

**Vulcan, VPX5
Electric Steamer Performance Test**

Application of ASTM Standard
Test Method F 1484-99

FSTC Report 5011.01.02

**Food Service Technology Center
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Executive Summary

The Food Service Technology Center (FSTC) tested the Vulcan, Model VPX5 connectionless, 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 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. The VPX5 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 VPX5's cooking energy efficiency for different cooking scenarios. The production capacities are shown in Figure ES-2.

The Vulcan VPX5 is an energy efficient and productive connectionless electric steamer. Researchers measured an average 17.6 minutes cook time for a full-load of frozen green peas with a corresponding cooking energy efficiency of 87.2%. Under partial-load (1 pan) conditions for the same food product, a 10.9 minutes cook time was recorded as well as a 64.3% cooking energy efficiency.

¹American 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 VPX5 had a rapid preheat time of 6.4 minutes and its cavity temperature remained at full operational capacity during idling periods (i.e 210°F). Maintaining a constant state of readiness did not require significant energy, however, as was demonstrated by the 0.5 kW idle energy rate.

Beyond its impressive productivity and cooking energy efficiencies, the steamer also exhibited low water usage. Typical water consumption during full-load cooking events was much lower than the unit's 2.5 gallon reservoir capacity.

Executive Summary

Table ES-1. Performance Summary, Vulcan, Model VPX5.

Preheat and Idle

Rated Energy Input Rate (kW)	15.0
Measured Energy Input Rate (kW)	14.9
Preheat Time (min)	6.4
Preheat Energy (kWh)	1.5
Idle Energy Rate (kW)	0.5

Full-Load Frozen Green Peas (5 pans)

Cook Time (min)	17.5
Cooking Energy Rate (kW)	12.1
Cooking Energy Efficiency (%)	87.1
Production Capacity (lb/h)	137
Water Consumption (gal/h)	<2.5

Light-Load Frozen Green Peas (1 pan)

Cook Time (min)	10.9
Cooking Energy Rate (kW)	5.3
Cooking Energy Efficiency (%)	64.3
Water Consumption (gal/h)	<2.5

Full-Load Red Potatoes (5 pans)

Cook Time (min)	23.9
Cooking Energy Rate (kW)	4.8
Cooking Energy Efficiency (%)	68.4
Production Capacity (lb/h)	101
Water Consumption (gal/h)	<2.5

Light-Load Red Potatoes (1 pan)

Cook Time (min)	20.2
Cooking Energy Rate (kW)	2.2
Cooking Energy Efficiency (%)	35.5
Water Consumption (gal/h)	<2.5

Executive Summary

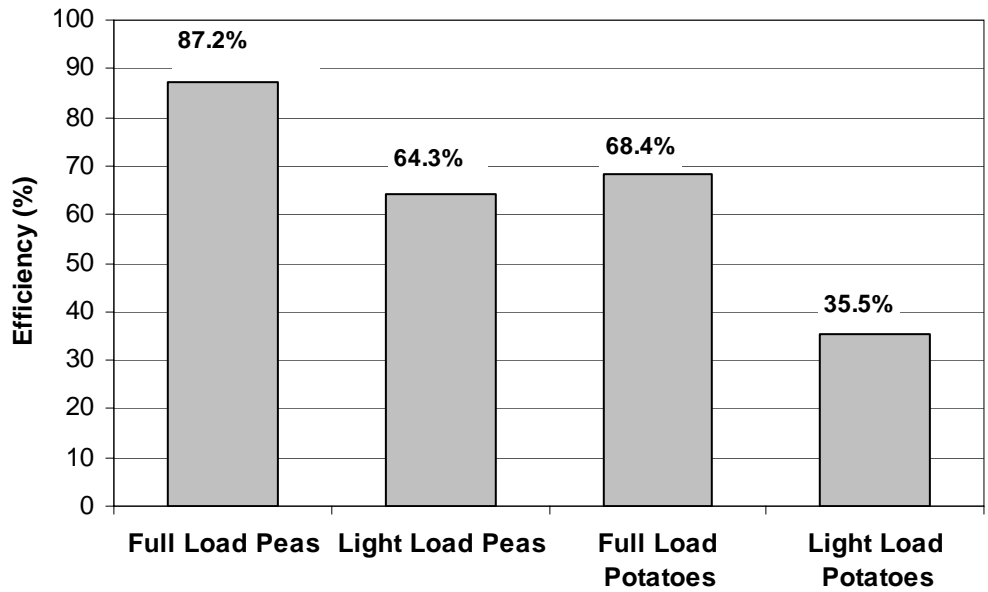


Figure ES-1.
Steamer Cooking
Energy Efficiency
Under Two Loading
Scenarios.

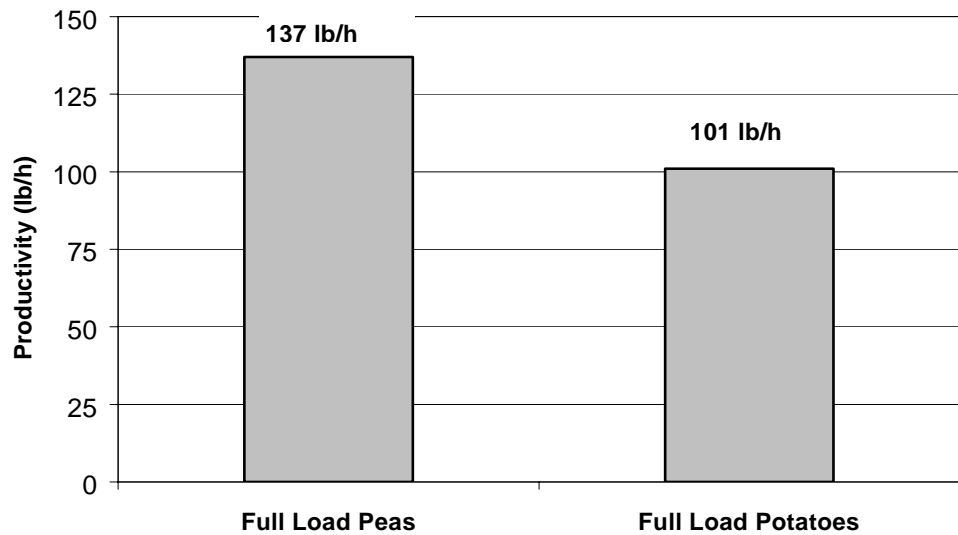


Figure ES-2.
Steamer Production
Capacity.

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 1484-99³ (originally published as F 1484-93²). Modification to the test method included replacing the ice-load test with frozen green peas to emulate real-world application.

The Vulcan, VPX5 is a single-compartment, electric connectionless steamer. The heating element is positioned beneath the water reservoir, eliminating the need for a separate boiler. The VPX5 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 VPX5 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 (5 pans), light-load frozen green peas (1 pan), full-load red potatoes (5 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

The VPX5 is a stainless steel, electric connectionless steamer with a single 15.0 kW heating element placed beneath 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 ten 12" x 20" x 1", five 12" x 20" x 2½" or three 12" x 20" x 4" perforated steamer pans. The VPX5 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 is opened.

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

Introduction



Table 1-1. Appliance Specifications.

Manufacturer	Vulcan Company
Model	VPX5
Generic Appliance Type	1-compartment, natural-convection, electric connectionless steamer.
Rated Input	15.0 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	10 (12" x 20" x 1") pans 5 (12" x 20" x 2½") pans 3 (12" x 20" x 4") pans
Dimensions	21" x 25" x 31½" (w×d×h)

*Figure 1-1.
The Vulcan VPX5 Steamer.*

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 $75 \pm 5^\circ\text{F}$. 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 the VPX5 instrumented with the data acquisition system.



*Figure 2-1.
The VPX5 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 VPX5'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. The VPX5 required 5 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 $0 \pm 5^\circ\text{F}$ 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.

Methods

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, the VPX5 required 5 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 $75 \pm 5^\circ\text{F}$. The potatoes were cooked to $195 \pm 2^\circ\text{F}$ 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 VPX5 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. The VPX5 drew a maximum input rate of 14.9 kW, 0.6% lower than the nameplate rate of 15.0 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 $70 \pm 5^\circ\text{F}$. The steamer was placed in "Constant Cooking" mode activating the heating elements. The preheat consumed 1.5 kWh during the 6.4 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 stabilize for one hour. Thereafter, the energy consumption was monitored over a 2-hour period and the idle energy rate was calculated to be 0.5 kW.

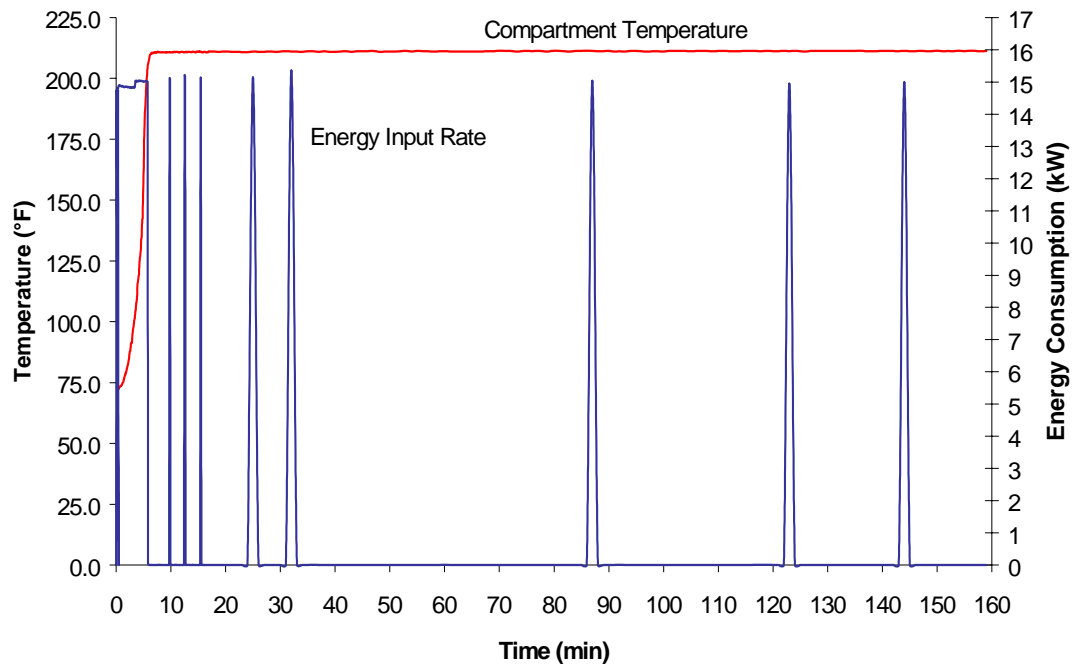
Results

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 VPX5.

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

Rated Energy Input Rate (kW)	15.0
Measured Energy Input Rate (kW)	14.9
Preheat to Operational Capacity	
Time (min)	6.4
Energy (kWh)	1.5
Idle Energy Rate (kW)	0.5



*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 (5 pans), light-load green peas (1 pan), full-load red potatoes (5 pans), and light-load red potatoes (1 pan). All cooking scenarios were conducted in the unit's "Constant Cooking" mode.

The VPX5 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 much less than the 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 (C_p) of 0.44 Btu/lb°F for frozen and 0.84 Btu/lb°F for thawed peas.⁴ The VPX5 required 17.6 minutes to cook the full load of frozen green peas and had a cooking energy efficiency of 87.2% and a production capacity of 137 lb/h.

The light-load test required an average of 10.9 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 (C_p) of 0.87 Btu/lb°F.⁴ A full load of potatoes averaged 23.9 minutes to reach a bulk cooked temperature of $195 \pm 2^\circ\text{F}$. The cooking energy efficiency and production capacity was 68.4% and 101lb/h, respectively.

The single pan of red potatoes required 20.2 minutes to achieve an average bulk temperature of $195 \pm 2^\circ\text{F}$. The light-load potato test exhibited a cooking energy efficiency of 35.5% and productivity of 24 lb/h.

Results

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 VPX5’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.

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

Results

	Full Load Peas	Light Load Peas
Number of Pans	5	1
Cook Time (min)	17.6	10.9
Cooking Energy Rate (kW)	12.2	5.3
Cooking Energy Efficiency (%)	87.2	64.3
Production Rate (lb/h)	137	44
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	5	1
Cook Time (min)	23.9	20.2
Cooking Energy Rate (kW)	4.8	2.2
Cooking Energy Efficiency (%)	68.4	35.5
Production Rate (lb/h)	101	24
Energy Consumption (Btu/lb)	162	312

Results

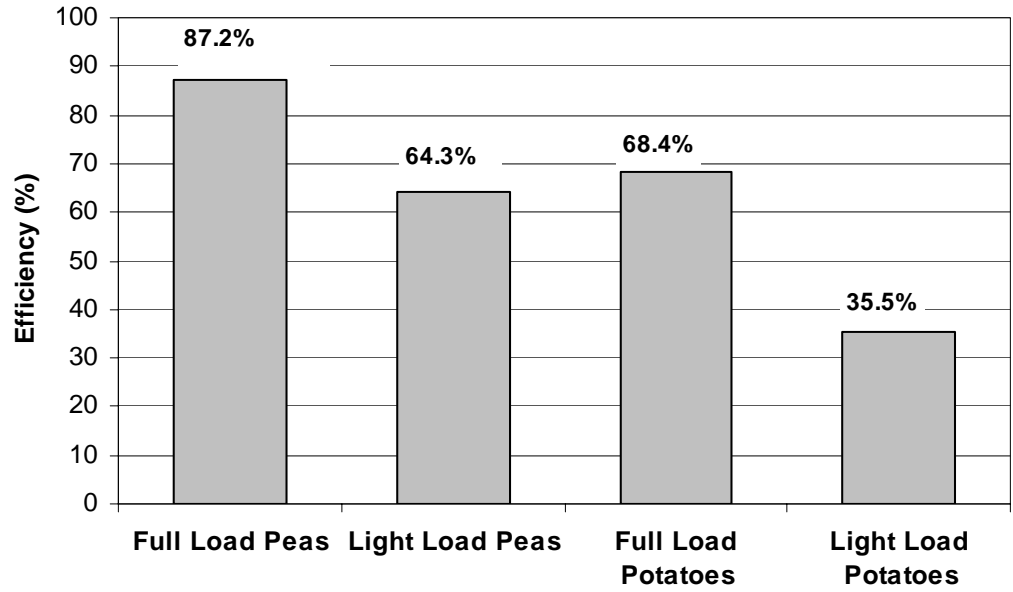


Figure 3-2.
Steamer Cooking
Efficiency Under Full-
and Light-Load
Scenarios.

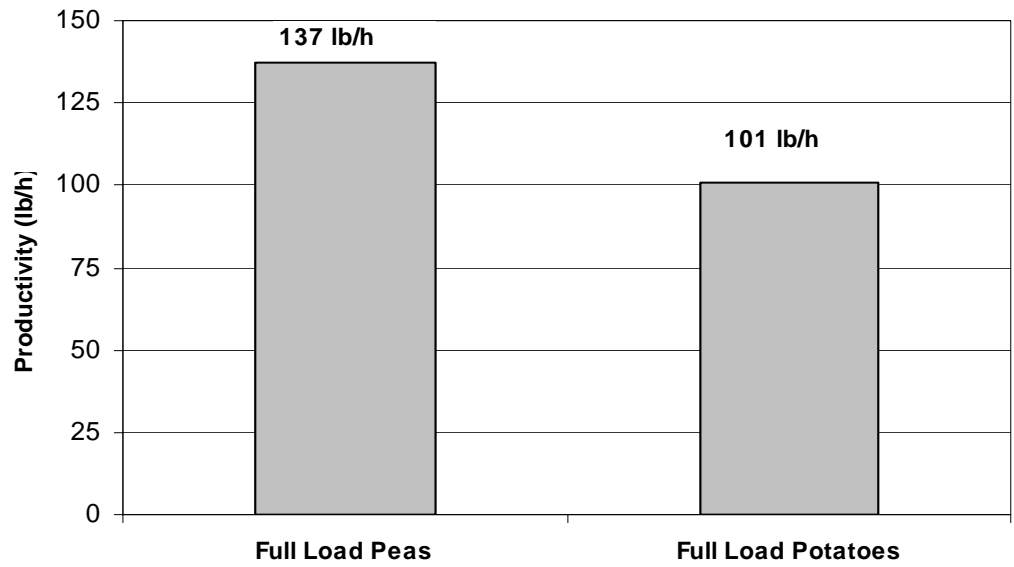
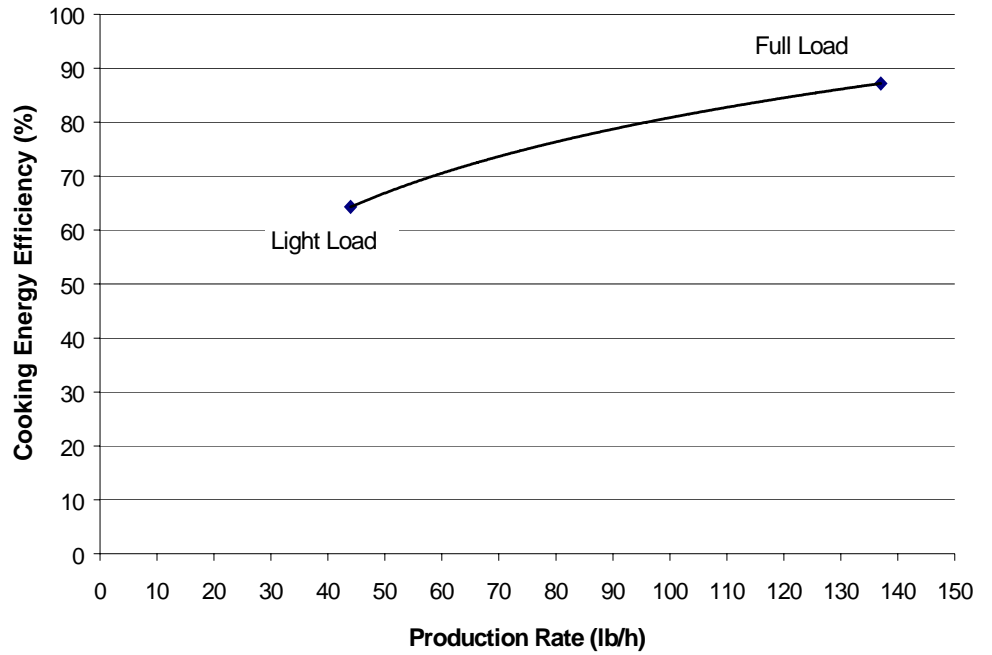


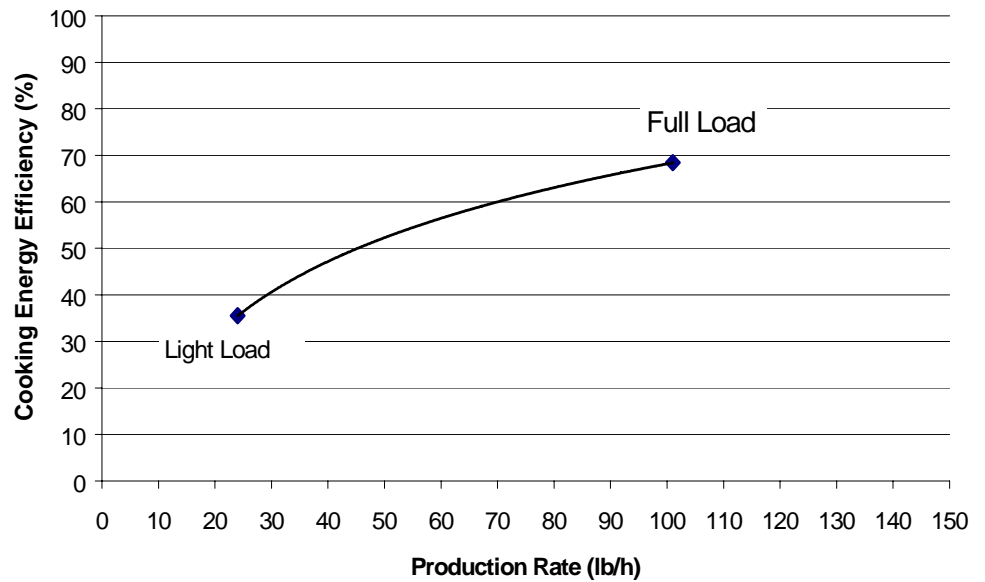
Figure 3-3.
Steamer Production
Capacities.

Results

*Figure 3-4.
Steamer Part-Load
Green Pea Cooking
Energy Efficiency.*



*Figure 3-5.
Steamer Part-Load
Red Potato Cooking
Energy Efficiency.*



Results

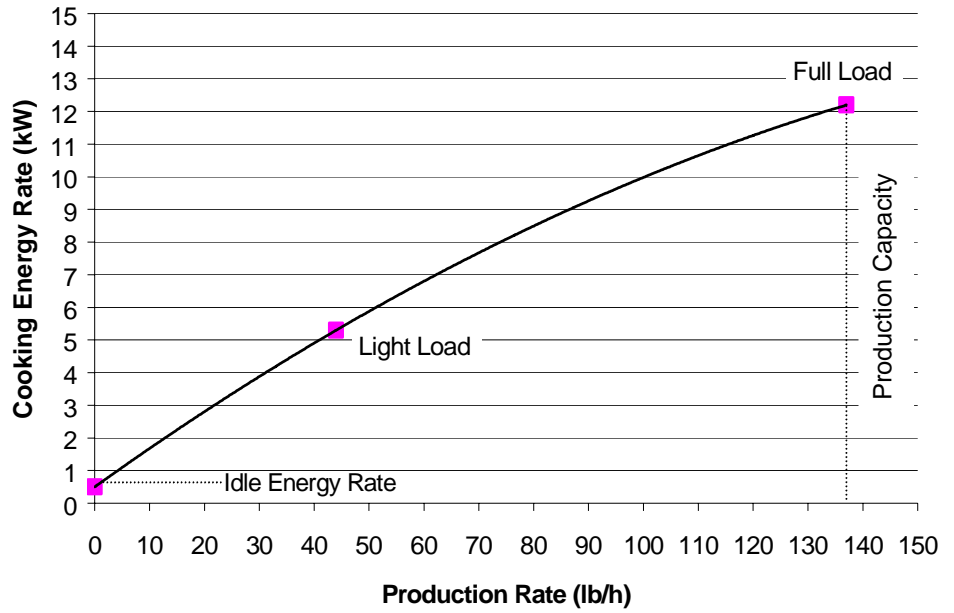


Figure 3-6.
Steamer Cooking Energy
Consumption Profile,
Green Peas.

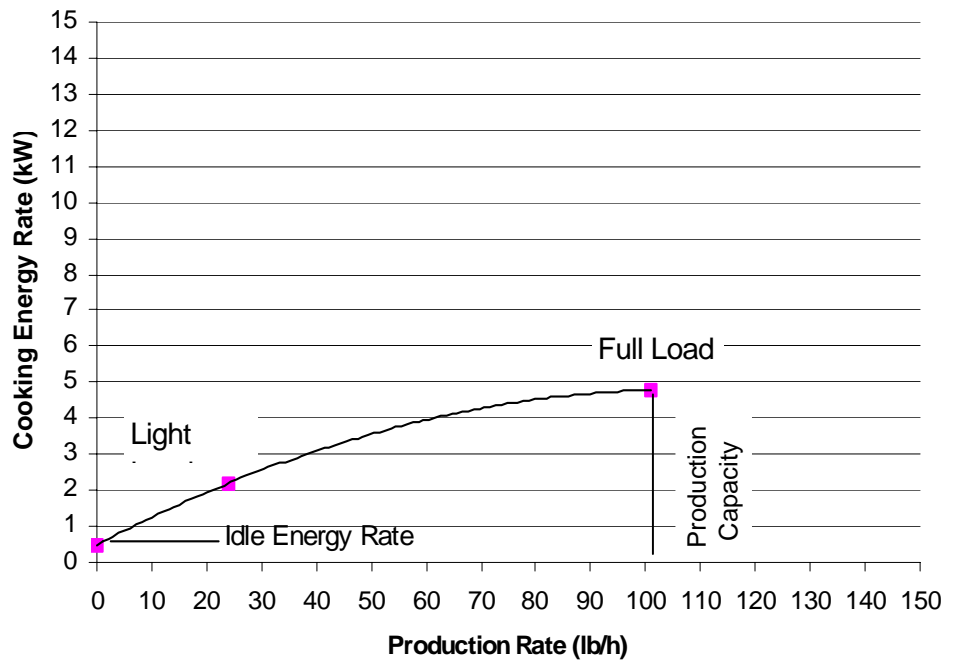


Figure 3-7.
Steamer Cooking Energy
Consumption Profile,
Red Potatoes.

4 Conclusions

The VulcanVPX5 exhibited the fastest full-load frozen green pea cook time of any connectionless steamer tested to date at the FSTC.^{5,6,7,9,11,12} Its 17.6 minutes cook time and corresponding production capacity of 137 lb/h, puts theVPX5 on par with boiler-based and steam generator type steamers previously tested in the lab.^{1,8}

Not only did the Vulcan steamer exhibit rapid cook times, its cooking energy efficiencies were high as well. An 87.2% cooking energy efficiency was calculated for the full-load frozen green pea cooking tests. When tasked with cooking a single pan, the unit demonstrated a cooking energy efficiency of 65%. Red potatoes served as the greatest challenge to the Vulcan steamer, but the appliance still delivered 68.4% of its cooking energy to this “tough” food product under full-load conditions and 35.5% under light.

Of the connectionless steamers subjected to the rigors of the ASTM performance test, the VPX5 had the fastest preheat time.^{5,6,7,9,11,12} On average the unit was fully operational in 6.4 minutes. Again, this result put the unit on par with steamer generator type steamers previously tested in the lab.^{1,8,13} The unit exhibited a low idle energy rate of 0.5 kW, while maintaining the cooking compartment at 210°F.

The VPX5 also exhibited very low water consumption for each of the testing scenarios. Researchers observed water use well below the unit’s 2.5 gallon capacity, significantly lower than boiler-based or steam generator type steamers.^{1,8,10,13} Operators need only refresh the water reservoir periodically by simply pouring water directly into the cooking compartment. A “Low Water” indicator light warns of insufficient water for steam generation.

Conclusions

With its fast cook times, the Vulcan VPX5 connectionless steamer offers end users high productivity and cooking energy efficiency without the complexities of boiler-based or steam generator type steamers that require water and drain connections. As a comparably easy to install and maintain appliance, the VPX5 has the potential to become a valuable energy saving appliance on 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 VPX5 steamer.

C Results Reporting Sheets

Manufacturer: Vulcan
Model: VPX5
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 $75 \pm 5^\circ\text{F}$. 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 10-second 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	14.9 kW
Rated	15.0 kW
Percent Difference between Measured and Rated	0.6%

Section 11.5 Appliance Preheat Energy Consumption and Duration

Energy Consumption	1.45 kWh
Duration	6.42 min

Section 11.6 Appliance Idle Energy Rate

Idle Energy Rate	0.5 kW
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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	17.58 min
Cooking Energy Efficiency	87.2 ±1.6%
Cooking Energy Rate	12.2 ± 0.4 kW
Production Capacity	136.5 ±2.8 lb/h
Water Consumption Rate	< 2.5 gal/h

Light Load:

Cooking Time	10.89 min
Cooking Energy Efficiency	64.3 ±1.6%
Cooking Energy Rate	5.3 ± 0.1 kW
Production Rate	44.1 ± 1.28 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	23.92 min
Cooking Energy Efficiency	68.4 ±1.5%
Cooking Energy Rate	4.8 ± 0.1 kW
Production Capacity	101.4 ± 2.9 lb/h
Water Consumption Rate	< 2.5 gal/h

Results Reporting Sheets

Light Load:

Cooking Time	20.2 min
Cooking Energy Efficiency	$35.5 \pm 2.2\%$
Cooking Energy Rate	$2.2 \pm 0.1\text{kW}$
Production Capacity	$24.1 \pm 1.0\text{ lb/h}$
Water Consumption Rate	$< 2.5\text{ gal/h}$

D Cooking Energy Efficiency Data

Table D-1. Preheat and Idle Data

Measured Values	Replication 1	Replication 2	Replication 3
Preheat Time (min)	6.33	6.58	6.33
Preheat Energy (kWh)	1.44	1.40	1.50
Idle Time (min)	120.0	120.0	120.0
Idle Energy (kWh)	1.02	1.02	1.06
Calculated Values			
Preheat Energy Rate (kW)	13.64	14.40	14.21
Idle Energy Rate (kW)	0.51	0.51	0.53

Cooking Energy Efficiency Data

Table D-2. Full-Load Peas Data

Measured Values	Replication 1	Replication 2	Replication 3
Number of Pan(s)	5	5	5
Cook Time (min)	17.50	17.75	17.50
Initial Water Temperature (°F)	48.6	43.5	46.5
Final Water Temperature (°F)	101.0	99.4	100.9
Frozen Food Temperature (°F)	-4.4	-4.4	-4.4
Weight of Empty Calorimeter (lb)	44.5	44.3	44.2
Weight of Full Calorimeter (lb)	134.5	134.5	134.4
Weight of Calorimeter Water (lb)	50.0	50.1	50.0
Weight of Cooked Food (lb)	40.1	40.1	40.2
Weight of Frozen Food (lb)	40.0	40.0	40.0
Weight of Stainless-Steel Pans (lb)	14.6	12.9	14.6
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)	32.4	32.4	32.4
Final Food Temperature (°F)	178.1	181.7	180.6
Cooking Energy (kWh)	3.52	3.58	3.60
Energy Consumed by Green Peas (Btu)	10260.7	10379.9	10342.8
Energy Consumed by Pans (Btu)	292.8	262.4	296.7
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	12013.8	12218.5	12286.8
Cooking Energy Rate (kW)	12.1	12.1	12.3
Productivity (lb/h)	137.1	135.2	137.1
Energy Efficiency (%)	87.8	87.1	86.6

Cooking Energy Efficiency Data

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)	11.00	10.92	10.75
Initial Water Temperature (°F)	49.7	47.5	45.4
Final Water Temperature (°F)	84.2	82.4	77.7
Frozen Food Temperature (°F)	-4.4	-4.4	-4.4
Weight of Empty Calorimeter (lb)	44.4	44.5	44.2
Weight of Full Calorimeter (lb)	72.4	72.3	72.2
Weight of Calorimeter Water (lb)	20.0	20.0	20.0
Weight of Cooked Food (lb)	8.0	7.8	8.0
Weight of Frozen Food (lb)	8.0	8.0	8.0
Weight of Stainless-Steel Pans (lb)	3.2	2.8	2.4
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)	6.5	6.5	6.5
Final Food Temperature (°F)	181.7	181.4	180.9
Cooking Energy (kWh)	0.98	0.96	0.96
Energy Consumed by Green Peas (Btu)	2076.3	2074.2	2042.6
Energy Consumed by Pans (Btu)	65.5	56.9	47.2
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	3344.7	3276.5	3276.5
Cooking Energy Rate (kW)	5.3	5.3	5.4
Productivity (lb/h)	43.6	44.0	44.7
Energy Efficiency (%)	64.0	65.0	63.8

Cooking Energy Efficiency Data

Table D-4. Full-Load Potatoes Data

Measured Values	Replication 1	Replication 2	Replication 3
Number of Pan(s)	5	5	5
Cook Time (min)	24.17	23.83	23.75
Temperature of Uncooked Potatoes (°F)	73.40	73.50	73.30
Temperature of Cooked Potatoes (°F)	195.00	0.00	0.00
Weight of Stainless-Steel Pans (lb)	13.36	12.46	12.47
Weight of Potatoes (lb)	40.31	40.63	40.34
Total Potato Count	243.00	244.00	247.00
Moisture Content (%)	84.07	84.07	84.07
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)	33.89	34.16	33.91
Average Weight of Each Potatoes (lb)	0.17	0.17	0.16
Cooking Energy (kWh)	1.92	1.90	1.92
Energy Consumed by Potatoes (Btu)	4279.18	4309.60	4285.57
Energy Consumed by Pans (Btu)	178.75	166.53	167.00
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	6551.04	6482.80	6551.04
Cooking Energy Rate (kW)	4.77	4.78	4.85
Productivity (lb/h)	100.08	102.29	101.90
Energy Efficiency (%)	68.05	69.05	67.97

Cooking Energy Efficiency Data

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)	20.00	20.00	20.50
Temperature of Uncooked Potatoes (°F)	72.60	73.90	73.40
Temperature of Cooked Potatoes (°F)	195.00	0.00	0.00
Weight of Stainless-Steel Pans (lb)	2.78	2.81	2.40
Weight of Potatoes (lb)	8.18	8.00	8.13
Total Potato Count	48.00	48.00	50.00
Moisture Content (%)	84.07	84.07	84.07
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)	6.88	6.73	6.83
Average Weight of Each Potatoes (lb)	0.17	0.17	0.16
Cooking Energy (kWh)	0.74	0.72	0.76
Energy Consumed by Potatoes (Btu)	874.08	845.76	863.05
Energy Consumed by Pans (Btu)	37.47	37.38	32.06
Energy of Boiler Re-init (Btu)	n/a	n/a	n/a
Energy Consumed by the Steamer (Btu)	2524.88	2456.64	2593.12
Cooking Energy Rate (kW)	2.22	2.16	2.22
Productivity (lb/h)	24.54	24.00	23.80
Energy Efficiency (%)	36.10	35.95	34.52

