

Rapid Cook Oven Test Method Revision

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Executive Summary

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 are reviewed periodically to ensure they remain up to date and continue to produce results that are meaningful to both manufacturers and end users. The test method examined in this study is ASTM designation F2238-03, Standard Test Method for Performance of Rapid Cook Ovens.¹

With a new generation of rapid cook ovens gaining momentum in the market, it was decided to revisit the test procedures in the ASTM test method, particularly with respect to preheat, idle and cooking tests.

The first proposed change is the addition of a procedure that dictates temperature setpoint. First generation rapid cook ovens did not allow adjustment of oven temperature, whereas now the feature is fairly common. The test method should specify that the oven setpoint, if present, be the temperature recommended by the manufacturer for cooking refrigerated cheese pizza.

Another proposed change is removing the single pizza tests due to challenges in obtaining consistent results, mainly because of the short length of the test. The cooking-energy efficiency and production capacity would be determined during the barrel load pizza tests. The individual final pizza temperature requirement would be relaxed to $195 \pm 5^{\circ}\text{F}$, while the average of the final pizza temperatures would remain $195 \pm 3^{\circ}\text{F}$.

It is also proposed that the chicken breast tests be removed from the procedure due to similar difficulties in final temperature measurement. Removing the tests also simplifies the results by not presenting two cooking-energy efficiency numbers.

¹ American Society for Testing and Materials. 2003. *Standard Test Method for Performance of Rapid Cook Ovens*. ASTM Designation F2238-03, in *Annual Book of ASTM Standards*, West Conshohocken, PA.

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Table ES-1 shows the results generated by applying the procedure as currently written and the proposed procedure to an electric rapid cook oven. The oven used for this testing combined microwave and air impingement technologies, and was representative of the current generation of rapid cook ovens.

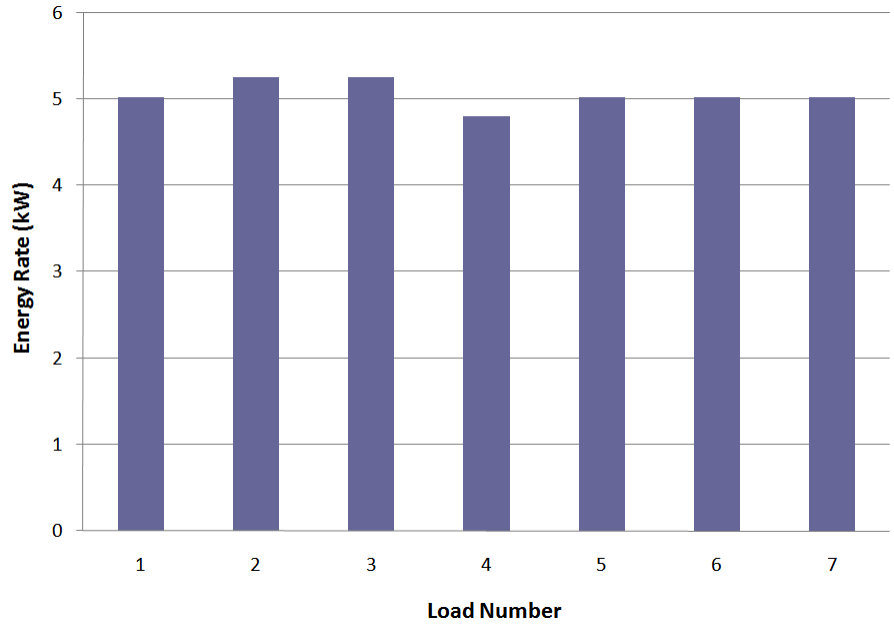
Table ES-1. Summary of Rapid Cook Oven Performance.

	Current Procedure	Proposed Procedure
Rated Energy Input Rate (kW)	5.5	5.5
Measured Energy Input Rate (kW)	5.3	5.3
Preheat to Operational Capacity (500°F):		
Time (min)	12.7	12.7
Electric Energy Consumption (Wh)	1040	1040
Idle Energy Rate @ 500°F (kW)	1.73	1.73
Pizza Tests:		
Cook Time (min)	1.75	1.75
Total Test Time (min)	2.5	17.4
Cooking Energy Rate (kW)	4.7	4.6
Oven Energy Consumption (Btu/lb)	475	399
Production Capacity (lb/h)	23.6 ± 0.8	27.5 ± 0.2
Cooking-Energy Efficiency (%)	29.8 ± 2.9	35.0 ± 1.0
Chicken Tests:		
Cook Time (min)	4.3	-
Total Test Time (min)	6.2	-
Cooking Energy Rate (kW)	4.6	-
Oven Energy Consumption (Btu/lb)	760	-
Production Capacity (lb/h)	20.7 ± 0.8	-
Cooking-Energy Efficiency (%)	37.6 ± 1.3	-

It is recommended the language describing the operation of the oven during the barreling test be changed to be consistent with the operation of current-generation rapid cook ovens. The procedure assumes a barreling test will produce declining energy rates for subsequent loads, due to heat build-up in the

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oven. As shown in Figure ES-1, this is not necessarily true for the latest models of rapid cook ovens.



*Figure ES-1.
Energy Rate by Load.*

1 Introduction

Background

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 are approved and ratified by the American Society for Testing and Materials (ASTM) and allow the benchmarking of equipment performance and energy use under laboratory conditions. The foodservice operator benefits by knowing how the new appliance may impact their energy bill and whether its performance can keep up with the demands of the kitchen.

The test methods are reviewed periodically to ensure they remain up to date and continue to produce results that are meaningful to both manufacturers and end users. The test method examined in this study is ASTM designation F2238-03, Standard Test Method for Performance of Rapid Cook Ovens.¹

Rapid cook oven technology has evolved since the Standard Test Method was developed and appliance design and operation has been refined. New players have entered the market, with countertop designs using a combination of microwave energy and air impingement dominating the offerings.

The test method characterizes rapid cook oven performance by preheat duration and energy consumption, idle energy rate, cooking-energy rate, cooking-energy efficiency and production capacity. The 2003 version of the method specifies two food products for the cooking energy efficiency tests. In addition to the second food product, the cheese pizza test is conducted under single-load and barrel-load conditions.

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

Objectives

The objective of this study was to examine ASTM designation F2238-03, Standard Test Method for Performance of Rapid Cook Ovens by applying the

Introduction

procedure to a current generation rapid cook oven, and to make recommendations for improving the repeatability of the test results while simplifying the overall procedure.

To validate the proposed changes in the test method, four oven models from separate manufacturers were subjected to the revised procedures, but for simplicity, the results from only one of the ovens is presented here.

Appliance Description

The oven documented in this report was an electric-powered, countertop rapid-cook oven utilizing a combination of microwave energy and air impingement technologies. Food is placed on a wire rack where hot air is impinged from both the top and bottom of the product. The oven operates using programmable microprocessor control with an operating temperature of 350 to 500°F. The oven had an input rate of 5.5kW and was a ventless design incorporating a built-in catalytic converter.

2 Methods

Setup and Instrumentation

The rapid cook oven was installed in accordance with the manufacturer's instructions in a conditioned test space. The room was maintained at an ambient condition of $75 \pm 5^\circ\text{F}$ during testing. Energy was measured with a watt/watt-hour transducer that generated a pulse for each 10 Wh used. The transducer was connected to a computerized data acquisition unit that recorded data every 5 seconds.

Energy Input Rate

The energy input rate was determined by turning the oven on and measuring the energy consumed from the time the oven first began operating until the heating elements first cycled off. The energy consumed and the time elapsed were used to calculate the maximum energy input rate.

Preheat and Idle Tests

The 2003 version of the test method does not dictate a procedure for adjusting oven temperature. At the time the test method was developed, rapid cook ovens did not employ controls based on a temperature setpoint.^{2,3,4} Current generation ovens now typically include this ability.^{5,6,7,8}

For the oven used in this study, cavity temperature was adjustable from 350 to 500°F. Because the oven manufacturer's recommended temperature for cooking both chicken breasts and cheese pizza was 500°F, the oven was set to 500°F for all tests, including preheat and idle.

The preheat test recorded the time and energy required for the oven to increase the cavity temperature from $75 \pm 5^\circ\text{F}$ to a ready-to-cook state, as indicated by the oven display, with the oven set to 500°F. Recording began when the oven was first turned on, so any time delay before the powering of the heating elements was included in the test.

Methods

After the oven preheated, it was allowed to stabilize for one hour, and then idle energy was monitored for a two-hour period with the oven set to 500°F.

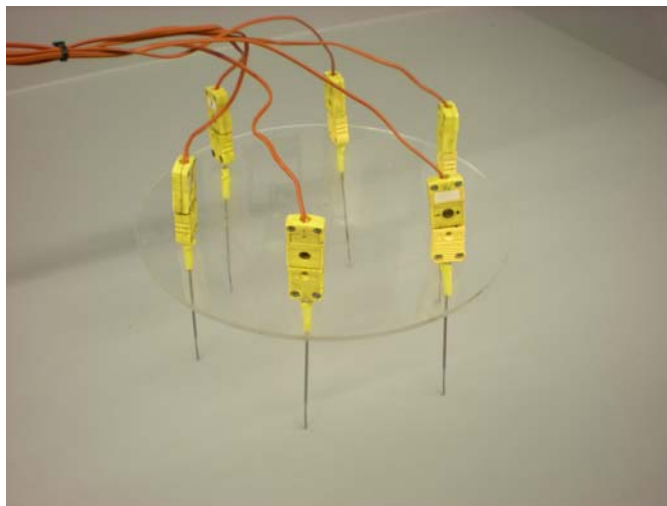
Cooking Tests

The cooking-energy efficiency and production capacity tests were conducted as specified by the 2003 test method. The two food products were cheese pizzas and chicken breasts. The cheese pizzas consisted of a 12-inch, par-baked pizza crust, simple tomato-based sauce and shredded mozzarella cheese. Chicken breasts were boneless and skinless with a nominal weight of 5-ounces each.

Pizza Tests

Pizzas were placed on a manufacturer-supplied cooking mat before being placed in the oven. The cooking recipe was determined experimentally along the manufacturer's guidelines to produce an acceptable combination of short cook time and final product quality.

Pizzas were cooked from a temperature of $38 \pm 2^\circ\text{F}$ to a final temperature of $195 \pm 3^\circ\text{F}$. Final pizza temperature was determined after removal from the oven using a rig consisting of six thermocouple probes held equidistant from one another and 3-inches from the center of the pizza (Figure 2-1).



*Figure 2-1.
Temperature Probes.*

Methods

Chicken Tests

Each chicken test consisted of three chicken breasts placed on a manufacturer-approved, pressed paperboard tray that prevented grease and liquids from dripping into the oven. The cooking recipe was determined experimentally to produce an acceptable combination of short cook time and final product quality.

Chicken breasts were cooked from a temperature of $38 \pm 2^{\circ}\text{F}$ to a final temperature of $170 \pm 3^{\circ}\text{F}$. Final temperature was determined after removal from the oven using a needle-type, sheathed thermocouple probe placed in the center of each chicken breast. The chicken test was performed a total of three times.

Barreling Energy Performance

The barreling energy performance test was performed as per the procedure in the test method. The barreling tests measured the oven's energy performance while the oven was used to cook eight individual pizza loads in succession. Fifteen seconds was allowed between each pizza for unloading and reloading of the oven. Final pizza temperature was determined by averaging the eight individual final pizza temperatures.

3 Results

Energy Input Rate

The measured energy input rate for the rapid cook oven was 5.3 kW— 1.8% lower than the nameplate rate of 5.5 kW, but within the 5% tolerance of the ASTM test method.

Preheat and Idle Rate Tests

At the time the test method was developed, rapid cook ovens operated using power levels, similar to a home microwave, and did not have adjustable cavity temperatures. At present, rapid cook ovens still incorporate adjustable power levels, but also have the ability to adjust cavity temperature based on a thermostat setpoint, similar to a conventional oven. It is proposed that the procedure state that for an oven with an adjustable temperature setpoint, the oven shall be set to the oven manufacturer's recommended temperature for cooking refrigerated cheese pizza.

During this study, the recommended oven temperature for cheese pizza was 500°F, and was used as the setpoint for preheat and idle tests. The oven reached an indicated ready-to-cook state in 12.7 minutes. The energy consumption during the preheat test was 1040 Wh.

The idle energy consumption rate while maintaining a ready-to-cook state at 500°F was 1.73 kW. Table 3-1 summarizes the results from the input, preheat and idle tests on the rapid cook oven.

Results

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

Rated Energy Input Rate (kW)	5.5
Measured Energy Input Rate (kW)	5.3
Preheat to Operational Capacity (500°F):	
Time (min)	12.7
Electric Energy Consumption (Wh)	1040
Idle Energy Rate @ 500°F (kW)	1.73

Cooking Tests

Single-Load Pizza Tests

During the single-load efficiency tests, pizzas cooked in 1.75 minutes. The recipe was a single stage of 40% microwave with a fan setting of 7. The cooking-energy efficiency was $29.8 \pm 2.9\%$ and the cooking energy rate was 4.7 kW. The tests showed a production capacity of 23.6 ± 0.84 lbs/h.

The single load pizza tests presented a challenge to obtaining a consistent final temperature. During such a short cooking event, the temperature of the pizza increased at a rate of nearly 1.5°F per second. This made the final temperature a rapidly moving target, and any small variance in the cook cycle would miss the tight $195 \pm 3^\circ\text{F}$ final temperature specified in the test method.

A second challenge is introduced by the oven's recovery period. After the short single-pizza test, recovery may consume as much energy as the cooking event itself. The recovery time and energy are included in the performance calculations, so cooking-energy efficiency and production capacity results are directly impacted by any difference in recovery.

Both of the above issues are introduced by the short cook time of the single-pizza test. When combined, they make it difficult to produce three test results within the 10% margin of error required by the test method.

Therefore, it is proposed that the single load pizza tests be dropped, and that pizza cooking-energy efficiency be determined during the barrel loading scenario. The eight loads of the barreling test allow final temperatures to be aver-

Results

aged, so there can be some variance in individual pizza temperatures while still meeting the final criteria. Recovery energy also becomes a much smaller fraction of the total energy consumed and has less impact on the final calculations.

Barreling Energy Performance

It is proposed that the barreling energy performance procedure be modified to include an energy efficiency calculation, and have the result reported as the cooking-energy efficiency of the oven. The barreling test would remain an eight-load test (one stabilization load and seven test loads) with 15 seconds between each load. To accommodate the variation in final pizza temperatures, the final temperature criteria for individual pizzas would be eased to $195 \pm 5^{\circ}\text{F}$, while the average of the seven test pizzas must still be $195 \pm 3^{\circ}\text{F}$.

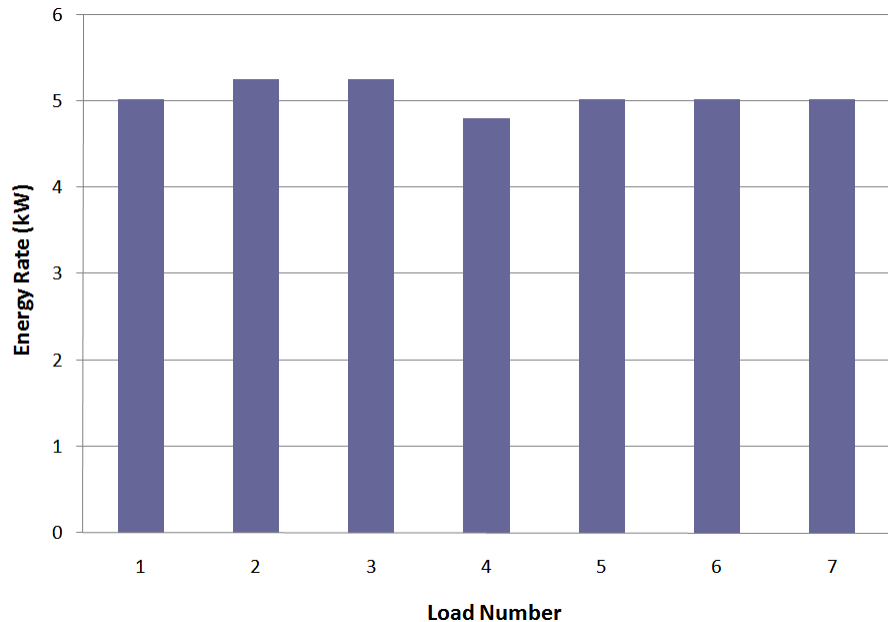
The length of the barrel-load test has two benefits which relate directly to the energy-efficiency and production capacity calculations. The longer test time minimizes the effect of small variances in energy consumption from load-to-load, as total energy is averaged across seven loads. Recovery energy has a smaller impact, as it becomes a much smaller percentage of the total energy consumed. Combined with the new final temperature criteria, the tests become easier to perform while producing more accurate and repeatable results.

When applied to the oven, the barreling procedure showed a cooking energy efficiency of $35.0 \pm 1.0\%$. The cooking energy rate was 4.6 kW and the production capacity was 27.5 ± 0.2 lbs/h.

The barreling energy test was originally incorporated to document a specific behavior of the first generation of rapid cook ovens. When the oven cooked food loads in succession, heat would build up and the energy rate typically began to drop for subsequent loads. The newer generation ovens do not necessarily exhibit this trait because control is now based on oven temperature. In fact, this oven demonstrated a slight increase in energy before stabilizing, as shown in Figure 3-1.

Results

It is recommended the language describing the operation of the oven during the barreling test be changed to drop the assumption that energy rates for subsequent loads will decrease.



*Figure 3-1.
Energy Rate by Load.*

Chicken Tests

During the chicken tests, the breasts were cooked in 4.3 minutes. The recipe was a single stage of 100% microwave with a fan setting of 9. The cooking-energy efficiency was $37.6 \pm 1.3\%$ and the cooking energy rate was 4.6 kW. The tests showed a production capacity of 20.7 ± 0.8 lbs/h and product shrinkage of 22.7%.

The chicken breasts presented an issue with temperature measurement as well. Because a single probe was used, a small variance in its position would return a temperature difference of up to 10°F, mostly due to stratification caused by the short cook time. This made it difficult to obtain a finished product in the proscribed temperature range without conducting many replicates, each of which had a suspicion of uncertainty.

Results

Since the barrel-load pizza test produced more consistent results, it is proposed that the chicken breast tests be removed from the test method. This would further simplify the procedure and eliminate reporting a second cooking-energy efficiency in the overall test results.

Table 3-2 summarizes the results of the cooking tests for the procedure as currently written, and for the procedure with the proposed changes.

Table 3-2. Summary of Rapid Cook Oven Performance.

	Current Procedure	Proposed Procedure
Pizza Tests:		
Cook Time (min)	1.75	1.75
Total Test Time (min)	2.5	17.4
Cooking Energy Rate (kW)	4.7	4.6
Oven Energy Consumption (Btu/lb)	475	399
Production Capacity (lb/h)	23.6 ± 0.8	27.5 ± 0.2
Cooking-Energy Efficiency (%)	29.8 ± 2.9	35.0 ± 1.0
Chicken Tests:		
Cook Time (min)	4.3	-
Total Test Time (min)	6.2	-
Cooking Energy Rate (kW)	4.6	-
Oven Energy Consumption (Btu/lb)	760	-
Production Capacity (lb/h)	20.7 ± 0.8	-
Cooking-Energy Efficiency (%)	37.6 ± 1.3	-

4 Conclusions

The Standard Test Method for Performance of Rapid Cook Ovens, ASTM designation F2238-03, would benefit from a streamlined procedure that recognizes the designs of the newest generation of rapid cook ovens.

Shifting the cooking-energy efficiency calculation to the barrel load pizza test while removing the single-load pizza and chicken breast tests would make the overall procedure easier and more cost effective to apply, while improving repeatability of the test replicates.

Changing the description of the operational characteristics of the rapid cook oven during the barreling test and adding an oven temperature setpoint procedure would acknowledge the advances that have been made in rapid cook oven control technologies over recent years.

Overall, the proposed changes would produce a tighter procedure with more consistent results, and keeps the test method up to speed with the appliance it is evaluating.

5 References

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A Glossary

Cooking Energy (kWh or kBtu)

The total energy consumed by an appliance as it is used to bake 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 product; expressed as a percentage of the quantity of energy input to the appliance during the cooking 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.

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 oven cavity heats during a preheat.

Glossary

Preheat Time (minute)

Preheat Period

The time required for an appliance to heat 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.

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.

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