Standard Test Method for Performance of Commercial Patio Heaters[1]

This standard is issued under the fixed designation F2644; 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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the heating performance and energy consumption of commercial radiant patio heaters. The food service operator can use this evaluation to select a commercial patio heater and understand its energy performance and effective heated area.

1.2 This test method is applicable to commercial gas and electric radiant patio heaters.

1.3 The patio heater can be evaluated with respect to the following:

1.3.1 Energy input rate (10.2),

1.3.2 Preheat energy consumption and time (10.3),

1.3.3 Temperature distribution (10.4), and

1.3.4 Effective heated area (10.4).

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given 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:*[2]

D3588 Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels

2.2 *ANSI Documents:*[3]

ANSI Z83.19 Gas-Fired High-Intensity Infrared Heaters

ANSI Z83.20 Gas-Fired Low-Intensity Infrared Heaters

2.3 *ASHRAE Documents:*[4]

ASHRAE 55–1992 Thermal Environmental Conditions for Human Occupancy

3. Terminology

3.1 *Definitions:*

3.1.1 *boundary, n*—the edge of the area being warmed under a patio heater that corresponds to 3°F above the design environment mean radiant temperature.

3.1.2 *design environment, n*—unheated environment for which test unit's performance is to be evaluated. Design environment is specified as having a mean radiant temperature of 60°F.

3.1.3 *effective heated area, n*—the amount of square footage that can be warmed to a specified temperature (3°F above the design environment mean radiant temperature) under a patio heater.

3.1.4 *energy input rate, n*—peak rate at which a patio heater consumes energy (kW or Btu/h), typically reflected during preheat.

3.1.5 *heating index, n*—the quotient of the effective heated area and the measured energy input rate.

3.1.6 *mean radiant temperature, n*—the uniform surface temperature of an imaginary black enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform space.

NOTE 1—Since all environments radiate thermal energy, the mean radiant temperature can be determined for an unheated as well as a heated environment.

3.1.7 *operative temperature, n*—the uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. Operative temperature is numerically the average of the air temperature (T_a) and the mean radiant temperature (T_r), weighted by their respective heat transfer coefficients (h_c and h_r) (see ASHRAE 55–1992):

$$T_o = \frac{(h_c \times T_a + h_r \times T_r)}{(h_c + h_r)}$$

[1] This test method is under the jurisdiction of ASTM Committee F26 on Food Service Equipment and is the direct responsibility of Subcommittee F26.06 on Productivity and Energy Protocol.

Current edition approved June 1, 2013. Published August 2013. Originally approved in 2007. Last previous edition approved in 2007 as F2644 – 07. DOI: 10.1520/F2644-07R13.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.

NOTE 2—In the absence of air movement, the operative temperature is equal to the mean radiant temperature.

3.1.8 *patio heater, n*—an appliance that is designed for warming outdoor areas using radiant heat.

3.1.9 *preheat energy, n*—amount of energy consumed by the patio heater while preheating the patio heater from ambient room temperature (75 ± 10°F) to its operating temperature.

3.1.10 *preheat rate, n*—average rate (°F/min) at which the patio heater comes up to its operating temperature from a 75 ± 10°F ambient temperature.

3.1.11 *preheat time, n*—time required for the patio heater to preheat from ambient room temperature (75 ± 10°F) to its operating temperature.

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

4. Summary of Test Method

4.1 The patio heater is connected to the appropriate metered energy source, and energy input rate is determined to confirm that the appliance is operating within 5 % of the nameplate energy input rate.

4.2 The amount of energy and time required to preheat the patio heater to its operating temperature is determined.

4.3 The amount of square footage that could be effectively warmed by a heater is determined and characterized.

5. Significance and Use

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

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

5.3 The temperature distribution of a patio heater can be used by operators and designers to determine the most effective layout for a patio heating system.

5.4 The effective heated area can be used by operators to choose a patio heater that meets their heating needs.

6. Apparatus

6.1 *Aspirated Thermocouples,* for measuring average bulk air temperature in the test space.

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

6.3 *Data Acquisition System,* for measuring energy and temperatures, capable of multiple channel displays updating at least every 2 s.

6.4 *Gas Meter,* for measuring the gas consumption of a patio heater, shall be a dry positive displacement type with a resolution of at least 0.01 ft^3 and a maximum uncertainty no greater than 1 % of the measured value for any demand greater than 2.2 ft^3/h. If the meter is used for measuring the gas consumed by the pilot lights, it shall have a resolution of at least 0.01 ft^3 and a maximum uncertainty no greater than 2 % of the measured value.

6.5 *Globe Thermometer,* comprised of a beaded-junction thermocouple located in the geometric center of a 2-star, precise round, ping-pong ball for determining mean radiant temperature. The globe shall be mounted on a length of 3⁄16-in. plastic tubing, which will house the thermocouple wire, and the entire assembly (globe and tubing) shall be painted flat black. See Fig. 1.

6.6 *Pressure Gauge,* for monitoring gas pressure. Shall have a range of zero to 15 in. H_2O, a resolution of 0.5 in. H_2O, and a maximum uncertainty of 1 % of the measured value.

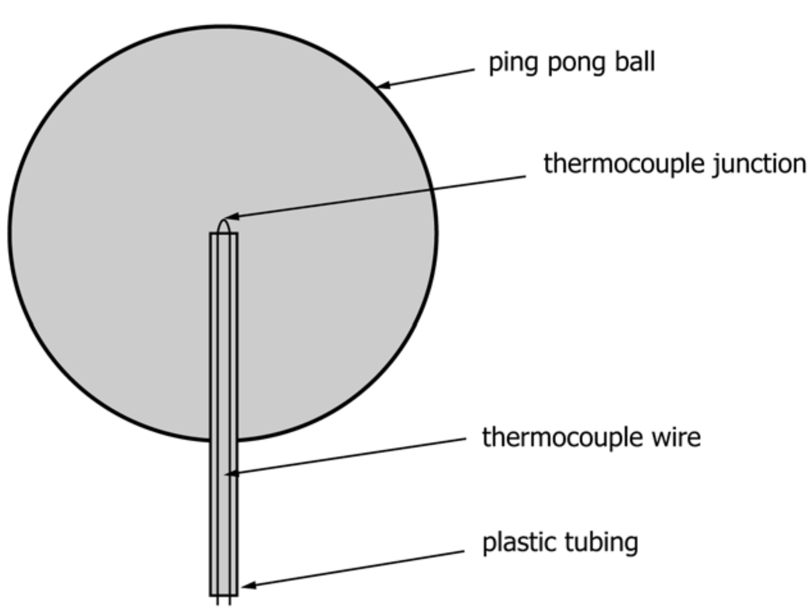

FIG. 1 Globe Thermometer

6.7 *Stop Watch,* with a 1 s resolution.

6.8 *Temperature Sensor,* for measuring gas temperature in the range of 50 to 100°F with an uncertainty of ±1°F.

6.9 *Thermocouple(s),* for measuring globe and ambient temperatures, industry standard type T or type K, 24 gauge thermocouple wire, welded and calibrated, with a range of 0 to 150°F and an uncertainty of ±1°F.

6.10 *Thermocouple Wire,* for measuring reflector temperature, shall be type K thermocouple wire with a range of 0 to 1000°F and an uncertainty of ±1°F.

6.11 *Watt-Hour Meter,* for measuring the electrical energy consumption of a patio 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 %.

7. Reagents and Materials

7.1 *Ping-Pong Balls,* two-star, precise round, weighing 2.5 ± 0.5 g for constructing globe thermometers.

7.2 *Model Airplane Control Rods,* for supporting the globe thermometers, shall be a minimum of 12 in. long with a nominal outside diameter of 3⁄16 in.

8. Sampling, Test Units

8.1 *Patio Heater*—Select a representative production model for performance testing.

9. Preparation of Apparatus

9.1 Install the patio heater in accordance with the manufacturer's instructions in the center of a 20 ft. square area (hereafter called, test cell) at the manufacturer's recommended working height. The test cell shall be free of drafts and obstructions of any kind. Record the distance from the bottom of the heating unit to the floor (mounted heaters).

NOTE 3—A high bay area may be required to provide suitable vertical clearances for testing mounted style patio heaters.

9.2 Connect the patio 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 patio 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 during tests if the voltage supply is not within ±2.5 % of the manufacturer's nameplate voltage.

9.3 For a gas patio heater, adjust (during maximum energy input) the gas supply pressure downstream from the appliance's pressure regulator to within ±2.5 % of the operating manifold pressure specified by the manufacturer. Make adjustments to the appliance following the manufacturer's recommendations for optimizing combustion. Proper combustion may be verified by measuring air-free CO in accordance with ANSI Z83.19 and ANSI Z83.20.

9.4 Confirm (while the elements are energized) that the supply voltage is within ±2.5 % of the operating voltage specified by the manufacturer. Record the test voltage for each test.

NOTE 4—It is the intent of the testing procedure herein to evaluate the performance of a patio heater at its rated electric voltage. If an electric unit is rated dual voltage (that is, designed to operate at either 208 or 240 V with no change in components), the voltage selected by the manufacturer and/or tester shall be reported. If a patio heater is designed to operate at two voltages without a change in the resistance of the heating elements, the performance of the unit (for example, preheat time) may differ at the two voltages.

9.5 Construct an array of globe thermometers for characterizing the heated area under the test patio heater. The globes shall be positioned at a height of 36 ± 1 in. from the floor, with no more than 24 in. horizontal spacing between adjacent globes. The globes shall be no closer than 24 in. to any wall or other partition.

NOTE 5—The globe thermometers can be effectively held in place by implanting the tubing into a length of 1-in. PVC pipe that has been mounted on a 2- by 4-in. sawhorse kit. See Fig. 2.

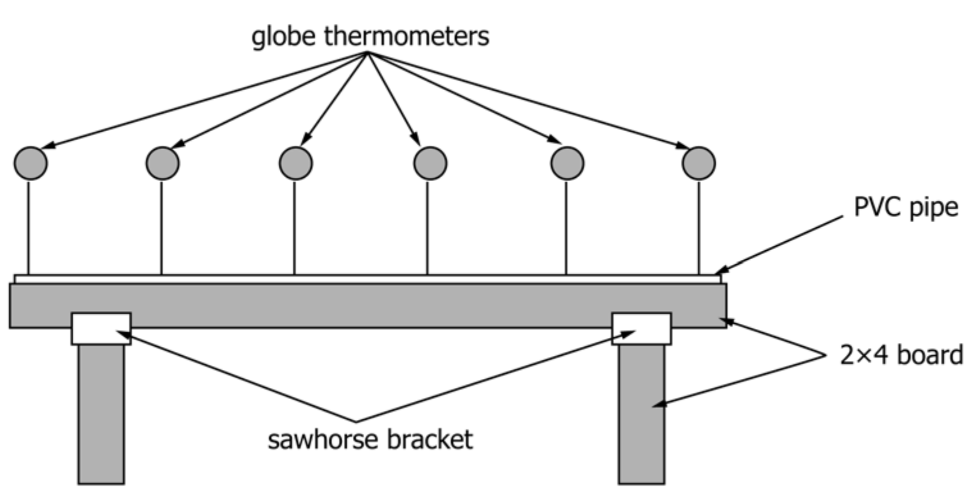

FIG. 2 Globe Thermometer Array

9.6 Divide the test area into four equal-sized quadrants. Position four aspirated thermocouples, one in the center of each quadrant at a height of 36-in. These four temperatures will be used to determine the average ambient temperature.

9.7 In preparation for the preheat test, tack-weld a thermocouple to the heater's reflector, centered as closely as possible.

10. Procedure

10.1 *General:*

10.1.1 For gas patio heaters, record the following for each test run:

10.1.1.1 Higher heating value,

10.1.1.2 Standard gas pressure and temperature used to correct measured gas volume to standard conditions,

10.1.1.3 Measured gas temperature,

10.1.1.4 Measured gas pressure,

10.1.1.5 Barometric pressure,

10.1.1.6 Average ambient temperature, and

10.1.1.7 Energy input rate during or immediately prior to test.

NOTE 6—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 patio heater under test. It is recommended that all testing be performed with natural gas having a higher heating value of 1000 to 1075 Btu/ft^3.

10.1.2 For gas patio heaters, record any electric energy consumption, in addition to gas energy for all tests.

10.1.3 For electric patio heaters, record the following for each test run:

10.1.3.1 Voltage while elements are energized,

10.1.3.2 Average ambient temperature, and

10.1.3.3 Energy input rate during or immediately prior to test run.

10.1.4 For each test run, confirm that the peak input rate is within ±5 % of the rated nameplate input. If the difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the patio heater.

10.2 *Energy Input Rate:*

10.2.1 For gas patio heaters, set the controls to achieve maximum input. Allow the unit to run for a period of 15 min, then monitor the time required for the patio heater to consume 5 ft^3 of gas.

10.2.2 For electric patio heaters, monitor the energy consumption for 15 min with the controls set to achieve maximum input. If the unit begins cycling during the 15 min interval, record the time and energy consumed for the time from when the unit was first turned on until it begins cycling.

10.2.3 Confirm that the measured input rate or power, (Btu/h for a gas patio heater and kW for an electric patio heater) is within 5 % of the rated nameplate input or power (It is the intent of the testing procedures herein to evaluate the performance of a patio heater at its rated energy input rate). If the difference is greater than 5 %, terminate testing and contact the manufacturer. The manufacturer may make appropriate changes or adjustments to the patio heater or supply another patio heater for testing.

10.3 *Preheat Energy Consumption and Time:*

NOTE 7—The preheat test should be conducted as the first appliance operation on the day of the test, starting at a 75 ± 10°F ambient temperature.

10.3.1 Confirm that the patio heater's reflector is at ambient temperature (75 ± 10°F). Turn the unit on with control(s) set to their maximum setting.

10.3.2 Commence monitoring globe and ambient temperatures. The ambient shall be 75 ± 10°F during the course of the test. If the ambient temperature is outside the specified range, the test is invalid and must be repeated.

10.3.3 Record the globe temperatures over a minimum of 10-s intervals during the course of preheat.

10.3.4 Record the energy and time to preheat the patio heater. Preheat is judged complete when the reflector reaches 95 % of its maximum temperature.

10.4 *Temperature Distribution and Effective Heated Area:*

10.4.1 The temperature distribution and effective heated area test shall be repeated a minimum of three times. Conduct each replicate on different days.

10.4.2 Record globe and ambient temperatures at 30-s intervals for a period of 5 min before the test unit is turned on. Both temperatures shall not vary more than ±0.5°F over the 5-min period. The ambient temperature shall be 75 ± 10°F at the start of the test.

10.4.3 Preheat the patio heater for a period of 15 ± 1 min.

10.4.4 Commence monitoring globe and ambient temperatures. The ambient shall be 75 ± 10°F during the course of the test. If the ambient temperature is outside the specified range, the test is invalid and must be repeated.

10.4.5 With the heater on and stabilized, record globe and ambient temperatures at 30-s intervals for a period of 5 min. Both temperatures shall not vary more than ±0.5°F over the 5-min period.

10.4.6 At the end of the 5-min. test period, stop recording temperatures and energy consumption and turn off the patio heater.

11. Calculation and Report

11.1 *Test Patio Heater:*

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

11.1.2 For mounted patio heaters, report the mounting height used for testing.

11.2 *Apparatus and Procedure:*

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

11.2.2 For electric patio heaters, report the voltage for each test.

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

11.3 *Gas Energy Calculations:*

11.3.1 For gas patio heaters, add electric energy consumption to gas energy for all tests, with the exception of the energy input rate test (10.2).

11.3.2 For all gas measurements, calculate the energy consumed based on:

$$E_{gas} = V \times HV \tag{1}$$

where:

E_{gas} = energy consumed by the appliance
HV = higher heating value
= energy content of gas measured at standard conditions, Btu/ft^3
V = actual volume of gas corrected for temperature and pressure at standard condition, ft^3
= $V_{meas} \times T_{cf} \times P_{cf}$

where:

V_{meas} = measured volume of gas, ft^3
T_{cf} = temperature correction factor
= $\frac{absolute\ standard\ gas\ temperature\ °R}{absolute\ actual\ gas\ temperature\ °R}$
= $\frac{absolute\ standard\ gas\ temperature\ °R}{[gas\ temp\ °F + 459.67]\ °R}$

P_{cf} = pressure correction factor
= $\frac{absolute\ actual\ gas\ pressure\ \text{psia}}{absolute\ standard\ pressure\ \text{psia}}$
= $\frac{gas\ gage\ pressure\ \text{psig} + barometric\ pressure\ \text{psia}}{absolute\ standard\ pressure\ \text{psia}}$

NOTE 8—The 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 D3588 are 14.696 psia (101.33 kPa) and 60°F (519.67°R (288.71°K)).

11.4 *Energy Input Rate:*

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

11.4.2 For gas or electric patio heaters, calculate and report the measured energy input rate (Btu/h or kW) based on the energy consumed by the patio heater during the period of peak energy input according to the following relationship:

$$q_{input} = \frac{E \times 60}{t} \tag{2}$$

where:

q_{input} = measured peak energy input rate, kW
E = energy consumed during period of peak energy input, kWh
t = period of peak energy input, min

11.4.3 Calculate and report the percent difference between the manufacturer's nameplate energy input rate and the measured energy input rate.

11.5 *Preheat Energy and Time:*

11.5.1 Report the preheat energy consumption (kWh) and preheat time (min).

11.5.2 Calculate and report the average preheat rate (°F/min) based on the preheat period. Also report the starting temperature of the patio heater's reflector.

11.5.3 Generate a graph showing the patio heater reflector temperature versus time based on the preheat period.

11.6 *Mean Radiant Temperature Distribution:*

11.6.1 Calculate the design mean radiant temperature for each globe location, based on:

$$T_{r1} = \{(T_{r2}+460)^4 + K_1 \times [h_{c3} \times (T_{g3} - T_{a3}) - h_{c4} \times (T_{g4} - T_{a4})]\}^{0.25} - 460 \tag{3}$$

where:

T_{r1} = design mean radiant temperature for each globe location, °F
T_{r2} = mean radiant temperature of the unheated design environment, or patio, °F
= 60°F
K_1 = constant, (h ft^2 °R^4)/Btu
= 4.903 × 10^8(h ft^2 °R^4)/Btu
h_{c3} = convection heat transfer coefficient for the heated test cell (see Table 1), Btu/(h ft^2 °F)
T_{g3} = temperature of each globe in the heated test cell, °F (see 10.4.5)
T_{a3} = average ambient temperature in the heated test cell, °F (see 10.4.5)
h_{c4} = convection heat transfer coefficient for the unheated test cell (see Table 1, Btu/(h ft^2 °F),
T_{g4} = temperature of each globe in the unheated test cell, °F (see 10.4.2)
T_{a4} = average ambient temperature in the unheated test cell, °F (see 10.4.2)

NOTE 9—For the purposes of this test method, it is assumed that the mean radiant temperature of the unheated design environment is equal to the ambient air temperature of the unheated design environment.

11.6.2 For each globe location, average the calculated mean radiant temperature from the three test runs. Report the average

TABLE 1 Globe Thermometer Convection Heat Transfer Coefficient

$T_g - T_a$ (°F)	$h_c\left(\frac{Btu}{hr\ ft^2\ °F}\right)$	$T_g - T_a$ (°F)	$h_c\left(\frac{Btu}{hr\ ft^2\ °F}\right)$
0.5	0.56	10.5	0.92
1.0	0.62	11.0	0.93
1.5	0.66	11.5	0.94
2.0	0.69	12.0	0.95
2.5	0.72	12.5	0.95
3.0	0.74	13.0	0.96
3.5	0.76	13.5	0.97
4.0	0.78	14.0	0.97
4.5	0.79	14.5	0.98
5.0	0.81	15.0	0.98
5.5	0.82	15.5	0.99
6.0	0.83	16.0	1.00
6.5	0.85	16.5	1.00
7.0	0.86	17.0	1.01
7.5	0.87	17.5	1.01
8.0	0.88	18.0	1.02
8.5	0.89	18.5	1.02
9.0	0.90	19.0	1.03
9.5	0.91	19.5	1.03
10.0	0.91	20.0	1.04

design mean radiant temperature for each globe location on a plan drawing of the test cell.

11.6.3 Create a distribution plot of design mean radiant temperature versus distance from the center of the heater for each of the heater's primary axes.

11.7 *Effective Heated Area:*

11.7.1 Determine the boundary corresponding to a design mean radiant temperature (MRT) that is 3°F higher than the mean radiant temperature of the design environment (60°F).

NOTE 10—This test method may be used to determine additional contour lines corresponding to different temperature ranges within the heated area.

11.7.1.1 Map out the globe MRT in a grid with the center of the heater corresponding to the origin.

11.7.1.2 Identify which globes have a MRT greater than or equal to the cutoff MRT (63°F). These are the heated globes.

11.7.1.3 For each heated globe, identify all adjacent globes (up, down, left, right, and diagonally) with a MRT less than the cutoff MRT. These will be referred to as boundary globes.

11.7.1.4 For each boundary globe, determine the number of boundary points. There will be one boundary point for every adjacent globe with a MRT less than the cutoff MRT. The number of boundary points for each globe may vary between 1 and 8 points.

11.7.1.5 Use linear interpolation to calculate the coordinates for each boundary point based on:

$$x_p = x_1 + (T_1 - T_p)*(x_2 - x_1)/(T_1 - T_2) \quad (4)$$

$$y_p = y_1 + (T_1 - T_p)*(y_2 - y_1)/(T_1 - T_2)$$

where:

x_p = x-coordinate for the boundary point
T_1 = MRT of the boundary globe, °F
T_p = cutoff MRT, °F
x_2 = x-coordinate for the adjacent globe
x_1 = x-coordinate for the boundary globe
T_2 = MRT of the adjacent globe, °F
y_p = y-coordinate for the boundary point
y_2 = y-coordinate for the adjacent globe
y_1 = y-coordinate for the boundary globe

11.7.1.6 Plot the calculated boundary points on the grid from 11.7.1.1 and fill in the boundary.

11.7.2 Calculate the area within the boundary determined in 11.7.1. This will be reported as the effective heated area under the patio heater.

11.7.2.1 Calculate the distance between each boundary point and the origin based on:

$$r_p = \sqrt{(x_p^2 + y_p^2)} \quad (5)$$

where:

r_p = distance of the boundary point from the origin, ft
y_p = y-coordinate for the boundary point
x_p = x-coordinate for the boundary point

11.7.2.2 For each boundary point, calculate the angle between the point and the origin based on:

$$\theta_p = arctan(y_p/x_p) \quad (6)$$

where:

θ_p = angle between the boundary point and the origin, degrees
y_p = y-coordinate for the boundary point
x_p = x-coordinate for the boundary point

11.7.2.3 Determine which quadrant in which each point is located and adjust the angle as follows:

(a) For points in quadrants I and IV, $\varphi = \theta$,
(b) For points in quadrant II, $\varphi = 180° + \theta$,
(c) For points in quadrant III, $\varphi = -180° + \theta$.

11.7.2.4 Starting with the angle closest to −180°, label the boundary points counter-clockwise from 1 to *n*, where *n* is the total number of boundary points.

11.7.2.5 Calculate the area within the boundary by dividing it up into adjacent slices with the center of the heater at the origin. Starting at point #1 (closest to −180°), calculate the area of each slice and sum the area of the individual slices based on:

$$A = \sum \frac{1}{2} \times r_n + 1 \times r_n \times \sin(\varphi_{n+1} - \varphi_n) \quad (7)$$

where:

A = heated area under the patio heater, sqf
n = number of boundary points
r_n = distance of boundary point *n* from the origin, ft
r_{n+1} = distance of boundary point *n*+1 from the origin, ft
φ_n = angle between boundary point *n* and the origin, degrees
φ_{n+1} = angle between the boundary point *n*+1 and the origin, degrees

11.8 *Patio Heater Heating Index:*

11.8.1 Calculate and report the efficiency index for the patio heater based on:

$$H_{index} = \frac{A_{effective}}{q_{input}} \quad (8)$$

where:

H_{index} = heating index for the patio heater, ft^2/kBtu/h or ft^2/kW
$A_{effective}$ = effective heated area under the patio heater as determined in 11.7, ft^2
q_{input} = measured energy input rate for the patio heater as determined in 11.4.2, Btu/h or kW

11.9 *Design Operative Temperature (Optional):*

11.9.1 The design operative temperature for a patio heater may be calculated based on (see ASHRAE 55–1992):

$$T_o = \frac{(h_{c1} \times T_{a1} + h_{r1} \times T_{r1})}{(h_{cl} + h_{r1})} \quad (9)$$

where:

T_o = design operative temperature for each globe location, °F
h_{c1} = convective heat transfer coefficient for the design environment, Btu/h ft^2 °F
= $0.107 \times \sqrt{V_{ac}}$

where:

V_{ac} = average local air velocity in the design environment, fpm

T_{a1} = ambient temperature of the design environment, °F

h_{r1} = radiant heat transfer coefficient for each globe location in the design environment, Btu/h ft² °F

$$= K_2 \times \left[\left(\frac{T_{r1} + T_{a1}}{2} \right) + 460 \right]^3$$

where:

K_2 = constant, Btu/(h ft² °R⁴)
= 4.868×10^9, Btu/(h ft² °R⁴)

T_{r1} = mean radiant temperature for each globe location as determined in 11.6.1, °F

12. Precision and Bias

12.1 *Precision:*

12.1.1 *Repeatability* (within laboratory, same operator and equipment).

12.1.1.1 The repeatability for each reported parameter is being determined.

12.1.2 *Reproducibility* (multiple laboratories).

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

12.2 *Bias:*

12.2.1 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.

13. Keywords

13.1 efficiency index; energy consumption; patio heater; preheat