Vanguard Powermax 200 Gas-Fired Booster Heater Performance Tests

Application of ASTM Standard
Test Method F 2022-01

FSTC Report 5011.02.10

Food Service Technology Center
November 2002

Prepared by:
David Cowen
David Zabrowski
Fisher-Nickel, Inc.

Contributors:
Shawn Knapp
Scott Minor
Fisher-Nickel Inc.

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

Acknowledgments

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

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

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

Advantica Restaurant Group

Applebee's International Group

California Energy Commission (CEC)

California Restaurant Association

Carl Karcher Enterprises, Inc.

DJ Horton & Associates

Electric Power Research Institute (EPRI)

Enbridge Gas Distribution

EPA Energy Star

Gas Technology Institute (GTI)

Lawrence Berkeley National Laboratories

McDonald's Corporation

National Restaurant Association

Pacific Gas and Electric Company

Safeway, Inc.

Southern California Edison

Underwriters Laboratories (UL)

University of California at Berkeley

University of California at Riverside

US Department of Energy, FEMP

Specific appreciation is extended Vanguard Technology Inc., for supplying the Food Service Technology Center with a gas-fired booster heater for controlled testing in the appliance laboratory.

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

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

Legal Notice

Contents

List of Figures and Tables

Figures

Tables

Executive Summary

Vanguard's Powermax 200 gas-fired booster heater is powered by a 199,990 Btu/h input woven ceramic infrared burner housed in a welded stainless steel enclosure. The booster heater is controlled by an advanced microprocessor that regulates the pump and thermostat. Figure ES-1 illustrates the Vanguard's Powermax 200 gas-fired booster heater, as tested at the Food Service Technology Center (FSTC).

Figure ES-1.
Vanguard Powermax 200 Gas-fired booster heater.

FSTC engineers tested the booster heater under the tightly controlled conditions of the American Society for Testing and Materials' (ASTM) standard test method.[1] Booster heater performance is characterized by preheat time and energy consumption, idle energy rate, energy efficiency, and flow rate.

Booster heater performance was determined by testing the unit under four conditions (maximum flow capacity with inlet water temperatures of 140°F and 110°F and 50% flow capacity with inlet water temperatures of 140°F and 110°F). The Powermax 200 achieved 88% energy efficiency with a maximum flow capacity of 8.19 gal/min.

Energy efficiency is a measure of how much of the energy that a booster heater consumes is actually delivered to the water during the testing process. Booster heater energy efficiency is therefore defined by the following relationship:

$$Energy\ Efficiency = \frac{Energy\ to\ Water}{Burner\ Energy + Pump/Control\ Energy}$$

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

[1] American Society for Testing and Materials. 2001. *Standard Test Method for the Performance of Booster Heaters.* ASTM Designation F 2022-01, in *Annual Book of ASTM Standards,* Philadelphia.

Executive Summary

Table ES-1. Summary of Booster Heater Performance.

Rated Energy Input Rate (Btu/h)	199,990
Measured Energy Input Rate (Btu/h)	196,436
Storage Capacity (gal)	6.2
140°F Inlet Temperature [a]	
Preheat Time (min)	1.94
Preheat Energy (Btu)	4,854
Flow Rate (gal/h)	491.5 ± 14.0 [b]
Temperature Rise (°F)	43.7
Energy Efficiency (%)	88.1 ± 2.0 [b]
110°F Inlet Water Temperature [a]	
Preheat Time (min)	2.77
Preheat Energy (Btu)	7,854
Flow Rate (gal/h)	288.8 ± 8.9 [b]
Temperature Rise (°F)	73.5
Energy Efficiency (%)	87.0 ± 0.6 [b]
Idle Energy Rate (Btu/h)	3,313
Idle Electric Energy Rate (W)	69.4

[a] Efficiency and flow rate are from the maximum capacity tests.

[b] This range indicates the experimental uncertainty in the test result based on a minimum of three test runs.

A booster heater's job is to raise the temperature of the water from the primary water heater to a minimum of 180°F to provide the sanitizing rinse for the dishwasher. Since most primary building water heaters provide water at 140°F (restaurants) or 110°F (schools and institutions), the ASTM test method evaluates booster heater performance under both conditions. Figure ES-2 and ES-3 display the Powermax 200's ability to maintain a 180°F outlet temperature during the maximum flow capacity tests for both the inlet temperatures.

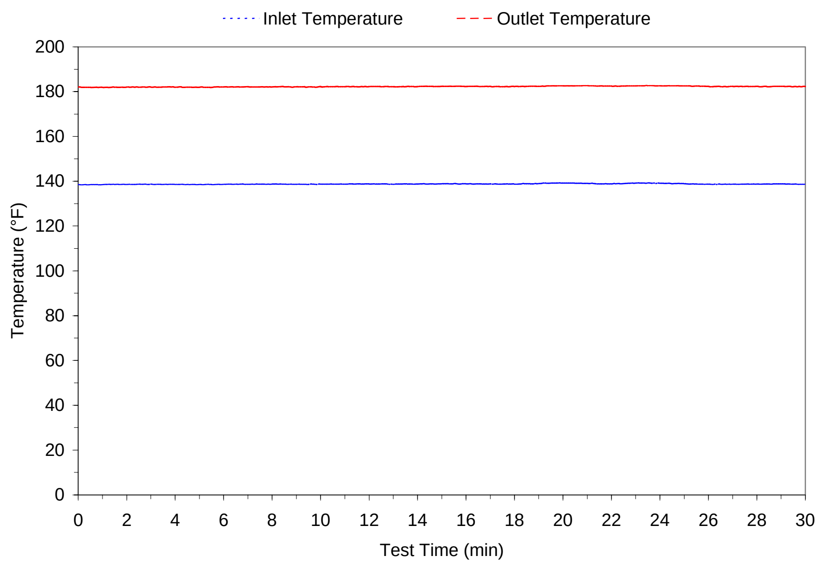


Figure ES-2.
140°F inlet water temperature during Max Capacity Test.

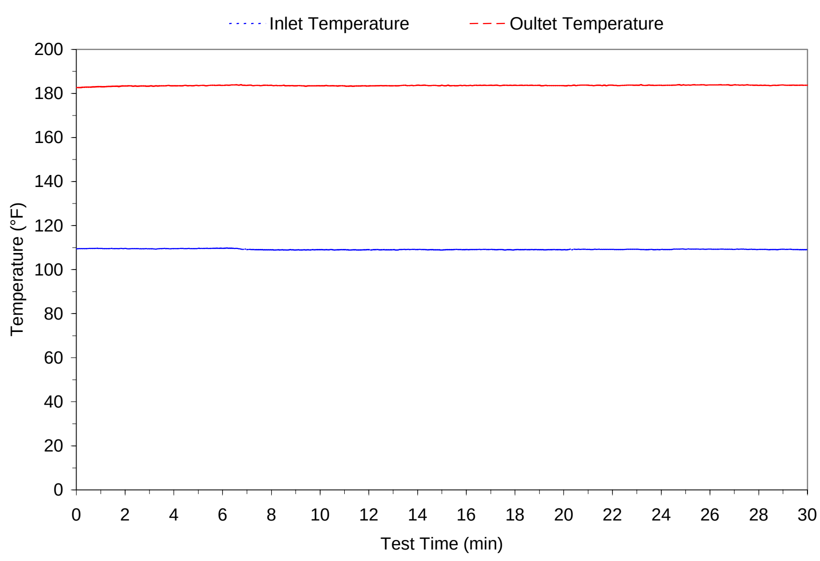


Figure ES-3.
110°F inlet water temperature during Max Capacity Test.

Executive Summary

Vanguard's Powermax 200 achieved excellent energy efficiency and flow capacity results during testing at the Food Service Technology Center. With 88% energy efficiency and a flow capacity approaching 500 gal/h, the Powermax 200 has established itself as a leader in gas-fired booster heaters. The Powermax's high efficiency was complimented by a fairly low idle rate. In fact, Vanguard's idle rate was among the lowest in its class.

The Powermax exhibited a short 1.9 minute preheat from 140°F, while requiring only slightly longer (2.8 minutes) to preheat from 110°F. With its high efficiency, low idle rate and quick preheat, Vanguard's Powermax 200 was an excellent all-around performer.

1 Introduction

Background

Dishrooms are one of the most energy-intensive segments of a food service operation, typically representing 18% of a restaurant's total energy bill.[1] The high energy costs associated with operating a large dishwasher are further exacerbated by the electric booster heater's costs, which provide the 180°F sanitizing rinse. A new generation of gas-fired booster heaters provides operators with a viable (and economic) alternative to the traditional electric booster heaters.

Dedicated to the advancement of the food service industry, the Food Service Technology Center (FSTC) has focused on the development of standard test methods for commercial food service equipment since 1987. The primary component of the FSTC is a 10,000 square-foot appliance laboratory equipped with energy monitoring and data acquisition hardware, 60 linear feet of canopy exhaust hoods integrated with utility distribution systems, appliance setup and storage areas, and a state-of-the-art demonstration and training facility.

The test methods, approved and ratified by the American Society for Testing and Materials (ASTM), allow benchmarking of equipment such that users can make meaningful comparisons among available equipment choices. By collaborating with the Electric Power Research Institute (EPRI) and the Gas Technology Institute (GTI) through matching funding agreements, the test methods have remained unbiased to fuel choice. End-use customers and commercial appliance manufacturers consider the FSTC to be the national leader in commercial food service equipment testing and standards, sparking alliances with several major chain customers to date.

FSTC engineers previously monitored the energy and water consumption of a dishroom utilizing a low-temperature dishwasher as a part of a whole-building monitoring project.[2,3] These studies reported that the dishroom accounted for 97% of a food service operation's total hot water consumption. Of that amount, the dishwasher consumed nearly half of the dishroom's hot water. The widespread usage of high-temperature dishwashers in the food service industry led the FSTC to develop test methods for quantifying the energy consumption and performance of these systems. These draft test methods were subsequently approved and ratified by ASTM. [4-6]

During the course of developing the test method for booster heaters (ASTM designation F2022-01), FSTC engineers tested several different units. [7] Booster heater performance is characterized by preheat time and energy consumption, idle energy consumption rate, pilot energy consumption rate, and energy efficiency and capacity at two supply temperatures (140°F and 110°F).

Vanguard's Powermax 200 gas-fired booster heater features a woven ceramic infrared burner in a welded stainless steel enclosure, with an advanced microprocessor to control ignition and thermostat response.

This report presents the results of applying the ASTM test method to the Vanguard's Powermax 200. The glossary in Appendix A is provided so that the reader has a quick reference to the terms used in this report.

Objectives

The objective of this report is to examine the operation and performance of Vanguard's Powermax 200, gas infrared booster heater under the controlled conditions of the ASTM standard test method. The scope of this testing is as follows:

1. Verify that the appliance is operating at the manufacturer's rated energy input.
2. Determine the time and energy required to preheat the appliance from an inlet supply water temperature of 140 $^{+0}/_{-3}$°F and 110 $^{+0}/_{-3}$°F to a thermostat setting of 183 ± 3°F.

3. Characterize the idle energy use with the booster heater tank stabilized with an inlet water supply temperature of 140 $^{+0}/_{-3}$°F and 110 $^{+0}/_{-3}$°F.
4. Document the flow capacity rate, energy rate, and energy efficiency with 140 $^{+0}/_{-3}$°F and 110 $^{+0}/_{-3}$°F inlet water supply temperature to the booster heater.
5. Document the energy rate and energy efficiency at 50% of flow capacity with 140 $^{+0}/_{-3}$°F and 110 $^{+0}/_{-3}$°F inlet water supply temperature to the booster heater.

Appliance Description

Vanguard's Powermax, gas-fired booster heater has an input rating of 199,990 Btu/h. The booster heater uses a microprocessor to control the temperature of a woven ceramic infrared burner housed in a welded stainless enclosure. A removable panel allows for easy access to booster heater internals for maintenance. See Figure 1-1.

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

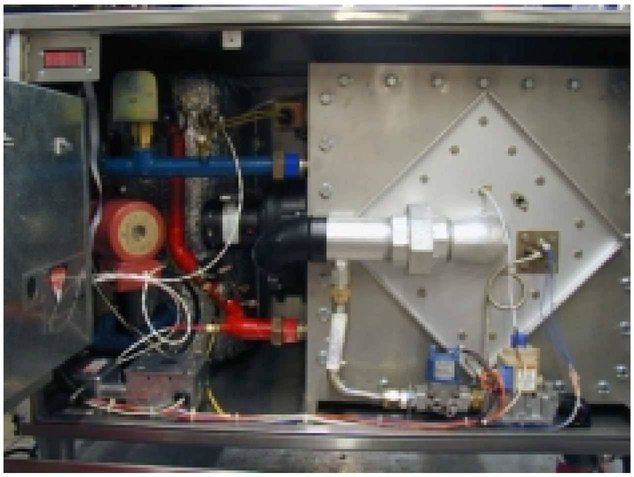


Figure 1-1. Powermax 200 heat exchanger.

Table 1-1. Appliance Specifications.

Manufacturer	Vanguard
Model	Powermax 200
Generic Appliance Type	Infrared gas-fired booster heater
Rated Input	199,990 Btu/h
Storage Capacity	6.2 gallons
Controls	Advanced Microprocessor
Construction	Stainless Steel

2 Methods

Setup and Instrumentation

FSTC researchers installed the gas-fired booster heater on a noncombustible floor in a conditioned space. There was at least 6 inches of clearance between the sides of the booster heater and any other appliance. A primary water supply system was installed upstream of the booster heater to provide a constant inlet temperature of 140 $^{+0}/_{-3}$°F and 110 $^{+0}/_{-3}$°F. Constant water pressure was maintained by installing a pressure regulator upstream of the booster heater. Water consumption was monitored by installing a calibrated flow meter between the booster heater and the pressure regulator.

A throttling valve and solenoid valve were installed in the outlet pipe, downstream from the outlet connection of the booster heater. To reduce turbulent water flow, a water hammer arrestor was installed immediately upstream of the solenoid valve. All water lines were insulated with standard insulation (R = 4°F·ft^2·hr/Btu) to minimize heat loss. Additionally, large radius turns were used for pipe elbows to reduce frictional losses in the piping system. All test apparatus were installed in accordance with Section 9 of the ASTM test method.[1] A schematic of the test setup is presented in Figure 2-1.

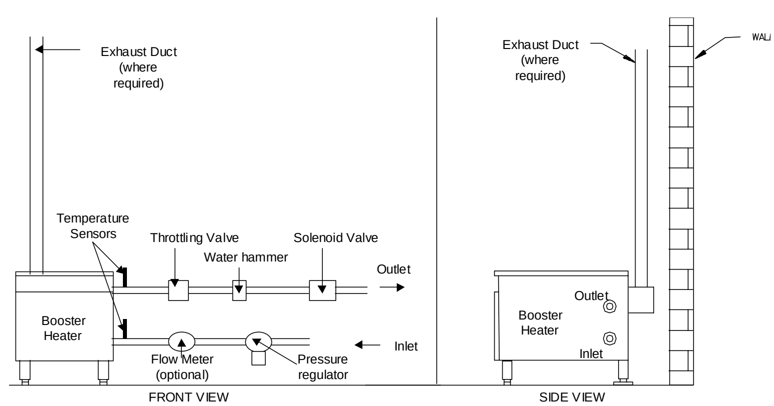


Figure 2-1. Typical equipment configuration.

Thermocouples were positioned in the inlet and outlet lines, 3-inches from the booster heater connections to monitor water temperature. Ambient room temperature was monitored with a temperature sensor placed 24-inches away from the front of the booster heater. The ambient temperature was maintained at 75 ± 5°F throughout the testing. Figure 2-2 illustrates the ambient temperature sensor placement for the booster heater tests.

Natural gas consumption was measured using a positive displacement-type gas meter that generated a pulse every 0.1 ft^3. The gas meter and the thermocouples were connected to an automated data acquisition unit that recorded data every 5 seconds. A chemical laboratory used a gas chromatograph to determine the gas heating value on each day of testing. All gas measurements were corrected to standard conditions.

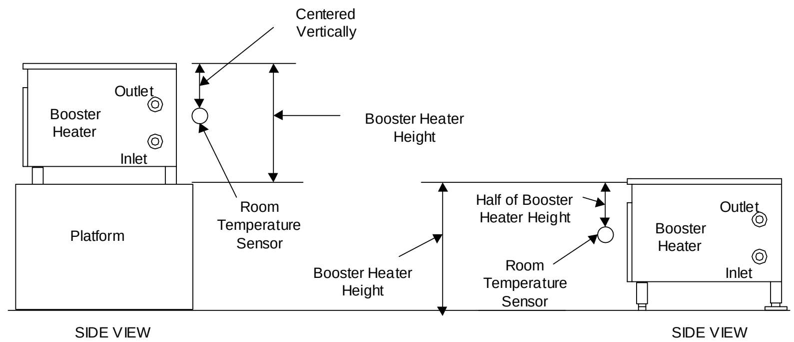


Figure 2-2.
Ambient thermocouple placement for testing.

Measured Energy Input Rate

Rated energy input rate is the maximum or peak rate at which the booster heater consumes energy—as specified on the booster heater's nameplate. Measured energy input rate is the maximum or peak rate of energy consumption, which is recorded during a period when the burners are operating (such as preheat). Researchers compared the measured energy input rate with the nameplate energy input rate to ensure that the booster heater was operating properly.

Efficiency and Flow Capacity Tests

Efficiency and flow capacity tests were run with two different incoming supply temperatures: 140 $^{+0}/_{-3}$°F and 110 $^{+0}/_{-3}$°F. For the maximum capacity tests, the booster heater controls were set for continuous burner operation. The throttling valve on the outlet was set so that the outgoing water stabilized at 183 ± 3°F. Time, energy consumption, water flow and water temperatures were monitored and recorded during the 30-minute test period. Control and pump energy (if applicable) were monitored during the testing.

Once the maximum capacity was established for a given supply temperature, the water flow was reduced by 50%, and the test was repeated. The half-capacity tests allowed the burners to cycle around the control setpoint. The outlet temperature was maintained at 183 ± 3°F for all efficiency and capacity tests.

Each flow capacity and efficiency test for 140 $^{+0}/_{-3}$°F and 110 $^{+0}/_{-3}$°F was repeated a minimum of three times. This procedure ensured that the reported energy efficiency and capacity results had an uncertainty of less than ±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.

3 Results

Energy Input Rate

Prior to testing, the energy input rate was measured and compared with the manufacturer's nameplate value. This procedure ensured that the booster heater was operating within its specified parameters. The energy input rate was 196,436 Btu/h (a difference of 1.78% from the nameplate rating).

Preheat and Idle Tests

Preheat Energy and Time

The booster heater was turned off overnight and allowed to stabilize at room temperature. With the unit off and the solenoid valve open, 140 $^{+0}/_{-3}$°F water was supplied to the booster heater. Water was run for 5 minutes, to allow the bulk of the booster heater components to equalize in temperature with the inlet supply water. After the 5-minute stabilization period, researchers closed the solenoid valve and set the thermostats controls to achieve a 183 ±3°F temperature. Energy consumption and elapsed time were recorded as soon as the booster heater was turned on.

Preheat time includes any delay between the time the unit was turned on and the time the burner actually ignited. Preheat was judged complete when the burner cycled off. The preheat tests were conducted at the beginning of a test day for both 140 $^{+0}/_{-3}$°F and 110 $^{+0}/_{-3}$°F inlet water temperatures. Vanguard's Powermax 200 gas-fired booster heater preheated in 1.94 minutes with an inlet supply of 140 $^{+0}/_{-3}$°F water, while consuming 4,854 Btu to reach the thermostat setpoint. With an inlet water temperature of 110 $^{+0}/_{-3}$°F, the unit required 2.77 minutes and 7,854 Btu to raise the water temperature 70°F.

Idle Energy Rate

Once the booster heater storage tank reached a setpoint of 183 ± 3°F, the booster heater was allowed to stabilize for one hour. Time and energy consumption was monitored for an additional six-hour period. The idle energy rate during this period was 3,313 Btu/h, a duty cycle of 1.7%.

Test Results

Input, preheat, and idle test results are summarized in Table 3-1.

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

Rated Energy Input Rate (Btu/h)	199,990
Measured Energy Input Rate (Btu/h)	196,436
Preheat 140°F Inlet Temperature:	
Time (min)	1.94
Energy (Btu)	4,854
Electric Energy Rate (Wh)	9.49
Preheat 110°F Inlet Temperature:	
Time (min)	2.77
Energy Consumption (Btu)	7,854
Electric Energy Rate (Wh)	13.93
Idle Energy Rate (Btu/h)	3,313
Idle Electric Energy Rate (W)	69.4

Efficiency and Flow Capacity Tests

The booster heater was tested under maximum capacity and half-capacity flow rates with both a 140 $^{+0}/_{-3}$°F supply and a 110 $^{+0}/_{-3}$°F supply. Researchers monitored test time, inlet and outlet water temperatures, water flow rate and booster heater energy consumption during these tests.

Results

Maximum Capacity Tests

The maximum capacity tests were designed to reflect a booster heater's peak performance. The booster heater energy consumption and flow rate were monitored while supplying as much 180°F water as possible with a fixed supply. These tests simulate a booster heater's performance while supplying rinse water to a conveyor-type dishwasher that calls for a continuous rinse.

The Powermax provided 491gal/h of 180°F rinse water with a 140°F supply while achieving 88.1% efficiency. With a 110°F supply, the Powermax produced 288.6 gal/h of 180°F water and exhibited 87.0% efficiency.

Half-Capacity Tests

The half-capacity tests represent a more typical usage pattern for a smaller, door-type dishwasher. The flow rate is reduced to 50% of the unit's maximum capacity, allowing the heaters to cycle on and off as needed. Researchers ensured that the outlet water did not fall below 180°F during the half-capacity tests.

Test Results

Energy efficiency is a measure of the performance of the entire system, including heat exchanger, pump and controls. The booster heater's energy efficiency is defined as the energy imparted to the water, expressed as a percentage of the amount of energy consumed by the booster heater, including pump motor and controls. A second quantity, thermal efficiency, quantifies the percentage of heat from the burners that was transferred to the water during the testing. A booster heater's thermal efficiency is always higher than its energy efficiency.

Maximum capacity energy efficiency results with a 140°F supply were 86.9%, 87.2%, 89.4% and 88.9%, yielding a maximum uncertainty of 2.1%. Figures 3-1 and 3-2 show the inlet and outlet water temperatures during the maximum capacity tests. Tables 3-2 and 3-3 summarize the results of the

ASTM efficiency and capacity tests. A complete summary of the data from the efficiency tests is presented in Appendix D.

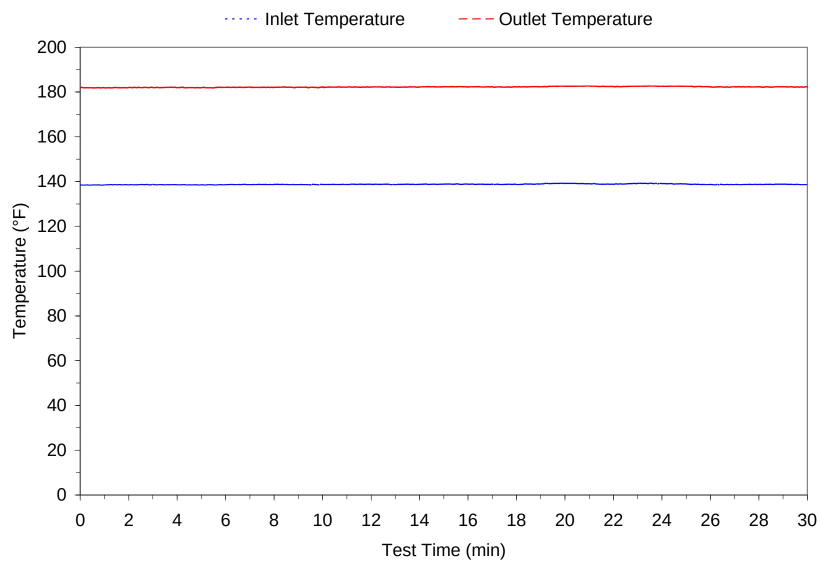


Figure 3-1.
Water temperatures during 140°F max capacity test.

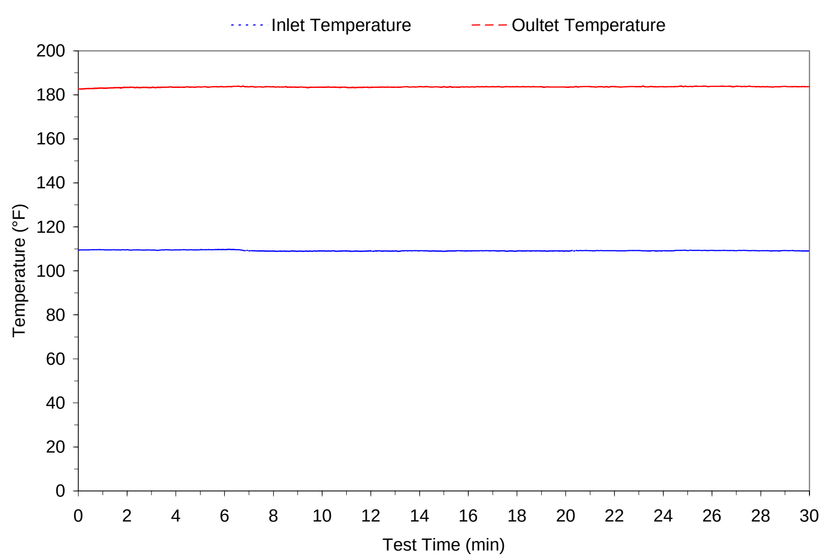


Figure 3-2.
Water temperature during 110°F Max Capacity Test.

Results

Table 3-2. Maximum Capacity Test Results.

	140°F Supply	***110°F Supply***
Flow Rate (gph)	491.5 ± 14.0	288.8 ± 8.9
Total Water Consumption (gal)	245.8	144.4
Temperature Rise (°F)	43.7	73.5
Gas Energy Rate (Btu/h)	196,436	196,200
Electric Energy Rate (W)	293.3	298.4
Energy Efficiency (%)	88.1 ± 2.0	87.0 ± 0.6
Thermal Efficiency (%)	88.2	87.5

Half-capacity energy efficiency results with a 140°F supply were 85.6%, 54.4%, 85.9% and 86.0%, 86.0%, 85.5% and 87.6, yielding a maximum uncertainty of 0.9%.

Table 3-3. Half-Capacity Test Results.

	140°F Supply	***110°F Supply***
Flow Rate (gal/min)	243.6 ± 4.5	141.9 ± 0.9
Total Water Consumption (gal)	121.8	70.9
Temperature Rise (°F)	47.9	78.9
Gas Energy Rate (Btu/h)	108,675	105,761
Electric Energy Rate (W)	293.3	264.7
Energy Efficiency (%)	86.0 ± 0.9	84.8 ± 0.3

4 Conclusions

Vanguard's Powermax 200 achieved excellent energy efficiency and flow capacity results during testing at the Food Service Technology Center. Gas-fired booster heaters have seen improvements in design and performance through collaboration between manufacturers and testing facilities such as the FSTC. The ASTM standardized test method for booster heaters can quantify design improvements, which have greatly impacted the acceptance of gas-fired booster heaters within the food service industry. During maximum flow capacity testing, Vanguard's Powermax 200 posted some of the highest energy efficiency results seen to date. With 88% energy efficiency and a flow capacity approaching 500 gal/h, the Powermax 200 has established itself as a leader in gas-fired booster heaters.

This Vanguard booster heater showed little drop-off in efficiency during the half-capacity tests, indicating that the unit will perform quite well with an intermittent load—such as a door-type dishwasher that washes one rack at a time. The 87% half-load energy efficiency was complimented by a fairly low idle rate. In fact, with a 1.7% idle duty cycle, Vanguard's idle rate was among the lowest for a gas-fired booster heater in its class.

Operators wanting to save energy by turning the booster heater off overnight will be pleased with the Powermax's short preheat. Preheat with a 140°F supply was a blazing 1.9 minutes, while a slightly longer 2.8 minute preheat was required for a 110°F supply. With its high efficiency, low idle rate and quick preheat, Vanguard's Powermax 200 was an excellent all-around performer.

5 References

1. Claar, C.N., R.P. Mazzucchi, J.A., Heidell. 1985. *The Project on Restaurant Energy Performance (PREP) – End-Use Monitoring and Analysis*. Prepared for the Office of Building Energy Research and Development, DOE, May.

2. Kaufman, D., Selden, M. 1990. *Learning Center Dining Building*. Prepared for the Department of Research and Development. Report No. 008.1-90.17. San Ramon, California: Pacific Gas and Electric Company.

3. Kaufman, D., Selden, M. 1990. *Dishroom and Warewasher Study Stero Single Rack, Low Temperature, Door Type Dishwasher*. Prepared for the Department of Research and Development. Report No. 008.1-91.1. San Ramon, California: Pacific Gas and Electric Company.

4. American Society for Testing and Materials. 1996. *Standard Test Method for Energy Performance of Single-Rack Hot Water Sanitizing, Commercial Dishwashing Machines.* ASTM Designation F1696-96, in *Annual Book of ASTM Standards,* Philadelphia.

5. American Society for Testing and Materials. 1998. *Standard Test Method for the Energy Performance of Rack-Conveyor, Hot Water Sanitizing, Door-Type Commercial Dishwashing Machines.* ASTM Designation F1920-98, in *Annual Book of ASTM Standards,* Philadelphia.

6. American Society for Testing and Materials. 2001. *Standard Test Method for the Performance of Booster Heaters.* ASTM Designation F2022-01, in *Annual Book of ASTM Standards,* Philadelphia.

7. Gil Ashton Publishing, LLC. *Gas-fired booster Heaters Take the Test,* Foodservice Equipment Reports, May, 2002.

A Glossary

Booster Heater

An appliance that raises water temperature (typically 110°F to 140°F) to 180°F or more to provide high temperature sanitizing rinse water for a dishwasher machine.

Dishwasher Machine

Machine that uniformly washes, rinses, and sanitizes eating and drinking utensils.

Batch Water Flow

Intermittent mode of water delivery at specified flow rate and elapse time. This is the typical style of water delivery of a booster heater supplying final rinse water to a door type dishwasher machine.

Booster Heater Energy Efficiency (%)

Quantity of energy imparted to the water while heating, expressed as a percentage of the total amount of energy consumed by the booster heater (including pump and control energy) during the capacity tests.

Booster Heater Inlet

The point of connection on the booster heater for the water line from the primary supply to the booster heater.

Booster Heater Outlet

The point of connection on the booster heater for the water line from the booster heater to the dishwasher.

Continuous Water Flow.

Uninterrupted water delivery by a booster heater at a specified flow rate. This is a typical mode of water delivery of a booster heater supplying water to a conveyor or rack-less (flight) type dishwasher machine.

Energy Rate (kW or kBtu/h)

Average energy rate of energy consumption during the continuous flow tests.

Flow Capacity (gal/min or gal/h)

Maximum water flow rate at which the booster heater can heat water from a specified inlet temperature to an outlet temperature of 183 ± 3°F during the continuous flow capacity test.

Heating Value (Btu/ft^3)

Heating Content

The quantity of heat (energy) generated by the combustion of fuel. For natural gas, this quantity varies depending on the constituents of the gas.

Idle Energy Rate (kW or Btu/h)

Idle Energy Input Rate
Idle Rate

The rate of appliance energy consumption while it is “idling” or “holding” at a stabilized operating condition or temperature.

Glossary

Idle Duty Cycle (%)
Idle Energy Factor

The idle energy consumption rate expressed as a percentage of the measured energy input rate.

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

Measured Input Rate (kW or Btu/h)

Measured Energy Input Rate
Measured Peak Energy Input Rate

The maximum or peak rate at which an appliance consumes energy, typically reflected during appliance preheat (i.e., the period of operation when all burners or elements are "on").

Pilot Energy Rate (kW or kBtu/h)

Average rate of energy consumption by a booster heater's continuous pilot (if applicable).

Preheat Energy (kWh or Btu)

Preheat Energy Consumption

The total amount of energy consumed by an appliance during the preheat period.

Preheat Rate (°F/min)

The rate at which the appliance heats during to its operating temperature.

Preheat Time (minute)

Preheat Period

The time required for an appliance to "preheat" from the ambient room temperature (75 ± 5°F) to a specified (and calibrated) operating temperature or thermostat setpoint.

Primary Supply

The service water heater system that supplies water to the booster heater under test.

Rated Energy Input Rate
(kW, W or Btu/h, Btu/h)

Input Rating (ANSI definition)
Nameplate Energy Input Rate
Rated Input

The maximum or peak rate at which an appliance consumes energy as rated by the manufacturer and specified on the nameplate.

Test Method

A definitive procedure for the identification, measurement, and evaluation of one or more qualities, characteristics, or properties of a material, product, system, or service that produces a test result.

Thermal Efficiency (%)

Quantity of energy imparted to the water, expressed as a percentage of energy consumed by the element(s), gas burner(s), steam coil(s), and/or steam injector(s) during the flow capacity tests. Thermal efficiency data is collected during the continuous flow capacity tests.

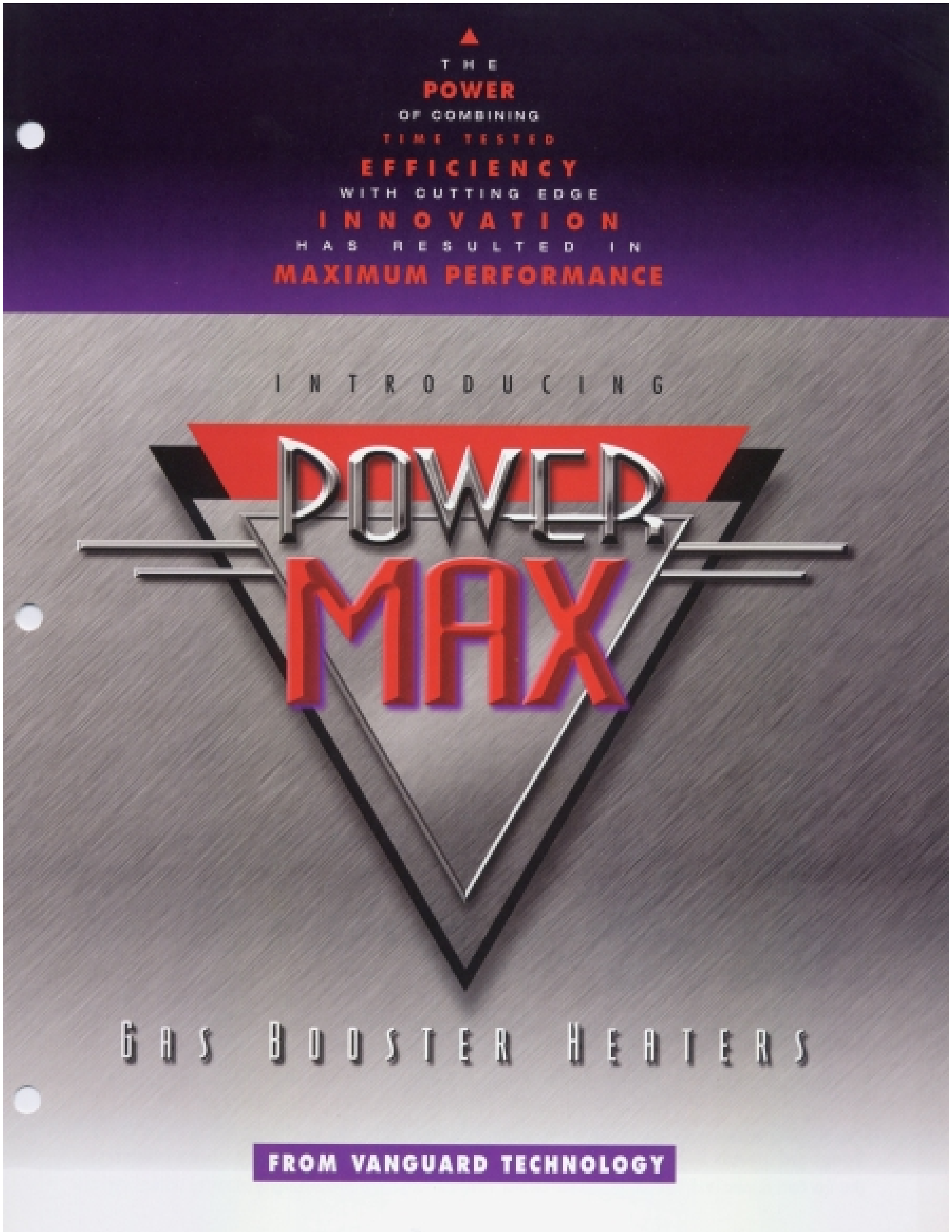
Uncertainty

Measure of systematic and precision errors in specified instrumentation or measure of a reported test result.

B Appliance Specifications

Appendix B includes the product literature for the Vanguard Power-max 200 booster heater.

B Appliance Specifications



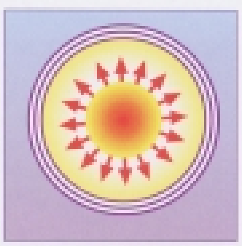
Vanguard Technology has pioneered the use of gas energy to heat water to sterilizing temperatures for dishmachines of all sizes. This has resulted in the **savings of millions of dollars in electricity costs** for Vanguard Gas Booster Heater owners. While other gas boosters come and go, **Vanguard's proven, patented design** has earned the reputation of being the dependable workhorse of gas boosters.

Introducing PowerMax™...

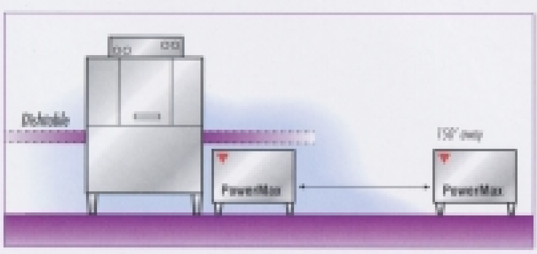
the Next Generation of Gas Booster Heaters from Vanguard Technology

INNOVATIONS INCLUDE:

- Rugged, high-efficiency, infrared, woven ceramic burners
- Advanced microprocessor-controlled ignition and temperature control
- All stainless steel welded frame, cabinet and tank
- Front access for quick, easy service
- Single point electric, water and gas connection
- Choice of 3 convenient ways to vent
- Pressure relief and regulating valves factory installed
- Heavy-duty finned copper heat exchanger
- Each unit hand-built and fire-tested before shipment



360° of heat transfer

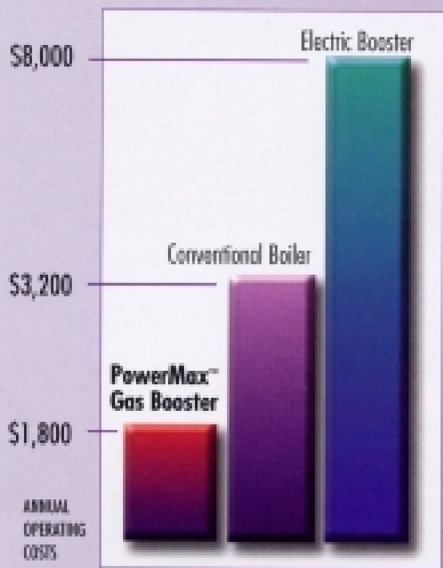


PowerMax™ can be installed up to 150' away from dishwasher or next to it under the dishtable

Continuous LED temperature display and diagnostics

Vanguard stands behind the PowerMax™ with the strongest warranty in the industry:
One Year Parts & Labor ▾ 5 Year Limited Warranty on heat exchanger ▾ Lifetime Limited Warranty on welded stainless steel tank

Why the owners of Vanguard Gas Boosters consider them the best investment they have ever made



Are you paying thousands a year in electricity costs that could be going to your bottom line profits?

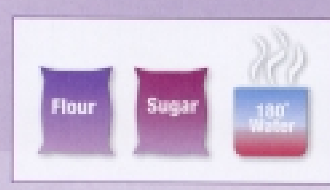
A typical example:

- Dishwasher Rinse = 325 gph
- Dishwasher Use = 5 hr/day
- Electricity = .055/kwh
- Electric Demand = $6.10/kw
- Natural Gas = .55/therm

When it comes right down to it, there are only two things that really matter about a booster heater:

1. Its ability to consistently and reliably produce all of the 180° rinse water your dishmachine needs...
2. And to produce that water at the least possible cost.

In your food service operation, hot water is a ***commodity*** item used in great quantities. It is the only commodity "manufactured" by you and its cost is in your control!!

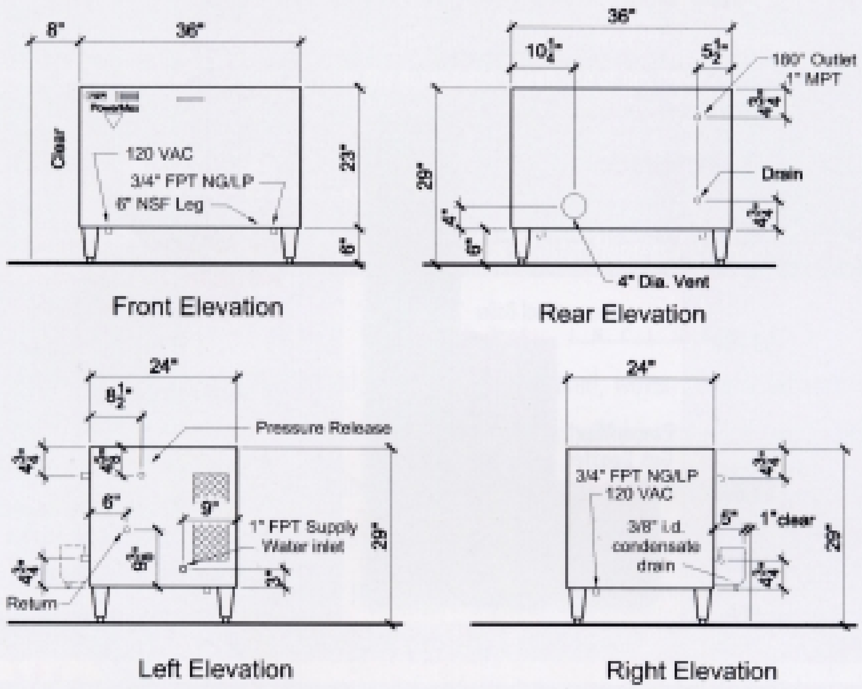


According to the *National Restaurant Association*, water heating accounts for an average *18%* of a restaurants annual energy costs. While utility prices vary in different areas, *gas generally is 50% to 70% less expensive than electricity.*

Discover how much you can save.

Visit the Vanguard Website or call your local gas utility or foodservice equipment specialist for assistance.

PowerMax 200



Model Number	BTUH Per Burner Natural or Propane	Gas Connection	Water Supply	Electrical Connection	Gas Pressure Regulators	Shipping Weight
PM 200	199,990	3/4" NPT	1" NPT	120 VAC 1ph 6 amps	One each supplied	468 lbs.

Natural Gas Pressure WC @ Inlet		LP Gas Pressure WC @ Inlet		Manifold Pressure WC		Water Pressure (Flow)		Dishwasher Rinse Re-Circulating Loop	Clearance From Combustible Surface			Vent Per Local Code
Min	Max	Min	Max	Nat.	LP	Min	Max	3/4" or 1" NPT*	Side	Top	Rear	Auxiliary Power Vent Required for extended flue lengths call factory
7"	10.5"	10"	14"	3.5"	7.5"	40 psi	80 psi	Required if outlet is more than 5 feet from rinse valve of dishwasher	8" L 2" R	1"	6"**	

Temperature Rise	40° Rise	50° Rise	60° Rise	70° Rise	140° Rise
Gallons Per Minute	8.7	7.0	5.5	5.0	2.5
Gallons Per Hour	520	420	330	300	150

*Contact factory if booster will be supplying dishwasher fill valves or tank heat in addition to rinse valve.
**1" from back of exhaust vent.

VANGUARD TECHNOLOGY INC.

The original... and still the best!

29495 Airport Road
Eugene, Oregon 97402
Phone: 800/624-4809
Fax: 541/461-6023
Email: vti1999@aol.com
www.vanguardtechnologyinc.com

Vanguard Technology, Inc. also manufactures high-efficiency production water heaters.

C Results Reporting Sheets

Manufacturer:	Vanguard
Models:	Powermax 200
Date:	May 2002

Test Fryers and Burners

Description of operational characteristics: Vanguard's Powermax gas-fired booster heater is rated at 199,990 Btu/h and features an advanced microprocessor that controls a woven ceramic infrared burner inside of a welded stainless steel tank. A stainless steel sides, bottom and top house all of the booster heater components.

Apparatus

__√__ Check if testing apparatus conformed to specifications in section 6.

Deviations: None.

Energy Input Rate

Gas Heating Value (Btu/scf)	1022
Name Plate (Btu/h)	199,990
Measured (Btu/h)	196,436
Percentage Difference (%)	1.78

Results Reporting Sheets

Preheat Energy and Time

Gas Heating Value (Btu/scf)	1018
140°F Inlet Temperature:	
Duration (min)	1.94
Energy Consumption (Btu)	4,854
Electric Energy Rate (Wh)	9.49
110°F Inlet Temperature:	
Duration (min)	2.77
Energy Consumption (Btu)	7,854
Electric Energy Rate (Wh)	13.93

Idle Energy Rate

Gas Heating Value (Btu/scf)	1022
Idle Energy Rate @ 350 °F (Btu/h)	3,313
Electric Energy Rate (W)	69.4

Energy Efficiency and Flow Rate at Maximum Capacity with 140°F inlet

Gas Heating Value (Btu/scf)	1022
Test Time (min)	30.0
Minimum Inlet Temperature (°F)	138.2
Maximum Inlet Temperature (°F)	139.0
Minimum Outlet Temperature (°F)	181.8
Maximum Outlet Temperature (°F)	182.9
Temperature Rise (°F)	43.7
Flow Rate (gal/H)	491.5 ± 14.0
Gas Energy Rate (Btu/h)	196,436
Electric Energy Rate (W)	293.3
Energy Efficiency (%)	88.1 ± 2.0

Results Reporting Sheets

Energy Efficiency and Flow Rate at Maximum Capacity with 110°F inlet

Gas Heating Value (Btu/scf)	1024
Test Time (min)	30.0
Minimum Inlet Temperature (°F)	108.7
Maximum Inlet Temperature (°F)	109.5
Minimum Outlet Temperature (°F)	182.0
Maximum Outlet Temperature (°F)	182.8
Temperature Rise (°F)	73.5
Flow Rate (gal/h)	288.8 ± 8.9
Gas Energy Rate (Btu/h)	196,200
Electric Energy Rate (W)	298.4
Energy Efficiency (%)	87.0 ± 0.6

Energy Efficiency and Flow Rate at 50% Capacity with 140°F inlet

Gas Heating Value (Btu/scf)	1022
Test Time (min)	30.0
Minimum Inlet Temperature (°F)	138.2
Maximum Inlet Temperature (°F)	139.0
Minimum Outlet Temperature (°F)	181.8
Maximum Outlet Temperature (°F)	182.9
Temperature Rise (°F)	47.9
Flow Rate (gal/h)	243.6 ± 4.5
Gas Energy Rate (Btu/h)	108,675
Electric Energy Rate (W)	293.3
Energy Efficiency (%)	86.0 ± 0.9

Results Reporting Sheets

Energy Efficiency and Flow Rate at 50% Capacity with 110°F inlet

Gas Heating Value (Btu/scf)	1022
Test Time (min)	30.0
Minimum Inlet Temperature (°F)	108.0
Maximum Inlet Temperature (°F)	109.2
Minimum Outlet Temperature (°F)	181.8
Maximum Outlet Temperature (°F)	190.2
Temperature Rise (°F)	78.9
Flow Rate (gal/h)	141.9 ± 0.9
Gas Energy Rate (Btu/h)	105,761
Electric Energy Rate (W)	264.7
Energy Efficiency (%)	84.8 ± 0.3

D Energy Efficiency Data

Table D-2. Maximum Capacity at 140°F Inlet Test Data.

	Repetition #1	Repetition #2	Repetition #3	Repetition #4
Measured Values				
Electric Energy Consumption (Wh)	148.08	145.95	145.79	146.85
Gas Energy (Btu)	98,275	97,852	98,372	98,373
Test Time (min)	**30.0**	**30.0**	**30.0**	**30.0**
Average Temperature Rise (°F)	44.1	43.5	43.7	43.7
Water Consumption (gal)	**240.51**	**243.79**	**249.93**	**248.79**
Flow Rate (gal/min)	8.02	8.13	8.33	8.29
Flow Rate (gal/h)	481.0	487.6	499.9	497.6
Inlet				
Average Inlet Temperature (°F)	139.2	138.8	138.3	138.2
Minimum Inlet Temperature (°F)	138.6	138.4	138.0	137.9
Maximum Inlet Temperature (°F)	139.8	139.2	138.7	138.5
Outlet				
Average Outlet Temperature (°F)	183.3	182.2	182.0	181.8
Minimum Outlet Temperature (°F)	182.2	181.8	181.7	181.5
Maximum Outlet Temperature (°F)	184.3	182.7	182.4	182.1
Flue				
Average Flue Temp (°F)	173.9	173.6	173.7	173.1
Minimum Flue Temp (°F)	173.0	172.8	173.2	172.2
Maximum Flue Temp (°F)	178.7	174.1	174.0	173.7
Energy Efficiency (%)	**86.9**	**87.2**	**89.4**	**88.9**
Thermal Efficiency (%)	**87.3**	**87.7**	**89.9**	**89.4**
Gas Energy Rate (Btu/h)	**196,550**	**195,705**	**196,743**	**196,745**
Electric Energy Rate (W)	**296.2**	**291.9**	**291.6**	**293.7**

Energy Efficiency Data

***Table D-3. Maximum Capacity at 110°F Inlet Test Data*.**

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Electric Energy Consumption (Wh)	150.10	148.72	148.85
Gas Energy (Btu)	96,840	98,430	98,546
Test Time (min)	**30.0**	**30.0**	**30.0**
Average Temperature Rise (°F)	74.4	71.3	71.4
Water Consumption (gal)	141.16	148.29	148.41
Flow Rate (gal/min)	4.71	4.94	4.95
Flow Rate (gal/h)	282.3	296.6	296.8
Inlet			
Average Inlet Temperature (°F)	109.2	109.3	109.5
Minimum Inlet Temperature (°F)	108.9	109.0	109.2
Maximum Inlet Temperature (°F)	109.9	109.7	109.9
Outlet			
Average Outlet Temperature (°F)	183.6	180.7	181.0
Minimum Outlet Temperature (°F)	182.7	180.4	180.3
Maximum Outlet Temperature (°F)	183.9	181.2	181.3
Flue			
Average Flue Temp (°F)	174.2	174.1	173.6
Minimum Flue Temp (°F)	172.4	173.0	172.8
Maximum Flue Temp (°F)	176.5	175.2	174.8
Energy Efficiency (%)	**87.2**	**86.6**	**86.7**
Thermal Efficiency (%)	**87.7**	**87.0**	**87.1**
Gas Energy Rate (Btu/h)	**193,681**	**196,861**	**197,094**
Electric Energy Rate (W)	**300.2**	**299.0**	**297.7**

Energy Efficiency Data

Table D-4. Maximum Capacity at 110°F Inlet Test Data cont'd.

	Repetition #4	Repetition #5
Measured Values		
Electric Energy Consumption (Wh)	150.06	148.37
Gas Energy (Btu)	98,565	98,118
Test Time (min)	**30.0**	**30.0**
Average Temperature Rise (°F)	75.1	75.2
Water Consumption (gal)	141.95	142.32
Flow Rate (gal/min)	4.73	4.74
Flow Rate (gal/h)	283.9	284.6
Inlet		
Average Inlet Temperature (°F)	108.3	108.5
Minimum Inlet Temperature (°F)	108.0	108.2
Maximum Inlet Temperature (°F)	109.1	108.7
Outlet		
Average Outlet Temperature (°F)	183.5	183.7
Minimum Outlet Temperature (°F)	183.1	183.3
Maximum Outlet Temperature (°F)	183.9	184.0
Flue		
Average Flue Temp (°F)	179.7	179.5
Minimum Flue Temp (°F)	179.2	178.9
Maximum Flue Temp (°F)	180.2	179.9
Energy Efficiency (%)	**87.0**	**87.8**
Thermal Efficiency (%)	**87.5**	**88.2**
Gas Energy Rate (Btu/h)	**197,131**	**196,236**
Electric Energy Rate (W)	**300.1**	**296.7**

Energy Efficiency Data

Table D-5. 50% Capacity at 140°F Inlet Test Data.

	Repetition #1	Repetition #2	Repetition #3
Measured Values			
Electric Energy Consumption (Wh)	136.0	134.5	135.3
Gas Energy (Btu)	54,498	54,406	54,327
Test Time (min)	**30.0**	**30.0**	**30.0**
Average Temperature Rise (°F)	47.9	47.5	48.3
Water Consumption (gal)	121.59	122.07	120.50
Flow Rate (gal/min)	4.05	4.07	4.02
Flow Rate (gal/h)	243.2	244.1	241.0
Inlet			
Average Inlet Temperature (°F)	138.0	137.9	138.1
Minimum Inlet Temperature (°F)	137.5	137.1	137.8
Maximum Inlet Temperature (°F)	138.9	138.8	138.4
Outlet			
Average Outlet Temperature (°F)	185.9	185.3	186.4
Minimum Outlet Temperature (°F)	180.4	179.3	181.1
Maximum Outlet Temperature (°F)	188.5	188.6	189.5
Flue			
Average Flue Temp (°F)	186.7	187.6	188.5
Minimum Flue Temp (°F)	182.4	183.4	184.5
Maximum Flue Temp (°F)	190.3	191.5	192.0
Energy Efficiency (%)	**85.6**	**85.4**	**85.9**
Thermal Efficiency (%)	**86.3**	**86.1**	**86.6**
Gas Energy Rate (Btu/h)	**108,995**	**108,812**	**108,655**
Electric Energy Rate (W)	**272.1**	**268.9**	**270.6**

Energy Efficiency Data

Table D-6. 50% Flow at 140°F Inlet Test Data cont'd.

	Repetition #4	Repetition #5	Repetition #6
Measured Values			
Electric Energy Consumption (Wh)	135.09	134.66	135.57
Gas Energy (Btu)	54,169	54,293	54,331
Test Time (min)	**30.0**	**30.0**	**30.0**
Average Temperature Rise (°F)	48.5	48.0	47.2
Water Consumption (gal)	120.00	120.66	125.93
Flow Rate (gal/min)	4.00	4.02	4.20
Flow Rate (gal/h)	240.0	241.3	251.9
Inlet			
Average Inlet Temperature (°F)	137.9	138.7	138.3
Minimum Inlet Temperature (°F)	137.6	138.3	137.7
Maximum Inlet Temperature (°F)	138.5	140.2	139.6
Outlet			
Average Outlet Temperature (°F)	186.4	186.8	185.5
Minimum Outlet Temperature (°F)	181.1	181.4	179.9
Maximum Outlet Temperature (°F)	188.9	189.6	188.4
Flue			
Average Flue Temp (°F)	187.3	186.4	188.1
Minimum Flue Temp (°F)	182.7	179.8	183.9
Maximum Flue Temp (°F)	191.3	190.1	192.0
Energy Efficiency (%)	**86.0**	**85.5**	**87.6**
Thermal Efficiency (%)	**86.8**	**86.3**	**88.3**
Gas Energy Rate (Btu/h)	**108,337**	**108,586**	**108,662**
Electric Energy Rate (W)	**270.2**	**269.3**	**271.1**

Energy Efficiency Data

Table D-7. 50% Flow at 110°F Inlet Test Data.

	Repetition #1	Repetition #2	Repetition #3	Repetition #4
Measured Values				
Electric Energy Consumption (Wh)	131.64	131.43	132.65	133.75
Gas Energy (Btu)	52,869	52,869	52,851	52,932
Test Time (min)	**30.0**	**30.0**	**30.0**	**30.0**
Average Temperature Rise (°F)	78.7	79.1	79.3	78.5
Water Consumption (gal)	142.1	141.9	141.2	142.5
Flow Rate (gal/min)	2.37	2.36	2.35	2.38
Flow Rate (gal/h)	142.1	141.9	141.2	142.5
Inlet				
Average Inlet Temperature (°F)	108.5	108.7	108.5	108.1
Minimum Inlet Temperature (°F)	108.1	108.2	108.1	107.7
Maximum Inlet Temperature (°F)	108.9	109.2	109.4	109.3
Outlet				
Average Outlet Temperature (°F)	187.1	187.8	187.8	186.6
Minimum Outlet Temperature (°F)	181.1	182.1	181.9	181.2
Maximum Outlet Temperature (°F)	190.0	190.6	190.9	189.4
Flue				
Average Flue Temp (°F)	188.9	189.8	189.3	188.7
Minimum Flue Temp (°F)	184.1	184.8	184.2	183.5
Maximum Flue Temp (°F)	193.0	193.9	194.9	192.6
Energy Efficiency (%)	**84.6**	**85.0**	**84.8**	**84.6**
Thermal Efficiency (%)	**85.4**	**85.7**	**85.5**	**85.4**
Gas Energy Rate (Btu/h)	**105,738**	**105,738**	**105,702**	**105,864**
Electric Energy Rate (W)	**263.3**	**262.9**	**265.3**	**267.5**

Energy Efficiency Data

Table D-8. Energy Efficiency.

	Energy Efficiency (%)			
	Max Capacity @ 140°F	Max Capacity @ 110°F	50 % Capacity @ 140°F	50 % Capacity @ 110°F
Replicate #1	86.9	87.2	85.6	84.6
Replicate #2	87.2	86.6	85.4	85.0
Replicate #3	89.4	86.7	85.9	84.8
Replicate #4	88.9	87.0	86.0	84.6
Replicate #5	---	87.8	85.5	---
Replicate #6	---	---	87.6	---
Average	**88.1**	**87.0**	**86.0**	**84.8**
Standard Deviation	1.3	0.5	0.8	0.2
Absolute Uncertainty	2.0	0.6	0.9	0.3
Percent Uncertainty	2.3	0.7	1.0	0.3

Table D-9. Flow Rates.

	Flow Rates (gal/h)			
	Max Capacity @ 140°F	Max Capacity @ 110°F	50 % Capacity @ 140°F	50 % Capacity @ 110°F
Replicate #1	481.0	282.3	243.2	142.1
Replicate #2	487.6	296.6	244.1	141.9
Replicate #3	499.9	296.8	241.0	141.2
Replicate #4	497.6	283.9	240.0	142.5
Replicate #5	---	284.6	241.3	---
Replicate #6	---	---	251.9	---
Average	**491.5**	**288.8**	**243.6**	**141.9**
Standard Deviation	8.8	7.2	4.3	0.5
Absolute Uncertainty	14.0	8.9	4.5	0.9
Percent Uncertainty	2.8	3.1	1.9	0.6