

Retherm Oven Performance Testing

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Executive Summary

Researchers at the Food Service Technology Center (FSTC) conducted an extensive study of the operating performance of four different retherm ovens for an institutional food service program to aid the program in its requisition of new appliances for its many kitchen facilities.

The primary aim of the study was to quantify the ovens' production capacities and energy consumption. These two elements of the testing process were key in determining the ovens' abilities to meet a facility's menu demands and calculating the utility costs resulting from their use. Researchers also measured the ovens' preheat times, idle energy rates and retherm-energy efficiency.

Retherm-energy efficiency is a measure of how much of the energy that an appliance consumes is actually delivered to the food product during the rethermalization process. Retherm-energy efficiency is therefore defined by the following relationship:

$$\textit{Retherm-Energy Efficiency} = \frac{\textit{Energy to Food}}{\textit{Energy to Appliance}}$$

Lastly, researchers analyzed the ovens' pan-to-pan rethermalization uniformities in order to evaluate the rethermalizing effect on food product quality.

With the data researchers were able to estimate the annual operating costs of the ovens. An energy cost model utilizing preheat energy, idle energy and rethermalization energy rate data was used to estimate the ovens' annual operating costs. The cost model assumed 12 hours of operation per day for

Executive Summary

erating costs. The cost model assumed 12 hours of operation per day for 365 days. During each 12-hour period the oven was preheated once and rethermalized 200 pounds of food. The cost model assumed that the oven idled for the remainder of the 12-hour period. The actual dollar cost was determined using an electric utility rate of \$0.15/kWh.

In order to characterize the operating performance of the ovens, researchers at the FSTC developed a standard test method to ensure testing accuracy and repeatability. Rethermalization tests were performed using 12 x 20 x 12 ½ in. hotel pans filled with 10 pounds of chili con carne stabilized at $38 \pm 2^\circ\text{F}$. Each pan was instrumented with a single thermocouple in the geometric center of the food product and covered with a standard hotel pan lid during testing. After being preheated to an operating temperature of 275°F and stabilized for one hour, the ovens were loaded to maximum capacity. Testing was considered complete when the last pan of chili reached 165°F .

Table ES-1 summarizes the results of the performance testing and the estimated annual operating costs of the large ovens.

Executive Summary

Table ES-1. Summary of Large Oven Performance.

	Unit A (22 pans)	Unit B (20 pans)
Rated Energy Input Rate (kW)	24.0	22.8
Measured Energy Input Rate (kW)	24.0	22.0
Preheat Time to 275°F (min)	6.92	3.17
Preheat Energy to 275°F (Wh)	1720	1080
Idle Energy Rate @ 275°F (kW)	1.3	1.6
Rethermalization Time (min)	217.5	65.0
Retherm Energy Rate (kW)	4.9	10.0
Retherm-Energy Efficiency (%)	36.6 ± 2.0 ^a	55.2 ± 2.0 ^a
Production Capacity (lb/h)	60 ± 2.6 ^a	185 ± 10.7 ^a
Annual Cost of Operation (\$)	1779 ^b	2074 ^b
Cost / Pan / Load (\$)	0.12 ^b	0.08 ^b

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

^b Cost estimate based on an electric utility rate of \$0.15/kWh.

Analysis of Unit A's rethermalization uniformity showed that the first pan reached 165°F in 53.8 minute. At that point, the pans in the cavity ranged from 75°F to 165°F. Unit B exhibited a tighter uniformity. When the first pan reached 165°F in 36.1 minutes, the pans ranged from 98°F to 165°F.

Executive Summary

Table ES-2 summarizes the test results of the performance testing and the estimated annual operating costs of the small ovens.

Table ES-2. Summary of Small Oven Performance.

	Unit C (5 pans)	Unit D (4 pans)
Rated Energy Input Rate (kW)	8.5	6.8
Measured Energy Input Rate (kW)	8.4	6.7
Preheat Time to 275°F (min)	3.25	6.17
Preheat Energy to 275°F (Wh)	440	580
Idle Energy Rate @ 275°F (kW)	0.5	0.8
Rethermalization Time (min)	50.4 ^a	41.1 ^a
Retherm Energy Rate (kW)	2.8	3.0
Retherm-Energy Efficiency (%)	63.1 ± 2.0 ^a	58.1 ± 1.0 ^a
Production Capacity (lb/h)	60 ± 4.3 ^a	58 ± 5.2 ^a
Annual Cost of Operation (\$)	876 ^b	1080 ^b
Cost / Pan / Load (\$)	0.07 ^b	0.08 ^b

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

^b Cost estimate based on an electric utility rate of \$0.15/kWh.

The two small ovens exhibited much better uniformity than their large counterparts. Unit C had the best uniformity, with the trailing pan only 10°F behind the lead pan. Unit D had a maximum temperature difference of 15°F between the hottest and coolest pans when the first pan achieved 165°F.

1 Introduction

Background

Dedicated to the advancement of the food service industry, the Food Service Technology Center (FSTC) has focused on the development of standard test methods for commercial food service equipment since 1987. The test methods, approved and ratified by the American Society for Testing and Materials (ASTM), allow benchmarking of equipment such that users can make meaningful comparisons among available equipment choices. End-use customers and commercial appliance manufacturers consider the FSTC to be the national leader in commercial food service equipment testing and standards, sparking alliances with several major chain customers to date.

This study was the result of testing conducted for an institutional food service program to benchmark the performance of retherm ovens being considered for use in the program's many satellite kitchen facilities. Under consideration were two large ovens (22 and 20 pans) and two small ovens (4 and 5 pans) offered by three manufacturers. The primary aim of the study was to determine the production capacity and energy consumption performance of each oven. Researchers were further able to calculate the ovens' preheat times, idle energy rates, and retherm-energy efficiencies. Using a cost model based on the test data allowed researchers to estimate the ovens' real world operating costs. Finally, researchers were able to show the ovens' retherm uniformity, thus characterizing the rethermalization effect on food quality.

Introduction

Retherm Oven Test Method Development

The test method used in this study evolved from prior testing conducted by the FSTC in 1998. During earlier testing, researchers used individual, plastic, compartmentalized entrees containing portions of chili and mashed potatoes. The ovens were not preheated prior to beginning the retherm test and were set to a temperature of 350°F for the retherm cycle. A “hold” test immediately followed the retherm test to characterize the oven’s energy consumption while maintaining the food product at a specified temperature.

The current test method sought to build on the foundation laid by the earlier testing procedure. Researchers chose chili con carne as the test food product for its consistency and ease of procurement. Standard 12 x 20 x 12 ½ in. hotel pans replaced the individual entrees for testing simplicity and ease of instrumentation. Reflecting a more typical use of retherm ovens, researchers preheated the ovens to 275°F before testing commenced. The hold test was eliminated and replaced with a rethermalization uniformity test to evaluate the ovens’ effects on food product quality.

This study further served as the basis for development of a new test method to be submitted for review to the American Society for Testing and Materials (ASTM) F26 Committee on food service equipment in the Fall of 2003. A glossary is provided in Appendix A so that the reader has a quick reference to the terms used in this report.

Introduction

Objectives

The objective of this report is to examine the operation and performance of four retherm ovens, under the controlled laboratory conditions. 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 appliance from room temperature to 275°F.
3. Characterize the idle energy use with the thermostat set at a calibrated 275°F.
4. Determine the retherm time performance of the oven while fully loaded; characterized by the time required to raise the last pan's food product temperature from 38°F ± 2°F to 165°F.
5. Determine the oven's energy consumption, energy efficiency and production capacity under fully loaded conditions.
6. Characterize the oven's rethermalization uniformity.

Appliance Description

Retherm ovens are designed to reheat food product that has been previously cooked and refrigerated. Typically, these ovens are found in large institutions such as prisons, hospitals and schools. Retherm ovens allow food preparation to occur off site, catering to centralized kitchens with satellite operations that have a minimum of other expensive cooking equipment, as well as associated kitchen ventilation systems.

In Unit A, air from the rethermalizing cabinet was circulated through a heating element compartment atop the cabinet by a fan in the front of the ceiling and was reintroduced to the rethermalizing cabinet via a duct at the rear of the cabinet.

Units B, C and D employed similar designs for heating the rethermalizing cabinet of their respective ovens. These manufacturers placed the heating elements inside the rethermalizing cabinet around a squirrel cage type fan.

Introduction

Table 1-1. Appliance Specifications.

Unit A	
Pan Capacity:	22 (12" x 20" x 12 ½") pans
Rated Input:	24 kW
Technology:	Heating elements in compartment separate from rethermalization cabinet through which a fan circulates air in and out of the rethermalization cabinet.
Controls:	Programmable, 12 cycle, multi function, electronic time and temperature control.
Construction:	Type 300 stainless-steel, 20 gauge interior and exterior.
Dimensions:	31 ½" x 69" x 39" (W x D x H)
Unit B	
Pan Capacity:	20 (12" x 20" x 12 ½") pans
Rated Input:	22.8 kW
Technology:	Heating elements inside of rethermalization cabinet placed around a squirrel cage type fan.
Controls:	Manually adjustable time and temperature dials with electronic display.
Construction:	Stainless-steel interior and exterior.
Dimensions:	46 ½" x 65 ½" x 38" (W x D x H)
Unit C*	
Pan Capacity:	5 (12" x 20" x 12 ½") pans
Rated Input:	8.5 kW
Technology:	Heating elements inside of rethermalization cabinet placed around a squirrel cage type fan.
Controls:	Programmable, four cycle, electronic time and temperature controls. Redundant temperature control thermostat on the rear of the unit.
Construction:	Type 304 stainless-steel interior and exterior, including hinges and door handles.
Dimensions:	31" x 29 ½" x 56 ¾" (W x D x H)
Unit D	
Pan Capacity:	4 (12" x 20" x 12 ½") pans
Rated Input:	6.8 kW
Technology:	Heating elements inside of rethermalization cabinet placed around a squirrel cage type fan.
Controls:	Manually adjustable time and temperature dials with electronic display.
Construction:	Stainless-steel interior and exterior.
Dimensions:	32 ½" x 27 ½" x 31 ½" (W x D x H)

* This unit consists of two, five pan, independently wired and operated ovens stacked one atop the other.

2 Methods

Setup and Instrumentation

FSTC researchers installed the ovens under a 4-foot-deep canopy hood. 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 ovens and the edge of the 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 thermocouples were connected to a computerized data acquisition unit that recorded data every 5 seconds. A voltage regulator, connected to the oven, maintained a constant voltage for all tests. A single thermocouple was placed in the geometric center of the cooking cabinet during temperature calibration and preheat tests.

Measured Energy Input Rate

The energy input rate was determined by measuring the energy consumed by the oven during a complete preheat cycle. The maximum power draw during this period was reported as the measured energy input rate. Researchers compared the measured energy input rate with the nameplate energy input rate to ensure that the oven was operating properly.

Retherm Test

Researchers specified Smart and Final brand chili con carne for all rethermalization tests. The 12 x 20 x 12 ½ in. hotel pans were filled with 10.00 ± 0.001 pounds of chili con carne and then stabilized in a refrigerator at 38 ± 2°F. Each pan was instrumented with a single thermocouple in the geometric center of the food product (Figure 2-1). After being preheated to an operational temperature of 275°F, and allowed to stabilize for one hour, the

Methods

ovens were loaded to maximum capacity. Testing was considered complete when the last pan of chili reached 165°F. The oven was stabilized for one-half hour between each test to ensure recovery to full operational capacity. For reporting accuracy the test was performed a minimum of three times so that the energy efficiency and production capacity results had an uncertainty of less than $\pm 10\%$.

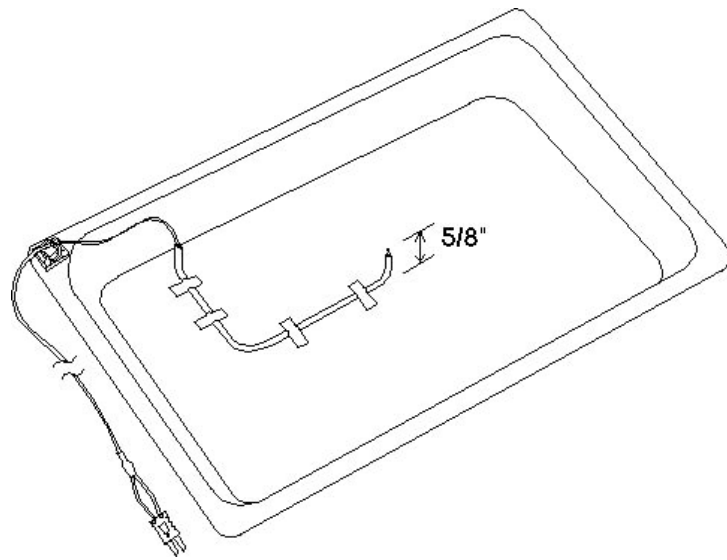


Figure 2-1.
Hotel pan instrumentation.

3 Results

Energy Input Rate

Energy input rate was measured prior to each day of testing to confirm that the oven was operating properly. Table 3-1 shows the measured input rate along with each oven's corresponding nameplate value.

Table 3-1. Energy Input Rate.

	Unit A	Unit B	Unit C	Unit D
Rated (kW)	24.0	22.8	8.5	6.8
Measured (kW)	24.0	22.0	8.4	6.7
Difference (%)	0.0	3.5	1.1	1.4

Preheat and Idle Tests

These tests show how the oven uses energy when it is not used to reheat food. The preheat time allows an operator to know precisely how long it takes for the oven to be ready to reheat food. The idle energy rate represents the energy required to maintain the set temperature, or the appliance's stand-by losses.

Preheat Energy and Time

The preheat test measures the amount of time and energy required by the oven to raise its cavity temperature from $75 \pm 5^{\circ}\text{F}$ to 275°F .

Results

Idle Energy Rate

Once the cavity temperature reached 275°F, the oven was allowed to stabilize for half an hour. Time and energy consumption was monitored for an additional two-hour period as the oven maintained the cavity temperature at 275°F.

Test Results

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

Table 3-2. Preheat and Idle Test Results.

	Oven A	Oven B	Oven C	Oven D
Preheat Time (min)	6.92	3.17	3.25	6.17
Preheat Energy (Wh)	1720	1080	440	580
Idle Energy Rate (kW)	1.3	1.6	0.5	1.4

Retherm Tests

Retherm performance was determined by loading the oven to maximum capacity with 12 x 20 x 12 ½ in. hotel pans filled with 10 lbs of chili con carne. Monitoring time and energy, the food product was rethermalized from a temperature of 38 ± 2°F to 165°F. The test was considered complete when the final pan of chili reached a temperature of 165°F.

Retherm-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. Retherm-energy efficiency is therefore defined by the following relationship:

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

Results

Tables 3-3 and 3-4 summarize the rethermalization performances of the four ovens.

Table 3-3. Large Oven Test Results.

	Oven A	Oven B
Rated Energy Input Rate (kW)	24.0	22.8
Measured Energy Input Rate (kW)	24.0	22.0
Preheat Time to 275°F (min)	6.92	3.17
Preheat Energy to 275°F (Wh)	1720	1080
Idle Energy Rate @ 275°F (kW)	1.3	1.6
Rethermalization Time (min)	217.5	65.0
Retherm Energy Rate (kW)	4.9	10.0
Retherm-Energy Efficiency (%)	36.3 ± 2.0 ^a	55.2 ± 2.0 ^a
Production Capacity (lb/h)	60 ± 2.6 ^a	185 ± 10.7 ^a

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

Table 3-4. Summary of Small Oven Test Results.

	Oven C	Oven D
Rated Energy Input Rate (kW)	8.5	6.8
Measured Energy Input Rate (kW)	8.4	6.7
Preheat Time to 275°F (min)	3.25	6.17
Preheat Energy to 275°F (Wh)	440	580
Idle Energy Rate @ 275°F (kW)	0.5	0.8
Rethermalization Time (min)	50.4	41.1
Cooking Energy Rate (kW)	2.8	3.0
Cooking-Energy Efficiency (%)	63.1 ± 2.0 ^a	58.1 ± 1.0 ^a
Production Capacity (lb/h) ^b	60 ± 4.3 ^a	58 ± 5.2 ^a

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

Results

Rethermalization Uniformity

Instrumentation of each hotel pan provided precise measurement of the food product temperature during the retherm test and showed the rethermalization uniformity of each oven. This information served as an indicator of the rethermalization process effect upon food product quality.

Analysis of Unit A's rethermalization uniformity showed that the first pan reached 165°F in 53.8 minutes. At that point, the pans in the cavity ranged from 75°F to 165°F, illustrated in Figure 3-1. Unit B exhibited a tighter uniformity. When the first pan reached 165°F in 36.1 minutes, the pans ranged from 98°F to 165°F, illustrated in Figure 3-2.

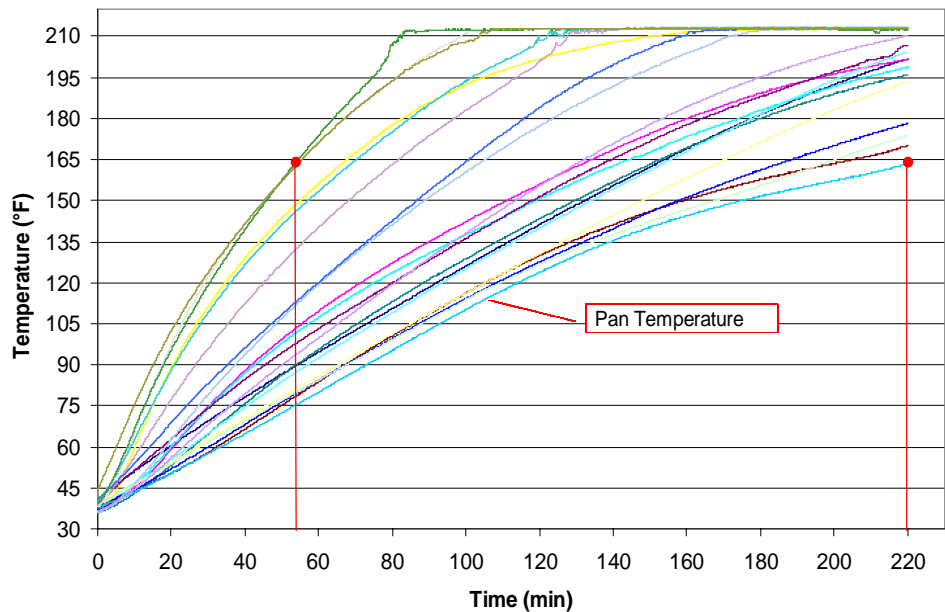


Figure 3-1.
Unit A
rethermalization
uniformity.

Results

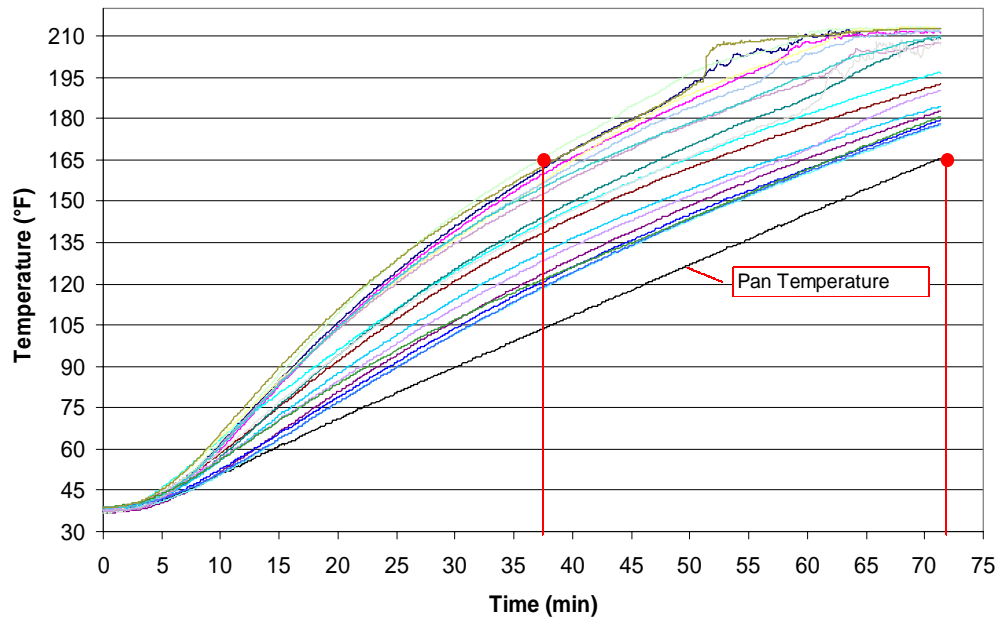


Figure 3-2.
Unit B
rethermalization
uniformity.

During the rethermalization uniformity tests in Unit C, the first pan to reach 165°F did so in 40.5 minutes. The hottest pan reached a final temperature of 186.0°F. The first pan to reach 165°F in Unit D did so in 38.2 minutes. The hottest pan reached a final temperature of 173.7°F. The rethermalization uniformity tests performed on both ovens are illustrated in Figures 3-3 and 3-4.

Results

Figure 3-3.
Unit C
rethermalization
uniformity.

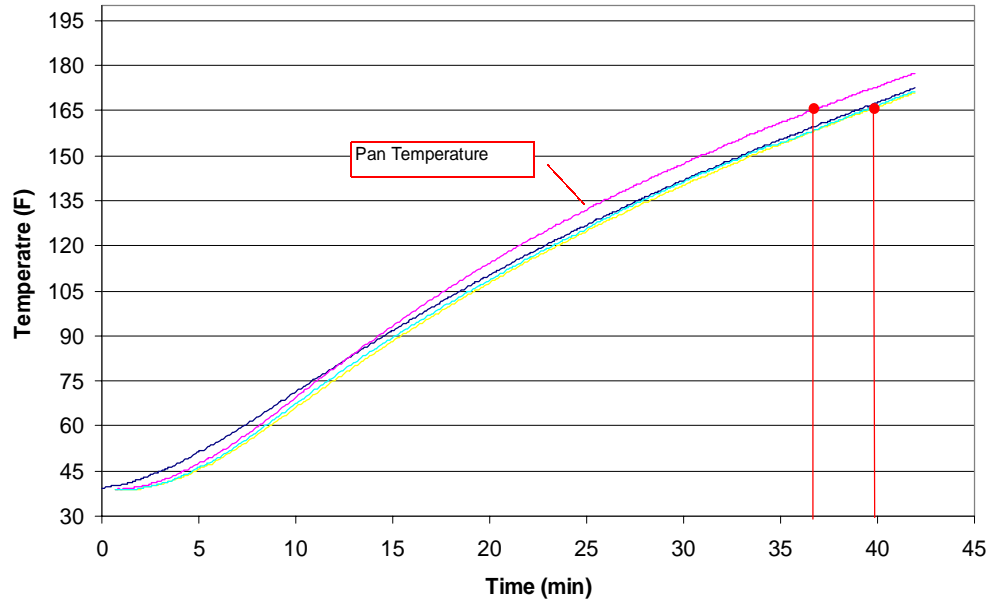
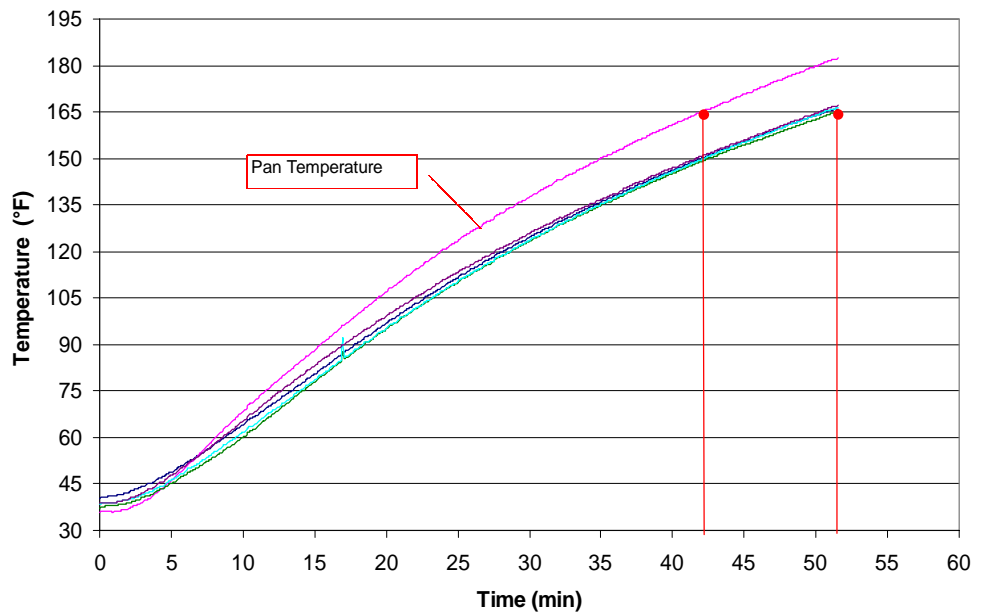


Figure 3-4.
Unit D
rethermalization
uniformity.



Results

Energy Cost Model

The test results can be used to estimate the operating cost of the four ovens in a real-world operation. The cost model assumed the oven operated 12 hours per day for 365 days. During each 12-hour period the oven was pre-heated once and rethermalized 200 pounds of food. The cost model assumed the oven idled for the remainder of the 12-hour period. The actual dollar cost was determined using an electric utility rate of \$0.15/kWh. Tables 3-5 and 3-6 summarize the estimated annual cost of operation for each of the ovens.

Table 3-5. Estimated Large Oven Energy Cost

	Oven A	Oven B
Avg. Energy Consumption Rate (kW)	2.8	3.2
Daily Energy consumption Rate (kW)	33.6	37.9
Annual Energy Consumption (kWh)	12,254 ^a	13,830 ^a
Annual Cost (\$/year)	1838^b	2074^b

^a 1 kW = 1,000 W

^b Oven energy costs are based on \$0.15/kWh.

Table 3-6. Estimated Small Oven Energy Cost

	Oven C	Oven D
Avg. Energy Consumption Rate (kW)	1.3	1.6
Daily Energy consumption Rate (kW)	16.0	19.7
Annual Energy Consumption (kWh)	843 ^a	7202 ^a
Annual Cost (\$/year)	876^b	1080^b

^a 1 kW = 1,000 W

^b Oven energy costs are based on \$0.15/kWh.

4 Convection Oven Testing

In many respects, retherm ovens are similar in design and function to convection ovens. In order to assess the rethermalization capabilities of a convection oven, researchers at the Food Service Technology Center (FSTC) applied the rethermalization test to a 10-pan capacity, 80,000 BTU/h input, gas, convection oven.

The convection oven had a retherm time of 42.9 minutes, resulting in a production capacity of 140 lb/h. The oven exhibited a retherm-energy efficiency of 37.5%.

The gas convection oven had an estimated annual operating cost of \$657. This cost estimate was determined using the same cost model to calculate the estimated operating costs for the retherm ovens.

The test results and estimated operating cost are summarized in Table 4-1.

Table 4-1. Convection Oven Test Results

Retherm Time (min)	42.9
Production Capacity (lb/h)	140 ± 2.7
Retherm Energy Rate (kBtu/h)	40
Retherm-Energy Efficiency (%)	37.4 ± 1.0
Annual Cost of Operation (\$)	657 ^a

^a Cost estimate based on a gas utility rate of \$0.70/therm.

Convection Oven Testing

Analysis of the convection oven's rethermalization uniformity showed that the first pan reached 165°F in 25.8 minutes. At that point, the pans in the cavity ranged from 121°F to 165°F. The rethermalization uniformity tests performed on the convection oven are illustrated in Figure 6.

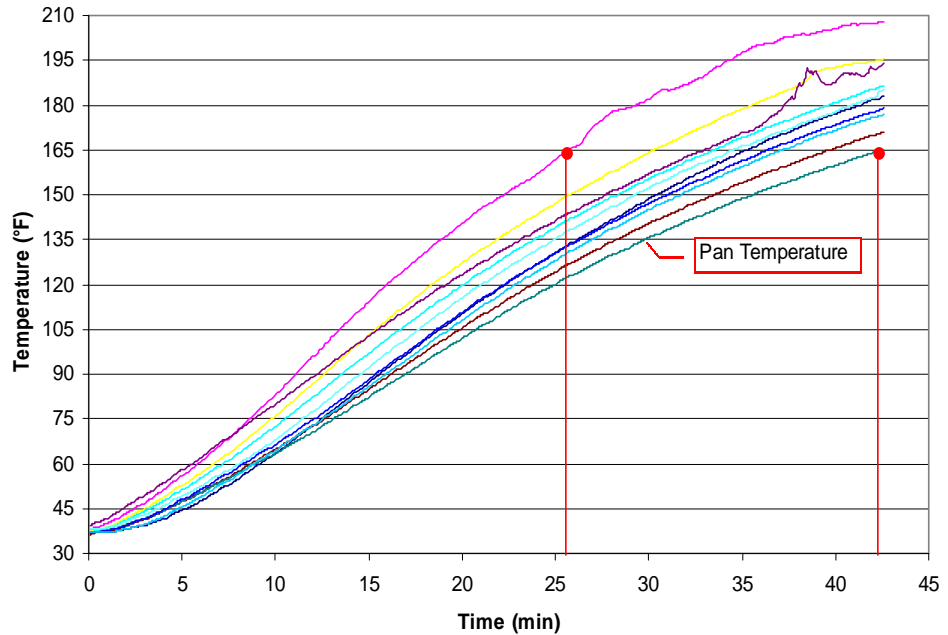


Figure 4-1.
Convection oven rethermalization uniformity.

The rethermalization performance of the convection oven suggests that it may be a viable alternative to a retherm oven. Careful consideration must be given to the installation requirements of a gas appliance, such as the availability of gas lines and ventilation of flue gases from the kitchen space. Convection ovens are readily available in electric versions, however, and these could be operated without a ventilation hood if operated in a rethermalization capacity only. Although the researchers at the FSTC only tested a gas oven, the gas oven's test results serve as a good indicator of an electric oven's performance capabilities.

5 Conclusion

As a result of the stringent application of a standardized test method on the four retherm ovens, researchers at the Food Service Technology Center (FSTC) were able to provide the institutional food service program requesting this study with a comprehensive assessment of the appliances' operating characteristics. The test results documented in this study provide insight into the capabilities of the competing ovens and whether they will satisfy the needs of the various satellite kitchen environments.

Testing of the two large ovens, Unit A and Unit B, revealed a significant disparity in performance. Most notable was the difference in retherm times and resulting production capacities of the two ovens. Unit B had a production capacity of 185 lb/h, over three times greater than the larger Unit A (60 lb/h). With a retherm-energy efficiency of 55.2%, Unit B was able to transfer 20% more of its available energy to the food product than Unit A, which exhibited a retherm-energy efficiency of 36.6%. Although Unit A had a lower estimated annual operating cost, its low production capacity may not satisfy a facility's menu demands.

The low retherm energy rate exhibited by Unit A suggests the oven has the potential to rethermalize the chili at a faster rate. An increase in the unit's rethermalizing cabinet fan power and redesign of the heat distribution ductwork could improve the unit's retherm performance. The performance of Unit B, C and D demonstrated the design

Conclusion

advantages of placing the heating elements and fan inside the rethermalizing cabinet. This design effectively forces air across the hotel pans, especially those pans located in center area of the rethermalizing cabinet. The low convective airflow of Unit A inhibited the oven's ability to heat the pans in the center area of the cabinet. Unit A could also benefit from improved thermostatic control and repositioning of the thermostat probe.

The two small ovens, Unit C and Unit D, exhibited comparable performance characteristics. The greatest difference between the two was seen during the preheat tests; Unit C was able to reach full operating capacity in 3.25 minutes, compared to the 6.17 minute preheat time for Unit D. Although Unit D had a shorter retherm time (41.1 minutes vs. 50.4 minutes), both ovens exhibited approximately the same production capacity (60 lb/h), due to unit C's larger pan capacity. Both of the small ovens exhibited competitive retherm-energy efficiencies, 58.1% and 63.1%, respectively. With its slightly lower idle and retherm energy rates, Unit C should cost approximately 19% less to operate than Unit D. In view of their comparable performance characteristics, other attributes, such as usability, ease of cleaning and safety should be considered before selecting one unit over the other.

Convection ovens present a viable alternative to retherm ovens, as shown by the application of the test method by researchers at the FSTC. The gas convection oven proved to be a productive appliance when tasked with rethermalizing 10 pans of chili (140 lb/h). Although the gas convection oven was less efficient compared to three of the electric retherm ovens, the lower utility cost associated with natural gas made the oven less expensive to operate, \$657 annually. Convection ovens can also operate at higher maximum temperatures

Conclusion

than retherm ovens, 500°F versus 350°F, giving them greater versatility in the kitchen.

Ultimately, this study serves to provide an unbiased assessment of each retherm oven's operating characteristics. The data provided should allow the institution operators to determine whether or not the ovens will satisfy their kitchen needs and what impact the oven's operation will have on utility costs.

A Glossary

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.

Idle Energy Rate (kW or Btu/h)

Idle Energy Input Rate

Idle Rate

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

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”).

Preheat Energy (kWh or Btu)

Preheat Energy Consumption

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

Preheat Rate (°F/min)

The rate at which the cook zone heats during a preheat.

Preheat Time (minute)

Preheat Period

The time required for an appliance to warm from the ambient room temperature ($75 \pm 5^\circ\text{F}$) to a specified (and calibrated) operating temperature or thermostat set point.

Glossary

Production Capacity (lb/h)

The maximum production rate of an appliance while rethermalizing 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 “rethermed” 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.

Retherm Energy (kWh or kBtu)

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

Retherm Energy Consumption Rate

(kW or kBtu/h)

The average rate of energy consumption during the rethermalizing period.

Retherm-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 rethermalization event.

Retherm Time (minutes)

The amount of time required by the appliance to rethermalize the food product to a predetermined retherm temperature.

Test Method

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

Typical Day

A sampled day of average appliance usage based on observations and/or operator interviews, used to develop an energy cost model for the appliance.

B Results Reporting Sheets

Test Ovens

Description of operational characteristics: All four retherm ovens were of stainless steel construction. Unit A had its heating elements in a separate compartment above the rethermalizing cabinet though which air was circulated in and out of the rethermalizing cabinet. Unit B, C, and D had the heating elements inside the rethermalizing cabinet around a squirrel cage type fan.

Apparatus

Check if testing apparatus conformed to specifications in section 2.

Deviations: None.

Energy Input Rate.

	Unit A	Unit B	Unit C	Unit D
Name Plate (kW)	24.0	22.8	8.5	6.8
Measured (kW)	24.0	22.0	8.4	6.7
Percentage Difference (%)	0.0	3.5	1.1	1.4

Preheat Energy and Time

	Unit A	Unit B	Unit C	Unit D
Duration (min)	6.92	3.17	3.25	6.17
Energy Consumption (kW)	1720	1080	440	580

Results Reporting Sheets

Idle Energy Rate

	Unit A	Unit B	Unit C	Unit D
Idle Energy Rate @ 275°F (kW)	1.3	1.6	0.5	0.8
Idle Duty Cycle %	5.4	7.0	5.8	11.7

Retherm Oven Retherm-Energy Efficiency and Retherm Energy Rate

	Unit A	Unit B	Unit C	Unit D
Load Size (lbs)	22.0	20.0	50.0	40.0
Retherm Time (min)	217.5	65.0	50.4	41.1
Production Capacity (lb/h)	60 ± 2.6	185 ± 10.7	60 ± 4.3	58 ± 5.2
Energy to Food (Btu)	20,577	18,891	4721	3737
Energy to Pan/Lid (Btu)	1525	1397	354	281
Energy to Oven (Btu)	60,933	36,974	8032	6917
Retherm Energy Rate (kW)	4.9	10.0	2.8	3.0
Retherm-Energy Efficiency (%)	36.6 ± 1.0	55.2 ± 2.0	63.1 ± 2.0	58.4 ± 1.0

Convection Oven Retherm-Energy Efficiency and Retherm Energy Rate

Load Size (lbs)	100.0
Retherm Time (min)	42.91
Production Capacity (lb/h)	140 ± 2.7
Energy to Food (Btu)	10,707
Energy to Oven (Btu)	28,595
Retherm Energy Rate (Btu/h)	39,9967
Retherm-Energy Efficiency (%)	37.4 ± 1.0

C Cooking-Energy Efficiency Data

Table D-1. Specific Heat and Latent Heat.

Specific Heat (Btu/lb, °F)	
Fat	0.400
Solids	0.200
Chili con carne	0.74
Latent Heat (Btu/lb)	
Fusion, Water	144
Fusion, Fat	44
Vaporization, Water	970

Cooking-Energy Efficiency Data

Table D-2. Unit A Retherm Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Wh)	18,260	17,260	18,040
Retherm Time (min)	223.3	208.8	225.75
Initial Weight (lb)	220.0	220.0	220.0
Initial Temperature (°F)	38.4	39.1	38.3
Final Temperature (°F)	165.0	165.0	165.0
Calculated Values			
Sensible (Btu)	20,577	20,491	20,632
Total Energy to Food (Btu)	20,577	20,491	20,632
Energy to Food (Btu/lb)	94	93	94
Energy to Pan/Lid (Btu)	1527	1518	1529
Total Energy to Oven (Btu)	60,933	58,908	61,571
Energy to Oven (Btu/lb)	277	268	280
Retherm-Energy Efficiency (%)	36.3	37.4	36.0
Retherm Energy Rate (kW)	4.9	5.0	4.8
Production Rate (lb/h)	59.1	63.2	58.5

Cooking-Energy Efficiency Data

Table D-3. Unit B Retherm Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Wh)	11,000	10,880	10,620
Retherm Time (min)	65.75	65.90	63.25
Initial Weight (lb)	220.0	220.0	220.0
Initial Temperature (°F)	36.8	37.5	37.8
Final Temperature (°F)	165.0	165.0	165.0
Calculated Values			
Sensible (Btu)	18,978	18,875	18,820
Total Energy to Food (Btu)	18,978	18,875	18,820
Energy to Food (Btu/lb)	86	86	86
Energy to Pan/Lid (Btu)	1403	1396	1392
Total Energy to Oven (Btu)	36,974	37,133	36,246
Energy to Oven (Btu/lb)	168	169	165
Retherm-Energy Efficiency (%)	54.3	54.6	55.8
Retherm Energy Rate (kW)	10.0	9.9	10.0
Production Rate (lb/h)	183.5	182.0	189.7

Cooking-Energy Efficiency Data

Table D-4. Unit C Retherm Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Wh)	2380	2360	2320
Retherm Time (min)	51.58	50.92	48.83
Initial Weight (lb)	50.0	50.0	50.0
Initial Temperature (°F)	38.2	36.2	37.9
Final Temperature (°F)	165.0	165.0	165.0
Calculated Values			
Sensible (Btu)	4693	4769	4702
Total Energy to Food (Btu)	4693	4769	4702
Energy to Food (Btu/lb)	94	95	94
Energy to Pan/Lid (Btu)	354	354	351
Total Energy to Oven (Btu)	8123	8055	7918
Energy to Oven (Btu/lb)	162	161	158
Retherm-Energy Efficiency (%)	62.1	63.6	63.8
Retherm Energy Rate (kW)	2.8	2.8	2.9
Production Rate (lb/h)	58.2	58.9	61.4

Cooking-Energy Efficiency Data

Table D-5 Unit D Retherm Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Wh)	2020	2020	2040
Retherm Time (min)	39.5	41.67	42.25
Initial Weight (lb)	40.0	40.0	40.0
Initial Temperature (°F)	38.8	39.1	38.4
Final Temperature (°F)	165.0	165.0	165.0
Calculated Values			
Sensible (Btu)	3735	3728	3748
Total Energy to Food (Btu)	3735	3728	3748
Energy to Pan/Lid (Btu)	281	281	282
Energy to Food (Btu/lb)	93	93	94
Total Energy to Oven (Btu)	6894	6894	6963
Energy to Oven (Btu/lb)	172	172	174
Retherm-Energy Efficiency (%)	58.3	58.2	57.9
Retherm Energy Rate (kW)	3.0	2.9	2.9
Production Rate (lb/h)	60.8	57.6	56.8

Cooking-Energy Efficiency Data

Table D-6 Convection Oven Retherm Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Total Energy (Btu)	29,512	28,503	27,769
Retherm Time (min)	43.87	42.20	42.46
Initial Weight (lb)	100.0	100.0	100.0
Initial Temperature (°F)	37.3	37.9	37.4
Final Temperature (°F)	165.0	165.0	165.0
Calculated Values			
Sensible (Btu)	10,727	10,676	10,718
Total Energy to Food (Btu)	10,727	10,676	10,718
Energy to Food (Btu/lb)	107	107	107
Total Energy to Oven (Btu)	29,512	28,503	27,769
Energy to Oven (Btu/lb)	295	285	278
Retherm-Energy Efficiency (%)	36.3	37.5	38.6
Retherm Energy Rate (Btu/h)	40,351	40,322	39,228
Production Rate (lb/h)	136.8	141.5	141.3