Vulcan, VPX3
Electric Steamer Performance Test

Application of ASTM Standard
Test Method F 1484-99

FSTC Report 5011.01.01

Food Service Technology Center

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Executive Summary

The Food Service Technology Center (FSTC) tested the Vulcan, Model VPX3 connectionless, electric steamer under the tightly 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 energy consumption and duration, idle energy rate, cooking energy rate and efficiency, production capacity, water consumption and condensate temperature from product testing. The spectrum of test products includes: full-load frozen green peas, light-load frozen green peas, full-load red potatoes and light-load red potatoes. TheVPX3 is without a condensate drain; the measurement of condensate temperature was not applied.

A summary of the test results is presented in Table ES-1. Figure ES-1 illustrates the VPX3's cooking energy efficiency for different cooking scenarios. The production capacities are shown in Figure ES-2.

The Vulcan VPX3 is an energy efficient connectionless, electric steamer. The steamer exhibited high cooking energy efficiencies for each of the full-load (3 pans) cooking scenarios, 88.4% for frozen green peas and 70.5% for red potatoes. Under partial load cooking scenarios (1 pan) the unit maintained respectable cooking energy efficiencies as well, 76.5% for frozen green peas and 49.3% for red potatoes.

[1] American Society for Testing and Materials. 1999. *Standard Test Method for the Performance of Steam Cookers*. ASTM Designation F1484-99, in the *Annual Book of ASTM Standards*, Philadelphia: American Society for Testing and Materials.

Executive Summary

The VPX3 had a preheat time of approximately nine minutes and maintained a low idle energy rate of 0.3 kW. During idle conditions the cooking compartment was maintained at full operational capacity (i.e. 210°F).

During both full-load green pea and full-load red potato cooking events the unit demonstrated rapid cook times, 18.9 minutes and 22.8 minutes, respectively. The full-load frozen green pea cooktime is the fastest cooktime of the three pan capacity connectionless steamers tested to date at the FSTC.[2,3]

Low cooking energy rates accompanied the steamer's respectable cook time performances as well. A maximum cooking energy rate of 6.7 kW was observed during the full-load (3 pans) frozen green pea tests. The lowest cooking energy rate was measured during the light-load (1pan) red potato tests, 1.6 kW. No matter the cooking event, however, water consumption was well below the unit's 2.5 gallon capacity.

[2] Food Service Technology Center. 1999. *Southbend Simple Steam, Model EZ-3 Electric Steamer Performance Test.* Report 5011.99.83. Report 5011.99.75. Product and Services Department. San Francisco, California: Pacific Gas and Electric Company.

[3] Food Service Technology Center. 2001. *Market Forge, ET-3E Electric Steamer Performance Test.* Report 5011.99.99. Product and Services Department. San Francisco, California: Pacific Gas and Electric Company.

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Table ES-1. Performance Summary, Vulcan, Model VPX3.

Preheat and Idle	
Rated Energy Input Rate (kW)	9.0
Measured Energy Input Rate (kW)	9.1
Preheat Time (min)	9.2
Preheat Energy (kWh)	1.4
Idle Energy Rate (kW)	0.3
Full-Load Frozen Green Peas (3 pans)	
Cook Time (min)	18.9
Cooking Energy Rate (kW)	6.7
Cooking Energy Efficiency (%)	88.4
Production Capacity (lb/h)	76
Water Consumption (gal/h)	<2.5
Light-Load Frozen Green Peas (1 pan)	
Cook Time (min)	11.1
Cooking Energy Rate (kW)	4.4
Cooking Energy Efficiency (%)	76.5
Water Consumption (gal/h)	<2.5
Full-Load Red Potatoes (3 pans)	
Cook Time (min)	22.8
Cooking Energy Rate (kW)	2.9
Cooking Energy Efficiency (%)	70.5
Production Capacity (lb/h)	64
Water Consumption (gal/h)	<2.5
Light-Load Red Potatoes (1 pan)	
Cook Time (min)	19.8
Cooking Energy Rate (kW)	1.6
Cooking Energy Efficiency (%)	49.3
Water Consumption (gal/h)	<2.5

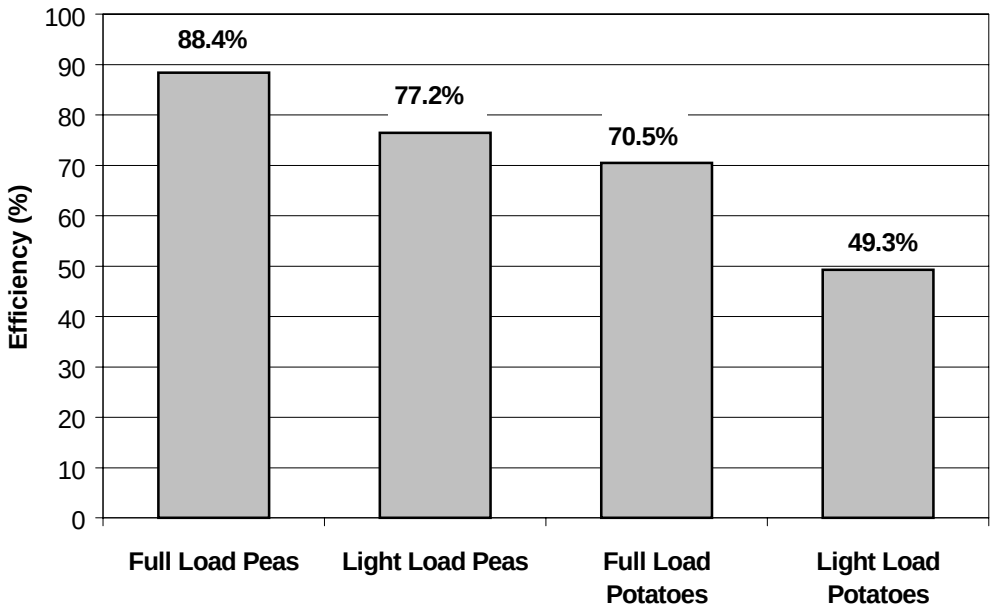

Figure ES-1.

Steamer Cooking Energy Efficiency Under Two Loading Scenarios.

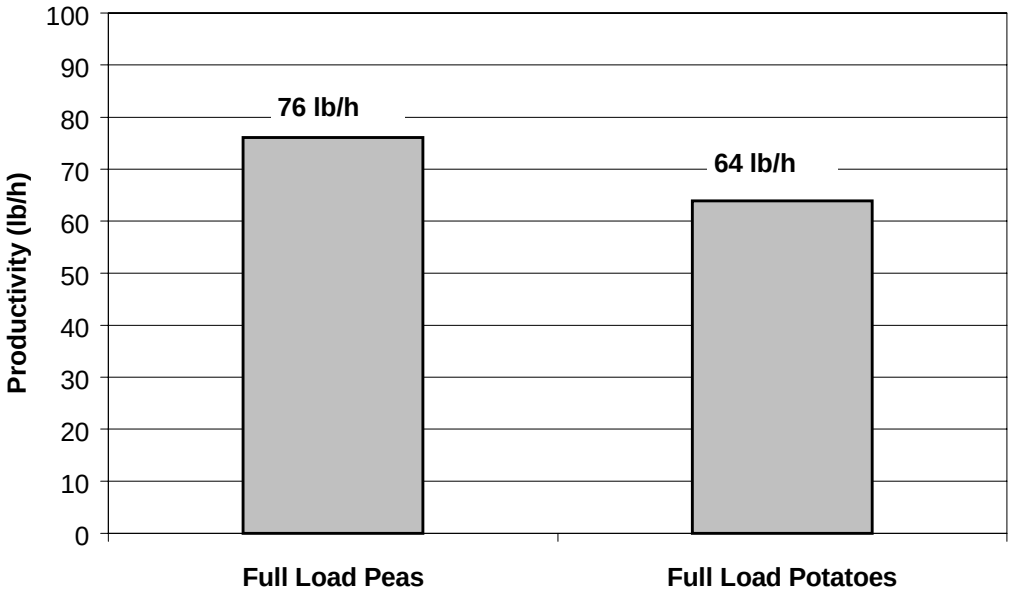

Figure ES-2.

Steamer Production Capacity.

1 Introduction

Background

Steaming provides a fast-cook option for preparing large quantities of food while retaining vital nutrients in the cooked product. Beyond the capital cost, steamers should be evaluated with regard to long-term performance and operational costs characterized by cooking energy efficiency, production capacity and water consumption.

The Pacific Gas and Electric Company's Food Service Technology Center (FSTC) developed a uniform testing procedure to evaluate the performance of gas and electric steam cookers. [1] This test procedure was submitted to the American Society for Testing and Materials (ASTM) and accepted as a standard test method in December 1993. [2] In keeping with ASTM's policy that a standard be periodically reviewed, the FSTC revised the steamer test method in February 1999 under Designation F 1484-99 [3] (originally published as F 1484-93[2]). Modification to the test method included replacing the ice-load test with frozen green peas to emulate real-world application.

The Vulcan, VPX3 is a single-compartment, electric connectionless steamer. The heating element is positioned beneath the water reservoir, eliminating the need for a separate boiler. TheVPX3 steamer was tested according to the ASTM procedure, and this report documents the results. The glossary in Appendix A provides a quick reference to the terms used in this report.

Introduction

Objectives

The objective of this report is to examine the operation and performance of the Vulcan VPX3 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 preheat duration and energy consumption of the steamer.
3. Measure the idle energy rate.
4. Determine the cooking energy efficiency under 4 scenarios: full-load frozen green peas (3 pans), light-load frozen green peas (1 pan), full-load red potatoes (3 pans) and light-load red potatoes (1 pan).
5. Determine the production capacity, cooking energy rate and cook time of each loading scenario.

Appliance Description and Operation

TheVPX3 is a stainless steel, electric connectionless steamer with a single 9.0 kW heating element placed underneath the cooking compartment's water reservoir (Figure 1-1). Steam is generated within the cooking compartment without a separate boiler. Water is added and drained manually at the beginning and end of the day. The cooking chamber accommodates six 12" x 20" x 1", three12" x 20" x 2½" or two 12" x 20" x 4" perforated steamer pans. The VPX3 has two cooking modes, "Timed Cooking" and "Constant Cooking". In "Time Cooking" mode, the 60-minute timer controls the units heating elements. In "Constant Cooking" mode, the heating elements are continuously engaged. The heating elements turn off when the steamer door in opened in either of the two cooking modes.

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

Introduction

Figure 1-1.
The Vulcan VPX3 Steamer.

Table 1-1. Appliance Specifications.

Manufacturer	Vulcan Company
Model	VPX3
Generic Appliance Type	1-compartment, natural-convection, electric connectionless steamer.
Rated Input	9.0 kW
Technology	Boiler-less steamer with natural-convection.
Construction	304 series stainless steel exterior. Stainless steel cooking compartment.
Controls	Three position control switch (Timed Cooking/OFF/Constant Cooking). 60-minute timer.
Compartment Capacity	6 (12'' x 20'' x 1'') pans 3 (12'' x 20'' x $2^1/_2$'') pans 2 (12'' x 20'' x 4'') pans
Dimensions	21'' x 25" x 25''(w×d×h)

2 Methods

Setup and Instrumentation

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 at 75 ±5°F. All test apparatus were installed in accordance with Section 9 of the ASTM test method.[3]

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 constant voltage for all tests. Figure 2-1 shows theVPX3 instrumented with the data acquisition system.

Figure 2-1. The VPX3 Instrumented for Testing.

Methods

Measured Energy Input, Preheat and Idle Rate

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, as when turned on for the first time in a day. In order to follow the intent of the test method it was necessary to modify the preheat test to accurately judge when the preheat cycle was complete. Recording began when the steamer was turned on and ended when the cooking compartment temperature reached 210°F. A thermocouple probe was placed in the geometric center of the cooking cavity in order to determine when the steamer had reached full operational capacity. Researchers had found through observation and experience that the VPX3's heating element cycled off prior to the cooking cavity reaching full steaming capacity. An hour after the preheat cycle, idle energy consumption was monitored for a 2-hour period.

Green Peas Full- and Light-Load Efficiency Tests

Individually flash-frozen, grade A green peas represented one of two food products for steamer performance testing. Standard, perforated, stainless-steel hotel pans (12" x 20" x 2½") are specified for cooking the green peas. TheVPX3 required 3 pans of green peas for a full load, while 1 pan, placed on the center rack of the steamer cavity, comprises a light load. Each pan contained 8.0 ± 0.2 lb of green peas. Pre-weighed green peas in perforated pans were stored in sealed plastic bags at 0 ± 5°F for at least 24 hours. 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.[3]

Since probing proves difficult and erroneous in measuring temperature of the small-sized green peas, a water-bath calorimeter was utilized to measure the final bulk temperature of the cooked green peas.

Red Potatoes Full- and Light-Load Efficiency Tests

Freshly packed, size B, red potatoes served as the second food product for steamer performance testing. Again, theVPX3 required 3 pans of red potatoes for a full load and 1 pan for a light load, each pan containing 8.0 ± 0.2 lb. of potatoes.

The red potatoes were loaded into perforated pans prior to the test and stabilized to a room temperature of 75 ± 5°F. The potatoes were cooked to 195 ± 2°F using a predetermined cook time. The final bulk temperature was determined by randomly probing potatoes using a hand-held digital thermocouple meter within 3 minutes after cooking was terminated.

Figure 2-2 shows the food products tested in the VPX3 steamer: frozen green peas, and red potatoes.

Figure 2-2. Products for Steamer Tests: Red Potatoes and Frozen Green Peas.

3 Results

Manufacturer's Rated Input and Maximum Energy Input Rate

Measured energy input rate and the manufacturer's nameplate value were compared prior to any testing to ensure that the steamer was operating within its specified parameters. TheVPX3 drew a maximum input rate of 9.1 kW, 1.1% higher than the nameplate rate of 9.0 kW, but within the 5% tolerance of the ASTM standard.

Preheat and Idle Tests

Preheat Energy and Time

The cavity was manually filled with two and a half gallons of water at 70 ±5°F. The steamer was placed in "Constant Cooking" mode activating the heating elements. The preheat consumed 1.4 kWh during the 9.2 minute period. The preheat time reflects the point from when the unit was turned on until its cooking compartment reached full steaming capacity of 210°F.

Idle Energy Rate

Following the preheat period, the steamer was allowed to stabilized for one hour. Thereafter, the energy consumption was monitored over a 2-hour period and the idle energy rate was calculated to be 0.3 kW.

Test Results

Rated energy input, preheat energy and idle rate test results are summarized in Table 3-1. Figure 3-1 illustrates the pre-heat and idle characteristics of the VPX3.

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

Rated Energy Input Rate (kW)	9.0
Measured Energy Input Rate (kW)	9.1
Preheat to Operational Capacity	
Time (min)	9.2
Energy (kWh)	1.4
Idle Energy Rate (kW)	0.3

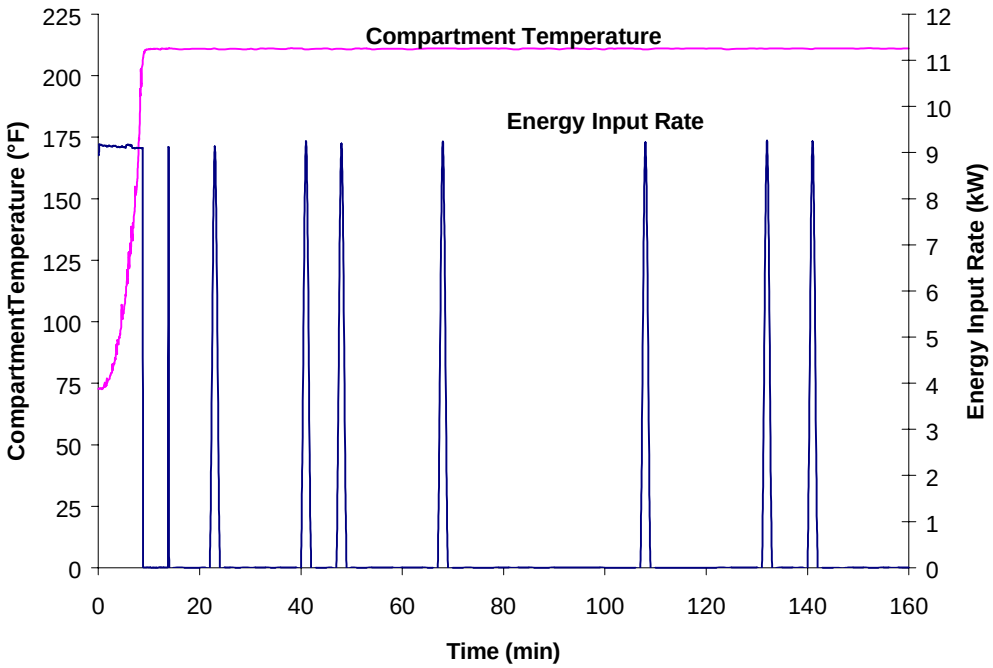

Figure 3-1. Preheat and Idle Characteristics.

Results

Cooking Tests

The steamer was tested with two test products under two loading scenarios: full-load green peas (3 pans), light-load green peas (1 pan), full-load red potatoes (3 pans), and light-load red potatoes (1 pan). All cooking scenarios were conducted in the unit's "Constant Cooking" mode.

TheVPX3 does not employ a separate boiler, water connection or drain. Therefore, water consumption and condensate temperature were not monitored. Two and a half gallons of water were poured into the bottom 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 was well below the unit's 2.5 gallon capacity.

Full- and Light-Load Green Peas Test

Moisture content of the frozen green peas was 81% by weight corresponding to specific heats (Cp) of 0.44 Btu/lb°F for frozen and 0.84 Btu/lb°F for thawed peas.[4] TheVPX3 required 18.9 minutes to cook the full load of frozen green peas and had a cooking energy efficiency of 88.4% and a production capacity of 76 lb/h.

The light-load test required an average of 11.1 minutes when cooking a single pan of frozen green peas. Cooking energy efficiency and productivity were determined to be 76.1% and 43 lb/h.

Full- and Light-Load Potatoes Test

The red potatoes contained 84% moisture by weight with the specific heat (Cp) of 0.87 Btu/lb°F.[4] A full load of potatoes averaged 22.8 minutes to reach a bulk cooked temperature of 195 ± 2°F. The cooking energy efficiency and production capacity was 70.5% and 64 lb/h, respectively.

The single pan of red potatoes required 19.8 minutes to achieve an average bulk temperature of 195 ± 2°F. The light-load potato test exhibited a somewhat lower cooking energy efficiency of 49.3% and productivity to 24 lb/h.

Result Discussion

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

Appendix D lists the physical properties and measured values of each test run. Using the detailed equations provided in section 11 of the Steamer ASTM Standard Test Method, the cooking energy efficiencies can readily be calculated. Tables 3-2 and 3-3 summarize the VPX3's cooking performance. Figures 3-2 and 3-3 compare these results in a graphical format. Figures 3-4 and Figure 3-5 illustrate the steamer's part-load energy efficiencies. Figures 3-6 and 3-7 illustrate the steamer's cooking energy profile.

Results

Table 3-2. Green Pea, Cooking Energy Efficiency and Production Capacity Test Results.

	Full Load Peas	Light Load Peas
Number of Pans	3	1
Cook Time (min)	18.9	11.1
Cooking Energy Rate (kW)	6.7	4.4
Cooking Energy Efficiency (%)	88.4	76.5
Production Rate (lb/h)	76	43
Energy Consumption (Btu/lb)	300	344

Table 3-3. Red Potato, Cooking Energy Efficiency and Production Capacity Test Results.

	Full Load Potatoes	Light Load Potatoes
Number of Pans	3	1
Cook Time (min)	22.8	19.8
Cooking Energy Rate (kW)	2.9	1.6
Cooking Energy Efficiency (%)	70.5	49.3
Production Rate (lb/h)	64	24
Energy Consumption (Btu/lb)	156	224

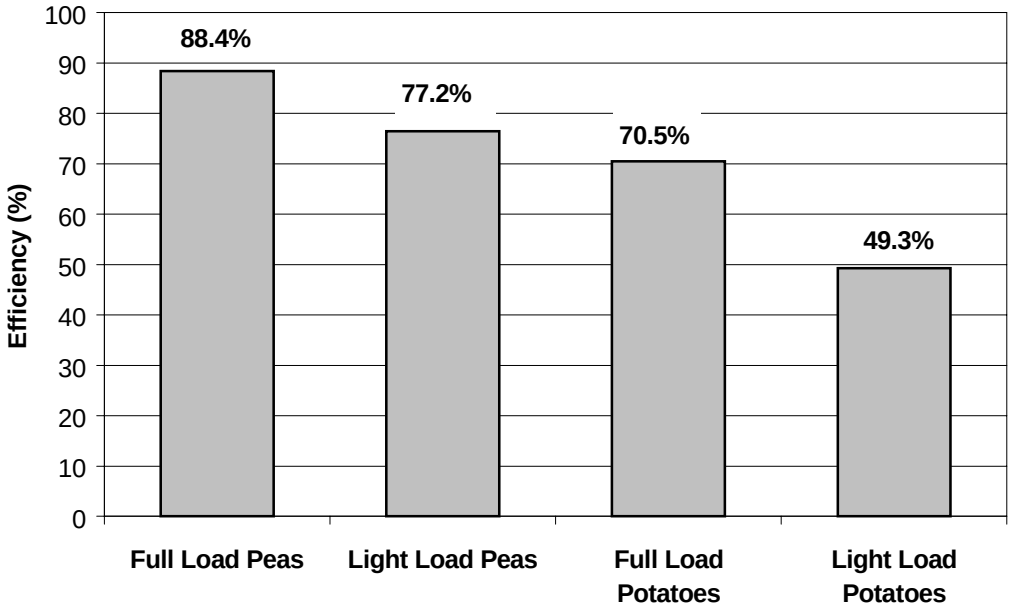

Figure 3-2.

Steamer Cooking Efficiency Under Full- and Light-Load Scenarios.

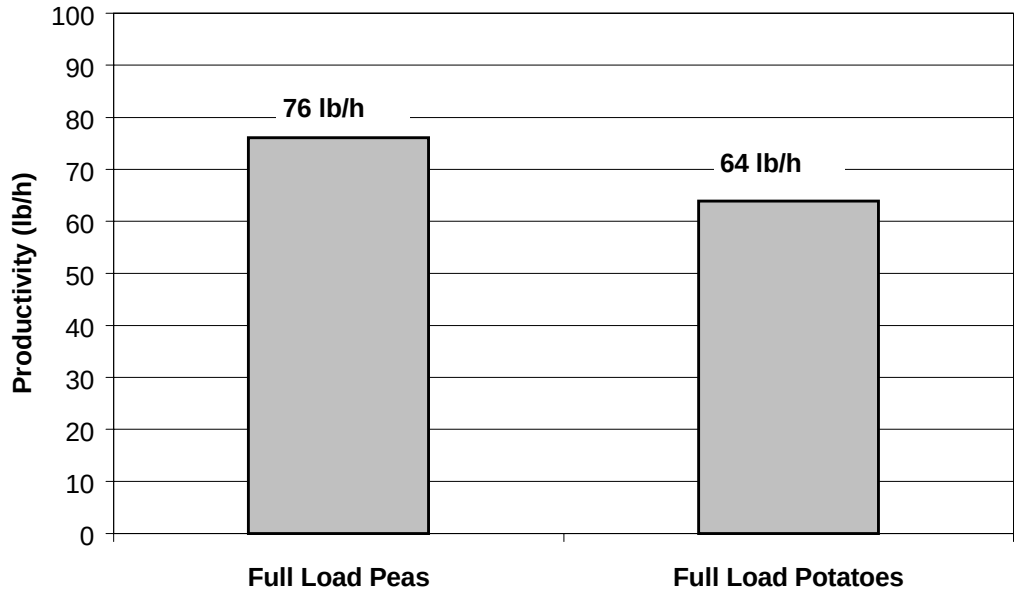

Figure 3-3.

Steamer Production Capacities.

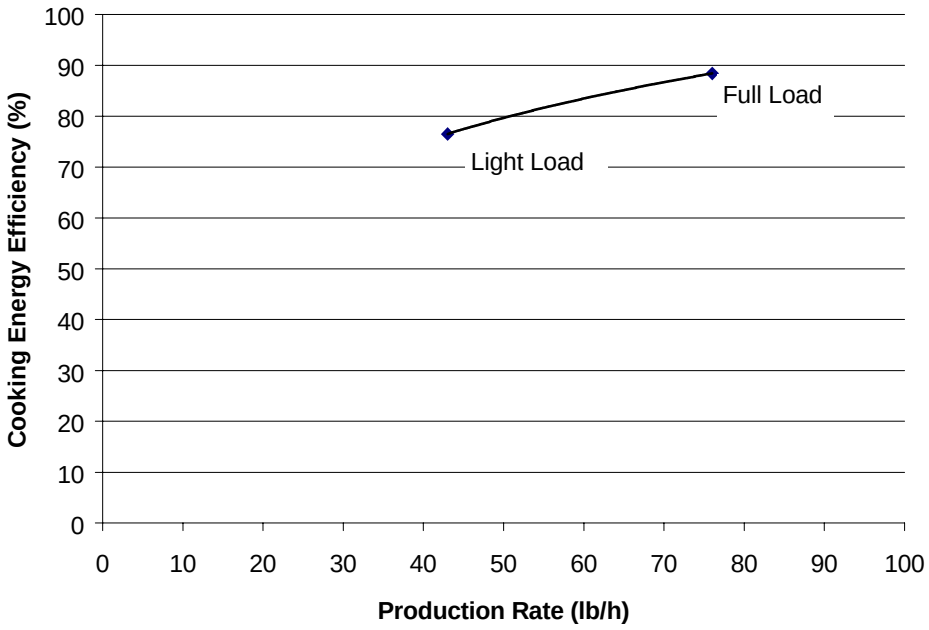

Figure 3-4.

Steamer Part-Load Green Pea Cooking Energy Efficiency.

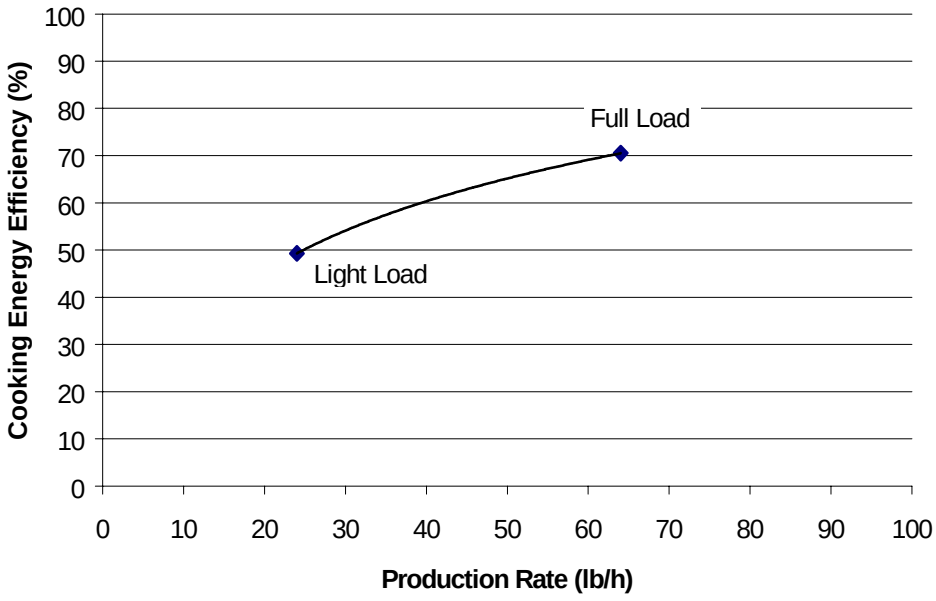

Figure 3-5.

Steamer Part-Load Red Potato Cooking Energy Efficiency.

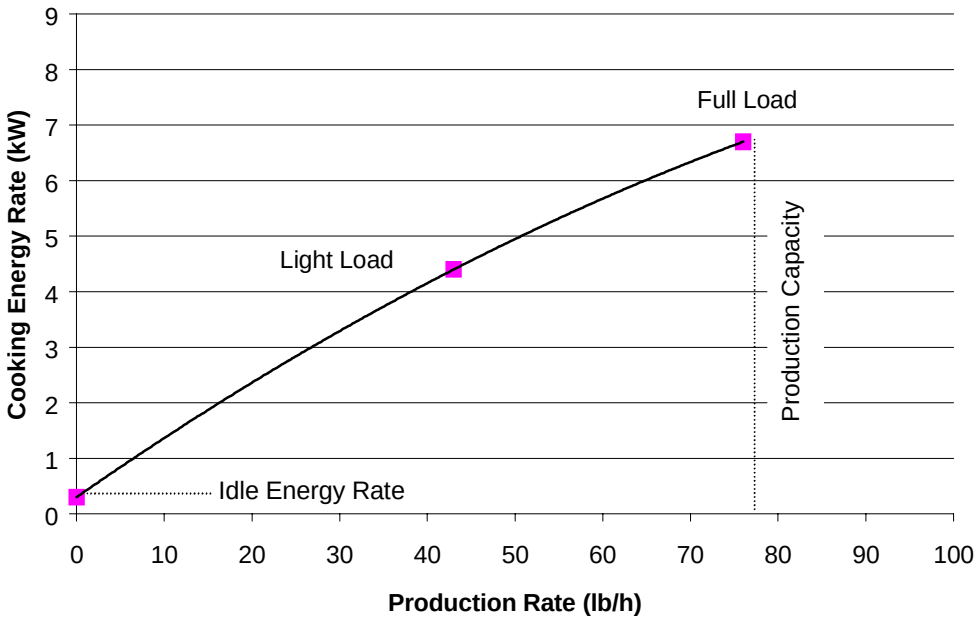

Figure 3-6.

Steamer Cooking Energy Consumption Profile, Green Peas.

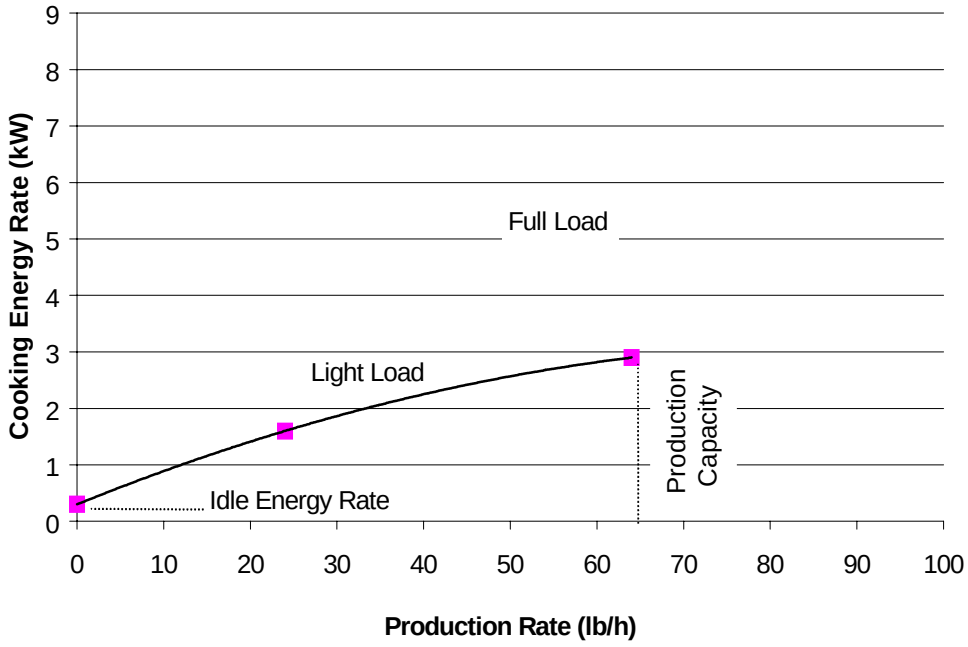

Figure 3-7.

Steamer Cooking Energy Consumption Profile, Red Potatoes.

4 Conclusions

The Vulcan VPX3 connectionless steamer is an example of a cooking appliance that puts function before form. Its simple design and straightforward controls take the guesswork out of cooking operation. Simplicity does not sacrifice cooking performance however. Of the three-pan capacity connectionless steamers tested to date at the FSTC the VPX3 exhibited the fastest cook times under full-load cooking conditions, 18.9 minutes for frozen green peas and 22.8 minutes for red potatoes.[7,11] Its single pan cook times, 11.1 minutes for frozen green peas and 19.8 minutes for red potatoes were on par with other connectionless steamers tested in the laboratory.[5,6,7,9,11,12]

The VPX3 is also energy efficient. Its 88.4% full-load frozen green pea cooking energy efficiency is an example of the steamer's ability to deliver most of its cooking energy to the food product. When challenged with a "tough" food product like red potatoes the VPX3 maintained a cooking energy efficiency of 70% during full-load cooking scenarios. Under partial-load (1pan) cooking conditions the steamer delivered cooking energy efficiencies of 70.5% for frozen green peas and 49.3% for red potatoes.

Regardless of the cooking event the VPX3 never reached its maximum rated input. The highest cooking energy rate, 6.7 kW, was measured during the full-load frozen green pea cooking tests. Significantly less energy was required to cook red potatoes as was demonstrated by the 2.9 kW cooking energy rate for a full-load. A low idle energy rate of 0.3 kW complimented the low cooking energy rates as well.

Conclusions

Another notable characteristic of the connectionless VPX3 steamer is its negligible water consumption. Typical water usage was well below the unit's 2.5 gallon capacity, significantly less than boiler-based or steam generator type steamers, which typically consume over 20 gal/h.[1,8,10]

The Vulcan VPX3 exhibited high cooking energy efficiency and productivity, yet maintained low cooking energy rates for each of the cooking scenarios. A low idle energy rate ensures that the appliance does not significantly impact utility costs during periods of non-use. These attributes, coupled with the inherent simplicity of a connectionless steamer make the VPX3 a potentially valuable appliance for many kitchens' hotlines.

5 References

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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 Idle Energy Rate
Idle Energy Rate
Idle Rate
Idle Energy Consumption Rate
Rate of energy consumed by the steam cooker while maintaining boiler operating pressure or temperature with no cooking taking place.

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

Boiler Preheat Duration
Preheat Time
Preheat Period
Total time required for preheat, from preheat initiation at controls to when the steam cooker is ready to cook.

Boiler Preheat Energy
Preheat Energy Consumption
Amount of energy consumed by the steam cooker during a preheat.

Boiler Preheat Energy Rate
Preheat Energy Rate
The rate of appliance energy consumption while it is preheating to a predetermined temperature.

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

Condensate Temperature
The temperature at which the condensate enters the floor drain.

Cooking Energy Efficiency
Energy Efficiency
Quantity of energy imparted to the specified food product expressed as a percentage of energy consumed by the steam cooker during the cooking event.

Cooking Energy Rate
Cooking Energy Consumption Rate
Average rate of energy consumption (kBtu/h or kW) during the cooking energy efficiency test. Refers to any loading scenario in the ice, pea or potato load tests.

Cook Time
Cooking Period
The period of time that the steamer is used for cooking.

Energy Input Rate
Peak rate at which a steamer consumes energy, typically reflects during preheat.

Glossary

Frozen Green Peas Load
12 x 20 x 2½ in. (300 x 500 x 65 mm) hotel pan filled with 8.0±0.2 lb (3630±90 g) of frozen, grade A, green peas subsequently frozen to 0±5°F (-18±2°C). One of two food product used to determine cooking energy efficiency and production capacity.

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

Idle Energy Consumption
Idle Energy Use
The amount of energy consumed by an appliance operating under an idle condition over the duration of an idle period.

Ice Load
12 x 20 x 2½ in. (300 x 500 x 65 mm) hotel pan filled with 8.0±0.2 lb (3630±90 g) of water and subsequently frozen to 0±5°F (-18±2°C). This is used to simulate a food product load in the ice load cooking energy efficiency and production capacity test.

Low-Pressure Steam Cooker
Steam cooker wherein the cooking compartment operates between 3 and 9.9 psig (ASTM F1217-92 Classification Type II).

Maximum Energy Input Rate
Measured Energy Input
Measured Peak Energy Input Rate
Peak Rate of Energy Input
Peak rate at which an appliance consumes energy.

Potato Load
12 x 20 x 2½ in. (300 x 500 x 65 mm) hotel pan filled with 8.0±0.2 lb (3.6±0.1 kg) of fresh, whole, US No. 1, size B, red potatoes. One of two food product used to determine cooking energy efficiency and production capacity.

Production Capacity
Maximum rate (lb(kg)/h) at which the steam cooker can bring the specified food product to a specified "cooked" condition.

Production Rate
Rate (lb(kg)/h) at which the steam cooker brings the specified food product to a specified "cooked" condition.

Rated Energy Input Rate
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.

Water Consumption
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 Specification Sheet

Appendix B includes the product literature for the Vulcan, Model VPX3 steamer.

C Results Reporting Sheets

Manufacturer: Vulcan
Model: VPX3
Date: May 2001

Section 11.1 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: Approximately two and a half gallons of water is manually poured into the steamer cooking compartment reservoir. Using the three position control switch, the operator can select either "Timed Cooking" or "Constant Cooking" modes of operation. Shutting the appliance door activated the heating elements. Upon shut-down the water reservoir is drained turning the drain lever to "Open".

Section 10.7 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 ±5°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 10-seconds intervals for the red potato tests and 5-second intervals for the rest. All test apparatus were installed in accordance with Section 9 of the ASTM test method.

Section 11.4 Energy Input Rate

Measured	9.1 kW
Rated	9.0 kW
Percent Difference between Measured and Rated	1.3%

Section 11.5 Appliance Preheat Energy Consumption and Duration

Energy Consumption	1.35 kWh
Duration	9.22 min

Section 11.6 Appliance Idle Energy Rate

Idle Energy Rate	0.3 kW

Results Reporting Sheets

Section 11.8 Frozen Green Peas Cooking Time, Energy Efficiency, Energy Rate, Production Capacity, and Water Consumption Rate

Full Load:

Cooking Time	18.9 min
Cooking Energy Efficiency	88.4 ±1.6%
Cooking Energy Rate	6.7 ± 0.3 kW
Production Capacity	76.1 ±1.5 lb/h
Water Consumption Rate	< 2.5 gal/h

Light Load:

Cooking Time	11.1 min
Cooking Energy Efficiency	76.5 ±2.4%
Cooking Energy Rate	4.4 ± 0.2 kW
Production Rate	43.4 ± 0.9 lb/h
Water Consumption Rate	< 2.5 gal/h

Section 11.9 Whole Red Potatoes Cooking Time, Energy Efficiency, Energy Rate, Production Capacity, and Water Consumption Rate

Full Load:

Cooking Time	22.8 min
Cooking Energy Efficiency	70.5 ±4.1%
Cooking Energy Rate	2.9 ± 0.2 kW
Production Capacity	63.9 ± 1.9 lb/h
Water Consumption Rate	< 2.5 gal/h

Results Reporting Sheets

Light Load:

Cooking Time	19.8 min
Cooking Energy Efficiency	49.3 ± 2.3%
Cooking Energy Rate	1.6 ± 0.2kW
Production Capacity	24.4 ± 1.3 lb/h
Water Consumption Rate	< 2.5 gal/h

D Cooking Energy Efficiency Data

Table D-1. Preheat and Idle Data

Measured Values	Replication 1	Replication 2	Replication 3
Preheat Time (min)	9.50	9.00	9.17
Preheat Energy (kWh)	1.40	1.30	1.34
Idle Time (min)	120.0	120.0	120.0
Idle Energy (kWh)	0.66	0.68	0.66
Calculated Values			
Preheat Energy Rate (kW)	8.84	8.67	8.77
Idle Energy Rate (kW)	0.33	0.34	0.33

Cooking Energy Efficiency Data

Table D-2. Full-Load Peas Data

Measured Values	Replication 1	Replication 2	Replication 3
Number of Pan(s)	3	3	3
Cook Time (min)	19.00	18.75	19.00
Initial Water Temperature (°F)	38.9	38.7	39.0
Final Water Temperature (°F)	95.9	95.1	96.7
Frozen Food Temperature (°F)	-4.4	-4.4	-4.4
Weight of Empty Calorimeter (lb)	44.1	44.3	44.3
Weight of Full Calorimeter (lb)	98.5	98.6	98.3
Weight of Calorimeter Water (lb)	30.0	30.3	30.0
Weight of Cooked Food (lb)	24.4	24.0	24.0
Weight of Frozen Food (lb)	24.0	24.0	24.0
Weight of Stainless-Steel Pans (lb)	7.6	8.4	8.4
Moisture Content (%)	81	81	81
Condensate Temperature (°F)	n/a	n/a	n/a
Water Consumption (gal/h)	<2.5	<2.5	<2.5
Calculated Values			
Moisture Weight in Green Peas (lb)	19.4	19.4	19.4
Final Food Temperature (°F)	178.5	179.0	181.8
Cooking Energy (kWh)	2.08	2.12	2.12
Energy Consumed by Green Peas (Btu)	6163.6	6174.2	6230.9
Energy Consumed by Pans (Btu)	153.1	169.7	172.3
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	7099.0	7235.6	7235.6
Cooking Energy Rate (kW)	6.6	6.8	6.7
Productivity (lb/h)	75.8	76.8	75.8
Energy Efficiency (%)	89.0	87.7	88.5

Table D-3. Light-Load Peas Data

Measured Values	Replication 1	Replication 2	Replication 3
Number of Pan(s)	1	1	1
Cook Time (min)	11.17	11.00	11.00
Initial Water Temperature (°F)	49.4	42.5	39.9
Final Water Temperature (°F)	82.6	78.3	75.2
Frozen Food Temperature (°F)	-4.4	-4.4	-4.4
Weight of Empty Calorimeter (lb)	45.1	44.3	45.3
Weight of Full Calorimeter (lb)	73.2	72.4	73.3
Weight of Calorimeter Water (lb)	20.1	20.0	20.0
Weight of Cooked Food (lb)	8.0	8.2	8.0
Weight of Frozen Food (lb)	8.0	8.0	8.0
Weight of Stainless-Steel Pans (lb)	2.4	2.4	2.3
Moisture Content (%)	81	81	81
Condensate Temperature (°F)	n/a	n/a	n/a
Water Consumption (gal/h)	< 2.5	< 2.5	< 2.5
Calculated Values			
Moisture Weight in Green Peas(lb)	6.5	6.5	6.5
Final Food Temperature (°F)	180.8	181.4	179.3
Cooking Energy (kWh)	0.80	0.82	0.80
Energy Consumed by Green Peas (Btu)	2070.1	2074.2	2032.0
Energy Consumed by Pans (Btu)	49.3	49.6	44.7
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	2730.4	2798.7	2730.4
Cooking Energy Rate (kW)	4.3	4.5	4.4
Productivity (lb/h)	43.0	43.6	43.6
Energy Efficiency (%)	77.6	75.9	76.1

Table D-4. Full-Load Potatoes Data

Measured Values	Replication 1	Replication 2	Replication 3
Number of Pan(s)	3	3	3
Cook Time (min)	22.83	22.67	23.00
Temperature of Uncooked Potatoes (°F)	73.80	73.80	73.10
Temperature of Cooked Potatoes (°F)	195.0	195.00	195.00
Weight of Stainless-Steel Pans (lb)	7.77	7.60	7.65
Weight of Potatoes (lb)	24.22	24.44	24.24
Total Potato Count	144	142	145
Moisture Content (%)	84	84	84
Condensate Temperature (°F)	n/a	n/a	n/a
Water Consumption (gal/h)	< 2.5	< 2.5	< 2.5
Calculated Values			
Moisture Weight in Potatoes (lb)	20.36	20.55	20.38
Average Weight of Each Potatoes (lb)	0.17	0.17	0.17
Cooking Energy (kWh)	1.08	1.14	1.12
Energy Consumed by Potatoes (Btu)	2562.34	2585.88	2579.59
Energy Consumed by Pans (Btu)	103.58	101.36	102.61
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	3686.04	3890.82	3822.56
Cooking Energy Rate (kW)	2.84	3.02	2.92
Productivity (lb/h)	63.64	64.69	63.23
Energy Efficiency (%)	72.32	69.07	70.17

Table D-5. Light-Load Potatoes Data

Measured Values	Replication 1	Replication 2	Replication 3
Number of Pan(s)	1	1	1
Cook Time (min)	20.25	19.42	19.67
Temperature of Uncooked Potatoes (°F)	73.60	73.40	74.70
Temperature of Cooked Potatoes (°F)	195.0	195.0	195.0
Weight of Stainless-Steel Pans (lb)	2.79	2.81	2.79
Weight of Potatoes (lb)	8.03	8.03	8.03
Total Potato Count	48	48	48
Moisture Content (%)	84	84	84
Condensate Temperature (°F)	n/a	n/a	n/a
Water Consumption (gal/h)	< 2.5	< 2.5	< 2.5
Calculated Values			
Moisture Weight in Potatoes (lb)	6.75	6.75	6.75
Average Weight of Each Potatoes (lb)	0.17	0.17	0.17
Cooking Energy (kWh)	0.52	0.54	0.52
Energy Consumed by Potatoes (Btu)	851.04	852.44	843.33
Energy Consumed by Pans (Btu)	37.19	37.54	36.85
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	1774.76	1843.02	1774.76
Cooking Energy Rate (kW)	1.54	1.67	1.59
Productivity (lb/h)	23.79	24.81	24.50
Energy Efficiency (%)	50.05	48.29	49.59