Refrigerated Prep Table Performance Testing

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Executive Summary

Changes to the FDA model food code in 1999 required refrigerated prep tables to maintain food in the open display area below 41°F.[1] In response, manufacturers have employed a variety of stratagem for meeting this stricter requirement without freezing the food. With varying designs available, there is potential for a wide range of performance among different units. The Food Service Technology Center (FSTC) worked with a large restaurant chain in an effort to benchmark the performance of eight refrigerated prep tables.

The prep tables were tested under two conditions: with the lid up to represent standard operation, and with the lid down to represent nighttime use. The lid-up test was conducted according to the American Society for Testing and Materials' (ASTM) standard test method,[2] and involved loading the prep tables with simulated food product in the open display area. The lid-down test was conducted over an 8-hour period immediately following the lid-up test.

A summary of the test results is presented in Table ES-1. Energy rates varied from as high as 463 watts to as low as 208 watts during the lid up test. Differences in cabinet insulation, compressor size and design can account for the variations in average energy rates between each prep table. The lid-down results show a significant reduction in energy use for six of the eight prep tables during nighttime operation.

[1] US Department of Health and Human Services, Public Health Service, Food and Drug Administration, 1999. *Food Code*. U.S. Department of Commerce, Technology Administration, National Technical Information Service report number PB99-115925, 5285 Port Royal Road, Springfield, VA 22161

[2] American Society for Testing and Materials. 2000. *Standard Test Method for the Performance of Open, Deep Fat Fryers.* ASTM Designation F 1361-99, in *Annual Book of ASTM Standards,* West Conshohocken, PA.

Executive Summary

Table ES-1. Summary of Prep Table Performance.

	Lid-Up Test		Lid Down Test	
	Average Pan Temperature (°F)	Energy Rate (W)	Average Pan Temperature (°F)	Energy Rate (W)
Unit #1	36.2	208	39.6	151
Unit #2	37.1	376	37.3	298
Unit #3	37.0	268	38.6	167
Unit #4	35.3	463	34.7	232
Unit #5	36.5	304	38.5	255
Unit #6	35.4	423	35.6	413
Unit #7	35.5	334	35.0	324
Unit #8	39.1	386	35.6	281

Researchers developed an energy usage/cost model to estimate annual user costs. The model is based on operational energy use from both the lid-up and lid-down tests. The model assumed 12 operating (lid-up) hours per day, 365 days per year. Figure ES-1 compares the 5-year operating cost for all eight of the refrigerated prep tables, based on this model. With a two-to-one difference in operating costs, the incremental cost for a more efficient unit can be returned in energy savings over the life of the unit.

Although all eight units were capable of maintaining temperature, however, there was a significant difference in the energy consumption from unit to unit. This difference in energy use reflects different design strategies to manage the difficult task of maintaining the open pans between 33°F and 41°F without freezing the contents of the compartment.

The operating cost analysis shows the importance of knowing the energy use of a perspective appliance. Since the expected life of all eight refrigerated prep tables is the same, the difference in life cycle cost between the highest

(Unit #6) and lowest (Unit #1) energy users could add up to the purchase cost of a second appliance.

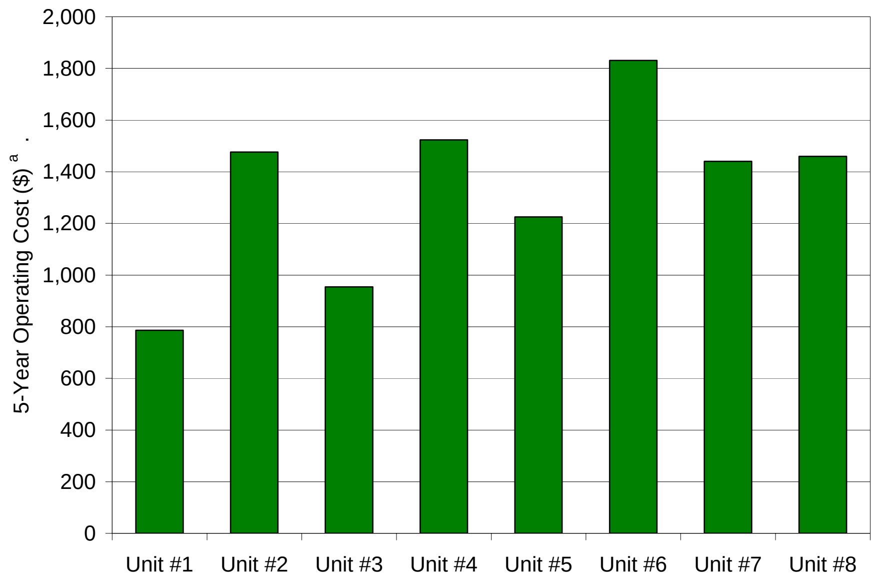

Figure ES-1.
5-year operating cost comparison.

[a] Operating costs are based on $0.10/kWh.

1 Introduction

Background

Many establishments rely on refrigerated prep tables to provide quick and easy access to commonly used refrigerated items. Changes to the FDA model food code in 1999 required refrigerated prep tables to maintain food in the open display area below 41°F. In response, manufacturers have employed a variety of stratagem for meeting this requirement without freezing the food.

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.

FSTC engineers previously conducted a bench-test to compare the performance of five different 48-inch refrigerated prep tables.[1] These test results showed a wide range in the energy consumption between different designs, leading the FSTC Advisory Board to recommend developing a comprehensive test method for quantifying the energy consumption and performance of these appliances. The draft test method was subsequently approved and ratified by ASTM as the *Standard Test Method for the Performance of Refrigerated Preparation and Buffet Tables* (Designation F2143-01). [2]

This study was part of a larger project with a major restaurant chain to benchmark the performance of the appliances typically used in their restaurants. Refrigerated preparation and buffet tables are widely used to have cold items readily available to cooks on the main line. In light of recent changes to the FDA model food code, it is doubly important to specify a unit that capably maintains the food below 41°F.

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 report is to examine the operation and performance of the selected 48-inch refrigerated prep tables, under the controlled conditions of the ASTM standard test method. The scope of this testing is as follows:

1. Verify that the appliance is operating at the manufacturer's rated energy input (current draw).
2. Document pan temperatures and appliance energy consumption with the lid in a raised (operating) position (ASTM test).
3. Characterize the idle energy use with the rail filled with product and the lid closed.
4. Estimate the operating cost based on a standardized cost model.

Appliance Description

Eight refrigerated prep tables were tested in the course of this study. The prep tables were nominally 4 feet wide, with an 18-pan capacity in the open display area. Each unit contained a refrigerated compartment underneath for additional storage. Specifications for the refrigerated prep tables tested are listed in Table 1-1.

Table 1-1. Appliance Specifications.

Unit #1	
External Dimensions	48" wide x 34" deep x 35 ½" high
Rail Pan Capacity	18 $^1/_6$-size pans
Compartment Dimensions	44" wide x 20" deep x 17 ½" high
Construction	Stainless-steel top, front sides and interior; galvanized steel rear and bottom panels
Unit #2	
External Dimensions	50" wide x 33" deep x 35" high
Rail Pan Capacity	18 $^1/_6$-size pans
Compartment Dimensions	26" wide x 25 ½" deep x 17 ½" high
Construction	Stainless-steel top, front sides and interior; galvanized steel rear and bottom panels
Unit #3	
External Dimensions	48" wide x 36" deep x 36" high
Rail Pan Capacity	18 $^1/_6$-size pans
Compartment Dimensions	45" wide x 27" deep x 26" high
Construction	Stainless-steel top, front sides and interior; galvanized steel rear and bottom panels
Unit #4	
External Dimensions	46 ½" wide x 34" deep x 35 ½" high
Rail Pan Capacity	18 $^1/_6$-size pans
Compartment Dimensions	41 ½" wide x 17" deep x 22" high
Construction	Stainless-steel top, front sides and interior; galvanized steel rear and bottom panels
Unit #5	
External Dimensions	48" wide x 31" deep x 34 ½" high
Rail Pan Capacity	18 $^1/_6$-size pans
Compartment Dimensions	44 ½" wide x 24 ½" deep x 24 ½" high
Construction	Stainless-steel top, front sides and interior; galvanized steel rear and bottom panels

Appliance Specifications Continued.

Unit #6	
External Dimensions	48¼" wide x 34" deep x 36" high
Rail Pan Capacity	18 1/6-size pans
Compartment Dimensions	44" wide x 24" deep x 20" high
Construction	Stainless-steel top, front sides and interior; galvanized steel rear and bottom panels
Unit #7	
External Dimensions	46 ½" wide x 34" deep x 35 ½" high
Rail Pan Capacity	18 1/6-size pans
Compartment Dimensions	41 ½" wide x 17" deep x 22" high
Construction	Stainless-steel top, front sides and interior; galvanized steel rear and bottom panels
Unit #8	
External Dimensions	50" wide x 33" deep x 35" high
Rail Pan Capacity	18 1/6-size pans
Compartment Dimensions	26" wide x 25 ½" deep x 17 ½" high
Construction	Stainless-steel top, front sides and interior; galvanized steel rear and bottom panels

2 Methods

Setup and Instrumentation

Laboratory Set-Up

Each refrigerated preparation table was installed in an insulated room in accordance with the provision of the ASTM test method. During testing, the room was held at 86 ± 2°F with a maximum relative humidity of 50%. Vertical temperature stratification was less than 1.5 °F per foot and the air velocity across the surface of the test pans was kept to below 50 ft/min.

Test Food Product

The tests were conducted using the industry standard $^{1}/_{6}$-size (1.6 liter or 1.5 quart capacity) stainless steel food pans, which were approximately 6 inches deep. Each pan was filled with a simulated food product (as specified by the ASTM test method) to ½ inch below the rim of the pan. The test food was a slurry of de-ionized water, salt, and hydroxypropyl methylcellulose (supplied by Dow Chemical under the trade name METHOCEL® K4M). The ingredients were thoroughly mixed to create a smooth and homogeneous mixture. The filled pans were covered and preconditioned in a refrigerator to a stable temperature of 35 ± 2°F before loading into the refrigerated rail.

Instrumentation

A total of ten thermocouples (two per pan) were used to measure simulated food product in five pans. The four corner pans and one pan in the center of the food rail were instrumented as illustrated in Figure 2-1. The first thermocouple in each pan was placed 1 inch below the food surface and the second thermocouple was placed $^{1}/_{8}$-inch above the bottom of the pan as illustrated. Each thermocouple was positioned ½-inch away from the sides of the pan.

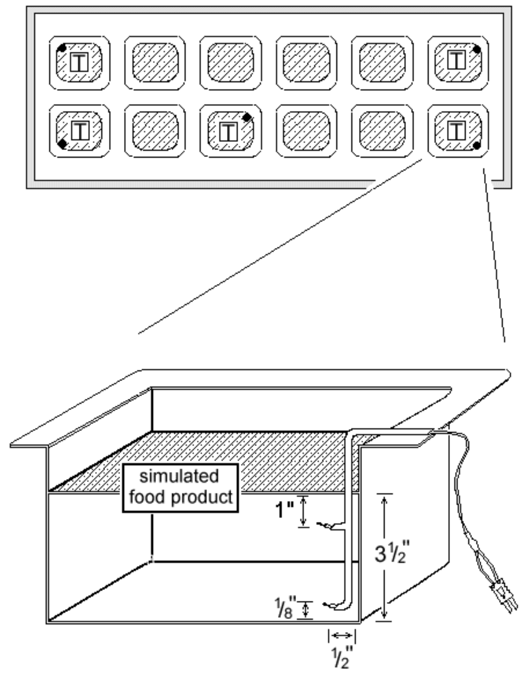

Figure 2-1.
Thermocouple locations and configuration.

Three thermocouples were used to measure the refrigerated cavity (box) temperatures below the refrigerated rail. No food load was placed in the refrigerated box. One thermocouple was placed on each side of the cavity (left and right side), five inches from the sides, two inches above the bottom surface and centered front to back of the cavity. The third thermocouple was placed in the geometric center of the cavity.

Electrical energy consumption was measured with a Watt-hour transducer that generated a pulse for every 0.00001 watt-hours. The transducer and thermocouples were connected to an automated data acquisition unit that recorded data every 5 seconds. Energy consumption and input rates were calculated and temperature profiles were generated from this information.

Test Procedure

Researchers conducted 4-hour tests with the simulated food in each pan and the lid of the refrigerated prep table in the open (lid-up) position. At the completion of the 4-hour lid-up test, the lid of the refrigerated prep table was closed (lid-down) and an 8-hour idle test was conducted. The compartment doors remained closed during both the lid-up and lid-down tests. Cabinet temperature was also monitored during testing.

3 Results

The eight prep tables were tested sequentially in a conditioned test cell. After installing a prep table in the testing area, each unit was set to the manufacturer's recommended settings and temperature calibration was verified using pans of chilled water. Control adjustments were made, as necessary, to achieve an average water temperature between 39°F and 41°F over two consecutive compressor cycles. Once calibrated, the unit was stabilized at temperature overnight prior to testing.

Lid-Up Test

Each refrigerated prep table was pre-conditioned for a minimum of four compressor cycles before commencing the lid-up test. Pans filled with 35°F water were used during the preconditioning period. Once testing began, the pans of water were replaced with pans of synthetic food that had been stabilized in a separate refrigerator overnight to 35 ± 2°F.

Researchers conducted 4-hour tests on the refrigerated prep tables with the simulated food in each pan. The lid was in the open position and the cabinet doors remained closed during the test. This lid-up test was designed to emulate normal operation during the day. Table 3-1 summarizes the average pan and cabinet temperatures for all eight refrigerated prep tables.

Pan temperature stratification represents the average temperature difference from the bottom of the pan to within one inch of the top for each of the 5 test pans. All eight prep tables demonstrated average pan temperatures between 35°F and 40°F during the 4-hour lid up test (see Figure 3-1).

The largest stratification between the upper and lower thermocouples was seen in Unit #8 with a total difference of 5.4°F and an average pan temperature of 39.1°F. Unit #1 displayed the least amount of stratification with a temperature difference of 2.4°F between the upper and lower thermocouples and an average pan temperature of 36.0°F.

Table 3-1. Pan and Cabinet Temperature During the Lid-Up Test.

	Average Pan Temperature (°F)	Average Cabinet Temperature (°F)
Unit #1	36.2	36.0
Unit #2	37.1	34.6
Unit #3	37.0	36.2
Unit #4	35.3	34.8
Unit #5	36.5	33.2
Unit #6	35.4	36.7
Unit #7	35.5	36.5
Unit #8	39.1	35.0

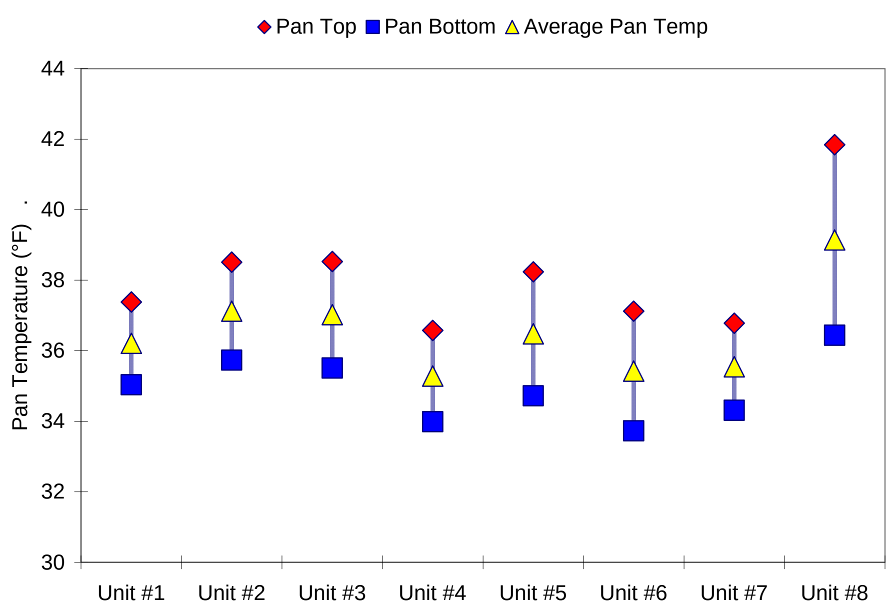

Figure 3-1.
Pan temperature stratification during the lid-up test.

Results

Energy rates varied from as high as 463 watts to as low as 208 watts during the lid-up test. Differences in cabinet insulation, compressor size and design can account for the variations in average energy rates between each prep table. Figure 3-2 represents the average power for each of the refrigerated prep tables during the 4-hour test. Units #1, #3, and #5 maintained low pan and cabinet temperatures, while consuming the least amount of energy during the 4-hour lid-up test.

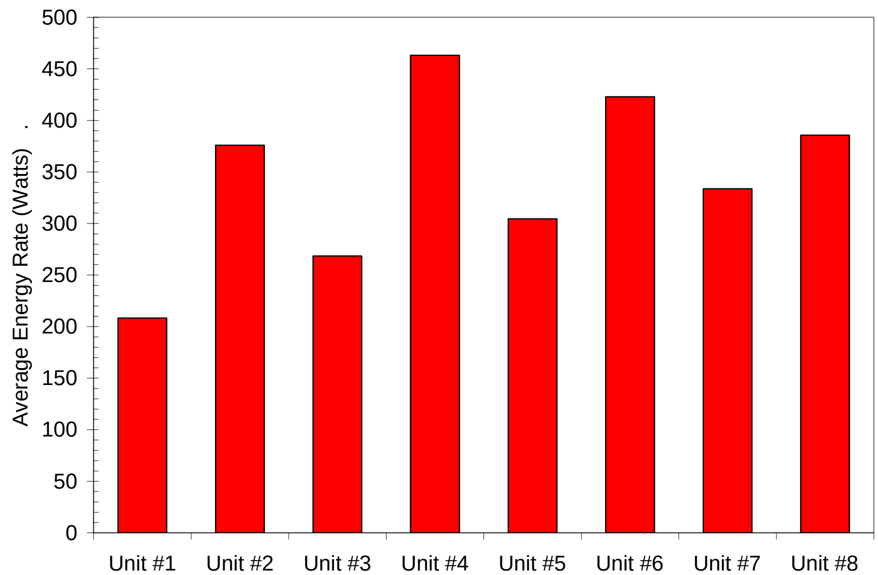

Figure 3-2.
Lid-up energy use.

Lid-Down Test

The lid-down test was conducted over an 8-hour period immediately following the 4-hour lid-up test. During the 8-hour lid-down test, both the lid and compartment doors remained closed to simulate nighttime (idle) operating conditions. All of the prep tables were able to maintain average pan temperatures below 41°F and above 33°F during the lid-down test. However, some of the prep tables demonstrated a slight increase in pan temperature during the test. This increase in pan temperature can be related to the reduction in duty cycle or the amount of compressor percentage run time. With the lid down, the refrigerated prep tables better retain the cold air generated by the compressor, reducing the amount of energy necessary to maintain the temperature of the pans between 41°F and 33°F. Table 3-2 summarizes the pan and cabinet temperatures for each of the refrigerated prep tables during the lid-down tests.

Table 3-2. Pan and Cabinet Temperature During the Lid-Down Test.

	Average Pan Temperature (°F)	Average Cabinet Temperature (°F)
Unit #1	39.6	43.1
Unit #2	37.3	34.7
Unit #3	38.6	37.4
Unit #4	34.7	34.6
Unit #5	38.5	34.9
Unit #6	35.6	37.1
Unit #7	35.0	35.8
Unit #8	35.6	33.2

The pan temperatures were more uniform during the lid-down tests, illustrating one of the benefits of closing the lid during standby periods. Figure 3-3 compares the pan temperature stratification during the lid-down tests. Again, Unit #8 exhibited the largest stratification from the top to the bottom of the pans (2.4°F). In contrast to the lid-up test results, the average pan temperatures during these lid-down tests showed more variation from unit to unit. For example, Unit #1 floated up to 40°F while Unit #4 remained at 35°F.

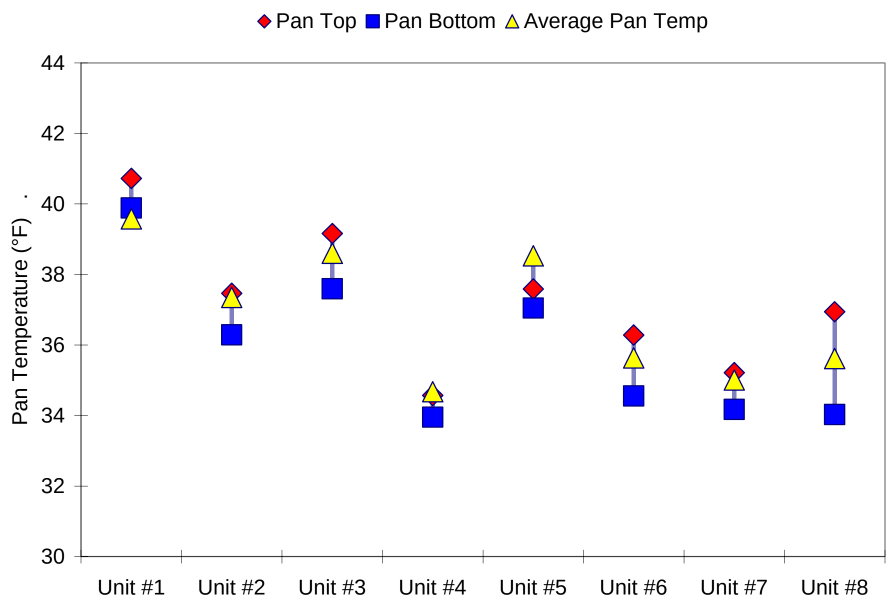

Figure 3-3.
Pan temperature stratification during the lid-down test.

Figure 3-4 compares the average power for each of the refrigerated prep tables during the 8-hour lid-down test. The results show a significant reduction in energy use for six of the eight prep tables when the lid is down. Unit #4 exhibited the largest reduction in energy consumption—nearly 50%. Units #6 and #7 showed little change in energy use between the lid-up and the lid-down tests. This may reflect a design approach, such as larger compressors or cooling the pans from below.

With the challenge of maintaining the temperature of the pans in the open top, it is possible for cabinet temperatures to drop below freezing (32°F). Effective circulation is key to maintaining the cavity temperature within the tight 33°F to 41°F range while minimizing stratification. Table 3-3 summarizes the cabinet temperature performance for all eight prep tables during the lid-up and lid-down tests.

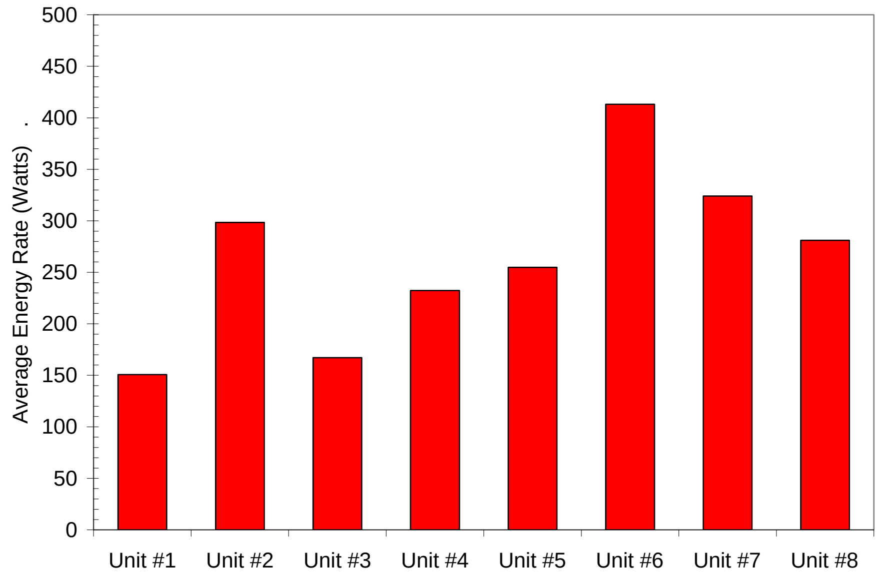

Figure 3-4.
Lid-down energy use.

Table 3-3. Cabinet Temperature Stratification (°F).

	Lid-Up Test		Lid-Down Test	
	Average Temperature	Temperature Stratification [a]	Average Temperature	Temperature Stratification [a]
Unit #1	35.9	1.5	35.9	0.9
Unit #2	34.6	4.5	34.6	2.9
Unit #3	36.2	1.0	36.2	1.3
Unit #4	34.8	2.6	34.8	1.9
Unit #5	33.2	2.6	33.2	2.2
Unit #6	36.7	1.4	36.7	2.3
Unit #7	36.5	1.7	36.5	0.9
Unit #8	35.0	3.3	35.0	2.4

[a] Cabinet temperature stratification represents the average temperature difference from the left side to the right side of the cabinet with no food load.

Results

Results Discussion

Compressor percentage run time, or duty cycle, was calculated for the two different operating conditions. Research has shown that sizing a compressor correctly, while combining the appropriate amount of insulation, can reduce the initial and operational cost associated with refrigerated prep tables. Figure 3-5 illustrates the differences between the duty cycles during the 4-hour lid-up and 8-hour lid-down tests for each of the refrigerated prep tables.

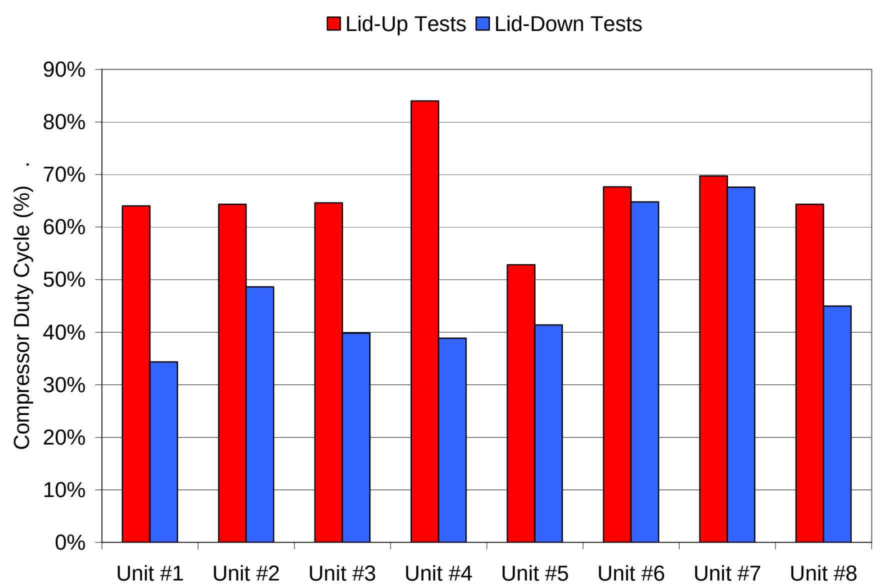

Figure 3-5.
Lid-up and lid-down compressor duty cycle comparison.

A balance between compressor size and insulation must be achieved for an effective prep table. A prep table with an undersized compressor could operate continuously achieving a 100% duty cycle and a high operational cost. While an oversized compressor will provide the horsepower to maintain a lower temperature but can increase the initial cost of the appliance as well as the operating cost. Good insulation allows a manufacturer to size a compressor for the appropriate type of operation. Tables 3-4 and 3-5 compare the test results for the lid-up and lid-down tests, respectively.

Table 3-4. Summary of Lid-Up Test Results.

	Average Pan Temperature (°F)	Pan Temperature Stratification (°F) [a]	Average. Energy Rate (W)	Compressor Duty Cycle (%)
Unit #1	36.2	2.3	208	64
Unit #2	37.1	3.5	376	64
Unit #3	37.0	3.0	268	65
Unit #4	35.3	2.6	463	84
Unit #5	36.5	3.5	304	53
Unit #6	35.4	3.4	423	68
Unit #7	35.5	2.5	334	70
Unit #8	39.1	5.4	386	64

[a] Pan temperature stratification represents the average temperature difference from the bottom of the pan to within one inch of the top.

Table 3-5. Summary of Lid-Down Test Results.

	Average Pan Temperature (°F)	Pan Temperature Stratification (°F) [a]	Average. Energy Rate (W)	Compressor Duty Cycle (%)
Unit #1	39.6	0.8	151	34
Unit #2	37.3	1.2	298	49
Unit #3	38.6	1.6	167	40
Unit #4	34.7	0.6	232	39
Unit #5	38.5	0.6	255	41
Unit #6	35.6	1.7	413	65
Unit #7	35.0	1.0	324	68
Unit #8	35.6	2.9	281	45

[a] Pan temperature stratification represents the average temperature difference from the bottom of the pan to within one inch of the top.

During the lid-up tests, which are representative of a daily operation, the prep tables demonstrated duty cycles ranging from as low as 53% to as high as 84%. The 8-hour lid-down test represents an idle or nighttime period of operation. The compressor does not cycle as much due to the decrease in energy loss to the environment with the lid down. Duty cycles ranged between a low of 34% for Unit #1 and a high of 68% for Unit #7 during the lid down tests.

Energy Cost Model

Researchers developed an energy usage/cost model to estimate annual user costs. The model is based on operational energy use from both the lid-up and lid-down tests. The lid-down test was used to estimate nighttime energy use of the unit, while the lid-up test was used to estimate typical operational use during the day. The model assumed 12 operating (lid-up) hours per day, 365 days per year. Energy consumption and operating cost are summarized in Table 3-6.

Table 3-6. Energy Consumption and Cost.

	Lid-Up Power (W)	Lid-Down Power (W)	Energy Consumption (kWh/yr)	Annual Operating Cost ($/yr) [a]
Unit #1	208	151	1,717	187
Unit #2	376	298	2,912	283
Unit #3	268	167	1,882	201
Unit #4	463	232	3,004	290
Unit #5	304	255	2,416	243
Unit #6	423	413	3,611	339
Unit #7	334	324	2,842	277
Unit #8	386	281	2,880	280

[a] Operating costs are based on $0.10/kWh.

Most appliances are designed to last between five and ten years of normal operation, when properly maintained. For many appliances, the 5-year operating cost equals or exceeds the initial purchase cost. A typical 48-inch refrigerated prep table lists between $1,200 and $1,800. Figure 3-6 compares the 5-year operating cost for all eight of the refrigerated prep tables. With a two-to-one difference in operational costs, the incremental cost for a more efficient unit can be returned in energy savings over the life of the unit.

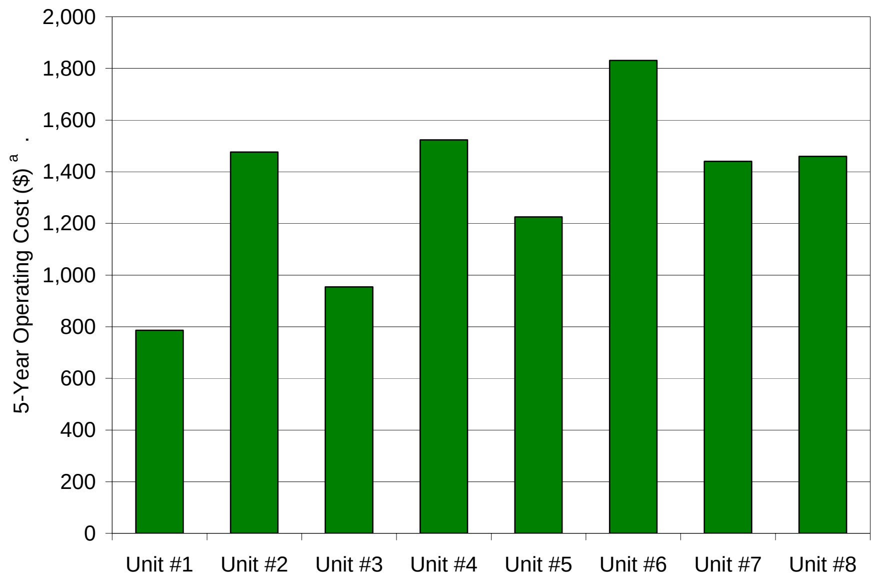

Figure 3-6.
5-year operating cost comparison.

[a] Operating costs are based on $0.10/kWh.

4 Conclusions

The latest generation of refrigerated prep tables offer a food service operator good temperature control, while meeting the difficult challenge of maintaining the temperature requirements of the exposed food product. Although the eight units were capable of maintaining temperature, there was a significant difference in the energy consumption from unit to unit. This difference in energy use reflects different design strategies to manage the difficult task of maintaining the open pans between 33°F and 41°F without freezing the contents of the compartment.

The design challenge for a refrigerated prep table is one of thermal distribution and control, not refrigeration capacity (at least for the eight units tested). Different strategies were employed, from using an air curtain over the exposed pans, to using separate controls for the open upper portion and the closed cabinet. While each approach has merit, some have an energy penalty.

The operating cost analysis shows the importance of knowing the energy use of a perspective appliance. Since the expected life of all eight refrigerated prep tables is the same, the difference in life cycle cost between the highest (Unit #6) and lowest (Unit #1) energy users could add up to the purchase cost of a second appliance.

5 References

1. Gil Ashton Publishing, LLC. *Probing New NSF 7 Prep Tables,* Foodservice Equipment Reports, November 1998.

2. American Society for Testing and Materials. 2001. *Standard Test Method for the Performance of Refrigerated Preparation and Buffet Tables.* ASTM Designation F2143-01, in *Annual Book of ASTM Standards*, Philadelphia.

3. Zabrowski, D., Cowen, D., 2002. *Continental Prep Table Performance Testing.* Food Service Technology Center Report 5011.02.21, October.

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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 “idling” or “holding” at a stabilized operating condition or temperature.

Idle Temperature (°F, Setting)

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

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 the initial appliance draw-down or cool-down period (i.e., the period of operation when the compressor(s) are “on”).

Capacity

The number of pans that can be held in the open display area of the refrigerated prep table.

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.

Relative Humidity
RH

A measurement of the degree of saturation of air, with 100% indicating completely saturated air and 0% indicating completely dry air.

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.