NBSIR 79-1951

Energy Test Method Development for Electric Heat Pump Water Heaters

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Product Performance Engineering Division
Center for Consumer Product Technology
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National Bureau of Standards
Washington, D.C. 20234

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Prepared for
United States Department of Energy
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Oak Ridge National Laboratory
Oak, Ridge, Tennessee

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U.S. DEPARTMENT OF COMMERCE, Philip M. Klutznick, *Secretary*

Luther H. Hodges, Jr., *Deputy Secretary*
Jordan J. Baruch, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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Summary

Modifications are proposed for the current U.S. Department of Energy test procedures for water heaters in order to make them applicable to electric heat pump water heaters. The modifications are in the areas of definitions and technical procedures. The latter include the test conditions, test procedures and measurements, and calculations. Reasons for making these modifications and laboratory test data are provided to support the modifications in the technical procedures. The main modifications include: 1) lowering the water supply temperature from 70°F to 55°F, 2) lowering the tank thermostat setting from 160°F to 145°F to maintain the same 90°F temperature rise, 3) measuring the power input instead of using the nameplate rating as in the case for an electric water heater, 4) measuring the recovery efficiency instead of calculating it by using the standby losses in the case for an electric water heater.

I. Introduction

This report is submitted to DOE/ORNL by the Product Performance Engineering Division, Center for Consumer Product Technology, NBS, under the Interagency Agreement No. EW-78-I-05-5750, Task A, as revised via Narrative Report for July 1978. The purpose of this report is to present proposed modifications to the current test procedure for water heaters to include electric heat pump water heaters and the rationale for these modifications. This report presents in section II the proposed modifications to part 430--Energy Conservation Program for Appliances, Test Procedures for Water Heaters--of the Code of Federal Regulations. That document, as published in the Federal Register, Vol. 42, No. 192, Tuesday, October 4, 1977, is attached as Appendix A for reference. This report presents in section III the rationale for making these modifications.

In section IIA, the additions to part 430.2--Definitions--are given. In section IIB, the modifications to the Appendix E (of the same part 430)--Uniform Test Method for Measuring the Energy Consumption of Water Heaters--(henceforth referred to as Test Method) are discussed. In it each section of the Test Method requiring changes is referred to specifically, and the necessary changes are given to include electric heat pump water heaters.

A final rule in the Test Method for the determination of first hour rating (FHR) of water heaters has not been published in the Federal Register. Therefore, FHR is not yet part of the regulations. NBS provided a test procedure for FHR to DOE and this has been published as a proposed rule in the Federal Register (Appendix A). As proposed, the FHR test procedure would require some modifications in order to be applicable to the electric heat pump water heater.

If a new section must be added, it is included in the format of the Test Method. Proposed additions to the text are indicated by underlines and deletions by ~~slashes~~.

In section IIIA the rationale for additions to part 430.2 are given. In section IIIB, each section of the Test Method requiring change and the additional sections are again referred to specifically and the rationale for changes or additions given.

The relevant results of the studies which provided the technical analysis and experimental data necessary to develop this report are summarized in Appendix B.

II. Proposed Modifications

A. Modifications to Part 430.2

430.2 Definitions

(5) "Heat pump" means an electrically-driven mechanical refrigeration device designed and made to transfer thermal energy from a low temperature level to a higher temperature level and includes all ancillary equipment such as fans, pumps, or controls necessary or the device to perform its function.

(5)(d) "Electric heat pump water heater" means a water heater which utilizes electricity as the energy source to supply the integral heat pump and immersed heating element, if any, 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. Proposed Modifications for the Test Method

1. Definitions

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

1.4 "Recovery efficiency" means the ratio of the heat imparted to the water to--

(c) in the case of an electric heat pump water heater, the combined energy input to the heating element, if any, and the heat pump during the period that the water temperature is raised from inlet temperature to the final temperature with the tank filled to capacity.

1.6 "Condensor coil" means that component of a heat pump whose function is to transfer thermal energy into the system at the higher temperature level.

1.7 "Evaporator" means that component of a heat pump whose function is to transfer thermal energy out of the system at the lower temperature level.

2. Test Conditions

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 for all gas, oil, and electric water heaters and between 53°F and 57°F for an electric heat pump water heater 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 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, an electric heat pump water heater, and for the auxiliary electrical system, if any, of an oil or gas water heater, maintain the electrical supply voltage to within $\pm$ 1 percent of the center voltage range specified by water heater manufacturer on the water heater nameplate throughout the entire operating portion of each test.

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 nonoverlapping 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, or condenser coil, if any. 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 the junction shielded against direct radiation from the water heater or air current due to the evaporator fan, if any, 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 $\pm 1^{\circ}$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 $160^{\circ}F \pm 5^{\circ}F$ for all gas, oil, or electric water heaters or $145^{\circ}F \pm 5^{\circ}F$ for an electric heat pump water heater. 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 $160^{\circ}F \pm 5^{\circ}F$ for all gas, oil, or electric water heaters or $145^{\circ}F \pm 5^{\circ}F$ for an electric heat pump water heater, 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 $160^{\circ}F \pm 5^{\circ}F$ for all gas, oil, or electric water heaters or $145^{\circ}F \pm 5^{\circ}F$ for an electric heat pump water heater as measured by the topmost thermocouple after cutout. The thermostat which controls the lower heating element or heat pump shall then be set to yield a maximum tank temperature of $160^{\circ}F \pm 5^{\circ}F$ for all gas, oil, or electric water heaters or $145^{\circ}F \pm 5^{\circ}F$ for an electric heat pump water heater after cutout.

2.8 Room Ambient Temperature. Maintain the ambient air temperature of the test room between $65^{\circ}F$ and $85^{\circ}F$ for all gas, oil, or electric water heaters or between $69^{\circ}F$ and $81^{\circ}F$ for an electric heat pump water heater 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 $\pm 7^{\circ}F$ for all gas, oil, or electric water heaters or more than $+3^{\circ}F$ or $-6^{\circ}F$ for an electric heat pump water heater 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.

3.2 Power Input Determination.

3.2.3 Power input determination for an electric heat pump water heater. Initiate the recovery operation of the electric heat pump water heater specified in section 3.3.3 and by using the appropriate instrumentation specified in section 2.7, determine the quantity of electrical energy used in the duration of the recovery test. The power input, P, expressed in kilowatts, is calculated as

$$P = \frac{Z_r}{t_r},$$

where Z_r is defined in section 4.1.4 and

t_r = duration of the recovery test determined in accordance with section 3.4.1.

3.3 Recovery efficiency.

3.3.3 Recovery efficiency for an electric heat pump water heater. 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 $55^{\circ}F \pm 2^{\circ}F$ record the mean tank temperature, initiate normal operation of the water heater, and begin measuring the energy flow to the heat pump and the heating element, if any, 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 electrical energy flow, Z_r, to the heat pump and the heating element, if any, of the water heater, from initiation to cutout. Record the temperature difference, ΔT_1, obtained by subtracting the initial from the final maximum mean tank temperature.

3.4 Standby Loss.

3.4.3 Standby loss for an electric heat pump water heater. 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 energy flow to the heat pump and the heating element, if any, of the water heater using the appropriate instrumentation specified in section 2.7. All water heaters to be tested must be equipped with immersed heating elements that have a design power rating of 4500 watts, if the water heaters are equipped with heating elements, 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.

At the end of the first 15 minute interval and at the end of each subsequent 15 minutes 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 heating element, if any, or heat pump is on at that time, in which case continue these measurements until the first subsequent cutout. When the test is terminated, record the total electrical energy flow, Z_r, to the heating element, if any, and heat pump, 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_3, between these two averages by substracting the latter from the former, and the difference, ΔT_4, between the final and initial mean tank temperatures by substracting the latter from the former.

4. Calculation of Derived Results from Test Measurements

4.1 Recovery efficiency.

4.1.4 Recovery efficiency for an electric heat pump water heater. For an electric heat pump water heater, calculate the recovery efficiency, E_r, expressed as a dimensionless quantity and defined as:

$$E_r = \frac{k \times V \times \Delta T_1}{Z_r \times 3412 \text{ Btu/kWh}}$$

where k, V, and ΔT_1 are defined in section 4.1.1.

Z_r = total electrical energy flow to the heat pump and the heating element, if any, in the recovery test, determined in accordance with section 3.3.3, expressed in kilowatt-hours.

4.2 Standby loss.

4.2.3 Standby loss for an electric heat pump water heater. Calculate the standby loss, S, expressed in $hour^{-1}$ and defined as:

$$S = \frac{Z_s \times 3412 \text{ Btu/kWh}}{k \times V \times \Delta T_3 \times t} - \frac{\Delta T_4}{\Delta T_3 \times t \times E_r^*}$$

where k and V are as defined in section 4.1.1.

Z_s = total electrical energy flow to the heat pump and heating element, if any, in the standby loss test, determined in accordance with section 3.4.3.

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 3.4.3, expressed in $^\circ$F.

ΔT_4 = difference between the initial and final mean tank temperatures, determined in accordance with section 3.4.3, expressed in $^\circ$ F.

t = duration of the standby loss test, determined in accordance with section 3.4.3, expressed in hours.

$E_r^* = E_r$ as calculated in section 4.1.4 for an electric heat pump water heater.

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, or section 4.2.3 for an electric heat pump water heater.

4.5 Average daily energy consumption.

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

$$C_y = \frac{1}{3412\ \text{Btu/kWh}} \times$$

$$[C_{Wh} + C_{us} \times (\frac{24\ \text{hrs}}{\text{day}} - \frac{C_{Wh}}{P \times 3412\ \text{Btu/kWh}}) - J_h - J_c]$$

C_{Wh} is as calculated in section 4.3.

c_{us} is as calculated in section 4.4.

J_h and J_c 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 or section 3.2.3 for electric heat pump water heaters, expressed in kilowatts.

III. Rationale for Modifications to Test Method

A. Modifications to Part 430.2.

430.2 Definitions

(5) This addition is made in order to define the term "heat pump."

(5)(d) This addition is made in order to define the term "electric heat pump water heater." The heat pump component, as defined here, is considered as an integral part of the water heater as manufactured in the factory. The heat pump is not designed and made as a separate package to be retrofitted to an existing water heater.

B. Modifications for the Test Method

1. Definitions

1.1 This change is made in order to include the heat pump as a source of heat in defining the term "cutout."

1.4 This change is also made in order to include the heat pump as a source of heat in defining the term "recovery efficiency."

1.6 This section is needed to define the heat pump condensor which is addressed in later sections of the Test Method.

1.7 This section is needed to define the heat pump evaporator which is addressed in later sections of the Test Method.

2. Test Conditions.

2.3 Water Supply. The National Bureau of Standards has determined that the national average water supply temperature is 55°F (Appendix A). The current test method specifies a 70°F water supply temperature for the reason that a 70°F water supply temperature is less burdensome to obtain for use in the testing of water heaters. Furthermore, for the general types of gas, oil, or electric storage type water heaters, the inlet water temperature has a negligible effect on the determination of the water heater's recovery efficiency. For most testing facilities, climatic conditions or other factors are such that for all or part of the year water supply temperatures exceed 55°F. Therefore, if a 55°F water supply temperature were specified in the current test method, these facilities would have an added cost of equipment and time to cool the available supply water prior to conducting a test.

Using the same 70°F water supply temperature for testing of an electric heat pump water heater, however, imposes a penalty on the recovery efficiency for this type of water heater. This is due to the fact that the heat pump works more efficiently at a lower condensor temperature (water temperature) than at a higher condensor temperature for the same evaporator temperature (room temperature) (Appendix B). A 55°F water supply temperature, therefore, is specified for the electric heat pump water heater in order to yield energy use information comparable to the information for the other types of water heaters using the 70°F water supply temperature.

In order to establish the same tolerance for variation as in the current test method requires the water supply temperature to the electric heat pump water heater inlet to be maintained between 53°F to 57°F.

2.4.1 Electrical supply. The change in this section is made to include the electric heat pump water heater.

2.5 Thermocouple Installation. The current test method requires that the thermocouples installed to measure the mean water temperature be positioned as far as possible from any obstructions such as the heating element, anodic protective device or a water tank or flue wall. In the case where there is a heat pump condensor coil in the water heater, the thermocouples should be positioned as far away as possible from the condensor coil also in order to minimize any direct effects the condensor coil may have on the accurate measurement of water temperature using thermocouples.

The current test method requires that the test room thermocouple be shielded against direct radiation from the water heater. The electric heat pump water heater also generates convective air currents around the water heater because of the evaporator fan, therefore, the test room thermocouple should also be shielded against this convective air current.

2.6 Setting the Tank Thermostat. Water heater thermostats are normally factory-set at 140°F for gas water heaters and at 150°F for electric water heaters. DOE uses the average value of the two common factory settings of water heater thermostats. Since NBS has determined that the national average water supply temperature is 55°F the difference between these two temperatures, 90°F, is the required water temperature rise in the current test method. The 55°F water supply temperature is now proposed for the electric heat pump water heater. With a required water temperature rise of 90°F then, the tank thermostat setting must be specified at 145°F.

The maximum mean tank temperature after cutout, therefore, should be 145°F ± 5°F to maintain the same temperature differential and tolerance as in the current test method.

2.8 Room Ambient Temperature. The tests conducted on the electric heat pump water heater in Ref. 2, indicate that both the standby loss and the recovery efficiency are affected by the variation of the room ambient temperature. Therefore, the room ambient temperature should not be allowed to vary over too wide a range. However, to maintain the room ambient temperature within a narrow range may require the use of an environmental chamber for testing which could become excessively burdensome.

The modified range of room ambient temperature, then, should be the narrowest achievable without the use of an environmental chamber. Results presented in Appendix B indicate that a range for the room ambient temperature of $75^{o}F \pm 6^{o}F$ can usually be achieved without the use of an environmental chamber.

The standby tests reported in Appendix B also indicate that during short periods of heat pump operation, the room ambient temperature may dip momentarily. It is impossible to avoid the dipping of the room ambient temperature without the use of a rapid response environmental chamber. Therefore, the test method is modified to allow for more undershooting than overshooting. This permits the room ambient temperature to dip momentarily during short periods of heat pump operation.

3. Test Procedures and Measurements

3.2 Power Input Determination.

3.2.3 Power input determination for an electric heat pump water heater. One major difference between the electric water heater with immersed elements and the electric heat pump water heater is in the manner they consume power. The former operate at a constant power when energized; the latter operates at variable power when the heat pump is energized. The amount of energy an electric heat pump water heater consumes depends strongly on its operating conditions. This fact is clearly documented in Appendix B.

The input power is used to determine the average number of hours the water heater is operating in the recovery mode as required in the equation to determine the average daily energy consumption for electric water heaters. The input power is an average power over the period of a recovery test. Therefore, the total electrical energy is measured for a recovery test and the average power is equal to that total electrical energy divided by the time elapsed for the test.

3.3 Recovery Efficiency

3.3.3 Recovery efficiency for an electric heat pump water heater. Because the power consumption of the electric heat pump water heater is variable, the recovery efficiency has to be experimentally determined. The test starts when the mean tank temperature is constant and within $55^{o}F \pm 2^{o}F$, the same temperature as the water supply. Then the test is done similarly to the recovery test for gas, oil, and electric water heater with other than immersed heating elements as specified in the current test method.

3.4 Standby Loss

3.4.3 Standby loss for an electric heat pump water heater. This type of water heater may have two different types of heat sources, the heat pump and the immersed heating element. The test should be conducted in the same manner as that for an electric water heater with immersed heating elements. The electric heat pump water heater under test should be equipped with a standard 4500 watt heating element unless such a power rating exceeds the maximum design power rating specified for the units to be tested. In which case the standby test for the units should be conducted using heating elements of a design power rating equal to that specified by the manufacturer for the units. This latter procedure is to maintain the same restrictions as those specified in the current test method for electric water heater with immersed heating elements.

4. Calculation of Derived Results from Test Measurements

4.1 Recovery Efficiency

4.1.4 Recovery efficiency for an electric heat pump water heater. The calculation of recovery efficiency for this type of water heater is the same as that for the electric water heaters with other than immersed heating elements. The inclusion of this section is meant to account for the different wordings and definitions in the calculation of the recovery efficiency.

4.2 Standby Loss

4.2.3 Standby loss for an electric heat pump water heater. The difference between the calculation of the standby loss for the electric heat pump water heater and for the electric water heater with immersed elements is that the recovery efficiency for the former is an experimentally determined value and for the latter is a predetermined value of 0.98.

4.4 Average Hourly Hot Water Storage Energy Consumption

The only modification in this section is to include the electric heat pump water heater.

4.5 Average Daily Energy Consumption

4.5.4 Average daily energy consumption for electric water heaters and electric heat pump water heaters. The only modification to the calculation in this section is in the determination of the water heater input power. In the case of electric water heaters with immersed heating elements, the input power is taken as the design power rating of the heating elements. In the case of electric water heaters with other than immersed heating elements, the input power is a measured value. In the case of the electric heat pump water heater, the input power is an average derived by dividing the electrical energy input duing a recovery test by the elapsed time of the test.

References

1. Wan, C.A. Letter Report for Tasks 1, 2, and 3, Energy Test Method Development for High Efficiency Water Heaters.

2. Wan, C.A. Letter Report for Task 4, Phases 1, 2, and 3, Energy Test Method Development for High Efficiency Water Heaters.

3. Chaddock, J. B., Feasibility Study of the Heat Pump Water Heater, Final Report, Purdue University, Lafayette, IN, August 31, 1961.

[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:

James A. Smith (Office of Conservation), Room 307 Old Post Office Building, 12th and Pennsylvania Avenue NW., Washington, D.C. 20461 (202-566-4635).

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

Sec.
430.1 Purpose and scope.
430.2 Definitions.

SUBPART B—TEST PROCEDURES

430.21 Purpose of scope.
430.22 Test procedures for measures of energy consumption.
(a) Refrigerators and refrigerator-freezers.
(b) Freezers.
(c) Dishwashers.
(d) Clothes dryers.
(e) Water heaters.
(f) Room air conditioners.

* * * * *

(h) Television sets.

* * * * *

(j) Clothes washers.
430.23 Units to be tested [reserved].
430.24 Representations regarding measures of energy consumption.
(a) Refrigerators and refrigerator-freezers.
(b) Freezers.
(c) Dishwashers.
(d) Clothes dryers.
(e) Water heaters.
(f) Room air conditioners.

* * * * *

(h) Television sets.

* * * * *

(j) Clothes washers.

APPENDICES TO SUBPART B

Appendix A1—Uniform Test Method for Measuring the Energy Consumption of Electric Refrigerators and Electric Refrigerator-freezers.
Appendix B—Uniform Test Method for Measuring the Energy Consumption of Freezers.
Appendix C—Uniform Test Method for Measuring the Energy Consumption of Dishwashers.
Appendix D—Uniform Test Method for Measuring the Energy Consumption of Clothes Dryers.
Appendix E—Uniform Test Method for Measuring the Energy Consumption of Water Heaters.
Appendix F—Uniform Test Method for Measuring the Energy Consumption of Room Air Conditioners.

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Appendix H—Uniform Test Method for Measuring the Energy Consumption of Television Sets.

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Appendix J—Uniform Test Method for Measuring the Energy Consumption of Clothes Washers.

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 thermostats 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 efficiency, E_r*, 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 prohibts 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 Subpart 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.

a. *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_r, 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_3, between these two averages by subtracting the latter from the former, and the difference, ΔT_4, 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_o, 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:

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

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_c=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_s, expressed in Btu per day and defined as:

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

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_v, expressed in kilowatt-hours per day and defined as:

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

C_{wh} is as calculated in section 4.3.
c_{us} is as calculated in section 4.4.
J_h and J_c 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.

[FR Doc.77-29000 Filed 10-3-77;8:45 am]

rules and regulations

This section of the FEDERAL REGISTER contains regulatory documents having general applicability and legal effect most of which are keyed to and codified in the Code of Federal Regulations, which is published under 50 titles pursuant to 44 U.S.C. 1510.

The Code of Federal Regulations is sold by the Superintendent of Documents. Prices of new books are listed in the first FEDERAL REGISTER issue of each month.

[1505-01]

Title 1—General Provisions

CHAPTER I—ADMINISTRATIVE COMMITTEE OF THE FEDERAL REGISTER

CFR CHECKLIST

1977 Issuances

This checklist, prepared by the Office of the Federal Register, is published in the first issue of each month. It is arranged in the order of CFR titles, and shows the revision date and price of the volumes of the Code of Federal regulations issued to date for 1977. New units issued during the month are announced on the back cover of the daily FEDERAL REGISTER as they become available.

For a Checklist of current CFR volumes comprising a complete CFR set, see the latest issue of the Cumulative List of CFR Sections Affected, which is revised monthly.

The rate for subscription service to all revised volumes issued for 1977 is $350 domestic, $75 additional for foreign mailing.

Order from Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

CFR Unit (Rev. as of Jan. 1, 1977):

Title	Price
1	$1.65
2 [Reserved]	
3	3.00
4	3.25
5	4.70
7 Parts:	
0-45	5.30
46-51	4.20
52	5.20
53-209	5.60
210-699	6.10
700-749	4.10
750-899	1.60
900-944	4.25
945-980	2.40
981-999	2.50
1000-1059	4.25
1060-1119	4.40
1120-1199	3.20
1200-1499	4.20
1500-end	7.25
8	2.60
9	6.80
10 Parts:	
0-199	4.40
200-end	4.60
11 (Rev. 5/1/77)	2.30
12 Parts:	
1-299	7.40
300-end	7.30
13	4.20
14 Parts:	
1-59	6.00
60-199	5.10
200-1199	6.20
1200-end	2.20
15	5.35
16 Parts:	
0-149	5.50
150-999	4.25
1000-end	3.00

CFR Unit (Rev. as of April 1, 1977):

Title	Price
17	6.75
18 Parts:	
1-149	4.25
150-end	4.00
19	5.75
20 Parts:	
01-399	3.25
400-499	5.00
500-end	4.00
21 Parts:	
1-99	3.25
100-199	4.75
200-299	2.10
300-499	5.00
500-599	4.00
600-1299	3.50
1300-end	4.25
22	4.50
23	5.50
24 Parts:	
0-499	5.00
500-end	5.25
25	4.50
26 Parts:	
1 (§§ 1.0-1.169)	4.75
1 (§§ 1.170-1.300)	4.00
1 (§§ 1.301-1.400)	3.75
1 (§§ 1.401-1.500)	4.00
1 (§§ 1.501-1.640)	4.00
1 (§§ 1.641-1.850)	4.35
1 (§§ 1.851-1.1200)	5.25
1 (§§ 1.1201-end)	6.75
2-29	4.50
30-39	4.35
40-299	4.50
300-499	4.35
600-end	2.40
27	7.00

CFR Unit (Rev. as of July 1, 1977):

Title	Price
29 Parts:	
0-499	5.75
1900-1919	6.00
1920-end	4.50
30	6.00
32 Parts:	
1-39 (V. I) (Rev. 7/1/76)	4.75
(V. II) (Rev. 7/1/76)	7.50
(V. III) (Rev. 7/1/76)	5.25
400-589	5.00
590-699	4.00
700-799	6.25
1000-1399	2.75
1400-1599	4.25
1600-end	2.75
32A	3.75
33 Parts:	
1-199	7.00
200-end	5.30
34	1.70
35	4.00
36	4.50
37	3.00
38	6.00
39	3.50
40 Parts:	
0-49	4.25
50-59	5.75
60-99	5.00
10-17	4.25
100-399	4.75
400-end	5.75
41 Chapters:	
1-2	5.25
3-6	5.50
7	2.75
8	2.30
9 (Rev. 9/26/77)	5.00
10-17	4.25
19-100	4.50
101-end	5.75

CFR Unit (Rev. as of Oct. 1, 1977):

Title	Price
43 Parts:	
1-999	4.00
46 Parts:	
70-89	3.25
90-109	3.00
110-139	3.00
49 Parts:	
1-99	3.00

[3128-01]

Title 10—Energy

CHAPTER II—FEDERAL ENERGY ADMINISTRATION[1]

PART 430—ENERGY CONSERVATION PROGRAM FOR APPLIANCES

Indefinite Suspension of Final Test Procedures for Water Heaters

AGENCY: Department of Energy.

ACTION: Suspension of final rule.

SUMMARY: The Department of Energy, by separate notice issued today, is proposing an amendment to its test procedures for water heaters, 10 CFR Part 430, Subpart B. Pending the hearing on this proposal and prescription of the final rule, the provisions of 10 CFR 430.22(e)(2) are hereby suspended.

EFFECTIVE DATE: March 29, 1978.

FOR FURTHER INFORMATION CONTACT:

James A. Smith, (Office of Conservation and Solar Applications), Old Post Office Building, Room 307,

[1] EDITORIAL NOTE: It is contemplated that Chapter II will be renamed at a future date to reflect the fact that it contains regulations administered by the Department of Energy, including regulations administered by the Office of Conservation and Solar Applications.

proposed rules

This section of the FEDERAL REGISTER contains notices to the public of the proposed issuance of rules and regulations. The purpose of these notices is to give interested persons an opportunity to participate in the rule making prior to the adoption of the final rules.

[3128-01]

DEPARTMENT OF ENERGY

Office of Conservation and Solar Applications

[10 CFR Part 430]

ENERGY CONSERVATION PROGRAM FOR APPLIANCES

Proposed Rulemaking and Public Hearing Regarding Test Procedures for Water Heaters

AGENCY: Department of Energy.

ACTION: Proposed rule.

SUMMARY: The Department of Energy hereby proposes to amend its test procedures for water heaters. These test procedures are a part of the appliance energy efficiency program established pursuant to the Energy Policy and Conservation Act, which requires that standard methods of testing be prescribed for covered appliances.

DATES: Comments by May 22, 1978; requests to speak by May 3, 1978; statements by May 15, 1978; hearing to be held on May 16, 1978.

ADDRESSES: Comments and requests to speak at the hearing to: Office of Public Hearing Management, Box SA, Department of Energy, Room 2313, 2000 M Street NW., Washington, D.C. 20461; statements to: Office of Public Hearing Management, Box SA, Department of Energy, Room 2313, 2000 M Street NW., Washington, D.C. 20461; hearing to be held at: Room 2105, 2000 M Street NW., Washington, D.C.

FOR FURTHER INFORMATION CONTACT:

James A. Smith (Office of Conservation and Solar Applications), Old Post Office Building, Room 307, 12th and Pennsylvania Avenue NW., Washington, D.C. 20461, 202-566-4635.

Robert C. Gillette (Hearing Procedures) 2000 M Street NW., Room 2222A, Washington, D.C. 20461, 202-254-5201.

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

William J. Dennison (Office of the General Counsel), 12th and Pennsylvania Avenue NW., Room 7148, Washington, D.C. 20461, 202-566-9750.

SUPPLEMENTARY INFORMATION:

A. Background

On October 1, 1977, the Department of Energy (DOE) assumed the authority of the Federal Energy Administration (FEA) for the energy conservation program for appliances, pursuant to section 301 of the Department of Energy Organization Act (DOE Act) (Pub. L. 95-91). The energy conservation program for appliances was established by FEA pursuant to title III, part B of the Energy Policy and Conservation Act (Act) (Pub. L. 94-163). Section 323 (42 U.S.C. 6293) of the Act requires that standard methods of testing be prescribed for covered appliances.

FEA proposed test procedures for water heaters 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. Final test procedures for water heaters were prescribed by FEA on September 27, 1977 (42 FR 54110, October 4, 1977).

DOE is today proposing to amend section 430.22(e)(2) of the final test procedures for water heaters and Appendix E to subpart B of part 430 in order to specify a different method of determining the energy factor for water heaters.

B. Discussion

A review of the final test procedures for water heaters revealed an error in the derivation of the energy factor. In both the proposed and final test procedures, the energy factor was computed by dividing the daily water heating energy consumption by the average daily energy consumption. The energy factor was intended to relate a water heater's useful output of services to its energy consumption. As currently formulated, the numerator of the equation used to determine the energy factor actually reflects a portion of the water heater's energy consumption rather than the water heater's useful output of services.

One approach to determining the useful output of a water heater is to determine the energy imparted by a water heater to the volume of water delivered by the water heater. The final water heater test procedures are based upon an average daily hot water usage of 64.3 gallons and an average temperature difference between the water heater inlet temperature and water heater outlet temperature of 90° F. Under these conditions, the useful output of a water heater would be the product of (a) 64.3 gallons per day, (b) a 90° F. temperature rise, and (c) the specific heat of water. The energy factor could be determined by dividing this measure of the useful output of a water heater by the energy consumption of the water heater.

Because of the importance of the energy factor to the efficiency target program and to any future energy efficiency standard program for appliances, DOE has decided to propose the methodology for determining the energy factor discussed above as an amendment to the final test procedures, As an ancillary matter, by separate notice also published today, DOE is suspending section 430.22(e)(2) of Title 10, Code of Federal Regulations, until the amendments proposed today are either adopted or withdrawn. No other provisions of Title 10 are affected by this suspension.

C. Comment Procedure

1. *Written comment.* Interested persons are invited to participate in this rulemaking by submitting data, views or arguments with respect to the proposed amendments set forth in this notice to Office of Public Hearing Management, Box SA, Washington, D.C. 20461. Comments may suggest alternative methods of determining the energy factor for water heaters, but any suggestions should discuss how they relate the useful output of services to the energy consumption of a water heater.

Comments should be identified on the outside of the envelope and on documents submitted to DOE with the designation "Water Heaters-Proposed Amendments." Fifteen copies should be submitted. All comments received by May 22, 1978, before 4:30 p.m., e.d.t., and all other relevant information, will be considered by DOE before final action is taken on the proposed regulation.

Any information or data considered by the person furnishing it to be confidential must be so identified and submitted in writing, one copy only. DOE reserves the right to determine the confidential status of the information or data and treat it according to its determination.

2. *Public hearings—a. Request procedures.* The time and place of the public hearing are indicated at the beginning of this preamble. The hearing will be continued, if necessary, on May 17, 1978.

DOE invites any person who has an interest in the proposed amendment issued today, or who is a representative of a group or class of persons that has an interest in today's proposed amendment, to make a written request for an opportunity to make an oral presentation. Such a request may be hand delivered to Office of Public Hearing Management, Box SA, Department of Energy, Room 2313, 2000 M Street NW., Washington, D.C. 20461, between the hours of 8 a.m. and 4:30 p.m., Monday through Friday. A request should be labeled both on the document and on the envelope "Water Heaters — Proposed Amendments.

The person making the request should briefly describe the interest concerned; if appropriate, state why she or he is a proper representative of a group or class of persons that has such an interest; and give a concise summary of the proposed oral presentation and a telephone number where she or he may be contacted through May 15, 1978.

DOE will notify, before 4:30 p.m., e.d.t., May 9, 1978, each person selected to appear at a hearing. Each person selected to be heard must submit 100 copies of her or his statement to the address and by the date given in the beginning of this preamble. In the event any person wishing to testify cannot meet the 100-copy requirement, alternative arrangements can be made with the Economic Regulatory Administration (ERA) in advance of the hearing by so indicating in the letter requesting an oral presentation or by calling the ERA at 202-254-3345.

b. *Conduct of hearings.* DOE reserves the right to select the persons to be heard at this hearing, to schedule their respective presentations and to establish the procedures governing the conduct of the hearing. The length of each presentation may be limited, based on the number of persons requesting to be heard.

A DOE official will be designated to preside at the hearing. This will not be a judicial or evidentiary-type hearing. Questions may be asked only by those conducting the hearing, and there will be no cross-examination of the persons presenting statements. Any decision made by DOE with respect to the subject matter of the hearing will be based on all information available to DOE. At the conclusion of all initial oral statements, each person who has made an oral statement will be given the opportunity, if she or he so desires, to make a rebuttal statement. The rebuttal statements will be given in the order in which the initial statements were made and will be subject to time limitations.

Any interested person may submit questions to be asked of any person making a statement at the hearing to Public Hearing Management, Box SA, DOE, 2000 M Street NW., Washington, D.C., before 4:30 p.m., e.d.t., May 9, 1978. DOE will determine whether the question is relevant, and whether the time limitations permit it to be presented for answer.

Any person who makes an oral statement and who wishes to ask a question at the hearing may submit the question, in writing, to the presiding officer. The presiding officer, will determine whether the question is relevant, and whether the time limitations permit it to be presented for answer.

Any further procedural rules needed for the proper conduct of the hearing will be announced by the presiding officer.

A transcript of the hearing will be made and the entire record of the hearing, including the transcript, will be retained by DOE and made available for inspection at the DOE Freedom of Information Office, Room 2107, Federal Building, 12th and Pennsylvania Avenue NW., Washington, D.C., between the hours of 8 a.m. and 4:30 p.m., Monday through Friday. Any person may purchase a copy of the transcript from the reporter.

D. Environmental and Inflationary Review

Pursuant to section 7(c)(2) of the FEA Act, a copy of this notice has been submitted to the Administrator of the Environmental Protection Agency for his comments concerning the impact of this proposal on the quality of the environment. The Administrator has no comments.

The National Environmental Policy Act of 1969 requires DOE to assess the environmental impacts of any proposal issued by the Department for "major Federal actions significantly affecting the quality of the human environment." Since test procedures under the energy conservation program for appliances will be used only to standardize the measurement of energy usage and will not affect the quality or distribution of energy usage, DOE has determined that the action of prescribing test procedures, by itself, will not result in any environmental impacts. On this basis, DOE has determined that, with respect to prescribing test procedures under the energy conservation program for appliances, no environmental impact statement is required.

The proposed rule has been reviewed in accordance with Executive Order 11821 as amended by Executive Order 11949, and OMB Circular No. A-107 and has been determined not to be a major proposal requiring evaluation of its economic impact as provided for therein.

(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; Department of Energy Organization Act, Pub. L. 95-91; E.O. 11790, 39 FR 23185.)

In consideration of the foregoing, it is proposed to amend Part 430 of Chapter II of Title 10, Code of Federal Regulations, as set forth below.

Issued in Washington, D.C., March 27, 1978.

William S. Heffelfinger,
Director of Administration.

1. Section 430.22 is amended by revising paragraph (e)(2) to read as follows:

(e) * * *

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

(i) For a gas or oil water heater, the quotient of the daily hot water energy consumption determined according to section 4.6 of Appendix E of this subpart divided by the average daily energy consumption as determined according to section 4.5.3 of Appendix E of this subpart, the resulting quotient then being rounded off to the nearest 0.01; and

(ii) For an electric water heater, the quotient of the daily hot water energy consumption determined according to section 4.6 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-hour, the resulting quotient then being rounded off to the nearest 0.01.

2. Appendix E to Subpart B of Part 430 is amended by adding a new section 4.6, to read as follows:

4.6 *Daily hot water energy consumption.* Calculate the daily hot water energy consumption, C_e, the energy content of the nominal daily hot water usage, expressed in Btu per day and defined as:

$$C_e = k \times U \times \Delta T_1,$$

Where:

k is as defined in section 4.1.1; and
ΔT_1 and U are as defined in section 4.3.

[FR Doc. 78-8591 Filed 3-31-78; 8:45 am]

[4810-33]

DEPARTMENT OF THE TREASURY

Comptroller of the Currency

[12 CFR Part 9]

FIDUCIARY POWERS OF NATIONAL BANKS AND COLLECTIVE INVESTMENT FUNDS

Extension of Comment Period

AGENCY: Comptroller of the Currency, Treasury.

ACTION: Extension of comment period.

[3128-01-M]

Title 10—Energy

CHAPTER II—FEDERAL ENERGY ADMINISTRATION [1]

PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS

Test Procedures for Water Heaters

AGENCY: Department of Energy.

ACTION: Final rule.

SUMMARY: The Department of Energy hereby amends its test procedures for water heaters as they relate to determining the energy factor for water heaters. These test procedures are a part of the consumer product energy efficiency program established pursuant to the Energy Policy and Conservation Act, which requires that standard methods of testing be prescribed for covered consumer products.

EFFECTIVE DATE: November 20, 1978.

FOR FURTHER INFORMATION CONTACT:

James A. Smith, Office of Conservation and Solar Applications, Room 2248, 20 Massachusetts Avenue NW., Washington, D.C. 20545, 202-376-4815.

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

William J. Dennison, Office of the General Counsel, Federal Building, Room 7148, 12th and Pennsylvania Avenue NW., Washington, D.C. 20461, 202-566-9750.

SUPPLEMENTARY INFORMATION:

A. Background

On October 1, 1977, the Department of Energy (DOE) assumed the authority of the Federal Energy Administration (FEA) for the energy conservation program for consumer products, pursuant to section 301 of the Department of Energy Organization Act (DOE Act) (Pub. L. 95-91). The energy conservation program for consumer products was established by FEA pursuant to title III, part B of the Energy Policy and Conservation Act (Act) (Pub. L. 94-163). Section 323 (42 U.S.C. 6293) of the Act requires that standard methods of testing be prescribed for covered consumer products.

FEA proposed test procedures for water heaters by notice issued April 21, 1977 (42 FR 21576, Apr. 27, 1977), and a public hearing on the proposed test procedures was held on June 13, 1977. Final test procedures for water heaters were prescribed by FEA on September 27, 1977 (42 FR 54110, Oct. 4, 1977).

A subsequent review of the final test procedures for water heaters revealed an error in the derivation of the energy factor. The energy factor is intended to be a measure of efficiency equal to the ratio of the useful output of a water heater to the energy input of the water heater, i.e., the total energy consumed to provide the useful output. The useful output of a water heater is the energy content of the water actually delivered by the water heater on a daily basis. The energy input to a water heater is the total energy consumed by the water heater on a daily basis. In the promulgated test procedures, the useful output of a water heater (the numerator of the energy factor ratio) was erroneously expressed as a water heater's "daily water heating energy consumption." This term, which is correctly utilized in other parts of the test procedures, includes both the energy content of the water actually delivered by the water heater on a daily basis (the useful output) and any additional energy which is dissipated as a result of any inefficiency in the heat transfer process, and which does not contribute to the useful output. The result was that the water heater efficiency was overstated since part of the term in the numerator of the energy factor was not attributable to useful output.

Today's amendment specifies that the useful output (the numerator of the energy factor) shall be the "daily hot water energy consumption," a term defined by new section 4.6 of appendix E to include only the energy content of the water actually delivered by the water heater on a daily basis.

By notice issued March 27, 1978 (43 FR 13888, Apr. 3, 1978), DOE proposed to amend § 430.22(e)(2) and appendix E to subpart B of part 430. The intent of the proposed amendments was to specify the proper method of determining the energy factor for water heaters. Pending a resolution of this matter, DOE suspended the provisions of the final water heater test procedures dealing with the determination of the energy factor, by notice issued March 29, 1978 (FR 13865, Apr. 3, 1978). A public hearing on the proposed amendment was scheduled for May 16, 1978, but no requests for the presentation of oral statements were received.

B. Discussion of Comments

One written comment was received from an engineering consulting firm, which contended that despite the proposed changes, the DOE test procedures would still substantially overstate the energy consumption of water heaters. In support of this contention, the commenter referred to data previously submitted to DOE. This issue was reviewed at the time the notice prescribing final test procedures for water heaters (42 FR 54110, Oct. 4, 1977) was promulgated.

Based on available data, FEA determined that the test procedures did not overstate the energy consumption of water heaters. In connection with today's amendment, DOE has again reviewed this issue and finds no basis for changing the original FEA determination.

C. Regulations Prescribed

The effect of today's rulemaking is to amend the test procedures for water heaters by substituting in 10 CFR 430.22 a new paragraph (e)(2) for determination of the energy factor for water heaters and by adding to appendix E a new section 4.6 for calculation of the daily hot water energy consumption of water heaters.

DOE's suspension of 10 CFR 430.22(e)(2) (43 FR 13865, Apr. 3, 1978), terminates when today's amendments become effective.

As part of today's rulemaking DOE is also changing the name of 10 CFR Part 430 to "Energy Conservation Program for Consumer Products." DOE believes that this change will eliminate any possible confusion regarding the contents of 10 CFR Part 430.

In accordance with the proposed DOE plan for implementing Executive Order 12044, "Improving Government Regulations," DOE has determined that this final rule to amend the test procedures for water heaters is not a significant regulation.

In consideration of the foregoing, part 430 of chapter II of Title 10, Code of Federal Regulations, is amended as set forth below, effective November 20, 1978.

Issued in Washington, D.C., October 13, 1978.

William P. Davis,
Deputy Director of Administration.

1. Section 430.22 is amended by revising paragraph (e)(2) to read as follows:

(e) * * *

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

(i) For a gas or oil water heater, the quotient of the daily hot water energy consumption determined according to section 4.6 of appendix E of this sub-

[1] Editorial Note.—It is contemplated that ch. II will be renamed at a future date to reflect the fact that it contains regulations administered by the Department of Energy, including regulations administered by the Office of Conservation and Solar Applications.

part divided by the average daily energy consumption as determined according to section 4.5.3 of appendix E of this subpart, the resulting quotient then being rounded off to the nearest 0.01; and

(ii) For an electric water heater, the quotient of the daily hot water energy consumption determined according to section 4.6 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-hour, the resulting quotient then being rounded off to the nearest 0.01.

2. Appendix E to subpart B of part 430 is amended by adding a new section 4.6, to read as follows:

4.6 *Daily hot water energy consumption.* Calculate the daily hot water energy consumption, C_e, the energy content of the nominal daily hot water usage, expressed in Btu per day and defined as:

$$C_e = k \times U \times \Delta T_5.$$

Where:

k is as defined in section 4.1.1; and
ΔT_5 and U are as defined in section 4.3.

3. The name of part 430 is changed to "Energy Conservation Program For Consumer Products," as set forth above.

[FR Doc. 78-29535 Filed 10-18-78; 8:45 am]

DEPARTMENT OF ENERGY

Office of Energy Conservation and Solar Applications

[10 CFR Part 430]

Energy Conservation Program for Consumer Products; Test Procedures for Water Heaters; Public Hearing

AGENCY: Department of Energy.

ACTION: Proposed rule.

SUMMARY: The Department of Energy hereby proposes to amend its test procedures for water heaters. These test procedures are a part of the energy conservation program for consumer products established pursuant to the Energy Policy and Conservation Act, as amended by the National Energy Conservation Policy Act, which requires that standard methods of testing be prescribed for covered products.

DATES: Written comments in response to this notice by July 9, 1979; requests to speak at the public hearing by June 14, 1979; statements by June 22, 1979; public hearing to be held on June 27, 1979, 9:30 a.m.

ADDRESSES: Written comments, requests to speak at the public hearing, and statements to: Margaret W. Sibley, U.S. Department of Energy, Office of Conservation and Solar Applications, Docket #CAS–rm–79–105, Mail Stop 2221C, 20 Massachusetts Avenue, NW., Washington, D.C. 20585.

PUBLIC HEARING TO BE HELD AT: Department of Energy, Room 3000A, Federal Building, 12th Street and Pennsylvania Avenue, NW., Washington, D.C. 20585.

FOR FURTHER INFORMATION CONTACT:

James A. Smith, U.S. Department of Energy, Office of Conservation and Solar Applications, Division of Buildings and Community Systems, Consumer Products Efficiency Branch, Room 2248, 20 Massachusetts Avenue, NW., Washington, D.C. 20585, (202) 376–4814.

Margaret W. Sibley (Hearing Procedures), U.S. Department of Energy, Office of Conservation and Solar Applications, 20 Massachusetts Avenue, NW., Mail Stop 2221C, Washington, D.C. 20585, (202) 376–1651.

Robert M. Mussler, U.S. Department of Energy, Office of General Counsel, 20 Massachusetts Avenue, NW., Room 3224, Washington, D.C. 20585, (202) 376–4100.

SUPPLEMENTARY INFORMATION:

A. Background

Title III, Part B of the Energy Policy and Conservation Act (Act) (Pub. L. 94–163) established an energy conservation program for consumer products. As part of this program, section 323 (42 U.S.C. 6293) of the Act requires that standard methods of testing to determine estimated annual operating cost and at least one other useful measure of energy consumption be prescribed for certain products, including water heaters.

Test procedures for water heaters were proposed by notice issued April 21, 1977 (42 FR 21576, April 27, 1977). Final test procedures for water heaters were prescribed on September 27, 1977 (42 FR 54110, October 4, 1977). DOE amended the test procedures for water heaters by notice issued October 13, 1978 (43 FR 48986, October 19, 1978) in order to specify a new method of determining the measure of efficiency of water heaters.

DOE is today proposing to amend the test procedures for water heaters, specifically Appendix E to Subpart B of Part 430, Code of Federal Regulations, in order to specify two new measures, first hour rating and recovery rate.

B. Discussion

When originally proposed on April 21, 1977, the test procedures for water heaters included the measures of hot water supply rating and recovery rate. Hot water supply rating was a measure of the maximum amount of hot water that a water heater could provide in one hour. Recovery rate was a measure of the rate at which a water heater could heat water. Both of these measures were included in the original proposed test procedures because they were likely to assist consumers in making purchasing decisions.

At the public hearing on the original proposed water heater test procedures, members of the water heater industry argued that the test procedures as proposed were unduly burdensome for the testing of electric water heaters with immersed heating elements due to the large number of models that would have to be tested and the attendant high cost of testing.

After reviewing those comments, a decision was made to revise the definition of a water heater basic model for the final test procedures to exclude immersed heating elements from consideration as a distinguishing feature of a basic model. This change was made only after a very careful evaluation led to acceptance of the commenters' claim that, for the purposes of the test procedures, the electrical characteristics of an electric water heater with immersed heating elements have only a minimal effect on its efficiency and hence its energy consumption. Since these characteristics did, however, have a significant effect on the proposed measures, hot water supply rating and recovery rate for electric water heaters, this revision of the definition of a water heater basic model made the proposed method for the determination of these measures unworkable.

Since hot water supply rating was a useful measure of the capacity of a water heater, members of the water heater industry expressed concern over the possible loss of this measure. They commented that the hot water supply rating of an electric water heater with immersed heating elements could be predicted by calculation; however, they had no such prediction scheme to present at the time. Neither did they submit any data from which a hot water supply rating prediction scheme might be developed.

While the development of a scheme for predicting the hot water supply rating of such a water heater was considered feasible, it was found that, lacking a proven hot water supply rating prediction scheme and lacking test data from which to attempt to develop such a scheme, the proposed measure, hot water supply rating, had to be deleted from the final test procedures for water heaters. However, a statement was included in the notice of the final rule on test procedures to the effect that further investigations into schemes for the prediction of hot water supply rating or for the determination of some other measure of hot water delivery performance for water heaters would be made. It was further stated that the water heater industry and other interested parties were invited to provide input concerning these investigations.

No comments on the original proposed test procedures for water heaters addressed the measure of recovery rate. This measure, sometimes referred to as "recovery capacity," accounted for the combined effect of a water heater's power input and recovery efficiency on the rate at which the water heater could heat water. In the proposed test procedures, recovery rate was to be determined independently of hot water supply rating and was intended to serve as a useful measure of the rate at which a water heater could recover from a large hot water draw. The higher the recovery rate, the more quickly the water heater could replenish its stored volume of hot water subsequent to a large water draw.

Revising the definition of a water heater basic model also made the proposed method for the determination of recovery rate unworkable. Again, lacking a proven recovery rate prediction scheme and the test data from which to attempt to develop such a scheme, this proposed measure, like hot water supply rating, had to be deleted from the final test procedures.

The investigation into schemes for the prediction of hot water supply rating or for the determination of some other measure of hot water delivery performance for water heaters was concluded by DOE at about the same time that two events occurred which reaffirmed the need for such measures to be included in the test procedures for water heaters. The first of these events was the release of the Federal Trade Commission's (FTC) final staff report on FTC's proposed rule concerning disclosure of energy cost and consumption information in labeling and advertising of consumer products. This report was released on February 12, 1979. In it, FTC made the following statement in the section dealing with the determination of the capacity of consumer products covered by the proposed rule:

"Historically, gas and oil water heater sales are based on recovery capacity, while electric water heater comparisons are based on storage capacity. Some participants [in the public hearing and written comments process] argued that the traditional methods of comparing water heaters are unsatisfactory. A system that reflects the energy needed both to store and to replace consumed hot water is more informative than one that measures only storage or recovery. The Recommended Rule reservedly bases capacity on tank storage, in accordance with current DOE test procedures. If the Department of Energy prescribes methods of measuring first hour recovery rates or hot water supply ratings before the Commission issues the final labeling rule, staff recommends that the final rule reflect the DOE procedure for measuring capacity in effect at that time."

The second event was the series of six public meetings held on DOE's advanced notice of proposed rulemaking regarding energy efficiency standards for nine types of consumer products. These public meetings were held over the period January 26 to February 8, 1979. Four of the participants in these public meetings, all representatives of the water heater industry, made statements to the effect that DOE should use the measure, first hour rating, as the measure of the capacity of a water heater and issue minimum energy efficiency standards which are a function of this capacity measure. (As it is used here, first hour rating can be considered to be equivalent to hot water supply rating.) These commenters claimed that the establishment of minimum energy efficiency standards as a function of tank volume, the present measure of the capacity of a water heater, would impose a more stringent requirement on water heaters with large tank volumes than those with small tank volumes. Such an approach would discriminate against water heaters with large tank volumes. It was pointed out that water heaters with large tank volumes provide a utility which cannot always be matched by those with smaller tank volumes, particularly in the case of electric water heaters. Commenters argued that consumers need water heaters with large tank volumes to satisfy their hot water needs in order to take advantage of off-peak or time-of-day electric utility rates to reduce their water heating energy bill.

In an effort to develop a more useful measure of water heater capacity, DOE is proposing to amend the test procedures for water heaters to incorporate two new measures, recovery rate and first hour rating.

Recovery rate as proposed in this notice is the same as it appeared in the original proposed test procedures except that a new method of determining the power input of an electric water heater with immersed heating elements is specified. Also, as proposed in this notice, recovery rate is used in the determination of first hour rating. After reviewing the rationale behind the decision to delete this measure from the original proposed test procedures for water heaters, DOE has determined that the measure should now be reconsidered. DOE finds that while the method for the determination of power input for electric water heaters with immersed heating elements may introduce some error into the determination of recovery rate, such error may not be of such a magnitude as to be unacceptable. The benefits of this measure, both with regard to its usefulness to consumers, discussed earlier, and its contribution toward the determination of first hour rating, may outweight concerns over any slight inaccuracy in the measure.

While first hour rating as herein proposed is equivalent to hot water supply rating as it appeared in the original proposed test procedures for water heaters, the different name for the measure has been chosen for two reasons: to eliminate possible confusion between the two versions of the measure since the methods for their determination differ and to eliminate the subjective term "hot" from the title. Consumers of differing sensibilities are likely to differ in their interpretation of what constitutes "hot" water. Since it is not DOE's intent to define "hot" water, the use of this term could be misleading to consumers. The new title "first hour rating" is a more appropriate title since it both identifies the time base of the measure, and hour, and, by use of the term "first", implies that the measure is only indicative of the performance of the water heater during its "first" hour of operation. While the consumer will not know the conditions for the determination of this measure, it is sufficient that the term will discourage the interpretation of the measure as a rate of hot water delivery performance which the water heater can maintain hour after hour.

The test for first hour rating proposed here is significantly less burdensome than the test for hot water supply rating previously proposed. Not only are fewer tests required for electric water heaters with immersed heating elements, but the test itself is a simpler, less time-consuming one than the hot water supply rating test previously proposed. Just as with the hot water supply rating test, the first hour rating test can be conducted right before or after a standby loss test. The only additional test instruments required will be a weighing container and a scale for weighing the water drawn from the water heater during the test or a water flow meter for determining directly the amount of water drawn from the water heater during the test.

The determination of the measure, first hour rating, is based partly on test results and partly on calculation. The test portion is intended to account for the influence of tank capacity, tank geometry, and water inlet/dip tube design. The calculation portion is intended to account for the influence of input power and recovery efficiency. This method of determining first hour rating overcomes the problem associated with the determination of hot water supply rating in that the influence of the electrical characteristics of an electric water heater with immersed heating elements on the first hour rating is determined by calculation rather than by test.

C. Comment Procedure

1. *Written Comment*

Interested persons are invited to participate in this rulemaking by submitting data, views or arguments with respect to the proposed amendments set forth in this notice to Margaret Sibley at the address indicated at the beginning of this preamble.

Comments should be identified on the outside of the envelope and on documents submitted to DOE with the designation "Water Heaters—Proposed Amendments (Docket No. CAS–RM–79–

105)." If possible, fifteen copies should be submitted. All comments received by July 9, 1979 and all other relevant information, will be considered by DOE before final action is taken on the proposed regulation. Late comments will be considered to the extent that time permits.

Pursuant to the provisions of 10 CFR 1004.11, any person submitting information which he or she believes to be confidential and exempt by law from public disclosure should submit one complete copy, and fifteen copies from which information claimed to be confidential has been deleted. In accordance with the procedures established at 10 CFR 1004.11, DOE shall make its own determination with regard to any claim that information submitted be exempt from public disclosure.

2. *Public Hearing*

a. *Request procedures.* The time and place of the public hearing are indicated at the beginning of this preamble. The hearing will be continued, if necessary, on June 28, 1979.

DOE invites any person who has an interest in the proposed amendment issued today, or who is a representative of a group or class of persons that has an interest in today's proposed amendment, to make a written request for an opportunity to make an oral presentation. Such a request should be directed to the address indicated at the beginning of this preamble and must be received before June 14, 1979. A request may be hand delivered to such address, between the hours of 8:00 a.m. and 4:30 p.m., Monday through Friday. A request should be labeled both on the document and on the envelope "Water Heaters—Proposed Amendments (Docket No. CAS-RM-79-105)."

The person making the request should briefly describe the interest concerned; if appropriate, state why he or she is a proper representative of a group or class of persons that has such an interest, and give a concise summary of the proposed oral presentation and a telephone number where he or she may be contacted.

DOE will notify, before 4:30 p.m., June 18, 1979, each person selected to appear at the hearing. Each person selected to be heard must submit 15 copies of his or her statement to the address and by the date given in the beginning of this preamble. In the event any person wishing to testify cannot meet the 15 copy requirement, alternative arrangements can be made with Margaret W. Sibley in advance of the hearing by so indicating in the letter requesting an oral presentation or by calling (202) 376-1651.

b. *Conduct of hearings.* DOE reserves the right to select the persons to be heard at this hearing, to schedule their respective presentations and to establish the procedures governing the conduct of the hearing. The length of each presentation may be limited, based on the number of persons requesting to be heard.

A DOE official will be designated to preside at the hearing. This will not be a judical or evidentiary-type hearing. Questions may be asked only by those conducting the hearing, and there will be no cross-examination of the persons presenting statements. Any decision made by DOE with respect to the subject matter of the hearing will be based on all information available to DOE. At the conclusion of all initial oral statements, each person who has made an oral statement will be given the opportunity if he or she so desires, to make a rebuttal statement. The rebuttal statements will be given in the order in which the initial statements were made and will be subject to time limitations.

Any person who wishes to ask a question at the hearing may submit the question, in writing, to the presiding officer. The presiding officer will determine whether the quesstion is relevant and whether the time limitations permit it to be presented for answer.

Any further procedural rules needed for the proper conduct of the hearing will be announced by the presiding officer.

A transcript of the hearing will be made and the entire record of the hearing, including the transcript, will be retained by DOE and made available for inspection at the DOE Freedom of Information Reading Room, Room GA152, Forrestal Building, 1000 Independence Avenue, S.W., Washington, D.C., between the hours of 8:00 a.m. and 4:30 p.m., Monday through Friday. For information concerning the availability of records at the Freedom of Information Reading Room, call 202-252-5969. In addition, any person may purchase a copy of the transcript from the reporter.

D. Environmental and Inflationary Review

Pursuant to section 7(c)(2) of the Federal Energy Administration Act of 1974, a copy of this notice has been submitted to the Administrator of the Environmental Protection Agency for his comments concerning the impact of this proposal on the quality of the environment. The Administrator has no comments.

The National Environmental Policy Act of 1969 requires DOE to assess the environmental impacts of any proposal issued by the Department for "major Federal actions significantly affecting the quality of the human environment." Since test procedures under the energy conservation program for consumer products will be used only to standardize the measurement of energy usage and will not affect the quality or distribution of energy usage, DOE has determined that the action of prescribing test procedures, by itself, will not result in any environmental impacts. On this basis, DOE has determined that, with respect to prescribing test procedures under the energy conservation program for appliances, no environmental impact statement is required.

The proposed rule has been reviewed in accordance with Executive Order 12044 and DOE Order 2030. From the regulatory analysis performed, it was determined that the proposal was significant in nature but did not have major impacts to manufacturers and consumers (imposing annual economic costs of $100 million or more).

(Energy Policy and Conservation Act, Pub. L. 94-163, 89 Stat. 871, 42 U.S.C. 6201 as amended by Pub. L. 95-619, 92 Stat. 3281; Department of Energy Organization Act, Pub. L. 95-91, 91 Stat. 565, 42 U.S.C. 7101).

In consideration of the foregoing, it is proposed to amend Part 430 of Chapter II of Title 10, Code of Federal Regulations, as set forth below.

Issued in Washington, D.C., May 3, 1979.

Maxine Savitz,

Deputy Assistant Secretary, Conservation and Solar Applications.

Appendix E to Subpart E—[Amended]

1. Appendix E to Subpart B of Part 430 is amended by adding a new section 3.7 to read as follows:

* * * * *

3.7 *First hour rating test.*

3.7.1 *First hour rating test for gas and oil water heaters and electric water heaters with other than immersed heating elements.* Establish normal water heater operation with the maximum mean tank temperature within the range specified in section 2.6 and with all air eliminated from the tank. Begin the first hour rating test immediately after a cutout by recording the time and withdrawing water from the water heater at a rate of 5.0 ± 0.25 gallons per minute. All water withdrawn from the water heater during this test shall be collected in a weighing container for the purpose of determining its weight. Alternatively, a water flow meter may be used to measure the volume of water withdrawn from the water heater directly. Continuously monitor the outlet water temperature from the start of the waterdraw and record the maximum value measured. For the purposes of this test, this recorded temperature shall be referred to as the initial outlet water temperature. Continue the withdrawal of water until the outlet water temperature drops to a value 40° F below the initial outlet water temperature, at which time terminate the withdrawal, record the time duration, t_f, of the test, in hours measured with an error no greater than 2 percent, and record the weight of the water withdrawn, W, in pounds, measured with an error no greater than 2 percent, or the volume of the water withdrawn, G, in gallons, measured with an error no greater than 2 percent. If the outlet water temperature does not drop 40° F after one hour, the test is to be terminated and the first hour rating expressed as greater than 300 gallons.

3.7.2 *First hour rating test for electric water heaters with immersed heating elements.* Except as provided in this section, all electric water heaters with an immersed heating element shall be tested with an immersed heating element that has a design power rating of 4.5 kilowatts. If 4.5 kilowatts exceeds the maximum design power rating specified by the manufacturer for the water heater to be tested, the first hour rating test shall be conducted with the water heater equipped with an immersed heating element of a design power rating equal to the manufacturer's specified maximum design power rating. All water heaters designed to operate with dual immersed heating elements shall be tested with dual immersed heating elements of equal design power rating in accordance with the provisions specified in this section. Tests shall be conducted in accordance with the same procedures as those specified in section 3.7.1.

2. Appendix E to Subpart B of Part 430 is amended by adding a new section 4.7 to read as follows:

* * * * *

4.7 *Recovery rate.*

4.7.1 *Recovery rate for gas and oil water heaters.* For a gas or oil water heater, calculate the recovery rate, R, expressed in gallons per hour and defined as:

$$R = \frac{P \times E_r}{k \times \Delta T_s}$$

Where:

k is as defined in section 4.1.1.
ΔT_s is as defined in section 4.3
E_r is as calculated in section 4.1.1.
P = power input to the burner, determined in accordance with section 3.2.1, expressed in Btu per hour.

4.7.2 *Recovery rate for electric water heaters.* For an electric water heater, calculate the recovery rate, R, expressed in gallons per hour defined as:

$$R = \frac{P^{*} \times E_r \times 3{,}412\ \text{Btu/kWh}}{k \times \Delta T_s}$$

Where:

k is as defined in section 4.1.1.
ΔT_s is as defined in section 4.3.
E_r is as calculated in 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.
P^{*} = P (power input to the heating elements, expressed in kilowatts, as 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) with the following exception: For electric water heaters with dual immersed heating elements which, in characteristic operation of the water heater, are not energized simultaneously at any time, P^{*} shall be taken as the design power rating of the heating element in closest proximity to the hot water outlet of the water heater, expressed in kilowatts.

Appendix E to Subpart B [Amended]

3. Appendix E to Subpart B of Part 430 is amended by adding a new section 4.8 to read as follows:

4.8 *First hour rating.* Calculate the first hour rating, F, expressed in gallons and defined as:

$$F = \frac{W}{d} + [R \times (1 - t_f)], \text{ or}$$

$$F = G + [R \times (1 - t_f)]$$

Where—

R is as calculated in section 4.7.1 for gas and oil water heaters, or section 4.7.2 for electric water heaters.
W = weight of the water withdrawn from the water heater during the first hour rating test, determined in accordance with section 3.7.1 for gas and oil water heaters and electric water heaters with other than immersed heating elements, or section 3.7.2 for electric water heaters with immersed heating elements, expressed in pounds.
d = 8.25 pounds per gallon, the nominal density of water.
G = volume of water withdrawn from the water heater during the first hour rating test, determined in accordance with section 3.7.1 for gas and oil water heaters and electric water heaters with other than immersed heating elements, or section 3.7.2 for electric water heaters with immersed heating elements, expressed in gallons.
t_f = duration of the water draw in the first hour rating test, determined in accordance with section 3.7.1 for gas and oil water heaters and electric water heaters with other than immersed heating elements, or section 3.7.2 for electric water heaters with immersed heating elements, expressed in hours.

[Docket No. CAS-RM-79-105]
[FR Doc. 79-14489 Filed 5-4-79; 4:38 pm]
BILLING CODE 6450-01-M

[10 CFR Part 436]

Federal Photovoltaic Utilization Program; Public Hearing

AGENCY: Department of Energy

ACTION: Proposed rule.

SUMMARY: The Department of Energy today proposes rules for the monitoring and assessment requirements of the Federal Photovoltaic Utilization Act, Title V, Part 4 of the National Energy Conservation Policy Act. The program implementing this legislation is referred to as the Federal Photovoltaic Utilization Program, and is summarized in the following preamble. Under this program, Federal agencies will receive funds from the Department of Energy for the installation of photovoltaic solar electric systems at Federal facilities. Today's proposed rules relate only to requirements for monitoring and assessing the performance and operation of systems installed as a part of the program.

DATES: Written comments must be submitted by July 9, 1979. Public hearings will be held on June 14, 1979, beginning at 9:30 a.m. Requests to testify at the hearing must be submitted by June 4, 1979.

ADDRESSES: Send written comments and requests to speak to Margaret W. Sibley, Office of Conservation and Solar Applications, Room 2221C, 20 Massachusetts Avenue, N.W., Washington, D.C. 20545. Hearing will be held at Room 3000A, 12th and Pennsylvania Avenue, Washington, D.C. Documents for public inspection or copying may be found at the DOE Reading Room, GA-152, Forrestal Building, 1000 Independence Avenue, S.W., Washington, D.C. 20585.

APPENDIX B

I. Introduction

This appendix summarizes the results of work done by the Product Performance Engineering Division, Center for Consumer Product Technology, National Bureau of Standards, in support of the DOE/ORNL Energy Conservation Program for Appliances. These results have been reported to DOE/ORNL in the form of memorandum reports. Specifically, this appendix presents the results of the analytical and laboratory studies leading to the proposals for modification of the Water Heater Test Procedures to cover electric heat pump water heaters. It is divided into four general sections. The first section reviews a typical design of an electric heat pump water heater. The second section discusses the differences in design between the common type electric water heaters and electric heat pump water heaters. The third section discusses the laboraory tests performed on an electric heat pump water heater for confirmatory purposes. The fourth section discusses a second series of laboratory tests performed by NBS under the more stringent conditions of a draw schedule to check the validity of the proposed modified test procedures.

II. Design Review of Electric Heat Pump Water Heaters

This review is mainly based on the information provided to NBS by manufacturers, which includes

1) Drawings, sketches, photographs, and laboratory test data;

2) Discussions with manufacturer's personnel; and

3) Inspection of typical electric heat pump water heaters.

This design review does not purport to review the validity of any particular engineering design of an electric heat pump water heater; it merely reviews those aspects of the design that may significantly conflict with the current DOE water heater test procedures as would be applied to the electric heat pump water heater.

The electric heat pump water heater, as shown in Figure 1.a., consists of a storage water tank, similar to that of an electric water heater, and a heat pump atop the storage tank, as shown in Figure 1.b. The heat pump operates as a heating mode only heat pump. Schematically, the electric heat pump water heater is shown in Figure 2, where the storage water tank is located beneath the heat pump which has the condensing coil entering through a "chimney" in the storage tank. The coil design shown in Figure 3 is typical of current designs.

A. The Ideal Thermodynamic Cycle

The analysis of the thermodynamic cycle of the heat pump determines the ratio of the amount of heat transferred to the stored water to the amount of energy to the heat pump; coefficient of performance, COP. The electric water heater always has a COP of 1.0; i.e., the heat generated by the resistance elements and the amount of energy transferred to the stored water are the same. The heat pump in its usual use environment, however, has a COP greater than 1.0.

1. Analysis of Heat Pump Cycle Processes

The ideal thermodynamic heat pump cycle is illustrated in Figure 4. The coordinates of this plot are pressure and enthalpy. The refrigerant in most cases is R-12. The ideal cycle follows the paths labeled 1-2s-3-4-1. This consists of four processes as follows:

1-2s Compression of the refrigerant gas from a superheated state 1, at pressure p_1, to a more highly superheated state 2s, at pressure p_2. This ideal compression process is reversible and adiabatic and, thereby, follows an isentropic path. Thus, state 2s is fixed by the pressure ratio p_2/p_1 and by the entropy of the gas at the compressor suction state 1. The ideal work input to the compressor, W_C, per pound of refrigerant pumped is equal to the the enthalpy change, $W_C = (h_{2s} - h_1)$.

2s-3 Condensation of the refrigerant at the constant pressure p_2. This process is more accurately described as desuperheating from "2s" to "a", condensation from "a" to "b" and subcooling from "b" to "3." The heat rejected, q_R, per pound of refrigerant circulated during this process is the "pumped" heat of the cycle, and is determined by the enthalpy change, $q_R = (h_{2s} - h_3)$.

3-4 Expansion of the refrigerant from the condensing pressure p_2 to the evaporating pressure p_1. This is an irreversible adiabatic throttling process accomplished by either an expansion valve or a capillary tube. In either case, the result is that the enthalpy of the refrigerant leaving the condenser is identical with the enthalpy entering the evaporator, $h_3 = h_4$.

4-1 Evaporation and superheating of the refrigerant at pressure p_1. The heat absorbed, q_A, per pound of refrigerant pumped during this process is furnished by a low grade energy source in this case by the ambient air, and is equal to the enthalpy change, $q_A = (h_1 - h_4)$.

2. Heat Pump Performance Measure

For a heat pump the useful effect desired is the maximum heat rejection rate from the condenser, q_R, with a minimum power input to drive the compressor, W_C. The ratio of q_R to W_C, both expressed in the same units is the COP,

$$COP = \frac{q_R}{W_C}$$

Theoretically, this number is always greater than 1.0 since

$$COP = \frac{q_R}{W_C} = \frac{q_A + W_C}{W_C} = 1 + \frac{q_A}{W_C}$$

and q_A is always greater than zero.

What is wanted of the heat pump is a COP as large as possible so that its the multiplicative effect on W_C gives the largest possible q_R for the least W_C. This can be seen readily since

$$q_R = (COP)W_C$$

from the definition of COP above.

3. Example

Calculate COP at three different condensing temperatures of 100°F, 120°F, and 140°F and a constant evaporator temperature of 80°F (Figure 5). Assumptions:

a. the compression process is isentropic;

b. the state of compressor suction is that of the saturated vapor;

c. the state of condenser outlet is that of the saturated liquid; and

d. the refrigerant is R-12.

Condition 1. The evaporator is maintained at 80°F and the condenser is maintained at 100°F.

$$COP = \frac{87.5 - 31.0}{87.5 - 85.0} = 22.6$$

Condition 2. The evaporator is maintained at 80°F and the condenser is maintained at 120°F.

$$COP = \frac{89.5 - 36.0}{89.5 - 85.0} = 11.9$$

Condition 3. The evaporator is maintained at 80°F and the condenser is maintained at 140°F.

$$COP = \frac{91.5 - 41.0}{91.5 - 85.0} = 7.8$$

Although the actual heat pump water heater does not operate with ideal processes, the underlining fact is that as the temperature of the stored water (i.e., condenser) increases, the COP decreases drastically.

B. Analysis of Components

The COP of a heat pump is influenced primarily by the designs of its various components--the efficiency of the motor-compressor, the design and sizing of the evaporator and condenser, the choice of refrigerant, and the sizing of the refrigerant lines which interconnect all the components. Some of these effects will be discussed later. The important operational factors which affect COP are the temperatures of the surroundings in which the heat pump must function (i.e., ambient air and stored water temperatures).

The heat absorbed at the evaporator, q_A, is heat absorbed from somewhere in the surroundings--the basement, closet, etc.,--where the heat pump water heater is located. The pumped heat, q_R, is rejected to the stored water. The COP is maximized by having the highest possible heat source temperature in the surroundings for a given temperature within the stored water.

The temperature of the surroundings if large enough is usually constant. The stored water is at its coldest at cold startup or at the beginning of the heat pump operation. As the stored water is heated the COP decreases. The impact of decreasing COP as the stored water temperature increased was illustrated in the preceeding example.

1. Motor Compressor

In a heat pump compressor there are two kinds of losses which add to the required work input. First there are the irreversibilties in the gas compression process within the cylinder and in the flow through the valves. These losses are accounted for by the so-called compression efficiency which is the ratio of the ideal work to the actual work input to the gas during compression. This efficiency is a function of the type of compressor and the pressure ratio across which it pumps. For the small hermetic compressors used in electric heat pump water heaters, the compression efficiency varies between 50% to 80%.

The second kind of losses in the compressor is the mechanical friction losses between the moving parts. These losses are accounted for by the mechanical efficiency of the compressor. The overall efficiency of the compressor, accounting for both compression and mechanical efficiency, is nearly a constant over a range of 50% to full load due to the compensating effect of the two efficiencies.

There is an additional loss due to the compressor motor which is accounted for by the motor efficiency. The motor efficiency of a hermetic compressor motor is a broad flat curve over the operating range of the compressor. The overall efficiency of the motor-compressor may therefore be taken as a constant for the 50 percent to full load range.

2. Evaporator Fan Work

The power input to the evaporator fan is a function of the air flow rate and pressure loss across the evaporator. This power input is independent of changing load on the compressor.

3. Heat Pumping Rate

In the ideal cycle the heat pumping rate, q_R, per pound of refrigerant circulated is determined by the enthalpy change ($h_{2s} - h_1$). In the actual cycle, state 2 at compressor discharge will depart somewhat from the isentropic state 2s due to the irreversibilities associated with the compression process (see Figure 4).

The product of the compression, mechanical, and motor efficiencies is very nearly 50% for most small hermetic motor-compressors. This means that approximately one-half of the energy input to the motor-compressor will be dissipated as heat losses. If these losses can be recovered as heat input to the storage tank, the heat pumping rate of the cycle can be increased by a much as 20% according to Reference B1.*

The electric heat pump water heater system has insulation between the storage tank and the compressor to reduce heat loss

* References are on page B-51.

during standby. Some of the dissipatd heat from by the compressor is recovered by the air which is drawn over the compressor before passing across the evaporator coil.

In order to recover directly the heat loss from the compressor and to minimize heat losses during standby, the compressor could be installed in close thermal contact with the stored water and the entire storage tank and compressor system be insulated. The resulting design would then be similar to that of a Harvey-Whipple design in which the motor-compressor unit is sunken into the storage tank (Reference B1). On the other hand, however, the manufacturing cost would be significantly higher and the compressor operated in a higher temperature environment--a condition detrimental to the durable operation of the compressor.

4. Condenser Coil

The installation of the condenser coil in the storage tank is shown in Figure 2. A typical detail coil design is shown in Figure 3. The double wall construction as shown in Figure 6 is used to satisfy local code requirements that potable water be separated from the refrigerant with two barriers. For heat transfer enhancement, the cavity between the two walls is filled with water.

5. Evaporator Coil

The evaporator coil for one design is shown in Figure 1.b. It is installed atop the storage tank jacket. The evaporator coil is a single tube, single row heat exchanger. The main consideration in designing the physical size and configuration of the coil, in this case, was aesthetic. To conform to the shape of the storage tank jacket (i.e., cylindrical shape) the tube bank has been formed with an arc.

As shown in Figure 2, The motor-compressor unit is installed atop the storage tank jacket. The evaporator fan is on top of the unit. The evaporator coil and a cover, a shown partially in Figure 2, surrounds the unit. The fan operation accomplishes two functions at the same time: 1) it draws ambient air into the coil cavity to cool the motor-compressor, thus recovering some of the heat resulting from motor-compressor inefficiency. and 2) then circulates the heated air across the evaporator coil which allows it to operate at a temperature higher than that of the ambient.

6. Throttling

For the throttling or expansion process, a thermal expansion valve is used. This valve has a superheat bulb which adjusts the valve to give a designed amount of superheat at compressor suction.

7. Water Storage Tank

The water storage tank used in the electric heat pump water heater is similar to that used in a standard electric water heater. Essentially, it consists of a cylindrical tank and a concentric cylindrical jacket, the gaps between the tank and jacket are filled with insulation. There are supply water inlet, hot water outlet, drain and pressure relief valves as used with the water storage tank of an electric water heater.

8. Resistance Heater

During a cold startup or for a fast recovery after a heavy water draw, or for periods when the ambient temperature is so low as to cause evaporator frosting, there is a resistance heater which operates. The resistance heater's function is similar to the upper heating element in an electric water heater; it heats water only in the upper portion of the tank.

C. Controls

There are two thermostats that regulate the water temperature. Similar to an electric water heater, both of the thermostats are installed on the side walls of the storage tank. One of the thermostats regulates the resistance heater; the other one regulates the heat pump. The resistance heater is designed to heat the upper 12 to 15 inches of water; the condenser coil of the heat pump is designed to input heat to the water at the lower level of the storage tank.

In the case of a cold start or after a heavy water draw, the resistance heater and the heat pump operate simultaneously. The simultaneity of operation of two separate heating components is one of the differences in operation of the electric heat pump water heater from that of an electric water heater having two high wattage resistance heating elements.

An over temperature safety thermostat limits the operation of either the backup heating element or the heat pump such that the water temperature never exceeds 173°F.

Another thermostat prevents the heat pump from operating when ambient temperature drops below 47°F to prevent frosting of the evaporator coil.

A thermal overload is provided to prevent overloading of the electric motor.

D. Summary

1. Figuratively speaking, the electric heat pump water heater is an electric water heater with its bottom heating element replaced by the condenser coil of a heat pump.

2. The heating capacity of the heat pump is a function of the operating conditions. These are the ambient air temperature which affects the evaporator performance and the stored and supply water temperature which affects the condenser performance.

3. Under favorable conditions, given one unit of energy input, the heat pump delivers more than one unit of energy to the stored water; while for the same one unit of energy input, the electric water heater delivers only one unit of energy in terms of hot water.

4. Under unfavorable conditions, the stored water in an electric heat pump water heater is heated by a resistance heating element operating as in an electric water heater.

III. Differences between Electric Water Heater and Electric Heat Pump Water Heater

The DOE test procedure for water heaters covers two types of electric water heaters: 1) electric water heaters with immersed heating elements, and 2) electric water heaters with other than immersed heating elements. The former is much more important than the latter in terms of unit in use and units shipped annually. Only the design differences between the electric water heater with immersed heating elements and the electric heat pump water heater will be discussed.

The differences between the electric water heater and the electric heat pump water heater may be classified into two categories: construction and operation. Both types of water heaters fulfill a basic requirement--converting of electrical energy into water thermal energy and subsequently delivering hot water on demand.

A. Differences in Construction

1. Electric Water Heater

The construction of an electric water heater with immersed heating elements is relatively simple. It consists of a water storage tank, electric heating elements, thermostats and some miscellaneous items. The water storage tank is a cylindrical tank with an external jacket concentric with the water tank. Insulating material fills the gap between the two. In the case of the residential water heaters, there are normally two resistance electric heating elements which penetrate the side walls of the water tank, and are totally immersed in the water. The thermostats, one for each heating element, control the on-off operation of the heating elements depending on local temperature and thermostat settings. The miscellaneous items include the water inlet (and dip tube) the water outlet, the anodic rod, the pressure relief valve, the drain valve and the electrical connecting terminal block.

2. Electric Heat Pump Water Heater

The electric heat pump water heater consists of a water storage tank, thermostats, a heat pump, a resistance electric heating element similar to the ones used in an electric water and some miscellaneous items also similar to those of the electric water heater, and a heat pump.

The heat pump system, however, is a relatively complicated machine. It consists of four basic components with connecting pipes and an air circulating fan. The pipes connect the four components: hermetic motor-compressor, condenser coil, thermal expansion valve, evaporator coil, and back to the motor compressor forming a closed loop. The air circulating fan, which is driven by a fractional horsepower motor, blows ambient air across the evaporator coil transferring thermal energy from the ambient air to the refrigerant. The detailed thermodynamic processes were described in the Design Review section.

The most important link between the heat pump and the water storage tank is the condenser coil. The condenser coil in the electric heat pump water heater is effectively replacing the bottom heating element of a two element electric water heater. The heat pump is essentially packaged into two units with connecting pipes. One unit consists of the hermetic-motor-compressor, the evaporator coil, the thermal expansion valve and the air circulating fan. This unit, having the appearance of a stub cylinder with the same diameter as the water storage tank, is installed atop the water storage tank. The second unit--the condenser coil--is installed in the middle of the water storage tank. For detailed component descriptions refer to the Design Review.

B. Differences in Operation

1. Electric Water Heater

Residential electric water heaters operate in two different modes: standby and recovery. The two heating elements normally do not operate at the same time. During the standby mode, the upper heating element is off. As the water temperature in the water storage tank reduces to a level lower than the setting of the bottom thermostat--the bottom heating element is turned on. As the water temperature rises above the setting of the lower thermostat, the heater is turned off. During a cold start or after a heavy water draw when the water temperature in the upper portion of the water tank is also low, the water heater goes into its recovery operation. The upper heating element will be turned on when the water temperature in the upper portion of the water tank drops below the setting of the upper thermostat. As the water temperature rises above the setting of the upper thermostat, the upper heating element will be turned off. Immediately, the lower heating element will be turned on to continue heating the water in the lower portion of the tank, until it rises above the setting of the lower thermostat. Thus, the upper element operates only during the recovery mode while the lower element may operate during the standby mode as well as the recovery mode.

The heated water is supplied on demand. This is accomplished by the fact that the water tank and the hot water line are pressurized by the water supply line and that the opening of a hot water fixture causes hot water to exit through the outlet of the water tank, located at the top of the water tank. Thermal stratification causes the warmest portion of the water to locate at the top of the tank and the coldest water at the bottom. The tank inlet with its dip tube supplies cold water to the tank from the bottom. As a result, the warmer portion of the water is always supplied to the hot water fixture.

The electric heating elements supply thermal energy to the stored water through resistance heating virtually at a fixed rate.

2. Electric Heat Pump Water Heater

The electric heat pump water heater also operates in two modes: standby and recovery. In the recovery mode, the resistance heater and the heat pump operate simultaneously. This usually occurs with a cold start or after a heavy water draw. The resistance heater is turned off by its thermostat when the upper portion of the water reaches the set temperature; the heat pump continues to operate until its thermostat, which controls the lower portion of the water temperature, reaches its set point. Only the heat pump normally operates during the standby mode and is controlled by its thermostat.

The resistance heater produces thermal energy at a fixed rate. The heat pump delivers thermal energy at a rate which is dependent on the temperatures of the stored water and the ambient air conditions from which the heat pump is extracting energy. If the ambient temperature is too low, the evaporator may start to form frost when operating. A thermostat is used to turn the heat pump off at that temperature. Below this temperature the resistance heating element will operate to heat the upper portion of the stored water.

C. Summary

1. The two-element electric water heater produces thermal energy at a virtually constant rate. Only one element operates at a time.

2. The electric heat pump water heater produces thermal energy at a variable rate. The resistance element and the heat pump may operate simultaneously or independently.

IV. Confirmatory Laboratory Tests

A series of tests were conducted in the laboratory of the Product Performance Engineering Division and included standby tests, and recovery tests. They were conducted at different combinations of water supply temperature, thermostat settings, and room ambient temperatures. The instantaneous thermal energy content of the stored water, room ambient temperature and electrical energy inputs were monitored continuously. Thermocouple temperature readings were sampled and recorded by a minicomputer. The watt-hour meter readings, however, were recorded manually.

A. Purposes of the Tests

In general, the tests were conducted to assist in developing the test procedure modification. Specifically, the purposes of the tests were: first, to subject the propose Test Method to actual use to find out how realistic are the specifications; second, to find out the degree of burdensomeness of testing; and third, to determine the effects of water supply temperature, thermostat setting, and room ambient temperature on the recovery efficiency, and the effects of thermostat setting and room ambient temperature on the standby loss. The results of these tests were then used to pinpoint any necessary changes to the proposed test procedure modifications.

B. Laboratory Setup

1. Description of the Laboratory

The water heater laboratory measures approximately 3.7 m (12 ft) high, 3.7 m (12 ft) wide, and 4.9 m (16 ft) deep. It's environment is controlled via the building's central HVAC system and therefore cannot be independently controlled. To change the room ambient temperature, however, a few provisions were made, among them: blocking of the air register, addition of room heaters, and blocking of the entrance door. Even with these provisions, the room ambient temperature could not be controlled to a predetermined value. One reason is that the heat removal rate is not known a priori without at least a moderate test program. Therefore, even though many of tests were designed to be conducted at some given room ambient temperature, it was not always achieved. Notwithstanding the above fact, the objectives of finding the effects on the standby loss and the recovery efficiency of room ambient temperature were achieved.

2. Instrumentation

In accordance with the DOE water heater test procedure with the proposed modifications, six thermocouples were installed within the storage tank of an electric heat pump water heater (121.9 cm (48 in) tall, 289.5 L (76.5 gal) in capacity), one at the level of the center point of each of six sections of equal volume from top to bottom of the tank. (See Figure 7 for a schematics of the setup.) They were used to determine the thermal energy content of the stored water. The actual location of the thermocouples is given in Table 1.

One thermocouple was carefully located in a part of the labortory shielded from any radiant or convective heat sources for the measurement of the room ambient temperature. Type K (chromel-alumel) thermocouples were used with a minicomputer data collection system, which sampled temperatures at any predetermined rate. An additional thermocouple was used to monitor the air temperature at the evaporator coil outlet. This thermocouple, a Type T (copper-constantan), was connected to a strip chart recorder for continuous monitoring of the air temperature.

A regulated power source of 240 VAC was used to supply the electric heat pump water heater. Three separate watt-hour meters were used to measure the energy consumed by the heat pump the backup heating element and the sum of the two.

3. Data Collection

The minicomputer used in the data sampling and collection system is an Interdata 7/32 Multi-Task computer.

4. Water Supply System

The water supply system consists of a reservoir, heat exchanger in a freezer, pump, mixing tank, and piping system. A schematic of the system is shown in Figure 7.

C. Tests

The Confirmatory Tests included a series of standby and recovery tests. Some of the tests were exploratory in nature and were conducted to gain experience and to find any probable pitfalls. The tests were planned to be conducted at given temperature combinations. The controlling temperatures were the water inlet, T_i, the average tank water temperature at thermostat cutout, T_f, and the ambient temperature, T_a. The inlet water temperature was conveniently controlled using the water supply system. The cutout temperature was not easily controlled because the thermostats did not always cutout at a fixed temperature for a given thermostat setting. The ambient temperature was not completely controlled due to the laboratory HVAC system and because operation of the heat pump affected the laboratory environment. Therefore, the temperature combinations of the actual tests were not exactly the same as those of the planned tests.

1. Standby Tests

The standby loss for an electric heat pump water heater was anticipated to be a function of two temperatures--the cutout temperature, T_f, and the ambient temperature, T_a. The tests were designed to find the effects of these two temperatures on the standby loss. Standby tests were conducted at different ambient temperatures while keeping the cutout temperature at a fixed value.

Similarly, standby tests were conducted at different cutout temperatures while keeping the ambient temperature at a fixed value.

2. Recovery Tests

The same approach was used to determine the individual effect of varying the water inlet temperature, T_i, the cutout temperature, T_f, and the ambient temperature, T_a, on the recovery efficiency.

3. Energy Consumption

To determine the effects of the floating temperature rises on the daily energy consumption, other recovery and standby tests were conducted.

These tests involved keeping ΔT_3 at approximately 50°C (90°F) and ΔT_4 at approximately 38.9°C (70°F) while changing the absolute temperature levels between which the temperature rise is derived. The ΔT_3 is defined as the temperature difference between the outlet and the inlet, (T_o-T_i), in tests with draw and between the cutout and the inlet, (T_f-T_i), in tests without draw. The ΔT_4 is defined as the difference between the cutout and the room ambient temperature, (T_f-T_a).

4. Power Measurement of the Heat Pump

The power consumption of the heat pump was anticipated to be a function of the stored water temperature for a fixed ambient temperature. To determine the relationship and the average power rating for the calculation of the daily energy consumption, the instantaneous power consumption was measured as a function of the average stored water temperature.

This measurement was accomplished through the measurement of the cumulative watt-hour and the simultaneous reading of average water temperature.

D. Results and Discussions

1. Standby Tests

The temperature recordings of a typical recovery/standby test are shown in Figures 8 and 9. For clarity of presentation, the temperature recording of thermocouples #1, #3, #5 and the ambient thermocouple are given in Figure 8 and those of thermocouples #2, #4, #6, and the average of the six thermocouples are given in Figure 9. The standby test lasts from the 21.7 hour mark till the 104.6 hour mark.

In Figure 10, the standby loss, S, is plotted as a function of the temperature difference between the mean cutout tank temperature and the average ambient air temperature (T_f-T_a). The standby loss increases as the temperature difference increases.

The standby loss results plotted in Figure 11 as a function of ambient temperature indicate that the standby loss decreases as the ambient temperature is increased when the cutout mean tank temperature is held approximately constant. The results are also tabulated in Table 3.

The standby loss plotted in Figure 12 as a function of the cutout mean tank temperature for an approximately constant ambient air temperature. The standby loss increases as the cutout temperature increases for the fixed ambient temperature. The results are also tabulated in Table 4.

The standby loss also indicates how well the storage tank is designed for storing the water thermal energy as well as how efficiently the heat pump can replace the dissipated thermal energy. The factor which indicates the effectiveness of a design is the characteristic time for cooldown (section IV). The thermal energy of the water in a storage tank dissipates in an approximately exponential fashion. The characteristic time is the time required for the thermal energy of the water to reach 36.8 percent (1/e = 0.368) of that at the start of the cooldown experiment. To illustrate this fact, the cooldown of the heat pump water heater is shown in Figure 13, where, as can be seen, the thermal energy of the stored water reduces to 36.8% of that at the start of the cooldown experiment in 88.0 hours. This is the characteristic time of this storage tank and indicates an energy loss of 1.13%/h.

2. Recovery Tests

The temperature data from a typical recovery test are shown in Figures 8 and 9, where, as described previously, the temperature recording of the six interior thermocouples, one ambient thermocouple, and the average temperature of the six thermocouples are plotted against time. The recovery test lasts from the 16.8 hour mark till the 21.7 hour mark, when the standby test was initiated.

The recovery efficiency is plotted in Figure 14 as a function of mean cutout temperature, T_f. Efforts were made to keep the inlet temperature, T_i, and the ambient temperature, T_a, fixed. These results are also shown in Table 5 along with the three temperatures.

The recovery efficiency is plotted in Figure 15 as a function of inlet temperature, T_i, while the mean cutout tank temperature, T_f, and the ambient air temperature, T_a, were kept approximately constant. The recovery efficiency and the three temperatures are summarized in Table 6.

The recovery efficiency is plotted in Figure 16 as a function of the ambient air temperature while the initial tank temperature and the mean cutout tank temperature were kept at constant values. The recovery efficiency and the three temperatures are summarized in Table 7.

Data from a typical recovery test are shown in Figure 17 where the average water temperature, average ambient temperature, cumulative energy consumption, and the heat pump energy consumption. Both the average water temperature and the cumulative energy consumption increase rapidly in the initial period of the test when both the heating element and the heat pump are operating. When the temperature of the water in the top portion of the storage tank reaches a preset level, the heating element cycles off. After the heating element cycles off, only the heat pump is operating Thus, both the average water temperature and the cumulative energy consumption increase at a slower rate. The heat pump energy consumption curve is almost linear and is parallel to the cumulative energy line. The difference between the two curves represents energy which was consumed by the electric heating element.

3. <u>Energy Consumption</u>

The results of the confirmation energy consumption tests are presented in Table 8. It contains the results of three tests. Each test consists of one recovery and one standby test. As mentioned previously, the purpose of the tests was to determine the daily energy consumption, C_y, for two fixed temperature differences, ΔT_3 and ΔT_4. Test 3, having a different ΔT_4, will be discussed later.) The inlet water and ambient temperatures were allowed to float. ΔT_3 in both tests was 50°C (90°F). ΔT_4 was 38.9°C (70°F) for the baseline case

(Test 1) and 37.8°C (68.1°F) for the floated case (Test 2). The experimentally determined recovery efficiencies and standby losses were used to calculate the daily energy consumption. The baseline case has a lower recovery efficiency, 1.61, and a higher standby loss, 0.64%/hours, when compared with the case for the floated temperatures which was 1.66 and 0.54%/hour, respectively. The daily energy consumptions, however, of 10.8 kWh/day and 10.2 kWh/day, differ by less than 6%.

The implication of this finding is that if the daily energy consumption, C_y, remains essentially the same for the same temperature differences regardless of the absolute temperature levels, then an electric heat pump water heater may be tested with controlled temperature differences only without specifications on the absolute temperature levels. The burdensomeness of testing will be significantly lessened. For example, a manufacturer of electric heat pump water heaters may conduct tests on the unit at any ambient temperature level of the laboratory by adjusting the inlet water temperature to produce a given ΔT_3 with a simple cold water supply system along with the water heater thermostat to produce a given ΔT_4. The lessening of the burdensomeness of testing is in the fact that adjustment of the laboratory ambient temperature--a substantial task--may be eliminated altogether.

Modifying the Test Method to take advantage of these findings would reduce the burdensomeness of testing. The modified Test Method would specify only the temperature differences for testing rather than the absolute temperature levels as currently required in the proposed test procedure. Before modifying the Test Method, however, more laboratory tests should be conducted in order to establish the repeatability of the conclusion and the limits of the absolute temperatures to which it would apply.

The daily energy consumption shown for Test 3 are the results from one standby test and one recovery test of the validation tests. The ΔT_3 and ΔT_4 were maintained at 50°C (90°F) and the calculated daily energy consumption, C_y, is 12.2 kWh/day. Test 3 and Test 1 have the same cutout and inlet temperatures but different ambient temperatures. From a comparison of these tests it is seen that when the unit is tested with a ΔT_4 of 50°C (90°F) the low recovery efficiency and high standby loss result is too high a calculated daily energy consumption.

4. Power Consumption of the Heat Pump

The power consumption of the electric heat pump alone is plotted against mean water temperature in Figure 18. At a fixed ambient temperature of 17.8°C (64.0°F), as anticipated, it increases as the water temperature increases. The power consumption is 720 watts at a water temperature of 18.3°C (65°F) and increases to 920 watts at 60°C (140°F).

E. Conclusions

1. The standby loss increases as the cutout water temperature is increased and decreases as the ambient temperature is increased.

2. The recovery efficiency depends on the ambient and the supply water temperatures. The recovery efficiency is not particularly sensitive to the cutout temperature in the range of the cutout temperatures tested.

3. Changes in absolute temperature levels have little effect on energy consumption provided the temperature differences between the cutout and the inlet water temperature, and the cutout and the room ambient remain constant.

4. The power consumption of the heat pump depends strongly on the tank mean water temperature when the room ambient remains constant.

V. Validation Tests

Additional validation tests were conducted on the electric heat pump water heater in an environmental chamber and consisted of standby, recovery and draw tests.

A. Purpose of Tests

The tests were conducted to establish the validity of the modified Test Method. Energy use and hot water delivery were measured. The tests were conducted under conditions which were different from those required by the modified test procedures, in that the tolerances of the test conditions were more stringent than those required by the modified Test Method and a draw schedule was imposed. The results are compared with those of the confirmatory tests conducted under the modified Test Method.

B. Laboratory Setup

A crucial component for this testing of the electric heat pump water heater was the environmental chamber. The ambient conditions in the regular laboratory were not easily adjusted to the desired conditions. Even when the ambient temperature of the laboratory was adjusted to a desired level, tolerances frequently could not be maintained to specifications more stringent than those in the proposed Test Method. Therefore, an environmental chamber was used.

1. Environmental Chamber. The environmental chamber measures 2.4 m high, 2.7 m wide, and 1.9 m deep. A refrigeration unit, electric heaters, and the associated controls are used to maintain the chamber temperature within narrow ranges at a given temperature level. The ambient temperature record of a typical standby test of the electric heat pump water heater is given in Figure 20. The average ambient temperature of this test was 12.8°C for more than 48 hours with a range of 11.3°C to 13.7°C and thus maintained a tolerance narrower than that of the proposed Test Method of 1.7°C below and 3.3°C above the average.

2. Instrumentation. Six T-type thermocouples were used to measure water temperature in a manner described in section IV. Two T-type thermocouples were used to measure ambient temperature. Three watt-hour meters were used to monitor the electric energy use by the heat pump, the heating element, and, as a check, the sum of the two.

   A water supply system similar to the one described in section II was used to supply water at the desired inlet water temperature.

3. Data Collection and Reduction. A 100 channel data logger was used to sample the thermocouples and the watt-hour meters at a predetermined sampling rate of one data point every four minutes. The data logger converted analog data into digital data which were recorded on a digital recorder. The recorded data then were processed using the NBS Univac 1108 computer.

C. Draw Tests

Draw tests were conducted by extensive use of the minicomputer and a microprocessor flow control. Delivery flow rates were controlled by the microprocessor which programmed three flow control valves. Choices of any single valve or any combination of the three valves gives seven different flow-rates. The draw schedule described in section IV for a 24-hour period is given in Table 2. The first column gives the time at the beginning and the end of a single individual draw, the second column gives the fraction of the total draw of the 24-hour period. For example, the first draw lasts 24 seconds and consumes 0.935% of the total draw. The total draw for the 24-hour period was planned for 243.4 L (64.3 gal). The fourth and the fifth columns are the supply and delivered water temperatures, respectively. The weighted average supply water temperature is 8.3°C (47°F) while the weighted average delivered water temperature is 74.21°C (165.6°F).

The temperature measurements of a typical draw test are shown in Figures 19 and 20. In Figure 19 the temperature recordings of the first three thermocouples are given versus the time. In Figure 20, the temperature recordings of the sixth thermocouple and the ambient thermocouple are shown versus time.

D. Results and Discussions

Data from a typical standby test prior to a draw test are shown in Figure 21 where the average water temperature, average ambient temperature, and cumulative energy consumption are plotted against time. The cumulative energy consumption follows a staircase curve.

It can be seen in Figure 21 that the average water temperature follows a regular, periodic pattern of heat pump off (cooldown) and on (recovery). The average water temperature stays with a 3°C band controlled by the thermostat.

The ambient temperature shown in Figure 21 is also plotted in Figure 22 only with a larger degree of resolution and as mentioned previously, the tolerance was narrower than that of the proposed Test Method.

The results from all draw schedule tests are summarized in Table 9. As can be seen for each test the measured daily energy consumption, Q_{in}, and the calculated daily energy condition, Q_c, based on actual ΔT_3 and ΔT_4 temperature differences, agree with one another to within 6%. The calculated daily energy consumption, C_y, based on the nominal temperature differences, ($\Delta T_5 = \Delta T_6 = 90^{\circ}F$), is insensitive to the actual temperature differences maintained during the tests (ΔT_3 and ΔT_4) as found in the confirmatory tests.

E. Conclusions

1. The daily energy consumptions, calculated from the standby loss and recovery efficiency measured under closely controlled environmental conditions, compare well with the confirmatory

test results which were calculated from the standby losses and recovery efficiencies measured according to the modified Test Method.

2. The calculated daily energy consumption, based on the actual temperature differences for tests under draw conditions, agrees with the actual measured energy consumptions. The average daily energy consumption, C_y, is sensitive to the temperature differences maintained during the tests, ΔT_3 and ΔT_4.

3. The modified Test Method determines energy consumption accurately under both draw and non-draw conditions.

Table 1 Location of the Interior Thermocouples

Distance from Bottom of Tank		Thermocouple No.
cm	in	
10.2	4	1
30.5	12	2
50.8	20	3
71.1	28	4
91.4	36	5
111.8	44	6

Table 2. Summary of Draw Tests

Time	Fractional Draw	T_i	T_o
7: 1: 0 7: 1:24	.00935	5.3 C (41.5 F)	72.0 C (161.6 F)
7: 5: 0 7:10: 0	.234	6.9 C (44.4 F)	71.5 C (160.7 F)
7:25: 0 7:25:24	.00935	8.1 C (46.6 F)	70.5 C (158.9 F)
8: 0: 0 8: 0:24	.00935	12.3 C (54.1 F)	70.9 C (159.6 F)
10: 0: 0 10: 2: 0	.125	8.3 C (46.9 F)	74.1 C (165.4 F)
10:22: 0 10:23: 0	.0623	8.6 C (47.5 F)	73.3 C (163.9 F)
10:30: 0 10:30:24	.00935	8.7 C (47.7 F)	72.0 C (161.6 F)
12: 0: 0 12: 0:24	.00935	9.9 C (49.8 F)	74.4 C (165.9 F)
12:45: 0 12:45:24	.00935	8.6 C (47.5 F)	75.8 C (168.4 F)
16: 0: 0 16: 0:24	.00935	10.0 C (50 F)	76.2 C (169.2 F)
17:20: 0 17:20:24	.00935	8.1 C (46.6 F)	75.7 C (168.3 F)
18: 0: 0 18: 0:24	.00935	8.2 C (46.8 F)	76.0 C (168.8 F)
18:20: 0 18:22: 0	.0467	11.4 C (52.5 F)	76.0 C (168.8 F)
18:28: 0 18:30: 0	.0467	8.6 C (47.5 F)	75.4 C (167.7 F)
18:36: 0 18:38: 0	.0467	9.1 C (48.4 F)	74.9 C (166.8 F)
18:44: 0 18:46: 0	.0467	8.8 C (47.8 F)	74.4 C (165.9 F)
18:52: 0 18:54: 0	.0467	8.4 C (47.1 F)	73.9 C (165.0 F)
22: 0: 0 22: 0:24	.00935	7.9 C (46.2 F)	76.2 C (169.2 F)
22: 5: 0 22:10: 0	.234	8.5 C (47.3 F)	76.0 C (168.8 F)
22:25: 0 22:25:24	.00935	8.4 C (47.1 F)	74.6 C (166.3 F)
23:30:0 23:30:24	.00935	11.0 C (51.8 F)	75.1 C (167.2 F)
WEIGHTED AVERAGE =		8.3 C (47.0 F)	74.2 C (165.6 F)

Table 3
Standby Loss Tests to Determine Effects of the Ambient Temperature

Standby Loss S	Cutout Temperature, T_f	Ambient Temperature, T_a	ΔT_4 ($T_f - T_a$)
0.74	63.1°C (145.6°F)	18.7°C (65.7°F)	44.4°C (79.9°F)
0.68	61.7°C (143.1°F)	22.0°C (71.6°F)	39.7°C (71.4°F)
0.64	62.4°C (144.3°F)	23.6°C (74.5°F)	38.8°C (69.8°F)

Table 4
Standby Loss Tests to Determine Effects of the Cutout Temperature

Standby Loss S	Cutout Temperature, T_f	Ambient Temperature, T_a	ΔT_4 ($T_f - T_a$)
0.57	55.6°C (132.1°F)	23.2°C (73.8°F)	32.4°C (58.3°F)
0.64	62.4°C (144.3°F)	23.6°C (74.5°F)	38.8°C (69.8°F)
0.71	62.6°C (144.7°F)	23.8°C (74.8°F)	38.8°C (69.8°F)
0.73	68.8°C (155.8°F)	23.5°C (74.3°F)	45.3°C (81.5°F)

Table 5
Recovery Tests to Determine Effects of the Cutout Temperature

Recovery Efficiency E_r	Inlet Water Temperature T_i	Cutout Temperature T_f	Ambient Temperature T_a	ΔT_3 ($T_f - T_a$)	ΔT_4 ($T_f - T_a$)
1.61	12.7°C (54.9°F)	57.3°C (135.1°F)	23.7°C (74.7°F)	44.6°C (80.3°F)	33.6°C (60.5°F)
1.62	12.8°C (55.0°F)	62.8°C (145.0°F)	21.7°C (71.1°F)	50.0°C (90.0°F)	41.1°C (74.0°F)
1.63	12.6°C (54.7°F)	71.1°C (160.0°F)	23.5°C (74.3°F)	58.5°C (105.3°F)	47.6°C (85.7°F)
1.61	13.2°C (55.8°F)	65.7°C (150.3°F)	23.7°C (74.7°F)	52.5°C (94.5°F)	42.0°C (75.6°F)

Table 6
Recovery Tests to Determine Effects of the Inlet Temperature

Recovery Efficiency E_r	Inlet Water Temperature T_i	Cutout Temperature T_f	Ambient Temperature T_a	ΔT_3 (T_f-T_i)	ΔT_4 (T_f-T_a)
1.64	15.4°C (59.7°F)	62.9°C (145.2°F)	23.7°C (74.7°F)	47.5°C (85.5°F)	39.2°C (70.6°F)
1.62	18.2°C (64.8°F)	62.8°C (145.0°F)	23.7°C (74.7°F)	44.6°C (80.3°F)	39.1°C (70.4°F)
1.56	27.7°C (81.9°F)	64.4°C (147.6°F)	17.9°C (64.2°F)	36.7°C (66.1°F)	46.5°F (83.7°F)
1.60	21.6°C (70.9°F)	62.8°C (145.0°F)	23.6°C (74.5°F)	41.2°C (74.2°F)	39.2°C (70.6°F)

Table 7
Recovery Tests to Determine Effects of the Ambient Temperature

Recovery Efficiency E_r	Inlet Water Temperature T_i	Cutout Temperature T_f	Ambient Temperature T_a	ΔT_3 (T_f-T_i)	ΔT_4 (T_f-T_a)
1.61	11.5°C (52.7°F)	60.7°C (141.3°F)	17.8°C (64.0°F)	49.2°C (38.6°F)	42.9°C (77.2°F)
1.66	12.2°C (54.0°F)	69°C (147.2°F)	21.2°C (70.2°F)	56.8°C (102.2°F)	47.8°C (86.0°F)
1.62	12.8°C (55.0°F)	62.8°C (144.0°F)	21.7°C (71.1°F)	50.0°C (90.0°F)	41.1°C (74.0°F)
1.64	15.4°C (59.7°F)	62.9°C (145.2°F)	23.7°C (74.7°F)	47.5°C (85.5°F)	39.2°C (70.6°F)

Table 8. Confirmatory Tests to Determine the Effects of Floating Temperature Rises in Daily Energy Consumption

Test No.	T_f	T_i	T_a	ΔT_3 $(T_f - T_i)$	ΔT_4 $(T_f - T_a)$	E_r	S h^{-1}	P kw	C_{wh}* Btu	c_{us}* Btu	C_y* kwh
1	62.8°C (145°F)	12.8°C (55°F)	23.9°C (75°F)	50 C (90 F)	38.9 C (70 F)	1.61	0.64	1.89	29 600	364.0	10.8
2	68.7°C (155.7°F)	18.7°C (65.7°F)	30.9°C (87.6°F)	50°C (90°F)	37.8°C (68.1°F)	1.66	0.54	2.08	28 800	307.0	10.2
3	62.8°C (145°F)	12.8°C (55°F)	12.8°C (55°F)	50°C (90°F)	50°C (90°F)	1.35	0.79	1.06	35 700	450.0	12.2

* Definitions and units of these symbols are given in the Test Method, Appendix A.

Table 9. Results of Validation Draw Tests for Daily Energy Consumption

Test No.	T_i	T_o	T_a	T_f	ΔT_3 $(T_o - T_i)$	ΔT_4 $(T_f - T_a)$	E_r	S h^{-1}	P kW	C_y kWh	Q^*_{in} kWh	Q^{**}_c kWh
1	8.3°C) (46.4°F)	74.2°C) (165.6°F)	24.6°C (76.3°F)	68.5°C (155.3°F)	65.9°C) (118.6°F)	43.9°C (79.0°F)	1.75	0.730	1.4	10.2	13.0	12.3
2	20.3°C (68.5°F	69.5°C (157.1°F)	23.5°C (74.3°F)	64.6°C (148.3°F)	49.2°C (88.6°F)	41.1°C (74.0°F)	1.62	0.695	1.9	10.9	10.0	10.4
3	14.7°C (58.5°F)	68.1°C (154.6°F)	23.5°C (74.5°F)	59.4°C (138.9°F)	53.4°C (96.1°F)	35.9°C (64.6°F)	1.63	0.660	1.9	10.7	10.1	10.7

*measured energy consumption
**calculated energy consumption based on test temperature differentials, ΔT_3 and ΔT_4.

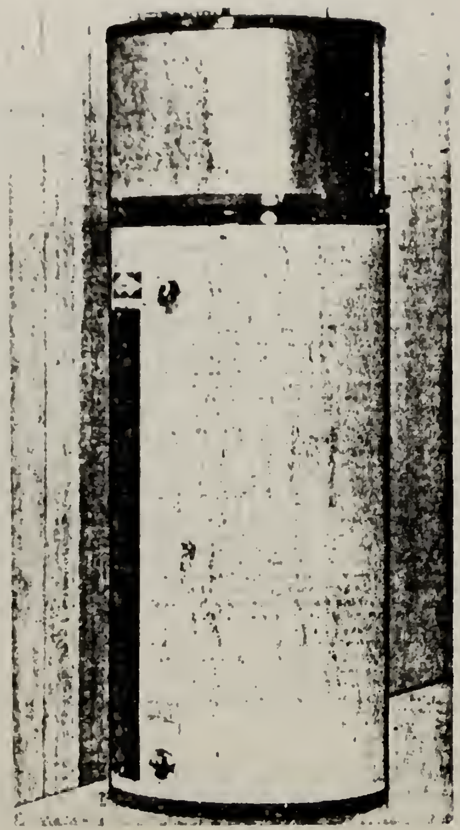

Figure 1a. Electric Heat Pump-Water Heater

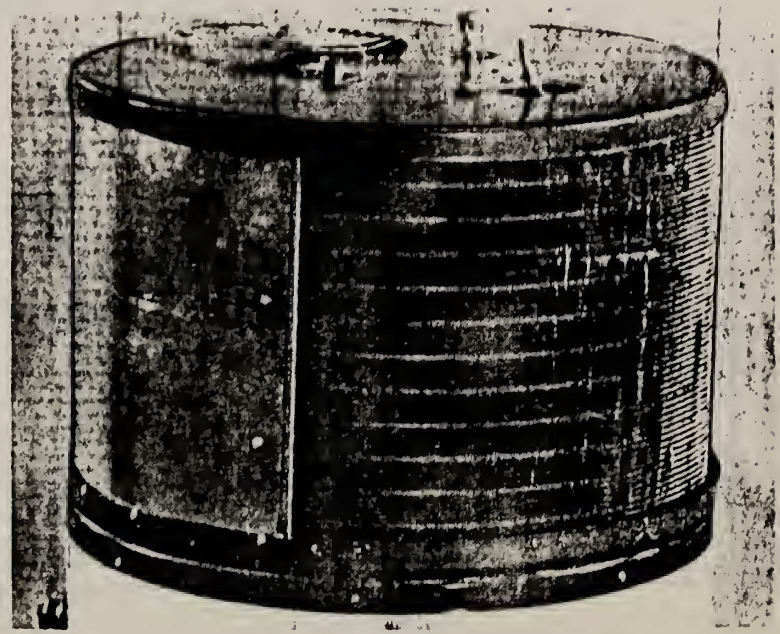

Figure 1b. Evaporator Coil and Compressor Unit

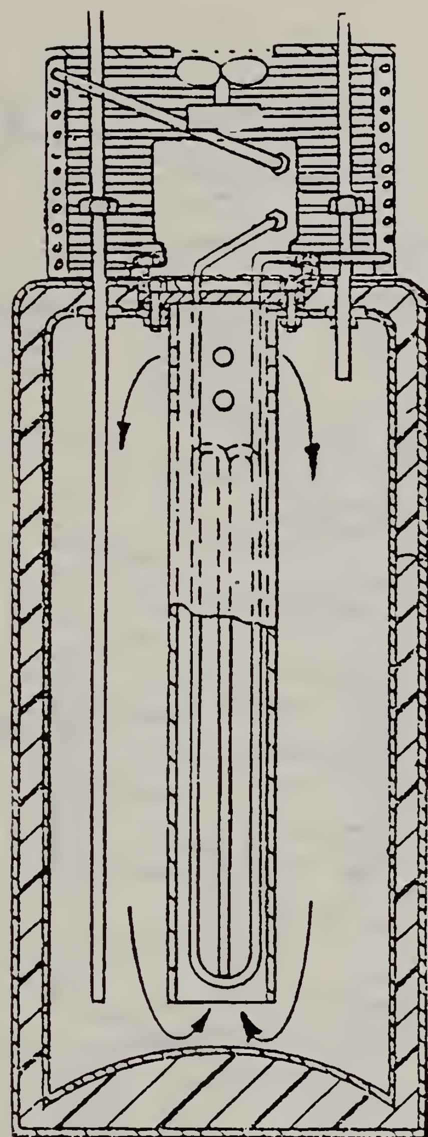

Figure 2.

Electric Heat Pump Water Heater--
Schematic Diagram

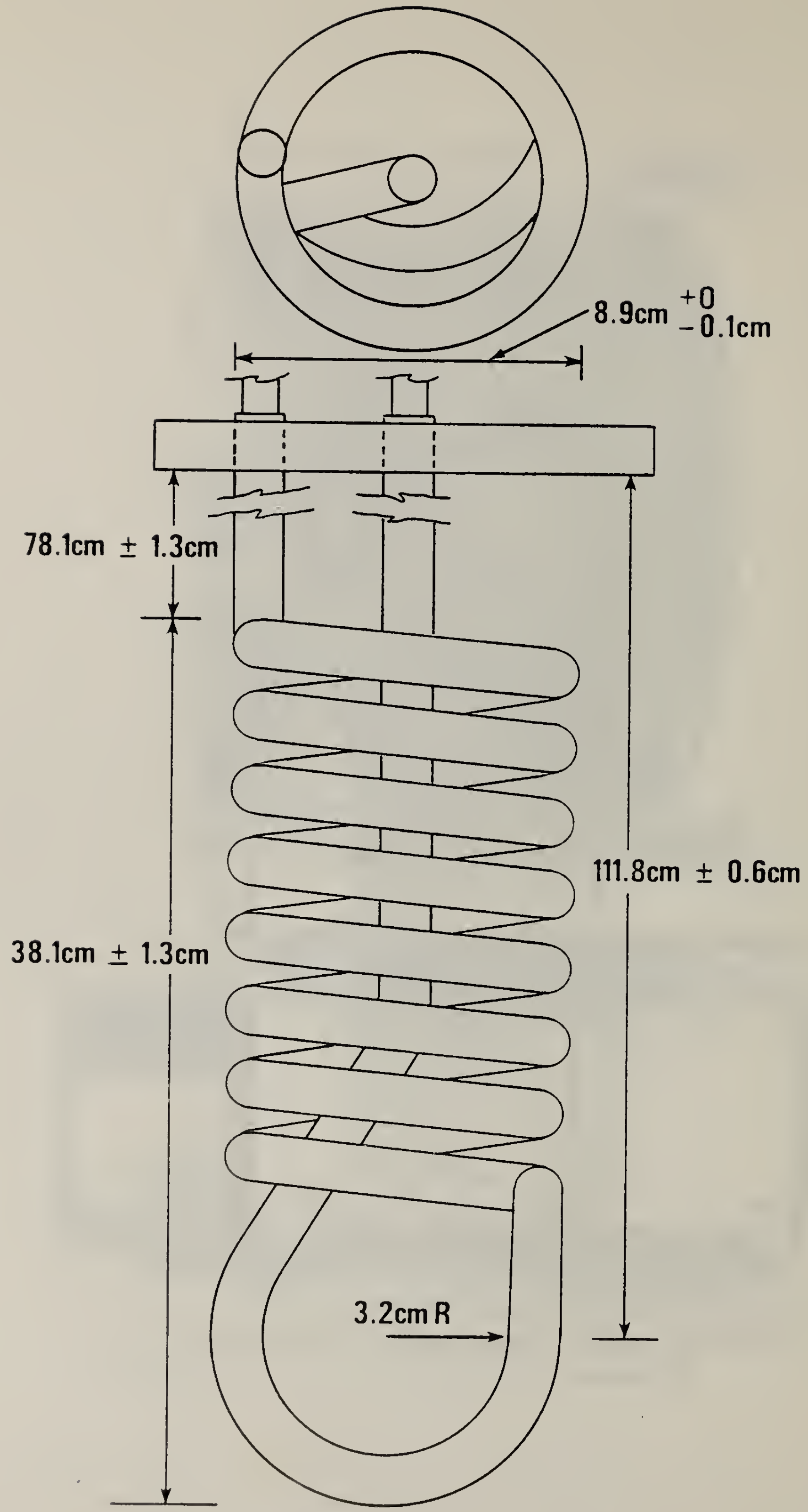

Figure 3. Condenser Coil

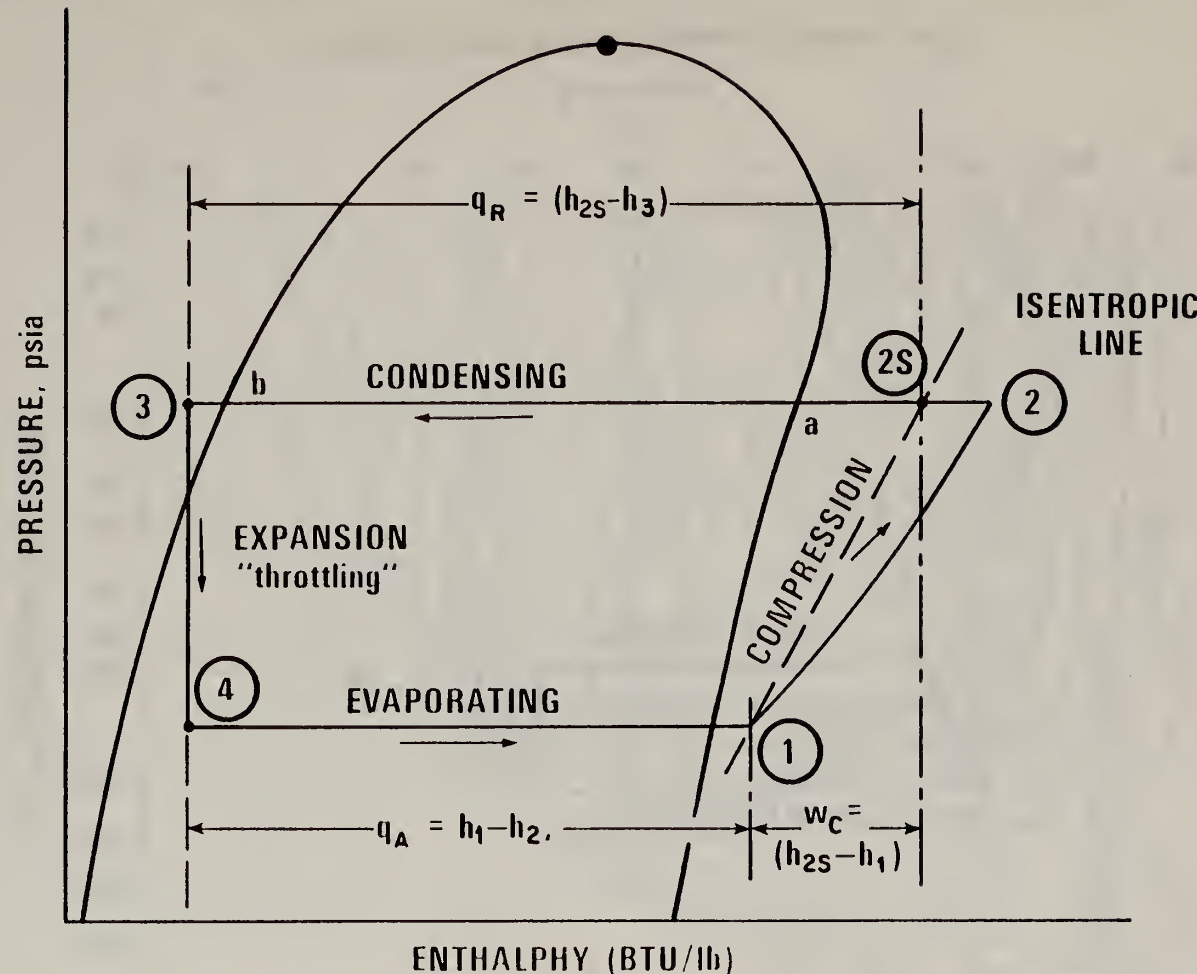

Figure 4. Pressure-Enthalpy Diagram of the Four Heat Pump Cycles.

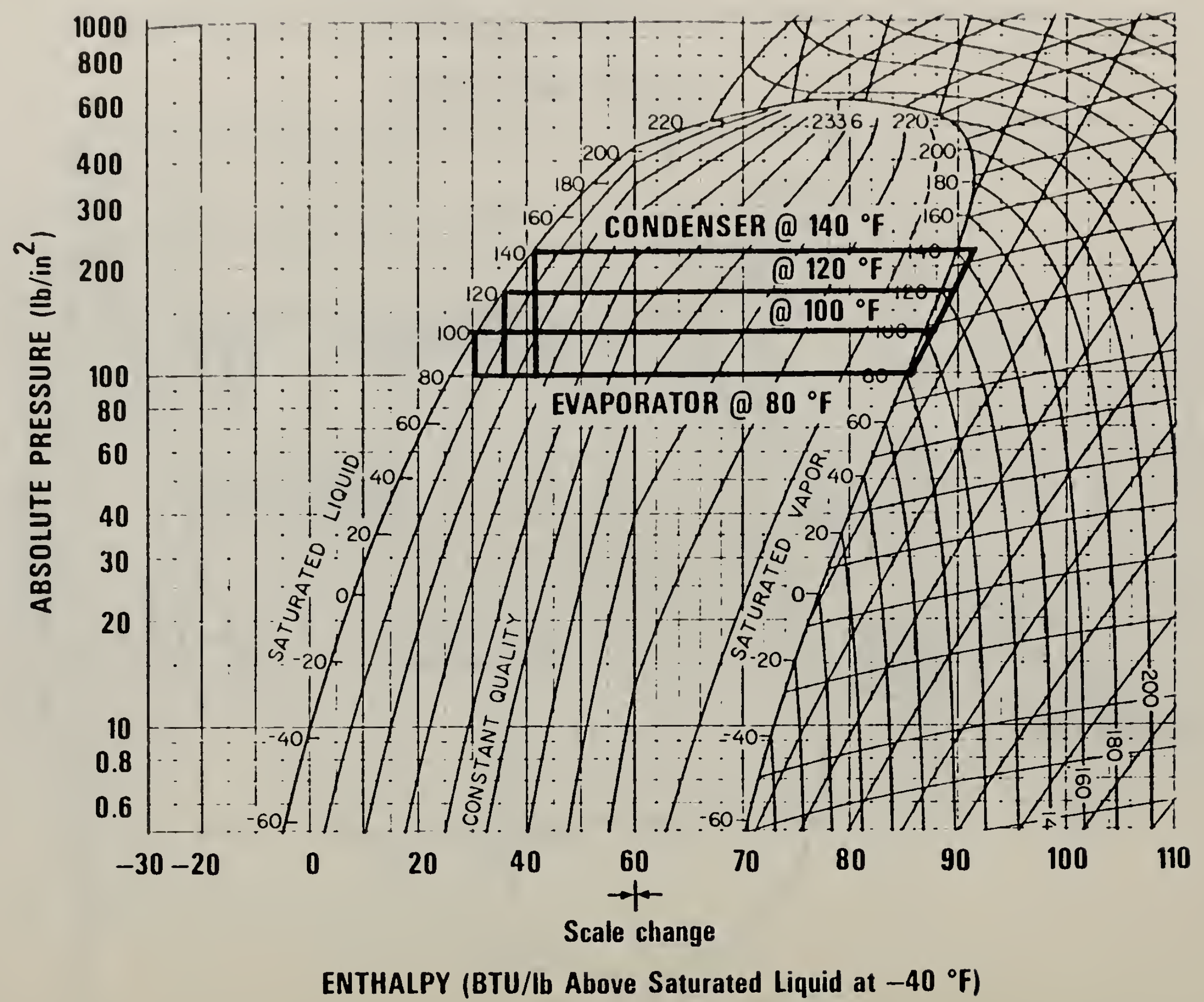

Figure 5. Operating Cycles of the Electric Heat Pump at Three Different Condenser Temperatures (R-12).

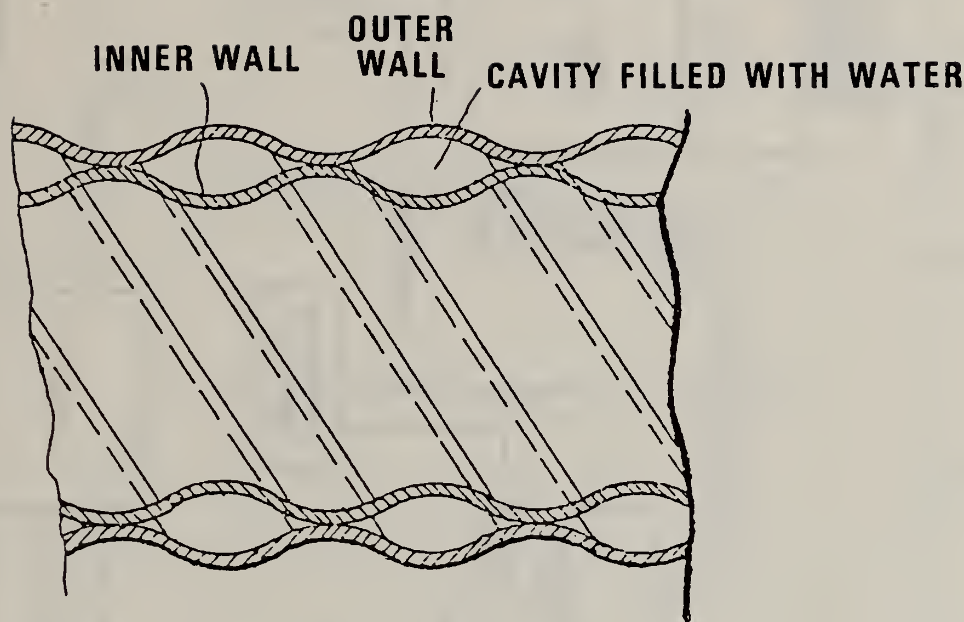

Figure 6. A Typical Construction of the Double-Walled Condenser Coil

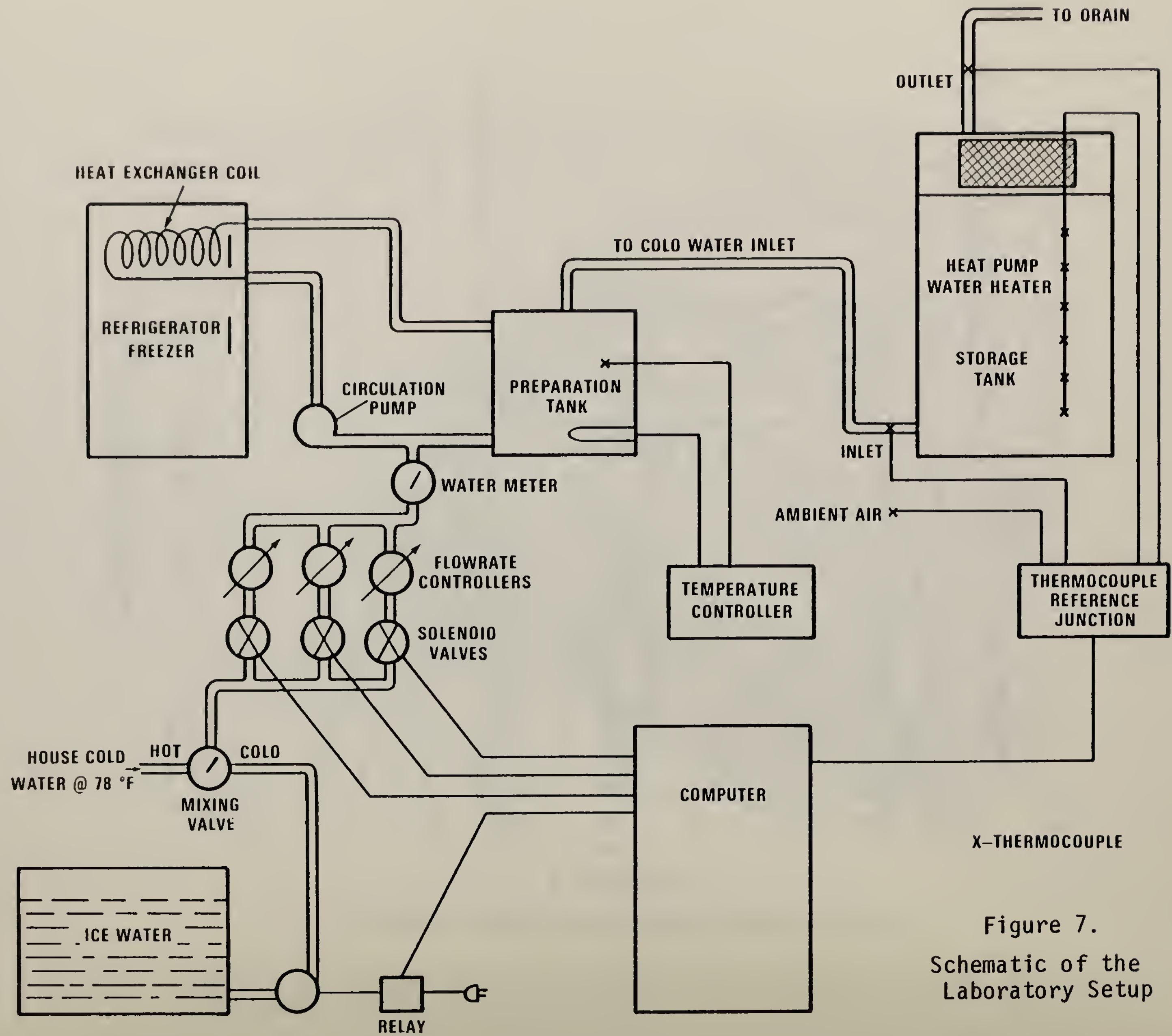

Figure 7.

Schematic of the Laboratory Setup

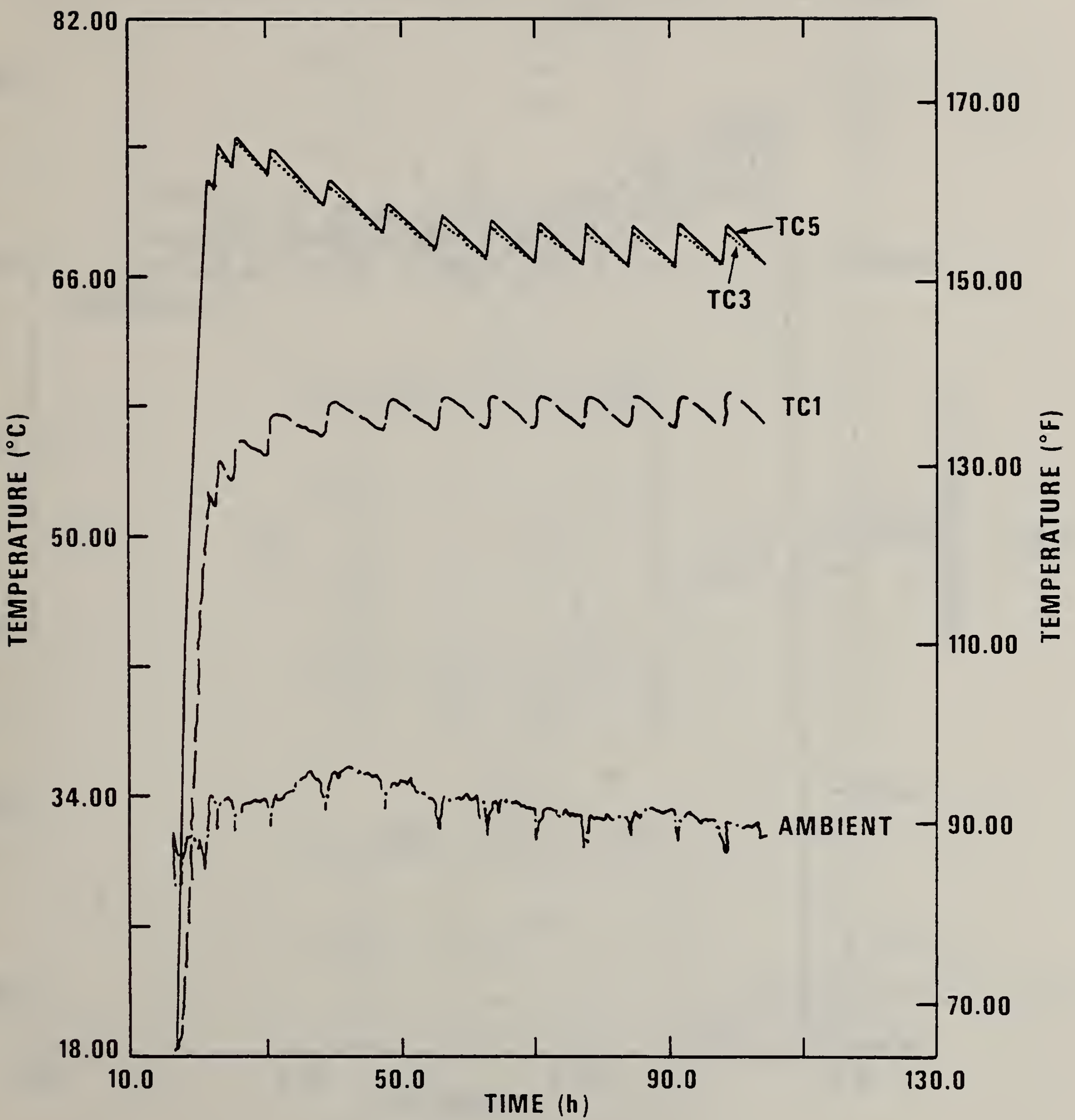

Figure 8. Typical Temperatures (Ambient, TC1, TC3, TC5) vs Time for a Recovery and Standby Test.

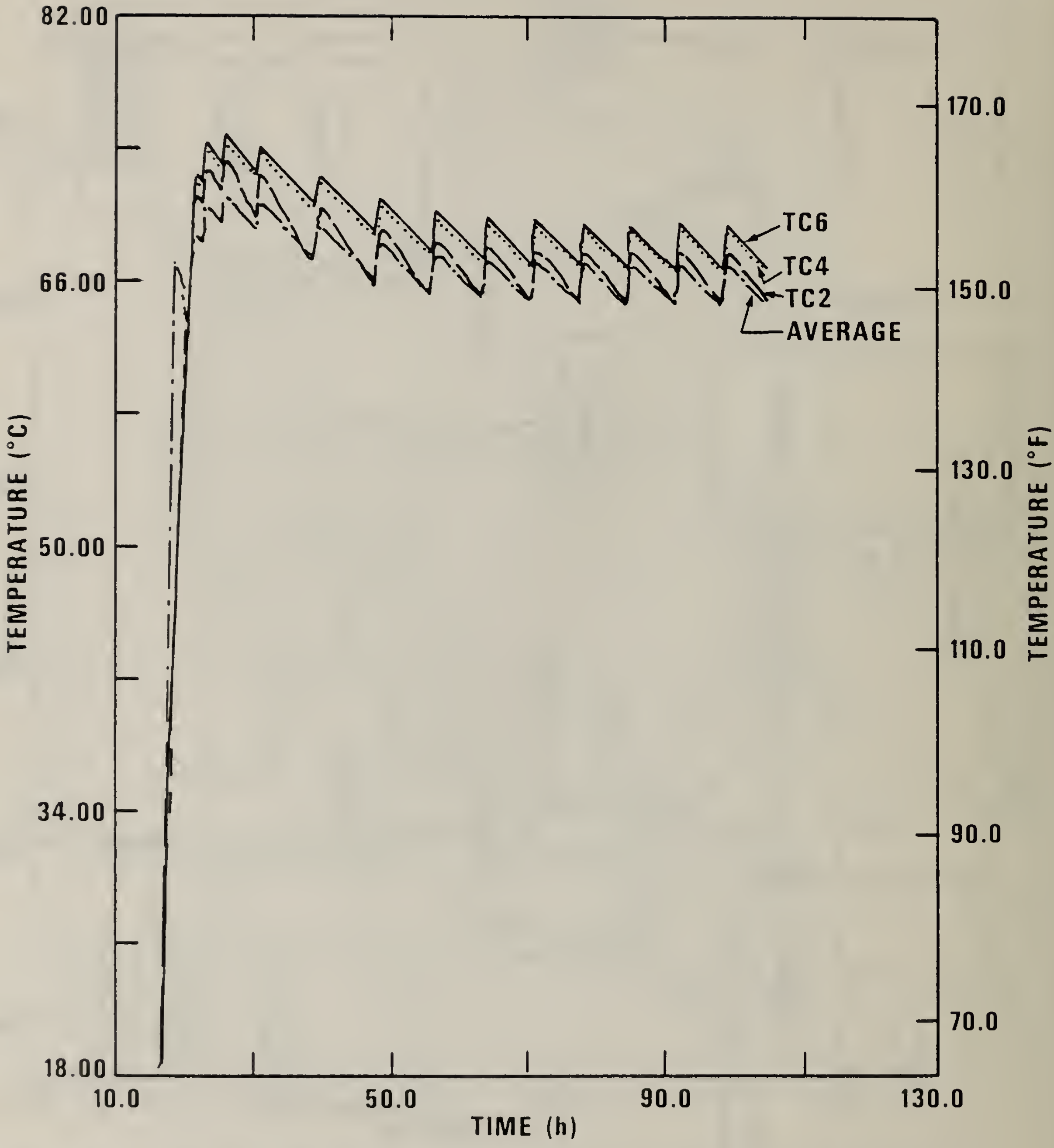

Figure 9. Typical Temperatures (TC2, TC4, TC6, and Water Average) vs Time for a Recovery and Standby Test.

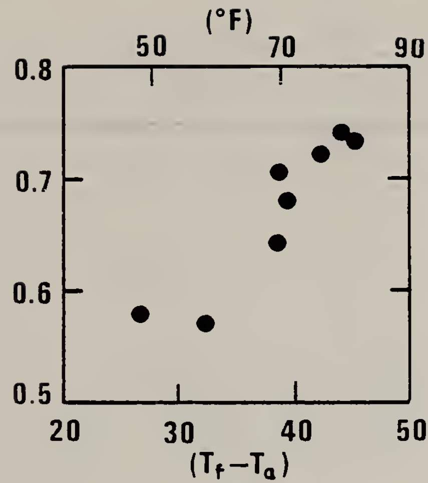

Figure 10
Standby Loss vs. $(T_f - T_a)$

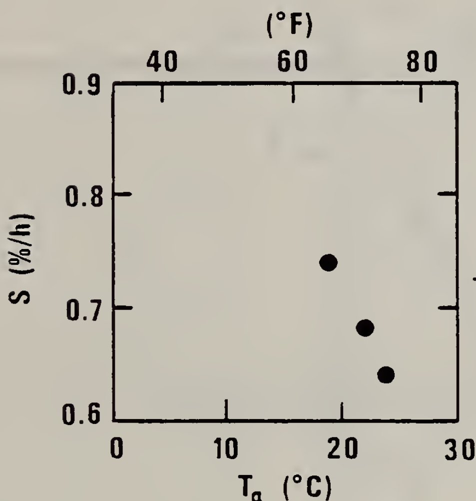

Figure 11
Standby Loss vs. Ambient Temperature, $T_f \cong 62.8°C$ (145°F)

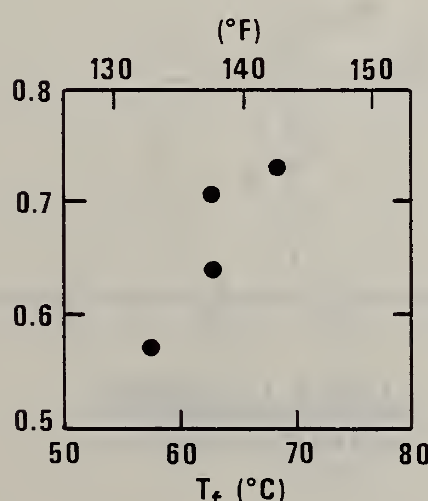

Figure 12
Standby Loss vs. Cutout Temperature, $T_a \cong 23.9°C$ (75°F)

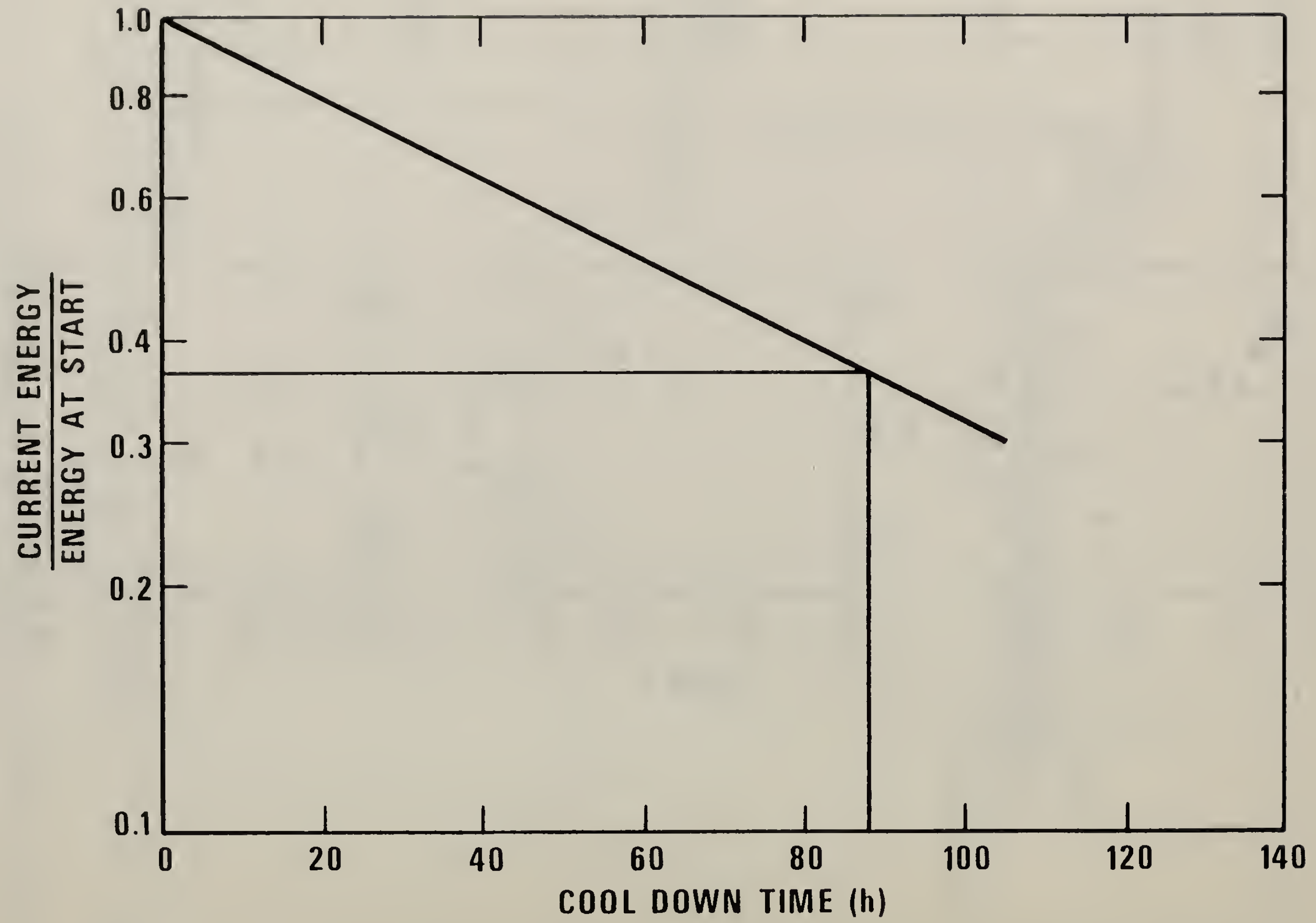

Figure 13. Cooldown Behavior of an Electric Heat Pump Water Heater Storage Tank

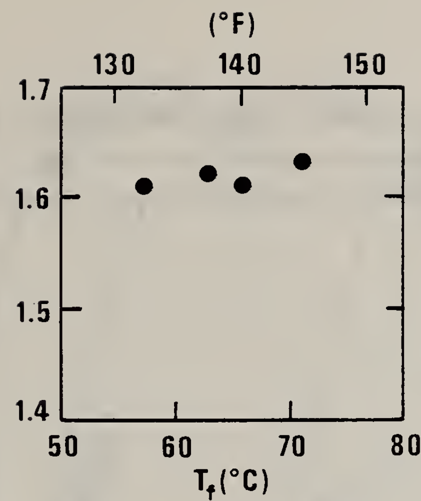

Figure 14

Recovery Efficiency vs. Cutout Temperature

$T_i \cong 12.8°C\ (55°F)$,

$T_a \cong 23.9°C\ (75°F)$

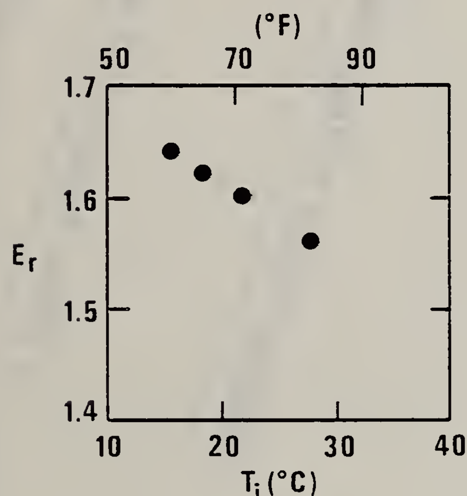

Figure 15

Recovery Efficiency vs. Inlet Temperature,

$T_f \cong 62.8°C\ (145°F)$,

$T_a \cong 23.9°C\ (75°F)$

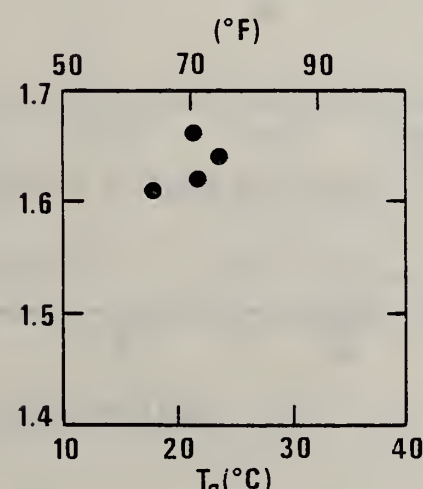

Figure 16

Recovery Efficiency vs. Ambient Temperature,

$T_i \cong 12.8°C\ (55°F)$

$T_f \cong 62.8°C\ (145°F)$

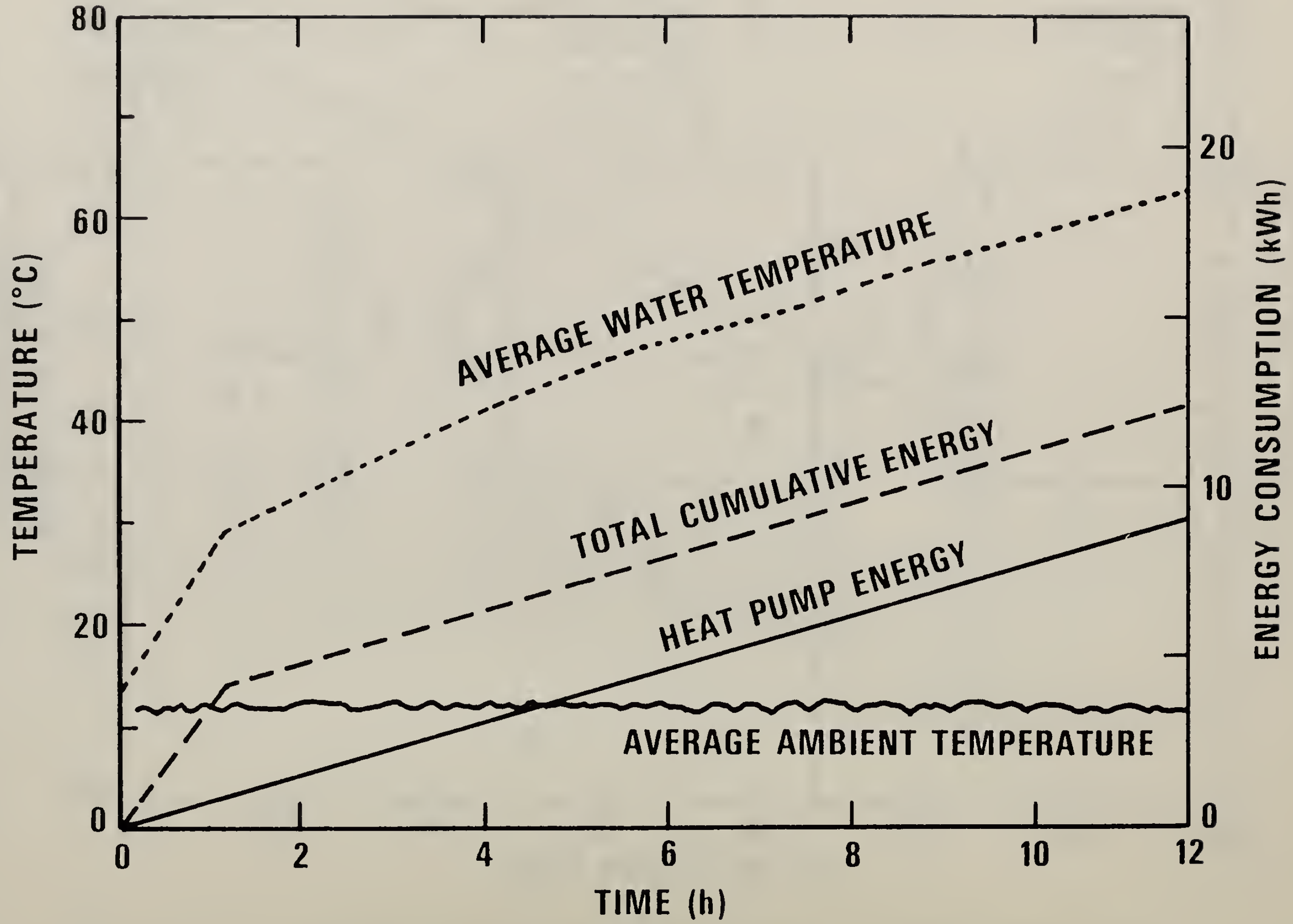

Figure 17. Average Water Temperature, Average Ambient Temperature, Heat Pump Energy, and Total Cumulative Energy vs Time for a Typical Recovery Test.

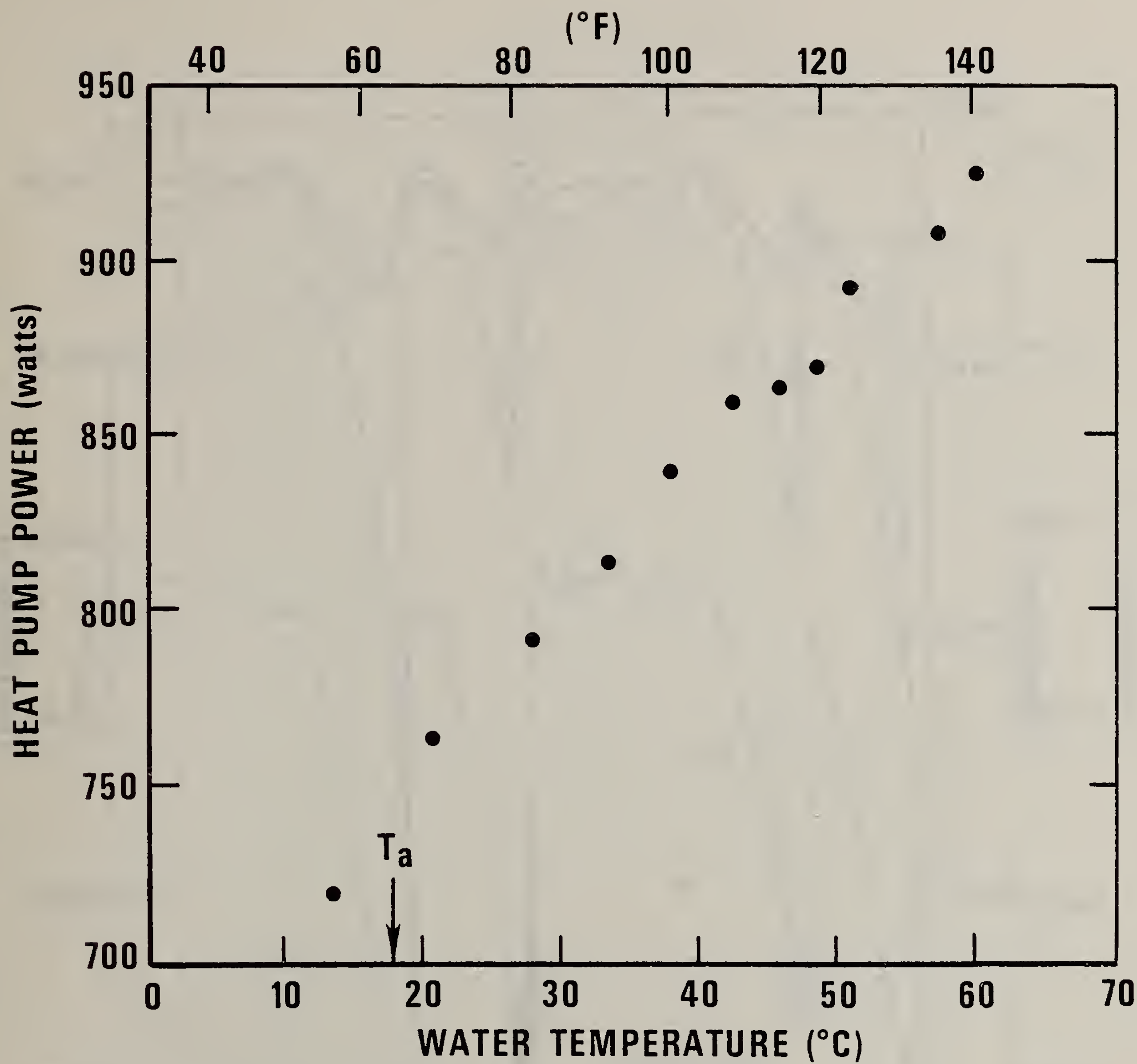

Figure 18. Heat Pump Power vs. Mean Water Temperature.

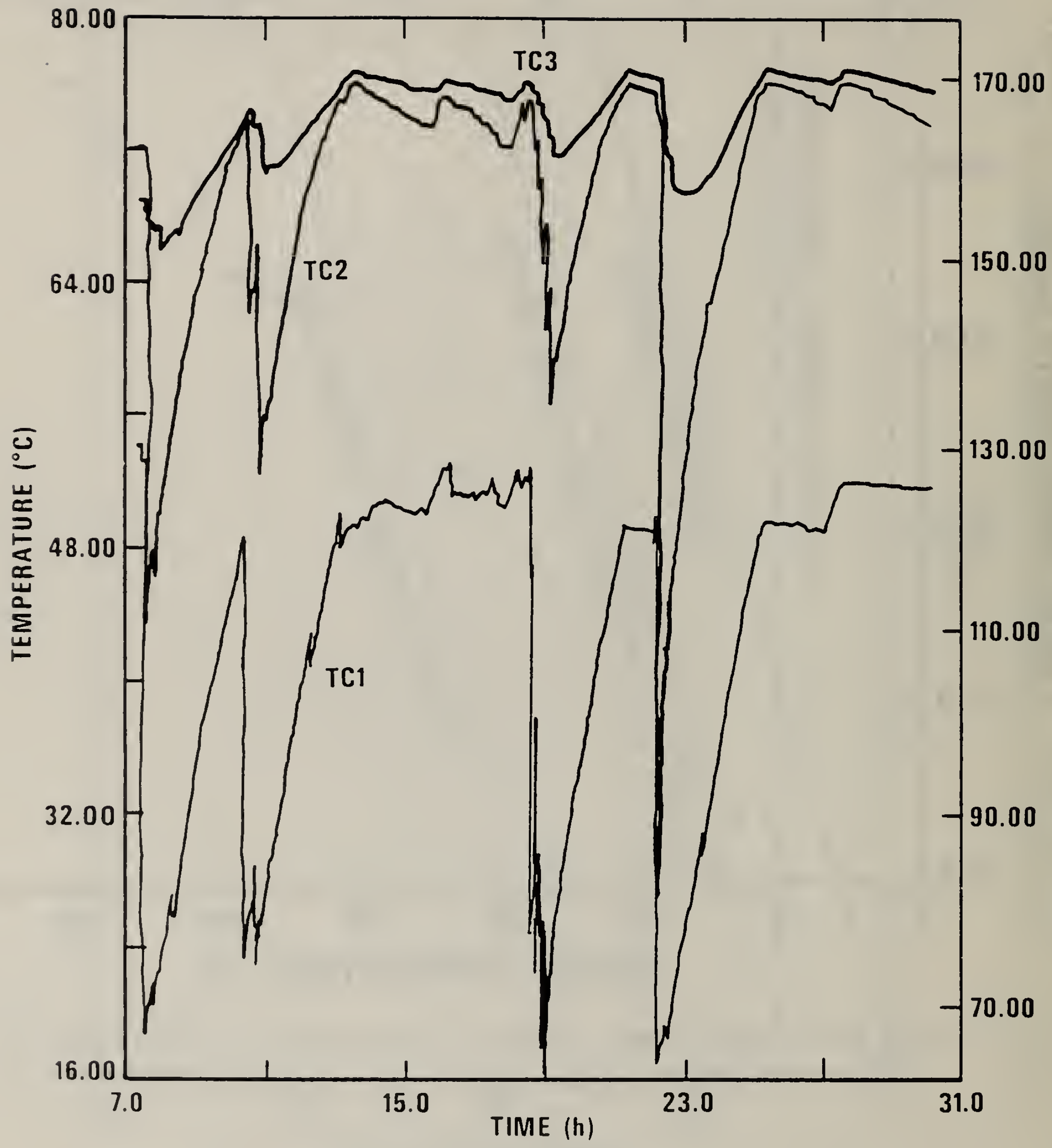

Figure 19. Draw Test-Temperature of TC1, TC2 and TC3 vs. Time.

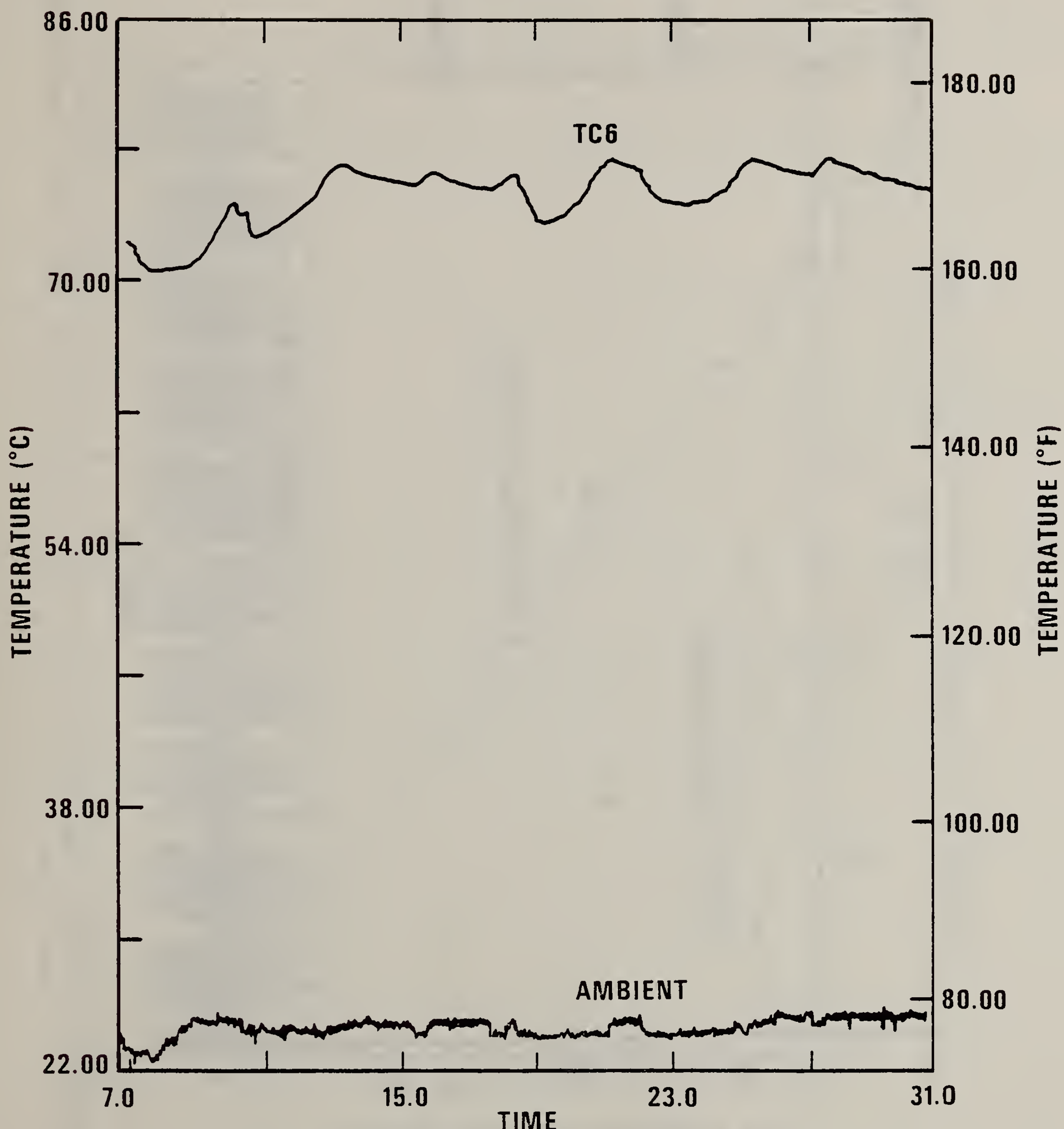

Figure 20. Draw Test-Temperatures of Ambient and TC6 vs. Time.

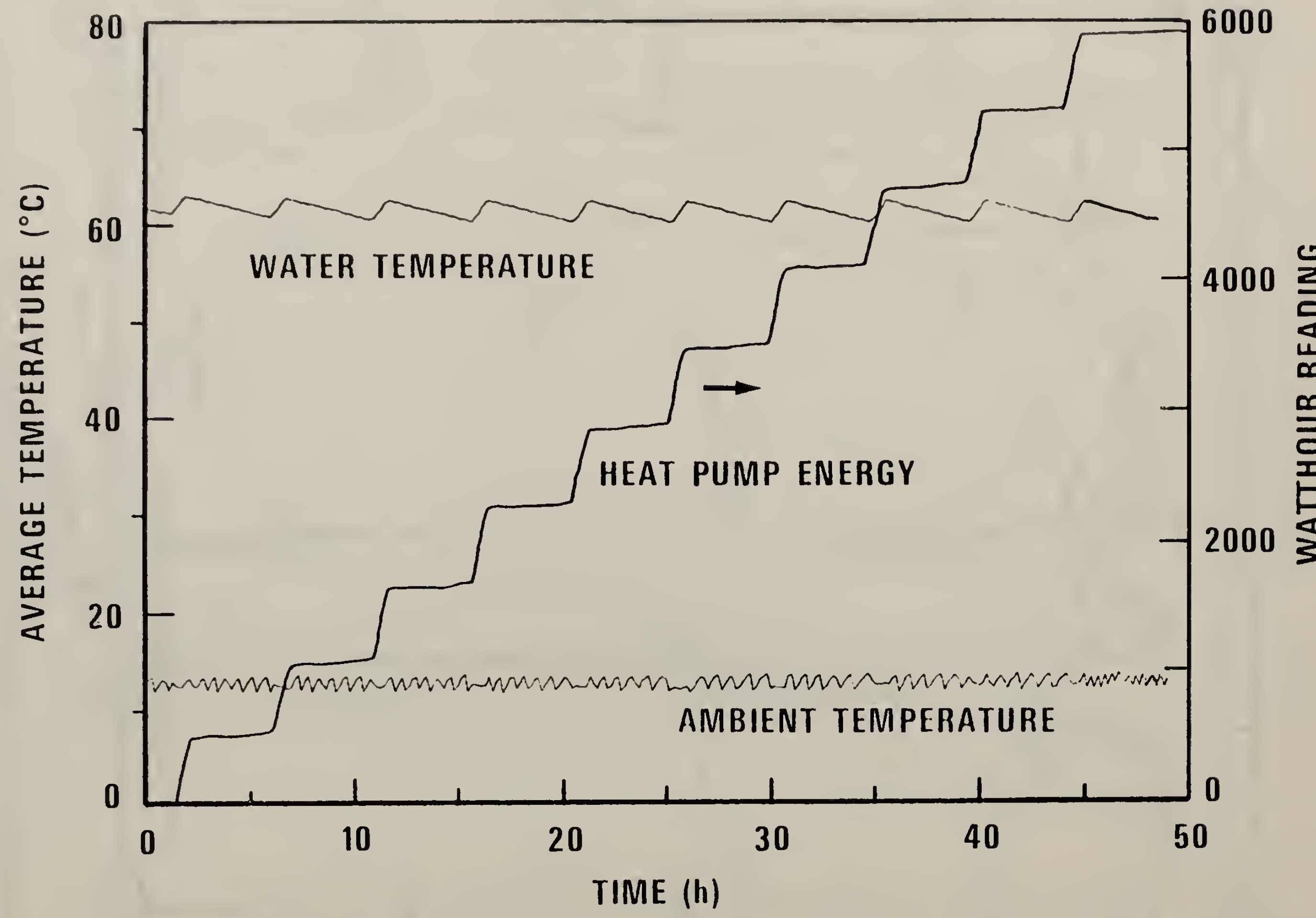

Figure 21. Water Temperature, Ambient Temperature, and Heat Pump Energy vs. Time.

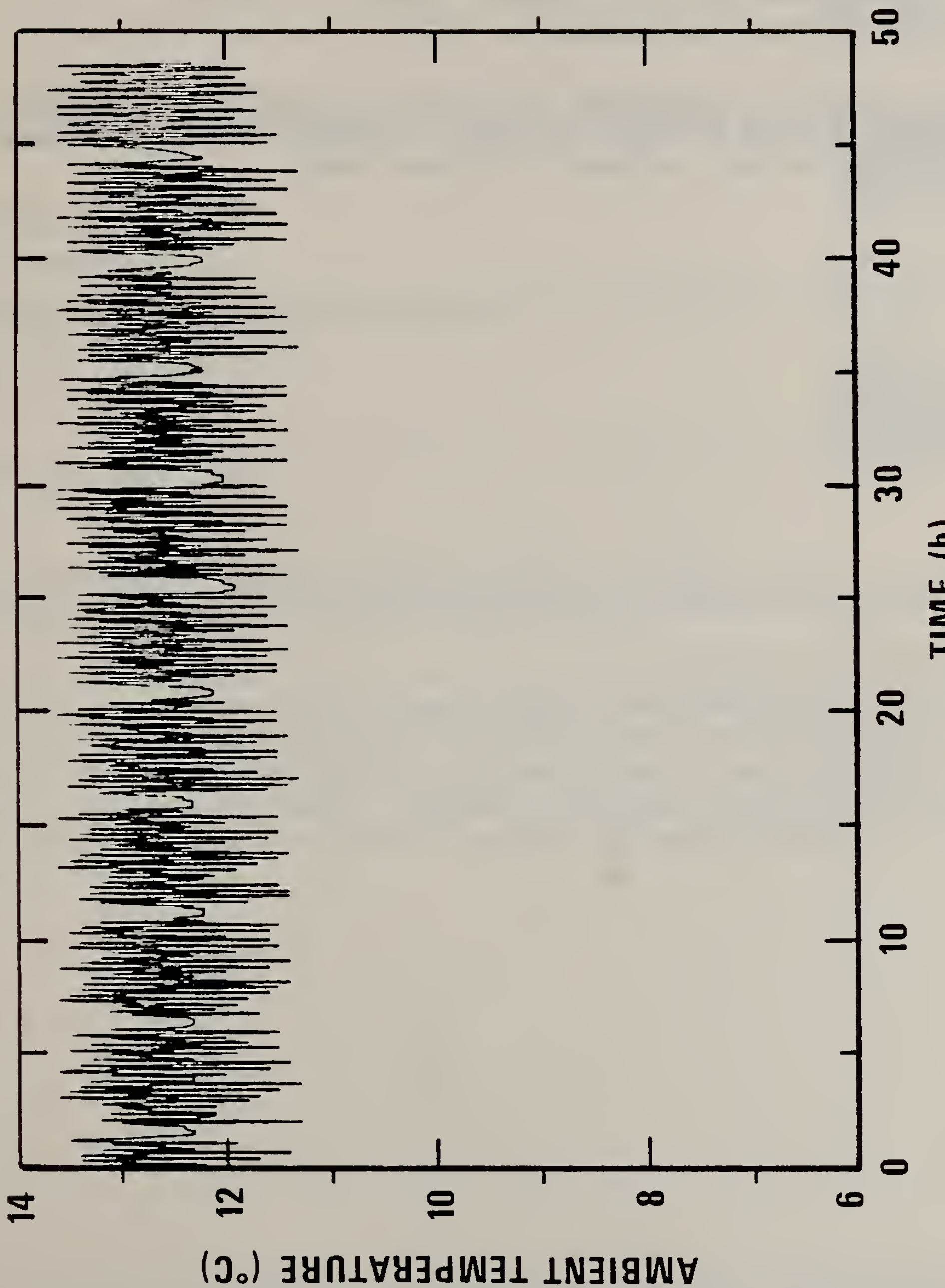

Figure 22. Ambient Temperature vs. Time

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B1. Chaddock, J. B. Feasbility Study of the Heat Pump Water Heater, Final Report, Purdue University, Lafayette, IN, August 31, 1961.

B2. Wan, C.A., Computer Simulation of Water Heater Standby Loss, Heat Transfer in Energy Conservation, Goldstein, R.J., et al., editors, 1977 WAM, ASME.

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Modifications are proposed for the current U.S. Department of Energy test procedures for water heaters in order to make them applicable to electric heat pump water heaters. The modifications are in the areas of definitions and technical procedures. The latter includes the test conditions, test procedures and measurements, and calculations. Reasons for making these modifications and laboratory test data are provided to support the modifications in the technical procedures.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Energy consumption; energy measurements; heat pump; laboratory tests; modifications test procedures; water heaters

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