



# Standard Test Method for Performance of Booster Heaters<sup>1</sup>

This standard is issued under the fixed designation F 2022; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method evaluates the energy efficiency, energy consumption and water heating performance of booster heaters. The food service operator can use this evaluation to select a booster heater and understand its energy consumption.

1.2 This test method is applicable to electric, gas, and steam powered booster heaters.

1.3 The booster heater can be evaluated with respect to the following (where applicable):

1.3.1 Energy input rate (9.2).

1.3.2 Pilot energy rate (9.3).

1.3.3 Flow capacity rate, energy rate, and energy efficiency with 110°F (43.3°C) and 140°F (60.0°C) supply to the booster heater inlet (9.4).

1.3.4 Thermostat calibration (9.5).

1.3.5 Energy rate and energy efficiency at 50% of flow capacity rate with 110°F (43.3°C) and 140°F (60.0°C) supply to the booster heater inlet (9.6).

1.3.6 Preheat energy and time (9.7). The preheat test is not applicable to booster heaters built without water storage and will not have auxiliary water storage connected to the booster heater to complete the water heating system.

1.3.7 Idle (standby) energy rate (9.8).

1.4 The values stated in inch-pound units are to be regarded as standard. The SI units in parentheses are for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards*:<sup>2</sup>

D 3588 Practice for Calculating Heating Value, Compressibility Factor, and Relative Density of Gaseous Fuels

2.2 *ANSI Standard*:<sup>3</sup>

ANSI Z223.1-1996 National Fuel Gas Code

2.3 *ASHRAE Handbook*:<sup>4</sup>

ASHRAE 1993 Fundamentals Handbook

2.4 *ASHRAE Guideline*:<sup>4</sup>

ASHRAE Guideline 2-1986 (RA90) Engineering Analysis of Experimental Data

2.5 *NSF Standards*:<sup>5</sup>

NSF Listing—Food Equipment and Related Components and Material

ANSI/NSF 3-1996 Commercial Spray-Type Dishwashing Machines and Glasswashing Machines

ANSI/NSF 5-1992 Water Heaters, Hot Water Supply Boilers, and Heat Recovery Equipment

ANSI/NSF 26-1980 Pot, Pan, and Utensil Washers

## 3. Terminology

3.1 *Definitions*:

3.1.1 *booster heater, n*—a water heater that raises the booster heater inlet water supply temperature (typically 110°F to 140°F (43.3°C to 60°C)) to 180°F (82.2°C) or more to provide high temperature sanitizing rinse water for a dishwasher machine.

3.1.2 *dishwasher machine, n*—(hereafter referred to as dishwasher) machine that uniformly washes, rinses, and heat sanitizes eating and drinking utensils. The machine shall be capable of removing physical soil from properly racked and pre-scraped items, and sanitizing multi-use eating and drinking utensils.

3.1.3 *uncertainty, n*—measure of systematic and precision errors in specified instrumentation or measure of repeatability of a reported test result.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *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.

3.2.2 *booster heater energy efficiency*—quantity of energy imparted to the water while heating, expressed as a percentage of total amount of energy consumed by the booster heater during the capacity tests.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee F26 on Food Service Equipment and is the direct responsibility of Subcommittee D26.06 on Productivity and Energy Protocol.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 05.06.

<sup>3</sup> Available from the American National Standard Institute (ANSI), 11 West 42<sup>nd</sup> Street, New York, New York 10036.

<sup>4</sup> Available from the American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc. 1791 Tullie Circle, NE, Atlanta, GA 30329.

<sup>5</sup> Available from NSF International, P.O. Box 130140, Ann Arbor, MI 48113-0140.

3.2.3 *booster heater inlet*—the point of connection on the booster heater for the water line from the primary supply to the booster heater.

3.2.4 *booster heater outlet*—the point of connection on the booster heater for the water line from the booster heater to the dishwasher.

3.2.5 *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 conveyor (flight) type dishwasher machine.

3.2.6 *energy rate*—average rate of energy consumption (Btu/h or kW, (kJ/h)) during the continuous flow tests.

3.2.7 *energy input rate*—peak rate at which a booster heater consumes energy (Btu/h or kW, (kJ/h)).

3.2.8 *flow capacity energy rate*—peak rate at which a booster heater consumes energy (Btu/h or kW, (kJ/h)) during the flow capacity tests. Refers to maximum energy rate while maximum flow capacity rate is supplied.

3.2.9 *flow capacity*—maximum water flow rate (gal/min, gal/h, (L/h)) at which the booster heater can heat water from a specified inlet temperature to an outlet temperature of  $183 \pm 3^\circ\text{F}$  ( $83.9 \pm 1.7^\circ$ ) during the continuous flow capacity test.

3.2.10 *pilot energy rate*—average rate of energy consumption (Btu/h) by a booster heater's continuous pilot (if applicable).

3.2.11 *primary supply*—the service water heater system that supplies water to the booster heater under test.

3.2.12 *thermal efficiency, n*—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 steam injector(s) during the flow capacity tests. Thermal efficiency data is collected during the continuous flow capacity tests.

## 4. Summary of Test Method

NOTE 1—An energy supply meeting the manufacturer's specification shall be provided for the gas, electric, or steam booster heater under test.

4.1 The booster heater under test is connected to the appropriate metered energy supply. The measured energy input rate is determined and checked against the rated input before continuing with testing.

4.2 Pilot energy rate is determined, when applicable, for gas booster heaters.

4.3 Flow capacity, energy rate and energy efficiency of the booster for continuous water flow is determined with the booster heater inlet water supplied at  $110 \pm 0.3^\circ\text{F}$  ( $43.3 \pm 0.17^\circ\text{C}$ ) and  $140 \pm 0.3^\circ\text{F}$  ( $60.0 \pm 0.17^\circ\text{C}$ ).

4.4 Flow rate, energy rate and energy efficiency of the booster for continuous water flow at 50% of flow capacity is determined with the booster heater inlet water supplied at  $110 \pm 0.3^\circ\text{F}$  ( $43.3 \pm 0.17^\circ\text{C}$ ) and  $140 \pm 0.3^\circ\text{F}$  ( $60.0 \pm 0.17^\circ\text{C}$ ).

4.5 The preheat energy consumption and time and idle/standby energy consumption rate are determined while the booster heater is operating with the thermostat(s) set at the calibrated setting(s) to deliver  $183 \pm 3^\circ\text{F}$  at the booster heater outlet. The booster heater is supplied with  $110 \pm 0.3^\circ\text{F}$  ( $43.3 \pm 0.17^\circ\text{C}$ ) and  $140 \pm 0.3^\circ\text{F}$  ( $60.0 \pm 0.17^\circ\text{C}$ ) water at the booster inlet.

## 5. Significance and Use

5.1 The energy input rate test is used to confirm that the booster heater is operating properly prior to further testing.

5.2 Booster heater flow capacity is an indicator of the booster heater's ability to supply hot water for sanitation. The booster heater's flow capacity can be used by the operator to determine the appropriate size booster heater for their operation. Booster heater energy rate is an indicator of the booster heater's energy consumption during continuous water flow. The energy rate can be used by food service operators to estimate the energy consumption of the booster heater. Booster heater energy efficiency is a precise indicator of a booster heater's energy performance during the continuous flow test. This information enables the food service operator to consider energy performance when selecting a booster heater.

5.3 Booster heater flow capacity at 50 % of the maximum capacity is an indicator of the booster heater's ability to provide hot water for sanitation at this reduce flow rate condition. Booster heater energy efficiency at a flow rate of 50 % of maximum capacity is an indicator of a booster heater's energy performance at this flow rate. The booster heater outlet temperature during the capacity test at a flow rate of 50 % of maximum capacity is an indicator of the booster heater's temperature response at this reduced flow rate.

5.4 Preheat energy and time can be useful to food service operators to manage power demands and to know how quickly the booster heater can be ready for operation.

5.5 Idle energy rate and pilot energy rate can be used to estimate energy consumption during standby periods.

## 6. Apparatus

6.1 *Barometer*, for measuring absolute atmospheric pressure, to be used for adjustment of measured natural gas volume to standard conditions. Shall have a resolution of 0.2 in. Hg and an uncertainty of 0.2 in. Hg.

6.2 *Exhaust Hood*, (if applicable) some gas booster heaters may require an exhaust hood for exhausting gas combustion products. Follow manufacturer's venting specifications.

6.3 *Flowmeter*, for measuring total water consumption of the booster heater. Shall have a resolution of 0.01 gal (40 mL) and an uncertainty of 0.01 gal (40 mL) at a flow rate as low as 0.2 gpm (13 mL/s). Shall be designed to operate with water temperatures between  $50^\circ\text{F}$  to  $195^\circ\text{F}$ . The flowmeter shall be calibrated at both  $110^\circ\text{F}$  and  $140^\circ\text{F}$  booster heater inlet temperatures and their corresponding test flow rates and booster heater outlet temperatures.

6.4 *Gas Meter*, for measuring the gas consumption of the booster heater (if applicable). Shall have a resolution of at least  $0.01 \text{ ft}^3$  ( $0.0003 \text{ m}^3$ ) and a maximum uncertainty no greater than 1 % of the measured value for any demand greater than  $2.2 \text{ ft}^3/\text{h}$  ( $0.06 \text{ m}^3/\text{h}$ ). If the meter is used for measuring the gas consumed by pilot lights, it shall have a resolution of at least  $0.01 \text{ ft}^3$  ( $0.0003 \text{ m}^3$ ) and have a maximum uncertainty no greater than 2 % of the measured value.

6.5 *Insulation*, for insulating all exterior fittings and plumbing. The insulation shall have a thermal insulation value (R value) of at least  $4 (\text{h} \times \text{ft}^2 \times ^\circ\text{F})/\text{Btu}$  ( $5.67 (\text{m}^2 \times ^\circ\text{C})/\text{W}$ ).

6.6 *Pressure Gage*, for monitoring natural gas pressure. Shall have a range of 0 to 10 in. H<sub>2</sub>O, a resolution of 0.5 in. H<sub>2</sub>O, and a maximum uncertainty of 1 % of the measured value.

6.7 *Pressure Gage*, for monitoring water pressure supplied to and from the booster heater. The pressure gage on the downstream side of the booster heater shall have a range of 15 to 25 psi, a resolution of  $\pm 1$  psi, and a maximum uncertainty of 1 % of the measured value. The pressure gage on the upstream side of the booster heater shall have a range of 0 to 200 psi, a resolution of  $\pm 5$  psi, and a maximum uncertainty of 1 % of the measured value.

6.8 *Stopwatch*, with a 1-s resolution.

6.9 *Temperature Sensor*, for measuring natural gas temperature in the range of 50°F to 100°F (10°C to 37.8°C), with a resolution of 0.5°F (0.3°C) and an uncertainty of  $\pm 1$ °F (0.6°C).

6.10 *Thermocouple Probe*, industry standard Type T or Type K thermocouples capable of immersion with a range of 50°F to 200°F (10°C to 93.3°C) and an uncertainty of  $\pm 1$ °F.

6.11 *Watt-Hour Meter*, for measuring the electrical energy consumption of a booster heater. Shall have a resolution of at least 10 Wh and a maximum uncertainty no greater than 1.5 % of the measured value for any demand greater than 100 W. For any demand less than 100 W, the meter shall have a resolution of at least 10 Wh and a maximum uncertainty no greater than 10 %.

6.12 *Water Pressure Regulator*, for controlling the water line pressure to and from the booster heater. Two regulators are required. Adjustable within a range of 10 to 30 psi for the regulator downstream of the booster heater. Adjustable within a range of 10 to 200 psi for the regulator upstream of the booster heater.

6.13 *Solenoid Valve*, for regulating water flow from the booster heater. Sized to booster heater manufacturer's pipe diameter specifications.

6.14 *Tempering Valve or Equivalent Temperature Control Device*, for regulating the temperature of the water being supplied to the booster heater inlet. Tempering valve shall be capable of operating within the delivered water temperature range from 100°F (37.8°C) to 150°F (65.6°C) and capable of maintaining  $\pm 1.5$ °F ( $\pm 0.8$ °C) of any specific delivery temperature set point within this range.

6.15 *Steam Flowmeters*, for measuring the flow of steam to the booster heater (if applicable). Shall have a resolution of 0.01 ft<sup>3</sup> (0.0003 m<sup>3</sup>) and a maximum uncertainty of 1 % of the measured value.

6.16 *Calibrated Exposed Junction Thermocouple Probes*, industry standard Type T or Type K thermocouple with a range from 50°F to 200°F (10 to 93.3°C), a resolution of 0.2°F (0.1°C), and an uncertainty of 1.0°F (0.5°C), for measuring temperature at the booster heater inlet and outlet connections. Calibrated Type K or Type T 24 GA thermocouple wire with stainless steel sheath and ceramic insulation is the recommended choice for measuring the booster heater inlet and outlet temperatures. The thermocouple probe shall be fed through a compression fitting so as to submerge the exposed junction in booster heater water inlet and outlet.

6.17 *Temperature and Pressure Relief Valve(s)*, sized to handle the maximum energy input of the booster heater with automatic reset and capable of releasing at temperatures and pressures above the booster heater maximum working conditions. The relief valve can be integral with both temperature and pressure relief capacity or separate valves for temperature and pressure control.

6.18 *Hammer Arrestor (Shock Absorber)*, to eliminate water hammer caused by the quick closing of the solenoid valve.

6.19 *Throttling Valve*, to adjust the water flow rate (gal/min and gal/h) from the booster heater. Maximum water flow through throttling valve shall be large enough to accommodate the largest water flow requirements of the booster heater. Throttling valve shall be gate type or equivalent industry standard. Valve shall be sized to booster heater manufacturer's pipe diameter specifications.

6.20 *Primary Supply*, water heating system capable of supplying water at each of the following temperature ranges of 110 <sup>+0/-3</sup>°F (43.3 <sup>+0/-1.7</sup> °C) or 140 <sup>+0/-3</sup> °F (60.0 <sup>+0/-1.7</sup> °C) for all water flow rates required by the booster heater.

6.21 *One Way Check Valve*, water valve that allows water flow in one direction only. Valves to be installed in water lines where flow should be directional.

6.22 *Platform Balance Scale*, or appropriate load cells, used to measure the collected booster heater outlet discharge during capacity tests. Shall have the capacity to accommodate the total weight of the water discharged during the test with resolution of 0.2 lb (10 g) and an uncertainty of 0.2 lb (10 g) .

## 7. Sampling, Test Units

7.1 *Booster Heater*— Select a representative model for performance testing.

## 8. Preparation of Apparatus

8.1 Install the booster heater in accordance with the manufacturer's instructions in a well ventilated area in compliance with local codes or, in the absence of local codes, the National Fuel Gas Code, ANSI Z 223.1. A booster heater designed for floor placement shall be installed on a noncombustible floor. In the case of a combustible floor, a suitable noncombustible material shall be placed between the booster heater and the floor. A booster heater designed for nonfloor placement shall be installed on a wall in accordance with the manufacturer's directions. Booster heaters not designed to be mounted to a combustible wall material shall have a suitable noncombustible material placed between the booster heater and the wall. Position the booster heater with at least 6 in. of space around the outside edges of the booster heater or to the manufacturer's specification if more space is required around the booster heater. For a gas-fired booster heater, install venting in accordance with manufacturer's specifications. If the manufacturer's specification does not specify venting requirements, then install vent ducting to comply with ANSI Z 223.1. The associated heating or cooling system shall be capable of maintaining an ambient temperature of 75  $\pm$  5°F (23.9  $\pm$  2.8°C) within the testing environment when the exhaust ventilation system and/or the booster heater are operating.



8.2 Connect the booster heater to a calibrated energy test meter. For gas installations, install a pressure regulator downstream from the meter to maintain a constant pressure of gas for all tests. Install instrumentation to record both the pressure and temperature of the gas supplied to the booster heater and the barometric pressure during each test so that the measured gas flow can be corrected to standard conditions. For electric installations, a voltage regulator may be required if the voltage supply is not within  $\pm 2.5\%$  of the manufacturer's nameplate voltage. For gas booster heaters, record gas temperature, pressure and heating value. Record barometric pressure.

NOTE 2—The booster heater heating element(s) or burner(s) energy consumption may be submonitored to separate their energy consumption from other components of the booster heater. Submonitored energy consumption of the element(s) or burner(s), the water flow rate and booster inlet and outlet temperatures can be used to calculate the thermal efficiency of booster heat exchanger. See 10.8.4 for equations to calculate the booster heater (heat exchanger) thermal efficiency.

8.3 Plumbing piping and fittings shall be constructed of the brass, copper or stainless steel using the booster heater manufacturer's recommended pipe sizes.

8.4 For an electric booster heater, confirm (while the booster heater elements are energized) that the supply voltage is within  $\pm 2.5\%$  of the operating voltage specified by the manufacturer. Record the voltage for each test.

NOTE 3—If an electric booster heater is rated for dual voltage (for example, 208/240 V), the booster heater shall be evaluated as two separate booster heaters in accordance with this standard test method.

8.5 For a gas booster heater, adjust (during maximum energy input) the gas supply pressure downstream from the booster heater's pressure regulator to within  $\pm 2.5\%$  of the operating manifold pressure specified by the manufacturer. Make adjustments to the booster heater following the manufacturer's recommendations for optimizing combustion.

8.6 Set the controls of the primary supply system to maintain the two temperature ranges of  $110^{+0}_{-3}$  °F ( $43.3^{+0}_{-1.7}$  °C) and  $140^{+0}_{-3}$  °F ( $60.0^{+0}_{-1.7}$  °C) at the booster heater inlet.

NOTE 4—The primary supply system water temperature requirements may require additional components attached to primary system. These components may include storage tanks, recirculating pumps, temperature

sensors, and tempering valves. The booster heater shall be tested under both booster heater inlet temperature conditions. The primary supply system may need energy inputs 2 to 3 times the booster heater input depending on incoming water temperatures to the primary supply, heating efficiency of primary supply and the output of the booster heater under test.

8.7 Install a water line pressure regulator upstream of the booster heater. Install a water pressure gage between the pressure regulator and booster heater. Adjust the regulator so that the water line pressure to the booster heater is maintained between 20 psi and the booster heater manufacturer's specified maximum pressure, when no water is flowing.

NOTE 5—A water flowmeter may come with factory calibration factors. Unless the flowmeter is calibrated at the factory with the same booster heater inlet and outlet temperatures and the same flow rate as the test conditions, the flowmeter will have to be recalibrated using the test condition booster heater inlet and outlet temperatures and flow rates. For the best flowmeter calibration accuracy, calibrate the flowmeter during each 30 min flow capacity test.

NOTE 6—For pipe elbows use large radius turns to reduce frictional losses in the piping system.

8.8 Install a tempering (mixing) valve or equivalent temperature control device, at least 10 pipe diameters upstream from the booster heater inlet.

8.9 Install the exposed junction thermocouple sensor in the center of the piping at the booster heater inlet and booster heater outlet. The thermocouple shall be installed no further than a maximum of 3 in. (8 cm) from the booster heater connection.

8.10 Install a flowmeter (optional) at least 10 pipe diameters upstream of booster heater. Position the flowmeter in accordance with the manufacturer's recommendations, away from pipe restrictions (pipe turns, temperature probes, tempering valves, pressure gages, and etc.) to ensure accurate readings (see Fig. 1). An alternative to using a flow meter is to collect the water discharge from the booster heater in a tank. Using a scale the weight of the water in the tank is measured directly.

8.11 Install a throttling valve (gate or ball) in the booster heater outlet pipe at least 20 pipe diameters away from the outlet connection of the booster heater. Position the throttling valve at least 10 pipe diameters away from other restrictions

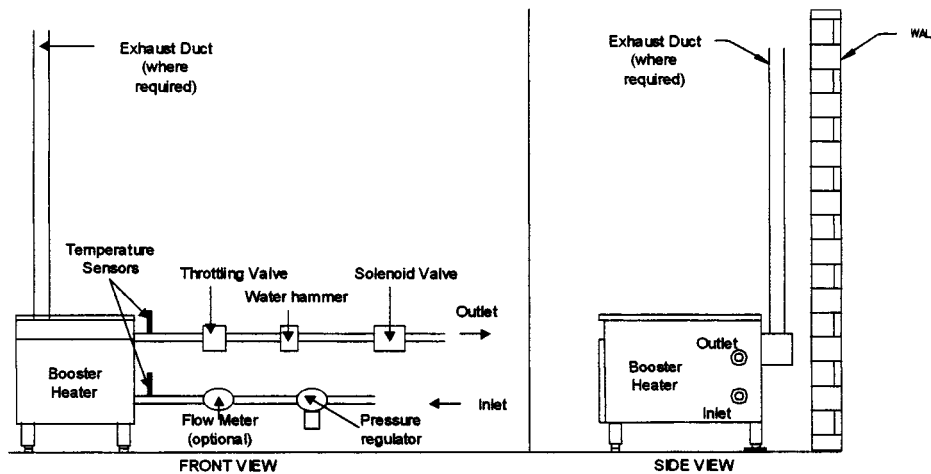


FIG. 1 Typical Equipment Configuration

(pipe turns, temperature probes, tempering valves, pressure gages, etc.) (see Fig. 1).

8.12 Insulate the inlet pipe from the booster heater to primary supply. Insulate the outlet piping from the booster heater for minimum length of 4 ft. The insulation material shall have thermal resistance (R) value of not less than  $4^{\circ}\text{F} \times \text{ft}^2 \times \text{hr}/\text{Btu}$  ( $0.7^{\circ}\text{K} \times \text{m}^2/\text{W}$ ).

8.13 Install a solenoid valve in the booster heater outlet pipe at least 20 pipe diameters away from the outlet connection of the booster heater. Position the solenoid valve 10 pipe diameters away from pipe restrictions (pipe turns, temperature probes, throttling valves, pressure gages, etc.) to reduce turbulent water flow. Install a water hammer right next to the solenoid valve on the upstream side of the solenoid valve (see Fig. 1).

8.14 Install a temperature sensor to record ambient temperatures of the test room. Measure the height of the booster heater. The sensor shall be placed 24 in. (610 mm) away from the front of the booster heater and at a height of half the booster heater's height (see Fig. 2).

**9. Procedure**

*9.1 General:*

9.1.1 The suite of tests (9.4-9.8) shall be conducted with the booster heater inlet supply water temperature at both  $110 \pm 0.3^{\circ}\text{F}$  ( $43.3 \pm 0.17^{\circ}\text{C}$ ) and  $140 \pm 0.3^{\circ}\text{F}$  ( $60.0 \pm 0.17^{\circ}\text{C}$ ) except for the input rate (9.2) and pilot (9.3) tests. Test results shall be reported separately for the two booster heater inlet water supply temperatures. Obtain and record the following for each run of every test (gas, electric, and steam units).

NOTE 7—Booster heaters can be found in both institutional and commercial food service operations. This test method uses two separate booster heater inlet water temperature ranges of  $110 \pm 0.3^{\circ}\text{F}$  ( $43.3 \pm 0.17^{\circ}\text{C}$ ) and  $140 \pm 0.3^{\circ}\text{F}$  ( $60.0 \pm 0.17^{\circ}\text{C}$ ) for testing conditions. The two temperature ranges are used to represent these two typical real-world operational conditions for booster heaters.

9.1.1.1 Record booster heater inlet and outlet water temperatures at 10 s intervals.

9.1.1.2 Ambient temperature of test room near appliance as described in 8.14.

9.1.2 For gas booster heaters, record the following for each test run:

- 1) Higher heating value,

- 2) Standard gas pressure and temperature used to correct measured gas volume to standard conditions,
- 3) Measured gas temperature,
- 4) Measured gas pressure,
- 5) Barometric pressure, and
- 6) Energy input rate during or immediately prior to test.

NOTE 8—For a gas appliance, the quantity of heat (energy) generated by the complete combustion of the fuel is known as the heating value, heat of combustion, or calorific value of that fuel. For natural gas, this heating value varies according to the constituents of the gas. It is measured in  $\text{Btu}/\text{ft}^3$ . The heating value shall be obtained during testing and used in the determination of the energy input to the appliance.

Using a calorimeter or gas chromatograph in accordance with accepted laboratory procedures is the preferred method for determining the higher heating value of gas supplied to the booster heater under test. It is recommended that all testing be performed with gas having a higher heating value of 1000 to  $1075 \text{ Btu}/\text{ft}^3$ . The use of "bottle" natural gas with a certified heating value within the specified 1000 to  $1075 \text{ Btu}/\text{ft}^3$  ( $37\ 300$  to  $40\ 100 \text{ kJ}/\text{m}^3$ ) range is an acceptable alternative.

9.1.3 For gas booster heaters, record all electric energy consumption along with gas energy for all tests, with the exception of the energy input rate test (9.2).

9.1.4 For electric booster heaters, record the following for each run of each test run:

- 1) Voltage while elements are energized, and
- 2) Energy input rate during or immediately prior to test run.

9.1.5 For booster heaters that use steam coils or steam injectors for heating the water, the supplied steam pressure, steam temperature at booster heater inlet, steam temperature at booster heater outlet, and average flow rate shall be recorded for each run of every test.

9.1.6 For each run of every test, confirm that the peak input rate is within  $\pm 5\%$  of rated "nameplate" input. If the difference is greater than  $5\%$ , testing shall be terminated and the manufacturer contacted. The manufacturer may make appropriate changes or adjustments to the booster heater. It is the intent of the procedures herein to evaluate the performance of the booster heater at its rated input.

*9.2 Energy Input Rate:*

9.2.1 For gas booster heaters, set the controls to achieve maximum energy input. Open the solenoid valve downstream of the booster heater and adjust the water flow rate to initiate

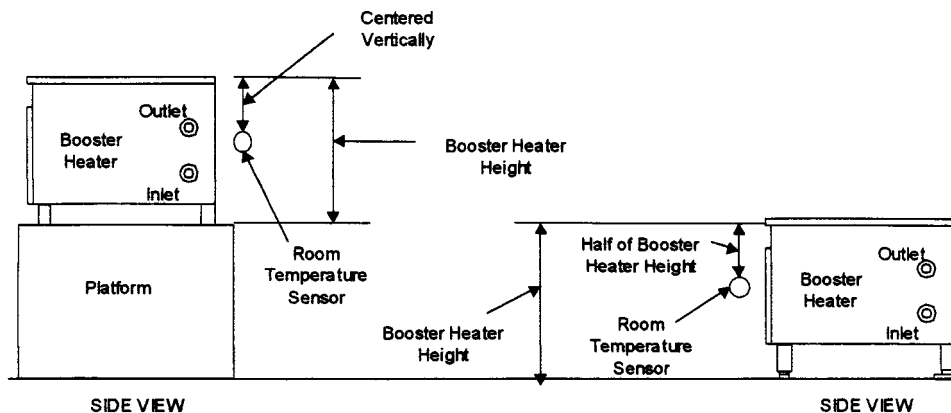


FIG. 2 Placement of Thermocouple to Measure Room Ambient Temperature

and maintain booster heater burner(s). Allow the booster heater to operate (with burners at maximum input) for a period of 15 min. After the 15-min stabilization, commence monitoring the energy consumption for an additional 15 min.

NOTE 9—For some gas appliances, the input rate changes as the manifold and burner orifices heat up from room temperature to operational temperature. 9.2.1 is provided to achieve a stable condition.

9.2.2 For electric booster heaters, set the controls to achieve maximum energy input. Open the downstream solenoid valve and adjust water flow to initiate booster heater element(s) and maintain at maximum input. Commence monitoring energy consumption for 15 min.

9.2.3 Calculate and report energy input rate in accordance with 10.4.

### 9.3 Pilot Energy Rate (Gas Models with Standing Pilots):

9.3.1 Where applicable, set the gas valve that controls gas supply to the appliance at the “pilot” position. Otherwise, set the booster heater temperature controls to the “off” position.

9.3.2 Light and adjust pilots in accordance with the manufacturer’s instructions.

9.3.3 Record the gas reading and time before and after a minimum of 8 h of pilot operation.

### 9.4 Flow Capacity and Efficiency Test with 110°F (43.3°C) and 140°F (60.0°C) Supply Temperature Water:

9.4.1 Supply the booster heater inlet with 110  $\pm$  3 °F (43.3  $\pm$  1.7 °C) temperature water. The water pressure to the booster heater shall be maintained in accordance with 8.7 during testing.

9.4.2 Close the throttling valve on the outlet side of the booster heater, and open the solenoid valve.

9.4.3 Slowly open the throttling valve to allow water to discharge from the booster heater. Set booster heater controls for continuous operation of burner(s) or element(s). Adjust the water flow rate from the booster heater until outlet temperature is 183  $\pm$  3°F (83.9  $\pm$  1.7°C).

9.4.4 Allow the outlet temperature to stabilize at 183  $\pm$  3°F (83.9  $\pm$  1.7°C) for 5 min.

NOTE 10—The intent of both the flow capacity and 50 % flow capacity test is to test the booster heater with an outlet temperature as close to 180°F (82.1°C) as possible without dropping the temperature below 180°F (82.1°C). The tester should adjust the flow rate so that the outlet temperature is stabilized close to 180°F (82.1°C), thus maximizing the water flow rate and reporting the highest flow capacity.

9.4.5 Start monitoring water flow, energy consumption, time, outlet and inlet temperatures for 30 min recording data every 10 s. Include energy consumption of all factory supplied booster heater components, including recirculating pumps and operating controls.

9.4.6 Repeat 9.4.1-9.4.5 using 140  $\pm$  3 °F (60.0  $\pm$  1.7 °C) supply temperature water at the booster heater inlet.

9.4.7 Repeat the flow capacity tests at least 2 more times (9.4.1-9.4.7).

9.4.8 Report booster heater energy efficiency, energy rate and flow capacity for each supply temperature separately as an average of at least three tests (see Appendix X1).

### 9.5 Thermostat Calibration:

9.5.1 Supply the booster heater inlet with 110  $\pm$  3 °F (43.3  $\pm$  1.7 °C) temperature water for the thermostat calibration test.

9.5.2 Open the water valve solenoid downstream of the booster heater and adjust the throttling valve so water flow is 50 % of recorded maximum capacity flow rate.

9.5.3 For a booster heater with adjustable thermostats, adjust the thermostat to provide 183  $\pm$  3°F (83.9  $\pm$  1.7°C) water at the booster heater outlet when 110  $\pm$  3 °F (43.3  $\pm$  1.7 °C) water is provided at the booster heater inlet. Follow the manufacturer’s instructions for the adjustment of the thermostat.

9.5.4 If the booster heater maintains 183  $\pm$  3°F (83.9  $\pm$  1.7°C) at the booster heater outlet, note that the thermostat adjustment position and initial calibration is complete.

9.5.5 If the booster heater after adjustment does not provide 183  $\pm$  3°F (83.9  $\pm$  1.7°C) water at the booster heater outlet, testing shall be terminated and the manufacturer shall be contacted. The manufacturer shall make appropriate changes or adjustments to the booster heater.

9.5.6 If the booster heater thermostat is not adjustable, then the booster heater may be tested as supplied providing the booster heater outlet temperature maintains between a minimum of 180°F (82.2°C) and maximum of 195°F (90.6°C).

9.5.7 If the booster heater with nonadjustable thermostat does not provide water with a minimum temperature of 180°F (82.2°C) and maximum of 195°F (90.6°C) at the booster heater outlet then the manufacturer shall be contacted. The manufacturer shall make appropriate changes or adjustments to the booster heater.

9.5.8 After using 110  $\pm$  3 °F (43.3  $\pm$  1.7 °C) supply temperature water for the booster heater inlet during the thermostat calibration test, the booster heater outlet temperature may not need to be recalibrated for the other booster heater inlet temperature range. Before performing any test with the second inlet temperature range, confirm that the booster heater is still maintaining the 183  $\pm$  3°F (83.9  $\pm$  1.7°C) at the booster heater outlet. If the outlet temperature is not 183  $\pm$  3°F (83.9  $\pm$  1.7°C) then recalibrate with new inlet temperature range.

### 9.6 Continuous Flow Capacity Test at 50 % of Maximum Continuous Flow:

9.6.1 Supply the booster heater with 110  $\pm$  3 °F (43.3  $\pm$  1.7 °C) temperature water. The water pressure to booster heater shall be maintained between 20  $\pm$  5 psi (137.9  $\pm$  34.5 kPa) and the manufacturer’s maximum operational pressure at all times.

9.6.2 Close the throttling valve on the outlet side of the booster heater. Set the solenoid valve to the open position.

9.6.3 Slowly open the throttling valve to allow water to discharge from booster heater. Adjust the water flow rate discharge from booster heater to 50 % of the maximum flow capacity rate (to determine maximum flow capacity rate see 9.4).

9.6.4 Allow the outlet temperature to stabilize at the 183  $\pm$  3°F (83.9  $\pm$  1.7°C) for 5 min. If the outlet temperature stabilizes at 183  $\pm$  3°F (83.9  $\pm$  1.7°C) for 5 min, note thermostat position and proceed to 9.6.10.

9.6.5 If outlet temperature does not stabilize at 183  $\pm$  3°F (83.9  $\pm$  1.7°C) adjust thermostat controls to achieve an outlet temperature of 183  $\pm$  3°F (83.9  $\pm$  1.7°C) with 50 % of maximum flow capacity rate, note thermostat position. Let outlet temperature stabilize at 183  $\pm$  3°F (83.9  $\pm$  1.7°C) for 5

min. If the outlet temperature stabilizes at  $183 \pm 3^{\circ}\text{F}$  ( $83.9 \pm 1.7^{\circ}\text{C}$ ) for 5 min, then note thermostat position and proceed to 9.6.10.

9.6.6 If the outlet temperature does not stabilize at  $183 \pm 3^{\circ}\text{F}$  ( $83.9 \pm 1.7^{\circ}\text{C}$ ), stop testing and contact booster heater manufacturer. The booster heater manufacturer may make changes or adjustments. If the booster is still unable to maintain  $183 \pm 3^{\circ}\text{F}$  ( $83.9 \pm 1.7^{\circ}\text{C}$ ) range after adjustment then the tester may test the booster by the requirements that pertain to nonadjustable thermostat boosters.

9.6.7 Booster heaters with nonadjustable thermostats shall maintain outlet water temperature between a minimum of  $180^{\circ}\text{F}$  ( $82.2^{\circ}\text{C}$ ) and a maximum of  $195^{\circ}\text{F}$  ( $90.6^{\circ}\text{C}$ ) at all times during the test.

9.6.8 For booster heaters with nonadjustable thermostats, allow the outlet water temperature to stabilize between a minimum of  $180^{\circ}\text{F}$  ( $82.2^{\circ}\text{C}$ ) and maximum of  $195^{\circ}\text{F}$  ( $90.6^{\circ}\text{C}$ ) for 5 min then proceed to 9.6.10.

9.6.9 If the nonadjustable thermostat booster heater does not maintain an outlet temperature between  $180^{\circ}\text{F}$  ( $82.2^{\circ}\text{C}$ ) and  $195^{\circ}\text{F}$  ( $90.6^{\circ}\text{C}$ ) after the 5 min stabilization, then stop the test and contact the manufacturer. The manufacturer shall make changes or adjustments to the booster heater.

9.6.10 Observe the electric heating element(s) or gas burner(s) as they cycle on and off. Start monitoring water flow, energy consumption, time, outlet and inlet temperatures when the elements or burners cycle on. Monitor water flow, energy consumption, time, outlet and inlet temperatures for a total of 30 min, recording data every 10 s. Include energy consumption of all factory supplied booster heater components including recirculating pumps and operating controls. Record barometric pressure during test.

9.6.11 At the end of the 30 min test close the throttling valve and solenoid valve.

9.6.12 Repeat 9.6.1-9.6.10 using  $140 \pm 3^{\circ}\text{F}$  ( $60.0 \pm 1.7^{\circ}\text{C}$ ) supply temperature water at the booster heater inlet.

9.6.13 Repeat the 50 % flow capacity tests at both inlet temperatures at least 2 more times (9.6.1-9.6.12).

9.6.14 Report booster heater energy efficiency, energy rate, and flow rate for each supply temperature separately as an average of at least three tests (see Appendix X1).

### 9.7 Preheat Energy and Time:

NOTE 11—The preheat test should be conducted prior to appliance operation on the day of test.

9.7.1 Open the solenoid valve and supply the booster heater inlet with  $110 \pm 3^{\circ}\text{F}$  ( $43.3 \pm 1.7^{\circ}\text{C}$ ) water. Monitor both the inlet and outlet water temperatures. When the inlet and outlet temperatures have stabilized to within  $1.0^{\circ}\text{F}$  ( $0.6^{\circ}\text{C}$ ) of each other over a 5 min period then close the solenoid valve.

NOTE 12—Section 9.7.1 is provided to stabilize the temperature of the booster heater before beginning the preheat test. Without stabilizing the booster heater the energy and time required to preheat the booster heater will vary as a function of the booster heater bulk temperature at the start of the test.

9.7.2 Set the booster heater thermostat controls to the settings determined in 9.6. Begin recording elapsed time and energy consumption as soon as the booster heater is turned on.

9.7.3 For gas booster heaters, the preheat time shall include any delay between the time the unit is turned on and the time the burner actually ignites. Preheat is judged complete when the burner(s) or element(s) cycle off, indicating that the water in the storage tank has reached the required idle/standby temperature. Record elapsed time and energy consumption at the end of preheat.

9.7.4 Report booster heater preheat energy consumption in accordance with 10.6.1.

9.7.5 Repeat 9.7.1-9.7.3, supplying  $140 \pm 3^{\circ}\text{F}$  ( $60.0 \pm 1.7^{\circ}\text{C}$ ) water at the booster heater inlet.

9.7.6 Report booster heater preheat energy consumption in accordance with 10.6.2.

### 9.8 Idle Energy Rate:

9.8.1 If the preheat test was conducted immediately before the start of the idle energy rate test then proceed to 9.8.2. Fill the storage tank with either  $110 \pm 3^{\circ}\text{F}$  ( $43.3 \pm 1.7^{\circ}\text{C}$ ) or  $140 \pm 3^{\circ}\text{F}$  ( $60.0 \pm 1.7^{\circ}\text{C}$ ) supply water. Set the booster heater's thermostat controls to the settings determined in 9.6. When the thermostat reduces energy consumption to minimum (indicating that the water in the storage tank has reached the required standby temperature) proceed to the next step.

9.8.2 Allow the booster heater to stabilize for 1 h. After the stabilization period, begin monitoring time and energy consumption. Allow the booster heater to idle for a minimum of 6 h. For gas booster heaters, monitor and record all gas and electric energy consumption during the idle test. Record elapsed time and energy consumption.

9.8.3 Calculate and report booster heater idle energy rate in accordance with 10.7.

## 10. Calculation and Report

### 10.1 Test Booster Heater:

10.1.1 Summarize the physical and operating characteristics of the booster heater. If needed, describe other design or operating characteristics that may facilitate interpretation of the test results.

### 10.2 Apparatus and Procedure:

10.2.1 Confirm that the testing apparatus conformed to all of the specifications in Section 6. Describe any deviations from those specifications.

10.2.2 For electric booster heaters, report the voltage for each test.

10.2.3 For gas booster heaters, report the higher heating value of the gas supplied to the booster heater during each test.

### 10.3 Gas Energy Calculations:

10.3.1 For gas booster heaters, report electric energy consumption for all tests, with the exception of the energy input rate test (9.2).

10.3.2 Calculate the energy consumed based on:

$$E_{gas} = V \times HV \quad (1)$$

where:

$E_{gas}$  = energy consumed by the booster heater,  
 $HV$  = higher heating value,  
 = energy content of gas measured at standard conditions, Btu/ft<sup>3</sup> (kJ/m<sup>3</sup>),



$V$  = actual volume of gas corrected for temperature and pressure at standard conditions,  $\text{ft}^3$  ( $\text{m}^3$ ),  
 $= V_{meas} \times T_{cf} \times P_{cf}$

where:

$V_{meas}$  = measured volume of gas,  $\text{ft}^3$  ( $\text{m}^3$ ),  
 $T_{cf}$  = temperature correction factor,  
 = absolute standard gas temperature,  $^{\circ}\text{R}$  ( $^{\circ}\text{K}$ )/  
 absolute actual gas temperature,  $^{\circ}\text{R}$  ( $^{\circ}\text{K}$ ),  
 = absolute standard gas temperature,  $^{\circ}\text{R}$  ( $^{\circ}\text{K}$ )/  
 [gas temperature,  $^{\circ}\text{F} + 459.67$ ],  $^{\circ}\text{R}$  ( $^{\circ}\text{K}$ ),  
 $P_{cf}$  = pressure correction factor,  
 = absolute actual gas pressure, psia (kPa)/  
 absolute standard pressure, psia (kPa),  
 = gas gage pressure, psig + barometric pressure,  
 psia/absolute standard pressure, psia

NOTE 13—Absolute standard gas temperature and pressure used in this calculation should be the same values used for determining the higher heating value. Standard conditions using Practice D 3588 are 14.696 psia (101.33 kPa) and 60°F (519.67°R, (288.71°K)).

#### 10.4 Energy Input Rate:

10.4.1 Report the manufacturer's nameplate energy input rate in Btu/h for a gas booster heater and kW for an electric booster heater.

10.4.2 For gas or electric booster heaters, calculate and report the measured energy input rate (Btu/h or kW (kJ/h)) based on the energy consumed by the booster heater during the period of peak energy input in accordance with the following relationship:

$$q_{input} = \frac{E \times 60}{t} \quad (2)$$

where:

$q_{input}$  = measured peak energy input rate, Btu/h or kW (kJ/h),  
 $E$  = energy consumed during period of peak energy input, Btu or kWh (kJ/h), and  
 $t$  = period of peak energy input, min.

#### 10.5 Pilot Rate:

10.5.1 Calculate and report the pilot energy rate (Btu/h (kJ/h)) based on:

$$q_{pilot} = \frac{E \times 60}{t} \quad (3)$$

where:

$q_{pilot}$  = pilot energy rate, Btu/h (kJ/h),  
 $E$  = energy consumed during the test period, Btu (kJ),  
 and  
 $t$  = test period, min.

#### 10.6 Preheat Energy and Time:

10.6.1 Report the preheat energy consumption (Btu or kWh, (kJ)) and preheat time (min) for 110  $\pm 3$  °F (43.3  $\pm 1.7$  °C) supply water.

10.6.2 Report the preheat energy consumption (Btu or kWh, (kJ)) and preheat time (min) for 140  $\pm 3$  °F (60.0  $\pm 1.7$  °C) supply water.

#### 10.7 Idle Energy Rate:

10.7.1 Calculate and report the idle energy rate (Btu/h or kW, (kJ/h)) as follows:

$$q_{idle} = \frac{E \times 60}{t} \quad (4)$$

where:

$q_{idle}$  = idle energy rate, Btu/h or kW (kJ/h),  
 $E$  = energy consumed during the test period, Btu or kWh (kJ), and  
 $t$  = test period, min.

#### 10.8 Booster Heater Flow Capacity, Energy Efficiency, and Energy Rate:

10.8.1 Calculate and report the booster heater energy efficiency for the maximum capacity (continuous flow) and capacity at 50 % of maximum capacity tests based on:

$$\eta_{booster} = \frac{E_{water}}{E_{booster}} \times 100 \quad (5)$$

where:

$\eta_{booster}$  = booster heater energy efficiency, %,  
 $E_{water}$  = energy into water, Btu (kJ),  
 $= T_{avg. outlet} - T_{avg. inlet} \times W \times C_p$

where:

$T_{avg. outlet}$  = average booster heater outlet water temperature °F (°C),  
 $T_{avg. inlet}$  = average booster heater inlet water temperature °F (°C),  
 $C_p$  = specific heat of water, Btu/(lb  $\times$  °F), (kJ/(kg  $\times$  °C)),  
 $= 1.00$  (4.19) at 140°F (60.0°C),  
 $W$  = weight of water, lb (kg).

To calculate weight of water ( $W$ ) when a flowmeter is used to measure the volume of water, use the following:

where:

$W$  =  $FR \times \text{test time} \times D$   
 $FR$  = flow rate, gal/min (L/min),  
 $\text{test time}$  = total test elapse time, min,  
 $D$  = density of water (look up value in Table 1),  
 $E_{booster}$  = energy into the booster heater, Btu (kJ),  
 $1 \text{ kWh} = 3413 \text{ Btu}$ .

10.8.2 Calculate and report the booster heater energy rate for the maximum capacity (continuous flow) and capacity at 50 % of maximum capacity tests based on:

$$q_{booster} = \frac{E \times 60}{t} \quad (6)$$

where:

$q_{booster}$  = booster heater energy rate, Btu/h or kW (kJ/h),  
 $E$  = energy consumed during capacity test, Btu or kWh (kJ),  
 $t$  = capacity test period, min.

For gas booster heaters, report separately a gas energy rate and an electric energy rate.

10.8.3 Calculate flow capacity and 50 % flow capacity (gpm, gph, (L/min, L/h)) based on the following:

$$C = \frac{G}{t} \text{ (gpm)} \quad (7)$$



**TABLE 1 Specific Volume and Density of Water at Different Temperatures<sup>A</sup>**

Average Outlet Temperature, °F	Specific Volume, ft <sup>3</sup> /lb	Specific Volume, m <sup>3</sup> /kg	Density (D), lb/gal <sup>B</sup>	Density (D), kg/L <sup>C</sup>
180	0.01651	0.00103	8.097	0.970
181	0.01651	0.00103	8.097	0.970
182	0.01652	0.00103	8.092	0.970
183	0.01653	0.00103	8.087	0.969
184	0.01653	0.00103	8.087	0.969
185	0.01654	0.00103	8.082	0.968
186	0.01654	0.00103	8.082	0.968
187	0.01655	0.00103	8.077	0.968
188	0.01656	0.00103	8.072	0.967
189	0.01656	0.00103	8.072	0.967
190	0.01657	0.00103	8.068	0.967
191	0.01658	0.00104	8.063	0.966
192	0.01658	0.00104	8.063	0.966
193	0.01659	0.00104	8.058	0.965
194	0.01659	0.00104	8.058	0.965
195	0.01660	0.00104	8.053	0.965

<sup>A</sup>Table 6-2 Thermodynamic Properties of Water at Saturation, 1993 ASHRAE Fundamentals Handbook.

<sup>B</sup>Based on volume conversion of 7.48055 gal/ft<sup>3</sup>.

<sup>C</sup>Based on volume conversion of 1000 L/m<sup>3</sup>.

$$C = \frac{G \times 60}{t} \text{ (gph)} \quad (8)$$

where:

$C$  = capacity of the booster heater, gal/m, gal/h, (L/min, L/h),

$G$  = total gallons of water heated during flow capacity heating test, gal (L),

$G = W \div D$ .

where:

$W$  = total weight of water produced during test, lb (kg),

$D$  = density, lb/gal (kg/L) (look up value in Table 1),

$t$  = total time of flow capacity water heating test, min.

#### 10.8.4 Booster Heater Thermal Efficiency:

10.8.4.1 Calculate and report the booster heater thermal efficiency for maximum continuous flow rate tests based on:

$$\eta_{thermal} = \frac{E_{water}}{E_{heat\ exchanger}} \times 100 \quad (9)$$

where:

$\eta_{thermal}$  = booster heater thermal efficiency, %,

$E_{water}$  = energy into water, Btu (kJ),

=  $T_{avg. outlet} - T_{avg. inlet} \times W \times C_p$

where:

$T_{avg. outlet}$  = average booster heater outlet water temperature, °F (°C),

$T_{avg. inlet}$  = average booster heater inlet water temperature, °F (°C),

$C_p$  = specific heat of water, Btu/(lb × °F), (kJ/(kg × °C)),  
= 1.00 (4.19) at 140°F (60.0°C),

$W$  = weight of water, lb (kg).

To calculate weight of water ( $W$ ) when flowmeter is used to measure the volume of water, use the following:

where:

$W = FR \times \text{test time} \times D$

$FR$  = flow rate, gal/min (L/min),

$\text{test time}$  = total test elapse time, min,

$G$  = water, gal (L),

$D$  = density of water (look up value in Table 1),

$E_{heat\ exchanger}$  = energy to the booster's heat exchanger (elements and burners, excluding pumps and motors), kWh, Btu, (kJ).

#### 10.8.5 Booster Heater Inlet and Outlet Temperatures:

10.8.5.1 Plot booster inlet and outlet temperatures every 10 s (see Fig. 3):

### 11. Precision and Bias

#### 11.1 Precision

11.1.1 *Repeatability* (within laboratory, same operator and equipment):

11.1.1.1 For the booster heater's energy and thermal efficiency, and flow capacity results, the percent uncertainty in each result has been specified to be no greater than ±10 % based on at least three test runs.

11.1.1.2 The repeatability of each reported parameter is being determined.

#### 11.1.2 *Reproducibility* (multiple laboratories)

11.1.2.1 The interlaboratory precision of the procedure in this test method for measuring each reported parameter is being determined.

#### 11.2 Bias

11.2.1 No statement can be made concerning the bias of the procedures in this test method because there are no accepted reference values for the parameters reported.

### 12. Keywords

12.1 booster; booster heater; capacity; dishwasher; dishwasher machine; efficiency; energy; performance; test method; water heater

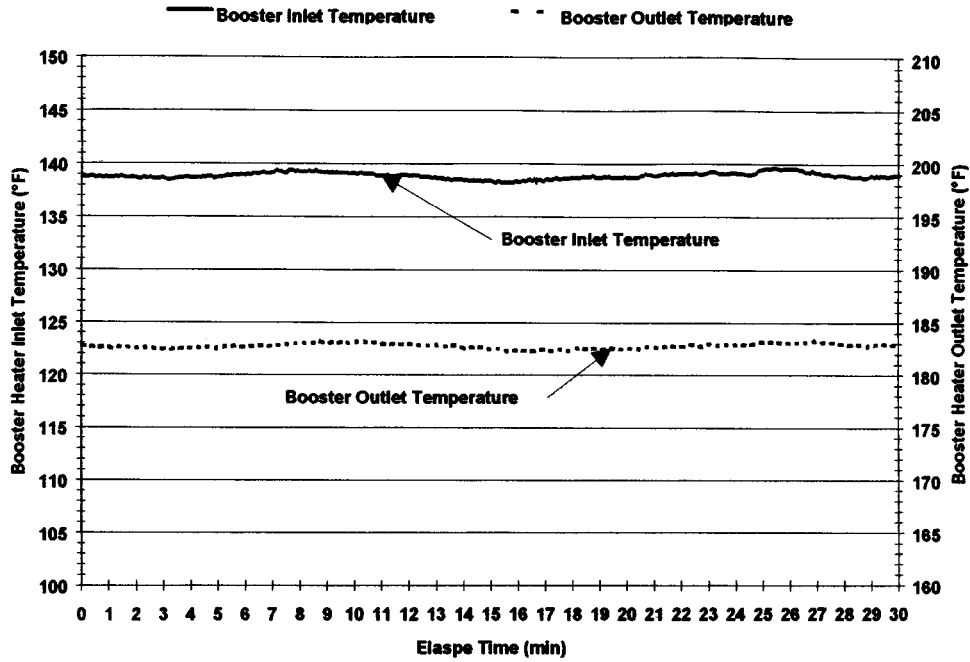


FIG. 3 Example of Booster Heater Inlet and Outlet Temperature Plot

APPENDIX

(Nonmandatory Information)

X1. RESULTS REPORTING SHEETS

Standard Test Methods for the Performance of Booster Heaters

Results Reporting Sheets

Manufacturer \_\_\_\_\_  
 Model \_\_\_\_\_  
 Date \_\_\_\_\_  
 Test Reference Number (optional) \_\_\_\_\_

X1.1 Booster Heater (see Section 10.1)

Additional description of operational characteristics:  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Booster Heater Manufacturer's Nameplate Information  
 Heater Rated Input \_\_\_\_\_ (Btu/h, kW or lb<sub>steam</sub>/h)  
 Voltage \_\_\_\_\_  
 Phase \_\_\_\_\_  
 Pump (if applicable)  
 Motor Horsepower \_\_\_\_\_  
 Voltage \_\_\_\_\_  
 Phase \_\_\_\_\_

X1.2 Apparatus (see Section 10.2)

\_\_\_\_\_ Check if testing apparatus conformed to specifications in Section 8.

Deviations \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Testing Voltage \_\_\_\_\_ Volts  
 Gas Heating Value, if applicable \_\_\_\_\_ Btu/ft<sup>3</sup>

X1.3 Maximum Energy Input Rate (see Section 10.4)

Testing Voltage (V) \_\_\_\_\_  
 Gas Heating Value (Btu/ft<sup>3</sup> (kJ/m<sup>3</sup>)) \_\_\_\_\_  
 Measured (Btu/h (kJ/h) or kW) \_\_\_\_\_  
 Rated (Btu/h (kJ/h) or kW) \_\_\_\_\_  
 Percent Difference between Measured and Rated \_\_\_\_\_ %

X1.4 Booster Heater Pilot Light Energy Rate (see Section 10.5)

Testing Voltage (V) \_\_\_\_\_  
 Gas Heating Value (Btu/ft<sup>3</sup>(kJ/m<sup>3</sup>)) \_\_\_\_\_  
 Pilot Energy Rate (Btu/h (kJ/h)) \_\_\_\_\_

**X1.5 Capacity Tests (see Section 10.8)**

X1.5.1 *Capacity Test at Continuous Flow with 110 <sup>+0/-3</sup> °F (43.3 <sup>+0/-1.7</sup> °C) Supply Water Temperature:*

	Maximum Capacity	50 % Maximum Capacity
Avg. Booster Inlet Temperature (°F, (°C))	_____	_____
Avg. Booster Outlet Temperature (°F, (°C))	_____	_____
Max. Booster Inlet Temperature (°F, (°C))	_____	_____
Max. Booster Outlet Temperature (°F, (°C))	_____	_____
Min. Booster Inlet Temperature (°F, (°C))	_____	_____
Min. Booster Outlet Temperature (°F, (°C))	_____	_____
Flow Rate (gal/h, gal/min, (L/h))	_____	_____
Gas Energy Rate (Btu/h, (kJ/h))	_____	_____
Electric Energy Rate (kW, (kJ/h))	_____	_____
Energy Efficiency (%)	_____	_____
Testing Voltage (V)	_____	_____
Gas Heating Value (Btu/ft <sup>3</sup> (kJ/m <sup>3</sup> ))	_____	_____

X1.5.2 *Capacity Test at Continuous Flow with 140 <sup>+0/-3</sup> °F (60.0 <sup>+0/-1.7</sup> °C) Supply Water Temperature:*

	Maximum Capacity	50 % Maximum Capacity
Avg. Booster Inlet Temperature (°F, (°C))	_____	_____
Avg. Booster Outlet Temperature (°F, (°C))	_____	_____
Max. Booster Inlet Temperature (°F, (°C))	_____	_____
Max. Booster Outlet Temperature (°F, (°C))	_____	_____
Min. Booster Inlet Temperature (°F, (°C))	_____	_____
Min. Booster Outlet Temperature (°F, (°C))	_____	_____
Flow Rate (gal/h, gal/min, (L/h))	_____	_____
Gas Energy Rate (Btu/h, (kJ/h))	_____	_____
Electric Energy Rate (kW, (kJ/h))	_____	_____
Energy Efficiency (%)	_____	_____
Testing Voltage (V)	_____	_____
Gas Heating Value (Btu/ft <sup>3</sup> (kJ/m <sup>3</sup> ))	_____	_____

**X1.6 Plot of Booster Heater Inlet and Outlet Temperatures (see Section 10.8.5)**

X1.6.1 See Fig. X1.1.

**X1.7 Booster Heater Preheat Energy Consumption (see Section 10.6)**

X1.7.1 *Booster Heater Preheat Energy Consumption with 110 <sup>+0/-3</sup> °F (43.3 <sup>+0/-1.7</sup> °C) Supply at the Booster Heater Inlet:*

(Btu (kJ) or kWh) \_\_\_\_\_  
 Preheat Time (min) \_\_\_\_\_  
 Controls and motors loads if monitored separately (kW, (kJ/h)) \_\_\_\_\_  
 Testing Voltage (V) \_\_\_\_\_  
 Gas Heating Value (Btu/ft<sup>3</sup>(kJ/m<sup>3</sup>)) \_\_\_\_\_

X1.7.2 *Booster Heater Preheat Energy Consumption with 140 <sup>+0/-3</sup> °F (60.0 <sup>+0/-1.7</sup> °C), Supply at the Booster Heater Inlet:*

Preheat Energy Consumption (Btu (kJ) or kWh) \_\_\_\_\_  
 Preheat Time (min) \_\_\_\_\_  
 Controls and motors loads if monitored separately (kW, (kJ/h)) \_\_\_\_\_  
 Testing Voltage (V) \_\_\_\_\_  
 Gas Heating Value (Btu/ft<sup>3</sup>(kJ/m<sup>3</sup>)) \_\_\_\_\_

**X1.8 Booster Heater Idle Energy Rate (see Section 10.7)**

(Btu/h (kJ/h) or kW) \_\_\_\_\_  
 Controls and motors loads if monitored separately (kW, (kJ/h)) \_\_\_\_\_  
 Testing Voltage (V) \_\_\_\_\_  
 Gas Heating Value (Btu/ft<sup>3</sup>(kJ/m<sup>3</sup>)) \_\_\_\_\_

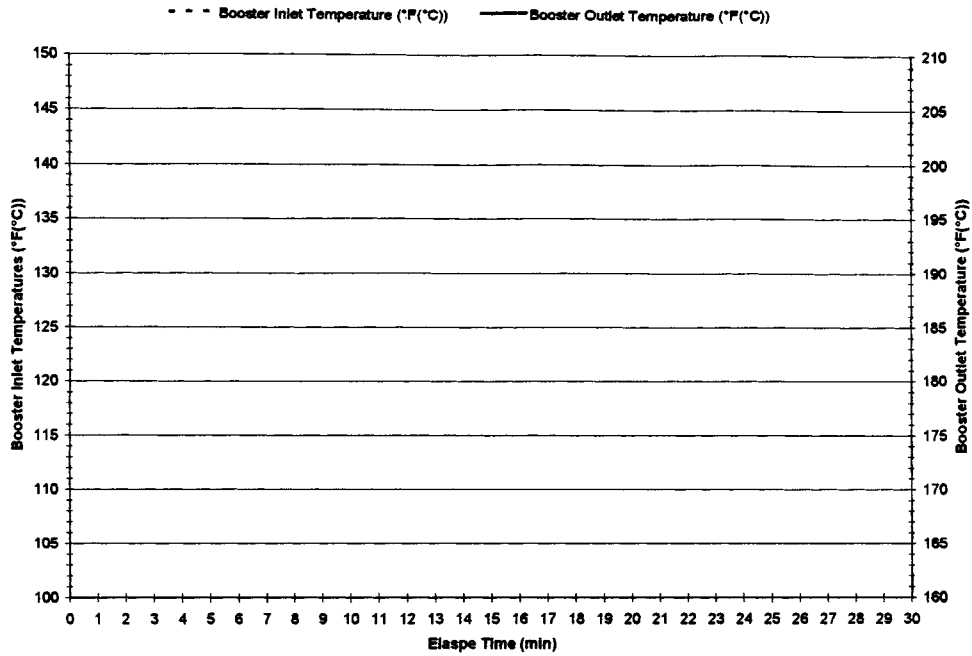


FIG. X1.1 Plot of Booster Heater Inlet and Outlet Temperatures

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