AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE
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October 4, 2016

Ms. Ashley Armstrong
U.S. Department of Energy
Building Technologies Office, Mailstop EE-5B
1000 Independence Avenue, SW
Washington, DC, 20585- 0121

Re: Docket number EERE-2015-BT-TP-0007; SNOPR for Test Procedures for the Conversion Factor for Consumer and Certain Commercial Water Heaters

Dear Ms. Armstrong,

On September 29, 2016 the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) submitted comments responding to the Department of Energy's (DOE) supplemental notice of proposed rulemaking (SNOPR) regarding the conversion factor for consumer and certain commercial water heaters issued in the August 30, 2016 *Federal Register*. On page 7 of those comments we noted that in 1977 an energy factor based efficiency test procedure was adopted for storage-type residential water heaters greater than 20-gallons and less than 120 gallons and cited 42 Fed. Reg. 54110, September 27, 1977. That citation is not completely accurate. The test procedure was issued by the Federal Energy Administration (DOE's precursor) on September 27, 1977 but was not published in the Federal Register until October 3, 1977. The complete citation is 42, No. 192, Fed. Reg. 54110

To avoid any potential for further confusion, a copy of that October 3, 1977 Federal Register notice is attached. It should be noted that in this final rule definitions for "water heater" and the various fuel types of water heaters are added in Section 430.2 on page 54116. Thus, these definitions are part of the regulation rather than definitions specific to the test procedure in Appendix E of Subpart B.

Respectfully submitted,

Frank A. Stanonik

Frank A. Stanonik
Chief Technical Advisor

Federal Register

TUESDAY, OCTOBER 4, 1977
PART III

FEDERAL ENERGY ADMINISTRATION

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ENERGY CONSERVATION PROGRAM FOR COMPLIANCES

Test Procedures for Water Heaters

[3128-01]

Title 10—Energy

CHAPTER II—FEDERAL ENERGY ADMINISTRATION

PART 430—ENERGY CONSERVATION PROGRAM FOR APPLIANCES

Test Procedures for Water Heaters

AGENCY: Federal Energy Administration.

ACTION: Final rule.

SUMMARY: This rule prescribes final test procedures for water heaters. Appliance test procedures are one element of the appliance energy efficiency program required by the Energy Policy and Conservation Act.

EFFECTIVE DATE: November 8, 1977.

FOR FURTHER INFORMATION CONTACT:

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Jim Merna (Media Relations), Room 3104 Federal Building, 12th and Pennsylvania Avenue NW., Washington, D.C. 20461 (202-566-9833).

Robert D. R. de Sugny (Office of the General Counsel), Room 5116 Federal Building, 12th and Pennsylvania Avenue NW., Washsington, D.C. 20461 (202-566-9750 or 202-566-9380).

SUPPLEMENTARY INFORMATION:

A. Background

The Federal Energy Administration (FEA) hereby amends Part 430, Chapter II of Title 10, Code of Federal Regulations, in order to prescribe test procedures for water heaters pursuant to section 323 (42 U.S.C. 6293) of the Energy Policy and Conservation Act (Pub. L. 94-163). Water heater test procedures were proposed by notice issued April 21, 1977 (42 FR 21576, April 27, 1977), and a public hearing on the proposed test procedures was held on June 13, 1977.

By notice issued May 24, 1977 (42 FR 27896, June 1, 1977), FEA established Subparts A and B of Part 430, Chapter II of Title 10, Code of Federal Regulations. Certain definitions and general provisions applicable to the energy conservation program for appliances have been promulgated in Subpart A. Final test procedures for room air conditioners, dishwashers, television sets, clothes dryers, electric refrigerators, freezers, and electric refrigerator-freezers, have been prescribed in Subpart B and the final test procedure for clothes washers has been issued today by separate notice. Several other test procedures have been proposed for inclusion in Subpart B and FEA has also proposed a Subpart C for appliance energy efficiency improvement targets. An outline of the provisions of Part 430 which have so far been established, including provisions in today's notice, is as follows:

Subpart A—General Provisions

B. Discussion of Comments

Comments were received from industry, consumers, and both Federal and State agencies. Those comments which were directly concerned with the labeling program under section 324 of the Act were forwarded to the Federal Trade Commission for consideration in developing labeling rules applicable to water heaters and they are not addressed here.

The following is a discussion of the issues raised by those comments which pertained to the technical aspects of the proposed water heater test procedures. The comments have been analyzed by topic, rather than source, since in many cases the same or similar comments were received from more than one person.

1. The burden of testing

Both the electric water heater manufacturing industry and the oil water heater manufacturing industry commented that the proposed test procedure was unduly burdensome, however, their objections were based on different grounds.

The basis of the electric water heater industry's objection was that testing costs would be prohibitive due to the extremely large number of basic models they would be considered to manufacture under the test procedure's proposed definition of basic model. That definition categorized units as different basic models not only if they differed in factors such as tank capacity and insulation, but also if they differed in heater element wattage or voltage ratings. As a consequence, one manufacturer commented that he theoretically offered 20,000 basic models. Another manufacturing firm stated that 144 different electrical input configurations are available for each of its electric water heater tank sizes.

FEA finds that the test procedure, as proposed, would prove unduly burdensome for manufacturers of electric water heaters with immersed heating elements in view of the large number of basic models that would have to be tested and the attendant high cost of testing. As a result, FEA has made changes to the proposed test procedure which are designed to reduce the burden of testing for manufacturers of electric water heaters with immersed heating elements. The changes are based on the fact noted at the hearing and in the comments that the electrical characteristics of an electric water heater with immersed heating elements have a minimal effect on efficiency for many purposes of the test procedure. It was therefore feasible to eliminate the distinction between units made on the basis of electrical characteristics. This reduces the number of basic models that most manufacturers would be considered to produce to twenty according to testimony received at the hearing.

As a consequence, several important changes in the test procedure have been made. First, the definition of a water heater basic model was revised to exclude immersed heating elements from consideration. Second, the standby loss test for electric water heaters with immersed heating elements was revised to require the installation of "standardized" heating elements in the water heaters to be tested. Third, the hot water supply rating test and the recovery rate calculation were deleted from the test procedure. Finally, the method for determining the power input for electric water heaters with immersed heating elements was changed. Each of these changes is discussed in detail in other sections of the preamble.

The oil water heater manufacturing industry also commented that the test procedure was burdensome as applied to them and they requested to be exempted from testing. They based their request on the fact that they represent only one percent of water heater sales and the

claim that their costs of testing would be higher than for manufacturers of other types of water heaters. The oil water heater manufacturing industry presented a cost analysis to demonstrate how the costs of testing would result in a much higher per unit cost increase for water heaters produced by a small manufacturer of oil water heaters with small production runs than for a large manufacturer of electric water heaters with large production runs. Thus, it was claimed, the much greater increase in price due to testing costs of oil water heaters over gas and electric water heaters would price the oil water heaters outside of the water heater market and lead to the demise of the oil water heater manufacturing industry.

FEA finds that insufficient evidence has been produced by the oil water heater manufacturing industry to establish grounds for excluding oil water heaters from the water heater test procedure. The cost analysis presented is a comparison of hypothetical cases. No evidence was presented to indicate that these hypothetical cases are representative of industry-wide conditions or that the costs would be any different for a small electric water heater manufacturer. The sampling plan used in the cost analysis was not the sampling plan which appeared in the proposed test procedure and the assumption was made that each manufacturer would test his own units even though independent testing laboratories could be utilized. FEA rejects the recommendation that oil water heaters be excluded from the water heater test procedure at this time but may reconsider its position upon the submission of sufficient evidence that the test procedure is unduly burdensome or significantly more burdensome to oil water heater manufacturers as compared to similar sized manufacturers of other types of water heaters.

2. FLUE REQUIREMENTS

A comment made was that a specification is needed for the attachment of a flue pipe extension to gas or oil water heaters having horizontal vent outlets. FEA concurs. The flue requirement specification in the proposed test procedure inadvertently addressed only water heaters with vertical vent outlets. Section 2.2 of Appendix E has been revised to incorporate a specification for attaching a flue pipe to a water heater with a horizontal vent outlet.

Another comment made was that the test procedure should require that a direct vent water heater be set up as specified in the manufacturer's instructions that accompany the water heater. FEA concurs with this comment with the proviso that the length of vertical flue pipe attached to the water heater must not be greater than the specified five foot length. Section 2.2 of Appendix E has been revised to incorporate this specification.

A third comment suggested the use of a longer flue pipe extension in the test procedure to better represent actual conditions of gas and oil water heater installation in the home. While it would be more representative of field conditions to use a longer length of flue pipe for testing water heaters, e.g., 15 feet instead of the specified 5 feet, the physical limitations of the manufacturer's test laboratories might make such a requirement unduly burdensome. FEA has therefore not adopted this suggestion.

3. FUEL HEATING VALUE

Many comments were directed toward Section 2.4 of Appendix E, "Energy Supply." Most of these comments concerned the heating values assigned to gas and oil fuels. One such comment was a recommendation that a manufacturer of oil water heaters be permitted to conduct testing either by using fuel oil with a presumably certified heating value of 138,000 Btu per gallon or by determining the actual heating value of the fuel oil used in the test. FEA has assumed that the figure 138,000 cited in the comment above was a typographical error in the comment and was supposed to be 138,500, the heating value of fuel oil in Btu per gallon cited in the proposed test procedure. Another comment was a recommendation that the heating value of natural gas and propane should be designated as approximate net values. A comment was also made that specifying a heating value for natural gas of 1025 Btu per standard cubic foot is unrealistic since the heating value of the natural gas supplied by local utilities varies with geographic location. A manufacturing firm implied that the requirement that the actual heating value of the natural gas used in the test be determined with an error no greater than one percent is unduly burdensome. This firm stated that it does not have the instrumentation available at its water heater manufacturing plants to measure the heating value of the natural gas supplied by the local utilities. It has been this firm's practice to rely on the local utility to furnish on an "as needed" basis the heating value of the natural gas supplied. The firm recommended allowing the use of the gas supplied by the local utility for testing on the condition that is identified by the utility as "natural gas." The firm also stated that its comments concerning the determination of the heating value of natural gas apply to propane gas as well. A comment was made that an ERDA report indicated that the heating value of fuel oil supplied by utilities may be as low as 120,000 Btu per gallon. It was also pointed out that FEA did not state what type of test was to be used for determining the heating value of fuel oil. This can have a dramatic impact on the results it was claimed. Finally, a comment recommended that the requirement that natural gas with a heating value of 1025 Btu per standard cubic foot be used in the test be deleted, the reason being that the manufacturers performing the tests would have no control over the gas supplied by the utilities.

The concerns expressed in the comments above fall into two categories: (1) the proposed test procedures specification of exact heating values for gas and oil fuels, and (2) the burden of having to determine the heating value of the fuel used in testing with an error of no greater than one percent.

In the proposed test procedure heating values for gas and oil fuels were inadvertently specified as exact values. The actual heating value of the fuel used in testing need only approximate the value specified for that fuel in the proposed test procedure. Therefore, section 2.4 of Appendix E has been revised to specify approximate heating values for gas and oil fuels.

FEA rejects the recommendations that a standard heating value be assumed for each fuel or that local utilities be relied upon to provide the heating value of the fuel they supply. Fluctuations in the heating value of fuels supplied by utilities do occur as studies have shown. FEA does not have sufficient information on the capability of local utilities to provide accurate and meaningful heating value information on the fuel or fuels they supply to warrant acceptance of this means of determining fuel heating value. On the other hand, FEA accepts the recommendation made at the public hearing that water heater manufacturers be permitted the option of purchasing "bottled" fuel which has had its actual higher heating value determined with an error of no greater than one percent as certified by the supplier. Thus, a manufacturer would have the choice of either purchasing a calorimeter, if one is not already available, to determine the actual heating value of the fuel or fuels supplied by the local utility or purchasing the necessary quantity of "bottled" fuel of a certified heating value. Section 2.4 of Appendix E has been revised to allow for the use of "bottled" gas or a tested oil of a certified heating value in the test procedure.

4. WATER TEMPERATURE RISE AND THERMOSTAT SETTING

Several comments were made which questioned the specification of 90° F. in the test procedure for the temperature rise through which a water heater under test must heat the inlet water. One comment recommend that values of temperature rise be selected on the basis of geographical regions to better reflect actual conditions where water heaters are marketed. In other words, the water heater test procedure should be regionalized to account for different water inlet temperatures which result in different temperature rises in various parts of the country. FEA rejects this recommendation on the basis that it would require water heater manufacturers to conduct many more tests than currently required and it would therefore be unduly burdensome.

Comments were made that the 90° F. temperature rise figure was too high and should be lowered to reflect conditions of operation advocated by FEA, i.e., that consumers should lower the thermostat settings on their water heaters to reduce energy consumption. FEA rejects this recommendation. Water heater thermo-

stats are normally factory-set for gas heaters at 140° F. and at 150° F. for electric water heaters. The fact that these settings may be adjusted both up or down by the installer or the homeowner is irrelevant to the determination of the cost of operation unless field surveys indicate that water heaters in representative use are normally adjusted to a different thermostat setting than at the time of purchase. No such field survey data was presented at the public hearing. Therefore, the test procedure uses the average value of the two common factory settings of water heater thermostats, 145° F., as the best approximation of the typical field water heater thermostat setting. Since, as stated in the proposed test procedure, NBS has determined that the national average inlet water temperature is 55° F., the difference between these two temperatures, 90° F., is used a the water temperature rise in the test procedure.

Further comments questioned FEA's selection of the inlet water temperature and the water heater thermostat setting for the purposes of the test procedure. It is true that these values, 70° F. and 160° F., respectively, do not represent field conditions as described by FEA. However, for some testing facilities, climatic conditions and/or other factors may be such that for all or part of the year tap water temperatures will exceed 55° F. Therefore, if a 55° F. inlet water temperature were to be specified in the test procedure, these facilities would have to purchase additional equipment to cool the available tap water prior to conducting a test. FEA believes that appropriate and comparable results can be obtained and the test procedure can be made less burdensome if water heaters are tested with an inlet water temperature of 70° F. This inlet water temperature can normally be achieved in laboratories throughout the country at any time of year without the need for cooling of the tap water. When the inlet water temperature of 70° F. is coupled with the requirement of a 90° F. water temperature rise, it results in a thermostat setting of 160° F. FEA finds that specifying an inlet water temperature of 70° F. and a water heater thermostat setting of 160° F. makes for a less burdensome test procedure which justifies their use.

5. OIL WATER HEATER DEFINITION

Comments were made that the definition of an oil water heater in the proposed test procedure included oil water heaters predominantly used in commercial and industrial facilities. To exclude commercial and industrial type units and thereby make the types of oil water heaters covered by the test procedures comparable to the types of gas and electric water heaters covered, it was recommended that the value of the maximum energy input rate, 172,500 But per hour in the proposed test procedure, be reduced to 103,875 Btu per hour which equates to an oil consumption rate of 0.75 gallons per hour. It was further recommended that the value of the maximum energy input rate, 172,500 Btu per the proposed definition of an oil water heater be reduced from 50 gallons to 40 gallons for the same reason.

FEA finds that the proposed definition of an oil water heater does cover units which are not normally purchased by individuals for household use. FEA has revised the proposed definition of an oil water heater to specify a maximum energy input rating of 103,875 Btu per hour (which equates to an oil consumption rate of 0.75 gallons per hour) but has not revised the specified maximum tank capacity value, 50 gallons. With the reduction of the maximum specified energy input rate, FEA finds that oil water heaters with 50 gallons tank capacities are purchased by individuals for household use and therefore will be covered by the test procedure.

6. HOT WATER USE RATE

Many comments questioned the daily hot water usage rate of 64.3 gallons per day specified in the test procedure to compute annual costs of operation. Most of these comments stated that this rate is too high to represent national average conditions. The reason for the apparent discrepancy between the hot water usage rate specified by FEA and the studies cited in the comments is that FEA's usage rate is based upon representative conditions of use of the types of water heaters covered by the proposed test procedure. The comments cited national average use rates based on household surveys which includes water usage data from households not serviced by the type of water heaters covered by the proposed test procedures such as apartment dwellings serviced by large commercial water heaters. Including these types of households also lowers the number of persons per household from four, which is used by FEA to determine the daily hot water usage rate, to three, further contributing to a lower usage rate than that used by FEA.

The hot water usage rate of 64.3 gallons per day was arrived at from a survey of 50 gas and 50 electric utility companies for hot water and energy usage data for water heaters. Eighteen of these companies supplied metered data. Data obtained were normalized to a family of four and to a 90° F. temperature rise. The family size of four was taken from Census Bureau data as the average family size. The types of water heaters covered by the proposed test procedure are usually found in the service of single families. The use of a 90° F. temperature rise is explained in the previous section, Water Temperature Rise and Thermostat Setting. When the hot water usage rate of 64.3 gallons per day and the temperature rise of 90° F. are inserted into the water heater test procedure equations along with typical water heater performance parameters of recovery efficiency and standby loss as determined by laboratory tests, the result correlates well with typical home energy usage as determined by the field survey.

Therefore no changes to the proposed test procedure are considered necessary with respect to the national average value of hot water usage rate as used in the calculation of average daily energy consumption.

7. WATER HEATERS NOT COVERED BY THE TEST PROCEDURES

Comments were made that the proposed test procedures do not address solar water heaters, water heater/boiler combinations, or recirculating water heaters. Although the Energy Policy and Conservation Act empowers the Administrator to include other energy sources, at this time only those appliances powered by electricity or fossil fuels are subject to testing. Therefore solar water heater manufacturers are not subject to the Act, however, they may use the present test procedure to provide the consumer with information concerning solar water heater performance if they so choose.

Boiler/water heater combinations are not considered in this test procedure because it is more appropriate to consider such combinations as systems rather than to attempt to consider the water heater and boiler components separately. Since the water heater portion of a boiler/water heater combination is a secondary system of the boiler, FEA finds that it is more appropriate to include boiler/water heater combinations with furnaces. Therefore the boiler/water heater type of appliance will be considered in, and subject to, the test procedure which is currently under development for furnaces.

The recirculating water heater is generally used in large apartment buildings or for other commercial applications such as office buildings where long runs of piping from the water heater to the point of use would result in a long delay period before hot water becomes available at the fixture if a recirculating system were not used. Very few of these systems are sold to the typical consumer and many are custom designed and custom built. Therefore, the inclusion of recirculating systems in the test procedure is not recommended at this time.

8. TEMPERATURE DIFFERENCE BETWEEN STORED WATER AND ROOM TEMPERATURE AS USED IN THE CALCULATIONS

A comment stated that the mean temperature difference between the stored water and room temperature is more likely in the range of 70–80° F. since most water heaters are located indoors. The proposed test procedure specifies that a temperature difference of 90° F. is to be used as the temperature difference between the stored water and the room temperature. Unlike all of the other values specified in this test procedure, this value for temperature difference is a derived value rather than a value determined by empirical data. FEA has no data on typical ambient temperatures where water heaters are installed, however, the assumed value of 90° F., when coupled with a hot water usage rate of 64.3 gallons per day heated through a 90° F. temperature rise, will yield values of calculated energy consumption that agree with actual energy consumption

data for water heaters. A change in this value would necessitate a change in one of the other parameters such as hot water usage rate, water temperature rise, etc., in order to maintain agreement between the energy consumption calculated by use of the test procedure and actual energy consumed in representative use. Therefore, no change to the specified temperature difference between stored water and room temperature is recommended.

9. MEASUREMENT AND CALCULATION OF STANDBY LOSS

Concerning the standby loss test, FEA concurs with the comments that standby loss for electric water heaters with immersed heating elements is virtually independent of energy input rating. Standby loss is a measure of the hot water storage performance of a water heater. This measure is primarily a function of the type and configuration of the tank insulation since most of the heat loss during standby is through the water heater jacket to the air surrounding the water heater. This is particularly true for electric water heaters which do not have flue losses and therefore their only other heat loss is through the inlet and outlet pipes when no heat traps are present. Because of this and because virtually all input energy to the heating elements goes towards heating water by the very nature of their design of having the heating elements in direct contact with the water in the water heater tank, standby loss will be the same for all electric water heaters with immersed heating elements of a given basic model. Therefore, FEA has adopted the recommendation that standby loss tests for electric water heaters with immersed heating elements be performed with the water heaters to be tested equipped with "standardized" heating elements. The procedure for determining standby loss for electric water heaters with immersed heating elements is presented in section 3.4.2 of Appendix E.

A suggestion was made that determining standby loss in terms of the fraction of the heat content of the stored water lost per hour instead of in units of energy lost per hour hides the actual value of standby loss. FEA finds that the determination of standby loss in terms of units of energy lost per hour can be accomplished by additional calculations which utilize the results obtained by the present test procedure. The determination of standby loss in terms of the fraction of the heat content of the stored water above room temperature lost per hour, however, allows the test for standby loss to be run without maintaining an exact 90° F. temperature difference between the stored water and the ambient laboratory room temperature since the test procedure compensates for ambient temperature and will yield the same value of standby loss as long as the ambient room temperature is within the range specified, 65° F. to 85° F. In order to directly determine standby loss in absolute terms of Btu per hour, the test would need to be run under conditions of a constant room temperature of 70° F. with stored water at 160° F. in order to obtain an exact 90° F. temperature difference. Alternatively, the stored water temperature would have to be adjusted depending on the laboratory room temperature at the time of tests.

Thus, the determination of standby loss in terms of the fraction of the heat content of the stored water lost per hour makes for a less burdensome test procedure than the one which would have to be developed if the suggestion that standby loss be determined in terms of units of energy lost per hour were to be adopted. In addition, it allows FTC to label the standby loss in the manner suggested if the FTC deems it appropriate. Therefore, the suggestion has not been adopted.

A comment was made that a calculation be included in the test procedure to determine a cost of operation for a water heater on standby in terms of dollars per month. FEA finds such a cost can be determined from the test results of the current test procedure. Therefore, FTC can adopt this proposal to determine a cost of operation of a water heater on standby as part of their water heater labeling program, if they so choose.

Another comment suggested that a single test be conducted to determine both standby loss and recovery efficiency. The test recommended consists of a 12-hour standby period followed by a draw period repeated enough times to provide acceptable accuracy. It was stated that the standby test proposed may not credit the savings to be expected from an electric ignition system and that recovery during dynamic conditions such as a water draw schedule may be different than recovery from 70° F. to 165° F., as proposed in the static test. Although no testing with intermittent ignition has been conducted by NBS to date, preliminary testing with a reduced pilot input rate has shown energy savings for a 72-hour standby test. The question of accurately predicting an energy savings for electric ignition alone seems to be a moot point since that design option is not considered economically practical unless it is accompanied by the use of a flue damper. In any event, NBS considers the test procedure as proposed to be sufficient to detect energy savings for intermittent ignition systems. FEA concurs with the NBS position. Therefore, this suggestion has not been adopted.

10. MEASUREMENT AND CALCULATION OF RECOVERY EFFICIENCY

A comment noted that a recovery efficiency of 100 percent is assumed for electric water heaters with immersed heating elements in the calculation of standby loss yet a value for the recovery efficiency of an electric water heater with immersed heating elements is calculated in a previous section. This apparent inconsistency results from the different methods used to calculate recovery efficiency and standby loss between the electric and gas or oil fueled heaters.

The recovery efficiency of an electric water heater with immersed heating elements is very near to 100 percent since, as explained in the section on standby loss, an immersed heating element delivers practically 100 percent of the energy input at the point of use to the water. To make a direct measurement of the recovery efficiency of such a water heater would be very difficult. The procedure would require that the temperature of the water in the water heater tank be determined very accurately. The six thermocouple array that is required to be installed in the tank according to section 2.5 for the purpose of measuring water temperature is not sufficient for the purpose of such a test. In fact, attempts made to measure the recovery efficiency of an electric water heater with this thermocouple array could result in values of recovery efficiency greater than 100 percent due to the error introduced by variations in water temperature which exist in the spherical portion at the bottom of the tank. An analysis would have to be made of the geometry of the tank and additional thermocouples would have to be used in order to achieve the accuracy requisite to directly measure recovery efficiency. The requirements of making such a direct measurement would result in a test procedure which would be unduly burdensome for a manufacturer to conduct.

Instead of requiring that the recovery efficiency of an electric water heater with immersed heating elements be determined directly, the test procedure provides for calculating the recovery efficiency as one minus the standby losses during recovery since standby loss is the only energy loss for such water heaters. This indirect method for determining recovery efficiency is more accurate than any direct method of determination which would not be unduly burdensome.

The standby loss measurement procedure is the same for each type of heater. However, the calculation differs in that an assignment of 0.98 for the recovery effciency, E_T*, is made for the electric water heater with immersed heating elements. Since one does not know the exact recovery efficiency for electric water heaters until the standby loss is measured and the standby loss contains a correction based on recovery efficiency, there exists two equations with three unknowns. It therefore becomes necessary to assign a recovery efficiency in the standby loss equation. In the proposed test procedure, an assignment of 1.00 was made. The actual value of the recovery efficiency is more likely in the range of 0.97 to 0.99. Therefore, in order to reduce the error introduced into the standby loss equation for electric water heaters with immersed heating elements, FEA has changed the assigned value for recovery efficiency from 1.00 to 0.98.

One comment proposed that the water heater tank should be preheated for the purposes of performing the recovery efficiency test since oil fueled heaters are affected more by a cold start test than either gas or electric heaters. Elimination of the tank preheating test reduced the test time and the cost of testing. NBS testing has revealed that the cold start

procedure gives test results 2 percent to 3 percent lower than if the tank were preheated for oil fueled water heaters. The preheated tank procedure would credit the recovery test with heat retained in the tank from the preheating of the tank. This does not represent actual field conditions since heat input is not obtained free in actual use. However, the cold start test as proposed also does not represent actual use in the field. In the interest of reducing the time and the costs required to include a tank preheating test in the test procedure, the use of a tank preheating test has not been adopted.

A comment stated that the static tests, without drawing water for measuring recovery efficiency, are not sufficiently accurate for determining the recovery efficiency of gas or oil fueled water heaters. Tests at NBS using a typical withdrawal schedule have shown a good correlation between the static test measurements and calculations compared to actual metered energy consumption for a 16-hour withdrawal schedule. Therefore, no change to the static test procedure has been made.

A comment was made that a calculation be included in the test procedure to determine a cost of operation for a water heater during the recovery stage in terms of dollars per 1000 gallons of hot water delivered per month. Such a cost can be determined from the test results of the current test procedure. Therefore, FTC can adopt this proposal to determine a cost of operation of a water heater on recovery as part of their water heater labeling program, if they so choose.

11. POWER INPUT DETERMINATION

As a result of the change made to the definition of a basic model of a water heater, a method for determining the power input for an electric water heater with immersed heating elements had to be developed. Section 3.2.2 of Appendix E of this subpart presents the method for making this determination. The method does not require that power input measurements be made. The manufacturer's assigned design energy ratings for the immersed heating elements that are installed in a water heater are used to calculate the power input term. Although this means of determining the power input for an electric water heater with immersed heating elements is an approximation of the actual value, the error that may be present will have little bearing on the two measures, recovery efficiency and average daily energy consumption, that use the power input term in their equations, by the nature of the equations themselves. The values determined from these equations are sufficiently insensitive to error in the power input term to justify using an approximation for power input and not requiring that it be directly measured.

12. HOT WATER SUPPLY RATING AND RECOVERY RATE

The hot water supply rating test and the recovery rate determination that were part of the proposed test procedure have been deleted from the test procedure on the basis that, in their present form, they would make the test procedure unduly burdensome for manufacturers of electric water heaters with immersed heater elements to conduct. Unlike standby loss, hot water supply rating and recovery rate determinations are very dependent on the actual wattage and location of the immersed heating elements installed in the water heater, the number of such elements installed, and the configuration of the auxiliary electrical system of the water heater which controls the operation of the heating elements. Testing for hot water supply rating and recovery rate would have to be done for all possible combinations of these factors which goes back to the problems associated with the proposed definition of a basic model of a water heater.

Comments were made that the hot water supply rating of an electric water heater with immersed heating elements could be predicted for all basic models of electric water heaters in much the same way that standby loss could be predicted. No hot water supply rating prediction scheme was presented. Neither was any data submitted from which a hot water supply rating prediction scheme might be developed. Without a hot water supply rating prediction scheme and without test data to verify that a particular prediction scheme is sufficiently accurate, FEA cannot consider making such a modification to the hot water supply rating test at the present time.

In the case of recovery rate, the power input to the water heater must be determined. The current procedure for determining power input for electric water heaters with immersed heating elements is to accept the design value assigned by the manufacturer. Unlike recovery efficiency and average daily energy consumption, recovery rate is sensitive to error in the power input term and the approximations of power input determined in section 3.2.2 would introduce a potentially significant error into the determination of recovery rate which would be unacceptable.

FEA finds that in the absence of a hot water supply rating prediction scheme and a recovery rate prediction scheme, the hot water supply rating test and the recovery rate determination must be deleted from the water heater test procedure at the present time. FEA recognizes that this deletion will eliminate an important measure of water heater performance from the test procedure. FEA also recognizes that without a hot water supply rating, or some other measure of hot water delivery performance, the test procedure leaves a consumer with less than the best information to select a water heater which will satisfy his needs. Therefore, FEA plans to investigate prediction schemes for the determination of hot water supply rating or for the determination of some other measure of hot water delivery performance for water heaters. The goal of this investigation will be to provide consumers with a useful measure of hot water delivery performance for water heaters while not imposing unduly burdensome test requirements on any segment of the water heater industry.

FEA hereby invites the water heater industry and any other interested parties to provide input to FEA concerning this proposed investigation. This investigation will be completed by December 1, 1977. In its present form, nothing in this final test procedure prohibits a manufacturer from making representations concerning the hot water supply rating of any of his water heater products.

13. SYMBOLS USED IN THE TEST PROCEDURE EQUATIONS

Coments were made that the symbols used in the equations of the proposed test procedure exhibited inconsistencies which made interpretation of the equations difficult. Further comments recomended that the symbols used be revised in accordance with standard practices. FEA concurs. The equations of section 4 of Appendix E of this subpart reflect the recommended changes.

14. TESTING CONDITIONS

Comments on section 2.5 of the proposed test procedure pointed out that the requirement that thermocouples be installed along the centerline of the water heater tank may lead to confusion since for many gas and oil water heaters the flue is located at the centerline of the tank. Section 2.5 has been revised to eliminate this potential source of confusion.

In response to a comment concerning the hook-up of the water heater inlet and outlet pipe connections to water supply and delivery pipes, the test procedure has been revised to require a heat trap type of configuration for water heaters with vertical inlet and/or outlet pipe connections.

15. CALCULATIONS OF THE ENERGY FACTOR

The proposed test procedure did not clearly state the appropriate section of Appendix E to be used in the calculation of the energy factor in section 430.22(e). This resulted in misinterpretation of the use of the average daily energy consumption. Section 430.22(e) has been corrected to properly reference the appropriate section of Appendix E.

16. INDIRECT ENERGY CONSUMPTION

A comment was made that the test procedure should account for the increased operating time and energy consumption of a furnace or air conditioner which is caused by gas and oil water heaters. The increased energy consumption arises from the fact that most gas and oil water heaters utilize interior air for combustion and draft maintenance which is then vented out of the house and replaced by the infiltration of exterior air which must then be heated by the furnace or cooled by the air conditioner depending on the season. The loss of interior conditioned air continues even when the water heater is not in the combustion state due to the natural draft of the flue unless the water heater is

equipped with a flue damper which is usually not the case.

FEA is sensitive to such hidden costs of operation and will incorporate them whenever they are of sufficient magnitude to warrant the burden of additional testing designed to measure and quantify such costs.

Secondary costs have been included in the final test procedures for dishwashers and clothes washers, and in the proposed test procedures for dehumidifiers and furnaces, however, FEA has decided not to incorporate these costs in the water heater test procedure at this time. FEA bases its decision on data forwarded by NBS which indicates that the secondary costs represent only 2 percent of the cost of operation of a water heater and that the testing burden to account for such costs would be large. Furthermore, NBS has reported to FEA that the potential dollar savings achieved by the use of a direct vent system, which utilizes exterior air rather then interior air and thereby avoids imposing additional costs on furnaces or air conditioners, is not sufficient to pay for the cost of such devices. Only when direct vent systems are combined with preheating devices do they become economically viable and the test procedure, as currently written, will measure most of the increased efficiency of water heaters so equipped. Therefore there is little justification for modifying the test procedures at this time.

Anyone with information indicating that direct vent systems alone are currently economically justified for water heaters or that the cost associated with the loss of interior conditioned air is greater than 2 percent of the cost of operation of a gas or oil water heater is hereby requested by FEA to submit such information. Should the assumptions on which FEA has based its decision be shown to be incorrect, FEA will consider modifying the water heater test procedure to incorporate the secondary costs of operation.

17. PRIMARY ENERGY LABELING

While a comment suggested primary energy labeling, i.e., taking into consideration the energy consumed by a power plant to produce the amount of electrical energy consumed by an appliance, the Energy Policy and Conservation Act specifically requires that the estimated annual operation cost of an appliance be calculated in terms of the retail cost of energy likely to be consumed in representative use. Therefore, this suggestion has not been adopted.

18. NUMBER OF UNITS TO BE TESTED

Some comments expressed objections to the sampling provision for water heaters. Proposed section 430.23(e) provided for sampling of each basic model to be tested when testing of water heaters is required by the Act or by program regulations of agencies responsible for administering the Act. This provision was intended both to provide an acceptable level of assurance that the test results are applicable to all units of a basic model for which testing is required and to minimize the testing burden on manufacturers.

Test procedures prescribed under section 323 of the Act are intended ultimately to be used, for example, for labeling under section 324, for monitoring the progress of manufacturers toward accomplishing the energy efficiency improvement targets under section 325, and for enforcement testing under section 326. These aspects of the appliance program have not, however, been implemented. It is quite possible that the objectives of appliance testing under each of these parts of the program, as well as the instructions as to how a test procedure should be applied, e.g., sampling of production units, may differ. FEA, NBS, and FTC are continuing to evaluate the appropriate method or methods for sampling the units to be tested in order to comply with the statute and satisfy all of the different elements of the appliance program.

While the various parts of the appliance program identified above are not in effect at this time, section 323(c) of the Act provides:

> Effective 90 days after a test procedure rule applicable to a covered product is prescribed under this section, no manufacturer, distributor, retailer or private labeler may make any representation—
>
> (1) In writing (including a representation on a label), or
>
> (2) In any broadcast advertisement,
>
> respecting the energy consumption of such product or cost of energy consumed by such product, unless such product has been tested in accordance with such test procedure and such representation fairly discloses the results of such testing.

In order to eliminate the problem discussed above associated with a general sampling provision, § 430.23 has been reserved in the final test procedure, and sampling requirements which apply only for purposes of advertising have been reorganized into § 430.24(e) of the final test procedures. Section 430.24(e) is similar to proposed § 430.23(e), but contains several revisions. Most notably, the units tested may now be either representative of production units, or actual production units. This change is intended to reduce the burden which might be caused by requiring post-production rating of basic models in every instance of testing pursuant to section 323(c) of the Act.

In addition, certain technical changes have been made in sampling language. Specifically, there is to be 90 percent confidence that the true mean of any measure of the basic model lies within ±10 percent of the mean of such measure of the sample. Comments pertaining to several proposed test procedures criticized the language of the proposed sampling provision. These comments suggested that a sampling provision should refer to the estimate of the mean rather than to the true mean. FEA has considered this suggestion and has determined that the language prescribed today is more technically correct because the statistical measure "estimate of the mean" and "mean of the sample" are generally considered to be identical. The final test procedures for room air conditioners and dishwashers used both these terms in a manner that could be confusing, and the language prescribed today is intended to eliminate this possibility.

Until a labeling rule has been implemented pursuant to section 324, manufacturers are not required to test unless they choose to make representations regarding a measure of energy consumption. It should be emphasized that the test procedures prescribed today apply only to the initial rating of a basic model.

19. MISCELLANEOUS

After careful consideration of all of the comments and further consultation with NBS and FTC, FEA has incorporated some minor changes in the proposed test procedures in the final rule that are not discussed above.

C. REGULATIONS PRESCRIBED

1. TEST PROCEDURES

The test procedures for water heaters prescribed today are included in Subpart B and are substantially the same as those proposed with the exception of the elimination of the hot water supply rating test and the recovery rate determination. As with the proposed procedures, test methods and conditions incorporate the approach contained in American National Standards Institute standard Z21.-10.1—1971 and C72.1—1972. The test procedure also uses the definition of the term "oil" contained in the American Society for Testing and Materials (ASTM) D396–71. Subsequent amendments of either the standard or the supplement made by the standard setting organization will have no effect on the test procedure which can only be amended by FEA.

Under the requirements of section 32 (c) of the Federal Energy Administration Act of 1974 (15 U.S.C. 761 et seq.) as amended by section 9 of the Federal Energy Administration Authorization Act of 1977 (Pub. L. 95–70), the Administrator is to consult with the Attorney General and the Chairman of the Federal Trade Commission concerning the impact on competition of any rules prescribed by FEA which utilize or incorporate any commercial standards.

The Administrator has transmitted copies of the final test procedures for water heaters, which incorporate the above mentioned commercial standards, to the Attorney General and the Chairman of the Federal Trade Commission for their comments concerning the impact of such standards on competition in accordance with section 32(c). Neither individual has any comments nor do they recommend against the incorporation or use of these commercial standards in the final test procedures for water heaters.

2. GENERAL PROVISIONS

Prescribed today are certain definitions applicable to water heaters which were previously proposed in Subpart A (41 FR 19977, May 14, 1976; 42 FR 15423, March 22, 1977). Comments were received regarding these definitions and the issues and changes have been discussed earlier in this notice. All definitions appearing in section 321 of the Act were incorporated by reference into Sub-

part A of Part 430 in the final test procedures for room air conditioners issued May 24, 1977 (42 FR 27896, June 1, 1977). Definitions of the terms "Administrator", "Btu" and "FEA" were also incorporated into Subpart A by the final room air conditioner test procedures. The definition of the term "basic model" for water heaters has been changed, as discussed above. Definitions of the terms "cutout" and "design power rating" have been added.

It should be noted that some of the definitions prescribed today may be applicable to test procedures for other appliances. While these definitions are final, comments to the effect that any of these definitions are inapplicable to a particular appliance will be evaluated to determine whether amendment or modification is appropriate.

3. APPLICATION OF TEST PROCEDURES

As discussed previously, the final water heater test procedures prescribed today must be applied before representations regarding a measure of energy consumption can be made. Because the purposes and needs of the different elements of the appliance program, such as labeling or targets, vary, application of the standard test methodology prescribed today may differ in some respects for each program element. Instructions on how to apply the standard test methodology will be proposed for comment as these other element of the appliance program are developed.

The requirements of § 430.24(e) of the final regulations apply until such time as final labeling requirements for a particular measure of energy consumption and the associated test procedure application provision are prescribed. After that time, all representations regarding a measure of energy consumption covered by a labeling rule must be the same as represented on the label.

D. UNIT COSTS OF ENERGY

Under section 323(b)(2) of the Act, FEA is to provide manufacturers information as to the representative average unit costs of energy. This information was provided by notice issued July 11, 1977 (42 FR 36549, July 15, 1977).

E. PREEMPTION

Today's rulemaking prescribing final test procedures for water heaters supersedes any State regulation to the extent required by section 327 of the Act. Pursuant to section 327, all State regulations which provide for the disclosure of information with respect to any measure of energy consumption of water heaters or which provide for any energy efficiency standard or similar requirement with respect to energy efficiency or energy use of water heaters must now employ test procedures identical to those specified in today's final rule.

In consideration of the foregoing, Chapter II of Title 10, Code of Federal Regulations is amended as set forth below, effective November 8, 1977.

(Energy Policy and Conservation Act, Pub. L. 94-163, as amended by Pub. L. 94-385; Federal Energy administration Act of 1974, Pub. L. 93-275, as amended by Pub. L. 94-385; E.O. 11790, 39 FR 23185.)

Issued in Washington, D.C., September 27, 1977.

ERIC J. FYGI,
Acting General Counsel,
Federal Energy Administration.

1. Section 430.2 is amended by adding paragraph (5) as part of the definition of "basic model" and by adding in appropriate alphabetical order the definition of "immersed heating element" and "water heater" to read as follows:

§ 430.2 Definitions.

* * * * *

"Basic model" means all units of a given type of covered product, or class thereof, manufactured by one manufacturer and:

* * * * *

(5) with respect to water heaters, which have the same primary energy source and which, with the exception of immersed heating elements, do not have any differing electrical, physical, or functional characteristics that affect energy consumption.

* * * * *

"Immersed heating element" means an electrically powered heating device which is designed to operate while totally immersed in water in such a manner that the heat generated by the device is imparted directly to the water.

* * * * *

"Water heater" means an automatically controlled thermally insulated vessel designed for heating water and storing heated water, which utilizes either oil, gas, or electricity as the fuel or energy source for heating the water, which is designed to produce hot water at a temperature of less than 180°F., and which includes the following products:

(a) "Electric water heater" means a water heater which utilizes electricity as the energy source for heating the water, which has a manufacturer's specified energy input rating of 12 kilowatts or less at a voltage no greater than 250 volts, and which has a manufacturer's specified storage capacity of not less than 20 gallons nor more than 120 gallons.

(b) "Gas water heater" means a water heater which utilizes gas as the energy source for heating the water, which has a manufacturer's specified energy input rating of 75,000 Btu per hour or less, and which has a manufacturer's specified storage capacity of not less than 20 gallons nor more than 100 gallons.

(c) "Oil water heater" means a water heater which utilizes oil as the energy source for heating the water, which has a manufacturer's specified energy input rating of 103,875 Btu per hour or less, and which has a manufacturer's specified storage capacity of 50 gallons or less.

* * * * *

2. Section 430.22 is amended by adding a paragraph (e), to read as follows:

§ 430.22 Test procedures for measures of energy consumption.

* * * * *

(e) *Water Heaters.* (1) The estimated annual operating cost for water heaters shall be—

(i) For a gas or oil water heater, the product of the representative average use cycle of 365 days per year times the sum of (A) The product of the average daily auxiliary electrical energy consumption in kilowatt-hours per day, determined according to section 4.5.1 of Appendix E of this subpart, times the representative average unit cost of electricity in dollars per kilowatt-hour as provided by the Administrator plus (B) The product of the average daily gas or oil energy consumption in Btu per day, determined according to section 4.5.2 of Appendix E of this subpart, times the representative average unit cost of gas or oil, as appropriate, in dollars per Btu as provided by the Administrator, the resulting product then being rounded off to the nearest dollar per year.

(ii) For an electric water heater, the product of the following three factors: (A) The representative average use cycle of 365 days per year, (B) The average daily energy consumption in kilowatt-hours per day, determined according to section 4.5.4 of Appendix E of this subpart, and (C) The representative average unit cost of electricity in dollars per kilowatt-hour as provided by the Administrator, the resulting product then being rounded off to the nearest dollar per year.

(2) The energy factor for water heaters shall be—

(i) For a gas or oil water heater, the quotient of the daily water heating energy consumption determined according to section 4.3 of Appendix E of this subpart divided by the product of the average daily energy consumption as determined according to section 4.5.4 of Appendix E of this subpart times 3,412 Btu per kilowatt-hours, the resulting quotient then being rounded off to the nearest 0.01.

(ii) For an electric water heater, the quotient of the daily water heating energy consumption determined according to section 4.3 of Appendix E of this subpart divided by the product of the average daily energy consumption as determined according to section 4.5.4 of Appendix E of this subpart times 3,412 Btu per kilowatt-hours, the resulting quotient then being rounded off to the nearest 0.01.

(3) Other useful measures of energy consumption for water heaters shall be those measures of energy consumption for water heaters which the Administrator determines are likely to assist consumers in making purchasing decisions and which are derived from the application of Appendix E of this subpart.

* * * * *

3. Section 430.24 is amended by adding a paragraph (e), to read as follows:

§ 430.24 Representations regarding measures of energy consumption.

* * * * *

(e) *Water heaters.* (1) Except as provided in paragraph (e)(3) of this section, no manufacturer, distributor, retailer, or private labeler of water heaters may make any representation with respect to or based upon a measure or measures of energy consumption described in § 430.22(e) unless a sample of sufficient size of each basic model for which such representation is made has been tested in accordance with applicable provisions of this subpart such that, for each such measure of energy consumption, there is at least 90 percent confidence that the true mean of such measures of the basic model is within ±10 percent of the mean of such measures of the sample.

(2) The sample selection for paragraph (e)(1) of this section shall be comprised of units which are production units, or which are representative of production units, of the basic model being tested.

(3) Whenever a rule applicable to water heaters has been prescribed under section 324 of the Act, this paragraph shall not apply to any label covered by such rule, and all representations of any measure of energy consumption covered by such rule shall be identical to the measure of energy consumption on the label.

* * * * *

4. Subpart B of Part 430 is amended to add an Appendix E, to read as follows:

APPENDIX E—UNIFORM TEST METHOD FOR MEASURING THE ENERGY CONSUMPTION OF WATER HEATERS

1. *Definitions.*

1.1 "Cutout" means the moment in time when a water heater thermostat has acted to reduce the energy or fuel input to the heating elements or burners to a minimum.

1.2 "Design Power Rating" means the nominal power rating that a water heater manufacturer assigns to a particular design of water heater heating element, expressed in kilowatts.

1.3 "Heat Trap" means a device which can be integrally connected, or independently attached, to the hot of 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 natural thermal convection between the water heater tank and its water supply pipes and thereby reduce the heat loss to the environment from the hot water stored in the water heater.

1.4 "Recovery Efficiency" means the ratio of the heat imparted to the water to—

(a) in the case of an electric water heater, the energy input to the heating elements during the period that the water temperature is raised from the inlet temperature to the final temperature with the tank filled to capacity.

(b) in the case of a gas or oil water heater, the heat content of the fuel consumed by the burners during the period that the water temperature is raised from the inlet temperature to the final temperature with the tank filled to capacity.

1.5 "Standby loss" means the ratio of the heat loss per hour to the heat content of the stored water above room temperature.

2. *Test conditions.*

2.1 *Installation.* Install the water heater according to the manufacturer's directions on a ¾-inch-thick plywood platform supported by three 2 x 4-inch runners. For water heaters without integral heat traps and with vertical inlet and outlet pipe connections, install the inlet and outlet piping with heat traps at the inlet and outlet ports. Such heat traps may be made using pipe fittings such as elbows connected in such a fashion that the inlet and outlet piping make vertically upward runs just before turning downward to connect to the inlet and outlet ports. For water heaters with integral heat traps or with horizontal inlet and outlet pipe connections, install the inlet and outlet piping in any convenient fashion.

Sufficient clearance shall be allowed between the water heater surface and the piping (including heat traps, if any) so that when the piping is insulated as specified below, the insulation does not contact any water heater surface except at the location where the pipe connections penetrate the water heater jacket. Insulate the water heater inlet and outlet piping (including heat traps, if any) for a length of four feet from the connection at the water heater with a material having a thermal resistance (R) value of not less than

$$4\ \frac{°F}{Btu/ft^2\text{-}hr}$$

2.2 *Flue requirements for gas and oil water heaters.*

2.2.1 *Flue requirements for gas water heaters.* For a gas water heater having a vertically discharging draft hood outlet, a 5 foot vertical flue pipe extension having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. For a gas water heater having a horizontally discharging draft hood outlet, a 90 degree elbow having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. A 5 foot length of flue pipe shall be connected to the elbow and oriented to discharge vertically upward. Perform all tests with the natural draft established by this length of flue pipe. Direct vent gas water heaters should be installed with venting equipment as specified in the manufacturer's instructions; however, the vertical length of the flue pipe shall be no greater than 5 feet.

2.2.2 *Flue requirements for oil water heaters.* For an oil fueled water heater, establish a draft at the flue collar equivalent to at least 0.02 inch of water column during periods of burner firing. For an oil water heater having a vertically discharging draft hood outlet, establish the draft by using a sufficient length of flue pipe connected to the water heater flue outlet and directed vertically upward. For an oil water heater having a horizontally discharging draft hood outlet, a 90 degree elbow having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. A length of flue pipe sufficient to establish the draft shall be connected to the elbow fitting and oriented to discharge vertically upward. Direct vent oil water heaters should be installed with venting equipment as specified in the manufacturer's instructions. When ceiling height limits the use of a sufficient length of vertical flue pipe for an oil water heater, a mechanical draft inducer may be used during periods of burner firing to establish the specified draft at the flue collar.

2.3 *Water supply.* During the entire test maintain the water supply to the water heater inlet at a temperature of between 68 and 72° F., and at a gauge pressure of between 40 pounds per square inch and the maximum pressure specified by the manufacturer for the water heater under test. If the water supply pressure varies outside of these limits during testing, the heater shall be isolated by use of a shut-off valve in the supply line with an expansion tank installed in the supply line downstream of the shut-off valve. There shall be no shut-off means between the expansion tank and the water heater inlet.

2.4 *Energy Supply.*

2.4.1 *Electrical supply.* For an electric water heater and for the auxiliary electrical system, if any, of an oil or gas water heater, maintain the electrical supply voltage to within ±1 percent of the center of the voltage range specified by the water heater manufacturer on the water heater nameplate throughout the entire operating portion of each test.

2.4.2 *Gas supply.*

2.4.2.2 *Natural gas.* For a gas water heater utilizing natural gas, maintain the gas supply at a normal inlet test pressure immediately ahead of all controls at 7 to 10 inches of water column. If the water heater is equipped with a gas appliance pressure regulator, the regulator outlet pressure at the normal test pressure shall be approximately that recommended by the manufacturer. All burners shall be adjusted to achieve an hourly Btu rating that is within ±2 percent of the hourly Btu rating specified by the manufacturer. Use natural gas with a higher heating value of approximately 1,025 Btu per standard cubic foot. Determine the actual higher heating value, H_n, in Btu per standard cubic foot, for the natural gas to be used in the test, with an error no greater than ±1 percent, and use that value for all calculations included herein. Alternatively, the test can be conducted using "bottled" natural gas of a higher heating value of approximately 1,025 Btu per standard cubic foot as long as the actual higher heating value of the bottled natural gas has been determined with an error no greater than ±1 percent as certified by the supplier.

2.4.2.2 *Propane gas.* For a gas water heater utilizing propane, maintain the gas supply at a normal inlet test pressure immediately ahead of all controls at 11 to 13 inches of water column. If the water heater is equipped with a gas appliance pressure regulator, the regulator outlet pressure at normal test pressure shall be approximately that recommended by the manufacturer. All burners shall be adjusted to achieve an hourly Btu rating that is within ±2 percent of the hourly Btu rating specified by the manufacturer. Use propane with a higher heating value of approximately 2,500 Btu per standard cubic foot. Determine the actual higher heating value, H_p, in Btu per standard cubic foot, for the propane to be used in the test, with an error no greater than ±1 percent, and use that value for all calculations included herein. Alternatively, the test can be conducted using "bottled" propane of a higher heating value of approximately 2,500 Btu per standard cubic foot as long as the actual higher heating value of the bottled propane has been determined with an error no greater than ±1 percent as certified by the supplier.

2.4.3 *Oil supply.* For an oil water heater utilizing fuel oil, maintain an uninterrupted supply of fuel oil to the water heater during the entire operating portion of the test cycle. Use fuel oil with a heating value of approximately 138,500 Btu per gallon. Determine the actual heating value, H_o, in Btu per gallon for the fuel oil to be used in the test, with an error no greater than ±1 percent, and use that value for all calculations

included herein. Alternatively, the tests can be conducted using a tested fuel oil with a certified higher heating value of approximately 138,500 Btu per gallon as long as the actual higher heating value of the test fuel oil has been determined with an error of no greater than ±1 percent as certified by the supplier.

2.5 *Thermocouple installation.* Install six thermocouples inside the water heater tank. Position each thermocouple measuring junction along a vertical line at the level of the center horizontal plane of each of six non-overlapping sections of approximately equal volume from the top to the bottom of the tank such that each thermocouple is surrounded by water and as far as possible from any heating element, anodic protective device, or a water tank or flue wall. The anodic protective device may be removed in order to install the thermocouples and all testing may be carried out with the device removed. Install thermocouples in both the cold-water inlet pipe and the hot-water outlet pipe not more than six inches from the connections to the water heater, or, where those connections are inaccessible, at the closest accessible point to those connections. Install in the test room a thermocouple with junction shielded against direct radiation from the water heater and positioned at the vertical mid-point of the heater at a perpendicular distance of approximately 24 inches from the surface of the water heater jacket. Provide an associated temperature measurement and indicator system to assure that the temperature indicated for the thermocouple location is within ±1° F. of the actual temperature at that location.

2.6 *Setting the tank thermostat.* Starting with a tank of unheated water, initiate normal operation of the water heater. After cutout, determine whether the maximum value of the mean tank temperature is within the range of 160° F. ±5° F. If not, turn off the water heater, adjust the thermostat, empty the tank and refill with unheated water, then initiate normal operation of the water heater, and once again determine the maximum mean tank temperature after cutout. Repeat this sequence until the maximum mean tank temperature after cutout is within the range of 160° F. ±5° F., at which time the thermostat is properly set. If a water heater has two thermostats, the thermostat which controls the upper heating element shall be set first to yield a maximum water temperature of 160° F. ±5° F. as measured by the topmost tank thermocouple after cutout. The thermostat which controls the lower heating element shall then be set to yield a maximum mean tank temperature of 160° F. ±5°F. after cutout.

2.7 *Fuel or energy consumption measurement.* Install one or more instruments which measure, as appropriate, and with an error no greater than ±1 percent, the quantity of electrical energy, natural gas, propane or fuel oil consumed by a water heater. Electrical energy consumption is to be expressed in units of kilowatt-hours. Natural gas and propane consumption shall be expressed in units of standard cubic feet, i.e., measured cubic feet corrected to standard conditions of 60° F. temperature and 30 inches of mercury column pressure. Fuel oil consumption is to be expressed in units of gallons. Also install one or more instruments which measure, as appropriate, and with an error no greater than ±1 percent, the rate of electrical energy, natural gas, propane or fuel oil consumption by a water heater. The rate of electrical energy consumption shall be expressed in units of kilowatts. The rate of natural gas and propane consumption shall be expressed in units of standard cubic feet per hour. The rate of fuel oil consumption shall be expressed in units of gallons per hour.

2.8 *Room ambient temperature.* Maintain the ambient air temperature of the test room between 65° F. and 85° F. at all times during the test, as measured according to section 3.5. The ambient air temperature during these tests shall not vary more than ±7° F. from the average ambient air temperature determined as the arithmetic average of the air temperatures measured periodically at intervals no greater than 15 minutes throughout the duration of the test.

3. *Test procedures and measurements.*

3.1 *Tank storage capacity.* Determine the storage capacity, V, of the water heater under test, in gallons, according to the method specified in section 2.26 of the American National Standard for Gas Water Heaters, Volume I, designated ANS Z21.10.1–1975.

3.2 *Power input determination.*

3.2.1 *Power input determination for gas and oil water heaters and electric water heaters with other than immersed heating elements.* Initiate normal operation of the water heater, and by using the appropriate instrumentation specified in section 2.7 and the appropriate fuel heating values of section 2.4, determine the power input, P, to the main burners (including pilot light power, if any) or heating elements of the water heater under test, in Btu per hour or kilowatts, as apropriate. In addition, determine the power input, p_r to any auxiliary electrical system of a gas or oil water heater when the main burners are in operation, in kilowatts; and the power input, p_s, to any auxiliary electrical system of a gas or oil water heater when the main burners are not in operation, in kilowatts.

3.2.2 *Power input determination for electric water heaters with immersed heating elements.* The power input, P, to the heating element of an electric water heater with one immersed heating element shall be taken to be the design power rating of the heating element. For an electric water heater with dual immersed heating elements, the power input, P, to the heating elements shall be taken to be the arithmetic mean of the design power ratings of the heating elements, if, in characteristic operation of the water heater, only one heating element will be energized at any time; otherwise, P shall be taken to be the sum of the design power ratings of the heating elements.

3.3 *Recovery efficiency.*

3.3.1 *Recovery efficiency for gas and oil water heaters and electric water heaters with other than immersed heating elements.* With the water heater turned off, fill the tank with water and eliminate any residual air remaining in the tank. If the mean tank temperature is constant and within 70° F.±2° F., record the mean tank temperature, initiate normal operation of the water heater, and begin measuring the fuel or energy flow to the burners (including pilot light fuel if any) or heating elements of the water heater using the appropriate instrumentation specified in section 2.7. After cutout determine the maximum mean tank temperature and record the total fuel flow, Q_r, for a gas or oil water heater, or the total electrical energy flow, Z_r, to the heating elements of an electric water heater, from initiation to cutout. Record the temperature difference, ΔT_1, obtained by subtracting the initial from the final maximum mean tank temperature.

3.3.2 *Recovery efficiency for electric water heaters with immersed heating elements.* The recovery efficiency for electric water heaters with immersed heating elements is derived from the results of the standby loss tests of section 3.4.2.

3.4 *Standby loss.*

3.4.1 *Standby loss for gas and oil water heaters and electric water heaters with other than immersed heating elements.* Establish normal water heater operation within the maximum mean tank temperature within the range specified in section 2.6 and with all air eliminated from the tank. Begin the standby loss test immediately after cutout. At the beginning of the standby loss test record the time, the mean tank temperature, the ambient air temperature, and begin measuring the fuel or energy flow to the burners (including pilot light fuel if any) or heating elements of the water heater using the appropriate instrumentation specified in section 2.7.

At the end of the first 15 minute interval and at the end of each subsequent 15 minute interval following the beginning of the test, record the mean tank temperature and the ambient air temperature. Continue these measurements until the end of a 48 hour period unless a main heating element or burner is on at that time, in which case, continue these measurements until the first subsequent cutout. When the test is terminated, record the total fuel flow, Q_s, for a or oil water heater, or the total electrical energy flow, Z_s, to the heating elements of an electric water heater, from the beginning to the end of the test period, the final mean tank temperature, the final ambient air temperature, and the time duration, t, of the standby loss test, in hours rounded off to the nearest tenth of an hour, which elapsed from the beginning to the end of the test period. Calculate the average of the recorded values of the mean tank temperatures and of the ambient air temperatures taken at the end of each time interval, including in each case the initial and final values. Determine the difference, ΔT_2, between these two averages by subtracting the latter from the former, and the difference, ΔT_3, between the final and initial mean tank temperatures by subtracting the latter from the former.

3.4.2 *Standby loss for electric water heaters with immersed heating elements.* All water heaters to be tested must be equipped with immersed heating elements that have a design power rating of 4,500 watts unless such a design power rating exceeds the maximum design power rating specified by the manufacturer for the water heater to be tested, in which case the standby loss test will be conducted with the water heater equipped with immersed heating elements of a design power rating equal to the manufacturer's specified maximum design power rating. All water heaters capable of operating with dual immersed heating elements will be equipped and tested with dual immersed heating elements of equal design power rating in accordance with the provisions specified above. Tests shall be conducted in accordance with the same procedures as those specified in section 3.4.1.

3.5 *Room temperature measurement.* Room temperature wherever specified shall be the temperature determined by using the test room thermocouple described in section 2.5.

3.6 *Mean tank temperature measurement.* Mean tank temperature, the average temperature of the water in a water heater tank, wherever specified shall be the mean of the temperatures determined by using the six water heater tank thermocouples described in section 2.5.

4. *Calculation of derived results from test measurements.*

4.1 *Recovery efficiency.*

4.1.1 *Recovery efficiency for gas and oil water heaters.* For a gas or oil water heater, calculate the recovery efficiency, E_r, expressed as a dimensionless quantity and defined as:

$$E_r = \frac{k \times V \times \Delta T_1}{Q_r \times H},$$

where

k=8.25 Btu per gallon °F., the nominal specific heat of water.
V=tank capacity, determined in accordance with section 3.1, expressed in gallons.
ΔT_1=difference between the initial and final mean tank temperatures, determined in accordance with section 3.3.1, expressed in °F.
Q_r=total fuel flow in the recovery test, determined in accordance with section 3.3.1, expressed in appropriate units.
H=higher heating value for the appropriate fuel type, H_n, H_p, or H_s, as determined in accordance with section 2.4, expressed in appropriate units.

4.1.2 *Recovery efficiency for electric water heaters with other than immersed heating elements.* For an electric water heater with other than immersed heating elements, calculate the recovery efficiency, E_r, expressed as a dimensionless quantity and defined as:

$$E_r = \frac{k \times V \times \Delta T_1}{Z_r \times 3{,}412 \text{ Btu/kWh}},$$

where k, V, and ΔT_1 are as defined in section 4.1.1.
Z_r=total electrical energy flow to the heating elements in the recovery test, determined in accordance with section 3.3.1, expressed in kilowatt-hours.

4.1.3 *Recovery efficiency for electric water heaters with immersed heating elements.* For an electric water heater with immersed heating elements, calculate the recovery efficiency, E_r, expressed as a dimensionless quantity and defined as:

$$E_r = 1 - \frac{S \times k \times V \times \Delta T_2}{P \times 3{,}412 \text{ Btu/kWh}},$$

where k and V are as defined in section 4.1.1
S=standby loss, as calculated in section 4.4.2.
ΔT_2=45° F., the nominal average difference between the mean tank temperature and the ambient air temperature during recovery.
P=water heater input power, determined in accordance with section 3.2.2, expressed in kilowatts.

4.2 Standby loss.

4.2.1 *Standby loss for gas and oil water heaters.* For a gas or oil water heater, calculate the standby loss, expressed in hour^{-1} and defined as:

$$S = \frac{Q_s \times H}{k \times V \times \Delta T_3 \times t} - \frac{\Delta T_4}{\Delta T_3 \times t \times E_r},$$

where k, V, and H are as defined in section 4.1.1.
E_r is as calculated in section 4.1.1
Q_s=total fuel flow in the standby loss test, determined in accordance with section 3.4.1, expressed in appropriate units.
ΔT_3=difference between the average value of the mean tank temperature and the average value of the ambient air temperature during the standby loss test, determined in accordance with section 3.4.1, expressed in °F.
ΔT_4=difference between the initial and final mean tank temperatures, determined in accordance with section 3.4.1, expressed in °F.
t=duration of the standby loss test, determined in accordance with section 3.4.1, expressed in hours.

4.2.2 *Standby loss for electric water heaters.* For an electric water heater, calculate the standby loss, S, expressed in hour^{-1} and defined as:

$$S = \frac{Z_s \times 3{,}412 \text{ Btu/kWh}}{k \times V \times \Delta T_3 \times t} - \frac{\Delta T_4}{\Delta T_3 \times t \times E_r^*}$$

where k and V are as defined in section 4.1.1.
Z_s=total electrical energy flow to the heating elements in the standby loss test, determined in accordance with section 3.4.1 for electric water heaters with other than immersed heating elements, or section 3.4.2 for electric water heaters with immersed heating elements, expressed in kilowatt-hours.
ΔT_3=difference between the average value of the mean tank temperature and the average value of the ambient air temperature during the standby loss test, determined in accordance with section 3.4.1 for electric water heaters with other than immersed heating elements, or section 3.4.2 for electric water heaters with immersed heating elements, expressed in kilowatt-hours.
ΔT_4=difference between the initial and final mean tank temperatures, determined in accordance with section 3.4.1 for electric water heaters with other than immersed heating elements, or section 3.4.2 for electric water heaters with immersed heating elements, expressed in kilowatt-hours.
t=duration of the standby loss test, determined in accordance with section 3.4.1 for electric water heaters with other than immersed heating elements, or section 3.4.2 for electric water heaters with immersed heating elements, expressed in hours.
E_r^*=E_r as calculated in section 4.1.2 for electric water heaters with other than immersed heating elements, or 0.98 for electric water heaters with immersed heating elements.

4.3 *Daily water heating energy consumption.* Calculate the daily water heating energy consumption, C_{wh}, the energy required to heat the nominal amount of hot water used daily, expressed in Btu per day and defined as:

$$C_{wh} = \frac{k \times U \times \Delta T_5}{E_r},$$

where k is as defined in section 4.1.1.
E_r is as calculated in section 4.1.1 for gas and oil water heaters, section 4.1.2 for electric water heaters with other than immersed heating elements, or section 4.1.3 for electric water heaters with immersed heating elements.
ΔT_5=90° F., the nominal difference between the water heater inlet and outlet water temperatures.
U=64.3 gallons per day, the nominal daily hot water usage.

4.4 *Average hourly hot water storage energy consumption.* Calculate the average hourly hot water storage energy consumption, c_{us}, the average energy required per hour to maintain stored water temperature, expressed in Btu per hour and defined as:

$$c_{us} = S \times k \times V \times \Delta T_6,$$

where k and V are as defined in section 4.1.1.
S is as calculated in section 4.2.1 for gas and oil water heaters, or section 4.2.2 for electric water heaters.
ΔT_6=90°F., the nominal difference between the mean tank temperature and the ambient air temperature.

4.5 *Average daily energy consumption.*

4.5.1. *Average daily auxiliary electric energy consumption for gas and oil water heaters.* For a gas or oil water heater, calculate the average daily auxiliary electrical energy consumption, C_{aux}, expressed kilowatt-hours per day and defined as:

$$C_{aux} = p_r \times \frac{C_{wh}}{P} + p_s \times \left(24 \frac{\text{hours}}{\text{day}} - \frac{C_{wh}}{P}\right),$$

where C_{wh} is as calculated in section 4.3.
P=power input to the burner, determined in accordance with section 3.2.1, expressed in Btu per hour.
p_r=power input to any auxiliary electrical system during periods of main burner operation, determined in accordance with section 3.2.1, expressed in kilowatts.
p_s=power input to any auxiliary electrical system during periods when the main burner is not in operation, determined in accordance with section 3.2.1, expressed in kilowatts.

4.5.2 *Average daily gas or oil energy consumption for gas and oil water heaters.* For a gas or oil water heater, calculate the average daily gas or oil energy consumption, C_f, as appropriate, expressed in Btu per day and defined as:

$$C_f = C_{wh} + c_{us} \times \left(24 \frac{\text{hours}}{\text{day}} - \frac{C_{wh}}{P}\right) - J_h - J_e,$$

C_{wh} is as calculated in section 4.3.
c_{us} is as calculated in section 4.4.
P is as defined in section 4.5.1.
J_h=daily energy credit for a heat trap installed in the outlet water connection of a water heater=1,311 Btu per day for water heaters that have such a heat trap as an integral part of the water heater, or zero for water heaters that do not.
J_e=daily energy credit for a heat trap installed in the inlet water connection of a water heater=983 Btu per day for water heaters that have such a heat trap as an integral part of the water heater, or zero for water heaters that do not.

4.5.3 *Average daily energy consumption for gas and oil water heaters.* For a gas or oil water heater, calculate the average daily energy consumption, C_x, expressed in Btu per day and defined as:

$$C_x = C_f + C_{aux} \times 3{,}412 \text{ Btu/kWh},$$

where
C_f is as calculated in section 4.5.2.
C_{aux} is as calculated in section 4.5.1.

4.5.4 *Average daily energy consumption for electric water heaters.* For an electric water heater, calculate the average daily energy consumption, C_y, expressed in kilowatt-hours per day and defined as:

$$C_y = \frac{1}{3{,}412 \text{ Btu/kWh}} \times \left[C_{wh} + c_{us} \times \left(24 \frac{\text{hours}}{\text{day}} - \frac{C_{wh}}{P \times 3{,}412 \text{ Btu/kWh}}\right) - J_h - J_e\right]$$

C_{wh} is as calculated in section 4.3.
c_{us} is as calculated in section 4.4.
J_h and J_e are as defined in section 4.5.2.
P=input power, determined in accordance with section 3.2.1 for electric water heaters with other than immersed heating elements or section 3.2.2 for electric water heaters with immersed heating elements, expressed in kilowatts.

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