

Conveyor 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 Conveyor Ovens.¹

The tests were conducted on a gas-fired, single deck conveyor oven with a belt width of 32" and a maximum rated input of 175,000 Btu/h. The oven incorporated a four-stage idle-energy saving feature to reduce gas and electric consumption while the oven was not cooking.

The test method needs to accommodate ovens incorporating energy-saving features during idle periods, and make clear which idle energy rate is reported for ovens with either manual or multiple energy-saving features. The test oven featured four idle modes. The first three modes were evaluated separately (the fourth mode was a hard shutdown) with a one-hour stabilization period before each test. The fourth A baseline test was conducted with the energy-saving features locked out. Idle test results are shown in Table ES-1.

Table ES-1. Idle-Energy Rate Test Results.

	Standard Idle	Second Stage Idle	Third Stage Idle	Baseline [†]
Gas Energy Rate (Btu/h)	37,464	29,773	0	51,244
Electric Energy Rate (kW)	0.640	0.600	0.030	1.260
Recovery Time (s)	0.0	30.6	varies	0.0

[†] Energy-saving features locked out; oven does not consume energy at this rate while idling.

¹ American Society for Testing and Materials. 2003. *Standard Test Method for Performance of Conveyor Ovens*. ASTM Designation F11817-03, in *Annual Book of ASTM Standards*, West Conshohocken, PA.

Executive Summary

It is recommended that the idle-energy rate procedure be revised as follows: if the oven incorporates an energy-saving mode, the test will be conducted one hour after cooking, in the mode the oven is *automatically* operating. If the oven incorporates a *manually* activated energy-saving feature, that feature may be evaluated and reported separately. If multiple idle modes are present, each mode may be evaluated and reported separately. The idle energy rate in the first stage of idle operation will be reported as the idle energy rate. Each idle test requires a one-hour stabilization period to precede it.

The heavy-load efficiency test determines the cooking-energy efficiency and production capacity under maximum loading conditions. However, the procedure may not represent the maximum loading conditions on all ovens and could be understating both energy efficiency and production capacity on these models.

Three tests were performed to determine the impact of an alternate loading pattern on cooking-energy-efficiency and production capacity. The first test followed the current procedure in the test method, using two rows of pizzas in a side-by-side arrangement. The second test used 16" pizzas in place of the 12" pizzas to cover the conveyor more completely. The third test used 12" pizzas in a staggered loading pattern. The staggered loading added a third row of pizzas just behind and, at a 45-degree angle to, the two rows dictated by the test method.

The results from each test are shown in Table ES-1.

Executive Summary

Table ES-1. Cooking-Energy Efficiency and Production Capacity Test Results.

	Current	Alternate 1	Alternate 2
Pizza Size	12"	16"	12"
Pizza Orientation	Parallel	Parallel	Staggered
Number of pizzas	20	16	30
ASTM Measured Cook Time (mm:ss)	4.50	4.50	4.50
Test Time (minutes)	6.79	6.58	7.43
Gas Cooking Energy Rate (Btu/h)	82,500	99,920	98,280
Electric Cooking Energy Rate (kW)	1.21	1.24	1.24
Energy Efficiency (%)	39.5 ± 2.0	49.4 ± 3.6	47.8 ± 3.9
Production Capacity (pizzas/h)	176.8 ± 1.5	145.9 ± 8.5	242.3 ± 18.3
Production Capacity (lb/h)	262.0 ± 0.9	368.5 ± 24.6	358.5 ± 27.4

Of the two alternate loading options, the staggered loading using 12" pizzas had distinct advantages over the 16" pizza test. Using the same diameter pizza for all ovens is highly preferable to one size for certain ovens and another size for others. With multiple pizza sizes, comparing production capacities in pizzas per hour (the industry standard) could be confusing. The larger number of pizzas used for the 12" staggered test showed the highest production capacity (in pizzas/h). Also, the procedure for staggering the 12" pizzas translates neatly to ovens of any conveyor width, where the 16" pizzas are useful only on conveyors whose widths are multiples of 16". For an oven with a conveyor width of 30", a 16" pizza test would not be applicable.

It is therefore recommended that the heavy-load test procedure be revised to state that pizzas may be loaded at an angle between 0° and 45° to maximize belt coverage.

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 F1817, Standard Test Method for Performance of Conveyor Ovens.¹

An important component of conveyor oven energy consumption is the idle energy use. Idle energy is measured after the oven is preheated and stabilized in a ready-to-cook state. New conveyors ovens may have multiple energy saving strategies during idle, and some may be based on timers or operator input. The test method needs to clearly state how to evaluate these modes, if present.

The heavy-load efficiency test determines the cooking-energy efficiency and production capacity under maximum loading conditions. However, the current procedure may not represent the maximum loading conditions on all ovens and could be understating both energy efficiency and production capacity on these models.

The test method specifies 12" cheese pizzas as the test product. The 12" pizza diameter was chosen because three pizzas fit comfortably on the 36" wide conveyors that were prevalent at the time. The 12" pie was also a standard

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size for the industry, making the crusts readily available. The testing of two ovens with 36" conveyor widths is documented in separate FSTC performance reports.^{2,3}

Testing with a larger pizza was first explored during the evaluation of a conveyor oven with a 32" belt width.⁴ In that case, the oven responded to 16" diameter pizzas with improved cooking-energy efficiency and production capacity numbers. Based on the results, the recommendation was made to consider different pizza sizes to best fit the particular oven under test.

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

Objective

The objective of this study was to examine of the cooking-energy efficiency procedure in ASTM designation F1817, Standard Test Method for Performance of Conveyor Ovens, and make recommendations for its improvement.

Appliance Description

The conveyor oven used in this study was a gas-fired, single deck conveyor oven with a belt width of 32" and a maximum rated input of 175,000 Btu/h. The oven incorporated a three-stage idle-energy saving feature to reduce gas and electric consumption while the oven was not cooking.

2 Methods

Setup and Instrumentation

Installation of the conveyor oven was in accordance with the ASTM test method. The oven was positioned under a 10-foot by 5-foot wall mounted canopy hood, with the lower edge of the hood mounted at 78 inches above the floor. The exhaust ventilation operated at a nominal rate of 3,000 CFM, or 300 CFM per linear foot of hood.

Gas consumption was measured using a positive displacement gas meter and power and energy were measured with a watt/watt-hour transducer. Temperature measurement of the cooked pizzas as well as measurement of the oven cavity temperature was accomplished using a data acquisition system that recorded data at 5-second intervals.

The oven was verified to be operating within 5% of its maximum rated input and the temperature calibrated to 475°F, as specified by the test method.

Idle Energy-Rate Discussion

Idle energy rate is determined after the oven has been preheated to operating temperature and stabilized for one hour. Because conveyor ovens lose a large amount of heat through the end openings, an opportunity exists to lower the idle energy use significantly. The test oven incorporated a laser “eye” to sense when food was loaded onto the conveyor. Based on the cook time, the oven was able to determine when the food had completed cooking. After the food exited the cooking chamber, the oven automatically reduced its fan speed to minimize the amount of heat forced out the end openings. This was the ovens standard idle mode. When the next food item was placed on the conveyor, the fan speed increased and cooking could resume.

The oven had three additional idle stages which could be programmed to engage after specific lengths of time, or not at all.

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The second stage reduced the oven's temperature to 100°F below the operating set-point and stopped the conveyor. After sensing a food load, the oven increased the fan speed but did not resume conveyor movement until the oven had reached operating temperature. This ensured the oven would not allow food to be under cooked.

The third stage shut the fan and gas burners off entirely. This mode allowed the oven to slowly cool for an indefinite period, but would resume operation if food was placed on the conveyor. As with the second stage, the conveyor would not move until operating temperature was reached.

The fourth stage was equivalent to a "hard" shutdown, and the operator would need to push the on/off switch to resume oven operation.

The test method needs to include procedures to evaluate these additional modes, and to specify which number is reported as the oven's idle energy consumption.

Idle Energy-Rate Tests

The first idle test was conducted after the oven had preheated and stabilized at a temperature of 475°F for one hour. The oven had automatically reduced its fan speed and stopped the conveyor just after preheating. The second and third idle stages were locked out to ensure the oven remained in its standard idle mode. The test lasted for a period of two hours.

For the second idle test, the controller was programmed to enter the second stage idle mode for a period of three hours. This allowed for a one-hour stabilization period and a two hour test.

The third idle test placed the oven in its third-stage, soft-shut down mode to determine how much energy the controller used as it waited to detect food being loaded. The test was two hours in duration.

A final idle test was conducted as a baseline to evaluate the oven's idle performance in the absence of any energy-saving features. A piece of tape was

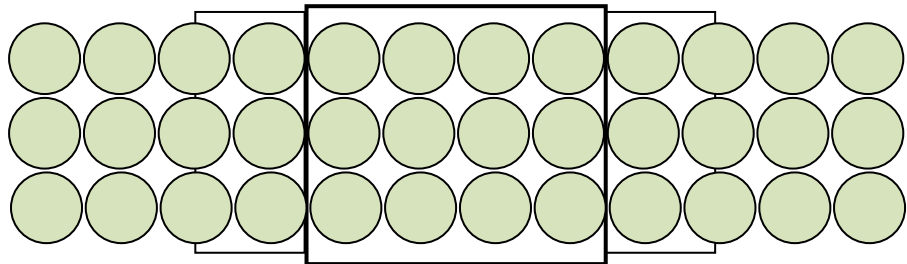
Methods

placed over the sensing eye to effectively lock the oven into continuous high-speed fan operation. This test also lasted a period of two hours

The incorporation of idle energy-saving features naturally raises questions of recovery times. If an oven requires a significant amount of time to return to a ready-to-cook condition, the speed of an operation could be impacted negatively. To address this concern, the oven was stabilized in the second stage (100°F lower set point, conveyor stopped) for one hour, then the sensor eye was tripped and the time to resume conveyor movement was measured.

Cooking Test Discussion

A conveyor oven's cooking-energy efficiency and production capacity are determined under heavy-load cooking conditions. The heavy load represents the maximum amount of food that can be reasonably placed on the oven when cooking for maximum throughput. The test method specifies 12" diameter pizzas placed in straight rows for the heavy-load test (Figure 2-1).



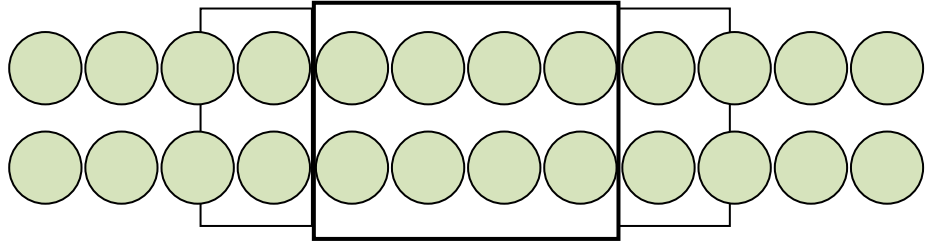
*Figure 2-1.
Pizza loading for 36"
conveyor width.*

This maximizes the loading for ovens with conveyor widths in multiples of 12". Very little surface area of the conveyor is left uncovered, maximizing the oven's ability to transfer heat to the food.

For a conveyor width that is not an even multiple of 12", the nominal width is determined by rounding down to the nearest 12". This results in an oven with a conveyor width of 32" being tested with two rows of pizzas (Figure 2-2).

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*Figure 2-2.
Pizza loading for 32"
conveyor width.*



Much less of the total conveyor area is covered when compared to the loading on the 36" oven. As a result, the test may not be showing the highest cooking-energy efficiency the oven can achieve. Production capacity is also a concern, as the 32" oven would show no increase in throughput when compared to a 24" oven (assuming equal cook times).

The goal of the test method is to dictate a procedure that is as fair as possible to ovens of any width. This requires a loading pattern that minimizes unused space on all ovens, regardless of size. The procedure needs to use readily available ingredients and not be overly complicated to understand and apply. Using the same diameter pizzas for all ovens would be preferable, but is not an absolute requirement.

Cooking Tests

Three heavy-load tests were performed, starting with a baseline test using 12" pizzas in the side-by-side loading dictated by the test method.

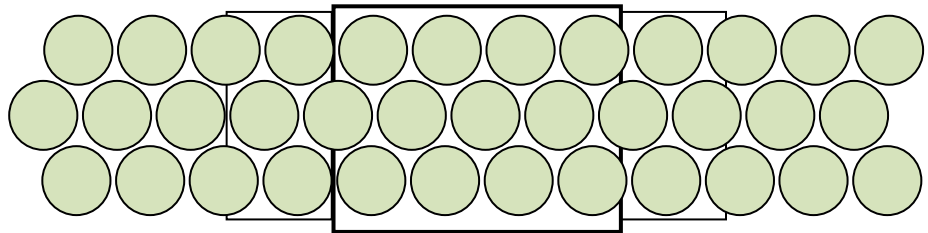
The second test used 16" pizzas, also in a side-by-side arrangement. The amounts of sauce and cheese were adjusted in proportion to the increase in diameter of the crust to create a comparable up-sized specification. Apart from the increase in pizza size, the heavy-load test procedure in the test method was followed as written.

The third test was designed for maximum loading while retaining the 12" pizza specification in the test method. Maximum loading was achieved by placing two pizza rows up against the edges of the conveyor, and adding a third row of pizzas in the space between them. The center row was placed

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behind the two outside rows at an angle of approximately 45 degrees. This layout was referred to as a staggered loading pattern, due to the offset leading edge of the center pizza row. The staggered loading pattern for the test oven is illustrated in Figure 2-3.

*Figure 2-3.
Staggered loading using
12" pizzas.*



The number of pizzas in the staggered load was determined from the tables in the test method and then adding 50% for the center row. For example, the test oven had a nominal conveyor width of 24", and a nominal oven cavity length of 60". The test method indicated 40 pizzas were required for each run of the heavy-load test. In the staggered loading pattern, these 40 pizzas comprised the two outer rows. The center row was then accounted for by adding an additional 20 pizzas for a total of 60 pizzas per heavy-load test run.

The number of pizzas for each heavy-load run would vary based on the belt width of the oven. Updating the tables in the test method to reflect the number of pizzas required for the staggered loading pattern would result in the numbers shown in Tables 2-1 and 2-2.

Table 2-1. Total Number of Pizzas Required for Each Run of a Heavy Load Test.

		Nominal Length, in.					
		12	24	36	48	60	72
Nominal Width, in.	12	4	8	12	16	20	24
	13 - 24	8	16	24	32	40	48
	25 - 36	12	24	36	48	60	72
	37 - 48	16	32	48	64	80	96

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Table 2-2. Total Number of Pizzas Required for a Complete Oven Test.

		Nominal Length, in.					
		12	24	36	48	60	72
Nominal Width, in.	12	24	36	48	60	72	84
	13 - 24	48	72	96	120	144	168
	25 - 36	72	108	144	180	216	252
	37 - 48	96	144	192	240	288	336

The addition of the extra pizzas did not affect the starting and stopping of the test time and energy consumption. The procedure in the test method was followed with the timing based on the two outside rows.

3 Results

Idle Energy-Rate Tests

The oven consumed gas at a rate of 37,464 Btu/h in the standard, low-fan speed idle mode. The electric energy consumption rate was 0.640 kW.

In the second stage idle mode with the oven set-point reduced by 100°F and the conveyor stopped, the gas energy rate dropped to 29,773 Btu/h with an electric energy rate of 0.600 kW. The tests to measure the recovery time to normal oven operation averaged 30.6 seconds.

The third stage, soft shut down mode consumed no gas and electric energy was used at a rate of 0.030 kW.

The baseline test with the energy-saving features overridden consumed 51,224 Btu/h and 1.260 kW. Note that the oven was forced to run in this state and this amount of energy would not be consumed during idle in normal operation.

The results of the idle energy-rate tests are summarized in Table 3-1.

Table 3-1. Idle-Energy Rate Test Results.

	Standard Idle	Second Stage Idle	Third Stage Idle	Baseline [†]
Gas Energy Rate (Btu/h)	37,464	29,773	0	51,244
Electric Energy Rate (kW)	0.640	0.600	0.030	1.260
Recovery Time (s)	0.0	30.6	varies	0.0

[†] Energy-saving features locked out; oven does not consume energy at this rate while idling.

Cooking Tests

The baseline test utilizing the 12" side-by-side loading procedure produced a cooking energy efficiency of 39.5% and a production capacity of 176.8 pizzas per hour. The cooking energy rate was 82,500 Btu/h. The belt speed was 3.83 minutes with a total test time of 6.79 minutes.

Results

A relatively large amount of conveyor area was left exposed on the sides of each row of pizzas. It was apparent the oven could handle a substantially heavier load.

The 16" pizzas covered the conveyor much more completely. The edges of the pizzas reached across the entire width of the conveyor, loading it to maximum capacity. The test showed an energy-efficiency of 49.4% while the production capacity was reduced to 145.9 pizzas per hour. The cooking energy rate was 99,920 Btu/h. Belt speed was 3.67 minutes with a total test time of 6.58 minutes.

With the staggered 12" pizzas, the oven was again presented with a much heavier load than the baseline test. There was a very small amount of empty conveyor, and the loading could be accurately described as maximum capacity. This test produced a cooking energy efficiency of 47.8% with a production capacity of 242.3 pizzas per hour. The belt speed was 3.83 minutes with a total test time of 7.43 minutes. The cooking energy rate was 98,280 Btu/h.

The results from each cooking test are included in Table 3-2.

Table 3-2. Cooking Test Results.

	Current	Alternate 1	Alternate 2
Pizza Size	12"	16"	12"
Pizza Orientation	Parallel	Parallel	Staggered
Number of pizzas	20	16	30
ASTM Measured Cook Time (mm:ss)	4.50	4.50	4.50
Test Time (minutes)	6.79	6.58	7.43
Gas Cooking Energy Rate (Btu/h)	82,500	99,920	98,280
Electric Cooking Energy Rate (kW)	1.21	1.24	1.24
Energy Efficiency (%)	39.5 ± 2.0	49.4 ± 3.6	47.8 ± 3.9
Production Capacity (pizzas/h)	176.8 ± 1.5	145.9 ± 8.5	242.3 ± 18.3
Production Capacity (lb/h)	262.0 ± 0.9	368.5 ± 24.6	358.5 ± 27.4

4 Conclusions

Evaluating the multiple idle-energy saving features was as simple as re-stabilizing the oven in each idle mode and then repeating the idle test. It is recommended that the idle-energy rate procedure be revised as follows: if the oven incorporates an energy-saving mode, the test will be conducted one hour after cooking, in the mode the oven is *automatically* operating. If the oven incorporates a *manually* activated energy-saving feature, that feature may be evaluated and reported separately. If multiple idle modes are present, each mode may be evaluated and reported separately. The idle energy rate in the first stage of idle operation will be reported as the idle energy rate. Each idle test requires a one-hour stabilization period to precede it.

During the energy-efficiency tests, both alternative loading scenarios showed a clear increase in energy efficiency over the two-row, side-by-side 12" pizza test. The increases were directly related to the more complete covering of the conveyor area with food product, allowing for a greater amount of heat to be transferred to the pizzas.

Of the two options, the staggered loading using 12" pizzas had distinct advantages over the 16" pizza test. Using the same diameter pizza for all ovens is highly preferable to one size for certain ovens and another size for others. With multiple pizza sizes, comparing production capacities in pizzas per hour (the industry standard) could be confusing. The larger number of pizzas used for the 12" staggered test showed the highest production capacity (in pizzas/h). Also, the procedure for staggering the 12" pizzas translates neatly to ovens of any conveyor width, where the 16" pizzas are useful only on conveyors whose widths are multiples of 16". For an oven with a conveyor width of 30", a 16" pizza test would not be applicable.

The 16" pizza test did produce the highest cooking-energy efficiency number by a slim margin, but the implications for the production capacity results and

Conclusions

the introduction of multiple product specifications overshadow the minor difference.

It is therefore recommended that the heavy-load test procedure be revised to state that pizzas may be loaded at an angle between 0° and 45° to maximize belt coverage. Tables indicating the number of pizzas required for each test will also be updated to reflect the change.

5 References

1. American Society for Testing and Materials, 1997. *Standard Test Method for Performance of Conveyor Ovens*. ASTM Designation F1817-03. In Annual Book of ASTM Standards, West Conshohocken, PA.
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3. Sorensen, D., Young, R., 1998. *Middleby Marshal Conveyor Oven, PS 360WB Conveyor Oven Performance Test*. Food Service Technology Center Report 5011.98.63, December.
4. Wilson, L., Zabrowski, D., 2006. *Q-Matic, Model Q-55 Conveyor Oven Performance Test*. Food Service Technology Center Report 5011.06.15, July.

Appendices

A Glossary

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.

Conveyor Speed (min)

Time required for a single point on the conveyor belt to travel through the oven cavity.

Cook Time (min)

Time required for an entire pizza to travel through the oven cavity, measured from the time when the leading edge of the pizza enters the oven cavity, to the time when the trailing edge of the pizza exits the oven cavity.

Cooking-Energy (kWh or kBtu)

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

Cooking-Energy Consumption Rate (kW or kBtu/h)

The average rate of energy consumption during the cooking period.

Cooking-Energy Efficiency (%)

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

Duty Cycle (%)

Load Factor

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

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

Energy Input Rate (kW or kBtu/h)

Energy Consumption Rate
Energy Rate

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

Heating Value (Btu/ft³)

Heating Content

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

Glossary

Idle Energy Rate (kW or Btu/h)

Idle Energy Input Rate
Idle Rate

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

Idle Temperature (°F, Setting)

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

Idle Duty Cycle (%)

Idle Energy Factor

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

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

Measured Input Rate (kW or Btu/h)

Measured Energy Input Rate
Measured Peak Energy Input Rate

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

Pilot Energy Rate (kBtu/h)

Pilot Energy Consumption Rate

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

Preheat Energy (kWh or Btu)

Preheat Energy Consumption

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

Preheat Rate (°F/min)

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

Preheat Time (minute)

Preheat Period

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

Production Capacity (lb/h)

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

Production Rate (lb/h)

Productivity

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

Glossary

Rated Energy Input Rate

(kW, W or Btu/h, Btu/h)

Input Rating (ANSI definition)

Nameplate Energy Input Rate

Rated Input

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

Recovery Time (minute, second)

The average time from the removal of the cooked food product from the appliance until the cooking cavity is within 10°F of the thermostat set point and the appliance is ready to be reloaded.

Test Method

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

B Cooking-Energy Efficiency Data

Table D-1. Physical Properties.

Specific Heat (Btu/lb °F)	
Pizza	0.593
Latent Heat (Btu/lb)	
Vaporization, Water	970

Cooking-Energy Efficiency Data

Table D-2. 12" Side-by-Side, Heavy-Load Pizza Efficiency Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Number of Pizzas	20	20	20
Conveyor Speed (min)	3.83	3.83	3.83
Initial Pizza Temperature (°F)	40.0	40.0	40.0
Final Average Pizza Temperature (°F)	197.3	195.6	196.4
Total Initial Pizza Weight (lb)	29.710	29.550	29.650
Total Final Pizza Weight (lb)	28.510	28.435	28.480
Test Time (min)	6.80	6.76	6.80
Gas Volume (ft ³)	9.5	9.5	9.5
Electric Energy (Wh)	140	140	140
Calculated Values			
Energy Consumed by Pizzas (Btu)	3,935	3,808	3,885
Gas Energy Consumed by Oven (Btu)	9,262	9,359	9,374
Electric Energy Consumed by Oven (Btu)	478	478	478
Total Energy Consumed by Oven (Btu)	9,740	9,837	9,851
Cooking Energy Efficiency (%)	40.4	38.7	39.4
Gas Cooking Energy Rate (Btu/h)	81,722	83,072	82,708
Electric Cooking Energy Rate (kW)	1.24	1.24	1.24
Production Rate (pizzas/h)	176.5	177.5	176.5
Production Rate (lb/h)	262.1	262.3	261.6

Cooking-Energy Efficiency Data

Table D-3. 16" Side-by-Side, Heavy-Load Pizza Efficiency Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Number of Pizzas	16	16	16
Conveyor Speed (min)	3.67	3.67	3.67
Initial Pizza Temperature (°F)	40.0	40.0	40.0
Final Average Pizza Temperature (°F)	197.2	197.6	196.5
Total Initial Pizza Weight (lb)	40.275	40.550	40.413
Total Final Pizza Weight (lb)	38.275	38.780	38.528
Test Time (min)	6.74	6.43	6.58
Gas Volume (ft ³)	11.5	10.5	11.0
Electric Energy (Wh)	140	136	139
Calculated Values			
Energy Consumed by Pizzas (Btu)	5,742	5,552	5,625
Gas Energy Consumed by Oven (Btu)	11,573	10,371	10,962
Electric Energy Consumed by Oven (Btu)	482	464	473
Total Energy Consumed by Oven (Btu)	12,055	10,835	11,434
Cooking Energy Efficiency (%)	47.6	51.2	49.2
Gas Cooking Energy Rate (Btu/h)	103,025	96,779	99,956
Electric Cooking Energy Rate (kW)	1.26	1.27	1.26
Production Rate (pizzas/h)	142.4	149.3	145.9
Production Rate (lb/h)	358.5	378.4	368.5

Cooking-Energy Efficiency Data

Table D-4. 12" Staggered, Heavy-Load Pizza Efficiency Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Number of Pizzas	30	30	30
Conveyor Speed (min)	3.67	3.67	3.67
Initial Pizza Temperature (°F)	40.0	40.0	40.0
Final Average Pizza Temperature (°F)	196.5	196.5	196.2
Total Initial Pizza Weight (lb)	44.375	44.440	44.360
Total Final Pizza Weight (lb)	42.325	42.515	42.410
Test Time (min)	7.70	7.30	7.30
Gas Volume (ft ³)	11.5	10.5	11.0
Electric Energy (Wh)	160	160	140
Calculated Values			
Energy Consumed by Pizzas (Btu)	6,131	6,015	6,024
Gas Energy Consumed by Oven (Btu)	11,883	12,047	12,559
Electric Energy Consumed by Oven (Btu)	546	546	478
Total Energy Consumed by Oven (Btu)	12,429	12,593	13,037
Cooking Energy Efficiency (%)	49.3	47.8	46.2
Gas Cooking Energy Rate (Btu/h)	92,596	99,017	103,228
Electric Cooking Energy Rate (kW)	1.25	1.32	1.15
Production Rate (pizzas/h)	233.8	246.6	246.6
Production Rate (lb/h)	345.8	365.3	364.6