

**AccuTemp STEAM 'n' HOLD, Model 208-D6-3.0
Electric Steamer Performance Test**

Application of ASTM Standard
Test Method F 1484-93

FSTC Report 5011.98.58

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The establishment of a Food Service Technology Center reflects PG&E's commitment to the food service industry. The goal of the research project is to provide PG&E's customers with information to help them evaluate technically innovative cooking appliances and make informed equipment purchases regarding advanced technologies and energy sources. The project was the result of many people and departments working together within PG&E and the overwhelming support of the commercial equipment manufacturers who supplied the cooking appliances for testing.

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Executive Summary

The 6-pan capacity AccuTemp STEAM 'n' HOLD, Model 208-D6-3.0, is a revolutionary innovation in countertop steam cooking. The vacuum cooking process allows the generation of steam at a lower temperature than the conventional atmospheric steamer. The boiler-less design eliminates the water feed and condensate drain, leaving a user-friendly and low maintenance machine. The thermostatic controls maintain food at a desired temperature until ready to serve.

The Food Service Technology Center (FSTC) tested the AccuTemp STEAM 'n' HOLD 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 pre-heat energy consumption and duration, idle energy rate, cooking energy efficiency, production capacity, water consumption and condensate temperature from product testing. Since the STEAM 'n' HOLD is without a condensate drain, the measurement of condensate temperature was not applied.

Beside the prescribed ice pan and red potato loads, the ASTM test method has been expanded to include frozen green peas as a test product. The spectrum of cooking tests for steamers includes: full-load ice pans, full-load frozen green peas, light-load frozen green peas, full-load red potatoes, and light-load red potatoes.

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

Executive Summary

Table ES-1. Summary of Performance: AccuTemp's STEAM 'n' HOLD, Model 208-D6-3.0.

Preheat and Idle

Rated Energy Input Rate (kW)	6.0
Measured Energy Input Rate (kW)	6.25
Preheat Time (min)	16.1
Preheat Energy (kWh)	1.67
Idle Energy Rate (kW)	1.1

Full-Load Ice Pans (6 pans)

Cook Time (min)	51.5
Cooking Energy Efficiency (%)	83.0
Production Capacity (lb/h)	56.1
Water Consumption Rate (gal/h)	< 0.2

Full-Load Frozen Green Peas (6 pans)

Cook Time (min)	40.7
Cooking Energy Efficiency (%)	88.0
Production Capacity (lb/h)	71.1
Water Consumption Rate (gal/h)	< 0.2

Light-Load Frozen Green Peas (1 pan)

Cook Time (min)	11.9
Cooking Energy Efficiency (%)	65.2
Water Consumption Rate (gal/h)	< 0.2

Full-Load Red Potatoes (6 pans)

Cook Time (min)	29.4
Cooking Energy Efficiency (%)	65.8
Production Capacity (lb/h)	98.1
Water Consumption Rate (gal/h)	< 0.2

Light-Load Red Potatoes (1 pan)

Cook Time (min)	26.2
Cooking Energy Efficiency (%)	29.0
Water Consumption Rate (gal/h)	< 0.2

Executive Summary

Figure ES-1.
Steamer cooking energy efficiency under two loading scenarios.

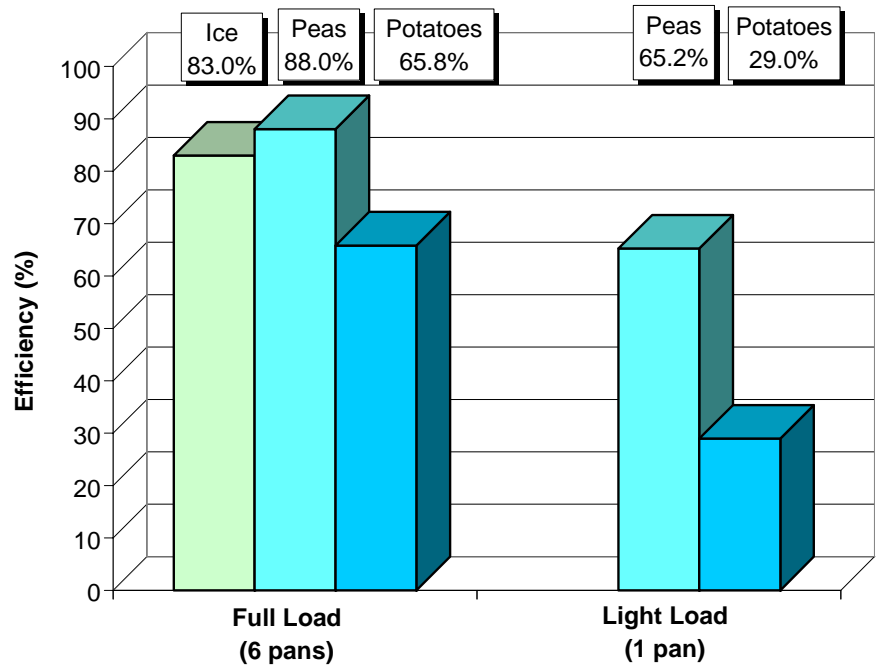
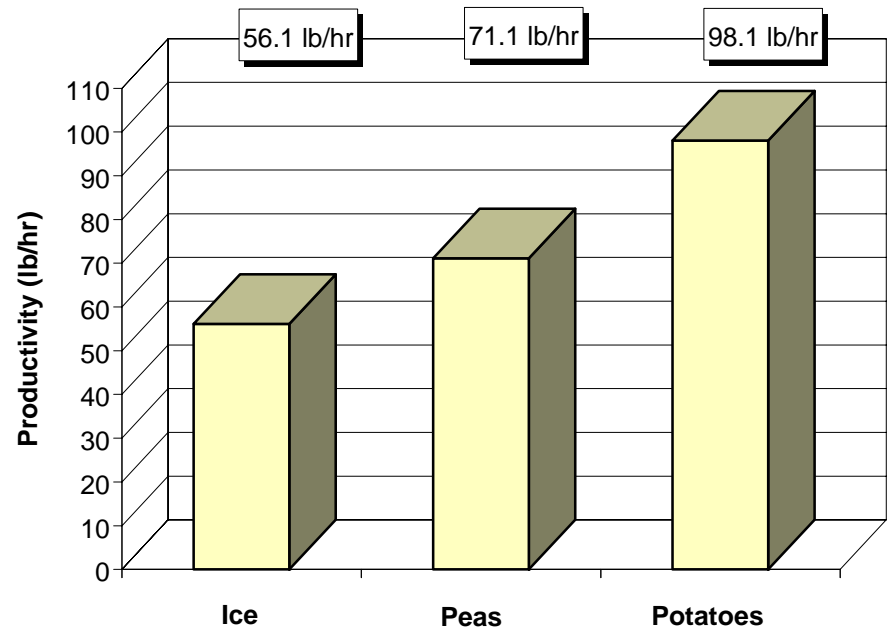


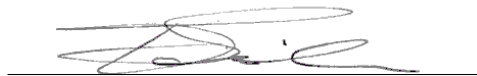
Figure ES-2.
Steamer production capacity.



Executive Summary

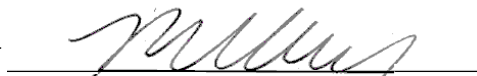
The significant feature of the STEAM ‘n’ HOLD is its ability to use water and energy efficiently. Unlike conventional, atmospheric steamers, the enclosed cavity minimizes the wasteful escape of excessive steam. The water consumption is minimal, at less than 3 gallons per day. Of the countertop steamers tested at the FSTC, the STEAM ‘n’ HOLD demonstrated the highest cooking energy efficiency performance of any steamer tested to date. While cooking “slow-to-cook” food product such as potatoes, the STEAM ‘n’ HOLD delivered an impressive 65.8% and 29.0% efficiency for full-load and light-load potatoes, respectively.

FSTC Manager



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1 Introduction

Background

The heating element is positioned under the cooking compartment, eliminating the need for a boiler.

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

With support from the Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI), PG&E's Food Service Technology Center (FSTC) developed a uniform testing procedure to evaluate the performance of gas and electric steamers. This test procedure was submitted to the American Society for Testing and Materials (ASTM) and accepted as a standard test method (Designation F 1484-93) in December 1993.¹ PG&E's *Development and Validation of a Uniform Testing Procedure for Steam Cooker* documents the developmental procedures and test results of several gas and electric steamers.²

In keeping with ASTM's policy that a standard be periodically reviewed, the FSTC is in the process of revising the steamer test method. In addition to the ice pans and red potatoes specified in the test method, frozen green peas are being added as a test product.

The AccuTemp STEAM 'n' HOLD, model 208-D6-3.0, is a one-compartment, 6-pan capacity, electric, vacuum steamer that delivers 6 kW of cooking energy. The heating element is positioned under the cooking compartment, eliminating the need for a boiler. The thermostat control allows food to be cooked to a desired temperature and held until ready for serving. The STEAM 'n' HOLD 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

Objective

The objective of this report is to examine the operation and performance of the AccuTemp STEAM 'n' HOLD, model 208-D6-3.0, 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 5 cooking scenarios: full-load ice pans (3 pans), 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 and the water consumption rate of each loading scenario.

Appliance Description

The STEAM 'n' HOLD is a stainless-steel, natural-convection steamer powered by a 6 kW electric heating element. Steam is generated within the food compartment without a separate boiler. Water is added and drained manually at the beginning and end of the day, eliminating the need for water feed and drain hookups. The cooking chamber can accommodate six 12" x 20" x 2½" pans, four 12" x 20" x 4" pans, or three 12" x 20" x 6" pans. The unique timer/hold feature allows food to be cooked to the desired temperature and held until it is ready to be served.

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

Introduction



Table 1-1. Appliance Specifications.

Manufacturer	AccuTemp Products, Inc.
Model	208-D6-3.0 STEAM 'n' HOLD™
Generic Appliance Type	1-compartment, natural-convection, electric, vacuum steamer
Rated Input	6 kW
Technology	Boiler-less steamer with natural-convection, vacuum-sealed chamber
Construction	Double-wall, stainless-steel. Interior 14 Ga. Exterior 22 Ga.
Controls	Main ON-OFF buttons. 60 minute mechanical timer with continuous steam and hold setting. Thermostat dial with temperature ranging from 140°F to 212 °F.
Pan Capacity	6 (12" x 20" x 2½") pans 4 (12" x 20" x 4") pans 3 (12" x 20" x 6") pans
Dimensions	23" x 23 ¼" x 30"

2 Methods

Setup and Instrumentation

The steamer was installed in accordance with the manufacturer's instruction on a metal table 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. All test apparatus were installed in accordance with Section 9 of the ASTM test method.¹

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 STEAM 'n' HOLD instrumented with the data acquisition system and voltage regulator.



*Figure 2-1.
The STEAM 'n' HOLD
instrumented for testing.*

Methods

Revisions to the ASTM Test Method

The ice-load test, due to its simplicity, repeatability, and reproducibility, was applied during the developmental phase of the test procedure as a quick indicator of steamer efficiency and productivity. However, ice-load test results do not always mirror the results of food products, particularly with respect to real-world cook times and associated production capacities. The revision to the ASTM steamer test method will list the ice-load test as an optional procedure.

The potato tests remain in the test method with two modifications. The method specified whole, U.S. No. 1, size B, red potatoes with an average weight of 0.14 ± 0.02 lb. Present tests showed a higher average weight of around 0.16 lb. The new method will call for red potatoes weighing 0.16 ± 0.02 lb. The prescribed cook temperature of 205°F is high since the maximum attainable temperature of steam under atmospheric pressure is 212°F. Qualitative tests, using texture, taste, and consistency as criteria, showed that potatoes are cooked to an acceptable doneness at 195°F. The temperature of 195 ± 2 °F will be adopted as the potato cook temperature.

The three-loading scenarios described in the test method have been reduced to two scenarios (full- and light-load tests). The full-load test determines the steamer's peak cooking energy efficiency and production capacity while the light-load test (1 pan) evaluates partial-load performance.

Full- and light-load tests of frozen green peas are being incorporated into the ASTM test method as a replacement for the ice-load tests. Since probing proves difficult and erroneous in measuring temperature of the small-sized green peas, a calorimeter was utilized to measure the final bulk temperature of the cooked green peas. The construction, test procedures, calculation and reporting of the green pea loads involving the calorimeter is listed in Appendix E of this report. Figure 2-2 shows the spectrum of products tested on the STEAM 'n' HOLD: ice pans, frozen green peas, and red potatoes.

Methods

*Figure 2-2.
Products for steamer tests: ice pans, frozen green peas, and red potatoes.*



Measured Energy Input, Preheat and Idle Rate

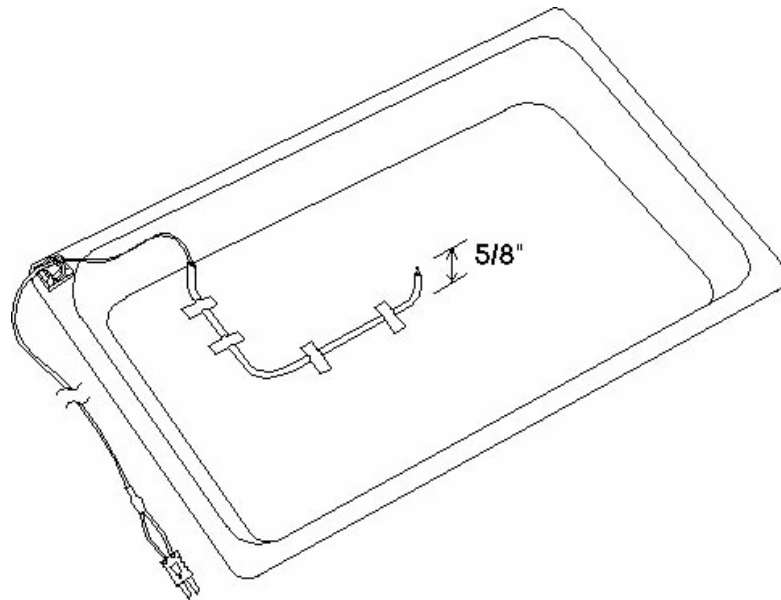
The energy input rate was determined by measuring the energy consumed by the steamer during a full preheat cycle. The maximum power draw during this period was reported as the measured energy input rate. Preheat tests recorded the time and energy required for the steamer to reach operating temperature from a cold start, as when turned on for the first time in a day. Recording began when the steamer was turned on and ended when its elements first cycled off. An hour after the preheat cycle, idle energy consumption was monitored for a 2-hour period.

Ice-Load Efficiency Tests

Standard, solid, stainless-steel hotel pans (12" x 20" x 2½") provided the vessel for ice-pan testing. The bulk temperature was measured with a type-T thermocouple probe welded to the center of the pan with the tip of the probe $\frac{5}{8}$ " from the bottom (see Figure 2-3).

Eight pounds of water (± 0.2 lb) were placed into each thermocoupled pan and frozen to $0 \pm 5^\circ\text{F}$. Ice pans were loaded according to the loading scenario outlined by Table 1 of the ASTM steamer test method. Ice/water temperatures, energy input rate, Watt-hours, water consumption, and condensate temperature were monitored during the "cooking" process. The test ended when the average temperature of the ice pans reached 180°F .

Methods



*Figure 2-3.
Hotel pan with thermo-
couple probe for bulk
temperature determina-
tion.*

Green Pea Light- and Full-Load Efficiency Tests

Individually flashed-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 STEAM 'n' HOLD required 6 pans of green peas for a full load, while 1 pan, placed on the center rack of the steamer cavity, is required for a light load, each pan containing 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.¹

Methods

Red Potatoes Light- and Full-Load Efficiency Tests

Freshly packed, size B, red potatoes served as the second food product for steamer performance testing. Again, the STEAM 'n' HOLD required 6 pans of red potatoes for a full load and 1 pan for a light load, each pan containing 8.0 ± 0.2 lb.

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°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.

For the food-load scenarios, iterative cooking time determination tests were required to establish the time necessary for the food product to reach the doneness temperature of $180 \pm 2^\circ\text{F}$ (for frozen green peas) and $195 \pm 2^\circ\text{F}$ (for red potatoes). The STEAM 'n' HOLD was tested in the following sequence: three replicates of the full-load ice test, three replicates full-load green pea test, three replicates of the light-load green pea test, three replicates full-load red potatoes test and three replicates of the light-load red potatoes test.

The replicates ensured that the reported cooking energy efficiency and production capacity results had an uncertainty of less than $\pm 10\%$. The results from each test run were averaged, and the absolute uncertainty was calculated based on the standard deviation of the results.

The ASTM results reporting sheets appear in Appendix C, and the cooking energy efficiency data sheets appear in Appendix D.

3 Results

Energy Input Rate

The energy input rate was measured and compared with the manufacturer's nameplate value prior to any testing to ensure that the steamer was operating within its specified parameters. The maximum energy input rate was 6.25 kW, 4.2% higher than the nameplate rate of 6.0 kW, but within the 5% tolerance of the ASTM standard.

Preheat and Idle Tests

Preheat Energy and Time

The cavity was manually filled with approximately 3 gallons of water at $70 \pm 5^\circ\text{F}$. The steamer was set to "Fast Cook" mode with the timer at the "Continuous" setting. The preheat cycle consumed 1.67 kWh during the 16.1 min period.

Idle Energy Rate

The steamer was allowed to stabilize for one hour following the preheat with the "Fast Cook/ Continuous" settings. Thereafter, the energy consumption was monitored over a 2-hour period and the idle energy rate was calculated to be 1.1 kW.

Test Results

Figure 3-1 shows the cavity vacuum in conjunction with the water and compartment temperatures during the preheat and idle test. The cavity reached an approximate peak vacuum of 20" Hg during the preheat but diminished during the idle period.

Results

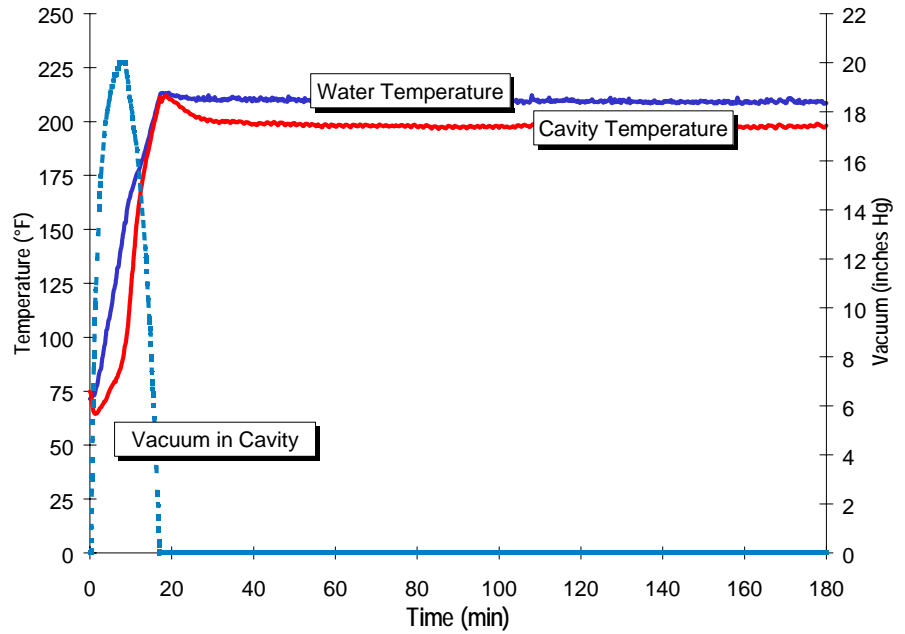


Figure 3-1. Preheat and idle characteristics.

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

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

Rated Energy Input Rate (kW)	6.0
Measured Energy Input Rate (kW)	6.25
Preheat	
Time (min)	16.1
Energy (kWh)	1.67
Idle Energy Rate	
Energy Rate (kW)	1.1

Results

Cooking Tests

The steamer was tested with two food products under two loading scenarios: full-load green peas (6 pans), light-load green peas (1 pan), full-load red potatoes (6 pans), and light-load red potatoes (1 pan). The optional full-load ice pan test was also performed for comparison purposes with previous data published by the FSTC. The energy consumption, elapsed cook time, ambient temperature and product temperature were monitored for the duration of each test at five-second intervals.

The STEAM 'n' HOLD does not employ a separate boiler, and does not require either a water connection or a drain; therefore, condensate temperature was not monitored. Three gallons of water were poured into the bottom of the cooking compartment before testing began and emptied at the end of the day as directed by the manufacturer's instructions. Water loss was less than 0.5 gallons for the heaviest day of testing (approximately 5 heavy loads and three hours at idle.)

Full-Load Ice-Pan Test

The ice-pan test was intended to emulate cooking frozen vegetables, while better meeting three essential testing criteria (repeatability, reproducibility, and simplicity). The STEAM 'n' HOLD heated the ice pans to an average temperature of 180°F with a cooking time of 51.5 minutes, while delivering 83.0% cooking efficiency and 56.1 lb/h production capacity.

Full- and Light-Load Green Peas Test

Moisture content of the green peas was 81% by weight corresponding to specific heats (C_p) of 0.44 Btu/lb°F for frozen and 0.85 Btu/lb°F for thawed peas.³ The STEAM 'n' HOLD required 40.7 minutes to cook the full load of frozen green peas with a cooking energy efficiency of 88.0% and production capacity of 71.1 lb/h.

Results

Typically, steamers are not loaded to full capacity. The light-load test emulates such a cooking scenario with a single pan of frozen green peas placed in the middle rack of the compartment. The cooking time was reduced dramatically to a repeatable 11.9 minutes. The one-pan loading scenario also reduced cooking energy efficiency and productivity, 65.2% and 40.4 lb/h, respectively.

Full- and Light-Load Potatoes Test

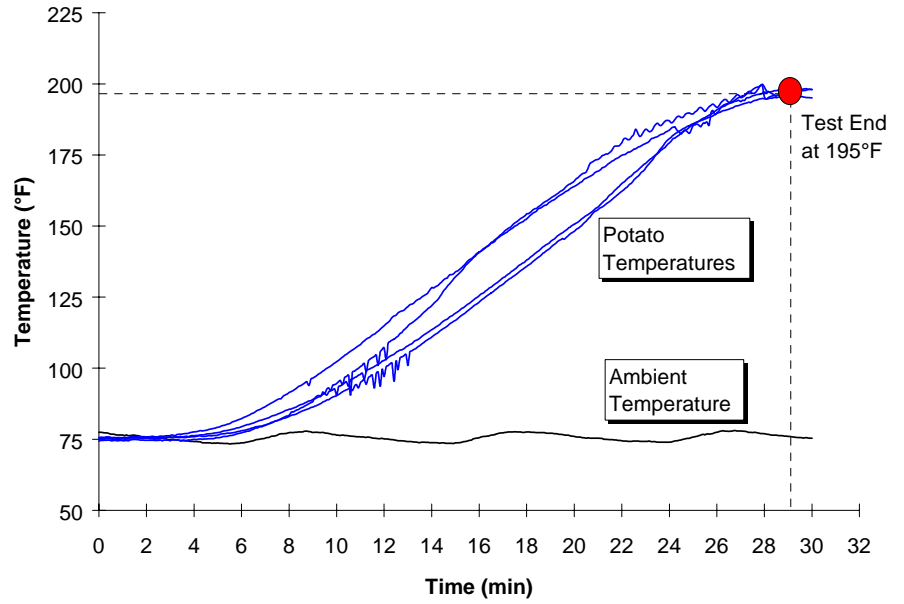
The red potatoes contained 84% moisture by weight with the specific heat (C_p) of 0.87 Btu/lb $^{\circ}$ F.³ The full-load potato test required 29.4 minutes to reach the average bulk cook temperature of 193.5 $^{\circ}$ F, with potato temperatures ranging from 184-203 $^{\circ}$ F. Both the cooking efficiency and productivity claimed an all-time high of 65.8% and 98.1 lb/h, respectively.

The single pan of red potatoes required 26.17 minutes to achieve an average bulk temperature of 195.7 $^{\circ}$ F, with the potato temperature range of 190-199 $^{\circ}$ F. As expected, the light-load potato test resulted in lower cooking energy efficiency of 29.0% and productivity of 18.4 lb/h.

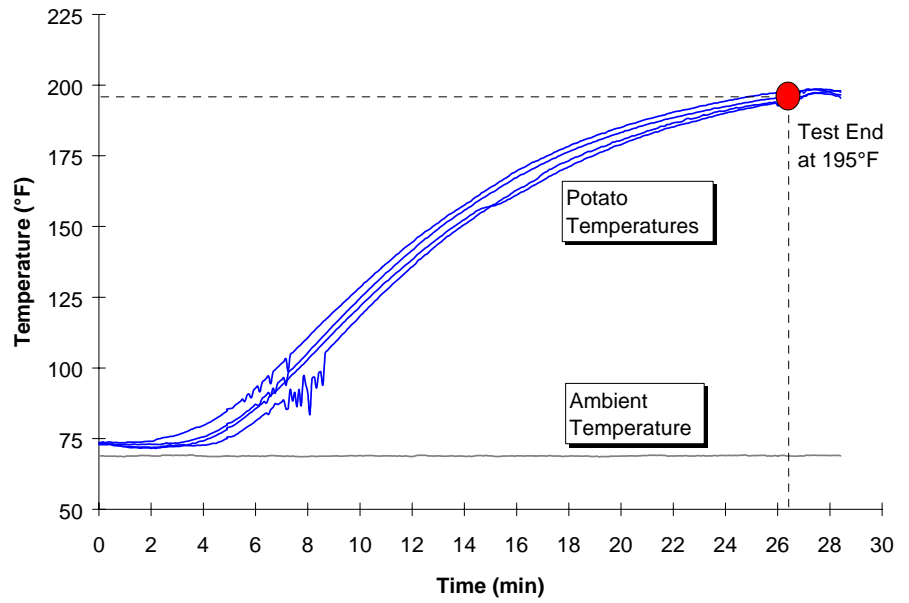
Figures 3-2 and 3-3 show the temperature profiles of selected potatoes during the full- and light-load tests.

Results

*Figure 3-2.
Temperature profiles of
potatoes in a full-load
test.*



*Figure 3-3.
Temperature profiles of
potatoes in a light-load
test.*



Test Results

Results

Cooking energy efficiency is defined as the quantity of energy consumed by the food expressed as a percentage of energy consumed by the steam cooker during the cooking event. The mathematical expression is therefore:

$$\text{Cooking Energy Efficiency \%} = \frac{E_{\text{food}}}{E_{\text{steamer}}} \times 100\%$$

Energy imparted into the cooked product is calculated by separating its various components. Since products must be cooked in stainless-steel hotel pans, the pan energy consumption is factored into the total energy equation. Ice-load consumption energy is defined as the energy consumed by the stainless-steel pans, heating of ice to 32°F, melting ice to water at 32°F, and heating the water to 180°F. The total energy consumption equation is:

$$E_{\text{ice load}} = E_{\text{(heat pans)}} + E_{\text{(heat ice)}} + E_{\text{(melt ice)}} + E_{\text{(heat water)}}$$

Frozen green peas follow similar calculations with several modified terms. The heat capacity changes as it transforms frozen green peas to a thawed state:

$$E_{\text{green peas}} = E_{\text{(heat pans)}} + E_{\text{(heat frozen peas)}} + E_{\text{(melt ice)}} + E_{\text{(heat thawed peas)}}$$

Steaming fresh red potatoes does not involve a phase change (ie. ice to water, frozen to thawed); therefore, the energy consumption is simplified to heating of the pans and the potatoes:

$$E_{\text{red potatoes}} = E_{\text{(heat pans)}} + E_{\text{(heat potatoes)}}$$

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.

Results

The rate at which steam condenses on food depends on the surface temperature and area of the food; therefore, frozen green peas (0°F) and red potatoes (room temperature) represent two extremities in steam cooking. Frozen green peas, having large surface area to weight 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 the slow nature of condensation. Steam that fails to condense on the potatoes goes unused, thus reducing efficiency. For both the full- and light-load scenarios, greater than 20% reduction in steamer cooking efficiencies were observed when comparing frozen green peas to fresh red potatoes: full load ($88.0\% - 65.8\% = 22.2\%$) and light load ($65.2\% - 29.0\% = 36.2\%$). Table 3-2 and 3-3 summarize the STEAM 'n' HOLD's performance under the strict ASTM test method. Figures 3-4 and 3-5 illustrate these results in graphical format.

Results

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

	Full Ice Pans	Full Pea Load	Light Pea Load	Full Potato Load	Light Potato Load
Number of pans	6	6	1	6	1
Cook Time (min)	51.5	40.7	11.9	29.4	26.2
Energy Rate (kW)	6.2	6.2	4.8	4.8	2.1
Energy Efficiency (%)	83.0	88.0	65.2	65.8	29.0
Production Rate (lb/h)	56.1	71.1	40.4	98.1	18.4

Table 3-3. Water Consumption Test Results.

	Full Ice Pans	Full Pea Load	Light Pea Load	Full Potato Load	Light Potato Load
Water Consumption (gal/h)*	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

* Water loss was less than 0.5 gallons for the heaviest day of testing. It was estimated that less than 0.2 gal/h of water was consumed during each cooking test.

Results

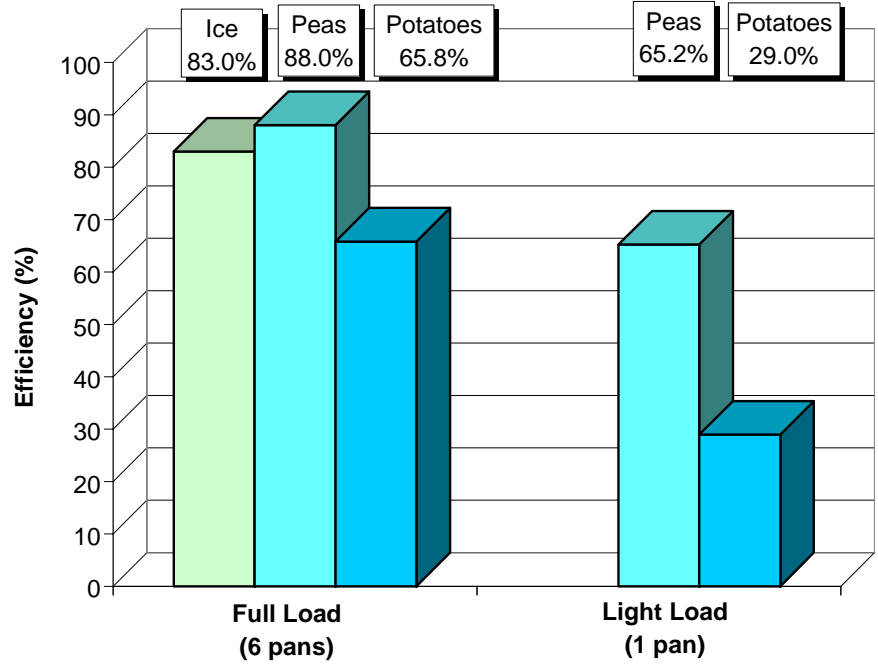


Figure 3-4.
Cooking energy efficiencies of various loading scenarios .

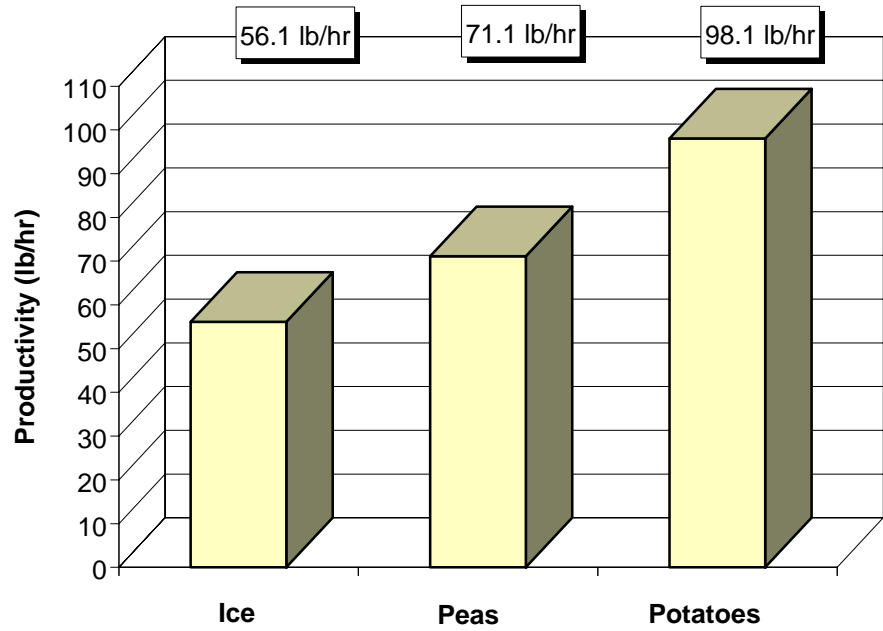


Figure 3-5.
Full-load production capacities of tested products.

4 Conclusions

**The STEAM ‘n’
HOLD demon-
strated the highest
cooking energy
efficiency among the
tested electric, coun-
tertop steamers.**

The AccuTemp STEAM ‘n’ HOLD, Model 208-D6-3.0, steamer performed well under the rigorous conditions of the ASTM standard test method. Its innovative design greatly reduces water and energy consumption, while retaining a user-friendly interface. The lack of a boiler, water feed, and condensate drain eliminate calcium carbonate buildup problems and expensive chemical costs. The water consumption is virtually nil, requiring less than 3 gallons on days of heavy usage.

Across-the-board, the STEAM ‘n’ HOLD demonstrated the highest efficiencies among the electric, countertop steamers tested to date at the FSTC. In cooking the frozen products, ice pans and green peas, the STEAM ‘n’ HOLD is 1-6% more efficient than other tested steamers⁴. Moreover, the steamer excelled in cooking slow-to-cook products such as red potatoes. The full-load efficiency of 65.8% is more than double and the light-load efficiency of 29% is almost triple the cooking energy efficiency of other tested steamers. The production rate of 98.1 lb/h is significant considering its relatively low 6 kW input rate.

The STEAM ‘n’ HOLD’s high cooking energy efficiency, low maintenance and ease in use make it an excellent option for routine, heavy-duty use. Evaluating this steamer in the real-world setting of PG&E’s production-test kitchen is being investigated to provide further knowledge about the unique technology applied by this steamer.

5 References

1. American Society for Testing and Materials. 1993. *Standard Test Method for the Performance of Steam Cookers*. ASTM Designation F 1484-93, in *Annual Book of ASTM Standards*, Philadelphia: American Society for Testing and Materials.
2. Food Service Technology Center. 1995. *Development and Application of a Uniform Testing Procedure for Steam Cookers*. Report 1022.95.19. Product and Services Department. San Francisco, California: Pacific Gas and Electric Company.
3. American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. 1994 ASHRAE Handbook. *Refrigeration Systems and Applications. I-P Edition*. Chapter 25: Commodity Storage Requirements. Atlanta, Georgia.
4. Foodservice Equipment Reports. *Lab Time! 3 Steamers Take the Test*. October 1997. Vol. 1. No. 10. Pp. 38-42. Gill Ashton Publishing, L.L.C., Ill.

Appendixes

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). These are 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 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.

Pressureless Steam Cooker

Steam cooker wherein cooking compartment operates between 0 and 2.9 psig (ASTM F1217-92 Classification Type I).

Production Capacity

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

Production Rate

Rate (lb(kg)/h) at which 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 Specifications

Appendix B includes the product literature for the AccuTemp STEAM 'n' HOLD, model 208-D6-3.0, steamer.

C Results Reporting Sheets

Manufacturer: AccuTemp
Model: STEAM 'n' HOLD, 208-D6-3.0
Date: April, 98

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 - One 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: Water is manually poured in the bottom of the cooking compartment prior to preheat. A pump draws a vacuum within the stainless-steel chamber to reduce vapor pressure, inducing quicker steam generation. Food is cooked with natural-convection steam to a desired temperature and held until ready to be served.

Section 11.2 Apparatus

The steamer was installed on a metal table under a 4-foot-deep canopy hood that was 6 feet 6 inches above the floor. The hood operated at a nominal exhaust rate of 150 cfm per linear foot of hood. There was at least 6 inches of clearance between the vertical plane of the steamer and the edge of the hood.

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. All test apparatus were installed in accordance with Section 9 of the ASTM test method.

Section 11.4 Energy Input Rate

Test Voltage	208 V
Measured	6.25 kW
Rated	6.0 kW
Percent Difference between Measured and Rated	4.2 %

Section 11.5 Boiler Preheat Energy Consumption and Duration

Test Voltage	208 V
Energy Consumption	1.7 kWh
Duration	16.1 min

Section 11.6 Boiler Idle Energy Rate

Test Voltage	208 V
Idle Energy Rate	1.1 kW

Results Reporting Sheets

Section 11.7 Ice Load Cooking Time, Energy Efficiency, Energy Rate, Production Capacity, and Water Consumption Rate

Full-Load:

Test Voltage	208 V
Cooking Time	51.5 min
Cooking Energy Efficiency	83.0 ± 2.8 %
Cooking Energy Rate	6.2 kW
Production Capacity	56.1 lb/h
Water Consumption Rate	<0.2 gal/h

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

Full Load:

Test Voltage	208 V
Cooking Time	40.7 min
Cooking Energy Efficiency	88.0 ± 0.54 %
Cooking Energy Rate	6.2 kW
Production Capacity	71.1 lb/h
Water Consumption Rate	<0.2 gal/h

Light Load:

Test Voltage	208 V
Cooking Time	11.9 min
Cooking Energy Efficiency	65.2 ± 1.4 %
Cooking Energy Rate	4.8 kW
Production Rate	40.4 lb/h
Water Consumption Rate	<0.2 gal/h

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

Results Reporting Sheets

Full Load:

Test Voltage	208 V
Cooking Time	29.4 min
Cooking Energy Efficiency	65.8 ± 2.0 %
Cooking Energy Rate	4.8 kW
Production Capacity	98.1 lb/h
Water Consumption Rate	<0.2 gal/h

Light Load:

Test Voltage	208 V
Cooking Time	26.2 min
Cooking Energy Efficiency	29.0 ± 2.3 %
Cooking Energy Rate	2.1 kW
Production Rate	18.4 lb/h
Water Consumption Rate	<0.2 gal/h

D Cooking Energy Efficiency Data

Table D-1. Physical Properties.

Specific Heat (Btu/lb °F)	
Ice	0.50
Water	1.00
Stainless-Steel Pan	0.11
Frozen Green Peas	0.44
Thawed Green Peas	0.85
Fresh Red Potatoes	0.87
Latent Heat (Btu/lb)	
Fusion, Water	144

Cooking Energy Efficiency Data

Table D-2. Full-Load Ice-Pan Test Data.

Measured Values	Repetition #1	Repetition #2	Repetition #3
Number of Pan(s)	6	6	6
Cook Time (min)	51.42	53.00	50.17
Temperature of Water (°F)	180.0	179.8	180.0
Temperature of Ice Pans (°F)	1.5	1.9	11.9
Weight of Stainless-Steel-Pans (lb)	16.12	15.95	16.67
Weight of Ice (lb)	48.51	48.26	47.82
Condensate Temperature (°F)	NA	NA	NA
Water Consumption (gal/h)	<0.2	<0.2	<0.2
Calculated Values			
Cooking Energy (Wh)	5350	5410	5170
Energy Consumed by Ice Pans (Btu)	14904	14809	14444
Energy Consumed by Stainless-Steel Pans (Btu)	316.4	312.2	308.5
Energy of Boiler Re-init (Btu)	0	0	0
Energy Consumed by the Steamer (Btu)	18260	18464	17645
Cooking Energy Rate (kW)	6.24	6.12	6.18
Productivity (lb/h)	56.6	54.6	57.2
Energy Efficiency (%)	83.4	81.9	83.6

Cooking Energy Efficiency Data

Table D-3. Full-Load Frozen Green Peas Test Data.

Measured Values	Repetition #1	Repetition #2	Repetition #3
Number of Pan(s)	6	6	6
Cook Time (min)	41	40.5	40.5
Initial Water Temperature (°F)	35.9	41.0	37.5
Final Water Temperature (°F)	95.9	96.1	94.9
Frozen Food Temperature (°F)	0.2	-2.2	-0.3
Weight of Empty Calorimeter (lb)	35.8	35.9	35.8
Weight of Full Calorimeter (lb)	144.2	144.1	144.1
Weight of Calorimeter Water (lb)	59.81	60.1	60.1
Weight of Cooked Food (lb)	48.6	48.2	48.2
Weight of Frozen Food (lb)	48.3	48.1	48.3
Weight of Stainless-Steel Pans (lb)	16.7	16.7	16.7
Moisture Content (%)	81	81	81
Condensate Temperature (°F)	NA	NA	NA
Water Consumption (gal/h)	<0.2	<0.2	<0.2
Calculated Values			
Moisture Weight in Green Peas(lb)	39.1	39.0	39.1
Final Food Temperature (°F)	182.9	177.1	177.73
Cooking Energy (Wh)	4280	4190	4210
Energy Consumed by Food (Btu)	12497.1	12259.5	12347.4
Energy Consumed by Stainless-steel Pans (Btu)	335.9	329.5	330.2
Energy of Boiler Re-init (Btu)	0	0	0
Energy Consumed by the Steamer (Btu)	14607.6	14300.5	14368.7
Cooking Energy Rate (kW)	6.3	6.2	6.2
Productivity (lb/h)	70.7	71.3	71.5
Energy Efficiency (%)	87.9	88.0	88.2

Cooking Energy Efficiency Data

Table D-4. Light-Load Frozen Green Peas Test Data.

Measured Values	Repetition #1	Repetition #2	Repetition #3
Number of Pan(s)	1	1	1
Cook Time (min)	11.92	11.92	11.92
Initial Water Temperature (°F)	39.2	39.9	40.3
Final Water Temperature (°F)	65.2	66.2	66.2
Frozen Food Temperature (°F)	-4.7	-3.2	0.2
Weight of Empty Calorimeter (lb)	35.8	35.7	35.9
Weight of Full Calorimeter (lb)	74.1	73.8	74.1
Weight of Calorimeter Water (lb)	30.1	30.1	30.1
Weight of Cooked Food (lb)	8.13	8.01	8.15
Weight of Frozen Food (lb)	8.03	8.01	8.02
Weight of Stainless-Steel Pans (lb)	2.8	2.8	2.8
Moisture Content (%)	81	81	81
Condensate Temperature (°F)	NA	NA	NA
Water Consumption (gal/h)	<0.2	<0.2	<0.2
Calculated Values			
Moisture Weight in Green Peas(lb)	6.5	6.5	6.5
Final Food Temperature (°F)	178.8	182.7	178.9
Cooking Energy (Wh)	960	960	940
Energy Consumed by Food (Btu)	2066.7	2082.9	2047.7
Energy Consumed by Stainless-Steel Pans (Btu)	56.9	57.8	54.8
Energy of Boiler Re-init (Btu)	0	0	0
Energy Consumed by the Steamer (Btu)	3276.5	3276.5	3208.2
Cooking Energy Rate (kW)	4.8	4.8	4.7
Productivity (lb/h)	40.4	40.3	40.4
Energy Efficiency (%)	64.8	65.3	65.5

Cooking Energy Efficiency Data

Table D-5. Full-Load Red Potatoes Test Data.

Measured Values	Repetition #1	Repetition #2	Repetition #3
Number of Pan(s)	6	6	6
Cook Time (min)	27.9	29.8	30.6
Temperature of Uncooked Potatoes (°F)	74.9	70.1	71.9
Temperature of Cook Potatoes (°F)	194.1	193.1	193.4
Weight of Stainless-Steel Pans (lb)	16.4	16.4	16.4
Weight of Potatoes (lb)	48.0	48.0	48.0
Total Potato Count	358	362	353
Moisture Content (%)	84.1	84.1	84.1
Condensate Temperature (°F)	NA	NA	NA
Water Consumption (gal/h)	<0.2	<0.2	<0.2
Calculated Values			
Moisture Weight in Potatoes(lb)	40.4	40.4	40.4
Average Weight of Each Potatoes (lb)	0.13	0.13	0.14
Cooking Energy (Wh)	2300	2400	2380
Energy Consumed by the Potatoes (Btu)	4998.3	5154.8	5091.9
Energy Consumed by Stainless-Steel Pans (Btu)	214.5	222.5	219.4
Energy of Boiler Re-init (Btu)	0	0	0
Energy Consumed by the Steamer (Btu)	7849.9	8191.2	8122.9
Cooking Energy Rate (kW)	4.9	4.8	4.7
Productivity (lb/h)	103.2	96.9	94.2
Energy Efficiency (%)	66.4	65.7	65.4

Cooking Energy Efficiency Data

Table D-6. Light-Load Red Potatoes Test Data.

Measured Values	Repetition #1	Repetition #2	Repetition #3
Number of Pan(s)	1	1	1
Cook Time (min)	24.42	26.25	27.83
Temperature of Uncooked Potatoes (°F)	74.8	73.3	73.3
Temperature of Cook Potatoes (°F)	196.6	195.8	194.6
Weight of Steel Pans (lb)	2.811	2.62	2.82
Weight of Potatoes (lb)	7.99	8.02	8.04
Total Potato Count	46	47	52
Moisture Content (%)	84.1	84.1	84.1
Condensate Temperature (°F)	NA	NA	NA
Water Consumption (gal/h)	<0.2	<0.2	<0.2
Calculated Values			
Moisture Weight in Potatoes(lb)	6.72	6.74	6.76
Average Weight of Each Potatoes (lb)	0.17	0.17	0.15
Cooking Energy (Wh)	3071.7	3105.8	3037.6
Energy Consumed by the Potatoes (Btu)	849.7	857.1	851.2
Energy Consumed by Stainless-Steel Pans (Btu)	37.7	35.3	37.6
Energy of Boiler Re-init (Btu)	0	0	0
Energy Consumed by the Steamer (Btu)	3071.7	3105.8	3037.6
Cooking Energy Rate (kW)	2.21	2.08	1.92
Productivity (lb/h)	19.6	18.3	17.3
Energy Efficiency (%)	28.9	28.7	29.3

E Procedure for Frozen Green Pea Test

The following is a supplemental procedure to the Standard Test Method for the Performance of Steam Cooker: ASTM Destination F 1484-93. The instruction details the construction of the water-bath calorimeter and the performance testing of frozen green pea in steam cookers.

1 Apparatus

1.1 *Hotel pans*, perforated 12 x 20 x 2½ in. (300 x 500 x 65 mm) stainless steel, weighing 2.8±0.2 lb (1.3±0.1 kg).

1.2 *Water-Bath Calorimeter*, for temperature determination of the green peas load. Comprised of 5 components: Inner Container— cylindrical, 0.087-in (2.2-mm) thick walled, plastic drum. Container capacity may vary depending on the tested load. Drum insulation— R-25 fiberglass insulation. Drum Lid— plastic lid double re-enforced with 2-in (50 mm) thick polystyrene board. Stirrer— 3-ft long, 1/4-in diameter, steel rod with propeller welded to one end. Thermocouple tree— 1/4-in diameter, copper pipe with 5 temperature sensor points placed 3-in laterally apart. A convenient way to construct the water-bath calorimeter is to place the inner container on a 2-in (50 mm) thick polystyrene board. Wrap the outside of the drum with 1 ft thick R-25 fiberglass insulation so no drum wall is exposed. Cover the fiberglass insulation with plastic liner to waterproof the interior. Construct the thermocouple tree by affixing 5 type T thermocouple probes 3 inches apart along the copper pipe. Fix the thermocouple tree vertically along the drum wall as to avoid contact with the stirrer. Drill a ½-in hole in the center of the plastic/polystyrene lid. Place the propeller end of the stirrer in the drum and close the lid, allowing the opposite end of the stirrer to pass through the center of the lid. Place the water-bath calorimeter on castors for ease in mobility. During test, the content could be agitated manually or with the aid of a mechanical stirrer.

1.3 *Platform Balance Scale* or appropriate load cells, used to measure the weight of the water-bath calorimeter and content during the frozen green peas test. Shall have capacity to accommodate the total

Procedure for Frozen Green Pea Test

weight of calorimeter plus the cooked food product and water. The resolution shall be 0.2 lb (10 g) and an uncertainty of 0.2 lb (10 g).

2 Green Peas Load Preparation

2.1 This section outlines preparation of the frozen green peas used in the green peas load cooking energy-efficiency and production-capacity test.

2.2 The number of green peas loads to be prepared depends on which loading scenario is to be performed. There are two loading scenarios: light and heavy. The heavy load is the manufacturer's stated capacity of 12 x 20 x 2½-in. (300 x 500 x 65-mm) hotel pans. Consult Table 1 for the number of green peas loads to prepare for the light loading scenarios.

NOTE 1—When the test calls for a less than capacity number of loads for a compartment, the loads should be placed in the most centrally located slots. When symmetry about the center is not possible, then use the upper central slots first. For example, one pan in a 4-pan capacity compartment should be located in the second slot from the top. Two loads in a 4-pan capacity compartment should be located in the second and third slots from the top (yielding symmetry about the center). One load in a 3-pan capacity compartment would be located in the center, and two loads would be located in the top and middle slots. Two pans in a 5 pan capacity compartment would be located in the second slot from the top and third slot from the top (center slot).

Procedure for Frozen Green Pea Test

Table 1 Number of Loads for Light Loading Scenario

	Light Loading Scenario		Light Loading Scenario
1 Compartment 3 Pan Capacity	1 Pan	2 Compartments 8 Pan Capacity Per Compartment	2 Pans in top compartment None in bottom
1 Compartment 4 Pan Capacity	1 Pan	3 Compartments 3 Pan Capacity Per Compartment	2 Pans in middle compartment None in top None in bottom
1 Compartment 5 Pan Capacity	1 Pan	3 Compartments 4 Pan Capacity Per Compartment	2 Pans in middle compartment None in top None in bottom
1 Compartment 6 Pan Capacity	1 Pan	3 Compartments 5 Pan Capacity Per Compartment	2 Pans in middle compartment None in top None in bottom
2 Compartments 3 Pan Capacity Per Compartment	1 Pan in top compartment None in bottom	3 Compartments 6 Pan Capacity Per Compartment	2 Pans in middle compartment None in top None in bottom
2 Compartments 4 Pan Capacity Per Compartment	1 Pan in top compartment None in bottom	3 Compartments 8 Pan Capacity Per Compartment	2 Pans in middle compartment None in top None in bottom
2 Compartments 5 Pan Capacity Per Compartment	2 Pans in top compartment None in bottom		
2 Compartments 6 Pan Capacity Per Compartment	2 Pans in top compartment None in bottom		

2.3 The perforated hotel pans shall be 12 x 20 x 2½-in. (300 x 500 x 65-mm) stainless steel, weighing 2.8±0.2 lb (1.3±0.1 kg).

2.4 Number each pan and record the weight of each of the (dry) pans. The weight of the pan(s) will be the total weight of all pan(s) used for the test.

Procedure for Frozen Green Pea Test

2.5 Load each pan with 8.0 ± 0.2 lb (3.6 ± 0.1 kg) of grade A, frozen, green peas sealed in plastic zip bags. Record the weight of the frozen green peas in each pan. Place the green peas load in the freezer and allow the temperature to stabilize at $0 \pm 5^\circ\text{F}$ ($-18 \pm 2^\circ\text{C}$) for a 24 hour period. The weight of the frozen green peas will be the total weight of the green peas in each of the pan(s).

2.6 The water-bath calorimeter shall be as specified in 1.2. Record the weight of the empty calorimeter using the platform balance scale.

2.7 For every load of green peas, place 10 lb of potable water into the calorimeter drum. (For example, the total weight of water for a heavy load test of a six-pan capacity, steamer would be 10 lb water/pan x 6 pans = 60 lb).

2.8 Record the weight of the water in the water-bath calorimeter.

NOTE 2—The initial water temperature for the water-bath need not be $70 \pm 5^\circ\text{F}$ ($21 \pm 3^\circ\text{C}$). As long as the initial and final temperatures are recorded, the change in water-bath temperature can be calculated.

3 Green Peas Load Cooking Energy Efficiency, Production Capacity, Water Consumption, and Condensate Temperature

3.1 This procedure applies to two possible loading scenarios: light and heavy. Repeat each loading scenario a minimum of three times. Additional test runs may be necessary to obtain the required precision for the reported test results. The reported values of cooking energy efficiency, production capacity, condensate temperature, and water consumption shall be the average of the replications (runs).

3.2 Prepare the frozen green peas load(s) in accordance with section 2. Record the weight of the empty pan(s) and the weight of the green peas load(s).

Procedure for Frozen Green Pea Test

3.3 Measure and record the average temperature of the green peas by probing the content of the sealed bags. Confirm that they are at $0\pm 5^{\circ}\text{ F}$ ($-18\pm 3^{\circ}\text{ C}$).

3.4 Choose a cooking time either based on the manufacturer's recommendation or by experience.

3.5 Allow the steam cooker to sit idle (boiler(s) on) for a minimum of one hour. If the manufacturer recommends leaving the cooking cavity doors open when not cooking, then leave them open during the idle period and record the door position during the idle period.

3.6 Start monitoring time. Transport the green pea loads to the testing location. Empty the zip-bagged green peas into the pan(s). Open one steam compartment, load the pan(s) into it, close it, and start steam to it. Note the starting time for that compartment. Open the next steam compartment (if applicable), empty peas into pan(s), load it, close it, start it, and note the starting time. Open, load, close, start, and note the starting time of the last compartment (if applicable). After starting steam to the first compartment, commence monitoring energy consumption, water consumption, and condensate temperature. For gas steam cookers, monitor and record the electric energy as well as gas consumption. The total loading time (the time from opening the first compartment to closing and starting the last compartment) shall be the total of 5 s per compartment plus 5 s for each load used. (For example, the total loading time for a heavy load test of a six-pan capacity, two-compartment steam cooker would be $5\text{ s/compartment} \times 2\text{ compartments} + 5\text{ s/load} \times 6\text{ loads} = 40\text{ s}$).

NOTE 3—Care shall be taken to minimize heat gain by the frozen green pea load(s) on the way from the freezer to the steam cooker. During that time, the load(s) shall be isolated from any warmer surface by R10 or better insulation. PG&E found 2 in (50 mm) thick square-edged polystyrene boards to be convenient as an insulating surface.

NOTE 4—For gas steamers, the "electric energy rate" during the heavy load test will be reported separately from the gas "cooking energy rate". The two values are reported separately so that the respective fuel prices may be applied to estimate energy costs.

Procedure for Frozen Green Pea Test

NOTE 5—The boiler is at maximum pressure when the test starts, but it may be at a lower pressure at the end of the test. This difference between the initial and final energy content (pressure/temperature) of the boiler must be added back to the boiler to correctly calculate the energy efficiency. Maximum, minimum and final boiler pressure is measured so that this energy deficit can be estimated. There are situations where the measurement of pressure in step 3.7 is not necessary, as noted in steps 3.9 and 3.11.

NOTE 6—The average condensate temperature for the final 3 minutes of the run is what will be reported, rather than the average over the entire run; therefore, condensate temperature monitoring need not begin immediately upon commencement of the test run.

3.7 For three cycles of the boiler pressure near the end of the test, measure the maximum and minimum pressures. Record the average maximum and average minimum boiler pressure.

3.8 Terminate steam to the compartments as the predetermined cooking time elapses for each compartment. After stopping steam to the last compartment, record the final time, water consumption, and average condensate temperature.

3.9 If the boiler is on when the cooking time for the last compartment has elapsed, continue to monitor energy consumption until the primary burners, elements, or steam coils cycle off. Record final energy. Note that the initial and final energy content of the boiler is the same; therefore, the pressure measurements in step 3.7 are not needed.

3.10 If the boiler is not on when the last compartment cooking time elapsed, proceed to one of the next two conditional steps (3.11 or 3.12).

3.11 Perform this step if the boiler pressure is controlled by a pressure switch that can be manually actuated. Otherwise, proceed directly to step 3.12. When the time for the last compartment has elapsed, continue to monitor energy consumption and actuate the pressure switch.

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This returns the boiler energy content to the initial test condition; therefore, the pressure measurements in step 3.7 and the energy measurements in step 10.4.2 (from the test method) are not necessary. Record the final energy.

3.12 Perform this step if the boiler pressure control cannot be manually actuated. When the cooking time for the last compartment has elapsed, record the final energy and the boiler pressure (used to calculate the energy deficit of the boiler, as described in note 5).

3.13 Record the initial temperature of the water-bath calorimeter immediately after the cook time elapsed. The unloading time shall be the same as the loading time. Remove the calorimeter lid and empty the cooked green peas load into the water-bath calorimeter. Replace the lid on the water-bath calorimeter.

3.14 Allow the contents of the water-bath calorimeter to stabilize for 5 minutes. Using the stirrer, agitate the content for 1 min. Repeat the stabilization and agitation process every 5 min until the final bulk temperature fluctuate less than $\pm 0.1^{\circ}\text{F}$ within a 5 min period. Record the final bulk temperature.

3.15 Record the total weight of the water-bath calorimeter containing the cooked green peas and water with the platform balance scale. This will be used to determine the thawed green peas weight.

3.16 In accordance with 4.2, calculate the final cooked bulk temperature of the green peas. The cook temperature must be $180 \pm 2^{\circ}\text{F}$ ($82 \pm 1^{\circ}\text{C}$). If the temperature does not fall in this range, the test must be repeated with an adjusted cook time.

3.17 If the temperature is within the range, prepare the next frozen green peas load (1) and the water-bath calorimeter, unless this was the final run (Run No. 3), and perform the test again (2).

3.18 Calculate the cooking energy efficiency, production capacity, water consumption, and average condensate temperature in accordance with 4.3, 4.6, 4.7, and 4.8 and report the results as the average of three replications.

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4.0 Frozen Green Peas Load Cooking Energy Efficiency, Production Capacity, Water Consumption, and Condensate Temperature

4.1 Report the average value from a minimum of three test runs for frozen green peas load cooking energy efficiency, production capacity, and water consumption.

4.2 Calculate the final cooked green peas load temperature by applying the following relationship:

$$T_{\text{peas, f}} = \frac{W_{\text{water}} \times C_{p\text{water}}}{W_{\text{peas}} \times C_{p\text{peas}}} \times (T_{\text{water, f}} \times T_{\text{water, i}}) + T_{\text{water, f}}$$

where:

W_{water} = weight of water in water-bath calorimeter, lb

$C_{p\text{water}}$ = specific heat of water, Btu/lb°F
= 1 Btu/lb°F

W_{peas} = weight of cooked green peas load, lb
= $W_{\text{full calorimeter}} - W_{\text{calorimeter}} - W_{\text{water}}$

$T_{\text{water, i}}$ = initial water temperature in water-bath calorimeter, °F

$T_{\text{water, f}}$ = final equilibrium temperature of water and cooked green peas mixture in water-bath calorimeter, °F

$C_{p\text{peas, thawed}}$ = specific heat of thawed green peas, Btu/lb°F
= 0.84 Btu/lb°F

4.3 Calculate the green pea load cooking energy efficiency according to the following relationship:

$$\eta_{\text{peas}} = \frac{E_{\text{peas}} + E_{\text{pan}} + E_{\text{boiler re-init}}}{E_{\text{steam cooker}}} \times 100\%$$

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where:

$$\eta_{\text{peas}} = \text{cooking energy efficiency (\%)} \\ E_{\text{peas}} = \text{heat gained by the green peas load} \\ = [W_{\text{peas,frozen}} \times C_{p\text{peas,frozen}} \times \Delta T_{\text{peas,frozen}}] + [W_{\text{peas,thawed}} \times C_{p\text{peas,thawed}} \times \Delta T_{\text{peas,thawed}}] + [W_{\text{moisture}} \times E_{\text{fusion}}]$$

where:

$$W_{\text{peas,frozen}} = \text{weight of frozen green peas, lb} \\ C_{p\text{peas,frozen}} = \text{specific heat of frozen green peas, Btu/lb}^\circ\text{F} \\ = 0.44 \text{ Btu/lb}^\circ\text{F} \\ \Delta T_{\text{peas,frozen}} = \text{temperature rise in frozen green peas, }^\circ\text{F} \\ = 32^\circ\text{F} - \text{initial temperature of frozen green peas load} \\ W_{\text{peas,thawed}} = \text{weight of thawed green peas, lb} \\ = \text{weight of full calorimeter} - \text{weight of empty calorimeter} - \text{weight of water in calorimeter} \\ C_{p\text{peas,thawed}} = \text{specific heat of thawed green peas, Btu/lb}^\circ\text{F} \\ = 0.84 \text{ Btu/lb}^\circ\text{F} \\ \Delta T_{\text{peas,thawed}} = \text{temperature rise in thawed green peas, }^\circ\text{F} \\ = \text{final temperature of cooked peas load} - 32^\circ\text{F} \\ E_{\text{fusion}} = \text{latent heat of fusion of ice} \\ = 144 \text{ Btu/lb} \\ W_{\text{moisture}} = \text{weight of moisture in frozen green peas-- 81\%} \\ = 0.81 \times W_{\text{peas,frozen}} \\ E_{\text{pan}} = \text{heat gained by the stainless-steel hotel pan(s)} \\ = W_{\text{pan}} \times C_{p\text{pan}} \times \Delta T_{\text{pan}}$$

where:

$$W_{\text{pan}} = \text{weight of pan (s), lb} \\ C_{p\text{pan}} = \text{specific heat of stainless-steel, Btu/lb}^\circ\text{F} \\ = 0.11 \text{ Btu/lb}^\circ\text{F} \\ \Delta T_{\text{pan}} = \text{temperature rise in pan }^\circ\text{F} \\ = T_f - T_i \\ = \text{final temperature of cooked green peas load} - \text{initial temperature frozen green peas load} \\ E_{\text{steam cooker}} = \text{total energy consumed by the steam cooker, Btu(kJ). Includes sum of all fuel types used (e.g. gas energy for heating plus electric energy used by steam circulating fans and/or controls)} \\ E_{\text{boiler re-init}} = \text{energy required to restore the final boiler energy content (pressure) to the initial boiler energy content (Btu(kJ)). Calculation of this energy quantity is required only if the conditional step 3.12 was applicable. Otherwise this energy quantity is already included in the } E_{\text{steam cooker}} \text{ value. If conditional step 3.12 was applicable, then } E_{\text{boiler re-init}} \text{ is calculated as follows:}$$

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$$= E_{cycle} \times \frac{P_{max} - P_{final}}{P_{max} - P_{min}}$$

where:

E_{cycle}	=energy required to raise the boiler pressure from minimum operating pressure to maximum operating pressure, Btu(kJ)
P_{max}	=the average maximum boiler pressure, psi(kPa)
P_{min}	=the average minimum boiler pressure, psi(kPa)
P_{final}	=the boiler pressure at the end of the test, psi(kPa)

4.4 Calculate the frozen green peas load cooking energy rate as follows:

$$q_{peas} = \frac{E_{steam\ cooker} + E_{boiler\ re\ -\ init}}{t} \times 60$$

where:

q_{peas}	= frozen green peas load cooking energy rate, Btu/h(kJ/h)
t	= test period, min
$E_{steam\ cooker}$ and $E_{boiler\ re\ -\ init}$	are as defined in the test method.

For gas steam cookers, $E_{steam\ cooker}$ in the above equation does not include the electric energy. The electric energy rate is reported separately in step 4.5. For direct steam or steam coil steam cookers, report the cooking energy rate in both Btu(kJ)/h and lb(kg)_{steam}/h.

4.5 This step applies to heavy load tests of gas, direct steam, and steam coil steam cookers only.

Calculate the frozen green peas load electric energy rate as follows:

$$q_{peas,ele} = \frac{E_{steam\ cooker, ele}}{t} \times 60$$

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where:

$q_{peas,ele}$ = frozen green peas load electric cooking energy rate, Btu/h(kJ/h)
 t = test period, min
 $E_{steam\ cooker, ele}$ = electric energy consumed by the steam cooker, Btu(kWh).

4.6 Calculate frozen green peas load production capacity (lb(kg)) using the following definition:

$$PC_{peas} = \frac{W_{pea}}{t} \times 60$$

where:

PC_{peas} = production capacity, lb/h(kg/h)
 W_{peas} = weight of frozen green peas load, lb(kg)
 t = test period, min

4.7 Report the frozen green peas load cooking water consumption rate, gal/h (L/h).

4.8 Report the average temperature of the frozen green peas load cooking condensate during the last five minutes of the test, °F(°C)