Energy Efficiency (%)	34.7	40.2	41.7
Cooking Energy Rate (kW)	8.0	7.0	7.0
Production Rate (pizzas/h)	39.6	39.6	39.6
Production Rate (lb/h)	57.1	57.1	57.1

Cooking Energy Efficiency Data

Table D-4. Single Load Chicken Test Data.

Measured Values	Repetition #1	Repetition #2	Repetition #3
Total Energy (Wh)	280	280	280
Cook Time (min)	1.6	1.6	1.6
Number of Breasts	6	6	6
Initial Weight (lb)	1.473	1.511	1.488
After-Cook Weight (lb)	1.335	1.362	1.342
Final Weight (lb)	1.159	1.173	1.158
Initial Temperature (°F)	40	40	40
Final Average Temperature (°F)	173.8	166.2	172.2
Calculated Values			
Sensible to Solids (Btu)	158	153	157
Latent- Water Vaporization (Btu)	137	148	145
Total Energy to Food (Btu)	295	301	303
Energy to Food (Btu/lb)	200	199	203
Total Energy to Oven (Btu)	956	956	956
Energy to Oven (Btu/lb)	649	632	642
Cooking Energy Efficiency (%)	30.9	31.5	31.7
Cooking Energy Rate (kW)	10.6	10.6	10.6
Product Shrinkage (%)	21.3	22.4	22.2

Cooking Energy Efficiency Data

Table D-5. Chicken Barreling Test Data.

Measured Values	Load #1	Load #2	Load #3
Total Energy (Wh)	280	260	260
Cook Time (min)	1.6	1.6	1.6
Number of Breasts	6	6	6
Initial Weight (lb)	1.392	1.386	1.334
After-Cook Weight (lb)	1.247	1.226	1.186
Final Weight (lb)	1.143	1.117	1.070
Initial Temperature (°F)	40	40	40
Final Average Temperature (°F)	173.5	174.1	166.7
Calculated Values			
Sensible to Solids (Btu)	149	149	135
Latent- Water Vaporization (Btu)	144	159	147
Total Energy to Food (Btu)	293	308	283
Energy to Food (Btu/lb)	211	222	212
Total Energy to Oven (Btu)	956	887	887
Energy to Oven (Btu/lb)	687	640	665
Cooking Energy Efficiency (%)	30.7	34.7	31.8
Cooking Energy Rate (kW)	10.6	9.9	9.9
Product Shrinkage (%)	17.9	19.4	19.8
Production Capacity (lb/h)	44.3	44.3	44.3

Cooking Energy Efficiency Data

Table D-5 (continued). Chicken Barreling Test Data.

Measured Values	Load #4	Load #5	Load #6
Total Energy (Wh)	220	220	220
Cook Time (min)	1.6	1.6	1.6
Number of Breasts	6	6	6
Initial Weight (lb)	1.427	1.338	1.421
After-Cook Weight (lb)	1.279	1.181	1.275
Final Weight (lb)	1.149	1.060	1.148
Initial Temperature (°F)	40	40	40
Final Average Temperature (°F)	173.0	172.1	167.3
Calculated Values			
Sensible to Solids (Btu)	152	141	145
Latent- Water Vaporization (Btu)	147	156	145
Total Energy to Food (Btu)	299	298	290
Energy to Food (Btu/lb)	210	223	204
Total Energy to Oven (Btu)	751	751	751
Energy to Oven (Btu/lb)	526	561	528
Cooking Energy Efficiency (%)	39.9	39.7	38.6
Cooking Energy Rate (kW)	8.4	8.4	8.4
Product Shrinkage (%)	19.5	20.8	19.2
Production Capacity (lb/h)	44.3	44.3	44.3

Cooking Energy Efficiency Data

Table D-6. Single Load Cooking Energy Efficiency Statistics.

	Pizza	Chicken
Replicate #1	32.3	30.9
Replicate #2	32.0	31.5
Replicate #3	32.2	31.7
Average	32.2	31.4
Standard Deviation	0.15	0.42
Absolute Uncertainty	0.36	1.0
Percent Uncertainty	1.1	3.3
