

**Stellar Steam, Model Altair
Electric Steamer Performance Test**

Application of ASTM Standard
Test Method F 1484-04

FSTC Report # 5011.05.03

**Food Service Technology Center
February 2005**

Prepared by:

**Victor Kong
David Zabrowski**
Fisher-Nickel, Inc.

Prepared for:

Pacific Gas & Electric Company
Customer Energy Efficiency Programs
PO Box 770000
San Francisco, California 94177

Mark Bramfitt
Senior Program Manager

© 2005 by Fisher-Nickel, inc. All rights reserved.

The information in this report is based on data generated at the Food Service Technology Center.

Acknowledgments

California consumers are not obligated to purchase any full service or other service not funded by this program. This program is funded by California utility ratepayers under the auspices of the California Public Utilities Commission.

Los consumidores en California no estan obligados a comprar servicios completos o adicionales que no esten cubiertos bajo este programa. Este programa esta financiado por los usuarios de servicios públicos en California bajo la jurisdiccion de la Comision de Servicios Públicos de California.

A National Advisory Group provides guidance to the Food Service Technology Center Project. Members include:

Applebee's International Group
California Energy Commission (CEC)
Denny's Corporation
East Bay Municipal Utility District
Enbridge Gas Distribution Inc.
EPA Energy Star
Gas Technology Institute (GTI)
In-N-Out Burger
National Restaurant Association
Safeway, Inc.
Southern California Edison
Underwriters Laboratories (UL)
University of California at Berkeley
University of California at Riverside
US Department of Energy, FEMP

Specific appreciation is extended to Stellar Steam for supplying the FSTC with a model Altair boilerless, electric steamer for controlled testing in the appliance laboratory.

Policy on the Use of Food Service Technology Center Test Results and Other Related Information

- Fisher-Nickel, inc. and the Food Service Technology Center (FSTC) do not endorse particular products or services from any specific manufacturer or service provider.
- The FSTC is *strongly* committed to testing food service equipment using the best available scientific techniques and instrumentation.
- The FSTC is neutral as to fuel and energy source. It does not, in any way, encourage or promote the use of any fuel or energy source nor does it endorse any of the equipment tested at the FSTC.
- FSTC test results are made available to the general public through technical research reports and publications and are protected under U.S. and international copyright laws.
- In the event that FSTC data are to be reported, quoted, or referred to in any way in publications, papers, brochures, advertising, or any other publicly available documents, the rules of copyright must be strictly followed, including written permission from Fisher-Nickel, inc. *in advance* and proper attribution to Fisher-Nickel, inc. and the Food Service Technology Center. In any such publication, sufficient text must be excerpted or quoted so as to give full and fair representation of findings as reported in the original documentation from FSTC.

Legal Notice

This report was prepared as a result of work sponsored by the California Public Utilities Commission (Commission). It does not necessarily represent the views of the Commission, its employees, or the State of California. The Commission, the State of California, its employees, contractors, and subcontractors make no warranty, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the use of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the Commission nor has the Commission passed upon the accuracy or adequacy of the information in this report.

Disclaimer

Neither Fisher-Nickel, inc. nor the Food Service Technology Center nor any of its employees makes any warranty, expressed or implied, or assumes any legal liability of responsibility for the accuracy, completeness, or usefulness of any data, information, method, product or process disclosed in this document, or represents that its use will not infringe any privately-owned rights, including but not limited to, patents, trademarks, or copyrights.

Reference to specific products or manufacturers is not an endorsement of that product or manufacturer by Fisher-Nickel, inc., the Food Service Technology Center or Pacific Gas & Electric Company (PG&E).

Retention of this consulting firm by PG&E to develop this report does not constitute endorsement by PG&E for any work performed other than that specified in the scope of this project.

Contents

	Page
Executive Summary	iii
1 Introduction	1-1
Background	1-1
Objectives	1-2
Appliance Description	1-2
2 Methods	2-1
Setup and Instrumentation	2-1
Non-Cooking Tests.....	2-2
Frozen Green Pea Efficiency Tests.....	2-2
Red Potato Efficiency Tests	2-3
Ice Load Cooking Uniformity Test.....	2-3
3 Results	3-1
Energy Input Rate	3-1
Preheat and Idle Tests	3-1
Cooking Tests	3-2
Ice Load Uniformity Test.....	3-7
4 Conclusions	4-1
5 References	5-1

Appendix A: Glossary

Appendix B: Appliance Specifications

Appendix C: Results Reporting Sheets

Appendix D: Cooking-Energy Efficiency Data

List of Figures and Tables

Figures

	Page
1-1 The Stellar Altair steamer	1-3
2-1 The Altair instrumented for testing.....	2-1
2-2 Frozen green pea load	2-2
2-3 Red potato load	2-3
2-4 Ice Load.....	2-3
3-1 Preheat characteristics	3-1
3-2 Steamer part-load cooking-energy efficiency	3-5
3-3 Comparison of steamer cooking-energy efficiencies	3-6
3-4 Steamer cooking energy consumption profile.....	3-7
3-5 Ice load temperature profile.....	3-8

Tables

	Page
1-1 Appliance Specifications.....	1-3
3-1 Average Input, Preheat and Idle Test Results	3-2
3-2 Frozen Green Pea Cooking Test Results	3-4
3-3 Red Potato Cooking Test Results.....	3-4
3-4 Ice Load Uniformity Test Results.....	3-8

Executive Summary

The Food Service Technology Center (FSTC) tested the Stellar Steam, model Altair boilerless, electric steamer under the controlled conditions of the American Society for Testing and Materials (ASTM) *Standard Test Method for the Performance of Steam Cookers*.¹ Steamer performance is characterized by preheat duration and energy consumption, idle energy rate, cooking energy rate and efficiency, production capacity, water consumption, and condensate temperature. Cooking tests were conducted with grade A frozen green peas and grade B red potatoes in accordance with ASTM test materials specifications for weight, size, and water content.¹ The steamer's cooking uniformity was determined heating ice loads and examining their temperature profiles. The Altair was equipped with an automatic water fill connection and the steamer's water consumption was monitored throughout all the tests.

The Stellar Steam, model Altair performed well compared to other boilerless steamers, exhibiting modest heavy-load (6 pan) cooking-energy efficiencies for frozen green peas (87.0%) and red potatoes (44.4%). The Altair also had exceptional cook times, achieving heavy-load production capacities of 108.6 lb/h for frozen green peas and 130.7 lb/h for red potatoes.

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

$$\text{Cooking Energy Efficiency} = \frac{\text{Energy to Food}}{\text{Energy to Steamer}}$$

¹ American Society for Testing and Materials, 2004. Standard Test Method for the Performance of Steam Cookers. ASTM Designation F1484-04, in the Annual Book of ASTM Standards, West Conshohocken, PA.

Executive Summary

A summary of the ASTM test results is presented in Table ES-1.

Table ES-1. Summary of the Altair Steamer Performance.

Rated Energy Input Rate (kW)	9.8
Measured Energy Input Rate (kW)	9.8
Preheat Time (min)	12.4
Preheat Energy (kWh)	2.0
Idle Energy Rate (kW)	0.19
Frozen Green Peas	
Light-Load Cooking-Energy Efficiency (%)	49.4 ± 4.2
Heavy-Load Cooking-Energy Efficiency (%)	87.0 ± 5.2
Production Capacity (lb/h)	108.6 ± 9.0
Red Potatoes	
Light-Load Cooking-Energy Efficiency (%)	11.0 ± 1.0
Heavy-Load Cooking-Energy Efficiency (%)	44.4 ± 4.4
Production Capacity (lb/h)	130.7 ± 12.7
Ice Loads	
Cook Time (min)	41.8
Maximum Temperature Difference (°F)	28.2
Maximum Time Delay (min)	8.4

Beyond its respectable productivity and high cooking-energy efficiencies, the Altair steamer also exhibited low water usage. Typical water consumption during heavy-load cooking tests was no more than 3.5 gallons per hour (gal/h). Other steam cooking technologies, such as boiler-based or steam generator-type steamers, typically consume between 20 and 60 gal/h while cooking.

1 Introduction

Background

Steaming provides a fast-cooking option for preparing large quantities of food, while retaining vital nutrients in the cooked product. Steamers are versatile appliances that can be used to prepare almost any food that does not require a crust. Delicate vegetables, such as asparagus and broccoli, are cooked without damage; frozen foods are defrosted and cooked in one step; and hard-to-cook meats, such as beef ribs, can be par-cooked quickly with less weight loss than oven roasting.

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 primary component of the FSTC is a 10,000 square-foot appliance laboratory equipped with energy monitoring and data acquisition hardware, 60 linear feet of canopy exhaust hoods integrated with utility distribution systems, appliance setup and storage areas, and a state-of-the-art demonstration and training facility.

The test methods, approved and ratified by the American Society for Testing and Materials (ASTM), allow benchmarking of equipment so that users can make informed comparisons among available equipment choices. By collaborating with the Electric Power Research Institute (EPRI) and the Gas Technology Institute (GTI) through matching funding agreements, the test methods have remained unbiased to fuel choice. 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.

Since the development of the ASTM test method for steam cookers in 1993,¹ the FSTC has tested a wide range of gas and electric steamers.²⁻²⁴

Introduction

The Stellar Steam Altair features a circulation fan in the top of the cooking compartment for convection steaming, a patented design with heating elements located within the walls of the cooking compartment for additional radiant heating, and a proprietary catch plate for maintaining clean reservoir water.

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 Stellar Steam, model Altair steamer, 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.
2. Determine the time and energy required to preheat the steamer to an operating condition.
3. Characterize the idle energy use of the steamer while maintaining a ready-to-cook state.
4. Determine the cooking-energy efficiency under four scenarios: heavy-load frozen green peas (6 pans), light-load frozen green peas (single-pan), heavy-load red potatoes (6 pans) and light-load red potatoes (single-pan).
5. Determine the production capacity, cooking energy rate and cook time for each loading scenario.
6. Characterize cooking uniformity by steaming ice loads.

Appliance Description

The Stellar Steam, model Altair is a 6-pan capacity, single compartment, electric, boilerless steamer (Figure 1-1). The steamer is powered by 9.8 kW electric heating elements located beneath the cooking compartment's water reservoir. Steam is generated within the cooking compartment without a separate boiler – water is automatically added from a supply water connection and drained manually. The cooking chamber can accommodate six, standard

Introduction

full-size, 2½-inch deep hotel pans. The Altair has three cooking modes labeled I, II, and III. Mode I is intended to be a standby or low temperature cooking option. Users can select this setting to hold the internal temperature at 180°F or to steam delicate food products. Mode II is selected if regular steaming is required. In this mode, the steamer will maintain full saturation of the compartment and cycle it's elements on and off accordingly. In Mode III, the Altair adds radiant heating to the features of Mode II. In this setting the steamer will maintain 230°F inside the compartment and is intended for frozen or dense food products. The Altair also features a catch plate located directly above the reservoir water that separates any food particles from contacting the boiling water below. A direct, open connection is maintained between this plate and the drain line at all times. The ceiling of the cooking compartment houses a small circulation fan that allows the steamer to cook with convection steaming.

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



Figure 1-1.
The Stellar Steam Altair steamer.

Table 1-1. Appliance Specifications.

Manufacturer	Stellar Steam
Model	Altair
Generic Appliance Type	Boilerless, 1-compartment, electric, atmospheric steamer with automatic water fill.
Rated Input	9.8 kW
Technology	Boilerless steamer with convection fan.
Construction	Stainless-steel exterior; aluminum cast interior.
Interior	356.1 Aluminum cast with hard anodized finish
Exterior	304 Stainless-steel
Controls	Main dial with 4 modes: Off, I, II, III. 60 minute mechanical timer that does not control steaming.
Compartment Capacity	6 (12" x 20" x 2½") pans
Dimensions	24" x 28.5" x 33.5" (w×d×h)

2 Methods

Setup and Instrumentation

The steamer was installed in accordance with the manufacturer's instructions and in accordance with Section 9 of the ASTM test method¹: under a 4-foot-deep canopy hood, with the lower edge of the hood 6 feet, 6 inches above the floor and a minimum of 6 inches inside the vertical front edge of the hood. The exhaust ventilation operated at a nominal rate of 150 cfm per linear foot of hood with the ambient temperature maintained at $75 \pm 5^\circ\text{F}$.

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 steamer, maintained a steady voltage for all tests. Figure 2-1 shows the Altair instrumented with the data acquisition system.



*Figure 2-1.
The Altair instrumented
for testing.*

Methods

Non-Cooking Tests

The energy input rate was determined by measuring the energy consumed by the steamer during a complete preheat cycle. The maximum power draw during this period was reported as the measured energy input rate. Preheat tests recorded the time and energy required for the steamer to reach operating temperature from a cold start when turned on for the first time in a day. An hour after the preheat cycle is completed, the steamer was placed in the “hold” mode (Mode I) and idle energy consumption was monitored over a 2-hour period.

Frozen Green Pea Efficiency Tests



*Figure 2-2.
Frozen green pea load.*

Individually flash-frozen, grade A green peas (Figure 2-2) represented one of two food products for steamer performance testing. Standard full-size (12" x 20" x 2½"), perforated stainless-steel hotel pans were used for cooking the green peas. The Altair required 6 pans of green peas for a full load, while a single pan placed on the center rack of the steamer cavity comprised a light load. Each pan contained 8.0 ± 0.01 lb of green peas. Pre-weighed green peas in perforated pans were stored in sealed plastic bags at $0 \pm 5^\circ\text{F}$ for at least 24 hours prior to testing. The pans of peas were transferred into an insulated box and transported to the testing location where the plastic bags were removed, and the pan(s) of green peas were loaded into the steamer according to the loading time prescribed in section 10.7.6 of the ASTM test method.¹

Since probing proves to be difficult and erroneous for measuring the temperature of small-sized green peas, a water-bath calorimeter was utilized to determine the final bulk temperature of the cooked green peas. The time required to cook the frozen peas to a bulk temperature of $180 \pm 2^\circ\text{F}$ was determined through an iterative process. Once the cook time was established, the test was replicated a minimum of three times to minimize the uncertainty in the test results.

Methods

Red Potato Efficiency Tests



*Figure 2-3.
Red potato load.*

Freshly packed, size B, red potatoes (Figure 2-3) served as the second food product for steamer performance testing. The Altair required 6 pans of red potatoes for a full load and a single pan for a light load. Each pan contained exactly 50 red potatoes weighing 8.0 ± 0.2 pounds.

The red potatoes were loaded into perforated pans prior to the test and stabilized to a room temperature of $75 \pm 5^\circ\text{F}$. The potatoes were then cooked to $195 \pm 2^\circ\text{F}$ using a predetermined cook time. The final temperature was determined by directly probing a minimum of 3 potatoes per pan during testing and then randomly probing potatoes (using a hand-held, digital thermocouple meter) within 3 minutes after cooking was terminated. Again, the test was replicated a minimum of three times to minimize the uncertainty in the test results.

Ice-Load Cooking Uniformity Test



*Figure 2-4.
Ice load.*

The ice load test required 6 full-size solid steam pans of ice. Each pan contained 8.0 ± 0.2 pounds of ice, which had been stabilized in a freezer at $0 \pm 5^\circ\text{F}$ for approximately 12 hours. Each pan was instrumented with a thermocouple positioned at the geometric center of the ice. This was used to monitor ice load temperature during the test. When the first pan reached a final temperature of 170°F , the time was noted; the ice loads remained in the steamer and steaming did not cease until the last pan of ice reached 170°F , when the temperatures and final cook time were recorded. Three replications of this test were performed.

The ASTM results reporting sheets appear in Appendix C.

3 Results

Energy Input Rate

Researchers compared the manufacturer's nameplate value for energy input rate with that measured in the lab prior to any testing to ensure that the steamer was operating within its specified parameters. Researchers determined that the Altair drew a maximum energy input rate of 9.8 kW.

Preheat and Idle Tests

Preheat Energy and Time

The cavity was automatically filled with approximately 2 gallons of water at $70 \pm 5^\circ\text{F}$. Mode III was then selected for preheating the compartment, as instructed by the user manual. Figure 3-1 illustrates the preheat and idle characteristics of the Altair.

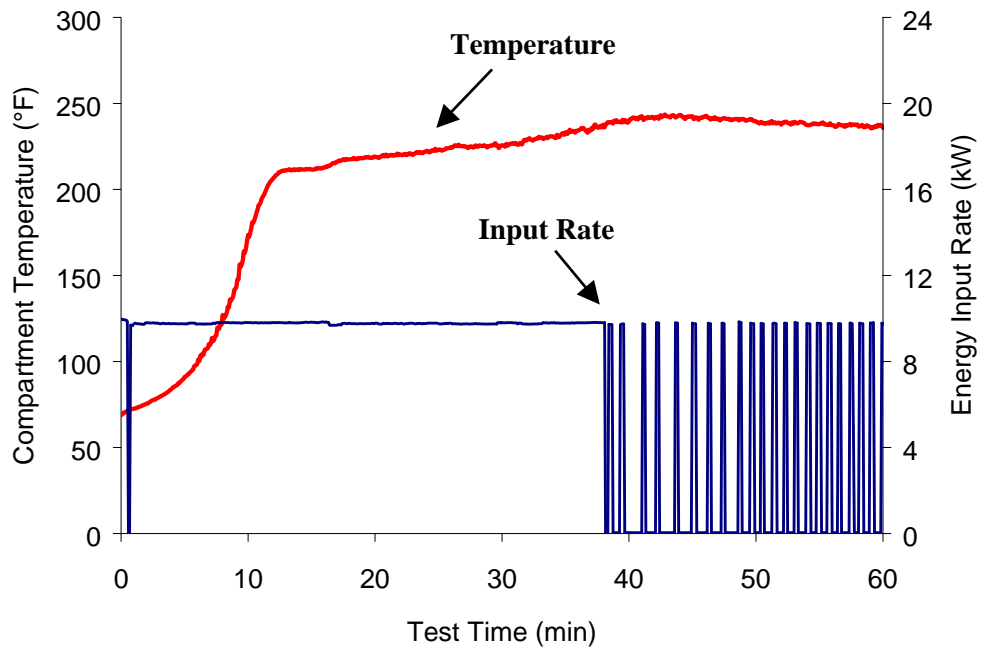


Figure 3-1. Preheat and idle characteristics.

Results

Idle Energy Rate

Following the preheat period, the steamer was switched to Mode I (standby) and allowed to stabilize for one hour. Then, the steamer was monitored over a 2-hour period and the idle energy rate was determined to be 0.19 kW.

Test Results

Rated energy input, preheat energy and idle rate test results are summarized in Table 3-1.

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

Rated Energy Input Rate (kW)	9.8
Measured Energy Input Rate (kW)	9.8
Preheat to Operational Capacity:	
Time (min)	12.4
Energy (kWh)	2.0
Idle Energy Rate (kW)	0.19

Cooking Tests

The steamer was tested using two different food products (green peas and red potatoes) under two loading scenarios—heavy (6 pans) and light (single pan). All cooking scenarios were conducted in Mode III (steaming plus radiant heat).

The Altair does not employ a separate boiler, but does include an automatic fill water connection and an open drain. Approximately two gallons of water are automatically filled into the reservoir at the back of the cooking compartment before testing began. The steamer was emptied at the end of the day, as directed by the manufacturer's instructions. Typical water usage for each cooking scenario was approximately 3 gal/h.

Results

Frozen Green Pea Tests

Moisture content of the frozen green peas was 81% by weight, corresponding to specific heats (C_p) of 0.44 Btu/lb°F for frozen and 0.84 Btu/lb°F for thawed peas.¹ The Altair required 26.5 minutes to cook a full load of frozen green peas and had a cooking-energy efficiency of 87.0% and a production capacity of 108.6 lb/h.

The light-load test required an average of 7.6 minutes when cooking a single pan of frozen green peas. Cooking-energy efficiency and productivity during the light-load tests were determined to be 49.4% and 63.1 lb/h, respectively.

Red Potato Tests

The red potatoes contained 84% moisture by weight with the specific heat (C_p) of 0.87 Btu/lb°F.¹ A full load of potatoes averaged 22.1 minutes to reach an average bulk cooked temperature of $195 \pm 2^\circ\text{F}$. The cooking-energy efficiency and production capacity was 44.4% and 130.7 lb/h, respectively.

The single pan of red potatoes required 17.0 minutes to achieve an average bulk temperature of $195 \pm 2^\circ\text{F}$. The light-load potato test resulted in a cooking-energy efficiency of 11.0% and a productivity of 28.4 lb/h.

Results Discussion

The rate at which steam condenses on food depends on the surface temperature and surface area of the food. Therefore, frozen green peas (at 0°F) and red potatoes (at room temperature) represent two extremes in steam cooking. Frozen green peas, having a large surface area to volume ratio, promote condensation. The heat transfer rate from steam to frozen food is high, resulting in greater cooking-energy efficiency and productivity. Potatoes are “tough” to cook, due to a low surface to volume ratio and the slower rate of condensation.

Results

Appendix D lists the physical properties of the test food product and measured values of each test run. Using the detailed equations provided in section 11 of the Steamer ASTM Standard Test Method 1484-04, the cooking energy efficiencies are calculated. Tables 3-2 through 3-3 summarize the Altair's cooking performance.

Table 3-2. Frozen Green Pea Cooking Test Results.

	Heavy-Load	Light-Load
Number of Pans	6	1
Cook Time (min)	26.5	7.6
Cooking Energy Rate (kW)	9.8	9.9
Cooking-Energy Efficiency (%)	87.0 ± 5.2	49.4 ± 4.2
Production Rate (lb/h)	108.6 ± 9.0	63.1 ± 5.3
Energy Consumption (Btu/lb)	307.7	533.8

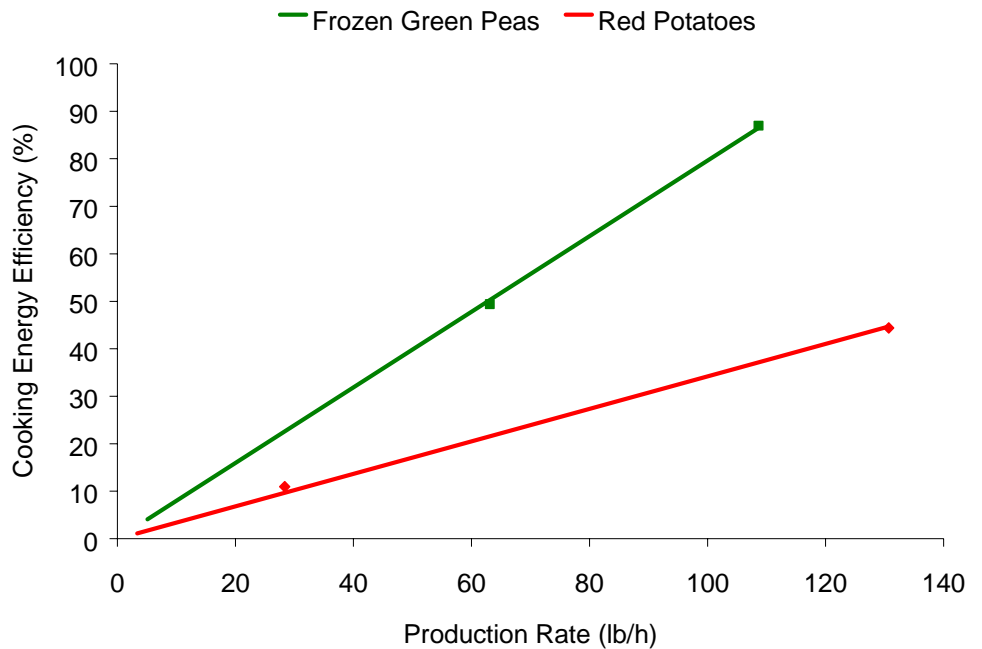
Table 3-3. Red Potato Cooking Test Results.

	Heavy-Load	Light-Load
Number of Pans	6	1
Cook Time (min)	22.1	17.0
Cooking Energy Rate (kW)	9.8	8.5
Cooking-Energy Efficiency (%)	44.4 ± 4.4	11.0 ± 1.0
Production Rate (lb/h)	130.7 ± 12.7	28.4 ± 2.1
Energy Consumption (Btu/lb)	256.6	1,027.2

Figure 3-2 illustrates the relationship between cooking-energy efficiency and production rate for this steamer, when cooking two different types of food product. The upper line represents the part-load efficiency curve for the

Results

steamer when cooking frozen vegetables and the lower curve represents the steamer's part-load efficiency while cooking more stubborn food products. Steamer production rate is a function of the cook time. Appendix D contains a table of the test data for each replicate of the cooking tests.



*Figure 3-2.
Steamer part-load cooking-energy efficiency.*

Note: Light-load = single pan/load; Heavy-load = 6 pans/load.

Figure 3-2 compares the cooking-energy efficiency of the steamer when cooking different types of food product at different loading scenarios. Heavy loads exhibit higher efficiencies due to better use of the available compartment space, as opposed to light-load single pan tests, where most of the space in the steamer compartment is empty. Furthermore, Figure 3-3 shows that the frozen green peas have higher cooking-energy efficiencies than the red potatoes due to their higher surface-to-volume ratio.

Results

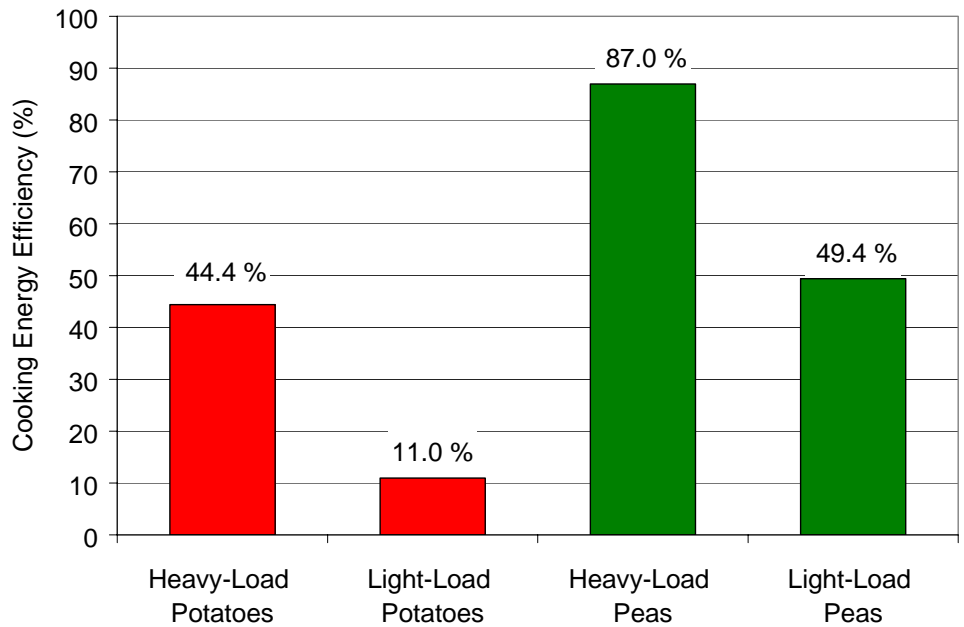


Figure 3-3. Comparison of steamer cooking-energy efficiencies.

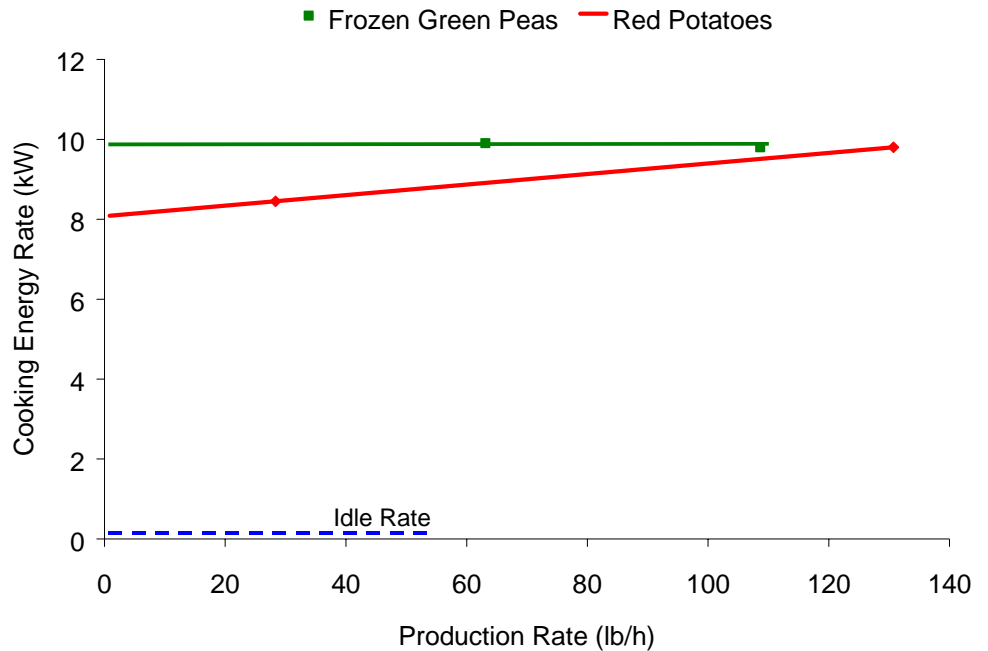
Note: Light-load = single pan/load; Heavy-load = 6 pans/load.

Figure 3-4 represents the cooking energy rate for two different food products at the two test load scenarios. The upper line represents the steamer’s energy consumption rate when cooking frozen vegetables, while the lower curve represents the steamer’s energy consumption rate while cooking more stubborn food products. All thermostatically controlled electric steamers with the ability to cycle their elements will exhibit similar cooking energy rate profiles for frozen vs. fresh food products; these steamers will operate at higher average energy rates for frozen foods than for fresh products. For most of the loading scenarios, the steamer was operating at or close to its maximum input rate, with little cycling occurring only in the light-load potato test.

This graph can be used as a tool to estimate the daily energy consumption and probable demand for the steamer in a real-world operation, based on the type of usage. The average energy consumption rates at 15, 30, and 60 pounds per hour of frozen vegetables are all going to be close to or approximately the measured maximum input rate for the steamer at 9.8 kW.

Results

Figure 3-4.
Steamer cooking energy
consumption profile.



Note: Light-load = single pan/load; Heavy-load = 6 pans/load.

Ice-Load Uniformity Test

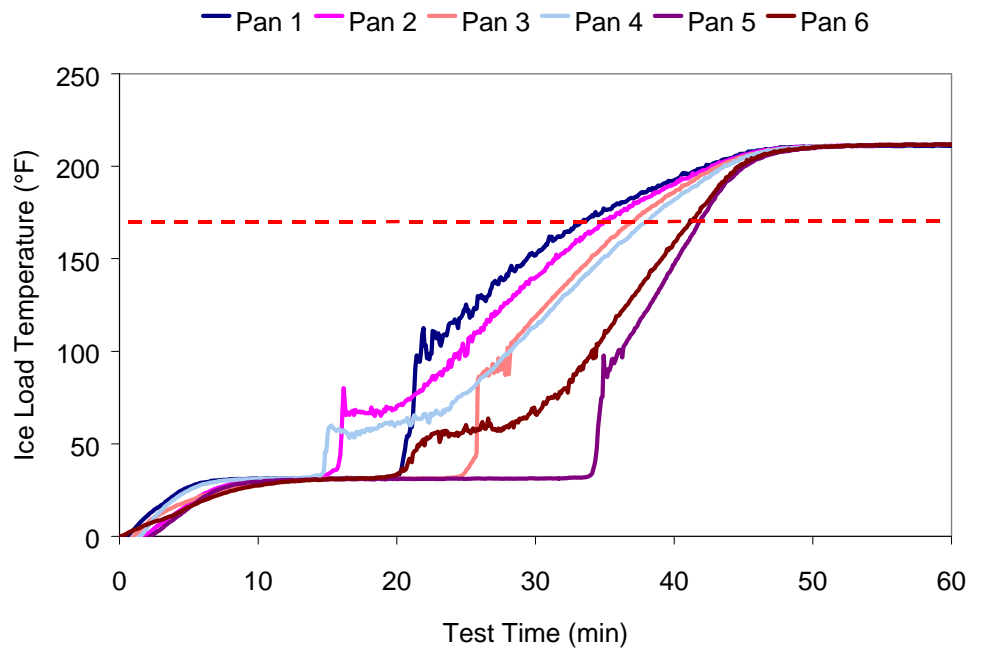
The ice-load uniformity test was designed to emulate frozen vegetables, while allowing researchers to accurately monitor simulated food temperature during the cooking event. For each test, 6 pans (full-load) of ice were used to determine the steaming uniformity within the compartment. The last pan reached 170°F in 41.8 minutes. At this time, the maximum temperature difference between the hottest and coldest pan was found to be 28.2°F. On average, the last pan to reach the 170°F endpoint required an additional 8.4 minutes beyond the cook time of the fastest pan. Table 3-4 summarizes the average results of the ice-load uniformity tests and Figure 3-5 shows the individual pan temperatures during a single ice-load test. Note that the final temperatures in Table 3-4 are averages of at least three replications and reflect the variations in results from each test.

Results

Table 3-4. Ice-Load Uniformity Test Results.

Number of Pans	6
Cook Time (min)	41.8
Initial Ice-Load Temperature (°F)	-2.2
Final Ice-Load Temperatures (°F):	
Pan 1 (Top)	197.8
Pan 2	197.4
Pan 3	193.4
Pan 4	190.6
Pan 5	170.3
Pan 6 (Bottom)	178.0
Maximum Temperature Difference (°F)	28.2
Maximum Time Delay* (min)	8.4

* Time required for ice load in last pan to reach 170°F after first pan reaches the endpoint.



*Figure 3-5.
Ice-load temperature
profile.*

4 Conclusions

The Stellar Altair is a fast and highly productive steamer. With its innovative heating strategies, the unit was able to achieve impressive production rates with minimal water consumption. The Altair includes a 9.8 kW heating element arrangement underneath the compartment, yielding over 108 lb/h of frozen vegetables and 130 lb/h of potatoes, while maintaining cooking-energy efficiencies above 40% throughout. During heavy-load cooking tests in Mode III, the Altair performed quite well due to innovative designs such as a supply water preheating system.

While the cooking tests revealed the steamer's ability to perform with minimal energy input, the Altair also exhibited a low idle rate of 0.19 kW. This is a credit to the sound design of the steamer – its ability to minimize heat loss that allows it to maintain a steady, standby temperature within the cooking compartment. Furthermore, ice load tests revealed that the Altair maintains pan-to-pan temperature uniformity inside the compartment when challenged with frozen food products. The average temperature difference between the coldest and hottest pan was 28.2°F. Included in the design is a circulation fan above the compartment that contributes to the steamer's convection steaming ability. While the Altair was challenged with a series of heavy and light-load cooking scenarios, the steamer consumed approximately 3.0 gallons of water per hour. Researchers recorded minimal refilling of the steamer through the automatic fill connection throughout all the tests. Steam-generator and boiler-based steamers typically consume between 20 and 60 gal/h while cooking, compared to approximately 3.0 gal/h for the Altair.²⁻²⁴

Throughout the rigorous ASTM tests, the Altair exhibited strong performance, especially considering its 9.8 kW input rate. In addition, the Altair provides three modes of cooking to accommodate various steaming requirements, automatic reservoir fill connection, and a two-inch deep reservoir. Due to its

Conclusions

impressive design features (convection fan, supply water preheat, auxiliary heating elements inside the walls), the Altair is able to achieve very high production rates for frozen food products as well as very dense foods such as potatoes. The Stellar Steam Altair is an ideal candidate for facilities looking to reduce operating costs without sacrificing performance. With its modest energy consumption, high production rates, and minimal water usage, it is a fine choice for kitchens with that demand high production rates.

5 References

1. American Society for Testing and Materials, 2004. *Standard Test Method for the Performance of Steam Cookers*. ASTM Designation F 1484–04. In annual book of ASTM Standards, West Conshohocken, PA.
2. Selden, M., 1995. *Development and Validation of a Uniform Testing Procedure for Steam Cookers*. Food Service Technology Center Report 1022.95.19, April.
3. Bell, T., Yap, D., 1999. *Southbend Simple Steam, Model EZ-3 Electric Steamer Performance Test: Application of ASTM Test Method F 1484-99*. Food Service Technology Center Report 5011.99.83, December.
4. Bell, T., Miner, S., Nickel, J., Zabrowski, D., 2001. *Stellar Steam CAPELLA Electric Steamer Performance Test: Application of ASTM Test Method F 1484-99*. Food Service Technology Report 5011.01.94, January.
5. Bell, T., Miner, S., 2001. *Vulcan VPX3 Electric Steamer Performance Test: Application of ASTM Test Method F 1484-99*. Food Service Technology Center Report 5011.01.01, May.
6. Bell, T., Miner, S., 2001. *Vulcan VPX5 Electric Steamer Performance Test: Application of ASTM Test Method F 1484-99*. Food Service Technology Center Report 5011.01.02, May.
7. Bell, T., Nickel, J., 2001. *Cleveland Range Inc., Electric Steamer Performance Test: Application of ASTM Test Method F 1484-99*. Food Service Technology Center Report 5011.00.84, November.
8. Bell, T., Miner, S., Nickel, J., Zabrowski, D., 2001. *Market Forge, ET-3E Electric Steamer Performance Test: Application of ASTM Test Method F 1484-99*. Food Service Technology Center Report 5011.01.99, April.
9. Bell, T., Miner, S., Nickel, J., Zabrowski, D., 2001. *Market Forge, ET-5E Electric Steamer Performance Test: Application of ASTM Test Method F 1484-99*. Food Service Technology Center Report 5011.01.98, April.

References

10. Yap, D., Ardley, S., 1998. *Groen HyperSteam, Model HY-3E Electric Steamer Performance Test: Application of ASTM Standard Test Method F1484-93*. Food Service Technology Center Report 5011.98.54, May.
11. Bell, T., Nickel, J., 2001. *Market Forge STP-6E Electric Steamer Performance Test: Application of ASTM Test Method F 1484-99*. Food Service Technology Center Report 5011.01.05, December.
12. Bell, T., Nickel, J., 2001. *Market Forge STP-6G Gas Steamer Performance Test: Application of ASTM Test Method F 1484-99*. Food Service Technology Center Report 5011.01.06, December.
13. Bell, T., Miner, S., Nickel, J., Zabrowski, D., 2000. *Vulcan-Hart Gas Steamer Performance Test, Model VL2GSS (Pressure) and Model VS3616G (Atmospheric) Steamer Performance Test: Application of ASTM Test Method F 1484-99*. Food Service Technology Report 5011.00.85, December.
14. Bell, T., Miner, S., Nickel, J., Zabrowski, D., 2001. *Vulcan-Hart Gas Steamer Performance Test, Model VHX24G-3 Steamer Performance Test: Application of ASTM Test Method F 1484-99*. Food Service Technology Report 5011.01.97, January.
15. Yap, D., Ardley, S., 1998. *AccuTemp Steam “n” Hold, Model 208-D6-3.0 Electric Steamer Performance Test: Application of ASTM Test Method F1484-99*. Food Service Technology Center Report 5011.98.58, May.
16. Yap, D., Bell, T., Knapp, S., 1999. *AccuTemp Steam ‘n’ Hold, Model 208-D8-300 Electric Steamer Performance Test: Application of ASTM Test Method F1484-99*. Food Service Technology Center Report 5011.99.75, September.
17. Bell, T., Zabrowski, D., 2003. *AccuTemp STEAM ‘N’ HOLD, Model 208-D12-300 Electric Steamer Performance Test: Application of ASTM Standard Test Method F1484-99*. Food Service Technology Center Report 5011.03.02, February.
18. Kong, V., Zabrowski, D., 2003. *Groen Vortex, Model VRC-6E Electric Steamer Performance Test: Application of ASTM Standard Test Method F1484-99*. Food Service Technology Center Report 5011.03.23, May.

References

19. Kong V., Zabrowski, D., 2004. *Intek XtremeSteam, Model 208-14-3 Electric Steamer Performance Test: Application of ASTM Standard Test Method F1484-04*. Food Service Technology Center Report 5011.04.10, August.
20. Kong V., Zabrowski, D., 2004. *Vulcan-Hart, Model VHX 10G Gas Steamer Performance Test: Application of ASTM Standard Test Method F1484-04*. Food Service Technology Center Report 5011.04.08, August.
21. Kong V., Zabrowski, D., 2004. *Vulcan-Hart, Model VSX 10GC Gas Steamer Performance Test: Application of ASTM Standard Test Method F1484-04*. Food Service Technology Center Report 5011.04.03, September.
22. Kong V., Zabrowski, D., 2004. *Intek XtremeSteam, Model 208-6-1 Electric Steamer Performance Test: Application of ASTM Standard Test Method F1484-04*. Food Service Technology Center Report 5011.04.09, December.
23. Kong V., Zabrowski, D., 2004. *AccuTemp Products, Inc., Model S62083D060 Electric Steamer Performance Test: Application of ASTM Standard Test Method F1484-04*. Food Service Technology Center Report 5011.04.16, December.
24. Kong V., Zabrowski, D., 2005. *Stellar Steam, Model Sirius Gas Steamer Performance Test: Application of ASTM Standard Test Method F1484-04*. Food Service Technology Center Report 5011.05.02, February.

A Glossary

Boiler

Self-contained electric, gas, or steam coil powered vessel wherein water is boiled to produce steam for the steam cooker. Also called a steam generator.

Boiler Preheat

Preheat

Process of bringing the boiler water from potable supply temperature to operating temperature (pressure).

Condensate

A mixture of condensed steam and cooling water, exiting the steam cooker and directed to the floor drain.

Condensate Temperature (°F)

The temperature at which the condensate enters the floor drain.

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.

Frozen Green Peas Load

12 x 20 x 2½ in. hotel pan filled with 8.0 ± 0.01 lb of frozen, grade A, green peas subsequently frozen to 0±5°F. One of two food products used to determine cooking-energy efficiency and production capacity.

Glossary

High-Pressure Steam Cooker

Steam cooker wherein cooking compartment operates between 10 and 15 psig (ASTM F1217-92 Classification Type III).

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.

Ice Load

12 x 20 x 2½ in. hotel pan filled with 8.0 ± 0.2 lb of water and subsequently frozen to 0±5°F. This is used to simulate a food product load in the ice load cooking uniformity test.

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.

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

Low-Pressure Steam Cooker

Steam cooker wherein the cooking compartment operates between 3 and 9.9 psig.

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).

Potato Load

12 x 20 x 2½ in. hotel pan filled with 8.0 ± 0.2 lb of fresh, whole, US No. 1, size B, red potatoes. One of two food products used to determine cooking-energy efficiency and production capacity.

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 cooking surface 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.

Production Rate (lb/h) Productivity

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

Steam Cooker

Cooking appliance wherein heat is imparted to food in a closed compartment by direct contact with steam. The compartment can be at or above atmospheric pressure. The steam can be static or circulated.

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.

Water Consumption (gal/h)

Water consumed by the steam cooker. Includes both water used in the production of steam and cooling water (if applicable) for condensing/cooling unused steam.

B Appliance Specifications

Appendix B includes the product literature for the Stellar Steam, model Altair electric steamer.



Job Name: _____

Item No.: _____ Quantity: _____

ALTAIR II

Convection Boilerless Steamer

Specifications: Altair II (all sizes)

Unit shall be Stellar Steam convection/circulating boilerless steam oven with automatic waterfill. Unit shall include internally preheated water for fast recovery, clean water reservoir system and rear drain. Altair II models shall be efficiently heated by electrical elements external to the water reservoir. Four-pan steamers shall be 8 kW; six-pan steamers shall be 9.8 kW per compartment. Operation shall be from steam generated in the cooking compartment. The walls and ceiling of the cooking compartment shall be heated to reduce steam condensing on these surfaces and shall reheat and revitalize partially condensed steam (US Patent 6,310,325). Steamer cavity shall have dual-direction convection fan that increases steam velocity and provides efficient steam distribution throughout the cavity by pulling steam past the cooking pans, then forcing it against the heated cooking chamber walls to be reheated. Cooking compartment shall be cast aluminum with a food-grade non-stick hard anodized finish. Cooking compartment acts as a heat sink, allowing for heat retention, quick recovery and reduced energy consumption. Standard controls shall be in English and Spanish with three cooking modes: slow cook, Super Steam and Steam Plus. A Clean Probe indicator light, a Heating indicator light and a 60-minute mechanical timer shall be included. The control panel shall pull out in drawer fashion for easy service access. The door shall be field reversible and shall be insulated. Safety shut offs are provided by a hidden magnetic door switch, low water/high limit heat switch, temperature probe, water sensing probe and waterfill timer.



Options

- PP-4, PP-6 - Prison package (tamperproof screws, locked controls, flanged feet)
- HWS-4, HWS-6 - Left side heat and water shield
- CPO - Cord & plug assembly
- CA - Heavy duty casters (2 with brakes)
- CON - condenser system and catch basin to reduce steam vented to kitchen
- SKE - stacking kit, electric steamers, to use when adding a second compartment to existing steamer in the field
- TRANS - transformer for 480V operation

Standard features:

- Controls:
 - ★ 4-position cooking mode selector: Off and three cooking positions
 - ★ Clean Probe indicator light
 - ★ Heating indicator light
 - ★ 60-minute timer - does not control cooking functions
- Internally preheated incoming water for quick recovery
- Clean water reservoir system keeps food out of the water
- Condensate trough plumbed to drain at rear
- Redundant safety systems
- Construction
 - ★ 304 Stainless, #4 finish (cabinet)
 - ★ 356.1 Aluminum cast cooking compartment with hard-anodized finish
- UL/CUL Safety & Sanitary (NSF-4)
- Two year parts and labor conditional warranty

Stands

Note: Stacked steamers (double compartment) do not require stands. Rugged frame construction allows steamers to be stacked on each other.

- MSS - mobile stand with shelf
- SSS - stationary stand with shelf
- PRM - pan rack assembly for MSS & SSS stands, holds 14 2½" deep pans
- EST - economy stand, shipped disassembled
- ESTM - mobile economy stand, shipped disassembled
- STSS - 12" high stand for 6- and 8-pan steamers only



by ColburnTreat

276 E Allen Street, Suite 5, Winooski, VT 05404
 www.stellarfoodequipment.com
 tel: 802-654-8603 fax:802-654-8618

Manufactured in USA
 7/04 Printed in USA

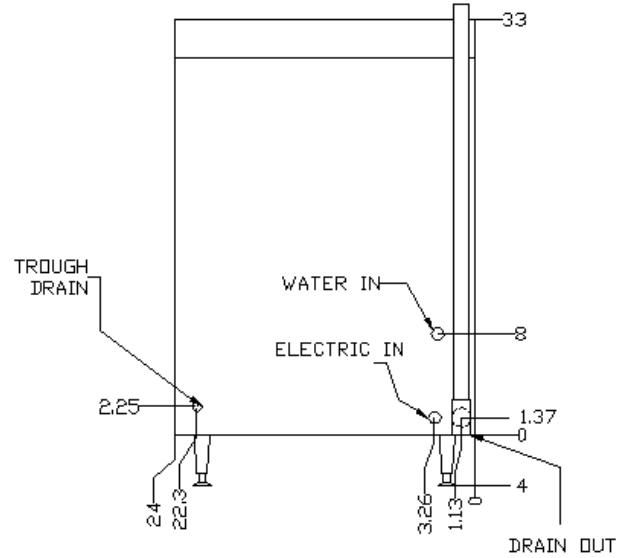
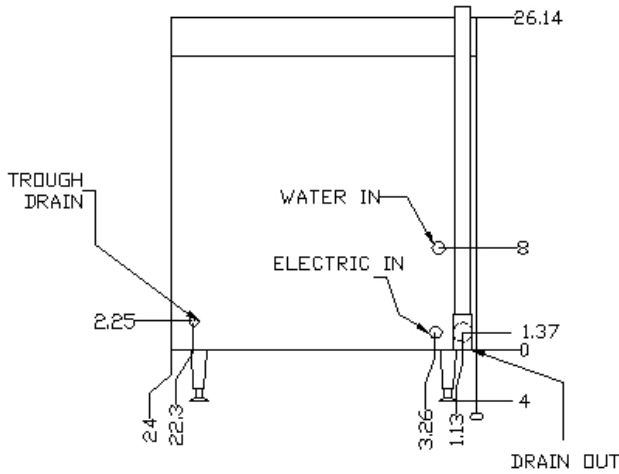
ColburnTreat practices continuous improvement; design and specifications are subject to change without notice

Altair II 4 Electrical Options

Voltage	Phase	kW	Amps			Total Amps
208	1	8	38.5			
208	3	8	24	24	18	24
240	1	8	33			
240	3	8	21	21	16	21
480 (Opt'l)	3	8	10	10	8	10

Altair II 6 Electrical Options

Voltage	Phase	kW	Amps			Total Amps
208	1	9.8	46.2			
208	3	9.8	30	26	26	30
240	1	9.8	40			
240	3	9.8	26	22	22	26
480 (Opt'l)	3	9.8	12	12	9	12



Altair II 4-pan rear view (dimensions in inches)

Altair II 6-pan rear view (dimensions in inches)

Connections for all Altair II sizes

- Water in: 3/4" male garden hose
- Trough drain: 1/2" MNTP
- Drain out: 1" FNPT

Model	Made up of	12 x 20 x 2 1/2" pan capacity	12 x 20 x 4" pan capacity	Height (all are 24 w x 28.5 D)	Shipping Weight (Class 85)
Altair II 4	Single compartment	4	2	26.5 + 4" legs	225 lbs
Altair II 6	Single compartment	6	4	33.25 + 4" legs	250 lbs
Altair II 8	2 Altair II 4	8	4	52.5 + 6-9 adj. legs	450 lbs
Altair II 10	Altair II 4 (top) + Altair II 6 (bottom)	10	6	59.5 + 6-9" adj. legs	475 lbs
Altair II 12	2 Altair II 6	12	8	66.25 + 6-9" adj. legs	500 lbs

Notes:

1. Each single compartment has two rear drain connections (one main drain, one condensate trough drain)
2. Each stacked steamer (two compartments) has a single main drain and two condensate trough drains
3. Each compartment, stacked or single, requires a separate power connection
4. Each compartment, stacked or single, requires a separate water connection
5. Water pressure should be set to fill reservoir in 45 seconds
6. 4" clearance left, right and rear is recommended
7. Location near a floor drain is recommended



by ColburnTreat

276 E Allen Street, Suite 5, Winooski, VT 05404

www.stellarfoodequipment.com

tel: 802-654-8603 fax:802-654-8618

C Results Reporting Sheets

Manufacturer: Stellar Steam
Model: Altair
Date: February 2005

Test Steam Cooker

ASTM F 1216 Classification (check one for each classification)

- Type I - Zero to 2.9 psig compartment pressure
- Type II - Three to 9.9 psig compartment pressure
- Type III - Ten to 15 psig compartment pressure

- Size 1-3 - One Compartment, 3 full-size pan capacity
- Size 1-4 - One Compartment, 4 full-size pan capacity
- Size 1-5 - One Compartment, 5 full-size pan capacity
- Size 1-6 - One Compartment, 6 full-size pan capacity
- Size 2-6 - Two Compartment, 6 full-size pan capacity
- Size 2-8 - Two Compartment, 8 full-size pan capacity
- Size 2-10 - Two Compartment, 10 full-size pan capacity
- Size 2-12 - Two Compartment, 12 full-size pan capacity
- Size 2-16 - Two Compartment, 16 full-size pan capacity
- Size 3-12 - Three Compartment, 12 full-size pan capacity
- Size 3-15 - Three Compartment, 15 full-size pan capacity
- Size 3-18 - Three Compartment, 18 full-size pan capacity
- Size 3-24 - Three Compartment, 24 full-size pan capacity

- Style A - Counter mounted
- Style B - Floor mounted on an open stand
- Style C - Floor mounted on a cabinet base
- Style D - Wall Mounted

- Class A - Direct connection to potable external steam source
- Class B - Self-contained steam coil steam generator
- Class C - Self-contained gas fired steam generator
- Class D - Self-contained electric steam generator

Results Reporting Sheets

Description of operational characteristics: The steamer has an automatic water fill connection and an open drain connection. Approximately 2.0 gallons of water automatically fill the reservoir prior to operation and manually drained at the end of the day. Users can choose to operate the steamer in three different modes: I, II, and III, with each one representing varying degrees of steaming and temperatures within the compartment. Mode I also represents a standby setting where users can hold the compartment at 180°F during periods of idling. All cooking tests were conducted using the steamer's Mode III setting.

Apparatus

The steamer was installed in accordance with the manufacturer's instructions under a 4-foot-deep canopy hood, with the lower edge of the hood 6 feet, 6 inches above the floor and a minimum of 6 inches inside the vertical front edge of the hood. The exhaust ventilation operated at a nominal rate of 150 cfm per linear foot of hood with the ambient temperature maintained between $75 \pm 5^\circ\text{F}$. All test apparatus were installed in accordance with Section 9 of the ASTM test method.¹

The steamer was instrumented with an electric transducer to measure power and energy; a voltage regulator was used to maintain constant voltage for all tests. A computerized data acquisition system recorded test information at 5-second intervals for the entire test method application. All test apparatus were installed in accordance with Section 9 of the ASTM test method.

Energy Input Rate

Test Voltage	208 V
Measured	9.8 kW
Rated	9.8 kW
Percent Difference between Measured and Rated	0.0 %

Appliance Preheat Energy Consumption and Duration

Test Voltage	208 V
Energy Consumption	2.0 kWh
Duration	12.4 min

Results Reporting Sheets

Appliance Idle Energy Rate

Test Voltage	208 V
Idle Energy Rate	0.2 kW

Frozen Green Peas Cooking Time, Energy Efficiency, Energy Rate, Production Capacity, and Water Consumption Rate

Heavy-Load:

Test Voltage	208 V
Cooking Time	26.5 min
Cooking-Energy Efficiency	87.0 ± 5.2 %
Cooking Energy Rate	9.8 ± 0.1 kW
Production Capacity	108.6 ± 9.0 lb/h
Water Consumption Rate	2.0 gal/h

Light-Load:

Test Voltage	208 V
Cooking Time	7.6 min
Cooking-Energy Efficiency	49.4 ± 4.2 %
Cooking Energy Rate	9.9 ± 0.2 kW
Production Rate	63.1 ± 5.3 lb/h
Water Consumption Rate	2.0 gal/h

Results Reporting Sheets

Whole Red Potatoes Cooking Time, Energy Efficiency, Energy Rate, Production Capacity, and Water Consumption Rate

Heavy-Load:

Test Voltage	208 V
Cooking Time	22.1 min
Cooking-Energy Efficiency	44.4 ± 4.4%
Cooking Energy Rate	9.8 ± 0.1 kW
Production Capacity	130.7 ± 12.7 lb/h
Water Consumption Rate	3.2 gal/h

Light-Load:

Test Voltage	208 V
Cooking Time	17.0 min
Cooking-Energy Efficiency	11.0 ± 1.0 %
Cooking Energy Rate	8.5 ± 0.6 kW
Production Capacity	28.4 ± 2.1 lb/h
Water Consumption Rate	3.1 gal/h

Ice-Loads Cooking Time, Temperature Uniformity

Test Voltage	208 V
Cooking Time	41.8 min
Initial Average Temperature	-2.2°F
Average Final Ice Load Temperatures	Pan 1 197.8 °F
	Pan 2 197.4 °F
	Pan 3 193.4 °F
	Pan 4 190.6 °F
	Pan 5 170.3 °F
	Pan 6 178.0 °F
Maximum Temperature Difference	28.2 °F
Maximum Time Delay	8.4 min

D Cooking-Energy Efficiency Data

Table D-1. Specific Heat and Latent Heat.

Specific Heat (Btu/lb, °F)	
Ice	0.50
Solids	0.20
Frozen Green Peas	0.84
Red Potatoes	0.87
Latent Heat (Btu/lb)	
Fusion, Water	144
Vaporization, Water	970

Cooking-Energy Efficiency Data

Table D-2. Heavy-Load Peas Data

	Replication 1	Replication 2	Replication 3
Measured Values			
Number of Pan(s)	6	6	6
Cook Time (min)	25.75	26.33	27.5
Initial Water Temperature (°F)	42.0	39.0	42.3
Final Water Temperature (°F)	98.3	96.0	100.8
Frozen Food Temperature (°F)	0.0	0.0	0.0
Weight of Empty Calorimeter (lb)	44.7	44.7	44.7
Weight of Full Calorimeter (lb)	155.3	154.9	155.1
Weight of Calorimeter Water (lb)	60	60	60
Weight of Cooked Food (lb)	50.6	50.2	50.4
Weight of Frozen Food (lb)	48	48	48
Weight of Stainless-Steel Pans (lb)	16.0	16.0	15.6
Moisture Content (%)	81	81	81
Condensate Temperature (°F)	n/a	n/a	n/a
Water Consumption (gal/h)	2.1	2.1	1.7
Calculated Values			
Moisture Weight in Green Peas (lb)	38.9	38.9	38.9
Final Food Temperature (°F)	177.8	177.1	183.8
Cooking Energy (kWh)	4.2	4.3	4.5
Energy Consumed by Green Peas (Btu)	12,471	12,394	12,694
Energy to Food (Btu/lb)	259.8	258.2	264.5
Energy Consumed by Pans (Btu)	313.5	312.3	315.8
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	14,331	14,672	15,286
Energy to Steamer (Btu/lb of food cooked)	298.6	305.7	318.5
Cooking Energy Rate (kW)	9.8	9.8	9.8
Productivity (lb/h)	111.8	109.4	104.7
Energy Efficiency (%)	89.2	86.6	85.1

Cooking-Energy Efficiency Data

Table D-3. Light-Load Peas Data

	Replication 1	Replication 2	Replication 3
Measured Values			
Number of Pan(s)	1	1	1
Cook Time (min)	7.33	7.83	7.67
Initial Water Temperature (°F)	39.0	39.1	39.5
Final Water Temperature (°F)	95.5	97.6	96.0
Frozen Food Temperature (°F)	0.0	0.0	0.0
Weight of Empty Calorimeter (lb)	44.7	44.7	44.7
Weight of Full Calorimeter (lb)	63.0	62.9	62.8
Weight of Calorimeter Water (lb)	10.0	10.0	10.0
Weight of Cooked Food (lb)	8.3	8.2	8.1
Weight of Frozen Food (lb)	8.0	8.0	8.0
Weight of Stainless-Steel Pans (lb)	2.4	2.8	2.4
Moisture Content (%)	81	81	81
Condensate Temperature (°F)	n/a	n/a	n/a
Water Consumption (gal/h)	2.6	0.84	2.6
Calculated Values			
Moisture Weight in Green Peas (lb)	6.5	6.5	6.5
Final Food Temperature (°F)	176.2	182.4	179.5
Cooking Energy (kWh)	1.2	1.3	1.3
Energy Consumed by Green Peas (Btu)	2,055	2,083	2,044
Energy to Food (Btu/lb)	256.9	260.4	255.5
Energy Consumed by Pans (Btu)	46.5	56.5	47.4
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	4,095	4,436	4,299
Energy to Steamer (Btu/lb of food cooked)	511.8	554.5	537.4
Cooking Energy Rate (kW)	9.8	9.9	9.9
Productivity (lb/h)	65.5	61.3	62.6
Energy Efficiency (%)	51.3	48.2	48.6

Cooking-Energy Efficiency Data

Table D-4. Heavy-Load Potatoes Data

	Replication 1	Replication 2	Replication 3
Measured Values			
Number of Pan(s)	6	6	6
Cook Time (min)	21.3	22.0	23.0
Temperature of Uncooked Potatoes (°F)	71.4	72.6	71.3
Temperature of Cooked Potatoes (°F)	195.1	195.1	194.0
Weight of Stainless-Steel Pans (lb)	15.3	15.3	15.3
Weight of Potatoes (lb)	48.0	48.1	48.1
Total Potato Count	300	300	300
Moisture Content (%)	84	84	84
Condensate Temperature (°F)	n/a	n/a	n/a
Water Consumption (gal/h)	3.3	3.0	3.1
Calculated Values			
Moisture Weight in Potatoes (lb)	40.3	40.3	40.3
Average Weight of Each Potato (lb)	0.16	0.16	0.16
Cooking Energy (kWh)	3.46	3.60	3.76
Energy Consumed by Potatoes (Btu)	5,165	5,288	5,192
Energy to Food (Btu/lb)	107.6	110.2	108.2
Energy Consumed by Pans (Btu)	239.3	250.1	247.9
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	11,806	12,284	12,830
Energy to Steamer (Btu/lb of food cooked)	246.0	255.9	267.3
Cooking Energy Rate (kW)	9.8	9.8	9.8
Productivity (lb/h)	135.6	131.1	125.4
Energy Efficiency (%)	45.8	45.1	42.4

Cooking-Energy Efficiency Data

Table D-5. Light-Load Potatoes Data

	Replication 1	Replication 2	Replication 3	Replication 4
Measured Values				
Number of Pan(s)	1	1	1	1
Cook Time (min)	17.4	15.8	17.5	17.2
Temperature of Uncooked Potatoes (°F)	72.5	71.3	70.2	72.3
Temperature of Cooked Potatoes (°F)	195.9	196.0	195.1	195.3
Weight of Stainless-Steel Pans (lb)	2.8	2.8	2.8	2.4
Weight of Potatoes (lb)	8.0	8.0	8.0	8.0
Total Potato Count	50	50	50	50
Moisture Content (%)	84	84	84	84
Condensate Temperature (°F)	n/a	n/a	n/a	n/a
Water Consumption (gal/h)	2.7	3.3	3.4	3.1
Calculated Values				
Moisture Weight in Potatoes (lb)	6.7	6.7	6.7	6.7
Average Weight of Each Potato (lb)	0.16	0.16	0.16	0.16
Cooking Energy (kWh)	2.3	2.5	2.4	2.6
Energy Consumed by Potatoes (Btu)	884.8	875.5	867.7	863.7
Energy to Food (Btu/lb)	110.6	109.4	108.5	108.0
Energy Consumed by Pans (Btu)	47.2	44.3	44.2	36.8
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	7,916	8,530	8,326	8,735
Energy to Steamer (Btu/lb of food cooked)	989.5	1,066.3	1,040.7	1,091.9
Cooking Energy Rate (kW)	8.0	9.5	8.4	9.0
Productivity (lb/h)	27.6	30.3	27.6	28.0
Energy Efficiency (%)	11.8	10.8	11.0	10.3

Cooking-Energy Efficiency Data

Table D-6. Frozen Green Pea Cooking-Energy Efficiency and Production Capacity Statistics.

	Cooking-Energy Efficiency		Production Capacity
	Heavy Load	Light Load	
Replicate #1	89.2	51.3	111.8
Replicate #2	86.6	48.2	109.4
Replicate #3	85.1	48.6	104.7
Average	87.0	49.4	108.6
Standard Deviation	2.1	1.7	3.6
Absolute Uncertainty	5.1	4.2	9.0
Percent Uncertainty	5.9%	8.4%	8.3%

Table D-7. Red Potato Cooking-Energy Efficiency and Production Capacity Statistics.

	Cooking-Energy Efficiency		Production Capacity
	Heavy Load	Light Load	
Replicate #1	45.8	11.8	135.6
Replicate #2	45.1	10.8	131.1
Replicate #3	42.4	10.9	125.3
Replicate #4		10.3	
Average	44.4	11.0	130.7
Standard Deviation	1.8	0.6	5.1
Absolute Uncertainty	4.1	1.0	12.7
Percent Uncertainty	9.9%	8.8%	9.7%