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Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters; Final Rule

DEPARTMENT OF ENERGY

Office of Energy Efficiency and Renewable Energy

10 CFR Part 430

[Docket No. EE–RM–94–230]

RIN 1904–AA52

Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters

AGENCY: Office of Energy Efficiency and Renewable Energy, Energy.

ACTION: Final rule.

SUMMARY: The Department of Energy (DOE or the Department) is amending its test procedure for water heaters. The first-hour rating for storage-type water heaters is revised to more accurately measure large storage-type water heaters. Also, electric and gas-fired instantaneous water heaters are rated at the maximum flow rate to distinguish them from storage-type water heaters.

EFFECTIVE DATE: This rule is effective June 10, 1998.

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SUPPLEMENTARY INFORMATION:

I. Introduction

A. Authority

Part B of Title III of the Energy Policy and Conservation Act, as amended (EPCA or the Act), establishes the Energy Conservation Program for Consumer Products other than Automobiles (Program).[1] The products currently subject to this Program include water heaters, which are the subject of today's Final Rule.

Under the Act, the Program consists essentially of three parts: testing, labeling, and the Federal energy conservation standards. The Department, in consultation with the National Institute of Standards and Technology (formerly the National Bureau of Standards), is required to amend or establish test procedures as appropriate for each of the covered products. Section 323 of EPCA, 42 U.S.C. 6293. The purpose of the test procedures is to produce test results that measure energy efficiency, energy use, or estimated annual operating cost of a covered product during a representative average use cycle or period of use. The test procedure must not be unduly burdensome to conduct. Section 323(b)(3) of EPCA, 42 U.S.C. 6293(b)(3).

Beginning 180 days after a test procedure for a product is prescribed, no manufacturer, distributor, retailer, or private labeler may make representations with respect to the energy use, efficiency, or cost of energy consumed by such products, except as reflected in tests conducted according to the DOE procedure. Section 323(c)(2) of EPCA, 42 U.S.C. 6293(c)(2).

Furthermore, DOE is required to determine to what extent, if any, an amended test procedure would alter the measured energy efficiency or measured energy use of any covered product as determined under the existing test procedure. Section 323(e)(1) of EPCA, 42 U.S.C. 6293(e)(1).

B. Background

Today's Final Rule amends DOE's test procedure for water heaters by revising the method used to determine the first-hour rating of storage-type water heaters, adding a new rating for electric and gas-fired instantaneous water heaters, and amending the definition of a heat pump water heater.

On March 23, 1995, DOE published in the **Federal Register** (60 FR 15330) a Notice of Proposed Rule and Public Hearing on proposed amendments to clarify the water heater test procedure and requested data, comments, and information regarding its applicability and workability. The Department conducted a public hearing on July 12, 1995, and a public workshop on February 12, 1997, and requested written comments.

The proposed amendments to the water heater test procedure included revisions to make the water heater test procedure applicable to electric and oil-fired instantaneous water heaters; coverage for testing storage-type water heaters with rated storage capacities less than 20 gallons (76 liters); revision of the first-hour rating for storage-type water heaters; amendment to the current definition for heat pump water heater; and the addition of new definitions for heat pump water heater storage tank, add-on heat pump water heater, integral heat pump water heater, and solar water heater. In addition, DOE requested comments on the adequacy of the test procedure for heat pump water heaters regarding the use of a backup electric resistance element(s).

II. Discussion of Comments

A. General Comments

Forty commenters submitted written comments in response to the proposed rulemaking on water heaters. After reviewing these comments and the comments presented during the public hearing, the Department held a public workshop on February 12, 1997, to solicit additional comments on the issues in the Proposed Rule. Workshop topics included the daily hot water consumption of 64.3 gallons (243.4 liters) and the thermostat setting of 135°F (57.2°C) in the existing test procedure. The notice for the public workshop was published in the **Federal Register** (62 FR 4202, January 29, 1997). Nine commenters submitted written comments prior to and after the workshop. Those written comments received prior to the workshop (from the Gas Appliance Manufacturers Association [GAMA], February 12, 1997, Water Heater Test Procedure Workshop Transcript [hereafter referred to as ''February 1997 Transcript''] at Appendix I; Electric Power Research Institute [EPRI], February 1997 Transcript at Appendices E and J; and Controlled Energy Corp. [CEC], February

[1] Part B of Title III of Energy Policy and Conservation Act, as amended, is referred to in this Final Rule as ''EPCA'' or the ''Act.'' Part B of Title III is codified at 42 U.S.C. 6291–6309.

1997 Transcript at Appendix H) were distributed to all participants at the beginning of the workshop for inclusion in the workshop session. During the rulemaking process, a number of commenters stated their support of the EPRI recommendations on all issues. These commenters included: Northeast Utilities Service Co., No. 11; The Dayton Power & Light Co., No. 15; Utilities District of Western Indiana, No. 16; National Rural Electric Coop. Assoc., No. 18; Decatur County REMC, No. 19; Pennsylvania Power & Light Co., No. 20; Central and South West Services, Inc., No. 21; Centerior Energy, No. 22; Hawaiian Electric Co., No. 23; Southern Company Services, Inc., No. 24; Potomac Electric Power Co., No. 26; East Kentucky Power Cooperative, Inc., No. 34; Ohio Edison Co., No. 39; Southern California Edison Co., No. 43; Duke Power Co., No. 44; and Nevada Power Co., No. 45.

The following is a summary of the public comments, presented during and after both the public hearing and the workshop, on each of the DOE proposed amendments/revisions, and on other issues concerning the existing test procedure.

On October 31, 1997, the comment period was reopened on the issues of the maximum gallons (liters) per minute rating for electric and gas-fired instantaneous water heaters and the energy factor of the heat pump water heater storage tank. (62 FR 58923, October 31, 1997.)

B. Product Specific Comments

1. Instantaneous Water Heaters

a. Coverage of Electric and Oil-Fired Instantaneous Water Heaters. The current test procedure does not address the testing of electric and oil-fired instantaneous water heaters, because they are not defined in the test procedure. In the 1995 proposed rulemaking for water heaters, DOE proposed definitions for these two types of instantaneous water heaters so they would be subject to the same test procedures as gas-fired instantaneous water heaters (i.e., the first-hour rating test and the 24-hour simulated use test).

GAMA agreed that electric and oil-fired instantaneous water heaters should be covered in the test procedures. However, GAMA said it is unaware of any residential oil-fired instantaneous models on the market. (GAMA, No. 1 at 2 and February 1997 Transcript at 119.) Edison Electric Institute (EEI), Bock Water Heaters (Bock), the Federal Trade Commission (FTC), and the Oregon Energy Office (Oregon) also stated that they know of no residential oil-fired instantaneous water heaters on the market. (EEI, February 1997 Transcript at 119; Bock, February 1997 Transcript at 120; FTC, February 1997 Transcript at 120; and Oregon, No. 51 at 3.) In response to the reopening notice of October 1997, Controlled Energy Corporation provided information on a kerosene-fired instantaneous water heater sold by Monitor Products, Inc. (CEC, No. 64 at 1.) The California Energy Commission (CAEC) also provided information on one oil-fired instantaneous water heater manufactured by Monitor Products of Princeton, NJ, which meets the definition in the test procedure for the input BTU rating. The CAEC also informed DOE that Monitor intends to introduce another smaller instantaneous water heater soon, and the CAEC opposed the DOE withdrawing coverage for oil-fired instantaneous water heaters. (CAEC, No. 68 at 1–2.)

Virginia Power stated that it does not support the testing and rating of electric units because of the small variance in efficiency among them. Virginia Power stated that electric units are not typically compared to oil or gas-fired instantaneous water heaters. Virginia Power claimed the incomparability is due to the difference in utilization between gas-fired and electric instantaneous water heaters. (Virginia Power, No. 50 at 2 and No. 66 at 3.) The Department interprets this statement to mean that gas-fired models are for whole-house applications, whereas electric models are for point-of-use applications such as kitchen or lavatory sinks.

EPRI stated that neither the existing nor the proposed test should be applied to instantaneous water heaters because a heating rating of more than 150,000 Btu per hour is needed to satisfy whole-house applications and all instantaneous water heaters for residential use are below that heating capacity. EPRI claimed that an instantaneous water heater should not have an efficiency rating because the efficiency rating would falsely imply an equivalency with tank-type water heaters. (EPRI, No. 56 at 11.)

The Oregon Energy Office suggested that an energy efficiency rating for instantaneous water heaters is needed, and suggested that a test procedure should be developed that would take into account the warm-up and cool-down losses during a draw for all units (as well as the flue and pilot light losses for gas-fired units). Oregon stated that the procedure for instantaneous water heaters should not be the same as for storage-type water heaters. (Oregon, No. 51 at 3.)

GAMA claimed for electric models that there are distinctions between larger models intended for multiple points of use and smaller models intended for a single point of use. GAMA suggested that DOE may need to make distinctions between such units by creating separate classes of instantaneous water heaters. (GAMA, No. 1 at 2.)

DOE believes that separate classes of electric instantaneous water heaters would require technical data on these models, such as: (1) The intended purpose of use; (2) the frequency of daily draws at the point of use; (3) the average volume of each draw; and (4) the average amount of the total daily draw. However, DOE believes that at the present time, the development of separate classes of electric instantaneous water heaters for residential application is not needed because, even at the proposed maximum input power rating of 12 kW (40,944 Btu/h), an electric instantaneous water heater can only supply a maximum of 1.06 gallons per minute (gpm) (4.01 liters per minute [L/min]) of water at a 77°F (42.8°C) temperature rise (from 58°F to 135°F [14.4°C to 57.2°C]) on a continuous draw basis. DOE believes this is far below the requirements of a whole-house application which could range from 3–5 gallons per minute. Furthermore, the limit on the input heating rate of electric instantaneous water heaters is not likely to change because it is limited by the current carrying capacity of wiring in most residential housing.

Additionally, DOE believes that the variation of the energy efficiency of electric instantaneous water heaters would be small for similar sized models, provided they are tested under similar conditions because energy losses only occur during the warm-up and cool-down of the heaters between water draws. However, test data are needed to determine the magnitude of these losses, which are functions of the water used during each draw and the frequency of draws. No field data is available on the average draw rate, amount per draw, and the average daily draw volumes for these small electric, point-of-use type instantaneous water heaters. The daily hot water usage of 64.3 gal (243.4 L) specified for whole-house application does not apply to these small heating capacity electric units. Consequently, the energy efficiency, and energy consumption cannot be determined for these units without additional data. Therefore, DOE will not test electric instantaneous water heaters for energy efficiency or energy consumption until a future rulemaking when the daily hot water usage data for point-of-use instantaneous water heaters are available.

DOE did not receive any indication until after the October 1997 notice of reopening that residential oil-fired instantaneous water heaters are on the market. DOE's belief that these water heaters were not being sold in the United States was supported by GAMA, Bock, EEI, the FTC, and the Oregon Energy Office. DOE believes that there is not time for adequate public review and comment to include oil-fired instantaneous water heaters in this rulemaking. Accordingly, DOE withdraws its proposal to test oil-fired instantaneous water heaters in today's Final Rule.

The Department will continue to require the testing of gas-fired instantaneous water heaters for energy efficiency and energy consumption because data is needed for the FTC labeling program.

b. GPM v. First-Hour Rating. In the 1995 proposed rulemaking, DOE proposed testing for electric and oil-fired instantaneous water heaters based on the first-hour rating currently used for gas-fired instantaneous water heaters. This proposal would test instantaneous water heaters in a manner equal to gas-fired storage-type water heaters. On October 31, 1997, DOE reopened the comment period on first-hour rating for instantaneous water heaters. In its reopening notice, DOE proposed to revise the first-hour rating for instantaneous water heaters from gallons per hour to a test that measures the maximum flow rate in gallons per minute (gpm) (liters per minute [L/min]) at a 77°F (42.8°C) temperature rise. DOE proposed to call this rating the maximum gpm rating.

DOE's proposed revision was in response to concerns raised by several commenters regarding the March 1995 proposed rule. EEI, EPRI and the Tennessee Valley Authority (TVA) considered the proposed first-hour rating procedure for instantaneous water heaters to be inappropriate because it would lead consumers to ''mistakenly compare instantaneous and storage-type water heaters as being equivalent.'' They argued that a storage-type water heater can supply a large amount of hot water during a short draw period, whereas an instantaneous water heater may not be able to supply a similar amount of hot water because it is limited by its heating rate. (EEI, No. 2 at 5, No. 27 at 5, and July 12–13, 1995, Public Hearing Transcript [hereafter referred to as July 1995 Transcript] at 22 and 27; EPRI, No. 17 at 4; and TVA, No. 14 at 2.)

During the 1997 workshop and in its written comments, EPRI recommended a rating based on the maximum gpm flow rate at a 50°F (27.8°C) temperature rise if a single rating value is used, and at both a 50°F and 77°F temperature rise if two rating values are used. EPRI stated that it prefers a rating at both a 50°F and 77°F temperature rise. (EPRI, No. 56 at 11.)

GAMA supported EPRI's alternative of a maximum flow rate. However, GAMA's alternative test procedure involves adjusting the flow rate to obtain a temperature rise of 77°F in the instantaneous water heater, and using this maximum gpm flow rate as the rating characteristic, rather than the current first-hour rating value. GAMA recommended that the temperature rise be the same as specified for storage-type water heaters—that is, 77°F, not 50°F as suggested by other commenters. (GAMA, No. 35 at 2.) GAMA stated it selected a temperature rise of 77°F because hot water also will be used for machine-related applications (dishwashers and clothes washers) that require a 135°F (57.2°C) temperature. (GAMA, February 1997 Transcript at 127 and 138.)

Virginia Power supports the proposal to rate instantaneous water heaters with a maximum gpm rating. (Virginia Power, No. 42 at 2 and No. 66 at 2–3.) However, Virginia Power supports dual maximum gpm ratings, at both 50–52°F and 77°F rise. Virginia Power stated that both temperature rises are used in applications (human-contact at 110°F [43.3°C] and machine use at 135°F [57.2°C]. Virginia further stated that DOE's statement in the October 1997 reopening notice that a 77°F temperature rise will ensure that consumers in cold regions of the country will have an acceptable water temperature is inconsistent with the rationale used to establish other parameters of the test procedure (i.e., establishing on the basis of national average values). (Virginia Power, No. 50 at 2 and No. 66 at 3.) EEI supported Virginia's position on this issue. (EEI, No. 65 at 1.) Oregon stated that both a 50°F and 77°F would be useful in sizing a unit properly. (Oregon, No. 51 at 3.) State Industry claimed that a rating value based on a nominal temperature rise of 50°F would not provide consumers with information on whether the heater is capable of delivering hot water at a 77°F temperature rise. (State Industry, February 1997 Transcript at 134.)

Based on the comments, DOE believes there is a consensus that the current first-hour rating for instantaneous water heaters may mislead consumers because it may overstate the capability of the instantaneous water heater to provide a given quantity of hot water at a given instant of time. The suggestion from GAMA, EEI, EPRI, and other commenters to replace the first-hour rating parameter with a maximum flow rate (gpm) over a specific temperature rise (77°F [42.8°C] or 50°F [27.8°C]) instead of a total volume flow over one hour is reasonable. This comparison measures the ability of instantaneous water heaters to deliver the maximum possible amount of hot water to the user at a specific temperature rise occurring any single moment. Because some consumer appliances require a hot water temperature in the 135–140°F (57.2–60°C) range, information on the amount of flow at a 77°F rise is needed. Also, a rating value based on a nominal temperature rise of 50°F would not provide consumers with information on whether the heater is capable of delivering hot water at 135°F. Therefore, DOE believes that the maximum flow rate at the rated energy input rate and at a temperature rise of 77°F across the water heater should be specified for rating the capability of instantaneous water heaters to deliver hot water. Furthermore, this maximum flow rate should be specified in place of the first-hour rating. The Department is therefore creating a new rating for instantaneous gas and electric water heaters using a ''maximum gpm draw rate at 77°F rise'' criterion, and renaming the criterion from ''First-Hour Rating'' to ''Maximum GPM Draw Rating'' in Sections 5.2 and 6.2 of today's Final Rule.

c. Water Temperature Rise. Regarding the outlet water temperature for gas-fired instantaneous water heaters, the Controlled Energy Corporation (CEC) submitted a written statement to DOE and distributed the statement at the February 1997 workshop. CEC stated that the outlet water temperature for an instantaneous water heater should be at 110–115°F because there is no practical domestic use for water at 135°F. (CEC, February 1997 Transcript at Appendix H at 4 and No. 63 at 3.) Additionally, CEC claimed the 135°F temperature specified for storage-type water heaters is simply to increase the heat content of the stored water and therefore is not relevant for instantaneous water heaters. (CEC, February 1997 Transcript at Appendix H at 4.)

Group Thermo suggested that a 50°F temperature rise is too low for some cold regions of the country, and Bock suggested it is too low for certain well water sources. EEI supported a temperature rise of 50°F because there are many places like Miami and Texas with high ground water temperatures for most, if not all, of the year. EPRI supported a 50°F temperature rise because that is representative of typical human usage and a rise of 77°F because that is typical of machine usage. A.O. Smith favored a single rating at a 77°F temperature rise because it is simpler and allows comparisons with storage-type water heaters. (Group Thermo, February 1997 Transcript at 133 and 138; Bock, February 1997 Transcript at 132; EEI, February 1997 Transcript at 136; A.O. Smith, February 1997 Transcript at 141; and EPRI, No. 56 at 11.)

The Department will continue to specify the test conditions for water heater temperatures at 58°F inlet (Title 10 CFR, Part 430, Subpart B, Appendix E, Section 2.3) with a 77°F rise to address (1) machine-use applications that require a 135°F water temperature for efficient operation, and (2) the performance of a water heater in regions of the country that may have a significantly lower supply (inlet) temperature. Additionally, a single value of 77°F rise will reduce the test burden on manufacturers.

d. Draw Schedule. DOE did not propose any changes in the draw schedule for instantaneous water heaters. There were several comments addressing this issue. During the 1997 workshop, EPRI commented that for large, whole-house, fossil-fueled instantaneous water heaters, the losses due to warm-up and cool-down after each water draw become significant because of the thermal mass of the water and the heat exchanger. Also, EPRI stated the number of draws (six) in the existing test procedure for energy factor (EF) tests is not high enough to account for the daily total cyclical loss that occurs in practice. EPRI claimed that in the field there are 20–50 draws per day. EPRI suggested that tests be conducted on smaller tank types and whole-house instantaneous water heaters to compare the difference in losses caused by a larger number of draws throughout the day. (EPRI, February 1997 Transcript at 166, 173, and 178.)

In its written statement, CEC also requested that the draw schedule in the 24-hour simulated use test for modulating gas-fired instantaneous water heaters be changed from an equal number of draws at the maximum and minimum firing rates (three at each) to 75% of the draws at the maximum firing rate and 25% at the minimum firing rate. CEC stated that this would reflect the fact that most of the daily hot water consumption is at the maximum firing rate, which, CEC stated, is when the efficiency of its heater is highest. CEC stated that the minimum firing rate is provided for the convenience of consumers for hand washing, etc. (CEC, February 1997 Transcript at Appendix H at 3 and No. 63 at 2.)

DOE recognizes that the number of draws will affect the energy factor and the annual energy consumption of instantaneous water heaters. The reason is that the warm-up and cool-down of the heat exchanger between hot water draws will reduce the measured average outlet temperature from the specified nominal 135°F resulting in a lower energy factor and a higher energy consumption when the outlet temperature is adjusted back to the nominal temperature in the calculation procedure. The decrease in outlet temperature is proportional to the number of draws under a constant total daily draw volume. However, DOE has no data on the amount of daily hot water usage at the minimum or maximum firing rate for modulating gas-fired instantaneous water heaters. Hence, there is no basis for DOE to change the number of draws for instantaneous water heaters at either a fixed firing rate or for modulating instantaneous water heaters at the minimum or maximum firing rate in the 24-hour simulated use test. Additionally, DOE needs data to substantiate any change to the number of draws during the 24-hour simulated use test for instantaneous water heaters because changing the number of draws is likely to reduce the energy factor for existing units thereby requiring a modification to the energy conservation standard for those products.

e. Energy Factor Measurement. DOE proposed a 24-hour simulated use test for instantaneous water heaters that is exactly the same as the 24-hour simulated use test for storage-type water heaters. The 24-hour simulated use test would determine the amount of fuel or electricity used during a 24-hour period to heat 64.3 gallons of water to 135°F with the water being drawn in six equal draws at one-hour intervals. Also, if the instantaneous water heater allows variable input rates, the fuel or electricity consumed to heat 64.3 gallons of water to 135°F during a 24-hour period would be determined with three draws at the maximum flow rate and three draws at the minimum flow rate. In the current test procedure, the recovery efficiency is calculated from the output energy of the first draw (determined from water mass, temperature, and specific heat) divided by the measured input energy used during the first draw of the 24-hour simulated use test for units with a single firing rate. For modulated units, the recovery efficiency is the average of the two recovery efficiencies calculated on the basis of data from the first draw (at the maximum input rate) and the fourth draw (at the minimum input rate) of the 24-hour simulated use test.

In its comments to the 1995 proposed rulemaking, Paloma Industries, Inc., suggested that for gas-fired instantaneous water heaters, two EF values should be determined in the test procedure. These values would reflect test conditions with (1) the pilot light being continuously on, and (2) the pilot light being off except when hot water is needed. The pilot-light-on condition is the case in which the pilot light is always on regardless of whether there is a demand for hot water. The second test condition is for the case in which a consumer turns the pilot light off when hot water is not needed. Paloma claims that with its Piezo-Elecric Ignition and Subsidiary Pilot Burner Assembly, the consumer can manually light the pilot easily (in about 10 seconds time) when hot water is needed. CEC concurred with Paloma. (Paloma Industries, No. 7 at 3; CEC, February 1997 Transcript at Appendix H at 4 and No. 63 at 2.) Furthermore, CEC stated that differentiating water heaters with pilot lights from those without is even more important because CEC will introduce a unit in 1998 with electronic ignition. (CEC, No. 63 at 2.)

With respect to the issue of the pilot light status between hot water draws, GAMA recognized that turning off the pilot will reduce energy consumption and increase the energy factor. GAMA also stated that turning off the pilot light may not be practical for a whole-house application. Bock expressed the same opinion. Oregon suggested that it is possible to have two energy factors, one based on the pilot light on between draws and one based on it being off. Oregon also recommended that a test procedure for instantaneous water heaters should account for warm-up, cool-down and pilot light losses. (GAMA, February 1997 Transcript at 170 and 176; Bock, February 1997 Transcript at 171; Oregon, No. 51 at 3.)

DOE believes the suggestion to compute two energy factors is valid only if the consumer can conveniently turn the pilot light off and on automatically at the point of use (e.g., at the faucet or showerhead) and if no other faucet or appliance requiring hot water is connected to the same water heater. Neither Paolma nor CEC indicated that such an approach was possible with their equipment although CEC has stated that it will introduce a model with electronic ignition in 1998. DOE believes that manual shut-off for pilot lights on instantaneous water heaters would not be practical for widespread use and energy savings. Therefore, DOE will continue to calculate one energy factor.

2. Storage-type Water Heaters With Rated Storage Capacities Less Than 20 Gallons

In the 1995 proposed rulemaking, DOE proposed to cover storage-type water heaters with rated storage capacitites less than 20 gallons (76 liters). This proposal was in response to a July 17, 1991, letter from GAMA that stated that storage-type water heaters less than 20 gallons (76 liters) are not covered by the existing test procedure.

To cover these water heaters, DOE proposed to adopt the draw rate and the schedules in ANSI/ASHRAE Standard 118.2–1993, ''Method of Testing for Rating Residential Water Heaters,'' to be used in the first-hour rating test and the 24-hour simulated use test. The draw schedules are as follows: (1) For units with rated storage less than 10 gallons (38 liters), a total volume of 9 gallons (34 liters) shall be withdrawn, and (2) for units with rated storage greater than or equal to 10 gallons (38 liters) but less than 20 gallons (76 liters), a total volume of 24 gallons (91 liters) shall be withdrawn. The draw rate for both draw schedules shall be 1.0 gallon ± 0.25 gallons per minute (3.8 liters †0.95 liters per minute). DOE also requested comments and data on its proposal to extend test procedure coverage to storage-type water heaters of less than 20 gallons (76 liters).

Several commenters objected to one or more of these proposals. These commenters variously cited the following reasons: (1) The existing minimum efficiency standards are based on field applications and usage requirements for larger volume water heaters and are inappropriate for smaller-volume water heaters, for example, fitting and connection losses would be unfairly treated for smaller-volume water heaters because those losses would represent a larger percentage of total losses; (2) it is difficult to install thermocouples and to control flow rates in smaller-volume water heaters; (3) smaller-volume water heaters cannot meet the efficiency requirement because they typically are installed in confined areas, which limits the amount of insulation used to reduce surface losses; and (4) a flow rate of 1 gpm during water draws is too large for smaller water heaters' it would quickly deplete the quantity of hot water in tanks of 2.5 gallons or less. (GAMA, No. 1 at 3, No. 35 at 3, and July 1995 Transcript at 12; EPRI, No. 17 at 2; EEI, No. 2 at 6, No. 27 at 5, and July 1995 Transcript at 28; Oregon, No. 51 at 3 and February 1997 Transcript at 164 and 195; TVA, No. 14 at 1; The Southern Company Services, Inc., No. 24 at 2; American Electric Power, No. 38 at 1; Potomac Electric Power, No. 26 at 3; CSW, No. 4 at 2; Centerion Energy, No. 22 at 1; Nevada Electric Power, No. 45 at 2; National Rural Electric Cooperative Association, No. 18 at 2; Decatur County REMC, No. 19 at 1; and Dayton Power and Light, No. 20 at 1.)

GAMA suggested that separate piping arrangement figures be used for floor-mounted models of less than 20 gallons storage capacity. GAMA provided the schematic drawings for its suggested changes. (GAMA, No. 1 at 6 and July 1995 Transcript 17.)

Vaughn Manufacturing Corporation claimed: (1) The number of units is a small percentage of the total; (2) this is a utilitarian product which is used to fit special circumstances when other alternatives are not available; and (3) the publication of energy factors will not cause the purchaser to choose a more efficient model to an extent that will make a significant difference in national energy conservation. (Vaughn, No. 31 at 2.)

However, AGA believed that the large number of such heaters sold justifies some measurement that could be used for a minimum standard. (AGA, February 1997 Transcript at 184-185.) GAMA proposed running only a stand-by loss test for the measurement, and EPRI proposed to base this measurement on the maximum stand-by loss without considering daily water consumption. GAMA argued that any standard would have to be connected to some level of daily consumption. The FTC pointed out that if the test procedure covers these products, they would have to be labeled, and the label has to contain a value for energy consumption. In its written comments, GAMA stated that the applicable maximum hourly stand-by loss requirement in ASHRAE 90A–1980 was 43W. GAMA asserted that because the ASHRAE loss was based on an 80°F temperature difference, the DOE maximum loss rate should be 36.3W, based on the 67.5°F temperature difference for the DOE test. GAMA concluded that the DOE proposal for the 24-hour simulated use test should be scrapped and that only an hourly stand-by loss should be measured by the test procedure. (GAMA, No. 35 at 4 and February 1997 Transcript at 165 and 185–186; EPRI, February 1997 Transcript at 183–184; and FTC, February 1997 Transcript at 186.) This proposal was not supported by Virginia Power, who claimed that losses for fittings were greater for small tanks and that specialized uses for these tanks may limit the kinds of modifications leading to improved efficiency. Oregon supported the stand-by loss proposal and added that heaters with capacity equal to or less than 2 gallons (7.6 liters) be exempt from coverage and that all water heaters less than 20 gallons (76 liters) be exempt from the Energy Guide labeling requirement. EPRI expressed general support for GAMA's proposal, but suggested that a combination of stand-by loss and recovery efficiency rather than a single energy efficiency term be used to determine the energy standard for small water heaters. (Virginia Power, No. 42 at 3; Oregon, No. 51 at 3 and February 1997 Transcript at 164 and 195; EPRI, No. 56 at 5 and February 1997 Transcript at 164, 183, and 188 and at Appendix J at 2.)

Although the Department believes the stand-by loss measurement for water heaters less than 20 gallons (76 liters) proposed by GAMA and EPRI may be feasible, DOE will reserve consideration of this proposal for a future revision of the test procedure. The reasons for this decision are: (1) Absence of data to determine the appropriate daily hot water consumption, and (2) DOE's need to develop and evaluate the stand-by loss procedure. Therefore, DOE is withdrawing its proposal in today's Final Rule.

3. Definitions

In the 1995 proposed rule making, DOE solicited comments on the addition to the test procedure of definitions of a heat pump water heater storage tank and a solar water heater. DOE also proposed to revise the definition of a heat pump water heater to specify two types, an integral heat pump water heater and an add-on heat pump water heater.

The following discussion ensued:

(i) Solar Water Heater. GAMA stated that it did not understand the purpose or intent of the expanded definitions or the need to define ''solar water heaters'' for the test procedure. GAMA suggested that the requirement that a solar water heater obtain 50% of its annual heating energy from the sun is not a definitive criterion because a solar water heater with less than 50% of its input energy from the sun is still a solar water heater. (GAMA, July 1995 Transcript at 15 and No. 1 at 5.)

(ii) Heat Pump Water Heater Storage Tank. During the February 1997 workshop, GAMA proposed that a 50-gallon tank standardized with respect to the energy factor is adequate and should be used to test any add-on heat pump water heater sold without a tank by its manufacturer. (The existing DOE test

procedure specifies a 47-gallon tank meeting the minimum standard energy factor or not greater than .02 EF above the minimum.) GAMA objected to the Department's proposal for a special heat pump water heater storage tank.

EPRI objected to the inclusion of a special heat pump water heater storage tank, and proposed that an add-on heat pump water heater be tested with a standard 50-gallon tank as required under the existing DOE test procedure. EPRI further stated that there are no storage tanks labeled and designed for use exclusively with heat pump water heaters. All other commenters, such as the Oregon Energy Office and Virginia Power, agreed with GAMA's and EPRI's proposals for a standard 50-gallon tank. The Oregon Energy Office called for a revision of the original definition. (GAMA, February 1997 Transcript at 229; EPRI, No. 17 at 5 and February 1997 Transcript at 227; Oregon, No. 51 at 6; Virginia Power, No. 50 at 4.)

(iii) Add-on Heat Pump Water Heaters. EEI expressed concerns about the definition of add-on heat pump water heaters. EEI and EPRI claimed the definition is inappropriate and should not be adopted. They stated that add-on heat pump water heaters are designed to work with any electric water heater tank and that some are designed to work with any tank. EPRI claimed the new definition limits the availability of tanks for use with add-on heat pump water heaters. EPRI believes that this new definition would increase the cost. Further, EEI found that this definition is ill-advised, because new tanks of essentially identical construction must meet two definitions, thus creating confusion and potentially increasing the cost of heat pump water heaters. (EEI, No. 2 at 7, and No. 27 at 7; EPRI, No. 17 at 5.)

Virginia Power proposed deleting ''heat pump'' from the last line of the definition. (Virginia Power, No. 50 at 4.)

Vaughn Manufacturing Corp. commented that the addition of more than one category of heat pump water heaters, or even solar water heaters, will add to the confusion because it may lead consumers to compare test results of dissimilar types of water heaters. (Vaughn, No. 31 at 4.)

(iv) Integral Heat Pump Water Heaters. GAMA suggested that, instead of the 1995 DOE proposed definitions of ''integral heat pump water heaters'' and ''add-on heat pump water heaters,'' the respective definitions should be ''heat pump water heaters with tanks'' and ''heat pump water heaters without tanks''.

Also, GAMA objected to the term ''integral heat pump water heaters'' because it implies that the heat pump is structurally integrated with a tank, whereas in reality, the heat pump and the tank can be physically separated, but are usually sold by the manufacturer as a packaged unit. (GAMA, February 1997 Transcript at 230.)

Virginia Power proposed deleting the definition of ''integral heat pump water heater.'' (Virginia Power, No. 50 at 4.)

(v) *Proposed Revisions.* DOE responded to these comments in the October 1997 reopening notice. In this notice, DOE proposed the following revisions:

- Withdraw the definition of solar water heaters.
- Withdraw the proposal for heat pump water heater storage tanks for testing with an add-on heat pump water heater.
- Delete the definition of integral heat pump water heaters.
- Replace the definition of ''integral heat pump water heaters'' with the definition, ''Heat pump water heater with storage tank means an air-to-water heat pump sold by the manufacturer with an insulated storage tank as a packaged unit. The tank may be integral with or separated from the heat pump.''
- Replace the definition of ''add-on heat pump water heater'' with the definition, ''Heat pump water heater without storage tank (also called add-on heat pump water heater) means an air-to-water heat pump designed for use with a storage-type water heater or with a storage tank that is not specified or supplied by the manufacturer.''

EEI, Virginia Power, and GAMA supported DOE's proposed definitional changes in the October 1997 notice of reopening. (EEI, No. 65 at 1; Virginia Power, No. 66 at 4; and GAMA, No. 67 at 1.) No commenter took issue with the proposed definitional changes.

Therefore, DOE is adopting in this Final Rule the proposed revision as stated above.

4. Heat Pump Water Heaters

a. Back-up Electric Resistance Heating. In the Proposed Rule, the Department requested comments on the adequacy of the existing test procedure regarding back-up electric heating elements for heat pump water heaters because the current test setup and parameters may not represent operating conditions requiring the resistance element(s) to be activated. The existing procedure does not account for energy used by these elements because most heat pump water heaters are capable of meeting the test draw requirements of the 24-hour simulated use test for the energy factor and, therefore, the back-up electric resistance heating element(s) is not activated.

GAMA stated that the current draw schedule is such that the back-up electric resistance element(s) does not turn on during testing. Although GAMA concluded from tests conducted at Intertek Testing Service (ITS) that changing the current draw schedule by increasing the volume of water withdrawn will not activate the elements, it still argued that in residential applications, a significant percentage of the energy for water heating (15–20%) comes from the back-up resistance element(s). GAMA asserted that this energy should be included in determining the annual energy consumption of the heat pump water heater. This view is shared by the Southern Company Services (SCS). (GAMA, No. 1 at 5, No. 35 at 5, July 1995 Transcript at 16, and February 1997 Transcript at 241; and SCS, No. 24 at 2.) Vaughn Manufacturing Corporation claimed that the one-hour recovery between the six small draws prejudices the test procedure in favor of heat pump water heaters. Furthermore, Vaughn claimed, this test profile is not based on a representative average use cycle. (Vaughn, No. 31 at 3.) Georgia Power recommended that the draw schedule continue to stipulate 10.7 gallons per draw for each hour. (Georgia Power, No. 54 at 2.)

GAMA recommended adding some electrical energy to the annual energy consumption calculation but GAMA did not recommend a specific amount of energy. GAMA claimed that this electrical energy was necessary because no resistance heating was measured during tests of heat pump water heaters using the DOE test procedure and GAMA claims that it is well accepted that heat pump water heaters use backup resistance heating during periods of heavy draws. (GAMA, No. 57 at 2 and February 1997 Transcript at 240–260.) The recommendation was supported by AGA and the Oregon Energy Office. (AGA, February 1997 Transcript at 254 and 263; Oregon, February 1997 Transcript at 248, 250, and 255; and Oregon, No. 51 at 5.)

However, EPRI claimed that its data shows that less than 10 percent of the energy consumption for water heating with heat pumps actually comes from the back-up resistance elements for customers who use about 64 gallons of hot water per day. EPRI argued that it would be improper to apply a correction factor to compensate for resistance elements that do not activate during average test conditions. Moreover, EPRI added that if a correction factor is applied to heat pump water heaters, then correction factors due to regional conditions would need to be applied to all types of water heaters. Based on these reasons, EPRI is opposed to the recommendation by GAMA. (EPRI, No. 56 at 2, February Transcript at 239, 248, 257 and 264 and at Appendix J at 2.) Virginia Power agreed with EPRI's comments. (Virginia Power, No. 50 at 4, and February 1997 Transcript at 249 and 258.)

Other opponents to GAMA's recommendation included Abrams and Associates, who commented that the purpose of the test procedures is to rate water heaters for comparison purposes rather than to reflect actual household applications. Lawrence Berkeley National Laboratory (LBNL) stated that heat pump water heaters do not need a separate test procedure to account for backup resistance heating because of their insignificant market share and greater efficiency. EEI commented that to activate the heating elements would require a draw in excess of 50 gallons, which is not realistic. AIL Research stated that no correction factor should be used until data becomes available. (Abrams, February 1997 Transcript at 260; LBNL, February 1997 Transcript at 252; EEI, February 1997 Transcript at 255; and AIL, February 1997 Transcript at 261–264.)

The Department believes that the 24-hour simulated use test for the energy factor must be based on average test conditions that also apply to other water heaters of comparable size and use so that all storage-type water heaters are tested and rated on a consistent and uniform basis. Furthermore, DOE notes that based on test data submitted by GAMA, the back-up heating elements for heat pump water heaters will not activate when the volume of hot water drawn is changed from 10.7 gallons to a more severe 21.4 gallons per draw during two of the six draws of the 24-hour simulated use test. The Department believes that any single draw in the draw schedule greater than the 21.4 gallons per draw (as tested) would not be considered as an average use pattern. Because the test procedure is for comparison purposes and is not intended to take into account all potential field use patterns (such as the draw-down of the storage tank), DOE considers that a revision to the current draw schedule of 10.7 gallons per draw for the six draws in the 24-hour simulated use test (for example, stipulating 21.4 gallons per draw for two of the six draws) is not necessary because it will not change the result. Furthermore, there is no agreement on an average percent of the annual energy consumption that comes from the resistance heating elements. Therefore, the Department concludes that applying a correction to the energy factor and/or annual energy consumption of the heat pump water heater to account for the energy used by the resistance elements that do not activate during testing is unwarranted and will not be included in today's Final Rule.

b. Installation Requirements. The installation requirements in Section 4.1 of Appendix E of the current test procedure state that a heat pump water heater without a manufacturer-supplied storage tank shall be connected to the storage tank in accordance with the manufacturer's instructions. The requirements further state, ''If installation materials are not provided by the heat pump manufacturer, use uninsulated 8 foot (2.44 m) long connecting hoses, having an inside diameter of 5/8 inch (1.6 cm).'' The intent of this requirement is to specify a uniform test setup for those units that do not include manufacturer's instructions. DOE asked for comments on this issue.

EPRI commented that the term ''installation materials'' in this context is unclear. EPRI suggested changing ''installation materials'' to a more descriptive term because most manufacturers of add-on heat pump water heaters, or any other type of water heater, do not provide the plumbing hardware and should not be penalized for not doing so. (EPRI, No. 17 attached report at 6.) American Electric Power claimed that the installation requriements were vague. (American Electric, No. 38 at 1.) Oregon suggested that in cases in which manufacturers do not include instructions, the test procedure should be performed using insulated hoses of sufficient length and size to properly mount the heat pump unit relative to the storage tank. (Oregon, No. 51 at 6.)

To make the wording clear, DOE is revising the text in section 4.1 of Appendix E from ''installation materials'' to ''installation instructions'' as suggested by EPRI. DOE disagrees with Oregon's comment because in most residences, the hot water pipes usually are not insulated. DOE believes that the 8-foot hose is adequate to make the heat-pump-to-water-heater connection and ensure that the heat loss from the uninsulated hose is equal for all add-on heat pump water heaters that do not have manufacturers' installation instructions.

c. Heat from the Ambient Air. The current and proposed test procedures use the same test conditions and test procedures for oil-fired, electric and heat pump water heaters. Vaughn claimed that because the DOE test procedure does not account for heat removed from the ambient air, the procedure favors heat pump water heaters. (Vaughn, No. 31 at 3.)

The Department has considered this topic and has concluded that the interactions between heat pump water heaters and the building environment are extremely complex and difficult to measure. Furthermore, in some cases, heat pump water heaters may be installed outside the building, in which case the heat removed from the ambient air is free and does not need to be counted. For these reasons, DOE will address building and heat pump interactions in a future rulemaking.

5. First-Hour Rating for Storage-type Water Heaters

In the 1995 proposed rulemaking, DOE proposed a revised test procedure for the first-hour rating for storage-type water heaters. The proposed revision specifies the start of a first draw at the beginning of the one-hour period, when the average tank temperature is at the specified limit of 135°F ± 5°F (57.2°C ± 2.8°C) and all the thermostats are satisfied. The first draw is terminated when the outlet water temperature decreases by 25°F (13.9°C) below the maximum outlet temperature recorded during the draw. Successive draws are initiated when the uppermost thermostat is satisfied following a tank recovery, and ended when the outlet water temperature decreases by 25°F (13.9°C) below the maximum outlet temperature recorded during each particular draw.

At the end of the one-hour period, a final draw is initiated if no draw is in progress. This draw is terminated when the outlet water temperature decreases to the value used to terminate the draw that was completed before this final draw. If a draw is in progress at the end of the one-hour period, this draw is continued until the outlet water temperature decreases by 25°F (13.9°C) below the maximum outlet temperature recorded during this draw. A temperature correction factor is applied to the last draw. The correction factor is a quotient in which the numerator is the average delivered water temperature of the last draw minus the minimum water temperature of the next-to-last draw and the denominator is the average delivered water temperature of the next-to-last draw minus the minimum water temperature of the next-to-last draw. The correction factor corrects for any significant reduction in energy content of the draw due to a lower average outlet water temperature over the draw than those obtained during the earlier draws.

Thermally compensating dip tubes and integral mixing valves result in higher first-hour ratings. DOE did not propose to apply a correction factor to water heaters employing these features because the Department was unaware of the existence of these features on currently manufactured water heaters. However, EPRI, EEI, and Nevada Power Company stated that because at least one U.S. manufacturer has purchased the right to manufacture and sell the equivalent of an ''internal mixing'' product, DOE should develop a procedure that accounts for differences in hot water delivery temperatures. (EEI, No. 27 at 5; EPRI, No. 17 at 12; and Nevada Power Company, No. 45 at 3.) Southern Company Services (SCS) argued that specifications for mixing valves (similar to internal mixing) are not relevant to efficiency and the use of mixing valves should not be restricted. Furthermore, SCS supported the test procedure proposed by Dr. Carl Hiller of EPRI, which it claimed would not be affected by mixing valves. (SCS, No. 24 at 2.)

EEI and EPRI commented that DOE's proposed first-hour rating procedure, while an improvement over the current (1991 Final Rule) and previous (1978) DOE procedures, is still flawed and should not be implemented. Both EEI and EPRI based their comments on the analysis of the DOE proposed procedure by Dr. Carl Hiller of EPRI. (EEI, No. 2 at 2, No. 27 at 2, and July 1995 Transcript at 22; and EPRI, No. 17 attached report at 2.)

Dr. Hiller commented that the DOE proposed procedure is based on unrealistic water consumption behavioral patterns, and bears little relevance to the sizing of hot water systems. Dr. Hiller stated that the procedure gives misleadingly high ratings to units having a high heat input rate, thus penalizing electric systems and systems with larger tanks. Dr. Hiller suggested that the entire proposed procedure should be abandoned and replaced with an alternative developed by EPRI. (EPRI, No. 17 at 9 and 13.)

Specifically, Dr. Hiller claimed that the DOE proposed first-hour rating procedure for storage-type water heaters is characterized by the following: (1) It penalizes large tanks because the draw rate of 3 gpm causes the draws to take longer for larger tanks, thus limiting useful reheat time; (2) the temperature correction factor applied to the last draw is cumbersome; (3) the draw at the end of the one-hour test results in a variable test time; (4) depending on the thermostat setting and behavior, two similar tanks may show dramatic differences in their first-hour ratings; (5) the one-hour time period in the procedure is arbitrary and relatively irrelevant to water heating system sizing; and (6) the procedure fails to account for the energy content of water delivered at different temperatures during the draws. (EPRI, No. 17 at 9–13.)

Dr. Hiller proposed three EPRI alternatives to DOE's first-hour rating procedure. The first alternative calculates first-hour rating as the sum of (1) the volume of water from an initial draw (multiplied by a factor to correct to a uniform delivery temperature of 110°F (43.3°C) and (2) the maximum useful reheat volume (water is heated to 110°F [43.3°C]) at the rated energy input between the end of the first recovery (after the first draw) and the end of a specified reheat time period. This EPRI proposal uses a calculation to determine the maximum useful reheat volume during the specific reheat period; EPRI notes that the maximum useful reheat volume could also be determined with actual draws. In this proposal, EPRI advocates a reheat period of 35–45 minutes instead of one hour. (EPRI, No. 17 at 13.)

The second EPRI alternative, proposed by Dr. Hiller at the February 1997 workshop, bases tank sizing on a graph of the way hot water is actually used over a specific time period together with graphical representations of hot water delivery capability (a stepwise function versus time due to reheat delay) for various water heaters. The water heater size is found by overlaying the two graphs of hot water delivery capability and hot water consumption requirement. EPRI provided examples of data for several tank sizes for hot water delivered not exceeding once per day, once per week and once per month derived from a 2½ year EPRI field study at 14 metered sites with electric storage-type water heaters. (EPRI, No. 56 at 6, and February 1997 Transcript at Appendix J at 4–10.)

In its comments after the February 1997 workshop, EPRI proposed a third alternative first-hour rating procedure, which modified its first proposal. In this procedure, hot water is drawn initially and during four reheat cycles. Data from the five corresponding draws (stepwise in form as in the second alternative) are used to establish a graphical representation of hot water availability versus time, including the reheat time delay between the first draw after recovery (on the basis of the cut-out of the uppermost thermostat) and the subsequent draw. From these measurements, the actual first draw volume available and the actual average reheat rate of the system are determined. After the first reheat is completed, a linear calculation is performed to estimate the number of additional gallons that can be produced based on the average reheat rate. Then the ''minimum'' maximum water availability curve is calculated. The hot water delivery rating from the graph is determined based on the minimum hot water availability curve together with a ''critical design time interval'' of 35 minutes. EPRI claimed that this procedure accounts for the first draw volume and the reheat rate, as well as the reheat time delay between the hot water run-out after the first draw and the completion of the recovery (on the basis of the cut-out of the uppermost thermostat). EPRI claimed that this procedure is better than the DOE proposed procedure because the reheat delay time is accounted for. The third alternative differs from the first alternative primarily because the third alternative involves four cycles of reheating, and the water temperature at the top of the tank after recovery is at 135°F (57.2°C) instead of 110°F (43.3°C). (EPRI, No. 56 attached report at 11–12.)

This proposal includes an optional method that permits manufacturers to list the first draw as the first draw rating because the 35-minute hot water delivery rating is typically at or near the first draw capability of the tank. This avoids the need to perform the four reheats and five draws. (EPRI, No. 56 attached report at 13.)

Virginia Power and American Electric Power (AEP) also stated their opposition to the DOE first-hour rating and their support of a maximum first draw rating. Virginia Power claimed that the maximum first draw rating more accurately represents typical consumer action. (Virginia Power, No. 50 at 2; AEP, No. 53 at 1.)

Rheem Manufacturing claimed the first-hour rating is seldom used by consumers in purchasing water heaters. (Rheem, February 1997 Transcript at 154–155.)

Georgia Power claimed that the first-hour rating is biased toward gas-fired water heaters. Georgia Power proposed an alternative method which involves checking the temperature in the top of the tank periodically after the first draw is complete. When the temperature is above the minimum setpoint temperature, a second draw should begin. It claimed that this procedure reflects the way a consumer would use hot water after a run-out. (Georgia Power, No. 54 at 1.)

GAMA stated that it does not support EPRI's alternative first-hour rating procedures. GAMA claimed that the current and proposed DOE test procedure, in which water is drawn from a tank full of heated water and then subsequent draws are made each time the tank returns to the setpoint temperature within an hour, is an appropriate way to evaluate a water heater's capability to provide heated water. GAMA stated that the DOE procedure may require some modifications and corrections in the calculations, but GAMA did not believe it is necessary to rewrite the entire first-hour rating procedure (as suggested by EPRI). (GAMA, No. 1 at 2, and No. 35 at 2, and July 1995 Transcript at 10.)

GAMA claimed the 1990 procedure gives a first-hour rating volume that may be smaller than the first draw volume for larger tanks. GAMA presented the results of tests conducted by its water heater manufacturer members that compared representative models of gas-fired and electric water heaters. The test results were compiled from both the current test procedure and the 1995 DOE proposed first-hour rating test procedure. The data show that the proposed procedure does provide a first-hour rating that reflects a combination of the water heater's storage capacity and recovery rate. In a written submittal at the February 1997 workshop, GAMA presented additional test results conducted by Intertek Testing Service on water heaters tested in the GAMA efficiency certification program. The data showed that 53 gas-fired water heaters (with storage capacities of 30–50 gallons) were tested, and the difference between the first-hour rating using the proposed procedure and the first-hour rating based on the current procedure varied from −0.2 gallons to 8.0 gallons with a standard deviation for each tank volume class tested of 3.7–6.0 gallons. The data also showed that 51 electric water heaters (with storage capacities of 30–82 gallons) were tested, and the differences in rating value were from 3.7 gallons to 5.5 gallons with a standard deviation for each tank volume class tested of 2.0–5.8 gallons. GAMA believed that the data is indicative of a general trend and that it does support the use of the proposed first-hour rating test procedure. (GAMA, No. 1 at 2, No. 35 at 2, and February 1997 Transcript at 91–92 and at Appendix I at 1–2.)

GAMA, in the same written submittal at the February 1997 workshop, claimed DOE should provide an alternative conservative calculation for the first-hour rating. GAMA's suggested calculations are based on 1995 and 1996 data from GAMA's efficiency certification program. The 1996 data show that the volume of the first draw compared to the rated volume is about 0.85 for gas-fired water heaters and 0.78–0.85 for electric water heaters. GAMA proposed three calculations for first-hour rating: (1) For gas-fired water heaters, the first-hour rating equals 0.8 of the tank volume plus an energy-based correction factor; (2) for dual-element electric water heaters, the first-hour rating equals 0.75 of the tank volume plus an energy-based correction factor; and (3) for a single element electric water heater, the first-hour rating equals 0.75 of the volume. GAMA claimed these calculations give conservative results. (GAMA, February 1997 Transcript at Appendix I at 1–2.)

GAMA, in a later submittal following the February 1997 workshop, stated that its proposed optional first-hour calculation for electric water heaters should be modified to provide a more accurate first-hour value for larger volume models. It stated that the original calculation leads to an assumption that no recovery will occur for 24 minutes with an 80-gallon tank. GAMA stated that because the lower heating element turns on in 2–5 minutes into the first-hour rating test in all electric water heaters, GAMA decided to modify the volume-related correction factor for dual-element electric water heaters to reflect this. (GAMA, No. 57 at 1.)

Supporters of the DOE proposal for determining the first-hour rating include the AGA, which finds it useful in determining the proper size of a water heater, stating that proper sizing is important for energy conservation, customer satisfaction and safety. (AGA, No. 55 at 1.) The Oregon Energy Office recommended DOE adopt its 1995 proposal and not adopt any part of the EPRI proposals because Oregon claimed EPRI put too much weight on the first draw volume, thus promoting larger tanks. (Oregon Energy Office, No. 51 at 2 and February 1997 Transcript at 110–112.) In a statement submitted after the February 1997 workshop, Battelle Columbus presented some experimental data and analysis of a 35,500 Btu/h, 50-gallon gas-fired water heater. Battelle presented data to show that the test water heater was able to satisfy the ''once a month'' draw schedules based on the EPRI field tests of 15 actual households. Battelle claimed that the test water heater could meet 12 of the 15 household hot water loads with a delivery temperature above 110°F. Battelle claimed the data showed that the DOE first-hour rating procedure is a good predictor of water heater performance. (Battelle, No. 58 at 1.)

George Kusterer of Bock Water Heaters stated that the information relating to EPRI's alternate first-hour rating method is inconclusive and recommended it not be accepted by DOE. Bock also claimed that a first-hour rating based only on the first draw will not work. (Bock, February 1997 Transcript at 146, 151 and 153.)

In response to EPRI's comments on the effect of the draw rate, DOE does not agree that a 3 gpm draw rate will result in a shorter reheat time for larger tanks. This is due to the fact that, for most electric water heaters, the bottom element will turn on within 5 minutes into the first draw. Also, a larger draw rate and a longer reheat time may not increase the total amount of hot water drawn because the heat input rate and not the draw rate will determine whether a tank can recover to a minimum temperature of 110°F. This recovery capability is the reason that the size of the storage tank is not the only criterion for first-hour rating.

Tank size is critical for simultaneous water usage, but tank recovery rate, either by a greater input rate or by dual—heating element design, could prove critical during times of consecutive hot water usages. While it is true that a consumer will not wait for the tank water temperature to reach 135°F or the thermostat to cut out before turning on the hot water faucet, the one-hour rating does provide a simple and easy to understand indication of the combined effects of tank size and recovery rate within a reasonable time frame where heavy use of hot water may occur (for example, during the morning hours). It is also a definitive procedure for manufacturers to use for labeling but it is not necessarily an appropriate criterion for tank sizing since that depends on consumer behavior and uses of hot water.

The temperature correction factor is used to adjust the volume of the last draw to account for the possible lower heat content of the last draw than those earlier draws with fully heated water. DOE has created the temperature correction factor as a simple arithmetic temperature ratio using temperature data that has already been measured during the test. DOE realizes that the temperature of the last draw may be at a lower temperature than those of earlier draws.

DOE does not believe that due to the imposition of the last draw at the one-hour mark, two similar tanks, one at 111°F and the other at 109°F, will result in a large difference in the amount of total volume drawn. The temperature correction factor is specifically applied to prevent that from happening. For example, assuming that the whole tank of water at 111°F is drawn, the temperature ratio, (111–110)/(130–110) = 0.05, will add only 5% of the last draw volume to the total volume drawn at the one-hour mark. (For illustration purposes, the maximum outlet temperature is assumed to be 135°F and the average outlet water temperature during a regular—not the imposed—draw is assumed to be 130°F.) DOE believes this difference of 5% of the volume of the tank is acceptable for grouping models of storage-type water heaters.

There were claims that the DOE test period of one hour is too long. The one-hour time period is related to a similar period of high water consumption in most residences. Although the EPRI data indicates a shorter time, DOE believes that more data is necessary to establish a national average pattern of use, and DOE does not believe that a reduction of 25 minutes in test time, as suggested by EPRI, is merited. There were no comments from manufacturers or GAMA that the shorter test time was desirable. Rather, Darrell Paul, EEI, Bock, and Group Thermo stated that people tend to adjust their hot water use pattern during high consumption periods to account for short periods without hot water. (Battelle Columbus, February 1997 Transcript at 47; EEI, February 1997 Transcript at 49; Bock, February 1997 Transcript at 52; Group Thermo, February 1997 Transcript at 53.)

Regarding the comment that a final draw results in a variable testing time, certainly the imposition of a final draw extends the test period beyond one hour. However, the procedure requires the cessation of input energy at the one-hour mark. Therefore, DOE believes this is an equitable way to account for all the usable heat energy input to the water heater within the one-hour time frame.

DOE does not believe that a correction factor for hot water tanks with induced interim mixing will improve the accuracy of the test procedure enough to warrant its inclusion. DOE does agree that a temperature correction factor should be applied to the water drawn during each of the draws if a thermally compensating dip tube or an internal mixing device is used. However, at the present time there is no water heater that employs a mixing valve or thermally compensating dip tube during its normal operation. One design that does employ a mixing device is a special application for utility demand-side management in which higher temperature hot water is heated and stored during periods of low electricity demand. However, such a tank can be tested under the proposed DOE test. Therefore, a correction factor for induced internal mixing is not needed at this time.

The Department reviewed and evaluated two of the proposals presented by EPRI (the second and the third, the latter of which is EPRI's modification of its first alternative). DOE considers that the second proposal, as stated by EPRI, is still in the development stage. DOE believes that when completely developed, the method may be included and used, in graphical or tabulated forms, in a design manual for use by designers to size the hot water tank for the needs of a particular customer. However, to adopt the procedure for a single number rating purpose would require the development of, and agreement by all concerned parties to, an average national utilization curve to be used in conjunction with EPRI's hot water delivery capability graphs for various models of water heaters. The Department believes that prospect will not be feasible in the near future. Furthermore, the Department believes that EPRI's third proposal should not be adopted. The reasons are (1) the procedure puts more weight on the first draw, which would tend to encourage the use of larger tanks; (2) the hot water produced during the recovery period is not included, even though it is available at the end of recovery; (3) the proposed four reheat cycles may require a very long test time, especially for larger electric tanks; (4) for water heaters with a lower heat input rate, the subsequent draw rate, which provides continuous 135°F (heated up from the 58°F inlet condition) water and is calculated on the basis of the reheat rate, will be much lower; and (5) the procedure, and any modification to it, has not been tested.

The Department has decided not to adopt the optional calculation procedure proposed by GAMA. The Department checked the optional calculation procedure against data published in the GAMA directory and found that the results for first hour rating varied among electric, gas-and oil-fired water heaters. Furthermore, the coefficients proposed by GAMA were based on the current test procedure for first hour rating. The Department believes that the optional calculation may have merit, but the coefficients need to be based on the first hour rating in this Final Rule. For these reasons, the Department has decided to adopt the 1995 proposed procedure for first-hour rating in today's Final Rule.

6. Installation of Under-the-Counter and Counter-Top Water Heaters

The installation requirements in section 4 of Appendix E of the proposed test procedure do not distinguish under-the-counter water heaters from counter-top water heaters. GAMA recommended these be addressed separately because they are intended for different installations. GAMA indicated that because the water connections for counter-top models are within the water heater jacket, they can be installed flush to the back wall, and that this is not true for under-the-counter models. GAMA also recommended that separate piping arrangements be provided for floor-mounted water heaters with storage capacities less than 20 gallons. GAMA submitted four figures illustrating these configurations. (GAMA, July 1995 Transcript at 17 and No. 1 at 6.) Intertek Testing Services confirmed that GAMA's suggested changes are consistent with the normal practice in testing these types of models. Intertek further furnished piping schematics for those under-the-counter models that have a side inlet port and a top center outlet port. (Intertek, No. 62 at 1.)

The Department supports these proposals. The Department understands that if a counter-top model is installed with the back surface of the water heater jacket flush against the wall, the heat loss through the back surface will be different from an installation in which the back surface is exposed directly to the ambient air. DOE also understands that for under-the-counter models, the limitation of space under the counter necessitates a short piping connection, which should be reflected in the installation requirement. Therefore, the installation figures for piping connections for under-the-counter and counter-top water heaters as provided by GAMA and Intertek are included in today's Final Rule (as Figures 3, 4, 5, 6, 7A, and 7B in Appendix E). Sections 4.1 and 4.3 of Appendix E are revised to indicate these new figures and the requirement for a simulated wall against the back side of a counter-top model.

7. Test Conditions

a. Daily Hot Water Usage. The current test procedure prescribes water heater testing to determine the energy factor must be based on a daily hot water usage of 64.3 gallons per day (gpd). DOE did not propose to change the daily hot water usage in the 1995 proposed rulemaking.

The American Gas Association (AGA) and Battelle Columbus argued that the current daily hot water usage is outdated and proposed it be lowered to 54 gpd to reflect a recent study. (AGA, No. 25 at 2; and Battelle, No. 46 at 1.) Virginia Power suggested lowering the daily hot water usage to 50 gpd or less. Virginia Power also stated that because the daily usage value is used in energy estimation and design calculations, changing it to a current value will maximize the usefulness and applicability of the test results. EEI suggested lowering the daily hot water usage to 50–57 gpd. Georgia Power argued for a value close to 50 gpd. (Virginia Power, No. 50 at 3 and February 1997 Transcript at 212 and 223; EEI, February 1997 Transcript at 201; and Georgia Power, No. 54 at 2.) EPRI stated that there is substantial evidence, based on its recent study of submetered electric utility load data from 28 different sources, that the daily hot water consumption should be less than 50 gallons. However, EPRI, as well as GAMA, the Oregon State Energy Office, A.O. Smith, and Effikal International (Effikal), indicated that lowering the gpd value would not alter the relative efficiency ranking (based on energy factor) of the water heaters, but would impose an additional cost burden on industry for retesting and relabeling. The five commenters, therefore, suggested that DOE maintain the current daily hot water usage of 64.3 gpd in the test procedure. GAMA also suggested that, if necessary, it is possible to use linear estimation of energy consumption based on a different daily usage. The Oregon Energy Office suggested that the variation of the daily usage value with individual consumers is quite large, and the current 64.3 gpd may not be too far from the average. (EPRI, No. 56 at 13 and February 1997 Transcript at 221 and at Appendix J at 2; GAMA, February 1997 Transcript at 215; Oregon State Energy Office, February 1997 Transcript at 219; A.O. Smith, February 1997 Transcript at 220; Effikal, February 1997 Transcript at 224; and Oregon, No. 51 at 4.)

The Department believes that the current value of 64.3 gpd is useful in determining an energy factor for consumers to use to compare water heaters. The Department believes that revising the value so it can be used to estimate or predict energy consumption will require a more detailed evaluation of individual installation locations, thermostat settings, and use patterns. Based on the fact that a revised daily hot water usage has not been agreed upon, and that the industry would be financially burdened, the Department concludes that revising the daily hot water usage is unwarranted in today's Final Rule.

b. Storage Tank Temperature. The existing test procedure uses a thermostat setting of 135°F ± 5°F (57.2°C ± 2.8°C). DOE did not propose to revise this setting in the 1995 proposed rulemaking. AGA suggested that the thermostat setting be lowered to 120°F ± 5°F (48.9°C ± 2.8°C) to reflect the manufacturers' recommendation to consumers to lower the temperature settings on water heaters thus preventing potential scalding. (AGA, No. 25 at 4.)

Both Virginia Power and Bock Water Heaters also supported lowering the current thermostat setting to 120°F (48.9°C). The reasons cited included: (1) The current setting of 135°F (57.2°C) does not reflect how consumers actually operate their water heaters; (2) most energy-related organizations advocate a setting of 120° ±F (48.9°C) when promoting energy efficiency and safety; (3) scalding by hot water at 135°F (57.2°C) is a major concern in some areas; and (4) certain local codes restrict the thermostat setting to be no higher than 120°F (48.9°C). EEI stated that for several years many customers have been told to set their thermostats at 120°F (48.9°C). (Virginia Power, No. 50 at 3 and February 1997 Transcript at 212 and 223; Bock Water Heaters, February 1997 Transcript at 207 and 211; and EEI, February 1997 Transcript at 201.)

In contrast, six commenters, individually or in support of another commenter's position, opposed lowering the thermostat setting from 135°F ± 5°F (57.2°C ± 2.8°C). (EPRI, No. 56 at 2 and February 1997 Transcript at 199, 208, and 218 and at Appendix J at 1; GAMA, February 1997 Transcript at 215 and at Appendix I at 3; Oregon State Energy Office, No. 51 at 4 and February 1997 Transcript at 201, 204, and 219; Group Thermo, February 1997 Transcript at 206; A.O. Smith, February 1997 Transcript at 220; and Effikal International, February 1997 Transcript at 224.) Their various comments are: (1) A setting at 120°F (48.9°C) could pose a potential health risk (e.g., legionella) to consumers; (2) a setting at 135°F (57.2°C) is necessary to meet consumers' expected hot water needs (as with machine-use for washing clothes); (3) a setting at 135°F (57.2°C) reflects realistic household settings; and (4) changing the thermostat setting from 135°F (57.2°C) will not alter the comparative ranking of water heaters but would result in a substantial cost to industry in retesting and relabeling. EEI stated that it would not object if the current requirement in the test procedure is not revised. (EEI, February 1997 Transcript at 220.)

Based on the comments in the record regarding actual field thermostat setting by consumers, potential health concerns and the potential burden on industry, the Department concludes that revision of the thermostat setting from 135°F ± 5°F (57.2°C ± 2.8°C) to 120°F ± 5°F (48.9°C ± 2.8°C) is unwarranted in today's Final Rule.

c. Ambient Air Temperature. The current DOE test procedure specifies ambient air temperature for heat pump water heaters to be 67½°F ± 1°F (19.7°C ± 0.6°C) and for all other water heater types to be between 65° F (18.3°C) and 70° F (21.1°C) . DOE did not propose a change to these values. EPRI stated that the existing ambient air temperature values are satisfactory, but suggested using a nationwide survey to determine more representative ambient air temperature values. (EPRI, No. 56. at 5.) DOE believes a survey is unnecessary and will continue to use the current values.

d. Supply Water Temperature. The current DOE test procedure specifies supply water temperature to be 58°F ± 2°F (14.4°C ± 1.1°C). DOE did not propose a change to this value. EPRI stated that the existing supply water temperature value is satisfactory, but suggested revisiting the value periodically because of the possible change of the average source temperature caused by regional shifts in the population. (EPRI, No. 56 at 5 and 6.) DOE believes the current value for supply water temperature is appropriate and that changing it would place an unreasonable burden on manufacturers.

e. Relative Humidity. The current DOE test procedure specifies relative humidity for heat pump water heaters to be between 49% and 51%. DOE did not propose a change to this value. EPRI stated that the existing humidity value is satisfactory, but suggested using weighted regional averages in the future to account for humidity extremes. (EPRI, No. 56 at 5 and 6.) DOE believes the current value for humidity is appropriate and that changing it would place an unreasonable burden on manufacturers.

8. Cost-Based Correction Factor for Fossil-Fueled Residential Appliances

The current procedure provides a test method to measure the energy efficiency of water heaters that is used to rate units of similar volumes for comparison purposes. This measure of energy efficiency is known as the energy factor (EF). DOE did not propose any amendment to the existing test method in the Proposed Rule.

AGA commented that because the energy factor is calculated from measurements of the consumption of energy at the site, the EF for fossil-fueled water heaters is substantially lower than the EF for electric water heaters. AGA also stated that gas-fired water heaters typically cost consumers considerably less to operate. AGA stated that there is no correlation between the current energy descriptor and the cost of operation. AGA believes this inconsistency between the energy descriptor and cost of operation can be extremely misleading to the consumer if a purchase decision is based primarily on the energy factor or annual energy consumption. Therefore, AGA suggested that the energy usage of the water heater be adjusted by a multiplication factor of 0.298 which represents the ratio of the average cost of fossil fuel to electricity. (AGA, No. 25 at 5.)

The 0.298 factor is the inverse of DOE's F-factor of 3.36 which was proposed in the furnaces/boilers, vented home heating equipment and pool heaters test procedures. The F-factor would have allowed the consumption of fossil fuel and electricity to be combined into a single value by placing the two energy types on a common basis. (60 FR 4348, January 20, 1995.)

In response to disagreement from an overwhelming majority of commenters regarding the proposed F-factor, the Department stated that the Energy Policy and Conservation Act, as amended, requires the energy efficiency of a furnace to be based on consumption of energy at the site per the definition of ''energy use,'' 42 U.S.C. 6291(4). The Department also concluded that the statute does not permit the promulgation of an energy efficiency standard that is expressed in terms of annual operating costs of the furnace. Based on this analysis, the Department withdrew the proposed F-Factor in its Final Rule Regarding Test Procedures for Furnaces/Boilers, Vented Home Heating Equipment and Pool Heaters. (62 FR 26140, May 12, 1997.) Likewise, DOE will not adjust the energy factor for electric water heaters to a source basis as proposed by AGA.

III. Procedural Requirements

A. Review Under the National Environmental Policy Act of 1969

In this rule, the Department will finalize amendments to test procedures that may be used to implement future energy conservation standards for water heaters. The Department has determined that this rule falls into a class of actions that are categorically excluded from review under the National Environmental Policy Act of 1969 (NEPA), 42 U.S.C. 4321 *et seq.* The rule is covered by Categorical Exclusion A5, for rulemakings that interpret or amend an existing rule without changing the environmental effect, as set forth in the Department's NEPA regulations at Appendix A to Subpart D, 10 CFR part 1021. This Final Rule will not affect the quality or distribution of energy usage and, therefore, will not result in any environmental impacts. Accordingly, neither an environmental impact statement nor an environmental assessment is required.

B. Review Under Executive Order 12866, ''Regulatory Planning and Review'

Today's Final Rule is not a ''significant regulatory action'' under Executive Order 12866, ''Regulatory Planning and Review.'' 58 FR 51735 (October 4, 1993). Accordingly, today's action is not subject to review under the Executive Order by the Office of Information and Regulatory Affairs.

C. Review Under the Regulatory Flexibility Act of 1980

The Regulatory Flexibility Act of 1980, 5 U.S.C. 601–612, requires that an agency prepare an initial regulatory flexibility analysis for any rule, for which a general notice of proposed rulemaking is required, that would have a significant economic effect on small entities unless the agency certifies that the rule, if promulgated, will not have a significant economic impact on a substantial number of small entities. 5 U.S.C. 605. DOE certified in the notice of proposed rulemaking that the rule would not have a significant economic impact on a substantial number of small entities. DOE estimates there are approximately 7 manufacturers of water heaters for specialty markets that may be small entities as defined in the Regulatory Flexibility Act. The manufacturers of heat pump water heaters and storage-type water heaters already make the types of measurements required by this rule, and the cost of compliance will be negligible. Today's revised test procedures will have no immediate impact on manufacturers of instantaneous water heaters because there currently are no energy efficiency standards for instantaneous water heaters; in any event, the cost of compliance would not be significant. DOE received no comments on its certification in the proposed rule.

D. ''Takings'' Assessment Review

DOE has determined pursuant to Executive Order 12630, ''Governmental Actions and Interference with Constitutionally Protected Property Rights,'' 53 FR 8859 (March 18, 1988), that this regulation, if adopted, would not result in any takings which might require compensation under the Fifth Amendment to the United States Constitution.

E. Federalism Review

Executive Order 12612, ''Federalism,'' 52 FR 41685 (October 30, 1987), requires that regulations, rules, legislation, and any other policy actions be reviewed for any substantial direct effects on States, on the relationship between the Federal Government and the States, or in the distribution of power and responsibilities among various levels of Government. If there are substantial direct effects, then this Executive Order requires preparation of a Federalism assessment to be used in all decisions involved in promulgating and implementing a policy action.

The Final Rule published today would not regulate the States. Accordingly, DOE has determined that preparation of a Federalism assessment is unnecessary.

F. Review Under the Paperwork Reduction Act

No new information or record keeping requirements are imposed by this rulemaking. Accordingly, no OMB clearance is required under the Paperwork Reduction Act, 44 U.S.C. 3501 *et seq.*

G. Review Under Executive Order 12988, ''Civil Justice Reform''

With respect to the review of existing regulations and the promulgation of new regulations, section 3(a) of Executive Order 12988, ''Civil Justice Reform,'' 61 FR 4729 (February 7, 1996), imposes on executive agencies the following requirements: (1) Eliminate drafting errors and ambiguity; (2) write regulations to minimize litigation; and (3) provide a clear legal standard for affected conduct rather than a general standard and promote simplification and burden reduction. With regard to the review required by sections 3(a) and 3(b) of the Executive Order specifically requires that Executive agencies make every reasonable effort to ensure that the regulation: (1) Clearly specifies the preemptive effect, if any; (2) clearly specifies any effect on existing Federal law or regulation; (3) provides a clear legal standard for affected conduct while promoting simplification and reducing burdens; (4) specifies the retroactive effect, if any; (5) adequately defines key terms; and (6) addresses other important issues affecting clarity and general draftsmanship under any guidelines issued by the Attorney General. Section 3(c) of the Executive Order requires Executive agencies to review regulations in light of applicable standards in sections 3(a) and 3(b) to determine whether they are met or it is unreasonable to meet one or more of them. DOE reviewed today's rule under the standards of section 3 of the Executive Order and determined that, to the extent permitted by law, it meets the requirements of those standards.

H. Review Under the Unfunded Mandates Reform Act of 1995

Title II of the Unfunded Mandates Reform Act of 1995, 2 U.S.C. 1531 *et seq.*, requires each Federal agency, to the extent permitted by law, to prepare a written assessment of the effects of any Federal mandate in a final agency rule that may result in the expenditure by State, local, and tribal governments, in the aggregate, or by the private sector, of $100 million or more (adjusted annually for inflation) in one year.

The Department has determined that this Final Rule does not include any requirements that would result in the expenditure of money by State, local, and tribal governments. It also would not result in costs to the private sector of $100 million or more in any one year. Therefore, the requirements of the Unfunded Mandates Reform Act of 1995 do not apply to this rulemaking.

I. Congressional Notification

Consistent with Subtitle E of the Small Business Regulatory Enforcement Fairness Act of 1996, 5 U.S.C. 801–808, DOE will submit to Congress a report regarding the issuance of today's Final Rule prior to the effective date set forth at the outset of this notice. The report will note the Office of Management and Budget's determination that this rule does not constitute a ''major rule'' under that Act. 5 U.S.C. 801, 804.

List of Subjects in 10 CFR Part 430

Administrative practice and procedure, Energy conservation, Household appliances.

Issued in Washington, D.C., on April 6, 1998.

Dan W. Reicher,

Assistant Secretary, Energy Efficiency and Renewable Energy.

For the reasons set forth in the preamble, Part 430 of Chapter II of Title 10 of the Code of Federal Regulations is amended as set forth below:

PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS

1. The authority citation for Part 430 continues to read as follows:

Authority: Part B, Title III, Energy Policy and Conservation Act, (42 U.S.C. 6291–6309), as amended.

2. Appendix E to Subpart B of Part 430 is revised to read as follows:

Appendix E to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Water Heaters

1. Definitions

1.1 *Cut-in* means the time when or water temperature at which a water heater control or thermostat acts to increase the energy or fuel input to the heating elements, compressor, or burner.

1.2 *Cut-out* means the time when or water temperature at which a water heater control or thermostat acts to reduce to a minimum the energy or fuel input to the heating elements, compressor, or burner.

1.3 *Design Power Rating* means the nominal power rating that a water heater manufacturer assigns to a particular design of water heater, expressed in kilowatts or Btu (kJ) per hour as appropriate.

1.4 *Energy Factor* means a measure of water heater overall efficiency.

1.5 *First-Hour Rating* means an estimate of the maximum volume of ''hot'' water that a storage-type water heater can supply within an hour that begins with the water heater fully heated (i.e., with all thermostats satisfied). It is a function of both the storage volume and the recovery rate.

1.6 *Heat Trap* means a device which can be integrally connected or independently attached to the hot and/or cold water pipe connections of a water heater such that the device will develop a thermal or mechanical seal to minimize the recirculation of water due to thermal convection between the water heater tank and its connecting pipes.

1.7 *Instantaneous Water Heaters*

1.7.1 *Electric Instantaneous Water Heater* Reserved.

1.7.2 *Gas Instantaneous Water Heater* means a water heater that uses gas as the energy source, initiates heating based on sensing water flow, is designed to deliver water at a controlled temperature of less than 180°F (82°C), has an input greater than 50,000 Btu/h (53 MJ/h) but less than 200,000 Btu/h (210 MJ/h), and has a manufacturer's specified storage capacity of less than 2 gallons (7.6 liters). The unit may use a fixed or variable burner input.

1.8 *Maximum gpm (L/min) Rating* means the maximum gallons per minute (liters per minute) of hot water that can be supplied by an instantaneous water heater while maintaining a nominal temperature rise of 77°F (42.8°C) during steady state operation.

1.9 *Rated Storage Volume* means the water storage capacity of a water heater, in gallons (liters), as specified by the manufacturer.

1.10 *Recovery Efficiency* means the ratio of energy delivered to the water to the energy content of the fuel consumed by the water heater.

1.11 *Standby* means the time during which water is not being withdrawn from the water heater. There are two standby time intervals used within this test procedure: $\tau_{stby,1}$ represents the elapsed time between the time at which the maximum mean tank temperature is observed after the sixth draw and subsequent recovery and the end of the 24-hour test; $\tau_{stby,2}$ represents the total time during the 24-hour simulated use test when water is not being withdrawn from the water heater.

1.12 *Storage-type Water Heaters*

1.12.1 *Electric Storage-type Water Heater* means a water heater that uses electricity as the energy source, is designed to heat and store water at a thermostatically controlled temperature of less than 180°F (82°C), has a nominal input of 12 kilowatts (40,956 Btu/h) or less, and has a rated storage capacity of not less than 20 gallons (76 liters) nor more than 120 gallons (450 liters).

1.12.2 *Gas Storage-type Water Heater* means a water heater that uses gas as the energy source, is designed to heat and store water at a thermostatically controlled temperature of less than 180°F (82°C), has a nominal input of 75,000 Btu (79 MJ) per hour or less, and has a rated storage capacity of not less than 20 gallons (76 liters) nor more than 100 gallons (380 liters).

1.12.3 *Heat Pump Water Heater* means a water heater that uses electricity as the energy source, is designed to heat and store water at a thermostatically controlled temperature of less than 180°F (82°C), has a maximum current rating of 24 amperes (including the compressor and all auxiliary equipment such as fans, pumps, controls, and, if on the same circuit, any resistive elements) for an input voltage of 250 volts or less, and, if the tank is supplied, has a manufacturer's rated storage capacity of 120 gallons (450 liters) or less. Resistive elements used to provide supplemental heating may use the same circuit as the compressor if (1) an interlocking mechanism prevents concurrent compressor operation and resistive heating or (2) concurrent operation does not result in the maximum current rating of 24 amperes being exceeded. Otherwise, the resistive elements and the heat pump components must use separate circuits. A heat pump water heater may be sold by the manufacturer with or without a storage tank.

a. Heat Pump Water Heater with Storage Tank means an air-to-water heat pump sold by the manufacturer with an insulated storage tank as a packaged unit. The tank and heat pump can be an integral unit or they can be separated.

b. Heat Pump Water Heater without Storage Tank (also called Add-on Heat Pump Water Heater) means an air-to-water heat pump designed for use with a storage-type water heater or a storage tank that is not specified or supplied by the manufacturer.

1.12.4 *Oil Storage-type Water Heater* means a water heater that uses oil as the energy source, is designed to heat and store water at a thermostatically controlled temperature of less than 180°F (82°C), has a nominal energy input of 105,000 Btu/h (110 MJ/h) or less, and has a manufacturer's rated storage capacity of 50 gallons (190 liters) or less.

1.12.5 *Storage-type Water Heater of More than 2 Gallons (7.6 Liters) and Less than 20 Gallons (76 Liters).* Reserved.

1.13 *ASHRAE Standard 41.1–86* means the standard published in 1986 by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., and titled Standard Measurement Guide: Section on Temperature Measurements.

1.14 *ASTM–D–2156–80* means the test standard published in 1980 by the American

Society for Testing and Measurements and titled ''Smoke Density in Flue Gases from Burning Distillate Fuels, Test Method for''.

1.15 *Symbol Usage* The following identity relationships are provided to help clarify the symbology used throughout this procedure:

C_p specific heat capacity of water
E_{annual} annual energy consumption of a water heater
E_f energy factor of a water heater
F_{hr} first-hour rating of a storage-type water heater
F_{max} maximum gpm (L/min) rating of an instantaneous water heater rated at a temperature rise of 77°F (42.8°C) across the heater
i a subscript to indicate an ith draw during a test
M_i mass of water removed during the ith draw (i=1 to 6) of the 24-hr simulated use test
M^*_i for storage-type water heaters, mass of water removed during the ith draw (i=1 to n) during the first-hour rating test
M_{10m} for instantaneous water heaters, mass of water removed continuously during a 10-minute interval in the maximum gpm (L/min) rating test
n for storage-type water heaters, total number of draws during the first-hour rating test
Q total fossil fuel and/or electric energy consumed during the entire 24-hr simulated use test
Q_d daily water heating energy consumption adjusted for net change in internal energy
Q_{da} adjusted daily water heating energy consumption with adjustment for variation of tank to ambient air temperature difference from nominal value
Q_{dm} overall adjusted daily water heating energy consumption including Q_{da} and Q_{HWD}
Q_{hr} hourly standby losses
Q_{HW} daily energy consumption to heat water over the measured average temperature rise across the water heater
Q_{HWD} adjustment to daily energy consumption, Q_{hw}, due to variation of the temperature rise across the water heater not equal to the nominal value of 77°F (42.8°C)
Q_r energy consumption of fossil fuel or heat pump water heaters between thermostat (or burner) cut-out prior to the first draw and cut-out following the first draw of the 24-hr simulated use test
$Q_{r,\ max}$ energy consumption of a modulating instantaneous water heater between cut-out (burner) prior to the first draw and cut-out following the first draw of the 24-hr simulated use test
$Q_{r,\ min}$ energy consumption of a modulating instantaneous water heater from immediately prior to the fourth draw to burner cut-out following the fourth draw of the 24-hr simulated use test
Q_{stby} total energy consumed by the water heater during the standby time interval $\tau_{stby,\ 1}$
Q_{su} total fossil fueled and/or electric energy consumed from the beginning of the first draw to the thermostat (or burner) cut-out following the completion of the sixth draw during the 24-hr simulated use test
T_{min} for modulating instantaneous water heaters, steady state outlet water temperature at the minimum fuel input rate
$\bar{T}_0$ mean tank temperature at the beginning of the 24-hr simulated use test
$\bar{T}_{24}$ mean tank temperature at the end of the 24-hr simulated use test
$\bar{T}_{a,\ stby}$ average ambient air temperature during standby periods of the 24-hr use test
$\bar{T}_{del}$ for instantaneous water heaters, average outlet water temperature during a 10-minute continuous draw interval in the maximum gpm (L/min) rating test
$\bar{T}_{del,\ i}$ average outlet water temperature during the ith draw of the 24-hr simulated use test
$\bar{T}_{in}$ for instantaneous water heaters, average inlet water temperature during a 10-minute continuous draw interval in the maximum gpm (L/min) rating test
$\bar{T}_{in,\ i}$ average inlet water temperature during the ith draw of the 24-hr simulated use test
$\bar{T}_{max,\ 1}$ maximum measured mean tank temperature after cut-out following the first draw of the 24-hr simulated use test
$\bar{T}_{stby}$ average storage tank temperature during the standby period $\tau_{stby,\ 2}$ of the 24-hr use test
$\bar{T}_{su}$ maximum measured mean tank temperature after cut-out following the sixth draw of the 24-hr simulated use test
$\bar{T}_{t,\ stby}$ average storage tank temperature during the standby period $\tau_{stby,\ 1}$ of the 24-hr use test
$\bar{T}^*_{del,\ i}$ for storage-type water heaters, average outlet water temperature during the ith draw (i=1 to n) of the first-hour rating test
$T^*_{max,\ i}$ for storage-type water heaters, maximum outlet water temperature observed during the ith draw (i=1 to n) of the first-hour rating test
$T^*_{min,\ i}$ for storage-type water heaters, minimum outlet water temperature to terminate the ith draw during the first-hour rating test
UA standby loss coefficient of a storage-type water heater
V_i volume of water removed during the ith draw (i=1 to 6) of the 24-hr simulated use test
V^*_i volume of water removed during the ith draw (i=1 to n) during the first-hour rating test
V_{10m} for instantaneous water heaters, volume of water removed continuously during a 10-minute interval in the maximum gpm (L/min) rating test
V_{max} steady state water flow rate of an instantaneous water heater at the rated input to give a discharge temperature of 135°F ± 5°F (57.2°C ± 2.8°C)
V_{min} steady state water flow rate of a modulating instantaneous water heater at the minimum input to give a discharge temperature of T_{min} up to 135°F ± 5°F (57.2°C ± 2.8°C)
V_{st} measured storage volume of the storage tank
W_f weight of storage tank when completely filled with water
W_t tare weight of storage tank when completely empty of water
η_r recovery efficiency
ρ density of water
$\tau_{stby,\ 1}$ elapsed time between the time the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hr simulated use test
$\tau_{stby,\ 2}$ overall standby periods when no water is withdrawn during the 24-hr simulated use test

2. Test Conditions

2.1 *Installation Requirements.* Tests shall be performed with the water heater and instrumentation installed in accordance with Section 4 of this appendix.

2.2 *Ambient Air Temperature.* The ambient air temperature shall be maintained between 65.0°F and 70.0°F (18.3°C and 21.1°C) on a continuous basis. For heat pump water heaters, the dry bulb temperature shall be maintained at 67.5°F ± 1°F (19.7°C ± 0.6°C) and, in addition, the relative humidity shall be maintained between 49% and 51%.

2.3 *Supply Water Temperature.* The temperature of the water being supplied to the water heater shall be maintained at 58°F ± 2°F (14.4°C ± 1.1°C) throughout the test.

2.4 *Storage Tank Temperature.* The average temperature of the water within the storage tank shall be set to 135°F ± 5°F (57.2°C ± 2.8°C).

2.5 *Supply Water Pressure.* During the test when water is not being withdrawn, the supply pressure shall be maintained between 40 psig (275 kPa) and the maximum allowable pressure specified by the water heater manufacturer.

2.6 *Electrical and/or Fossil Fuel Supply.*

2.6.1 *Electrical.* Maintain the electrical supply voltage to within ± 1% of the center of the voltage range specified by the water heater and/or heat pump manufacturer.

2.6.2 *Natural Gas.* Maintain the supply pressure in accordance with the manufacturer's specifications. If the supply pressure is not specified, maintain a supply pressure of 7–10 inches of water column (1.7–2.5 kPa). If the water heater is equipped with a gas appliance pressure regulator, the regulator outlet pressure shall be within ± 10% of the manufacturer's specified manifold pressure. For all tests, use natural gas having a heating value of approximately 1,025 Btu per standard cubic foot (38,190 kJ per standard cubic meter).

2.6.3 *Propane Gas.* Maintain the supply pressure in accordance with the manufacturer's specifications. If the supply pressure is not specified, maintain a supply pressure of 11–13 inches of water column (2.7–3.2 kPa). If the water heater is equipped with a gas appliance pressure regulator, the regulator outlet pressure shall be within ± 10% of the manufacturer's specified manifold pressure. For all tests, use propane gas with a heating value of approximately 2,500 Btu per standard cubic foot (93,147 kJ per standard cubic meter).

2.6.4 *Fuel Oil Supply.* Maintain an uninterrupted supply of fuel oil. Use fuel oil having a heating value of approximately 138,700 Btu per gallon (38,660 kJ per liter).

3. Instrumentation

3.1 *Pressure Measurements.* Pressure-measuring instruments shall have an error no greater than the following values:

Item measured	Instrument accuracy	Instrument precision
Gas pressure	± 0.1 inch of water column (± 0.025 kPa)	± 0.05 inch of water column (± 0.012 kPa).
Atmospheric pressure	± 0.1 inch of mercury column (± 0.34 kPa)	± 0.05 inch of mercury column (± 0.17 kPa).
Water pressure	± 1.0 pounds per square inch (± 6.9 kPa)	± 0.50 pounds per square inch (± 3.45 kPa).

3.2 *Temperature Measurement*

3.2.1 *Measurement.* Temperature measurements shall be made in accordance with the Standard Measurement Guide: Section on Temperature Measurements, ASHRAE Standard 41.1–86.

3.2.2 *Accuracy and Precision.* The accuracy and precision of the instruments, including their associated readout devices, shall be within the following limits:

Item measured	Instrument accuracy	Instrument precision
Air dry bulb temperature	± 0.2°F (± 0.1°C)	± 0.1°F (± 0.06°C)
Air wet bulb temperature	± 0.2°F (± 0.1°C)	± 0.1°F (± 0.06°C)
Inlet and outlet water temperatures	± 0.2°F (± 0.1°C)	± 0.1°F (± 0.06°C)
Storage tank temperatures	± 0.5°F (± 0.3°C)	± 0.25°F (± 0.14°C)

3.2.3 *Scale Division.* In no case shall the smallest scale division of the instrument or instrument system exceed 2 times the specified precision.

3.2.4 *Temperature Difference.* Temperature difference between the entering and leaving water may be measured with any of the following:

a. A thermopile
b. Calibrated resistance thermometers
c. Precision thermometers
d. Calibrated thermistors
e. Calibrated thermocouples
f. Quartz thermometers

3.2.5 *Thermopile Construction.* If a thermopile is used, it shall be made from calibrated thermocouple wire taken from a single spool. Extension wires to the recording device shall also be made from that same spool.

3.2.6 *Time Constant.* The time constant of the instruments used to measure the inlet and outlet water temperatures shall be no greater than 5 seconds.

3.3 *Liquid Flow Rate Measurement.* The accuracy of the liquid flow rate measurement, using the calibration if furnished, shall be equal to or less than ± 1% of the measured value in mass units per unit time.

3.4 *Electric Energy.* The electrical energy used shall be measured with an instrument and associated readout device that is accurate within ± 1% of the reading.

3.5 *Fossil Fuels.* The quantity of fuel used by the water heater shall be measured with an instrument and associated readout device that is accurate within ± 1% of the reading.

3.6 *Mass Measurements.* For mass measurements greater than or equal to 10 pounds (4.5 kg), a scale that is accurate within ± 1% of the reading shall be used to make the measurement. For mass measurements less than 10 pounds (4.5 kg), the scale shall provide a measurement that is accurate within ± 0.1 pound (0.045 kg).

3.7 *Heating Value.* The higher heating value of the natural gas, propane, or fuel oil shall be measured with an instrument and associated readout device that is accurate within ± 1% of the reading. The heating value of natural gas and propane must be corrected for local temperature and pressure conditions.

3.8 *Time.* The elapsed time measurements shall be measured with an instrument that is accurate within ± 0.5 seconds per hour.

3.9 *Volume.* Volume measurements shall be measured with an accuracy of ± 2% of the total volume.

4. Installation

4.1 *Water Heater Mounting.* A water heater designed to be freestanding shall be placed on a ¾ inch (2 cm) thick plywood platform supported by three 2 × 4 inch (5 cm × 10 cm) runners. If the water heater is not approved for installation on combustible flooring, suitable non-combustible material shall be placed between the water heater and the platform. Counter-top water heaters shall be placed against a simulated wall section. Wall-mounted water heaters shall be supported on a simulated wall in accordance with the manufacturer-published installation instructions. When a simulated wall is used, the recommended construction is 2 × 4 inch (5 cm × 10 cm) studs, faced with ¾ inch (2 cm) plywood. For heat pump water heaters that are supplied with a storage tank, the two components, if not delivered as a single package, shall be connected in accordance with the manufacturer-published installation instructions and the overall system shall be placed on the above-described plywood platform. If installation instructions are not provided by the heat pump manufacturer, uninsulated 8 foot (2.4 m) long connecting hoses having an inside diameter of ⅝ inch (1.6 cm) shall be used to connect the storage tank and the heat pump water heater. With the exception of using the storage tank described in 4.10, the same requirements shall apply for heat pump water heaters that are supplied without a storage tank from the manufacturer. The testing of the water heater shall occur in an area that is protected from drafts.

4.2 *Water Supply.* Connect the water heater to a water supply capable of delivering water at conditions as specified in Sections 2.3 and 2.5 of this appendix.

4.3 *Water Inlet and Outlet Configuration.* For freestanding water heaters that are taller than 36 inches (91.4 cm), inlet and outlet piping connections shall be configured in a manner consistent with Figures 1 and 2. Inlet and outlet piping connections for wall-mounted water heaters shall be consistent with Figure 3. For freestanding water heaters that are 36 inches or less in height and not supplied as part of a counter-top enclosure (commonly referred to as an under-the-counter model), inlet and outlet piping shall be installed in a manner consistent with Figures 4, 5, and 6. For water heaters that are supplied with a counter-top enclosure, inlet and outlet piping shall be made in a manner consistent with Figures 7A and 7B, respectively. The vertical piping noted in Figures 7A and 7B shall be located (whether inside the enclosure or along the outside in a recessed channel) in accordance with the manufacturer-published installation instructions.

All dimensions noted in Figures 1 through 7 shall be achieved. All piping between the water heater and the inlet and outlet temperature sensors, noted as T_{IN} and T_{OUT} in the figures, shall be Type ''L'' hard copper having the same diameter as the connections on the water heater. Unions may be used to facilitate installation and removal of the piping arrangements. A pressure gauge and diaphragm expansion tank shall be installed in the supply water piping at a location upstream of the inlet temperature sensor. An appropriately rated pressure and temperature relief valve shall be installed on all water heaters at the port specified by the manufacturer. Discharge piping for the relief valve shall be non-metallic. If heat traps, piping insulation, or pressure relief valve insulation are supplied with the water heater, they shall be installed for testing. Except when using a simulated wall, clearance shall be provided such that none of the piping contacts other surfaces in the test room.

4.4 *Fuel and/or Electrical Power and Energy Consumption.* Install one or more instruments which measure, as appropriate, the quantity and rate of electrical energy and/or fossil fuel consumption in accordance with Section 3. For heat pump water heaters that use supplemental resistive heating, the electrical energy supplied to the resistive element(s) shall be metered separately from the electrical energy supplied to the entire appliance or to the remaining components (e.g., compressor, fans, pumps, controls).

4.5 *Internal Storage Tank Temperature Measurements.* Install six temperature measurement sensors inside the water heater tank with a vertical distance of at least 4 inches (100 mm) between successive sensors. A temperature sensor shall be positioned at the vertical midpoint of each of the six equal volume nodes within the tank. Nodes designate the equal volumes used to evenly partition the total volume of the tank. As much as is possible, the temperature sensor should be positioned away from any heating elements, anodic protective devices, tank walls, and flue pipe walls. If the tank cannot accommodate six temperature sensors and meet the installation requirements specified above, install the maximum number of sensors which comply with the installation requirements. The temperature sensors shall be installed either through (1) the anodic device opening; (2) the relief valve opening; or (3) the hot water outlet. If installed through the relief valve opening or the hot water outlet, a tee fitting or outlet piping, as applicable, shall be installed as close as possible to its original location. If the relief valve temperature sensor is relocated, and it no longer extends into the top of the tank, a substitute relief valve that has a sensing element that can reach into the tank shall be installed. If the hot water outlet includes a heat trap, the heat trap shall be installed on top of the tee fitting. Added fittings shall be covered with thermal insulation having an R value between 4 and 8 h•ft^2•°F/Btu (0.7 and 1.4 m^2•°C/W).

4.6 *Ambient Air Temperature Measurement.* Install an ambient air temperature sensor at the vertical mid-point of the water heater and approximately 2 feet (610 mm) from the surface of the water heater. The sensor shall be shielded against radiation.

4.7 *Inlet and Outlet Water Temperature Measurements.* Install temperature sensors in the cold-water inlet pipe and hot-water outlet pipe as shown in Figures 1, 2, 3, 4, 5, 6, 7a and 7b, as applicable.

4.8 *Flow Control.* A valve shall be installed to provide flow as specified in sections 5.1.4.1 for storage tank water heaters and 5.2.1 for instantaneous water heaters.

4.9 *Flue Requirements.*

4.9.1 *Gas-Fired Water Heaters.* Establish a natural draft in the following manner. For gas-fired water heaters with a vertically discharging draft hood outlet, a 5-foot (1.5-meter) vertical vent pipe extension with a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. For gas-fired water heaters with a horizontally discharging draft hood outlet, a 90-degree elbow with a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. A 5-foot (1.5-meter) length of vent pipe shall be connected to the elbow and oriented to discharge vertically upward. Direct vent gas-fired water heaters shall be installed with venting equipment specified in the manufacturer's instructions using the minimum vertical and horizontal lengths of vent pipe recommended by the manufacturer.

4.9.2 *Oil-Fired Water Heaters.* Establish a draft at the flue collar at the value specified in the manufacturer's instructions. Establish the draft by using a sufficient length of vent pipe connected to the water heater flue outlet, and directed vertically upward. For an oil-fired water heater with a horizontally discharging draft hood outlet, a 90-degree elbow with a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. A length of vent pipe sufficient to establish the draft shall be connected to the elbow fitting and oriented to discharge vertically upward. Direct-vent oil-fired water heaters should be installed with venting equipment as specified in the manufacturer's instructions, using the minimum vertical and horizontal lengths of vent pipe recommended by the manufacturer.

4.10 *Heat Pump Water Heater Storage Tank.* The tank to be used for testing a heat pump water heater without a tank supplied by the manufacturer (see Section 1.12.3b) shall be an electric storage-type water heater having a measured volume of 47.0 gallons ±1.0 gallon (178 liters ±3.8 liters); two 4.5 kW heating elements controlled in such a manner as to prevent both elements from operating simultaneously; and an energy factor greater than or equal to the minimum energy conservation standard (as determined in accordance with Section 6.1.7) and less than or equal to the sum of the minimum energy conservation standard and 0.02.

5. Test Procedures

5.1 *Storage-type Water Heaters, Including Heat Pump Water Heaters.*

5.1.1 *Determination of Storage Tank Volume.* Determine the storage capacity, V_{st}, of the water heater under test, in gallons (liters), by subtracting the tare weight—measured while the tank is empty—from the gross weight of the storage tank when completely filled with water (with all air eliminated and line pressure applied as described in section 2.5) and dividing the resulting net weight by the density of water at the measured temperature.

5.1.2 *Setting the Thermostat.*

5.1.2.1 *Single Thermostat Tanks.* Starting with a tank at the supply water temperature, initiate normal operation of the water heater. After cut-out, determine the mean tank temperature every minute until the maximum value is observed. Determine whether this maximum value for the mean tank temperature is within the range of 135°F±5°F (57.2°C±2.8°C). If not, turn off the water heater, adjust the thermostat, drain and refill the tank with supply water. Then, once again, initiate normal operation of the water heater, and determine the maximum mean tank temperature after cut-out. Repeat this sequence until the maximum mean tank temperature after cut-out is 135°F±5°F (57.2°C±2.8°C).

5.1.2.2 *Tanks with Two or More Thermostats.* Follow the same sequence as for a single thermostat tank, i.e. start at the supply water temperature, operate normally until cutout. Determine if the thermostat that controls the uppermost heating element yields a maximum water temperature of 135°F±5°F (57.2°C±2.8°C), as measured by the in-tank sensors that are positioned above the uppermost heating element. If the tank temperature at the thermostat is not within 135°F±5°F (57.2°C±2.8°C), turn off the water heater, adjust the thermostat, drain and refill the tank with supply water. The thermostat that controls the heating element positioned next highest in the tank shall then be set to yield a maximum water temperature of 135°F±5°F (57.2°C±2.8°C). This process shall be repeated until the thermostat controlling the lowest element is correctly adjusted. When adjusting the thermostat that controls the lowest element, the maximum mean tank temperature after cut-out, as determined using all the in-tank sensors, shall be 135°F±5°F (57.2°C±2.8°C). When adjusting all other thermostats, use only the in-tank temperature sensors positioned above the heating element in question to evaluate the maximum water temperature after cut-out.

For heat pump water heaters that control an auxiliary resistive element, the thermostat shall be set in accordance with the manufacturer's installation instructions.

5.1.3 *Power Input Determination.* For all water heaters except electric types having immersed heating elements, initiate normal operation and determine the power input, P, to the main burners (including pilot light power, if any) after 15 minutes of operation. If the water heater is equipped with a gas appliance pressure regulator, the regulator outlet pressure shall be set within ± 10% of that recommended by the manufacturer. For oil-fired water heaters the fuel pump pressure shall be within ± 10% of the manufacturer's specified pump pressure. All burners shall be adjusted to achieve an hourly Btu (kJ) rating that is within ± 2% of the value specified by the manufacturer. For an oil-fired water heater, adjust the burner to give a CO_2 reading recommended by the manufacturer and an hourly Btu (kJ) rating that is within ± 2% of that specified by the manufacturer. Smoke in the flue may not exceed No. 1 smoke as measured by the procedure in ASTM–D–2156–80.

5.1.4 *First-Hour Rating Test.*

5.1.4.1 *General.* During hot water draws, remove water at a rate of 3.0±0.25 gallons per minute (11.4±0.95 liters per minute). Collect the water in a container that is large enough to hold the volume removed during an individual draw and suitable for weighing at the termination of each draw. Alternatively, a water meter may be used to directly measure the water volume(s) withdrawn.

5.1.4.2 *Draw Initiation Criteria.* Begin the first-hour rating test by imposing a draw on the storage-type water heater. After completion of this first draw, initiate successive draws based on the following criteria. For gas-and oil-fired water heaters, initiate successive draws when the thermostat acts to reduce the supply of fuel to the main burner. For electric water heaters having a single element or multiple elements that all operate simultaneously, initiate successive draws when the thermostat acts to reduce the electrical input supplied to the element(s). For electric water heaters having two or more elements that do not operate simultaneously, initiate successive draws when the applicable thermostat acts to reduce the electrical input to the element located vertically highest in the storage tank. For heat pump waters heaters that do not use supplemental resistive heating, initiate successive draws immediately after the electrical input to the compressor is reduced by the action of the water heater's thermostat. For heat pump waters heaters that use supplemental resistive heating, initiate successive draws immediately after the electrical input to the compressor or the uppermost resistive element is reduced by the action of the applicable water heater thermostat. This draw initiation criterion for heat pump water heaters that use supplemental resistive heating, however, shall only apply when the water located above the thermostat at cut-out is heated to 135°F±5°F (57.2°C±2.8°C).

5.1.4.3 *Test Sequence.* Establish normal water heater operation. If the water heater is not presently operating, initiate a draw. The draw may be terminated anytime after cut-in occurs. After cut-out occurs (i.e., all thermostats are satisfied), monitor the internal storage tank temperature sensors described in section 4.5 every minute.

Initiate a draw after a maximum mean tank temperature has been observed following cut-out. Record the time when the draw is initiated and designate it as an elapsed time of zero ($\tau^* = 0$). (The superscript * is used to denote variables pertaining to the first-hour rating test.) Record the outlet water temperature beginning 15 seconds after the draw is initiated and at 5-second intervals thereafter until the draw is terminated. Determine the maximum outlet temperature that occurs during this first draw and record it as $T^*_{max,\ 1}$. For the duration of this first draw and all successive draws, in addition, monitor the inlet temperature to the water heater to ensure that the required 58°F±2°F (14.4°C±1.1°C) test condition is met. Terminate the hot water draw when the outlet temperature decreases to $T^*_{max,1} - 25°F$ ($T^*_{max,1} - 13.9°C$). Record this temperature as $T^*_{min,1}$. Following draw termination, determine the average outlet water temperature and the mass or volume removed during this first draw and record them as $T^*_{del,1}$ and M^*_1 or V^*_1, respectively.

Initiate a second and, if applicable, successive draw each time the applicable draw initiation criteria described in section 5.1.4.2 are satisfied. As required for the first draw, record the outlet water temperature 15 seconds after initiating each draw and at 5-second intervals thereafter until the draw is terminated. Determine the maximum outlet temperature that occurs during each draw and record it as $T^*_{max,\ i}$, where the subscript i refers to the draw number. Terminate each hot water draw when the outlet temperature decreases to $T^*_{max,\ i} - 25°F$ ($T^*_{max,\ i} - 13.9°C$). Record this temperature as $T^*_{min,\ i}$. Calculate and record the average outlet temperature and the mass or volume removed during each draw ($T^*_{del,\ i}$ and M^*_i or V^*_i, respectively). Continue this sequence of draw and recovery until one hour has elapsed, then shut off the electrical power and/or fuel supplied to the water heater.

If a draw is occurring at an elapsed time of one hour, continue this draw until the outlet temperature decreases to $T^*_{max,\ n} - 25°F$ ($T^*_{max,\ n} - 13.9°C$), at which time the draw shall be immediately terminated. (The subscript n shall be used to denote quantities associated with the final draw.) If a draw is not occurring at an elapsed time of one hour, a final draw shall be imposed at one hour. This draw shall be immediately terminated when the outlet temperature first indicates a value less than or equal to the cut-off temperature used for the previous draw ($T^*_{min,\ n-1}$). For cases where the outlet temperature is close to $T^*_{min,\ n-1}$, the final draw shall proceed for a minimum of 30 seconds. If an outlet temperature greater than $T^*_{min,\ n-1}$ is not measured within 30 seconds, the draw shall be immediately terminated and zero additional credit shall be given towards first-hour rating (i.e., $M^*_n = 0$ or $V^*_n = 0$). After the final draw is terminated, calculate and record the average outlet temperature and the mass or volume removed during the draw ($T^*_{del,\ n}$ and M^*_n or V^*_n, respectively).

5.1.5 *24-Hour Simulated Use Test.* During the simulated use test, a total of 64.±3 1.0 gallons (243±3.8 liters) shall be removed. This value is referred to as the daily hot water usage in the following text.

With the water heater turned off, fill the water heater with supply water and apply pressure as described in section 2.5. Turn on the water heater and associated heat pump unit, if present. After the cut-out occurs, the water heater may be operated for up to three cycles of drawing until cut-in, and then operating until cut-out, prior to the start of the test.

At this time, record the mean tank temperature ($\overline{T}_o$), and the electrical and/or fuel measurement readings, as appropriate. Begin the 24-hour simulated use test by withdrawing a volume from the water heater that equals one-sixth of the daily hot water usage. Record the time when this first draw is initiated and assign it as the test elapsed time (τ) of zero (0). Record the average storage tank and ambient temperature every 15 minutes throughout the 24-hour simulated use test unless a recovery or a draw is occurring. At elapsed time intervals of one, two, three, four, and five hours from $\tau = 0$, initiate additional draws, removing an amount of water equivalent to one-sixth of the daily hot water usage with the maximum allowable deviation for any single draw being ± 0.5 gallons (1.9 liters). The quantity of water withdrawn during the sixth draw shall be increased or decreased as necessary such that the total volume of water withdrawn equals 64.3 gallons ± 1.0 gallon (243.4 liters ± 3.8 liters).

All draws during the simulated use test shall be made at flow rates of 3.0 gallons ± 0.25 gallons per minute (11.4 liters ± 0.95 liters per minute). Measurements of the inlet and outlet temperatures shall be made 15 seconds after the draw is initiated and at every subsequent 5-second interval throughout the duration of each draw. The arithmetic mean of the hot water discharge temperature and the cold water inlet temperature shall be determined for each draw ($\overline{T}_{del,\ i}$ and $\overline{T}_{in,\ i}$). Determine and record the net mass or volume removed (M_i or V_i), as appropriate, after each draw.

At the end of the recovery period following the first draw, record the maximum mean tank temperature observed after cut-out, $\overline{T}_{max,\ 1}$, and the energy consumed by an electric resistance, gas or oil-fired water heater, Q_r. For heat pump water heaters, the total electrical energy consumed during the first recovery by the heat pump (including compressor, fan, controls, pump, etc.) and, if applicable, by the resistive element(s) shall be recorded as Q_r.

At the end of the recovery period that follows the sixth draw, determine and record the total electrical energy and/or fossil fuel consumed since the beginning of the test, Q_{su}. In preparation for determining the energy consumed during standby, record the reading given on the electrical energy (watt-hour) meter, the gas meter, and/or the scale used to determine oil consumption, as appropriate. Record the maximum value of the mean tank temperature after cut-out as $\overline{T}_{su}$. Except as noted below, allow the water heater to remain in the standby mode until 24 hours have elapsed from the start of the test (i.e., since = 0). Prevent the water heater from beginning a recovery cycle during the last hour of the test by turning off the electric power to the electrical heating elements and heat pump, if present, or by turning down the fuel supply to the main burner at an elapsed time of 23 hours. If a recovery is taking place at an elapsed time of 23 hours, wait until the recovery is complete before reducing the electrical and/or fuel supply to the water heater. At 24 hours, record the mean tank temperature, $\overline{T}_{24}$, and the electric and/or fuel instrument readings. Determine the total fossil fuel or electrical energy consumption, as appropriate, for the entire 24-hour simulated use test, Q. Record the time interval between the time at which the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hour test as $_{stby,\ 1}$. Record the time during which water is not being withdrawn from the water heater during the entire 24-hour period as $_{stby,\ 2}$.

5.2 *Instantaneous Gas and Electric Water Heaters*

5.2.1 *Setting the Outlet Discharge Temperature.* Initiate normal operation of the water heater at the full input rating for electric instantaneous water heaters and at the maximum firing rate specified by the manufacturer for gas instantaneous water heaters. Monitor the discharge water temperature and set to a value of 135°F ± 5°F (57.2°C ± 2.8°C) in accordance with the manufacturer's instructions. If the water heater is not capable of providing this discharge temperature when the flow rate is 3.0 gallons ± 0.25 gallons per minute (11.4 liters ± 0.95 liters per minute), then adjust the flow rate as necessary to achieve the specified discharge water temperature. Record the corresponding flow rate as V_{max}.

5.2.2 *Additional Requirements for Variable Input Instantaneous Gas Water Heaters.* If the instantaneous water heater incorporates a controller that permits operation at a reduced input rate, adjust the flow rate as necessary to achieve a discharge water temperature of 135°F ± 5°F (57.2°C ± 2.8°C) while maintaining the minimum input rate. Record the corresponding flow rate as V_{min}. If an outlet temperature of 135°F ± 5°F (57.2°C ± 2.8°C) cannot be achieved at the minimum flow rate permitted by the instantaneous water heater, record the flow rate as V_{min} and the corresponding outlet temperature as T_{min}.

5.2.3 *Maximum GPM Rating Test for Instantaneous Water Heaters.* Establish normal water heater operation at the full input rate for electric instantaneous water heaters and at the maximum firing rate for gas instantaneous water heaters with the discharge water temperature set in accordance with Section 5.2.1. During the 10-minute test, either collect the withdrawn water for later measurement of the total mass removed, or alternatively, use a water meter to directly measure the water volume removed.

After recording the scale or water meter reading, initiate water flow throughout the water heater, record the inlet and outlet water temperatures beginning 15 seconds after the start of the test and at subsequent 5-second intervals throughout the duration of the test. At the end of 10 minutes, turn off the water. Determine the mass of water collected, M_{10m}, in pounds (kilograms), or the volume of water, V_{10m}, in gallons (liters).

5.2.4 *24-hour Simulated Use Test for Gas Instantaneous Water Heaters.*

5.2.4.1 *Fixed Input Instantaneous Water Heaters.* Establish normal operation with the discharge water temperature and flow rate set to values of 135°F ± 5°F (57.2°C ± 2.8°C) and V_{max} per Section 5.2.1, respectively. With no draw occurring, record the reading given by the gas meter and/or the electrical energy meter as appropriate. Begin the 24-hour simulated use test by drawing an amount of water out of the water heater equivalent to one-sixth of the daily hot water usage. Record the time when this first draw is initiated and designate it as an elapsed time, τ, of 0. At elapsed time intervals of one, two, three, four, and five hours from $\tau = 0$, initiate additional draws, removing an amount of water equivalent to one-sixth of the daily hot water usage, with the maximum allowable deviation for any single draw being ± 0.5 gallons (1.9 liters). The quantity of water drawn during the sixth draw shall be increased or decreased as necessary such that the total volume of water withdrawn equals 64.3 gallons ± 1.0 gallons (243.4 liters ± 3.8 liters).

Measurements of the inlet and outlet water temperatures shall be made 15 seconds after the draw is initiated and at every 5-second interval thereafter throughout the duration of the draw. The arithmetic mean of the hot water discharge temperature and the cold water inlet temperature shall be determined for each draw. Record the scale used to measure the mass of the withdrawn water or the water meter reading, as appropriate, after each draw. At the end of the recovery period following the first draw, determine and record the fossil fuel or electrical energy consumed, Q_r. Following the sixth draw and subsequent recovery, allow the water heater to remain in the standby mode until exactly 24 hours have elapsed since the start of the test (i.e., since $\tau = 0$). At 24 hours, record the reading given by the gas meter and/or the electrical energy meter as appropriate. Determine the fossil fuel or electrical energy consumed during the entire 24-hour simulated use test and designate the quantity as Q.

5.2.4.2 *Variable Input Instantaneous Water Heaters.* If the instantaneous water heater incorporates a controller that permits continuous operation at a reduced input rate, the first three draws shall be conducted using the maximum flow rate, V_{max}, while removing an amount of water equivalent to one-sixth of the daily hot water usage, with the maximum allowable deviation for any one of the three draws being ± 0.5 gallons (1.9 liters). The second three draws shall be conducted at V_{min}. If an outlet temperature of 135°F ± 5°F (57.2°C ± 2.8°C) could not be achieved at the minimum flow rate permitted by the instantaneous water heater, the last three draws should be lengthened such that the volume removed is:

$$V_{4,5,6} = \frac{64.3\text{ gal}}{6} \times \left[\frac{77^\circ\text{F}}{(T_{min} - 58^\circ\text{F})}\right]$$

or

$$V_{4,5,6} = \frac{243\text{ L}}{6} \times \left[\frac{42.8^\circ\text{C}}{(T_{min} - 14.4^\circ\text{C})}\right]$$

where T_{min} is the outlet water temperature at the flow rate V_{min} as determined in Section 5.2.1, and where the maximum allowable variation for any one of the three draws is ± 0.5 gallons (1.9 liters). The quantity of water withdrawn during the sixth draw shall be increased or decreased as necessary such that the total volume of water withdrawn equals (32.15 + 3T1•$V_{4,5,6}$) ± 1.0 gallons ((121.7 + 3•$V\cdot_{4,5,6}$) ± 3.8 liters).

Measurements of the inlet and outlet water temperatures shall be made 5 seconds after a draw is initiated and at every 5-second interval thereafter throughout the duration of the draw. Determine the arithmetic mean of the hot water discharge temperature and the cold water inlet temperature for each draw. Record the scale used to measure the mass of the withdrawn water or the water meter reading, as appropriate, after each draw. At the end of the recovery period following the first draw, determine and record the fossil fuel or electrical energy consumed, $Q_{r,\ max}$. Likewise, record the reading of the meter used to measure fossil fuel or electrical energy consumption prior to the fourth draw and at the end of the recovery period following the fourth draw, and designate the difference as $Q_{r,min}$. Following the sixth draw and subsequent recovery, allow the water heater to remain in the standby mode until exactly 24 hours have elapsed since the start of the test (i.e., since τ=0). At 24 hours, record the reading given by the gas meter and/or the electrical energy meter, as appropriate. Determine the fossil fuel or electrical energy consumed during the entire 24-hour simulated use test and designate the quantity as Q.

6. Computations

6.1 *Storage Tank and Heat Pump Water Heaters.*

6.1.1 *Storage Tank Capacity.* The storage tank capacity is computed using the following:

$$V_{st} = \frac{(W_f - W_t)}{\rho}$$

Where:

V_{st} = the storage capacity of the water heater, gal (L).

W_f = the weight of the storage tank when completely filled with water, lb (kg).

W_t = the (tare) weight of the storage tank when completely empty, lb (kg).

ρ = the density of water used to fill the tank measured at the temperature of the water, lb/gal (kg/L).

6.1.2. *First-Hour Rating Computation.* For the case in which the final draw is initiated at or prior to an elapsed time of one hour, the first-hour rating shall be computed using,

$$F_{hr} = \sum_{i=1}^{n} V_i^*$$

Where:

n = the number of draws that are completed during the first-hour rating test.

V^*_i = the volume of water removed during the *ith* draw of the first-hour rating test, gal (L)

or, if the mass of water is being measured,

$$V_i^* = \frac{M_i^*}{\rho}$$

Where:

M^*_i = the mass of water removed during the ith draw of the first-hour rating test, lb (kg).

ρ = the water density corresponding to the average outlet temperature measured during the *ith* draw, ($T^*_{del,\ I}$), lb/gal (kg/L).

For the case in which a draw is not in progress at the elapsed time of one hour and a final draw is imposed at the elapsed time of one hour, the first-hour rating shall be calculated using

$$F_{hr} = \sum_{i=1}^{n-1} V_i^* + V_n^* \left(\frac{\overline{T}^*_{del,n} - T^*_{min,n-1}}{\overline{T}^*_{del,n-1} - T^*_{min,n-1}} \right)$$

where n and V^*_i are the same quantities as defined above, and

V^*_n = the volume of water drawn during the nth (final) draw of the first-hour rating test, gal (L)

$\overline{T}^*_{del,n-1}$ = the average water outlet temperature measured during the $(n-1)$th draw of the first-hour rating test, °F (°C).

$\overline{T}^*_{del,n}$ = the average water outlet temperature measured during the nth (final) draw of the first-hour rating test, °F (°C).

$\overline{T}^*_{min,n-1}$ = the minimum water outlet temperature measured during the $(n-1)$th draw of the first-hour rating test, °F (°C).

6.1.3 *Recovery Efficiency*. The recovery efficiency for gas, oil, and heat pump storage-type water heaters is computed as:

$$\eta_r = \frac{M_1 C_{p1} \left(\overline{T}_{del,1} - \overline{T}_{in,1} \right)}{Q_r} + \frac{V_{st} \rho_2 C_{p2} \left(\overline{T}_{max,1} - \overline{T}_o \right)}{Q_r}$$

Where:

M_1 = total mass removed during the first draw of the 24-hour simulated use test, lb (kg), or, if the volume of water is being measured,

$M_1 = V_1 \rho_1$

Where:

V_1 = total volume removed during the first draw of the 24-hour simulated use test, gal (L).

ρ_1 = density of the water at the water temperature measured at the point where the flow volume is measured, lb/gal (kg/L).

C_{p1} = specific heat of the withdrawn water, $(\overline{T}_{del,1} + \overline{T}_{in,1}) / 2$, Btu/lb°F (kJ/kg°C).

$\overline{T}_{del,1}$ = average water outlet temperature measured during the first draw of the 24-hour simulated use test, °F (°C).

$\overline{T}_{in,1}$ = average water inlet temperature measured during the first draw of the 24-hour simulated use test, °F (°C).

V_{st} = as defined in section 6.1.1.

ρ_2 = density of stored hot water, $(\overline{T}_{max,1} + \overline{T}_o)/2$, lb/gal (kg/L).

C_{p2} = specific heat of stored hot water evaluated at $(\overline{T}_{max,1} + \overline{T}_o) / 2$, Btu/lb°F (kJ/kg°C).

$\overline{T}_{max,1}$ = maximum mean tank temperature recorded after cut-out following the first draw of the 24-hour simulated use test, °F (°C).

$\overline{T}_o$ = maximum mean tank temperature recorded prior to the first draw of the 24-hour simulated use test, °F (°C).

Q_r = the total energy used by the water heater between cut-out prior to the first draw and cut-out following the first draw, including auxiliary energy such as pilot lights, pumps, fans, etc., Btu (kJ). (Electrical auxiliary energy shall be converted to thermal energy using the following conversion: 1 kWh = 3,412 Btu.)

The recovery efficiency for electric water heaters with immersed heating elements is assumed to be 98%.

6.1.4 *Hourly Standby Losses*. The hourly standby energy losses are computed as:

$$Q_{hr} = \frac{Q_{stby} - \frac{V_{st} \rho C_p \left(\overline{T}_{24} - \overline{T}_{su} \right)}{\eta_r}}{\tau_{stby,1}}$$

Where:

Q_{hr} = the hourly standby energy losses of the water heater, Btu/h (kJ/h).

Q_{stby} = the total energy consumed by the water heater between the time at which the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hour test period, Btu (kJ).

V_{st} = as defined in section 6.1.1.

ρ = density of stored hot water, $(\overline{T}_{24} + \overline{T}_{su}) / 2$, lb/gal (kg/L).

C_p = specific heat of the stored water, $(\overline{T}_{24} + \overline{T}_{su}) / 2$, Btu/lb•°F (kJ/kg•°C).

$\overline{T}_{24}$ = the mean tank temperature at the end of the 24-hour simulated use test, °F (°C).

$\overline{T}_{su}$ = the maximum mean tank temperature observed after the sixth draw, °F (°C).

η_r = as defined in section 6.1.3.

$\tau_{stby,1}$ = elapsed time between the time at which the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hour simulated use test, h.

The standby heat loss coefficient for the tank is computed as:

$$UA = \frac{Q_{hr}}{\overline{T}_{t,stby,1} - \overline{T}_{a,stby,1}}$$

Where:

UA = standby heat loss coefficient of the storage tank, Btu/h•°F (kJ/h•°C).

Q_{hr} = as defined in this section.

$\overline{T}_{t,stby,1}$= overall average storage tank temperature between the time when the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hour simulated use test, °F (°C).

$\overline{T}_{a,stby,1}$= overall average ambient temperature between the time when the maximum mean tank temperature is observed after the sixth draw and the end of the 24-hour simulated use test, °F (°C).

6.1.5 *Daily Water Heating Energy Consumption*. The daily water heating energy consumption, Q_d, is computed as:

$$Q_d = Q - \frac{V_{st} \rho C_p \left(\overline{T}_{24} - \overline{T}_o \right)}{\eta_r}$$

Where:

Q = total energy used by the water heater during the 24-hour simulated use test including auxiliary energy such as pilot lights, pumps, fans, etc., Btu (kJ). (Electrical auxiliary energy shall be converted to thermal energy using the following conversion: 1 kWh = 3,412 Btu.)

V_{st} = as defined in section 6.1.1.

ρ= density of the stored hot water, $(\overline{T}_{24} + \overline{T}_o) / 2$, lb/gal (kg/L).

C_p = specific heat of the stored water, $(\overline{T}_{24} + \overline{T}_o) / 2$, Btu/lb•°F (kJ/kg•°C).

$\overline{T}_{24}$ = mean tank temperature at the end of the 24-hour simulated use test, °F (°C).

$\overline{T}_o$ = mean tank temperature at the beginning of the 24-hour simulated use test, recorded one minute before the first draw is initiated, °F (°C).

η_r = as defined in section 6.1.3.

6.1.6 *Adjusted Daily Water Heating Energy Consumption*. The adjusted daily water heating energy consumption, Q_{da}, takes into account that the temperature difference between the storage tank and surrounding ambient air may not be the nominal value of 67.5°F (135°F–67.5°F) or 37.5°C (57.2°C–19.7°C) due to the 10°F (5.6°C) allowable variation in storage tank temperature, 135°F ± 5°F (57.2°C ± 2.8°C), and the 5°F (2.8°C) allowable variation in surrounding ambient temperature 65 °F (18.3°C) to 70°F (21.1°C). The adjusted daily water heating energy consumption is computed as:

$$Q_{da} = Q_D - [(\overline{T}_{stby,2} - \overline{T}_{a,stby,2}) - (135°F - 67.5°F)]\ UA\tau_{stby,2}$$

or $$Q_{da} = Q_D - [(\overline{T}_{stby,2} - \overline{T}_{a,stby,2}) - (57.2°C - 19.7°C)]\ UA\tau_{stby,2}$$

Where:

Q_{da} = the adjusted daily water heating energy consumption, Btu (kJ).

Q_d = as defined in section 6.1.5.

$T_{stby,2}$ = the mean tank temperature during the total standby portion, $\tau_{stby,2}$, of the 24-hour test, °F (°C).

$\overline{T}_{a,stby,2}$ = the average ambient temperature during the total standby portion, $\tau_{stby,2}$, of the 24-hour test, °F (°C).

UA = as defined in section 6.1.4.

$\tau_{stby,2}$ = the number of hours during the 24-hour simulated test when water is not being withdrawn from the water heater.

A modification is also needed to take into account that the temperature difference between the outlet water temperature and supply water temperature may not be equivalent to the nominal value of 77°F

(135°F–58°F) or 42.8°C (57.2°C–14.4°C). The following equations adjust the experimental data to a nominal 77°F (42.8°C) temperature rise.

The energy used to heat water, Btu/day (kJ/day), may be computed as:

$$Q_{HW} = \sum_{i=1}^{6} \frac{M_i C_{pi} \left(\overline{T}_{del,\,i} - \overline{T}_{in,\,i} \right)}{\eta_r}$$

Where:

M_i = the mass withdrawn for the *i*th draw (i = 1 to 6), lb (kg).

C_{pi} = the specific heat of the water of the *i*th draw, Btu/lb•°F (kJ/kg•°C).

$\overline{T}_{del,\,i}$ = the average water outlet temperature measured during the *i*th draw (i=1 to 6), °F (°C).

$\overline{T}_{in,\,i}$ = the average water inlet temperature measured during the *i*th draw (i=1 to 6), °F (°C).

η_r = as defined in section 6.1.3.

The energy required to heat the same quantity of water over a 77°F (42.8°C) temperature rise, Btu/day (kJ/day), is:

$$Q_{HW,\,77°F} = \sum_{i=1}^{6} \frac{M_i C_{pi} (135°F - 58°F)}{\eta_r}$$

$$\text{or } Q_{HW,\,42.8°C} = \sum_{i=1}^{6} \frac{M_i C_{pi} (57.2°C - 14.4°C)}{\eta_r}$$

The difference between these two values is:

$Q_{HWD} = Q_{HW,\,77°-F} - Q_{HW}$
or $Q_{HWD} = Q_{HW,42.8°-F} - Q_{HW}$
which must be added to the adjusted daily water heating energy consumption value. Thus, the daily energy consumption value which takes into account that the temperature difference between the storage tank and ambient temperature may not be 67.5°F (37.5°C) and that the temperature rise across the storage tank may not be 77°F (42.8°C) is:

$Q_{dm} = Q_{da} + Q_{HWD}$

6.1.7 Energy Factor. The energy factor, Ef, is computed as:

$$E_f = \sum_{i=1}^{6} \frac{M_i C_{pi} (135°F - 58°F)}{Q_{dm}}$$

or

$$E_f = \sum_{i=1}^{6} \frac{M_i C_{pi} (57.2°C - 14.4°C)}{Q_{dm}}$$

Where:

Q_{dm} = the modified daily water heating energy consumption as computed in accordance with section 6.1.6, Btu (kJ).

M_i = the mass withdrawn for the ith draw (i = 1 to 6), lb (kg).

C_{pi} = the specific heat of the water of the ith draw, Btu/lb °F (kJ/kg °C).

6.1.8 *Annual Energy Consumption.* The annual energy consumption for storage-type and heat pump water heaters is computed as:

$E_{annual} = 365 \times Q_{dm}$

Where:

Q_{dm} = the modified daily water heating energy consumption as computed in accordance with section 6.1.6, Btu (kJ).

365 = the number of days in a year.

6.2 *Instantaneous Water Heaters.*

6.2.1 *Maximum GPM (L/min) Rating Computation.* Compute the maximum gpm (L/min) rating as:

$$F_{max} = \frac{M_{10m} \left(\overline{T}_{del} - \overline{T}_{in} \right)}{10(\rho)(135°F - 58°F)}$$

$$\text{or } F_{max} = \frac{M_{10m} \left(\overline{T}_{del} - \overline{T}_{in} \right)}{10(\rho)(57.2°C - 14.4°C)}$$

which may be expressed as:

$$F_{max} = \frac{M_{10m} \left(\overline{T}_{del} - \overline{T}_{in} \right)}{10(\rho)(77°F)}$$

$$\text{or } F_{max} = \frac{M_{10m} \left(\overline{T}_{del} - \overline{T}_{in} \right)}{10(\rho)(42.8°C)}$$

Where:

M_{10m} = the mass of water collected during the 10-minute test, lb (kg).

$\overline{T}_{del}$ = the average delivery temperature, °F (°C).

$\overline{T}_{in}$ = the average inlet temperature, °F (°C).

ρ = the density of water at the average delivery temperature, lb/gal (kg/L).

If a water meter is used the maximum gpm (L/min) rating is computed as:

$$F_{max} = \frac{V_{10m} \left(\overline{T}_{del} - \overline{T}_{in} \right)}{10(77°F)}$$

$$\text{or } F_{max} = \frac{V_{10m} \left(\overline{T}_{del} - \overline{T}_{in} \right)}{10(42.8°C)}$$

Where:

V_{10m} = the volume of water measured during the 10-minute test, gal (L).

$\overline{T}_{del}$ = as defined in this section.

$\overline{T}_{in}$ = as defined in this section.

6.2.2 *Recovery Efficiency*

6.2.2.1 *Fixed Input Instantaneous Water Heaters.* The recovery efficiency is computed as:

$$\eta_r = \frac{M_1 C_{p1} \left(\overline{T}_{del,1} - \overline{T}_{in,1} \right)}{Q_r}$$

Where:

M_1 = total mass removed during the first draw of the 24-hour simulated use test, lb (kg), or, if the volume of water is being measured,

$M_1 = V_1 \cdot \rho$

Where:

V_1 = total volume removed during the first draw of the 24-hour simulated use test, gal (L).

ρ= density of the water at the water temperature measured at the point where the flow volume is measured, lb/gal (kg/L).

C_{p1} = specific heat of the withdrawn water, $(\overline{T}_{del,1} + \overline{T}_{in,1})$ / 2, Btu/lb °F (kJ/kg °C).

$\overline{T}_{del,\,1}$ = average water outlet temperature measured during the first draw of the 24-hour simulated use test, °F (°C).

$\overline{T}_{in,\,1}$ = average water inlet temperature measured during the first draw of the 24-hour simulated use test, °F (°C).

Q_r = the total energy used by the water heater between cut-out prior to the first draw and cut-out following the first draw, including auxiliary energy such as pilot lights, pumps, fans, etc., Btu (kJ). (Electrical auxiliary energy shall be converted to thermal energy using the following conversion: 1 kWh = 3,412 Btu.)

6.2.2.2 *Variable Input Instantaneous Water Heaters.* For instantaneous water heaters that have a variable firing rate, two recovery efficiency values are computed, one at the maximum input rate and one at the minimum input rate. The recovery efficiency used in subsequent computations is taken as the average of these two values. The maximum recovery efficiency is computed as:

$$\eta_{r,\,max} = \frac{M_1 C_{p1} \left(\overline{T}_{del,\,1} - \overline{T}_{in,\,1} \right)}{Q_{r,\,max}}$$

Where:

M_1 = as defined in section 6.2.2.1.

C_{p1} = as defined in section 6.2.2.1.

$\overline{T}_{del,\,1}$ = as defined in section 6.2.2.1.

$\overline{T}_{in,\,1}$ = as defined in section 6.2.2.1.

$Q_{r,\,max}$ = the total energy used by the water heater between burner cut-out prior to the first draw and burner cut-out following the first draw, including auxiliary energy such as pilot lights, Btu (kJ).

The minimum recovery efficiency is computed as:

$$\eta_{r,\,min} = \frac{M_4 C_{p4} \left(\overline{T}_{del,\,4} - \overline{T}_{in,\,4} \right)}{Q_{r,\,min}}$$

Where:

M_4 = the mass withdrawn during the fourth draw, lb (kg), or, if the volume of water is being measured,

$M_4 = V_4\, \rho$

Where:

V_4 = total volume removed during the first draw of the 24-hour simulated use test, gal (L).

ρ = as defined in 6.2.2.1

C_{p4} = the specific heat of water, Btu/lb°F (kJ/kg °C).

$\overline{T}_{del,\,4}$ = the average delivery temperature for the fourth draw, °F (°C).

$\overline{T}_{in}$, 4 = the average inlet temperature for the fourth draw, °F (°C).

$Q_{r,\,min}$ = the total energy consumed between the beginning of the fourth draw and burner cut-out following the fourth draw, including auxiliary energy such as pilot lights, Btu (kJ).

The recovery efficiency is computed as:

$$\eta_r = \frac{\eta_{r,\,max} + \eta_{r,\,min}}{2}$$

Where:

$\eta_{r,max}$ = as calculated above.
$\eta_{r,min}$ = as calculated above.

6.2.3 *Daily Water Heating Energy Consumption.* The daily water heating energy consumption, Q_d, is computed as:

$Q_d = Q$

Where:

Q = the energy used by the instantaneous water heater during the 24-hr simulated use test.

A modification is needed to take into account that the temperature difference between the outlet water temperature and supply water temperature may not be equivalent to the nominal value of 77°F (135°F − 58°F) or 42.8°C (57.2°C − 14.4°C). The following equations adjust the experimental data to a nominal 77°F (42.8°C) temperature rise.

The energy used to heat water may be computed as:

$$Q_{HW} = \sum_{i=1}^{6} \frac{M_i C_{pi} \left(\overline{T}_{del,\,i} - \overline{T}_{in,\,i}\right)}{\eta_r}$$

Where:

M_i = the mass withdrawn during the ith draw, lb (kg).
C_{pi} = the specific heat of water of the ith draw, Btu/lb°F (kJ/kg (°C).
$\overline{T}_{del,i}$ = the average delivery temperature of the ith draw, °F (°C).
$\overline{T}_{in,i}$ = the average inlet temperature of the ith draw, °F (°C).
η_r = as calculated in section 6.2.2.2.

The energy required to heat the same quantity of water over a 77°F (42.8°C) temperature rise is:

$$Q_{HW,\,77°F} = \sum_{i=1}^{6} \frac{M_i C_{pi} (135° F - 58° F)}{\eta_r}$$

$$\text{or } Q_{HW,\,42.8°C} = \sum_{i=1}^{6} \frac{M_i C_{pi} (57.2°C - 14.4°C)}{\eta_r}$$

Where:

M_i = the mass withdrawn during the *i*th draw, lb (kg).
C_{pi} = the specific heat of water of the ith draw, Btu/lb°F (kJ/kg (°C).
η_r = as calculated above.

The difference between these two values is:

$Q_{HWD} = Q_{HW,\,77°F} - Q_{HW}$
or $Q_{HWD} = Q_{HW,\,42.8°C} - Q_{HW}$
which much be added to the daily water heating energy consumption value. Thus, the daily energy consumption value which takes into account that the temperature rise across the storage tank may not be 77°F (42.8°C) is:
$Q_{dm} = Q_d + Q_{HWD}$

6.2.4 *Energy Factor.* The energy factor, E_f, is computed as:

$$E_f = \sum_{i=1}^{6} \frac{M_i C_{pi} (135° F - 58° F)}{Q_{dm}}$$

$$\text{or } E_f = \sum_{i=1}^{6} \frac{M_i C_{pi} (57.2° C - 14.4° C)}{Q_{dm}}$$

Where:

Q_{dm} = the daily water heating energy consumption as computed in accordance with section 6.2.3, Btu (kJ).
M_i = the mass associated with the *i*th draw, lb (kg).
C_{pi} = the specific heat of water computed at a temperature of (58°F + 135°F) / 2, Btu/lb °F [(14.4°C + 57.2°C) / 2, kJ/kg °C].

6.2.5 *Annual Energy Consumption.* The annual energy consumption for instantaneous type water heaters is computed as:

$E_{annual} = 365 \times Q_{dm}$

Where:

Q_{dm} = the modified daily energy consumption, Btu/day (kJ/day).
365 = the number of days in a year.

7. Ratings for Untested Models

In order to relieve the test burden on manufacturers who offer water heaters which differ only in fuel type or power input, ratings for untested models may be established in accordance with the following procedures. In lieu of the following procedures a manufacturer may elect to test the unit for which a rating is sought.

7.1 *Gas Water Heaters.* Ratings obtained for gas water heaters using natural gas can be used for an identical water heater which utilizes propane gas if the input ratings are within ± 10%.

7.2 *Electric Water Heaters*

7.2.1 *First-Hour Rating.* If an electric storage-type water heater is available with more than one input rating, the manufacturer shall designate the standard input rating, and the water heater need only be tested with heating elements at the designated standard input ratings. The first-hour ratings for units having power input rating less than the designated standard input rating shall be assigned a first-hour rating equivalent to the first draw of the first-hour rating for the electric water heater with the standard input rating. For units having power inputs greater than the designated standard input rating, the first-hour rating shall be equivalent to that measured for the water heater with the standard input rating.

7.2.2 *Energy Factor.* The energy factor for identical electric storage-type water heaters, with the exception of heating element wattage, may use the energy factor obtained during testing of the water heater with the designated standard input rating.

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