

OPERATIONS MANUAL

RESIDENTIAL WATER HEATERS CERTIFICATION PROGRAM



AHRI RWH OM – JANUARY 2022

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PREFACE

The following manual outlines the procedures and policies of the Performance Certification Program for Residential Water Heaters (RWH) operated by the Air-Conditioning, Heating, and Refrigeration Institute (AHRI). This manual is to be used in conjunction with the AHRI General Operations Manual for AHRI Certification Programs. Where the AHRI General Operations Manual and this product-specific manual differ, this product-specific operations manual shall prevail.

The revision of this manual supersedes all previous revisions. The current edition of this manual, as well as the AHRI General Operations Manual, can be accessed through the AHRI website, www.ahrinet.org.

The RWH Certification Program by AHRI provides for independent verification of the Commercial Water Heater manufacturers' stated equipment performance. Safety criteria are not within the scope of this program.

Participation in the program is voluntary. Any manufacturer, regardless of AHRI membership, may obtain approval of Program Ratings and use of the AHRI RWH Certification Mark hereinafter referred to as the "Mark". The Mark is the Participant's public representation that the ratings of randomly selected units have been verified by an independent laboratory in accordance with test procedures prescribed by this operations manual. A Certification Agreement is executed between the manufacturer and AHRI specifying the conditions under which such Ratings and the Mark may be used. No manufacturer has the right to use Program Ratings or to state that their products have been tested in conformance with the procedures outlined in this Rating Procedure unless and until they have received written authority from AHRI to use the Mark as applied to the specific approved Program Ratings.

This Operations Manual has been prepared to assure that administration of the program is carried out in a uniform manner. It is an amplification of the Certification Agreement signed by licensees and AHRI. General information, procedural details, and copies of forms are included in this Operations Manual. Provisions of the Operations Manual may be amended as provided in the Certification Agreements

This certification program complies with requirements of the ISO/IEC Standard 17065:2012, *General Requirements for Bodies Operating Product Certification Systems*.

Note:

This manual supersedes the Residential Water Heater Operations Manual, September 2020.

CERTIFICATION OPERATIONS MANUAL FOR

RESIDENTIAL WATER HEATERS

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1. Program Overview

1.1 Applicable Rating Standards. It is mandatory for program Participants to comply with the procedures outlined in this Operations Manual and the provisions of the latest edition of the following Standards:

1.1.1 Applicable U.S. Rating Standard. 10 CFR Part 430 Subpart B Appendix E (Uniform Test Method for Measuring the Energy Consumption of Water Heaters).

1.1.2 Applicable Canadian Rating Standard. CAN/CSA P.3-15 (Testing method for measuring energy consumption and determining efficiencies of gas-fired and fuel oil-fired water heaters).

A copy of the CFR is available for download from the U.S. Government Printing Office website, GPO Access, at <http://www.gpo.gov/fdsys/>.

1.2 Product Definitions. All terms in this document shall follow the AHRI General Operations Manual and the Standard definitions unless otherwise defined in this section.

1.2.1 Residential Water Heater. A product which utilizes oil, gas, or electricity to heat potable water for use outside the heater upon demand, including the following:

1.2.1.1 Electric Storage Water Heater. A water heater that uses electricity as the energy source, has a nameplate input rating of 12 kW (40,956 Btu/h) or less, has a DOE Rated Storage Volume of not less than 20 gallons nor more than 120 gallons, and contains more than one gallon of water per 4,000 Btu per hour of input.

1.2.1.1.1 Grid-Enabled Water Heater. Grid-Enabled Water Heater means an electric resistance water heater that:

- Has a DOE Rated Storage Volume of more than 75 gallons;
- Is manufactured on or after April 16, 2015;
- Is equipped at the point of manufacture with an activation lock; and
- Bears a permanent label applied by the manufacturer that identifies the product as such.

1.2.1.1.1.1 Activation Lock. Activation lock means a control mechanism (either by a physical device directly on the water heater or a control system integrated into the water heater) that is locked by default and contains a physical, software, or digital communication that must be activated with an activation key to enable the product to operate at its designed specifications and capabilities and without which the activation of the product will provide not greater than 50 percent of the rated first hour delivery of hot water certified by the manufacturer.

1.2.1.2 Heat Pump Water Heater. A water heater with a maximum current rating of 24 amperes (including the compressor and all auxiliary equipment such as fans, pumps, controls, and, if on the same circuit, any resistive elements) at an input voltage of no greater than 250 volts, has a DOE Rated Storage Volume of not less than 20 gallons nor more than 120 gallons, and is designed to transfer thermal energy from one temperature level to a higher temperature level for the purpose of heating water, including all ancillary equipment such as fans, storage tanks, pumps, or controls necessary for the device to perform its function.

1.2.1.3 Gas Storage Water Heater. A water heater that uses gas as the main energy source, has a nameplate input rating less than or equal to 75,000 Btu/h, has a DOE Rated

Storage Volume greater than or equal to 20 gallons and less than or equal to 100 gallons, and contains more than one gallon of water per 4,000 Btu per hour of input

1.2.1.4 Gas Instantaneous Water Heater. A water heater that uses gas as the main energy source, has a nameplate input rating greater than 50,000 Btu/h but less than or equal to 200,000 Btu/h, has a DOE Rated Storage Volume of less than 2 gallons, and contains no more than one gallon of water per 4,000 Btu per hour of input.

1.2.1.5 Oil Storage Water Heaters. A water heater that uses oil as the main energy source, has a nameplate input rating less than or equal to 105,000 Btu/h, has a DOE Rated Storage Volume capacity of 50 gallons or less, and contains more than one gallon of water per 4,000 Btu per hour of input.

1.2.1.6 Electric Instantaneous Water Heaters. A water heater that has a nameplate input rating with energy input ratings less than or equal to 12 kilowatts, has a DOE Rated Storage Volume of less than 2 gallons, and contains no more than one gallon of water per 4,000 Btu per hour of input.

1.2.2 Residential-duty Commercial Water Heater. Any gas-fired storage, oil-fired storage, or electric instantaneous commercial water heater that meets the following conditions:

- For models requiring electricity, uses single-phase external power supply;
- Is not designed to provide outlet hot water at temperatures greater than 180°F; and
- Is not one of the following:
 - Gas-fired Storage: Gas-fired Storage Water Heaters with a rated input greater than 105 kBtu/h or a DOE Rated Storage Volume greater than 120 gallons.
 - Oil-fired Storage: Oil-fired Storage Water Heaters with a rated input greater than 140 kBtu/h or a DOE Rated Storage Volume greater than 120 gallons.
 - Electric Instantaneous: Electric Instantaneous Water Heaters with a rated input greater than 58.6 kW or a DOE Rated Storage Volume greater than 2 gallons.

1.3 Program Scope. This program applies to Production Models of Residential Water Heaters, as defined in Section 1.2, with nameplate input ratings and capacities within the Standard.

1.3.1 Program Scope Exclusions. The following are excluded from the RWH Certification Program:

- Residential Water Heaters, as defined in Section 1.2 that are sold exclusively in Canada.

1.3.2 Voluntary Program Scope Inclusions.

1.3.2.1 Models Sold Exclusively in Canada. Residential Water Heaters, as defined in Section 1.2, that are sold exclusively in Canada and meeting the scope of the Standard may be included in the Program at the Participant's option. However, for all products meeting the Program Scope and not subject to Section 1.3.1, the requirement pertaining to the AHRI General OM Section 7, Certify-All Policy shall be met.

1.3.2.2 Other Voluntary Scope Inclusions. Residential Water Heaters as defined in this section that meet the scope of the Standard may be included in the Program at the Participant's option. However, for all products meeting the Program Scope, the requirement pertaining to the AHRI General OM Section 7, Certify-All Policy shall be met.

1.3.2.2.1 Electric Storage Water Heater. A water heater that uses electricity as the energy source, has a nameplate input rating of 12 kW (40,956 Btu/h) or less, has a DOE Rated Storage Volume of less than 20 gallons or greater than 120, and contains more than one gallon of water per 4,000 Btu per hour of input.

1.3.2.2.2 Gas Storage Water Heater. A water heater that uses gas as the main energy source, has a nameplate input rating less than or equal to 75,000 Btu/h, has a DOE Rated Storage Volume of less than 20 gallons or greater than 100 gallons, and contains more than one gallon of water per 4,000 Btu per hour of input.

1.3.2.2.3 Gas Instantaneous Water Heaters. A water heater that uses gas as the main energy source, has a nameplate input rating of 50,000 Btu/h or less, contains no more than one gallon of water per 4,000 Btu per hour of input, and does not fall under Section 1.2.1.4 of this OM.

1.3.2.2.4 Oil Storage Water Heaters. A water heater that uses oil as the main energy source, has a nameplate input rating less than or equal to 105,000 Btu/h, has a DOE Rated Storage Volume greater than 50 gallons, and contains more than one gallon of water per 4,000 Btu per hour of input.

1.3.2.2.5 Oil Instantaneous Water Heaters. A water heater that uses oil as the main energy source, has a nameplate input rating of 210,000 Btu/h (220 MJ/h) or less, and contains no more than one gallon of water per 4,000 Btu per hour of input.

Participants must ensure that certified Residential Water Heaters and non-certified Residential Water Heaters have a separate name and or designation to avoid marketplace confusion. It is a violation of the program if a buyer can look on the AHRI Directory of Certified Product Performance (Directory) and find the name of the “non-certified” unit listed. AHRI certified units must be a different model number and that model number must always be sold as certified. It is permissible for a participant to have another set of model numbers for uncertified units as long as certification is not implied or claimed.

1.4 Intended Market. The Intended Market for this Certification Program includes all products defined in Section 1.3 that are sold for use in the U.S. (including U.S. Territories) and Canada.

1.5 Basic Model. A Participant’s listings of models shall be grouped by product families such that they do not have differing electrical, physical or functional characteristics that affect energy consumption.

1.5.1 Grandfathered Basic Models. Residential Water Heaters and Residential-Duty Commercial Water Heaters as defined in Section 1.2 that:

- Have been introduced in commerce prior to July 13, 2015;
- Have ratings that met or exceeded the applicable federal standards at the time; and
- Have UEF ratings that fall below the federal minimums.

1.6 Draw Pattern. Residential Water Heaters and Residential-duty Commercial Water Heaters, as defined in Section 1.2, shall be tested under a draw profile that depends upon the First Hour Rating (FHR) or the Maximum GPM whichever is applicable. See 10 CFR Part 430 Subpart B Appendix E for more details.

2. Qualification Process

2.1 Original Equipment Manufacturer (OEM) Applicants. With the additions noted below, the OEM qualification process shall proceed according to the AHRI General Operations Manual, Section 4.

STEP 2.1.1 Certification Application Package. In addition to the Application for AHRI Certification and Annual Sales Volume Form noted in the AHRI General Operations Manual, Section 4, STEP 1.

Applicants shall also submit data for all Basic Models seeking qualification. Product data submitted for acceptance shall be supported by a minimum of two (2) tests reports on different samples per each Basic Model, showing the applicable certified test results as follows:

- All types of Residential Storage Water Heaters – Uniform Energy Factor (UEF) and First Hour Rating (FHR)
- All types of Residential Instantaneous Water Heaters – Uniform Energy Factor (UEF) and Maximum GPM Rating
- All Grid-Enabled Water Heaters – Uniform Energy Factor (UEF) and First Hour Rating (FHR) in the unlocked condition

The test reports shall be produced by either a manufacturer's laboratory or by a Nationally Recognized Testing Laboratory (NRTL). The Applicant may request certification of efficiencies supported by the supplied test results in accordance with 10 CFR 429.17(1).

An Applicant requesting AHRI to submit data to the California Energy Commission (CEC) shall submit test reports in the current CEC approved test data format and compliance form. Additional information may be needed to meet EPA ENERGY STAR® program requirements.

STEP 2.1.2 Processing Application Package.

STEP 2.1.2.1 Performance Certification Agreement for Original Equipment Manufacturer (OEM Agreement). No further action required beyond that listed in Section 4, STEP 4.2 of the AHRI General Operations Manual.

STEP 2.1.2.2 Participation and Licensing Fee Invoice. Payment of the Participation and Licensing Fee is due within 30 calendar days of the invoice issue date. Testing shall not be conducted until the invoice is paid in full. No further action required beyond that listed in Section 4, STEP 4.2 of the AHRI General Operations Manual.

STEP 2.1.3 Selection and Acquisition of Test Samples.

STEP 2.1.3.1 Number of Qualification Tests. Thirty percent (30%) of an Applicant's Basic Models shall be tested. Fractional models should be rounded to the nearest whole number using traditional rounding methods. Each Applicant shall test a minimum of one (1) Residential Water Heater Basic Model.

STEP 2.1.3.2 Acquisitions of Qualification Test Samples/Selection Criteria. Within 30 calendar days of a request from AHRI, the Applicant shall have samples available for selection. Samples shall be acquired in accordance with Section 3 of this manual.

STEP 2.1.4 Qualification Testing. AHRI shall supply the Laboratory with the Applicant's published ratings. The Laboratory shall conduct the testing of the samples in accordance with the Standard, against the published ratings.

STEP 2.1.4.1 Successful Completion of All Qualification Tests. If all qualification tests pass, proceed to STEP 2.1.5.

STEP 2.1.4.1.1 Maximum GPM. Required on all Instantaneous Water Heaters.

For qualification testing, the Maximum GPM test results shall be greater than or equal to 95.0% of the rated value.

STEP 2.1.4.1.2 First Hour Rating (FHR). Required on all Storage Water Heaters.

For qualification testing the FHR test results shall be greater than or equal to 95.0% of the rated value.

STEP 2.1.4.1.3 Uniform Energy Factor (UEF). Required on all Water Heaters.

For qualification testing, the UEF test results shall be greater than or equal to 98.0% of the rated value.

STEP 2.1.4.2 Qualification Test Failure. In the event that the qualification tests fail according to Section 3.8, the Applicant shall have the options described in Section 3.9.

STEP 2.1.5 Welcome to the Program. No further action required beyond that listed in Section 4, STEP 6 of the AHRI General Operations Manual.

2.2 Private Brand Marketer (PBM) Applicants. With the additions noted below, the PBM qualification process shall proceed according to the AHRI General Operations Manual, Section 5.

PBM Applicants are not required to undergo qualification testing. PBM product certification is contingent upon the certification of the associated OEM product.

STEP 2.2.1 Certification Application Package. In addition to the Application for AHRI Certification Form noted in the AHRI General Operations Manual, Section 4, STEP 1, the Applicant shall also complete product data submittal spreadsheets. These spreadsheets, which show the correlation between PBM Participant and OEM Participant samples, are available from AHRI. These spreadsheets shall be correctly completed in their entirety, and returned to AHRI, for the qualification process to continue.

STEP 2.2.2 Processing Application Package.

STEP 2.2.2.1 Performance Certification Agreement for Private Brand Marketer (PBM Agreement). In addition to the Application for AHRI Certification Form noted in the AHRI General Operations Manual, Section 5, STEP 5.1, Applicants shall submit the following documentation to AHRI:

- An Applicant requesting AHRI to submit data to CEC, DOE, FTC, and NRCan shall submit third-party authorization, compliance forms and other necessary information.
- Additional information may be needed to meet EPA ENERGY STAR® program requirements.

STEP 2.2.2.2 OEM Agreement on Behalf of the PBM Applicant. No further action required beyond that listed in Section 5, STEP 5.2.2 of the AHRI General Operations Manual.

STEP 2.2.2.3 Licensing Fee Invoice. Payment of the Licensing Fee is due within 30 calendar days of the invoice issue date.

STEP 2.2.3 Welcome to the Program. No further action required beyond that listed in Section 5, STEP 3 of the AHRI General Operations Manual.

3. Equipment Selection and Testing

3.1 Annual Testing Requirement. Thirty percent (30%) of a Participant's Basic Models shall be tested per year. Fractional models shall be rounded to the nearest whole number using traditional rounding methods. Each program Participant shall test a minimum of one (1) Residential Water Heater Basic Model per year.

3.2 Location of Tests. Testing shall be performed at the Laboratory and the sample shall be installed in the test facility in accordance with the Participant's published installation instructions in printed or electronic format.

3.2.1 Presence of Participant Personnel at the Laboratory. Refer to Section 9 of the General Operations Manual.

3.3 Selection of Test Samples. Selections shall be made based on data contained in the Directory. AHRI shall inform the Participant, in writing, of the sample(s) selected for test.

3.4 Methods for Acquiring Test Samples. AHRI, or its representative, shall make a Random Sample Selection from the Participant's stock inventory; a minimum of three (3) samples of each selected model shall be available. Selected samples shall be shipped to the Laboratory accompanied by written installation and operating instructions. Whenever possible and practical, shipped sample(s) should be placed on pallets (multiple samples per pallet is preferred) to ensure efficient handling and storage. Grid-Enabled Water Heaters shall be shipped with the Activation Lock that has not been disabled and instructions for unlocking it.

3.4.1 Method for Acquiring Three (3) Additional Test Samples. If a participant has chosen to test three (3) additional samples after a first sample failure (described in Section 3.8), a minimum of four (4) samples of the failed model shall be made available for the Random Sample Selection.

3.5 Sample Acquisition Timeframe. Within 30 calendar days of a request from AHRI, the Participant shall have each selected Basic Model available for Random Sample Selection as described in Section 3.4.

3.6 Testing Punch List. The Participant shall complete and provide a Punch List (refer to the AHRI website) in electronic format to the Laboratory prior to sample arrival at the Laboratory. The Participant may choose to furnish a single Punch List for multiple tests.

The Punch List shall not contradict the installation and operations manual provided by the Participant, nor shall it contradict the guidelines provided in Appendix A of this operations manual. If there is a discrepancy between notes written on the Punch List, Installation and Operations Manual, products specific operations manual, applicable test procedure and/or the Directory, AHRI shall determine which document takes precedence.

3.7 Inoperable Samples. In addition to the requirements for Inoperable Samples in the General Operations Manual, samples received at the Laboratory which produce more than 400 ppm air-free CO (sample taken at steady state following the procedure described in ANSI Z21.10.1) at normal input shall be deemed Inoperable Samples.

3.7.1 Disposition of Inoperable Samples. All Inoperable Samples shall be returned, with all costs associated with the Inoperable Sample borne by the Participant. Time limitation on the acquisition of a new sample shall be the same as Section 3.5.

3.8 Certified Data. Within the program, tests shall be conducted to verify the following certified data:

3.8.1 Maximum GPM. Required on all Instantaneous Water Heaters.

For annual testing, if the Maximum GPM test results confirm the rated Draw Pattern, the Maximum GPM test results shall be greater than or equal to 90.0% of the certified rating. If the Maximum GPM test results give the sample a different Draw Pattern, the Maximum GPM Rating test results shall be greater than or equal to 95.0% of the certified rating.

3.8.2 First Hour Rating (FHR). Required on all Storage Water Heaters.

For annual testing, if the FHR test results confirm the rated Draw Pattern, the FHR test results shall be greater than or equal to 90.0% of the certified rating. If the FHR test results give the sample a different Draw Pattern, the FHR test results shall be greater than or equal to 95.0% of the certified rating.

3.8.3 Uniform Energy Factor (UEF). Required on all Water Heaters.

For annual testing, the UEF test results shall be greater than or equal to 95.0% of the certified rating.

3.8.4 Additional Requirements for Grid-Enabled Water Heaters. For annual testing of Grid-Enabled Water Heaters, the UEF test results in unlocked condition shall be greater than or equal to 95.0% of the certified rating. If the FHR test results in unlocked condition confirm the rated Draw Pattern, the FHR test results in unlocked condition shall be greater than or equal to 90.0% of the certified rating. If the FHR test results in unlocked condition give the sample a different Draw Pattern, the FHR test results in unlocked condition shall be greater than or equal to 95.0% of the certified rating. The FHR test results in locked condition shall be less than or equal to 50.0% of the certified rating.

For qualification testing of Grid-Enabled Water Heaters, the UEF test results in unlocked condition shall be greater than or equal to 98.0% of the certified rating. The FHR test results in unlocked condition shall be greater than or equal to 95.0% of the certified rating. The FHR test results in locked condition shall be less than or equal to 50.0% of the certified rating.

3.8.5 Rounding to Determine Compliance. The required number of significant digits, per the Applicable Rating Standard, shall be used for calculations. The result of the FHR shall be rounded to the nearest whole number using traditional rounding to determine compliance and the measured draw pattern. The results of the Maximum GPM test shall be rounded to one decimal place using traditional rounding to determine compliance and the measured draw pattern. The result of the UEF test shall be rounded to two decimal places using traditional rounding to determine compliance.

When determining compliance using the results of more than two samples, the mean of the applicable test results shall be determined before rounding.

3.9 Test Failures.

3.9.1 Options Following First Sample Failure. If the FHR or Maximum GPM test has a result that confirms the Draw Pattern, refer to Section 3.9.1.1. If the FHR or Maximum GPM test has a failing result that gives the sample a different Draw Pattern, refer to Section 3.9.1.2.

3.9.1.1 First Sample Failure with the Same Draw Pattern. When the Participant is notified of a first sample certified rating failure, the Participant has seven (7) calendar days to select one of the following options:

- Re-rate the Basic Model and its derivatives proportionate to the failed test results (Not available for Grid-Enabled Water Heater failing FHR in locked condition). If the Basic Model is a Grandfathered Model and the Participant chooses to re-rate the UEF, an EF test shall be conducted on the sample to determine compliance with the federal minimum. The EF test result shall be greater than or equal to 95.0% of the federal minimum;
- Test additional samples (up to 3). The Participant shall establish the number of additional samples to be tested at the time of choosing this option (samples shall be available within the time frame and procedure allotted in Section 3 following notification of decision to AHRI via Manufacturer's Decision Form [MDF]). Please refer to section 3.9.3 for information on how compliance will be determined when testing additional samples; or
- Obsolete the basic model and its derivatives.

3.9.1.2 *First Sample Failure with a Different Draw Pattern.* If the FHR or Maximum GPM test has a failing result that gives the sample a different Draw Pattern, the Laboratory shall conduct the UEF test to the measured draw pattern. When the Participant is notified of a first sample certified rating failure that gives the sample a different Draw Pattern, the Participant has seven (7) calendar days to select one of the following options:

- Test additional samples (up to 3). The Participant shall establish the number of additional samples to be tested at the time of choosing this option (samples shall be available within the time frame and procedure allotted in Section 3 following notification of decision to AHRI via Manufacturer's Decision Form [MDF]). Please refer to section 3.9.2 for information on how compliance will be determined when testing additional samples; or
- Obsolete the basic model and its derivatives. The Participant shall indicate whether the UEF test shall be conducted to the rated Draw Pattern or the measured Draw Pattern.

3.9.2 *Test Additional Samples Option.* The Laboratory shall conduct the FHR or Maximum GPM test on the second sample. If the second sample FHR or Maximum GPM test is a passing result, the Laboratory shall conduct the UEF test on the second sample using the rated Draw Pattern. If the second sample UEF test is a passing result, testing shall cease and the unit shall be determined compliant.

If the second sample FHR, Maximum GPM, or UEF test is a failing result, the Laboratory shall conduct the FHR or Maximum GPM test on all additional samples and use the mean of the results, including the first sample result, to determine compliance. If the mean FHR or Maximum GPM is a passing result, the Laboratory shall conduct the UEF test on all samples using the rated Draw Pattern. If the mean FHR or Maximum GPM is a failing result, the Laboratory shall conduct the UEF test on all samples using the Draw Pattern determined by the mean of the FHR or Maximum GPM tests. Compliance shall be determined by the mean of all test results.

3.9.3 *Options Following Additional Sample Failure.* When the Participant is notified of a second-sample or additional sample certified rating failure, the Participant has seven (7) calendar days to select one of the following options

- Re-rate the Basic Model. The re-rating of the affected Basic Model shall be no better than the mean results of the tested samples (Not available for Grid-Enabled Water Heater failing FHR in locked condition). If the Basic Model is a Grandfathered Model and the Participant chooses to re-rate the UEF, an EF test shall be conducted on all samples, and the mean result will be used to determine compliance with the federal minimum. The EF test result shall be greater than or equal to 95.0% of the federal minimum; or
- Obsolete the basic model and its derivatives.

3.10 Discontinuing or Changing Ratings for a Basic Model.

3.10.1 Voluntarily Changed Rating.

- The Participant may voluntarily discontinue or lower the certified rating for any existing model at any time prior to the Program's selection for compliance testing of that model or any of its associated models.
- The Participant may increase the certified rating if supporting data is submitted following the requirements of Section 2.1 STEP 2.1.1. The increased rating shall not be included in the program until any questions concerning the re-rating are answered to the satisfaction of AHRI. Models with increased ratings may be subject to increased review and selection for verification testing.

3.11 Requirement for Adding New Basic Model to the Directory. Product data submitted for acceptance shall meet the requirements of Section 2.1 STEP 2.1.1.

3.12 Relisting a Discontinued Product. Models previously discontinued for which the Participant is seeking relisting, shall meet the requirements of Section 2.1 STEP 2.1.1. Those models meeting the requirements of Section 2.1 STEP 2.1.1 shall not require qualification testing. Test reports originally submitted are acceptable.

4. Challenge Tests

The Challenge Test process shall proceed according to the AHRI General Operations Manual, Section 10.

5. AHRI Directory of Certified Product Performance

All certified products shall be listed in the Directory, www.ahridirectory.org. Certification shall not be implied nor claimed for any product not listed in the Directory. Except as noted below, the Participant shall follow the steps outlined in Section 11 of the AHRI General Operations Manual.

5.1 Publication of Ratings in Certified Directory. The following information pertaining to each model certified shall be published in the Directory:

- AHRI Certified Reference Number
- Model Status
- Brand Name
- Model Number(s) or Designation(s)
- Energy Source
- Heater Type
- Usage Bin
- UEF
- FHR (GPH)¹
- Maximum GPM (GPM)²
- Nominal Capacity (gallons)
- DOE Rated Storage Volume (gallons)
- Input (MBtu/h or kW)
- UED Recovery Efficiency (%)

¹ Required on all Storage Water Heaters

² Required on all Instantaneous Water Heaters

Additional data may be shown for products sold in areas requiring further product information/ratings or EPA ENERGY STAR® listings.

5.2 Data Forms. Each Participant shall list its products, by Basic Model. OEM and PBM Participants shall submit/edit product data via the Directory.

6. Assessment and Payment of Certification Fees

Refer to Section 12 of the AHRI General Operations Manual.

7. Issuance of Violations and/or Termination

Refer to Section 14 of the AHRI General Operations Manual.

8. Program Hierarchy, Complaints, and the Appeals Process

Refer to Section 15 of the AHRI General Operations Manual.


9. Proper Use of the AHRI Certification Mark and Claims to Certification


Refer to Section 8 of the AHRI General Operations Manual.


9.1 Advertising with Metrics Not Certified by AHRI


9.1.1 Advertising with Commercial Water Heater Metrics: Pursuant to the February 8, 2019 Department of Energy (DOE) Enforcement Policy Statement for Water Heater Efficiency Representations, manufacturers will not receive a program violation for a model advertised in the AHRI Directory as a Residential Water Heater that is also advertised in the market with metrics in accordance with 10 CFR Part 431 Subpart G provided that the following criteria are met:

- Should be able to provide test reports in accordance with 10 CFR Part 431 Subpart G.
- The model does not fall within the scope of the DOE Enforcement Policy for Circulating Water Heaters effective September 5, 2019 and ending December 31, 2021.
- The model does not fall within the scope of the DOE Enforcement Policy for Certain Consumer Water Heaters effective October 1, 2019 and ending December 31, 2021.
- AHRI Certification and AHRI Certification Mark only apply to the model as a Residential Water Heater. All product literature clearly differentiates between AHRI Certified and non-certified metrics, and program Ratings and other data shall be placed into a table meeting the specified format found in the examples below or equivalent.

Example 1a: Residential Water Heater Performance Data Shown With Optional Thermal Efficiency and Standby Loss In The Same Table						
Model Number	Rated Volume, Gal	Input Rate, Btu/h			Ratings Not Certified by AHRI	
			F.H.R., Gal	UEF	Thermal Efficiency %	Standby Loss Btu/hr
WH04050	40	50,000	80	0.80	90	600

Example 1b: Residential Water Heater Performance Data Shown With Optional Thermal Efficiency and Without Standby Loss In The Same Table				
Model Number	Input Rate, Btu/h			Ratings Not Certified by AHRI
		Max GPM	UEF	Thermal Efficiency %
WH199	199,000	5.7	0.93	95

Example 2a: Residential Water Heater Performance Data Shown With Optional Thermal Efficiency and Standby Loss In Two Tables				
Model Number	Rated Volume, Gal	Input Rate, Btu/h		
			F.H.R., Gal	UEF
WH04050	40	50,000	80	0.80
Model Number	Rated Volume, Gal	Input Rate, Btu/h	Ratings Not Certified by AHRI	
			Thermal Efficiency, %	Standby Loss Btu/hr
WH04050	40	50,000	90	600

Example 2b: Residential Water Heater Performance Data Shown With Optional Thermal Efficiency and Without Standby Loss In Two Tables			
Model Number	Input Rate, Btu/h		
		Max GPM	UEF
WH199	199,000	5.7	0.93
Model Number	Input Rate, Btu/h	Ratings Not Certified by AHRI	
		Thermal Efficiency, %	
WH199	199,000	95	

9.1.2 Advertising with Energy Factor (EF): For sales in the U.S., manufacturers of covered products are restricted from making energy efficiency representations that are not in accordance with the Department of Energy (DOE) test procedures. (42 U.S. Code § 6293 (c)(1)) Manufacturers must use the prescribed DOE test procedure as the basis for certifying to DOE that their products comply with the applicable energy

conservation standards adopted under EPCA. (42 U.S.C. 6295(s)) Members are strongly discouraged from making energy efficiency representations that are not DOE accepted metrics.

APPENDIX A. GUIDELINE FOR TESTING UNIFORM ENERGY FACTOR FOR ELECTRIC, GAS, AND OIL-FIRED RESIDENTIAL AND RESIDENTIAL-DUTY COMMERCIAL WATER HEATERS

Note: The purpose of this guideline is to provide details on the specific instrumentation, test setup, and testing procedures used to measure water heater efficiency. This document is an adjunct to the Department of Energy (DOE) test method for determining the energy efficiency of residential water heaters as published in the July 11, 2014 Federal Register notice 10 CFR Part 430 Subpart B Appendix E. It is used by the AHRI Residential Water Heater Certification Program as a guideline providing clarification on how testing is conducted by the contracted third-party laboratory. None of the details contained in this document are counter to or inconsistent with the DOE test method.

Section A1. Test Guidelines

A1.1 Test Preparation.

A1.1.1 Documentation.

A1.1.1.1 Reference Standard. The following standard shall be referenced:
10 CFR Part 430 Subpart B Appendix E and ANSI Z21.10.1.

A1.1.1.2 Operator shall initiate a new test file and assign a new test number for each test unit.

A1.1.2 Instrumentation. At a minimum, all instruments shall meet the accuracies listed in Table A1.

A1.1.2.1 The flow shall be measured on the inlet side of the water heater, which is where the mass should be used from when conducting calculations. The volume measured on the inlet shall be converted to obtain the volume withdrawn using the ratio of the inlet to outlet densities, as detailed in Section A1.4.3.

A1.1.3 Calibration. Instruments shall be calibrated at a minimum of every 12 months (refer to Table A2). Instrument calibration records shall be maintained and instruments shall be labeled with an identification number matching its calibration record. Operator shall ensure that calibrations are current and, if applicable, instruments are zeroed out prior to test. Instruments shall be calibrated by an ISO 17025 certified laboratory unless:

A1.1.3.1 When using external calibration services:

A1.1.3.1.1 Traceability of measurements is assured by the use of calibration services for laboratories that can demonstrate competence, measurement capability and traceability and;

A1.1.3.1.2 Calibration certificates issued by these laboratories contain the measurement results for the ranges being used.

A1.1.3.2 When equipment is internally calibrated:

A1.1.3.2.1 Laboratory established traceability of its own measurement standards and measuring instruments by means of an unbroken chain of calibrations or comparisons linking them to the relevant primary standards of the units of measurement and;

A1.1.3.2.2 The link to units achieved by reference to national measurement standards (i.e. measurement standards and instruments directly

traceable to the National Institute of Standards and Technology (NIST) or other nationally recognized organization such as A2LA, UKAS, SCC, IAS, etc.).

A1.1.4 *Thermocouples Submerged in Water.* Thermocouples submerged in water shall be of the sheathed, ungrounded type. For the thermocouple tree, beaded-type thermocouple wires may be used instead of probes when:

- Using the outlet fitting, its diameter is insufficient to pass the six probe assembly without restricting the water flow; or
- There is a top center outlet with no anode, requiring an offset in the TC's in order to clear the elements; or
- There are side relief openings where the TC's require a 90-degree bend, which would destroy probes; or
- Encountering other circumstances after the testing agency and the manufacturer have consulted and agreed it is necessary.

A1.1.5 *Use of Quick Connect Fittings.*

A1.1.5.1 Quick connect fittings shall only be used to: connect water supply, bypass, and return hoses to the piping; and on the thermocouple tree.

A1.1.5.2 Quick connect fittings shall not be used to connect the inlet and outlet piping to the water heater's fittings.

A1.1.5.3 The acceptable quick connect fittings are described in A1.2.2.5. Any other alternatives to these fittings shall be approved by the WHTC and Lab Evaluation WG prior to their use.

Table A1. Minimum and Preferred Instrument Accuracies

Measurement	Units	Source	Minimum	DOE Test Method Requirement (For information only)
Electric Power	watt-hour	transducer	±0.25%	±0.5% of RDG
Water Flow Rate	gpm or lbm/min	flow meter	±0.25%	±1% of RDG
W_f	lbm	scale	±0.5%	±0.5% of RDG
Barometric Pressure	in. Hg	barometer	±0.05% (0.017 in Hg)	±0.1 in Hg
Volume of Gas	cu-ft or cu-ft/min	gas meter	±1%	±1% of RDG
HHV	Btu/cu-ft	Gas Chromatograph, Calorimeter or spectrometer	±0.5%	±1% of RDG
P_2	psig	pressure gauge or transducer	±1 psi	±1 psi
P_{gas}	in. H ₂ O	manometer	±0.1 inch of water column	±0.1 inch of water column
Water I/O Temperature	°F	TC or RTD	±0.2 °F	±0.2 °F
Tank Temperature	°F	TC or RTD	±0.5 °F	±0.5 °F
Ambient Temperature	°F	TC or RTD	±0.2 °F	±0.2 °F
Gas Temperature	°F	TC or RTD	±0.5 °F	N/A
Time	hr		0.000139 hr	0.000139 hr
Volt	volts	transducer	1.0 volt	None
Amps	amp	amp transducer	0.1 amp	None
Relative Humidity	%	transducer	±1.5%	±1.5%

Table A2. Instruments Calibration Timetable

Equipment	Calibration Cycle
Natural Gas Calorimeter	Every year
Gas Chromatograph	Quarterly
Water Flow Meter	Every year
Manometer	Every year
Temperature Readout	Every year
Stopwatch	Every year
Pressure Transducer	Every year
Scale	Every year
Water Heater Test Stand	Every year
U-Tube Manometer	Every year
T/C Assembly	Every year
Pressure Transducer	Every year
Pressure gauge	Every year
Digital Multimeter	Every year

CO / CO2 Analyzer	verify daily if used, calibrate annually
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A1.2 Test Setup.

A1.2.1 Test Unit Preparation and Storage Vessel Capacity.

A1.2.1.1 The unit shall be placed in a conditioned space for at least 24 hours. The conditioned space must be maintained at a minimum of 65°F.

A1.2.1.2 If applicable, operator shall install relief valves and water connections.

A1.2.1.3 The water heater shall be connected to a compressed air supply and a drain hose shall be connected to the water heater's drain valve.

A1.2.1.4 The water heater's drain valve shall be opened and the compressed air supply shall be turned on.

A1.2.1.4.1 Tip the water heater towards its drain valve while the air supply is turned on to allow all water that may be inside the tank to be drained off. After all water is removed, remove the drain hose and compressed air supply line.

A1.2.1.5 Test unit shall be weighed and dry weight recorded.

A1.2.1.6 Water heater shall be filled with water at a minimum pressure of 40 psi and checked for leaks.

A1.2.1.7 Air shall be purged from the water heater during this process, including any other time the water heater is filled, transferred to a different test station, or disconnected from the water supply. A top spud location shall be used to purge any air from the water heater.

A1.2.1.8 Temperature of water shall be noted, and density of water at that temperature shall be used to calculate the volume.

A1.2.1.9 Water heater shall be weighed. The weight of the water minus the weight of the water in the pipe connections (W) shall be recorded in the test report.

A1.2.2 Thermocouple Placement.

A1.2.2.1 Standard Tank Height Measurement Procedure (Top water connections on a storage water heater).

A1.2.2.1.1 Measure the height of the hot water outlet spud or anode spud using a tape measure by hooking the tape under the tank, directly under the spud. This is dimension "S" in Figure A10.

A1.2.2.1.2 Insert the rod fitting into the hot water outlet spud so that the top of the fitting is "Y" inches above the top of the spud.

A1.2.2.1.3 Insert the rod through the fitting until it bottoms out against the bottom of the tank. The tight clearance between the rod and fitting ensures the rod is straight.

A1.2.2.1.4 Place a mark or piece of masking tape on the rod at the top of the rod fitting.

- A1.2.2.1.5** Remove the rod and measure dimension "L" from the bottom of the rod to the mark.
- A1.2.2.1.6** Calculate Tank Height $H = L - S - Y$ in inches.
- A1.2.2.1.7** Place the water heater on a level floor.
- A1.2.2.1.8** Insert two fittings (or nipples) into the hot and cold spuds.
- A1.2.2.1.9** Place a level across the two fittings.
- A1.2.2.1.10** Lower or raise the fittings as appropriate to zero the level.
- A1.2.2.1.11** Remove level and measure the length "X" from the bottom of the spud to the top of the fittings (using tape measure and method from A1.2.2.1.1).
- A1.2.2.1.12** Mark the top of the tank "T" on the water heater jacket by replacing level and measuring down "X" inches as determined in A1.2.1.11 from bottom of level.
- A1.2.2.1.13** Place mark for water heater tank bottom "B" by measuring down from the tank top mark from A1.2.1.12 a distance equal to the tank height determined in A1.2.1.6.
- A1.2.2.1.14** An acceptable alternate method for determining thermocouple placement for side outlet water heaters is also described in A1.2.3.1 through A1.2.3.4.

A1.2.2.2 Thermocouple Placement Procedure.

- A1.2.2.2.1** For water heaters with rated storage volumes greater than or equal to 20-gallons, use a six thermocouple tree with a vertical distance of at least 4 inches between successive sensors.
- A1.2.2.2.2** For water heaters with rated storage volumes between 2 and 20 gallons, use a three thermocouple tree inside the water heater tank.
- A1.2.2.2.3** Position a thermocouple at the vertical midpoint of each of the six equal volume nodes within a tank larger than 20 gallons or the three equal volume nodes within a tank between 2 and 20 gallons. Nodes designate the equal volumes used to evenly partition the total volume of the tank. As much as is possible, the thermocouple should be positioned away from any heating elements, anodic protective devices, tank walls, and flue pipe walls.
- A1.2.2.2.4** If the tank cannot accommodate six thermocouples and meet the installation requirements above, install the maximum number of sensors that comply with the installation requirements. Thermocouple wires may be used instead of probes when:
- Using the outlet fitting, its diameter is insufficient to pass the six probe assembly, without restricting the water flow; or
 - There is a top center outlet with no anode, requiring an offset in the TC's in order to clear the elements; or
 - There are side relief openings where the TC's require a 90 degree bend, which would destroy probes; or
 - Encountering other circumstances after the testing agency and the manufacturer have consulted and agreed it is necessary.
- A1.2.2.2.5** Install clear 0.25 in. i.d. tube on drain cock. Draw tube up the side of the water heater jacket and affix to top of jacket.

A1.2.2.2.6 Using the weight of water in tank (W) as determined in A1.1.1.6, determine placement of thermocouples.

A1.2.2.2.7 Open the water heater drain valve.

A1.2.2.2.8 For tree with six thermocouples, fill tank with $W/12 \pm 0.5$ lb. of water. For tree with three thermocouples, fill tank with $W/6 \pm 0.5$ lb. of water.

A1.2.2.2.9 Allow the water level in the tube to stabilize. Mark water level in tube on water heater jacket.

A1.2.2.2.10 For tree with six thermocouples, P1 is the measured distance from mark indicating tank bottom to mark indicating 1/12 capacity. For tree with three thermocouples, P1 is the measured distance from mark indicating tank bottom of mark indicating 1/6 capacity.

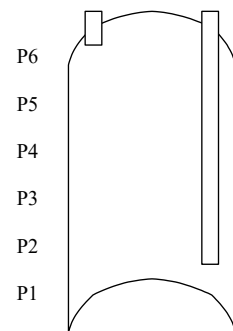
A1.2.2.3 For tree with six thermocouples, calculate the remaining thermocouple positions as follows:

$$\begin{aligned} P2 &= (H - 2P1)/10 + 2P1 \\ P3 &= (H - 2P1)/5 + P2 \\ P4 &= (H - 2P1)/5 + P3 \\ P5 &= (H - 2P1)/5 + P4 \\ P6 &= (H - 2P1)/5 + P5 \end{aligned}$$

Where:

H = Height of the water heater inside the tank.

P_i = Position of the thermocouples.



For tree with three thermocouples, calculate the remaining thermocouple positions as follows:

$$\begin{aligned} P2 &= (H - 2P1)/4 + 2P1 \\ P3 &= (H - 2P1)/2 + P1 \end{aligned}$$

A1.2.2.4 Using thermocouple placements determined in A1.2.2.3 and taking into account thread engagement of the thermocouple tree fitting, set thermocouples in tree within ± 0.25 " of the calculated thermocouple positions. See Figures A10 and A11 for suggestions.

A1.2.2.5 Install thermocouple tree in the anode spud on the test unit. Ensure tree is straight and is not in contact with any component inside the water heater, such as an element. If the tree cannot be installed in the anode spud, install the tree in the outlet spud. Ensure that any fittings are insulated with a minimum R-value of 8 ft²·°F·h/Btu.

To address the problem of nipple engagement depth on the TC probe, use the rod fitting with a camlock fitting, McMaster-Carr Part Nos. 52155K51 and 52155K21, at the end. Use an O-ring on the bottom thread to make a perfect seal between the spud and the rod fitting and allow the fitting to bottom out on spud.

A1.2.2.6 Install piping on the unit per the diagrams shown in Figures A1 through A8.

A1.2.2.7 If applicable, operator shall install fittings, heat traps, and insulation (if provided) on pipes, relief valves, and water connections. Any other supplied components with the water

heater must be installed per the manufacturer's installation instructions. This includes, but is not limited to the following: blowers, burners, controls, etc.

A1.2.2.7 If the heat trap is removed on the outlet side of the water heater to install the temperature probe, the heat trap must be incorporated into the remainder of the outlet piping.

A1.2.2.8 Fill the water heater and examine it for leaks at a minimum pressure of 40 psi.

A1.2.2.9 Operator shall install insulation with a minimum R-Value of $8 \text{ h} \cdot \text{ft}^2 \cdot ^\circ\text{F}/\text{Btu}$ on top of thermocouple tree and any additional fittings that were added by the operator. All insulation must be tightly secured to minimize heat loss potential.

A1.2.3 Side-Inlet Tank Height Measurement and Thermocouple Placement Procedure (use only if tank does not have a top outlet, anode, or T&P fitting available on Storage Water Heaters).

A1.2.3.1 Install a clear 0.25 in. i.d. tube on tank drain cock. Draw tube up the side of the water heater jacket and affix to top of jacket.

A1.2.3.2 Fill tank with water.

A1.2.3.3 Open drain cock and allow water level to stabilize in tube. Ensure the water level comes up to outlet spud. CAUTION: Do not overfill! Should overfill occur and insulation become wet, heater will be considered defective and must be replaced with a new unit.

A1.2.3.4 Place tank top mark "T" on the water heater jacket at level of full water heater.

A1.2.3.5 For tree with six thermocouples, Using the weight of the water in the tank (W), remove $W/12 \pm 0.5 \text{ lb.}$ of water. For tree with six thermocouples, Using the weight of the water in the tank (W), remove $W/6 \pm 0.5 \text{ lb.}$ of water.

A1.2.3.6 Allow the water level in the tube to stabilize. Mark water level in tube on water heater jacket. For tree with six thermocouples, P6 is the measured distance from mark indicating tank top (T) to mark indicating 1/12 capacity. For tree with three thermocouples, P3 is measured distance from mark indicating tank top (T) to mark indicating 1/6 capacity.

A1.2.3.7 For tree with six thermocouples, remove $W/6 \pm 0.5 \text{ lb.}$ of water for each successive thermocouple. For tree with three thermocouples, remove $W/3 \pm 0.5 \text{ lb.}$ of water for each successive thermocouple. After each draw, allow the water level in the tube to stabilize.

A1.2.3.8 Mark water level in tube on water heater jacket.

A1.2.3.9 Measure distance from previous thermocouple mark to successive thermocouple mark until all thermocouple locations have been identified.

A1.2.3.10 Using thermocouple placements determined in A1.2.3.6 through A1.2.3.9, and taking into account placement of the thermocouple tree fitting, set thermocouples in tree within $\pm 0.25"$ of the measured thermocouple positions. See Figures A10 and A11.

A1.2.4 Thermocouple Placement Procedure (Tankless Water Heaters Only).

A1.2.4.1 Install piping on the unit per the DOE test procedure document (see Figures A1 through A8).

A1.2.4.2 If applicable, operator shall install fittings, heat traps, and insulation (if provided) on pipes, relief valves, and water connections. Any other supplied components with the water

heater must be installed per the manufacturer's installation instructions. This includes, but is not limited to the following: blowers, burners, controls, etc.

A1.2.4.3 Operator shall install insulation with a minimum R-Value of 8 ft²·°F·h/Btu on inlet and outlet thermocouples and any additional fittings that were added by the operator. All insulation must be tightly secured to minimize heat loss potential.

A1.2.5 Test Unit Setup.

A1.2.5.1 For power vent, power direct vent, and direct vent gas-fired water heaters only, install the minimum length venting, per the manufacturer's instructions. For atmospheric vent water heaters, connect a 5-foot vertical vent pipe extension to the outlet of the water heater's draft hood.

A1.2.5.2 For oil-fired water heaters only, install the minimum length venting, per the manufacturer's instructions.

A1.2.5.2.1 Then, adjust the vent length according to 10 CFR Part 430 Subpart B Appendix E to achieve the proper chimney/stack draft.

A1.2.5.3 For heat pump water heaters, a minimum of one (1) humidity sensor shall be located 18" away from the water heater air inlet. If there is more than one, the sensors shall be spaced evenly around the circumference of the water heater. Vertically, the sensor(s) must be located halfway between the top and bottom of the heat pump portion of the water heater and shielded from direct airflow out of the heat pump. The sensor(s) must monitor the surrounding area's humidity for all testing conducted.

A1.2.5.4 At least one picture must be taken of the water heater, including its venting, piping, etc. This picture must be saved with the test file and be provided, upon request.

A1.2.5.5 All air movement across and/or on the water heater shall be eliminated prior to starting any test. No air movement is determined by airflow around the unit to be less than 50 fpm.

A1.3 Test Procedure.

A1.3.1 Electric Storage Water Heaters (including Heat Pump Water Heaters):

A1.3.1.1 Test Setup.

Note: Section A1.2, Test Setup shall be followed prior to proceeding to this section.

A1.3.1.1.1 Install Electrical connections

A1.3.1.1.2 Install current clamp to upper most element.

A1.3.1.1.3 Inlet and outlet thermocouples shall be located as indicated in Figure A5.

A1.3.1.1.4 Fill the water heater and test it for leaks at a minimum pressure of 40 psi. Isolate the water heater from the expansion tank by closing a ball valve between the two. The pressure inside the tank must be monitored to see if it changes over a period of 10 minutes. The starting and ending pressures shall be recorded.

A1.3.1.1.5 Adjust the water heater setpoint to allow the main power source to cut-in

A1.3.1.1.6 Turn on the water heater and set the water heater thermostat(s) for approximately 120°F.

A1.3.1.1.7 Set the voltage to nameplate voltage +/- 1%

A1.3.1.1.8 Setting the outlet discharge temperature procedure: Drain and refill with supply water at 58 +/- 2°F. Initiate operation of water heater. After cut-out, initiate a draw based on part 1, 2, or 3 below. Document thermostat setting by photographing the position of the thermostat and record the maximum outlet temperature on the test report.

(1) For storage volumes less than 20 gallons. After cutout initiate a draw of 1.0 gpm +/- .25 gpm for 2 minutes. Starting 15 seconds after start of draw and every 15 second interval record the outlet temperature. Determine if the maximum outlet temperature is within the range of 125 +/- 5F. If not turn heater off adjust thermostat drain and refill the tank with supply water then repeat the 2 minute outlet temperature test.

(2) For storage volumes greater than and equal to 20 gallons. After cutout initiate a draw of 1.7 gpm +/- .25 gpm for 5 minutes. Starting 15 seconds after start of draw and every 15 second interval record the outlet temperature. Determine if the maximum outlet temperature is within the range of 125 +/- 5F. If not turn heater off adjust thermostat drain and refill the tank with supply water then repeat the 5 minute outlet temperature test.

(3) For flow activated water heaters. At full input rating or maximum fire set the outlet discharge temperature to 125 +/- 5F. If the heater cannot provide this condition at 1.7 gpm +/- .25gpm then adjust flow rate to achieve 125 +/- 5F outlet temperature:

- If the outlet discharge temperature can be achieved above 1 gpm, then the unit must be operated at the adjusted flow rate and maximum input rate during the maximum gpm test. However, during the simulated use test, the firing rate must be reduced to maintain the outlet discharge temperature at 1 gpm.
- If the outlet discharge temperature cannot be achieved above 1 gpm, then the adjusted flow rate is the flow rate to be used during maximum gpm test and simulated use test.

(4) Tanks with Two or More Temperature Controllers. Verify the temperature controller set-point while removing water in accordance with the procedure set forth for the First Hour rating test.

(a) At least 50 percent of the water drawn during the first draw of the First Hour rating test procedure shall be delivered at a temperature of 125 °F ± 5 °F (51.7 °C ± 2.8°C).

(b) No water is delivered above 130 °F (54.4 °C) during First Hour rating test.

(c) The delivery temperature measured 15 seconds after commencement of each draw begun prior to an elapsed time of 60 minutes from the start of the test shall be at 125°F ± 5°F (51.7 °C ± 2.8 °C).

A1.3.1.1.9 If these conditions are not met, turn off the water heater, adjust the temperature controllers and then drain and refill the tank with supply water. Repeat A1.3.1.1.8 until the criteria for setting the temperature controllers is met. Once the setting

is met, the temperature controllers shall remain at the setting for the First Hour Rating test and Simulated Use Test.

A1.3.1.1.10 Allow the test unit to soak-in for a minimum period of 12 hours. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

A1.3.1.2 Electric Storage Water Heaters (including Heat Pump Water Heaters): First Hour Rating (FHR) Test.

Note: Section A1.2 and A1.3.1, Test Setup shall be followed prior to proceeding to this section.

A1.3.1.2.1 After the setting the outlet discharge, turn the power off, and disconnect the electrical connections if transferring between a warm-up station and test station. At the test station, connect the ambient, tank, inlet and outlet thermocouples, current sensors, and power cord. Seal any gaps in water heater jacket due to sensor leads to minimize heat loss. At no time shall the unit be disconnected from its energy supply for more than 1 hour when transferring stations.

A1.3.1.2.2 Ensure the water heater's temperature controllers are set to the same setting when setting the outlet discharge temperature was determined.

A1.3.1.2.3 If the water heater is not presently operating, initiate a draw. Terminate the draw when the outlet temperature drops 15 °F below the maximum recorded outlet temperature or when cut-in occurs, whichever is longer. If the water heater is operating, wait for max. mean tank temperature after cut-out or for thirty-minutes, whichever is shorter, then initiate a draw. Terminate the draw when the outlet temperature drops 15 °F below the maximum recorded outlet temperature or when cut-in occurs, whichever is longer.

A1.3.1.2.4 Initiate the FHR test and data acquisition system. Conduct the test as detailed in Section 5.3.3 of 10 CFR Part 430 Subpart B Appendix E.

A1.3.1.2.5 T-mean max is defined as the temperature at which the rolling 60 second average (of readings taken every (5) seconds) T-mean temperature drops 0.05°F from the previous rolling average reading.

A1.3.1.2.6 Starting fifteen seconds into the draw, record temperatures every five seconds, until the outlet water temperature drops 15°F below the maximum recorded outlet temperature.

A1.3.1.2.7 Allow the test unit to recover and draw, at cut-out, as many times as possible in one hour. On water heaters with two or more thermostats, recovery is determined by the cut-out of the upper thermostat or thermocouple.

A1.3.1.2.8 Confirm section **A1.3.1.1.9 (4)** has been met for water heater with two or more temperature controllers. If not, repeat section **A1.3.1.1.9**.

A1.3.1.2.9 Compile data and save report.

A1.3.1.2.10 Validate the test results.

A1.3.1.3 Electric Storage Water Heaters (including Heat Pump Water Heaters): Simulated Use Test (SUT).

- A1.3.1.3.1** Refer to section 3.7 to determine the draw pattern to be used for the SUT.
- A1.3.1.3.2** After the FHR test turn on the water heater and allow it to fully recover.
- A1.3.1.3.3** Water heater shall sit idle for (1) hour after cut-out prior to the start of the 24-hour SUT. No water can be withdrawn from the unit during this period.
- A1.3.1.3.4** Initiate the 24-hour simulated use test and data acquisition system after the 1 hour idle period. Using the draw pattern determined in section A1.3.1.2, conduct the test as detailed in Section 5.4 of 10 CFR Part 430 Subpart B Appendix E.
- A1.3.1.3.5** Compile data and save report.
- A1.3.1.3.6** Validate the test results.

A1.3.2 Gas-Fired Storage Water Heaters:

A1.3.2.1 Test Setup

Note: Section A1.2 must be followed prior to proceeding to this section

- A1.3.2.1.1** Install the gas line and the manifold pressure line.
- A1.3.2.1.2** Connect the gas meter.
- A1.3.2.1.3** Inlet and outlet thermocouples shall be located as indicated in Figures A1 through A9.
- A1.3.2.1.4** Fill the water heater and test it for leaks at a minimum pressure of 40 psi. Isolate the water heater from the expansion tank by closing a ball valve between the two. The pressure inside the tank must be monitored to see if it changes over a period of 10 minutes. The starting and ending pressures shall be recorded.
- A1.3.2.1.5** Light the pilot, if applicable. Otherwise, turn on the water heater.
- A1.3.2.1.6** Adjust the water heater setpoint to allow the burner to fire.
- A1.3.2.1.7** Check the entire gas train for leaks using a liquid leak detector or combustible gas detector.
- A1.3.2.1.8** Check the input rate. It must be within $\pm 2\%$ of its rated value using the method detailed in ANSI Z21.10.1. The manifold pressure shall be within $\pm 10\%$ of that printed on the rating plate.
- A1.3.2.1.9** If input rate is not within $\pm 2\%$ of the rated value, the operator shall adjust manifold pressure, assuming he stays within the allowed $\pm 10\%$ to attempt to achieve $\pm 2\%$ of the rated input.
- A1.3.2.1.10** If adjusting the manifold pressure does not achieve the rated input, the operator shall re-orifice the unit using an alternate orifice supplied by the manufacturer. [Note: Manufacturers are to supply test facility with a selection of orifices for use at the test facility. When a test unit is re-orificed, the test facility will notify the manufacturer of the alternate orifice used, and the manufacturer shall re-supply the test facility with a replacement orifice.

A1.3.2.1.11 The operator shall check the entire gas train for leaks after re-orificing the water heater. Any leaks discovered shall be fixed.

A1.3.2.1.12 Combustion must only be checked when the water heater is very clearly operating abnormally (e.g. CO alarms are going off, producing smoke (when it is not supposed to), flames are shooting out of the vent, etc.).

A1.3.2.1.13 Install unit on test station, connect the fuel supply, ambient, tank, inlet and outlet thermocouples, current sensors, and power cord. Seal any gaps in water heater jacket due to sensor leads to minimize heat loss. At no time shall the unit be disconnected from its energy supply for more than (1) hour when transferring stations.

A1.3.2.1.14 Setting the outlet discharge temperature procedure: Drain and refill with supply water at 58 +/- 2°F. Initiate operation of water heater. After cut-out, initiate a draw based on part 1, 2, 3 or 4 below. Document thermostat setting by photographing the position of the thermostat and record the maximum outlet temperature on the test report.

(1) For storage volumes less than 20 gallons. After cutout initiate a draw of 1.0 gpm +/- .25 gpm for 2 minutes. Starting 15 seconds after start of draw and every 15 second interval record the outlet temperature. Determine if the maximum outlet temperature is within the range of 125 +/- 5F. If not turn heater off adjust thermostat drain and refill the tank with supply water then repeat the 2 minute outlet temperature test.

(2) For storage volumes greater than and equal to 20 gallons. After cutout initiate a draw of 1.7 gpm +/- .25 gpm for 5 minutes. Starting 15 seconds after start of draw and every 15 second interval record the outlet temperature. Determine if the maximum outlet temperature is within the range of 125 +/- 5F. If not turn heater off adjust thermostat drain and refill the tank with supply water then repeat the 5 minute outlet temperature test.

(3) For flow activated water heaters. At full input rating or maximum fire set the outlet discharge temperature to 125 +/- 5F. If the heater cannot provide this condition at 1.7 gpm +/- .25 gpm then adjust flow rate to achieve 125 +/- 5F outlet temperature. The adjusted flow rate is the flow rate to be used during the maximum gpm test and simulated use test.

(4) Tanks with Two or More Temperature Controllers. Verify the temperature controller set-point while removing water in accordance with the procedure set forth for the First Hour rating test.

(a) At least 50 percent of the water drawn during the first draw of the First Hour rating test procedure shall be delivered at a temperature of 125 °F ± 5 °F (51.7 °C ± 2.8°C).

(b) No water is delivered above 130 °F (54.4 °C) during First Hour rating test.

(c) The delivery temperature measured 15 seconds after commencement of each draw begun prior to an elapsed time of 60 minutes from the start of the test shall be at 125°F ± 5°F (51.7 °C ± 2.8 °C).

A1.3.2.1.15 If these conditions are not met, turn off the water heater, adjust the temperature controllers and then drain and refill the tank with supply water. Repeat

A1.3.2.14 until the criteria for setting the temperature controllers is met. Once the setting is met the temperature controllers shall remain at the setting for the FHR test and SUT.

A1.3.2.1.16 Allow the test unit to soak-in for a minimum period of 12 hours. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

A1.3.2.2 Gas-Fired Storage Water Heaters: First Hour Rating Test.

Note: Section A1.2 shall be completed before proceeding with this section

A1.3.2.2.1 Ensure the water heater's temperature controllers are set to the same setting when setting the outlet discharge temperature was determined.

A1.3.2.2.2 If the water heater is not presently operating, initiate a draw. Terminate the draw when the outlet temperature drops 15 °F below the maximum recorded outlet temperature or when cut-in occurs, whichever is longer. If the water heater is operating, wait for max. mean tank or for thirty-minutes, whichever is shorter, temperature after cut-out then initiate a draw. Terminate the draw when the outlet temperature drops 15 °F below the maximum recorded outlet temperature or when cut-in occurs, whichever is longer.

A1.3.2.2.3 T-mean max is defined as the temperature at which the rolling 60 second average (of readings taken every (5) seconds) T-mean temperature drops 0.05°F from the previous rolling average reading.

A1.3.2.2.4 Initiate the FHR test and data acquisition system. Conduct the test as detailed in Section 5.3.3 of 10 CFR Part 430 Subpart B Appendix E.

A1.3.2.2.5 Starting (15) seconds into the draw, record temperatures every (5) seconds, until the outlet water temperature drops 15°F below the maximum recorded outlet temperature.

A1.3.2.2.6 Allow the test unit to recover and draw, at cut-out, as many times as possible in one hour.

A1.3.2.2.7 Compile data and save report.

A1.3.2.2.8 Validate the test results.

A1.3.2.3 Gas-Fired Storage Water Heaters: Simulated Use Test.

A1.3.2.3.1 Manifold pressure shall be monitored throughout the test to detect improper gas valve operation or leaks.

A1.3.2.3.2 Refer to section 3.7 to determine the draw pattern to be used for the SUT.

A1.3.2.3.3 After the FHR test, turn on the water heater and allow it to fully recover.

A1.3.2.3.4 The water heater shall sit idle for 1 hour prior to the start of the 24-hour SUT. No water can be withdrawn from the unit during this period.

A1.3.2.3.5 Initiate the 24-hour simulated use test and data acquisition system after the 1 hour idle period. Using the draw pattern determined in step A1.3.2.2, conduct the test as detailed in Section 5.4 of 10 CFR Part 430 Subpart B Appendix E.

A1.3.2.3.6 Compile data and print report.

A1.3.2.3.7 Validate the test results.

A1.3.3 Oil-Fired Storage Water Heaters:

A1.3.3.1 Test Setup

Note: Section A1.2 shall be followed prior to proceeding to this section.

A1.3.3.1.1 Install the fuel line quick connect fitting.

A1.3.3.1.2 Install a pressure gauge.

A1.3.3.1.3 Install the electrical sensing leads.

A1.3.3.1.4 Connect the fuel supply line.

A1.3.3.1.5 Fill the water heater and test it for leaks at a minimum pressure of 40 psi. Isolate the water heater from the expansion tank by closing a ball valve between the two. The pressure inside the tank must be monitored to see if it changes over a period of 10 minutes. The starting and ending pressures shall be recorded.

A1.3.3.1.6 Turn the water heater on and check the entire fuel train for leaks by confirming that the fuel stream contains no bubbles while priming the oil pump.

A1.3.3.1.7 Using the pressure gage, verify the pump is operating within the manufacturer's specifications and adjust only if necessary.

A1.3.3.1.8 After the burner has been on for 10 minutes, check the input rate. It must be within $\pm 2\%$ of the rated value.

A1.3.3.1.9 Adjust the burner for minimum stack, or over fire draft, as outlined in the manufacturer's instructions.

A1.3.3.1.10 Without exceeding a #1 smoke, the CO₂ level shall be adjusted, as outlined in the manufacturer's instructions.

A1.3.3.1.11 Install unit on test station, connect the fuel supply, ambient, tank, inlet and outlet thermocouples, current sensors, and power cord. Seal any gaps in water heater jacket due to sensor leads to minimize heat loss. At no time shall the unit be disconnected from its energy supply for more than (1) hour when transferring stations.

A1.3.3.1.12 Setting the outlet discharge temperature procedure: Drain and refill with supply water at 58 \pm 2°F. Initiate operation of water heater. After cut-out, initiate a draw based on part 1, 2, or 3 below. Document thermostat setting by photographing the position of the thermostat and record the maximum outlet temperature on the test report.

(1) For storage volumes less than 20 gallons. After cutout initiate a draw of 1.0 gpm \pm .25 gpm for 2 minutes. Starting 15 seconds after start of draw and every 15 second interval record the outlet temperature. Determine if the maximum outlet temperature is within the range of 125 \pm 5F. If not turn heater off adjust thermostat drain and refill the tank with supply water then repeat the 2 minute outlet temperature test.

(2) For storage volumes greater than and equal to 20 gallons. After cutout initiate a draw of 1.7 gpm +/- .25 gpm for 5 minutes. Starting 15 seconds after start of draw and every 15 second interval record the outlet temperature. Determine if the maximum outlet temperature is within the range of 125 +/- 5F. If not turn heater off adjust thermostat drain and refill the tank with supply water then repeat the 5 minute outlet temperature test.

(3) For flow activated water heaters. At full input rating or maximum fire set the outlet discharge temperature to 125 +/- 5F. If the heater cannot provide this condition at 1.7 gpm +/- .25gpm then adjust flow rate to achieve 125 +/- 5F outlet temperature. The adjusted flow rate is the flow rate to be used during the maximum gpm test and simulated use test.

(4) Tanks with Two or More Temperature Controllers. Verify the temperature controller set-point while removing water in accordance with the procedure set forth for the First Hour rating test.

(a) At least 50 percent of the water drawn during the first draw of the First Hour rating test procedure shall be delivered at a temperature of 125 °F ± 5 °F (51.7 °C ± 2.8°C).

(b) No water is delivered above 130 °F (54.4 °C) during First Hour rating test.

(c) The delivery temperature measured 15 seconds after commencement of each draw begun prior to an elapsed time of 60 minutes from the start of the test shall be at 125°F ± 5°F (51.7 °C ± 2.8 °C).

A1.3.3.1.13 If these conditions are not met, turn off the water heater, adjust the temperature controllers and then drain and refill the tank with supply water. Repeat A1.3.3.1.12 until the criteria for setting the temperature controllers is met. Once the setting is met the temperature controllers shall remain at the setting for the FHR test and SUT.

A1.3.3.1.14 Allow the test unit to soak-in for a minimum period of 12 hours. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

A1.3.3.2 *Oil-Fired Storage Water Heaters: First Hour Rating Test.*

Note: Section A1.2 shall be completed before proceeding with this section

A1.3.3.2.1 Ensure the water heater's temperature controllers are set to the same setting when setting the outlet discharge temperature was determined.

A1.3.3.2.2 If the water heater is not presently operating, initiate a draw. Terminate the draw when the outlet temperature drops 15 °F below the maximum recorded outlet temperature or when cut-in occurs, whichever is longer. If the water heater is operating, wait for max. mean tank or for thirty-minutes, whichever is shorter, temperature after cut-out then initiate a draw. Terminate the draw when the outlet temperature drops 15 °F below the maximum recorded outlet temperature or when cut-in occurs, whichever is longer.

A1.3.3.2.3 Initiate the FHR test and data acquisition system. Conduct the test as detailed in Section 5.3.3 of 10 CFR Part 430 Subpart B Appendix E.

A1.3.3.2.4 Starting (15) seconds into the draw, record temperatures every (5) seconds, until the outlet water temperature drops 15°F below the maximum recorded outlet temperature.

A1.3.3.2.5 Allow the test unit to recover and draw, at cut-out, as many times as possible in one hour.

A1.3.3.2.6 Compile data and save report.

A1.3.3.2.7 Validate the test results.

A1.3.3.3 Oil-Fired Storage Water Heaters: Simulated Use Test.

A1.3.3.3.1 Manifold pressure shall be monitored throughout the test to detect improper gas valve operation or leaks.

A1.3.3.3.2 Refer to section 3.7 to determine the draw pattern to be used for the SUT.

A1.3.3.3.3 After the FHR test turn on the water heater and allow it to fully recover.

A1.3.3.3.4 The water heater shall sit idle for 1 hour prior to the start of the 24-hour SUT. No water can be withdrawn from the unit during this period.

A1.3.3.3.5 Initiate the 24-hour simulated use test and data acquisition system after the 1 hour idle period. Using the draw pattern determined in step **A1.3.3.2**, conduct the test as detailed in Section 5.4 of 10 CFR Part 430 Subpart B Appendix E.

A1.3.3.3.6 Compile data and save report.

A1.3.3.3.7 Validate the test results.

A1.3.4 Gas-Fired Tankless Water Heaters:

Note: Section A1.2, Test Setup shall be followed prior to proceeding to this section.

A1.3.4.1 Test Setup

A1.3.4.1.1 Install the gas line and the manifold pressure line.

A1.3.4.1.2 Connect the gas meter.

A1.3.4.1.3 Inlet and outlet thermocouples shall be located as indicated in Figure A3.

A1.3.4.1.4 Fill the water heater and test for leaks at a minimum pressure of 40 psi.

A1.3.4.1.5 Turn on the water heater.

A1.3.4.1.6 Allow water to flow through the unit to allow the burner to fire at its maximum input rate.

A1.3.4.1.7 Check the entire gas train for leaks using a liquid leak detector or combustible gas detector.

A1.3.4.1.8 Check the input rate. It must be within $\pm 2\%$ of its maximum rated value using the method detailed in ANSI Z21.10.3. The manifold pressure shall be within $\pm 10\%$ of that printed on the rating plate.

A1.3.4.1.9 If input rate is not within $\pm 2\%$ of the maximum rated value, the operator shall adjust manifold pressure, assuming he stays within the allowed $\pm 10\%$ to attempt to achieve $\pm 2\%$ of the rated input.

A1.3.4.1.10 If adjusting the manifold pressure does not achieve the rated input or it cannot be adjusted, the operator shall re-orifice the unit using (an) alternate orifice(s) supplied by the manufacturer.

Note: Manufacturers are to supply test facility with a selection of orifices for use at the test facility. When a test unit is re-orificed, the test facility will notify the manufacturer of the alternate orifice(s) used, and manufacturer shall re-supply the test facility with a replacement orifice(s).

A1.3.4.1.11 The operator shall check the entire gas train for leaks after re-orificing the water heater. Any leaks discovered shall be fixed.

A1.3.4.1.12 Combustion shall only be checked when the water heater is very clearly operating abnormally (e.g. CO alarms are going off, producing smoke (when it is not supposed to), flames are shooting out of the vent, etc.).

A1.3.4.1.13 Set the water heater to 125°F. If the water heater cannot be set exactly at 125°F, the unit shall be set within $125 \pm 5^\circ\text{F}$.

A1.3.4.1.14 Draw water from the unit for approximately 30 minutes. Allow the test unit to soak-in for a minimum period of (4) hours. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

A1.3.4.1.15 After soak-in period, turn off gas. Disconnect gas supply connections if transferring between a warm-up station and a test station. At no time shall the unit be disconnected from its energy supply for more than (1) hour.

A1.3.4.1.16 Ensure the water supply temperature is $58^\circ\text{F} \pm 2^\circ\text{F}$.

A1.3.4.1.17 Set the outlet discharge temperature based on below.

For flow activated water heaters. At full input rating or maximum fire set the outlet discharge temperature to $125 \pm 5^\circ\text{F}$. If the heater cannot provide this condition at 1.7 gpm ± 0.25 gpm then adjust flow rate to achieve $125 \pm 5^\circ\text{F}$ outlet temperature. The adjusted flow rate is the flow rate to be used during the maximum gpm test and simulated use test.

A1.3.4.2 Gas-Fired Tankless Water Heaters: Maximum GPM Rating Test.

Note: Section 4.2, Test Setup shall be followed prior to proceeding to this section.

A1.3.4.2.1 Establish a target flow for the “Maximum GPM Rating” test for a period of 5 minutes or until the conditions stabilize, whichever is greater.

A1.3.4.2.2 Initiate the “Maximum GPM Rating” test. Conduct the test as detailed in section 5.3.2 of 10 CFR Part 430 Subpart B Appendix E.

A1.3.4.2.3 Draw water from the test unit for 10 minutes. Using a water meter, or an alternative means, measure the amount of water drawn over the course of the test. Throughout the test, record the inlet and outlet water temperatures.

A1.3.4.2.4 Compile data and save report.

A1.3.4.2.5 Validate the test results.

A1.3.4.3 Gas-Fired Tankless Water Heaters: Simulated Use Test.

Note: Section 4.2, Test Setup shall be followed prior to proceeding to this section.

A1.3.4.3.1 Refer to section 3.7 to determine the draw pattern to be used for the SUT.

A1.3.4.3.2 The water heater must sit in an idle state for (1) hour prior to the start of the SUT. The water heater controls are active during this period but no water is withdrawn.

A1.3.4.3.3 Manifold pressure shall be monitored throughout the test to detect improper gas valve operation or leaks.

A1.3.4.3.4 Initiate 24-hour SUT and the data acquisition system. Conduct the test as detailed in Section 5.4.3 of 10 CFR Part 430 Subpart B Appendix E.

A1.3.4.3.5 Compile data and save report.

A1.3.4.3.6 Validate the test results.

A1.3.5 Electric Tankless Water Heaters:

Note: Section A1.2, Test Setup shall be followed prior to proceeding to this section.

A1.3.5.1 Test Setup

A1.3.5.1.1 Connect a power cord if one is not provided.

A1.3.5.1.2 Inlet and outlet thermocouples shall be located as indicated in Figures A1 through A8.

A1.3.5.1.3 Fill the water heater and test for leaks at a minimum pressure of 40 psi.

A1.3.5.1.4 Turn on the water heater.

A1.3.5.1.5 Allow water to flow through the unit to allow the heater to operate at its maximum input rate.

A1.3.5.1.6 Set the water heater thermostat to 125°F. If the water heater cannot be set exactly at 125°F, the unit shall be set within 125± 5°F.

A1.3.5.1.7 Install the unit in a test station. Connect the ambient, inlet and outlet thermocouples, any current sensors, and power cords.

A1.3.5.1.8 Ensure the water supply temperature is 58°F ± 2°F.

A1.3.5.1.9 Set the outlet discharge temperature based below.

(1) For flow activated water heaters. At full input rating or maximum fire set the outlet discharge temperature to 125 +/-5F. If the heater cannot provide this condition at 1.7 gpm +/- .25gpm then adjust flow rate to achieve 125 +/- 5F outlet temperature. The adjusted flow rate is the flow rate to be used during the maximum gpm test and simulated use test. Document thermostat setting by photographing the position of the thermostat and record the maximum outlet temperature on the test report.

A1.3.5.1.10 Draw water from the unit for approximately 30 minutes. Allow the test unit to soak-in for a minimum period of 4 hours. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

A1.3.5.2 Electric Tankless Water Heaters: Maximum GPM Rating Test.

Note: Section A1.2, Test Setup shall be followed prior to proceeding to this section.

A1.3.5.2.1 Establish a target flow for the “Maximum GPM Rating” test for a period of 5 minutes or until the conditions stabilize, whichever is greater.

A1.3.5.2.2 Initiate the “Maximum GPM Rating” test. Conduct the test as detailed in Section 5.3.2 of 10 CFR Part 430 Subpart B Appendix E.

A1.3.5.2.3 Draw water from the test unit for 10 minutes. Using a water meter, or an alternative means, measure the amount of water drawn over the course of the test. Throughout the test, record the inlet and outlet water temperatures.

A1.3.5.2.4 Compile data and save report.

A1.3.5.2.5 Validate the test results.

A1.3.5.3 Electric Tankless Water Heaters: Simulated Use Test:

Note: Section A1.2, Test Setup shall be followed prior to proceeding to this section.

A1.3.5.3.1 Initiate the 24-hour simulated use test and the data acquisition system. Conduct the test as detailed in Section 5.2.4 of 10 CFR Part 430 Subpart B Appendix E.

A1.3.5.3.2 Refer to section 3.7 to determine the draw pattern to be used for the SUT.

A1.3.5.3.3 The water heater must sit in an idle state for (1) hour prior to the start of the SUT. The water heater controls are active during this period but no water is withdrawn.

A1.3.5.3.4 Initiate 24-hour SUT and the data acquisition system. Conduct the test as detailed in Section 5.4.3 of 10 CFR Part 430 Subpart B Appendix E.

A1.3.5.3.5 Compile data and save report.

A1.3.5.3.6 Validate the test results.

A1.4 Calculation Methods.

A1.4.1 Heating Value Calculation Method for Gas-Fired Water Heaters.

Fossil fuel Btu on gas-fired water heaters are calculated using Equation 1 or 1A.

$$Q = HHV \cdot [(V \cdot \text{Corr}) \cdot (520/(460 + T)) \cdot (B + P \cdot 0.0735559) / 30] \quad 1$$

Where:

B = Barometric pressure, in Hg
 Corr = Meter correction (meter correction gets applied here because it changes depending on rate)
 HHV = Higher heating value, Btu per cubic-foot
 P = Gas pressure, in H₂O WC
 T = Gas temperature, °F
 V = Volume of gas, cubic feet

Fossil fuel BTU on gasfired appliances, Qt

$$Q_t = \sum_{V_i=0}^{V_i=t} HHV_t * [(V_i * \text{Corr}_t) * \left(\frac{520}{(460+T_t)}\right) * \left(\frac{B_t+P_t*0.073559}{30}\right)] \quad 1A$$

Where:

B_t = Barometric pressure update at a minimum of 180 seconds, in Hg
 Corr_t = Meter correction, constant.
 HHV_t = HHV updated at a minimum of 30 minutes, Btu/ft³
 P_t = Gas pressure updated at a minimum of 60 seconds, in. H₂O
 T_t = Gas temperature updated at a minimum of 60 seconds, °F
 V_i = Uncorrected Gas consumption, ft³
 t = time of test.

Fossil fuel Btu on gas-fired water heaters for the 24-hr simulated use test (SUT) are determined using Equation 2 or 2A.

1. Q_t = Total fossil fuel Btu consumed during the entire 24-hr SUT

$$Q_t = HHV_t \cdot [(V_t \cdot \text{Corr}) \cdot (520/(460 + T_t)) \cdot (B_t + P_t \cdot 0.0735559) / 30] \quad 2$$

Where:

B_t = Average barometric pressure in Hg during entire 24-hr SUT
 Corr = Meter correction
 HHV_t = Average higher heating value during entire 24-hr SUT, Btu per cubic-foot
 P_t = Average Gas pressure in WC during entire 24-hr SUT
 T_t = Average Gas temperature °F during entire 24-hr SUT
 V_t = Volume of gas consumed during entire 24-hr SUT, cubic-feet

Fossil fuel Btu on a gas-fired appliance, Qt

$$Q_t = \sum_{V_i=0}^{V_i=t} HHV_t * [(V_i * \text{Corr}_t) * \left(\frac{520}{(460+T_t)}\right) * \left(\frac{B_t+P_t*0.073559}{30}\right)] \quad 2A$$

B_t = Barometric pressure update at a minimum of 180 seconds, in. Hg
 $Corr_t$ = Meter correction, constant.
 HHV_t = HHV updated at a minimum of 30 minutes, Btu/ft³
 P_t = Gas pressure updated at a minimum of 60 seconds, in. H₂O
 T_t = Gas temperature updated at a minimum of 60 seconds, °F
 V_i = Uncorrected Gas consumption, ft³
 t = time of test.

2. Q_r = Storage tank and instantaneous water heater fossil fuel Btu consumed from the start of the SUT ($t=0$) to the cut-out following the first recovery period, recovery efficiency using Equation 3 or 3A.

$$Q_r = HHV_r \cdot [(V_r \cdot Corr) \cdot (520/(460 + T_r) \cdot (B_r + P_r \cdot 0.073559) / 30)] \quad 3$$

Where:

B_r = Average barometric pressure in Hg during recovery efficiency
 $Corr$ = Meter correction
 HHV_r = Average higher heating value during recovery efficiency, Btu per cubic foot
 P_r = Average Gas pressure in WC during recovery efficiency
 T_r = Average Gas temperature, °F during recovery efficiency
 V_r = Volume of gas consumed during recovery efficiency, cubic-feet

Fossil fuel Btu on a gas-fired appliance, Q_t

$$Q_t = \sum_{V_i=0}^{V_i=t} HHV_t * [(V_i * Corrt) * \left(\frac{520}{(460+T_t)}\right) * \left(\frac{B_t+P_t*0.073559}{30}\right)] \quad 3A$$

B_t = Barometric pressure update at a minimum of 180 seconds, in. Hg
 $Corr_t$ = Meter correction, constant.
 HHV_t = HHV updated at a minimum of 30 minutes, Btu/ft³
 P_t = Gas pressure updated at a minimum of 60 seconds, in. H₂O
 T_t = Gas temperature updated at a minimum of 60 seconds, °F
 V_i = Uncorrected Gas consumption, ft³
 t = time of test.

A1.4.2 Converting Volume (gal) to mass (lbm) using Equation 4 or 4A.

$$M_i = V_i \times \rho_i \quad 4$$

Where:

M_i = Mass withdrawn for the i^{th} draw ($i = 1$ to i_{th}), lbm
 V_i = Total volume water measured at the point where flow volume is measured, gal
 ρ_i = Density of the water based on water temperature measured at the point where the flow volume is measured, lb/gal

A1.4.3 Converting Volume (gal) at the inlet to volume at the outlet. This is required because in the DOE procedure all draws are based on gallons removed from the water heater not put into the water heater. V_o shall be used for tank determination, 1st hr. test, max gpm test and 24 hr. test.

For flow meters located on the inlet of the water heater. The total volume of water at the outlet, V_o

$$V_o = V_i \times \rho_i / \rho_o \quad 4A$$

Where:

V_i = Total volume water measured at the inlet, gal

ρ_i = Density of the water based on water temperature measured at inlet, lb/gal (using ASME steam table equation)

ρ_o = Density of the water based on water temperature measured at T_{out} , lb/gal (using ASME steam table equation)

A1.4.4 Converting Volume (gal) to mass (lbm) using Equation 5, M_o

$$M_o = V_o \times \rho_o \quad 5$$

V_o = Total volume water measured at the outlet, gal

ρ_o = Density of the water based on water temperature measured at T_{out} , lb/gal (using ASME steam table equation)

Section A2. Figures – Normative

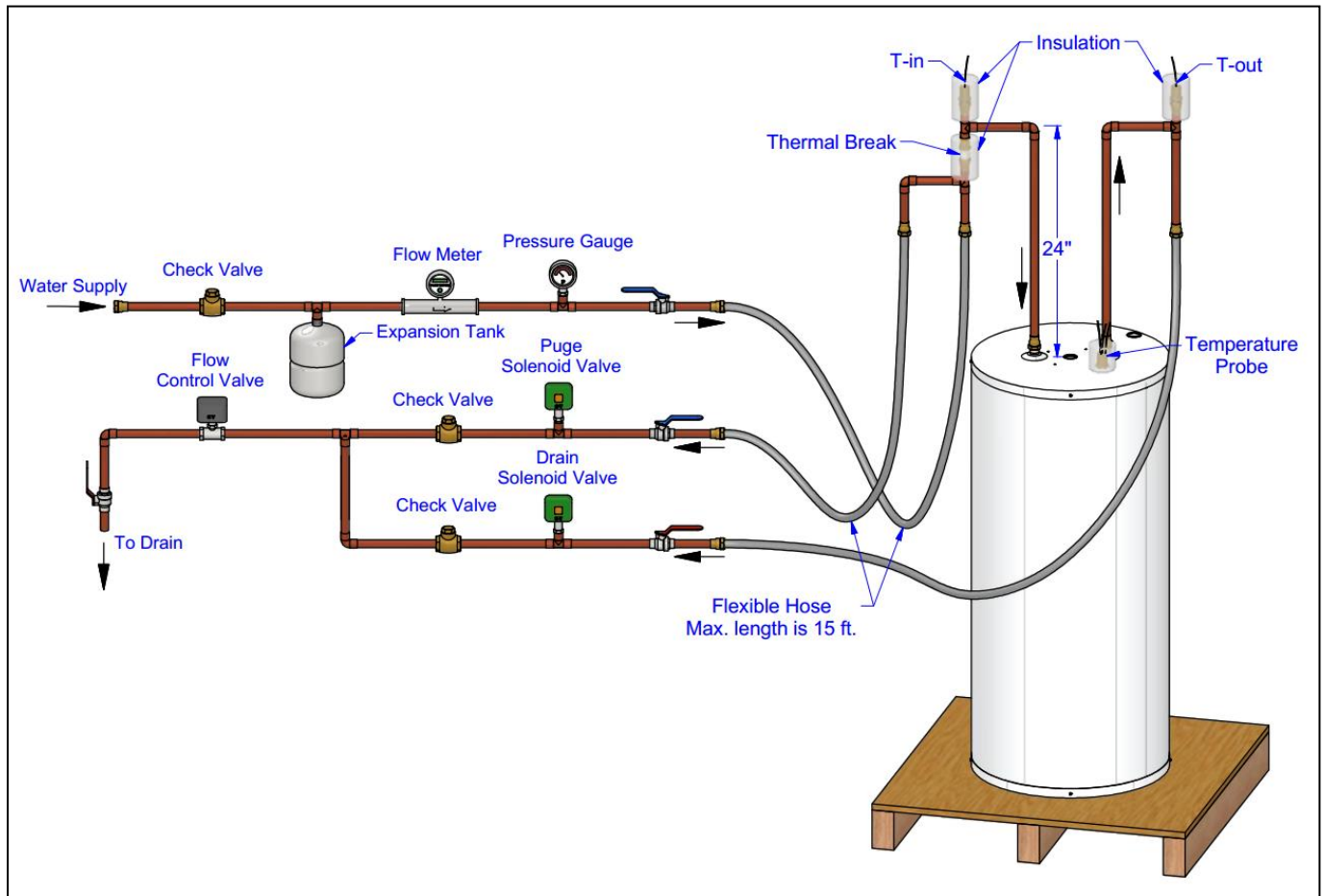


Figure A1. Residential, Top Inlet

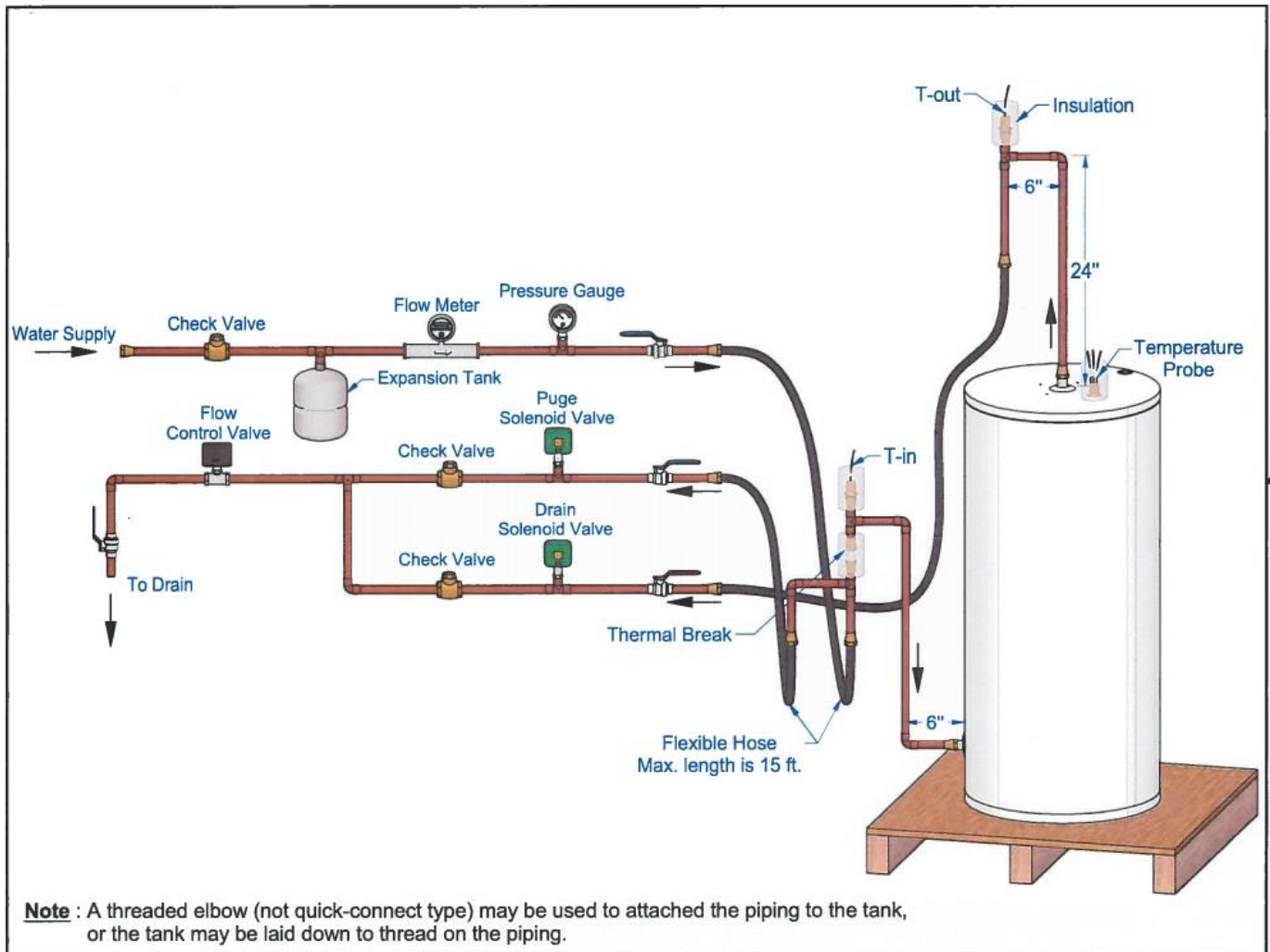


Figure A2A. Residential, Bottom Inlet, Top Outlet

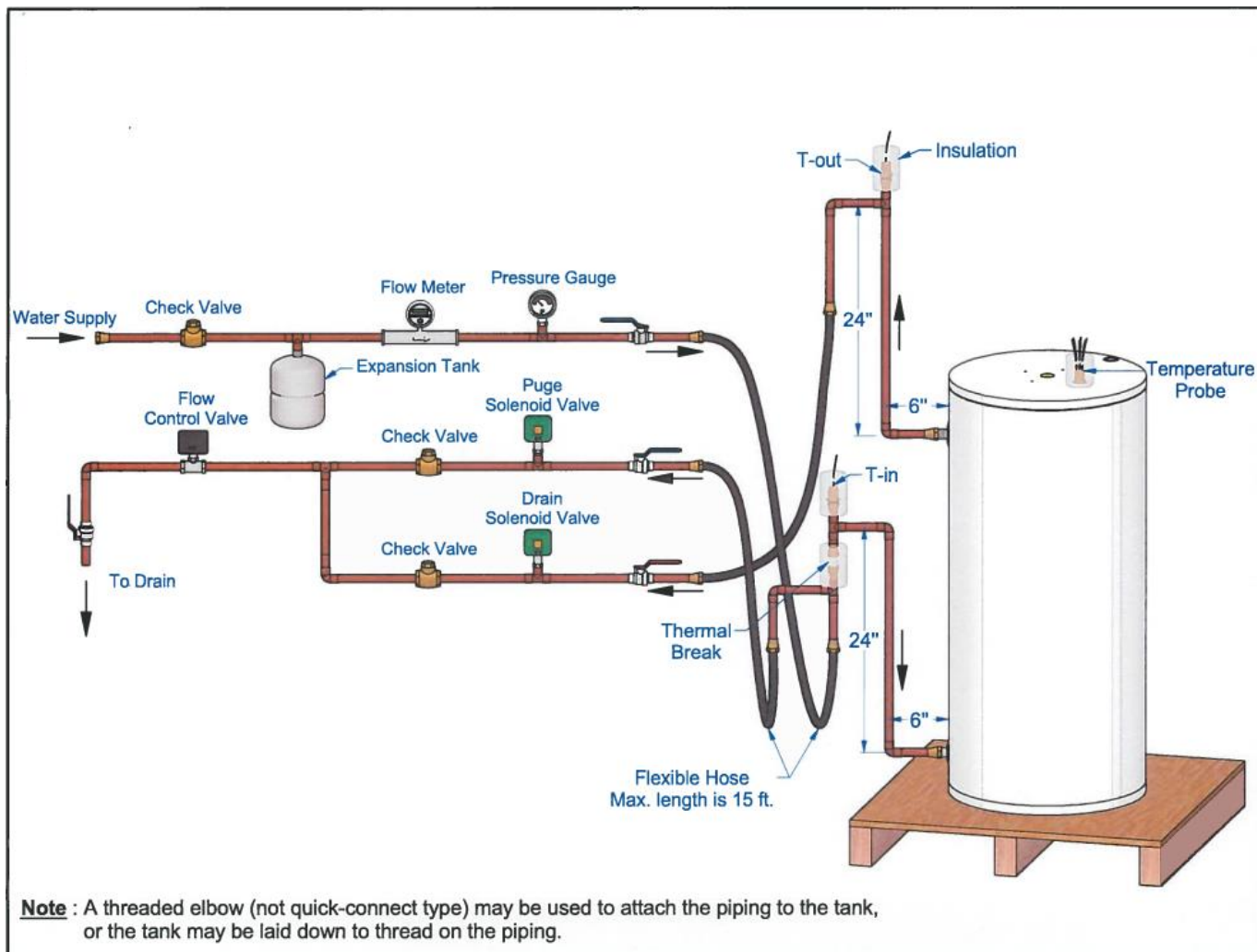


Figure A2B. Residential, Bottom Inlet, Side Outlet

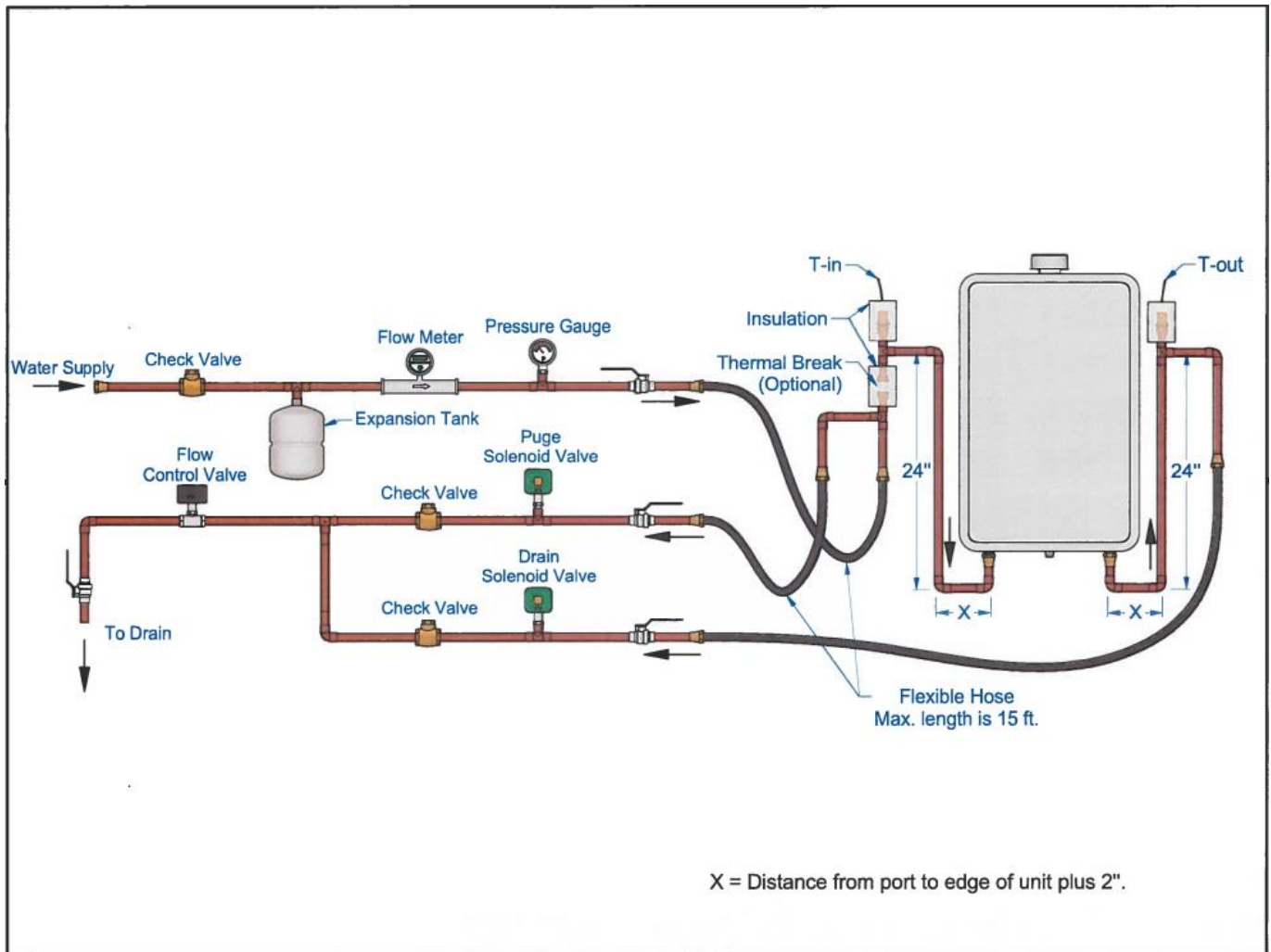


Figure A3A. Tankless, Bottom Inlet, Bottom Outlet

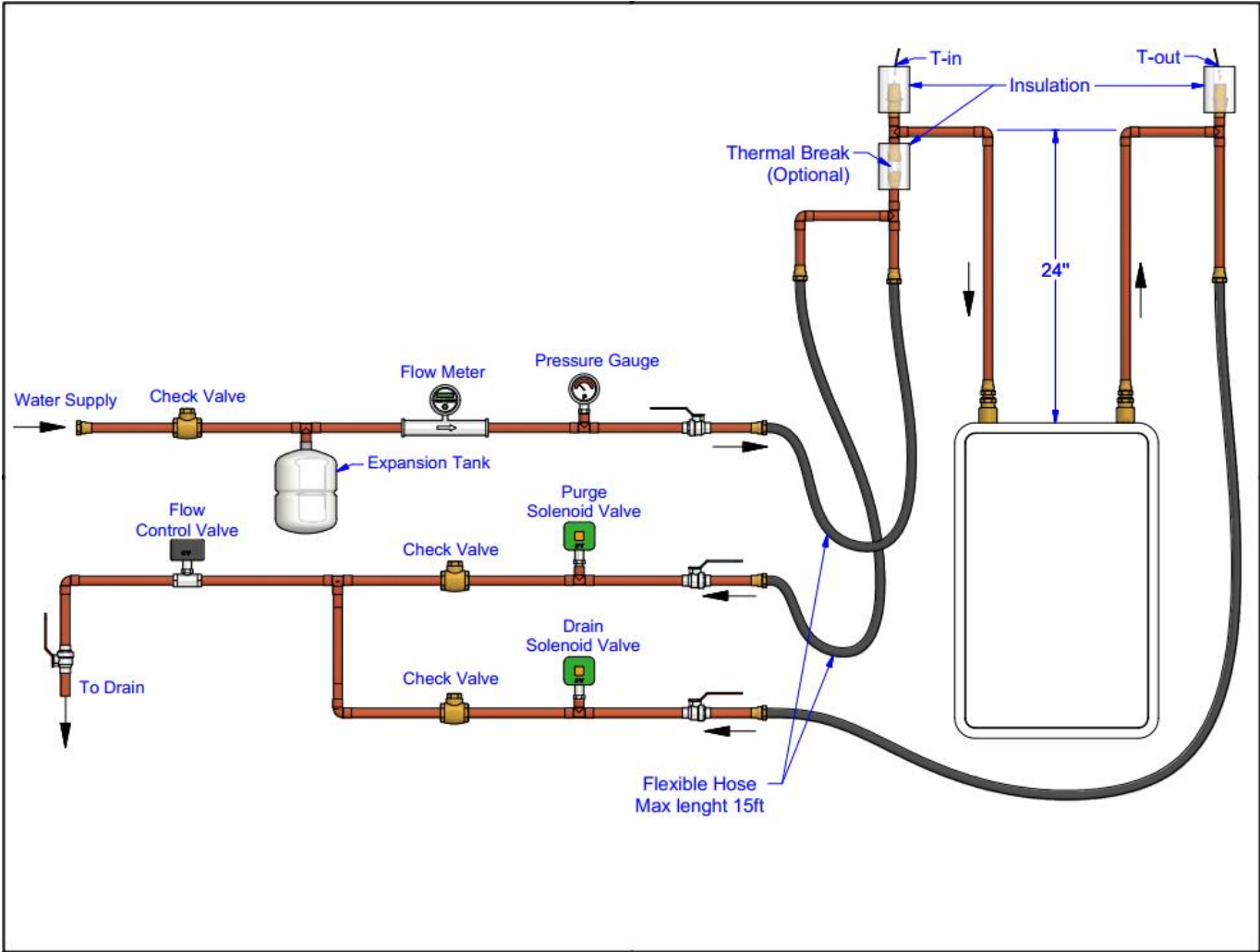


Figure A3B. Tankless, Top Inlet, Top Outlet

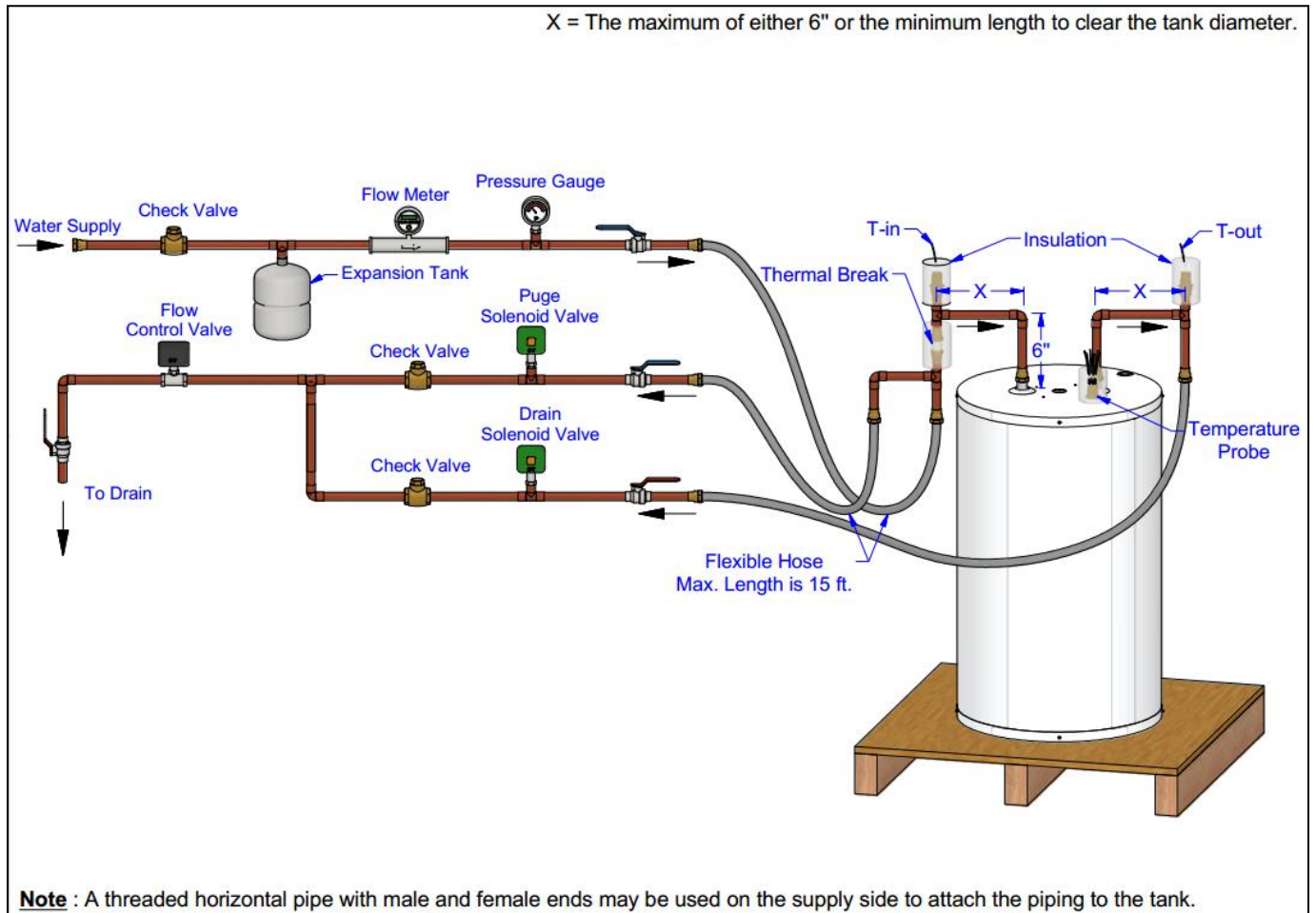


Figure A4. Compact, Top Inlet

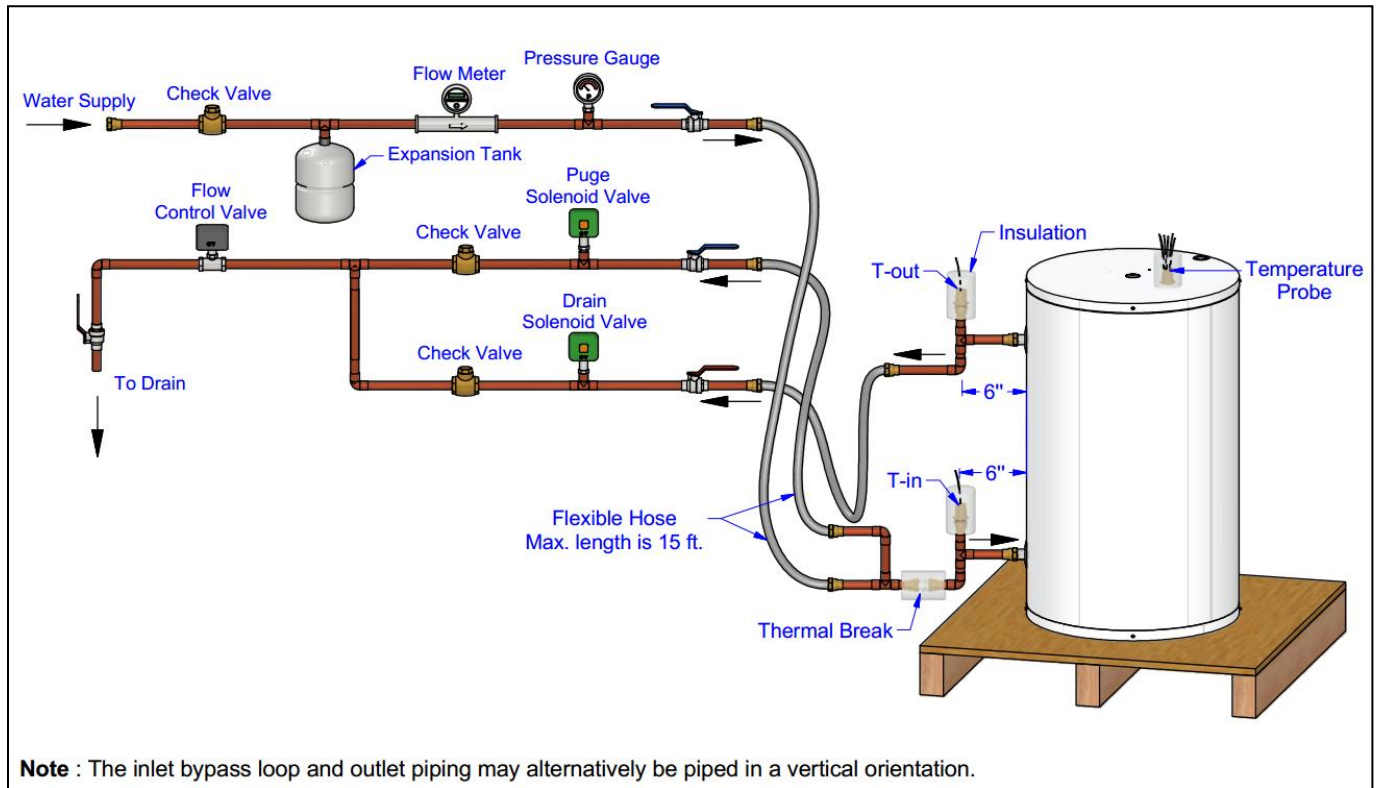


Figure A5. Compact, Bottom Inlet, Side Outlet

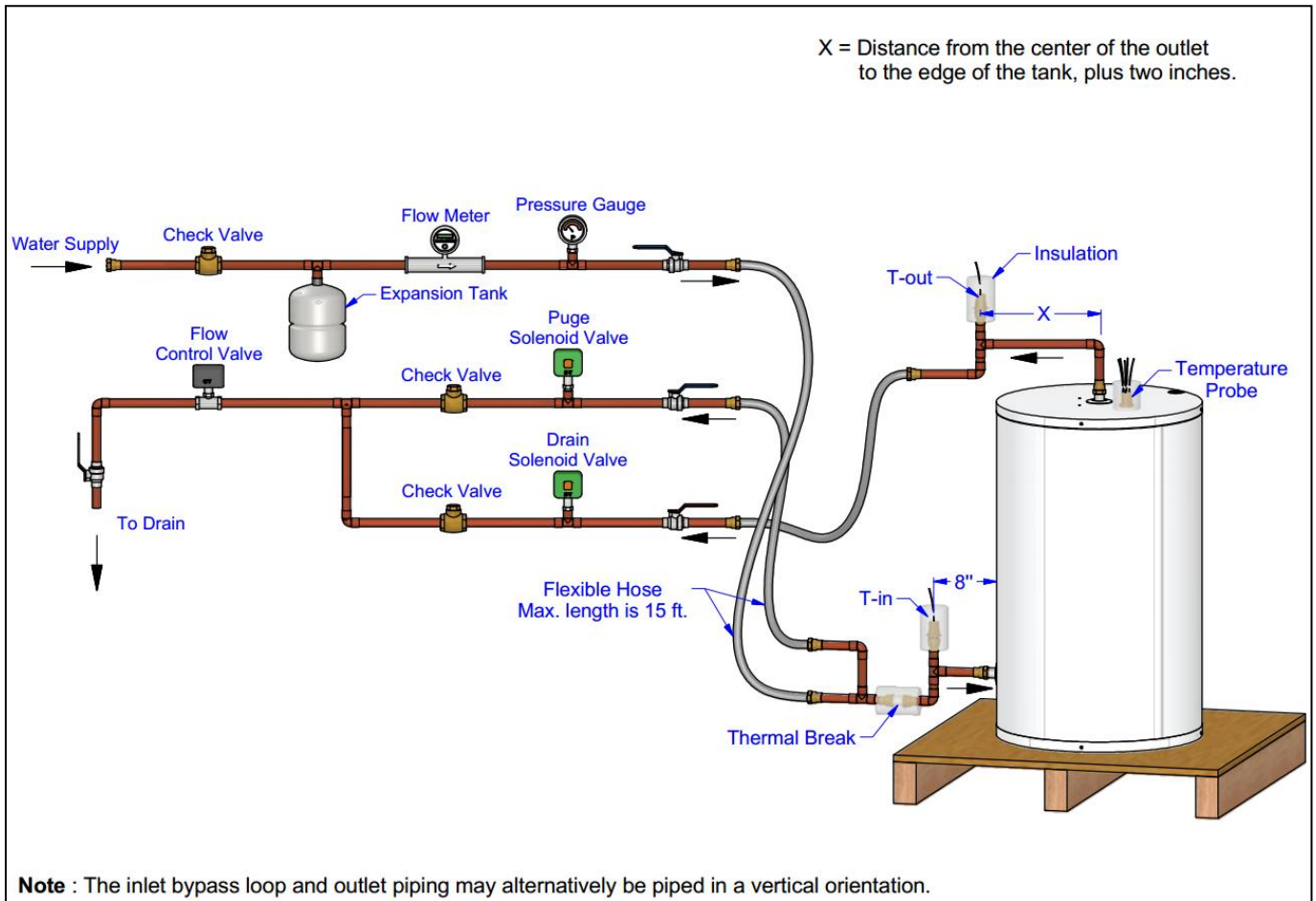


Figure A6. Compact, Bottom Inlet, Top Outlet

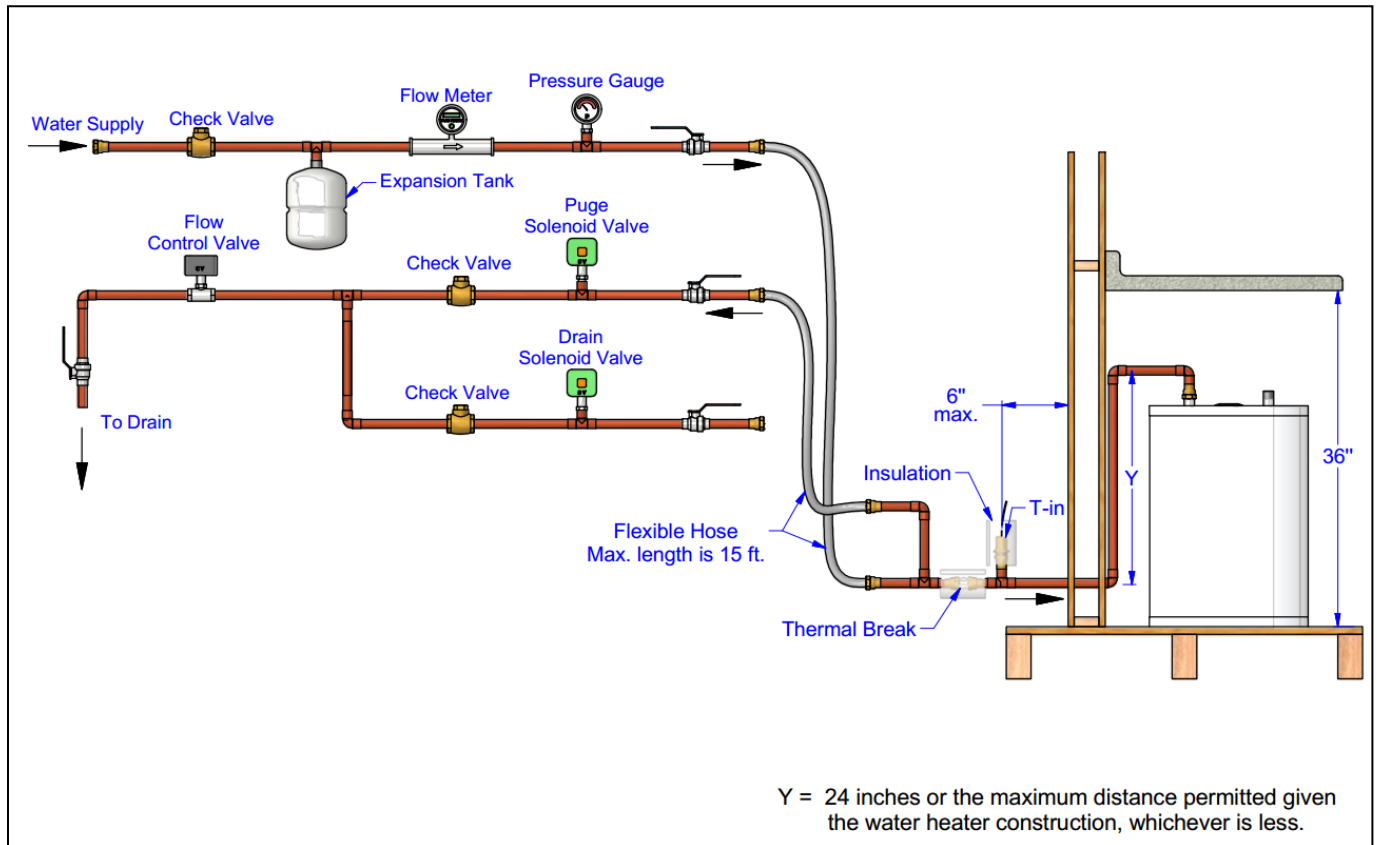


Figure A7A. Tabletop Water Heater Inlet Piping Diagram

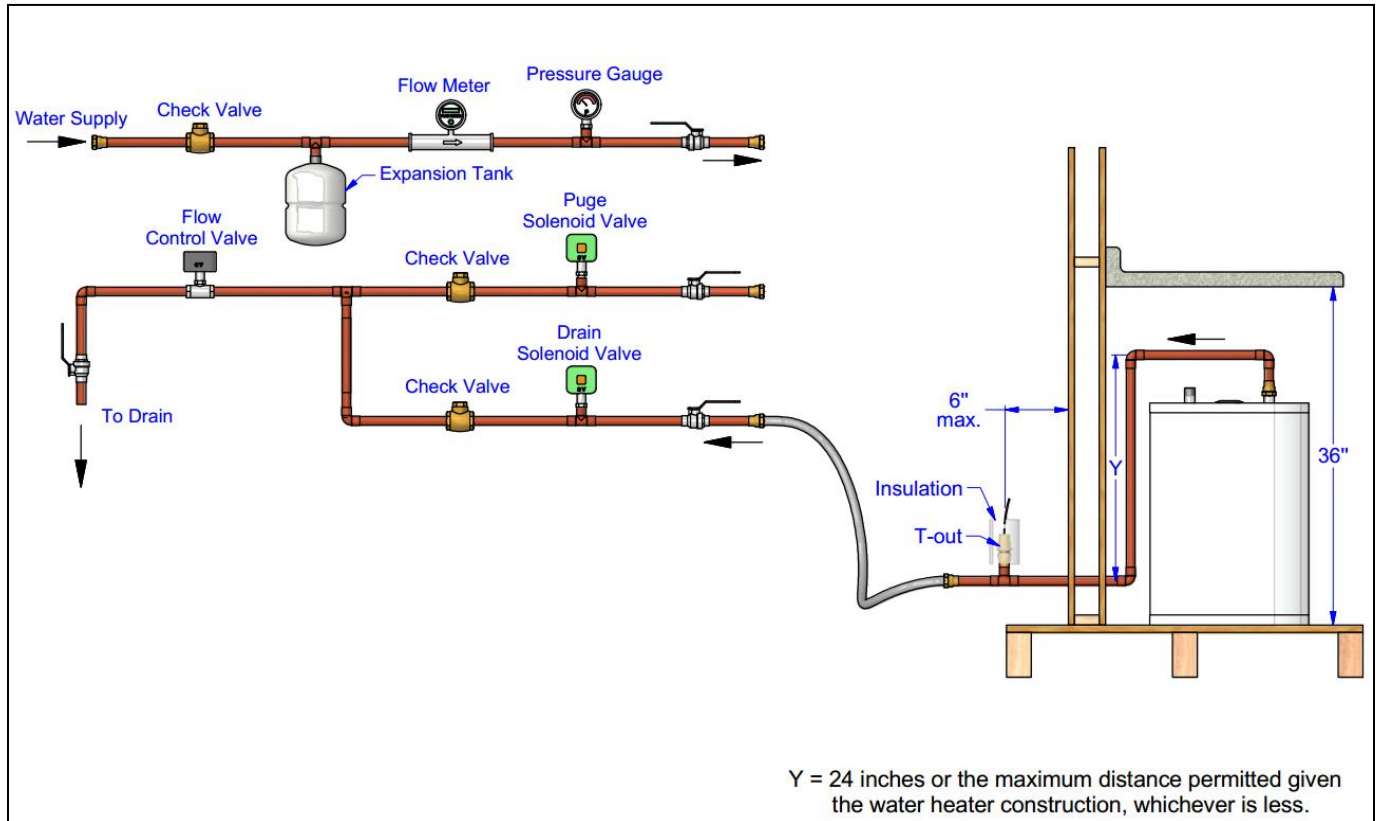


Figure A7B. Tabletop Water Heater Outlet Piping Diagram

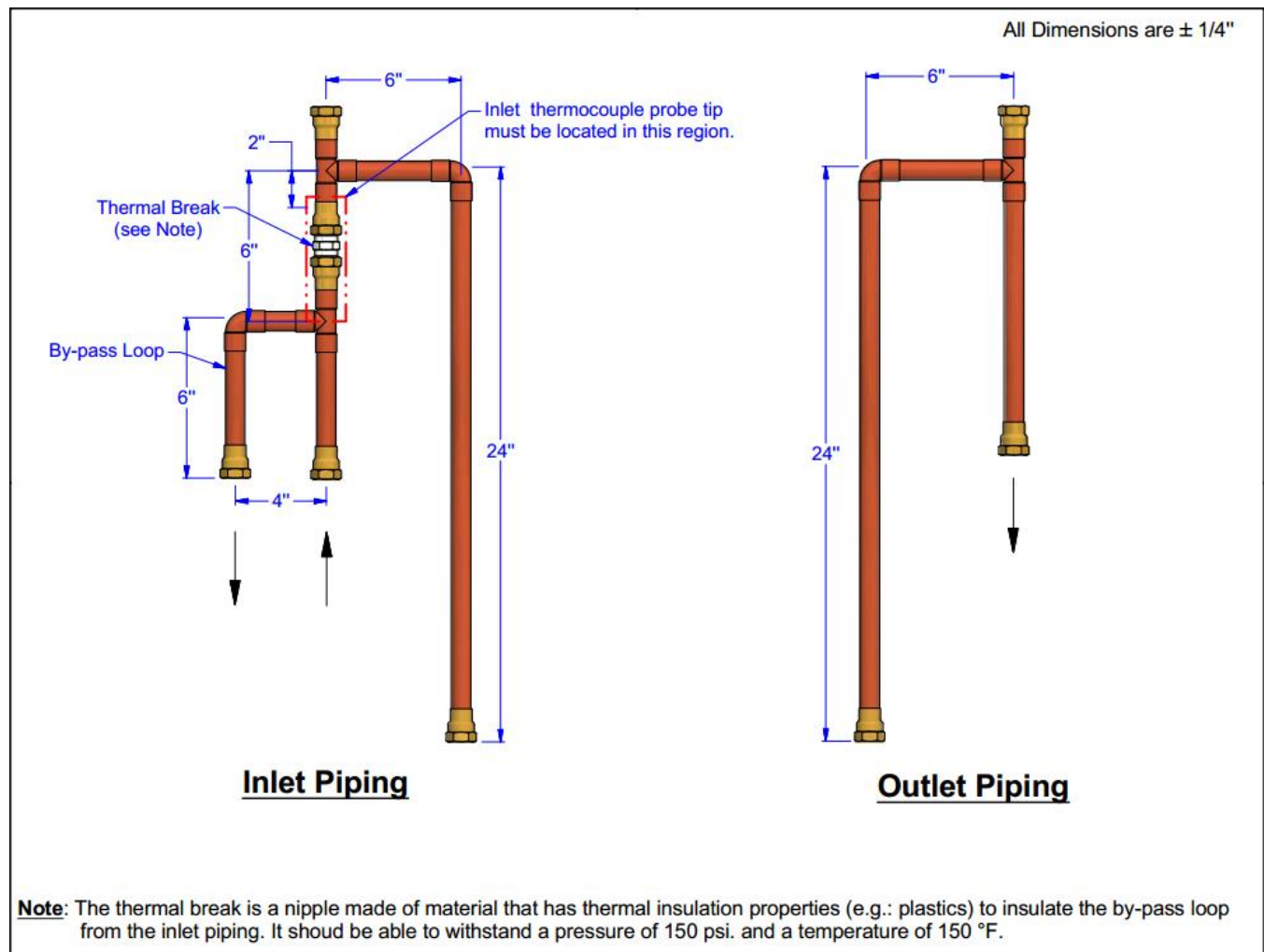
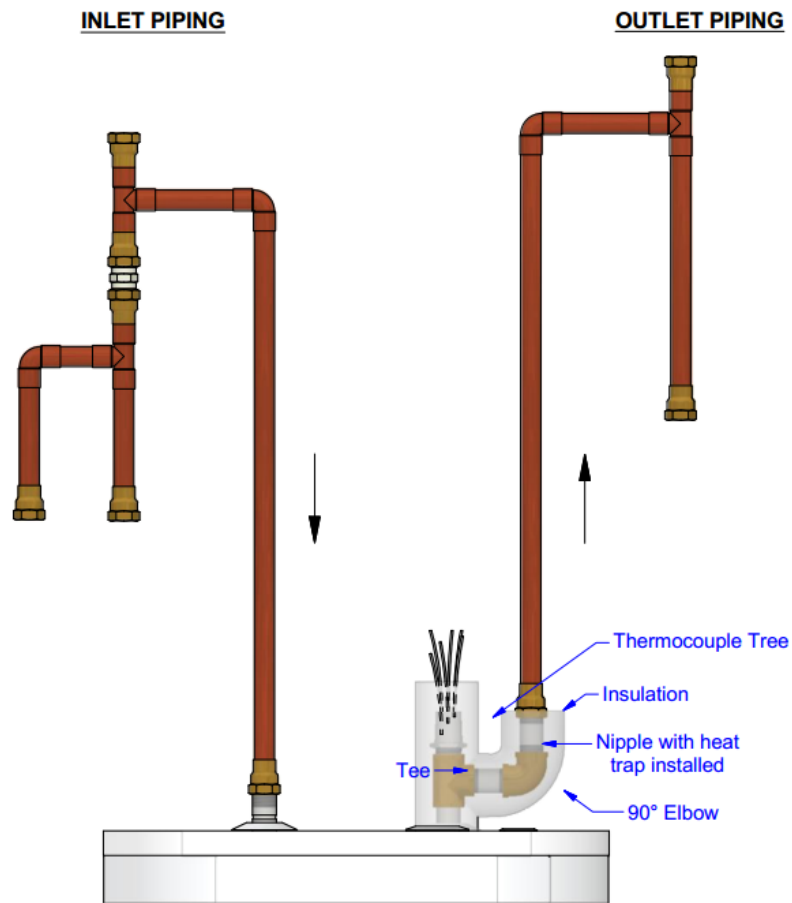


Figure A8A. Inlet and Outlet Piping

Set-up 1 using heat trap nipple.**Figure A8B. Inlet and Outlet Piping Set-up 1**

Set-up 2 using heat trap nipple.

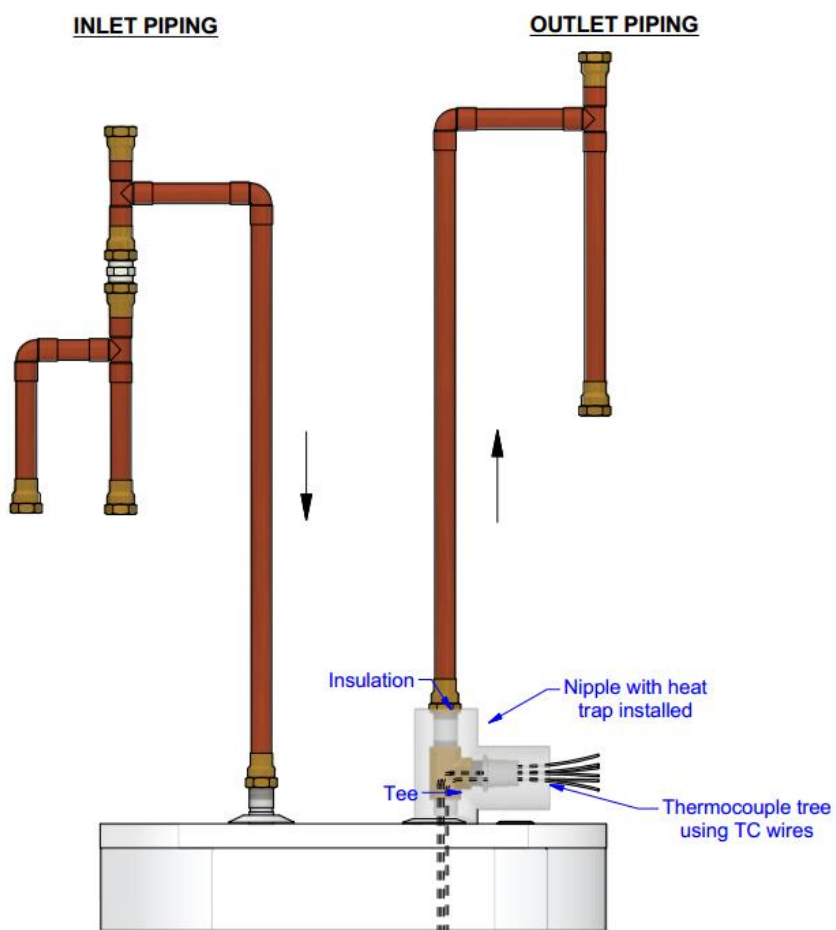


Figure A8C. Inlet and Outlet Piping Set-up 2

Section A3. Figures - Informative

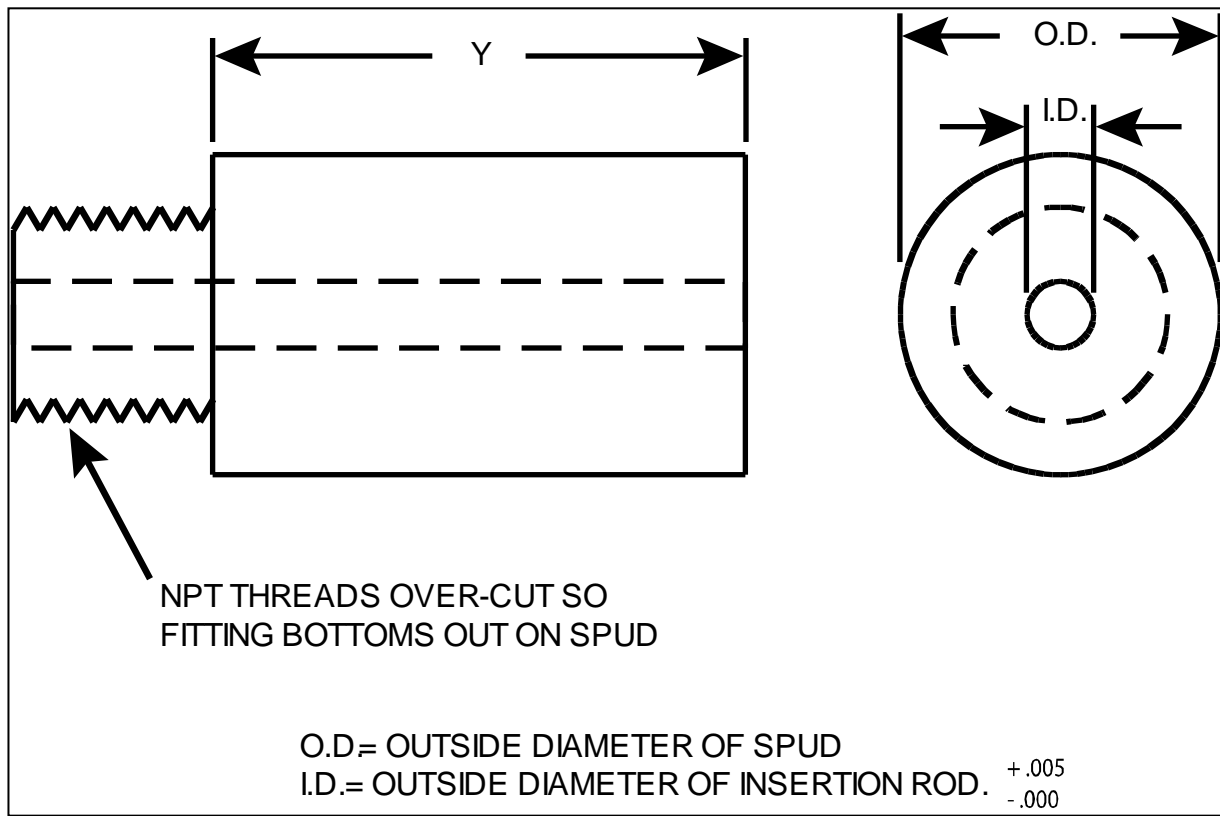


Figure A9. Tank Height Rod Fitting

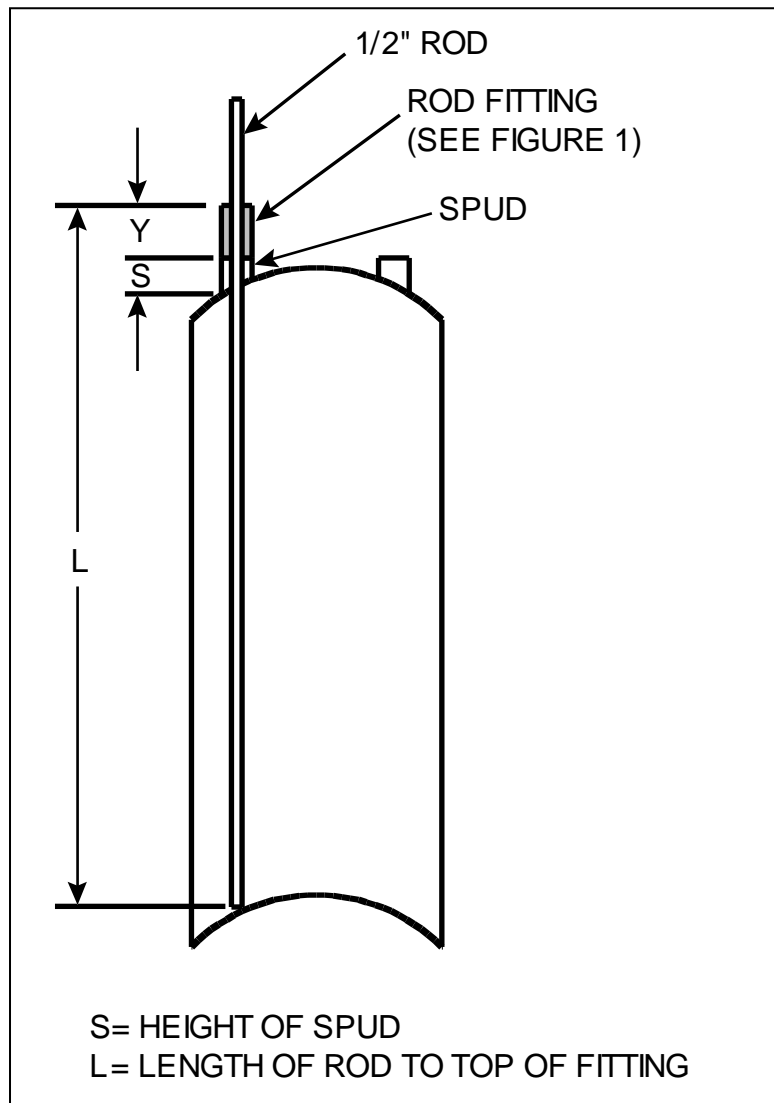


Figure 10. Tank Height Determination

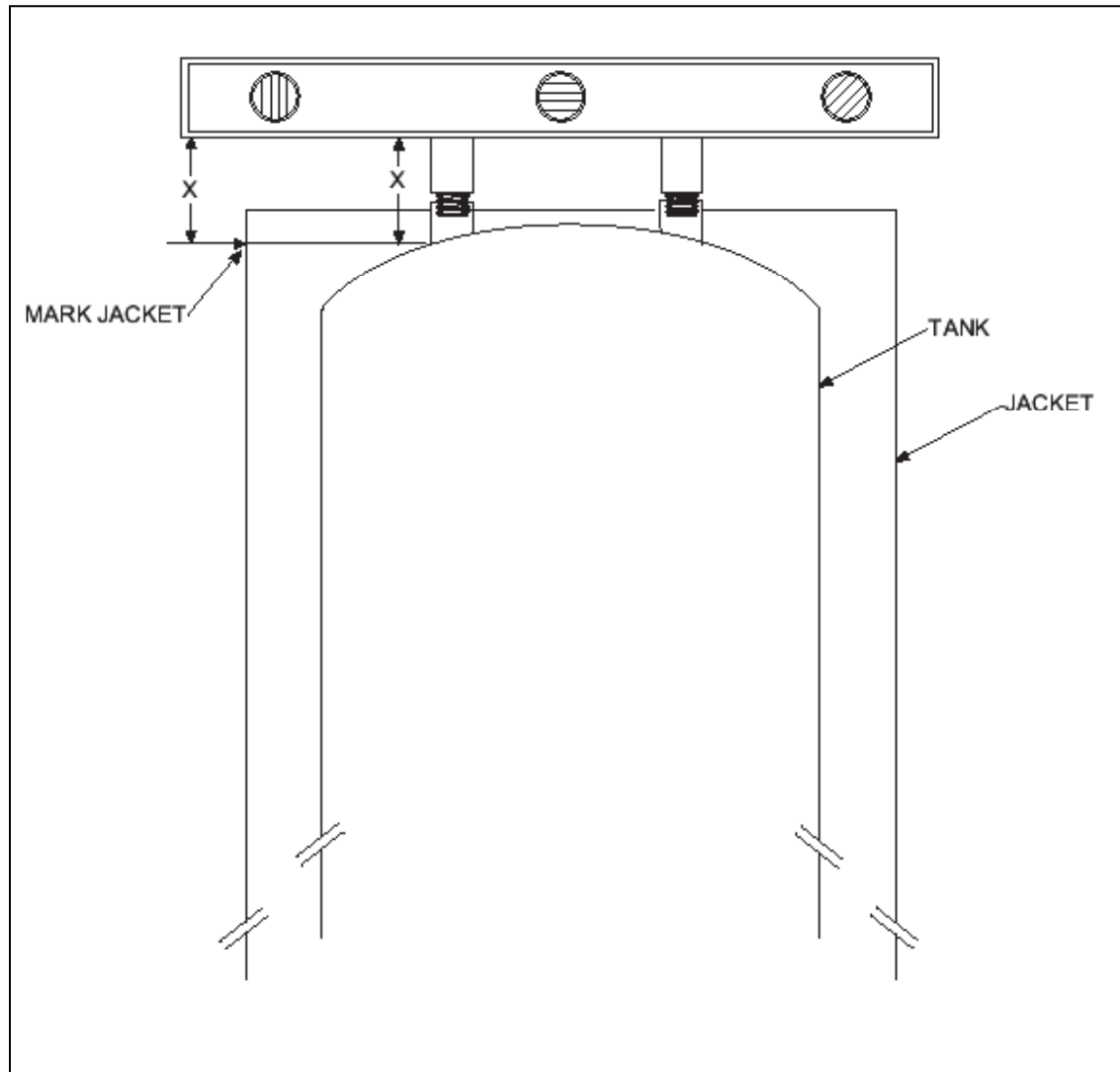


Figure 11. Marking Tank Height on Water Heater Jacket

Section A4. Standard Conversion - Informative

For conversion purposes, one may use either the ASME Int. Steam Tables Published in 2000 ASME Steam Tables are formulated under IAPWS-IF97 or the curve fit present below:

Curve Fit: Water Specific Heat vs. Temperature

2000 ASME Steam Tables (IAPWS-IF97)

$$C_p = -4.903944E-09T^3 + 2.584046E-06T^2 - 0.000375475T + 1.015074$$

$$R \text{ Squared} = 0.9973$$

Curve Fit: Water Density vs. Temperature

2000 ASME Steam Tables (IAPWS-IF97)

$$C_p = -7.36376E-5T^2 + 0.002427088T + 62.48442$$

$$R \text{ Squared} = 0.9999$$

Section A5. References - Informative

A5.1 ANSI Z21.10.1-2013/CSA 4.1-2013 - Gas water heaters - Volume I, storage water heaters with input ratings of 75,000 Btu per hour or less. CSA Group, 8501 East Pleasant Valley Road, Cleveland, Ohio 44131-5575.

A5.2 ASHRAEwiki, Terminology. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc, Web. 07 June 2013 <http://wiki.ashrae.org/>.

A5.3 International Steam Tables - Properties of Water and Steam based on the Industrial Formulation IAPWS-IF97, Second Edition, Wagner and Kretzschmar, Springer, February 6, 2008.

A5.4 ISO/IEC 17025:2005 - General requirements for the competence of testing and calibration laboratories. International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

A5.5 U.S. Department of Energy (DOE) Appendix E to Subpart B of 10 CFR Part 430 - Uniform Test Method for Measuring the Energy Consumption of Water Heaters, *Federal Register*, 63 FR 25996 (May 11, 1998).

APPENDIX B. ENERGY FACTOR TESTING GUIDELINE FOR ELECTRIC, GAS, AND OIL-FIRED RESIDENTIAL WATER HEATERS

Note: This document is an adjunct to the Department of Energy (DOE) test method for determining the energy efficiency of residential water heaters as published in the May 11, 1998 Federal Register notice 10 CFR Part 430 Subpart B Appendix E. It is used by the AHRI Residential Water Heater Certification Program as a guideline providing clarification on how testing is conducted by the contracted third-party laboratory. None of the details contained in this document are counter to or inconsistent with the DOE test method.

Section B1. Purpose

B1.1 *Purpose.* The purpose of this guideline is to provide details on the specific instrumentation, test setup, and testing procedures used to measure water heater efficiency. This document has been drafted as an adjunct to the Department of Energy (DOE) test method for determining the energy efficiency of residential water heaters as published in the May 11, 1998 Federal Register notice 10 CFR Part 430 Subpart B Appendix E.

B1.1.1 *Intent.* This guideline is intended for the guidance of the industry, including manufacturers and third-party laboratories.

B1.1.2 *Review and Amendment.* This guideline is subject to review and amendment as technology advances.

Section B2. Scope

B2.1 *Scope.* These guidelines apply to Residential Water Heaters, as defined in Section B3.

B2.2 *Exclusions.* These guidelines do not apply to the rating and testing of any other type of systems providing potable hot water.

Section B3. Definitions

All terms in this document will follow the standard industry definitions on the ASHRAE Terminology page (<https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology>), unless otherwise defined in this section.

B3.1 *Published Rating.* A statement of the assigned values of those performance characteristics, under stated Rating Conditions, by which a unit may be chosen to fit its application. These values apply to all units of like nominal size and type (identification) produced by the same manufacturer. The term Published Rating includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated Rating Conditions.

B3.1.1 *Application Rating.* A rating based on tests performed at application Rating Conditions (other than Standard Rating Conditions).

B3.1.2 *Standard Rating.* A rating based on tests performed at Standard Rating Conditions.

B3.2 *Rating Conditions.* Any set of operating conditions under which a single level of performance results and which causes only that level of performance to occur.

B3.2.1 *Standard Rating Conditions.* Rating Conditions used as the basis of comparison for performance characteristics.

B3.3 *Shall.* “Shall” is used to indicate provisions which are mandatory.

B3.4 Residential Water Heater. A closed vessel, in which water is heated by the combustion of fuels, electricity and is withdrawn for use external to the vessel, including the apparatus by which heat is generated and all controls and devices necessary to prevent water temperatures from exceeding 210°F .

B3.4.1 Electric Storage Water Heaters. Electric Storage Water Heaters with energy input ratings less than or equal to 12 kilowatts and has a storage capacity of not less than 20 gallons nor more than 120 gallons, and is designed to heat and store water at a thermostatically controlled temperature less than 180°F .

B3.4.2 Heat Pump Water Heaters. Heat Pump Water Heaters that use electricity as the energy source, are designed to heat and store water at a thermostatically controlled temperature of less than 180°F , have a maximum current rating of 24 amperes for an input voltage of 250 volts or less, and a storage capacity of not less than 20 gallons nor more than 120 gallons. Auxiliary water heating electric heat pumps with maximum current ratings of 24 amperes for an input voltage of 250 volts or less, intended for connection to an existing water heater or storage tank installation.

B3.4.3 Gas Storage Water Heaters. Gas Storage Water Heaters with energy input ratings less than or equal to 75,000 Btu/h, has a storage capacity of not less than 20 gallons nor greater than 100 gallons, and designed to heat and store water at a thermostatically controlled temperature less than 180°F .

B3.4.4 Gas Instantaneous Water Heaters. Gas Instantaneous Water Heaters with energy input greater than 50,000 Btu/h but less than 200,000 Btu/h, designed to deliver water at a controlled temperature less than 180°F , and with a storage capacity of less than 2 gallons.

B3.4.5 Oil Storage Water Heaters. Oil Storage Water Heaters with energy input less than or equal to 105,000 Btu/h and has a storage capacity of 50 gallons or less.

B3.4.6 Electric Instantaneous Water Heaters. Electric Instantaneous Water Heaters with energy input ratings less than or equal to 12 kilowatts.

B3.5 Energy Factor (EF). A measure of water heater overall efficiency, is the ratio of useful energy output from the water heater to the total amount of energy delivered to the water heater.

B3.6 First Hour Rating (FHR). A measure of the maximum volume of hot water (in gallons) that a storage water heater can supply within an hour that begins with the water heater fully heated.

B3.7 Maximum Gallons per Minute (GPM) Test. The maximum amount of hot water that can be supplied by an instantaneous water heater per minute while maintaining a nominal temperature rise of 77°F during steady state operation.

B3.8 Simulated Use Test (SUT). A 24-hour test with six water draws, conducted every hour, for the first six hours of the test. Between and during a water draw, the water heater is allowed to recover. After the last water draw, the test goes into a standby period.

B3.9 Storage Vessel Capacity (SVC). A test to measure the actual volume (in gallons) of stored water inside the water heater.

Section B4. Test Guidelines

B4.1 Test Preparation.

B4.1.1 Documentation.

B4.1.1.1 Reference Standard. The following standard shall be referenced:

10 CFR Part 430 Subpart B Appendix E and ANSI Z21.10.1.

B4.1.1.2 *Operator shall initiate a new test file and assign a new test number for each test unit.*

B4.1.2 Instrumentation. At a minimum, all instruments shall meet the accuracies listed in Table B1.

B4.1.3 Calibration. Instruments shall be calibrated at a minimum of every 12 months (refer to Table B2). Instrument calibration records shall be maintained and instruments shall be labeled with an identification number matching its calibration record. Operator shall ensure that calibrations are current and, if applicable, instruments are zeroed out prior to test. Instruments shall be calibrated by an ISO 17025 certified laboratory unless:

B4.1.3.1 When using external calibration services:

B4.1.3.1 Traceability of measurements is assured by the use of calibration services for laboratories that can demonstrate competence, measurement capability and traceability and;

B4.1.3.1.2 Calibration certificates issued by these laboratories contain the measurement results for the ranges being used.

B4.1.3.2 When equipment is internally calibrated:

B4.1.3.2.1 Laboratory established traceability of its own measurement standards and measuring instruments to the International System of Units (SI) by means of an unbroken chain of calibrations or comparisons linking them to the relevant primary standards of the SI units of measurement and;

B4.1.3.2.2 The link to SI units achieved by reference to national measurement standards (i.e. measurement standards and instruments directly traceable to the National Institute of Standards and Technology (NIST) or other nationally recognized organization such as A2LA, UKAS, SCC, IAS, etc.).

B4.1.4 Thermocouples. Thermocouples submerged in water shall be of the sheathed, ungrounded type.

Table B1. Minimum and Preferred Instrument Accuracies				
Measurement	Units	Source	Minimum	DOE Test Method Requirement (For information only)
Electric Power	watt-hour	transducer	±0.25%	±1%
Water Flow Rate	gpm or lbm/min	flow meter	±0.5 %	±1% RDG
W_f	lbm	scale	0.5%	None
Barometric Pressure	in Hg	barometer	0.05% (0.017 in Hg)	±0.1 in Hg
Volume of Gas	cu-ft or cu-ft/min	gas meter	1%	±1%
HHV	Btu/cu-ft	Calorimeter or spectrometer	±1%	±1%
P_2	psig	pressure gauge or transducer	±1 psi	±1 psi
P_{gas}	in H ₂ O	manometer	1%	±0.1 inch of water column
Water I/O Temperature	°F	TC or RTD	±0.2 °F	±0.2 °F
Tank Temperature	°F	TC or RTD	±0.5 °F	±0.5 °F
Ambient Temperature	°F	TC or RTD	±0.2 °F	±0.2 °F
Gas Temperature	°F	TC or RTD	±0.5 °F	N/A
Time	hr		0.000139 hr	no greater than 5 seconds
Volt	volts	transducer	1.0 volt	None
Amps	amp	amp transducer	0.1 amp	None

Table B2. Instruments Calibration Timetable	
Equipment	Calibration Cycle
Natural Gas Calorimeter	Every year
Water Flow Meter	Every year
Manometer	Every year
Temperature Readout	Every year
Stopwatch	Every year
Scale	Every year
Pressure Transducer	Every year
Scale	Every year
Water Heater Test Stand	Every year
U-Tube Manometer	Every year
T/C Assembly	Every year
Pressure Transducer	Every year
Pressure gauge	Every year
Digital Multimeter	Every year
CO / CO ₂ Analyzer	Every year

4.2 Test Set-up.

B4.2.1 Test Unit Preparation and Storage Vessel Capacity.

B4.2.1.1 Operator shall place the unit on a test platform in a conditioned space for at least 24 hours. The conditioned space must be maintained at a minimum of 65°F. The test stand must match the construction that is detailed in the applicable efficiency testing standard.

B4.2.1.2 If applicable, operator shall install relief valves and water connections.

B4.2.1.3 Test unit shall be weighed and dry weight recorded.

B4.2.1.4 Water heater shall be filled with water at a minimum pressure of 40 psi and checked for leaks.

B4.2.1.4.1 Air shall be purged from the water heater during this process, including any other time the water heater is filled, transferred to a different test station, or disconnected from the water supply. A top spud location shall be used to purge any air from the water heater.

B4.2.1.5 Temperature of water shall be noted, and density of water at that temperature shall be used to calculate the volume.

B4.2.1.6 Water heater shall be weighed. The weight of the water minus the weight of the water in the pipe connections (W) shall be recorded in the test report.

B4.2.2 Thermocouple Placement.

B4.2.2.1 Standard Tank Height Measurement Procedure (Top water connections on a storage water heater)

B4.2.2.1.1 Measure the height of the hot water outlet spud or anode spud using a tape measure by hooking the tape under the tank, directly under the spud. This is dimension "S" in Figure 2.

B4.2.2.1.2 Insert the rod fitting into the hot water outlet spud so that the top of the fitting is "Y" inches above the top of the spud.

B4.2.2.1.3 Insert the rod through the fitting until it bottoms out against the bottom of the tank. The tight clearance between the rod and fitting ensures the rod is straight.

B4.2.2.1.4 Place a mark or piece of masking tape on the rod at the top of the rod fitting.

B4.2.2.1.5 Remove the rod and measure dimension "L" from the bottom of the rod to the mark.

B4.2.2.1.6 Calculate Tank Height $H = L - S - Y$ in inches.

B4.2.2.1.7 Place the water heater on a level floor.

B4.2.2.1.8 Insert two fittings (or nipples) into the hot and cold spuds (Figure 3).

B4.2.2.1.9 Place a level across the two fittings.

B4.2.2.1.10 Lower or raise the fittings as appropriate to zero the level.

B4.2.2.1.11 Remove level and measure the length "X" from the bottom of the spud to the top of the fittings (using tape measure and method from B4.2.2.1.1).

B4.2.2.1.12 Mark the top of the tank "T" on the water heater jacket by replacing level and measuring down "X" inches as determined in B4.2.1.11 from bottom of level.

B4.2.2.1.13 Place mark for water heater tank bottom "B" by measuring down from the tank top mark from B4.2.1.12 a distance equal to the tank height determined in B4.2.1.6.

B4.2.2.1.14 An acceptable alternate method is also described in B4.2.3.1 through B4.2.3.4.

B4.2.2.2 Thermocouple Placement Procedure.

B4.2.2.2.1 Use a 6-thermocouple tree required by the DOE test procedure. Thermocouple wires may be used instead of probes when:

- Using the outlet fitting, its diameter is insufficient to pass the six probe assembly, without restricting the water flow; or
- There is a top center outlet with no anode, requiring an offset in the TC's in order to clear the elements; or
- There are side relief openings where the TC's require a 90 degree bend, which would destroy probes; or
- Encountering other circumstances after the testing agency and the manufacturer have consulted and agreed it is necessary.

B4.2.2.2.2 Install clear 0.25 in. i.d. tube on drain cock. Draw tube up the side of the water heater jacket and affix to top of jacket.

B4.2.2.2.3 Using the weight of water in tank (W) as determined in B4.1.1.6, determine placement of thermocouples.

B4.2.2.2.4 Open the water heater drain valve.

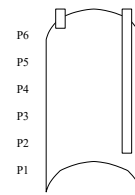
B4.2.2.2.5 For tree with 6 thermocouples, fill tank with $W/12 \pm 0.5$ lbm of water.

B4.2.2.2.6 Allow the water level in the tube to stabilize. Mark water level in tube on water heater jacket.

B4.2.2.2.7 Measure distance from mark indicating tank bottom to mark indicating 1/12 capacity. This value is P1.

B4.2.2.3 Calculate the remaining thermocouple positions as follows:

$$\begin{aligned} P2 &= (H - 2P1)/10 + 2P1 \\ P3 &= (H - 2P1)/5 + P2 \\ P4 &= (H - 2P1)/5 + P3 \\ P5 &= (H - 2P1)/5 + P4 \\ P6 &= (H - 2P1)/5 + P5 \end{aligned}$$



Where:

H = Height of the water heater inside the tank.

P_i = Position of the thermocouples.

B4.2.2.4 Using thermocouple placements determined in B4.2.2.3, and taking into account thread engagement of the thermocouple tree fitting, set thermocouples in tree within ± 0.063 " of the calculated thermocouple positions. See Figures 6 and 7 for suggestions.

B4.2.2.5 Install thermocouple tree in the anode spud on the test unit. Ensure tree is straight and is not in contact with any component inside the water heater, such as an element. If the tree cannot be installed in the anode spud, install the tree in the outlet spud.

B4.2.2.6 Install piping on the unit per the DOE test procedure document (see Figure 5 in Section B7 and Figures B1 through B7 in 10 CFR Part 430 Subpart B Appendix E for detailed schematics). Note that the 24 in. dimension in Section B7, Figure B5 is referenced from the top of the plumbing connection fitting supplied with the heater (spud or nipple).

B4.2.2.7 If applicable, operator shall install fittings, heat traps, and insulation (if provided) on pipes, relief valves, and water connections. Any other supplied components with the water heater must be installed per the manufacturer's installation instructions. This includes, but is not limited to the following: blowers, burners, controls, etc.

B4.2.2.7.1 If the heat trap is removed on the outlet side of the water heater to install the temperature probe, the heat trap must be incorporated into the remainder of the outlet piping.

B4.2.2.8 Fill the water heater and examine it for leaks at a minimum pressure of 40 psi.

B4.2.2.9 Operator shall install insulation with a minimum R-Value of 8 h/ft² °F /BTU on top of thermocouple tree and any additional fittings that were added by the operator. All insulation must be tightly secured to minimize heat loss potential.

B4.2.3 Side-Inlet Tank Height Measurement and Thermocouple Placement Procedure (use only if tank does not have a top fitting available on Storage Water Heaters).

B4.2.3.1 Install a clear 0.25 in. i.d. tube on tank drain cock. Draw tube up the side of the water heater jacket and affix to top of jacket.

B4.2.3.2 Fill tank with water.

B4.2.3.3 Open drain cock and allow water level to stabilize in tube. Ensure the water level comes up to outlet spud. CAUTION: Do not to overfill! Should overfill occur and insulation become wet, heater will be considered defective and must be replaced with a new unit.

B4.2.3.4 Place tank top mark "T" on the water heater jacket at level of full water heater.

B4.2.3.5 Using the weight of the water in the tank (W), remove $W/12 \pm 0.5$ lbm of water.

B4.2.3.6 Allow the water level in the tube to stabilize. Mark water level in tube on water heater jacket. Measure distance from mark indicating tank top (T) to indicate 1/12 capacity. This value is P6.

B4.2.3.7 Remove $W/6 \pm 0.5$ lbm of water for each successive thermocouple. After each draw, allow the water level in the tube to stabilize.

B4.2.3.8 Mark water level in tube on water heater jacket.

B4.2.3.9 Measure distance from previous thermocouple mark to successive thermocouple mark until all 6 thermocouple locations have been identified.

B4.2.3.10 Using thermocouple placements determined in B4.2.3.6 through B4.2.3.9, and taking into account placement of the thermocouple tree fitting, set thermocouples in tree within ± 0.063 " of the measured thermocouple positions. See Figures 6 and 7.

B4.2.4 Thermocouple Placement Procedure (Tankless Water Heaters Only).

B4.2.4.1 Install piping on the unit per the DOE test procedure document (see Figure 4 in Section B7 and Figures 1 through 7 in 10 CFR Part 430 Subpart B Appendix E for detailed schematics).

B4.2.4.2 If applicable, operator shall install fittings, heat traps, and insulation (if provided) on pipes, relief valves, and water connections. Any other supplied components with the water heater must be installed per the manufacturer's installation instructions. This includes, but is not limited to the following: blowers, burners, controls, etc.

B4.2.4.3 Operator shall install insulation with a minimum R-Value of 8 ft²·°F·h/Btu on inlet and outlet thermocouples and any additional fittings that were added by the operator. All insulation must be tightly secured to minimize heat loss potential.

B4.2.4.3.1 Confirm that all thermocouples are calibrated and clearly marked with an appropriate tag.

B4.2.5 Test Unit Set-up.

B4.2.5.1 For gas-fired water heaters only, install the minimum length venting, per the manufacturer's instructions.

B4.2.5.2 For oil-fired water heaters only, install the minimum length venting, per the manufacturer's instructions.

B4.2.5.2.1 Then, adjust the vent length according to 10 CFR Part 430 Subpart B Appendix E to achieve the proper chimney/stack draft.

B4.2.5.3 For heat pump water heaters, a minimum of one (1) humidity sensor shall be located 18" away from the water heater air inlet. If there is more than one, the sensors shall be spaced evenly around the circumference of the water heater. Vertically, the sensor(s) must be located half way between the top and bottom of the heat pump portion of the water heater and shielded from direct airflow out of the heat pump. The sensor(s) must monitor the surrounding area's humidity for all testing conducted.

B4.2.5.4 At least one picture must be taken of the water heater, including its venting, piping, etc. This picture must be saved with the test file and be provided, upon request.

B4.2.5.5 All air movement across and/or on the water heater shall be eliminated prior to starting any test.

B4.3 Test Procedure.

B4.3.1 Electric Storage Water Heaters (including Heat Pump Water Heaters): Simulated Use Test.

Notice: Section B4.2, Test Set-up shall be followed prior to proceeding to this section.

B4.3.1.1 Fill the water heater and test it for leaks at a minimum pressure of 40 psi.

B4.3.1.2 Turn the power on and set the water heater thermostat(s) for approximately 135°F. Allow the test unit to soak-in for a minimum period of 24 hours and the average tank temperature has reached a temperature of 135°F ± 5°F. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

B4.3.1.3 After the soak-in period, turn the power off, and disconnect the electrical connections if transferring between a warm-up station and test station. At the test station, connect the ambient, tank, inlet and outlet thermocouples, current sensors, and power cord. Seal any gaps in water heater jacket due to sensor leads to minimize heat loss. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

B4.3.1.4 Ensure the water supply temperature is 58°F ± 2°F and at a flow rate of 3 ± 0.25 gpm.

B4.3.1.5 Set thermostat(s) to 135°F. Initiate a water draw and continue draw until bottom element or heat pump cut-in.

B4.3.1.5.1 For electric water heaters only, monitor tank temperatures located above upper element and force the upper element to cut-out when the temperatures are 135°F ± 5°F.

B4.3.1.5.2 For electric water heaters only, monitor tank temperatures and force the lower element to cut-out when average tank temperature is 135°F ± 5°F.

B4.3.1.5.3 Ensure the average tank temperature is 135°F ± 5°F. If the average tank temperature is not 135°F ± 5°F, initiate a water draw until lower element cut-in or heat pump cut-in and repeat the thermostat setting procedure above.

B4.3.1.6 Unless specified by the manufacturer in advance of the test, perform one pre-draw until cut-in. The number of pre-draws is limited to three.

B4.3.1.7 Initiate the 24-hour simulated use test and data acquisition system after lower element cut-out. Conduct the test as detailed in Section 5.1.5 of 10 CFR Part 430 Subpart B Appendix E.

B4.3.1.8 Compile data and print report.

B4.3.2 Electric Storage Water Heaters (including Heat Pump Water Heaters): First Hour Rating Test.

Notice: Section B4.2, Test Set-up shall be followed prior to proceeding to this section.

- B4.3.2.1** If the heater has just completed the 24 hr simulated use test:
- B4.1.3.1.1** Initiate a water draw until lower element or heat pump cut-in.
- B4.1.3.1.2** After element or heat pump cut-out, confirm that the average tank temperature is within the limit specified in B4.3.1.5.
- B4.1.3.1.3** Initiate the "First Hour Rating" test.
- If the heater has not just completed a 24 hr. simulated use test, set thermostats per B4.3.1.5 above. Initiate a water draw until lower element or heat pump cut-in, then initiate first hour rating test after lower element or heat pump cut-out.
- B4.3.2.2** Water shall be supplied for first hour rating test at $58 \pm 2^{\circ}\text{F}$ and at a rate of 3 ± 0.25 gpm.
- B4.3.2.2.1** Wait 60 seconds before beginning to monitor T-mean.
- B4.3.2.3** Record T-mean at 60 second intervals.
- B4.3.2.4** Initiate the First Hour Rating Test and data acquisition system at T-mean max after cut-out ($135 \pm 5^{\circ}\text{F}$). Conduct the test as detailed in Section 5.1.4.3 of 10 CFR Part 430 Subpart B Appendix E.
- B4.3.2.4.1** T-mean max is defined as the temperature at which the rolling 60 second average (of readings taken every 5 seconds) T-mean temperature drops 0.05°F from the previous rolling average reading.
- B4.3.2.4.2** Record temperatures every five seconds, until the outlet water temperature drops 25°F below the maximum recorded outlet temperature.
- B4.3.2.4.3** Allow the test unit to recover and draw, at cut-out, as many times as possible in one hour. On electric water heaters, recovery is determined by the cut-out of the upper thermostat or thermocouple.
- B4.3.2.5** Compile data and print report.

B4.3.3 Gas-Fired Storage Water Heaters: Simulated Use Test.

Note: Section B4.2, Test Set-up shall be followed prior to proceeding to this section.

- B4.3.3.1** Install the gas line and the manifold pressure line.
- B4.3.3.2** Connect the gas meter.
- B4.3.3.3** Inlet and outlet thermocouples shall be located as indicated in Figure 5.
- B4.3.3.4** Fill the water heater and test it for leaks at a minimum pressure of 40 psi.
- B4.3.3.5** Light the pilot, if applicable. Otherwise, turn on the water heater.
- B4.3.3.6** Adjust the water heater set point to allow the burner to fire.
- B4.3.3.7** Check the entire gas train for leaks.

B4.3.3.8 Check the input rate. It must be within $\pm 2\%$ of its rated value using the method detailed in ANSI Z21.10.1. The manifold pressure shall be within $\pm 10\%$ of that printed on the rating plate.

B4.3.3.8.1 If input rate is not within $\pm 2\%$ of the rated value, the operator shall adjust manifold pressure, assuming he stays within the allowed $\pm 10\%$ to attempt to achieve $\pm 2\%$ of the rated input.

B4.3.3.8.2 If adjusting the manifold pressure does not achieve the rated input, the operator shall re-orifice the unit using an alternate orifice supplied by the manufacturer. [Note: Manufacturers are to supply test facility with a selection of orifices for use at the test facility. When a test unit is re-orificed, the test facility will notify the manufacturer of the alternate orifice used, and the manufacturer shall re-supply the test facility with a replacement orifice.]

B4.3.3.8.3 The operator shall check the entire gas train for leaks after re-orificing the water heater. Any leaks discovered shall be fixed.

B4.3.3.8.4 Combustion must only be checked when the water heater is very clearly operating abnormally (e.g. CO alarms are going off, producing smoke (when it is not supposed to), flames are shooting out of the vent, etc.).

B4.3.3.9 Set the water heater thermostat for approximately 135°F. Allow the test unit to soak-in for a minimum period of 24 hours and the average tank temperature has reached a temperature of 135°F \pm 5°F. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

B4.3.3.10 After soak-in period, turn off gas. Disconnect gas supply connections if transferring between a warm-up station and test station. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

B4.3.3.11 Install the unit in a test station, connect the gas meter, manifold pressure line, and manifold pressure transducer. Connect the ambient, tank, inlet and outlet thermocouples, any current sensors, and power cords.

B4.3.3.12 Ensure the water supply temperature is 58°F \pm 2°F and at a flow rate of 3 \pm 0.25 gpm.

B4.3.3.13 Manifold pressure shall be monitored throughout the test to detect improper gas valve operation or leaks.

B4.3.3.14 Set thermostat to 135°F. Initiate a water draw and continue the draw until cut-in.

B4.3.3.14.1 Monitor tank temperature and cut-out when the average tank temperature is 135°F \pm 5°F.

B4.3.3.14.1 Ensure average tank temperature is 135°F \pm 5°F. If the average tank temperature is not 135°F \pm 5°F, initiate a water draw until cut-in and repeat thermostat setting procedure above.

B4.3.3.15 Unless specified by the manufacturer in advance of the test, perform one pre-draw until cut-in. The number of pre-draws is limited to three.

B4.3.3.16 Initiate 24-hour simulated use test and data acquisition system after burner cut-out. Conduct the test as detailed in Section 5.1.5 of 10 CFR Part 430 Subpart B Appendix E.

B4.3.3.17 Compile data and print report.

B4.3.4 Gas-Fired Storage Water Heaters: First Hour Rating Test.

Note: Section B4.2, Test Set-up must be followed prior to proceeding to this section.

B4.3.4.1 If the heater has just completed the 24 hr simulated use test:

B4.3.4.1.1 Initiate a water draw until cut-in.

B4.3.4.1.2 After cut-out, confirm that the average tank temperature is within the limit specified in B4.3.3.14.

B4.3.4.1.3 Initiate the "First Hour Rating" test.

If heater has not just completed a 24 hr. simulated use test, set thermostats per Section B4.3.3.14 above. Initiate water draw until burner cut-in, then initiate first hour rating test after burner cut-out.

B4.3.4.2 Ensure the water supply temperature is $58 \pm 2^{\circ}\text{F}$ and at a rate of 3 ± 0.25 gpm.

B4.3.4.3 Wait 60 seconds before beginning to monitor T-mean.

B4.3.4.4 Record T-mean at 60 second intervals.

B4.3.4.5 Initiate the first hour rating test and data acquisition system at T-mean max after cut-out ($135 \pm 5^{\circ}\text{F}$). Conduct the test as detailed in Section 5.1.4.3 of 10 CFR Part 430 Subpart B Appendix E.

B4.3.4.5.1 T-mean max is defined as the temperature at which the rolling 60 second average (of readings taken every 5 seconds) T-mean temperature drops 0.05°F from the previous rolling average reading.

B4.3.4.5.2 Record temperatures every five seconds, until the outlet water temperature drops 25°F below the maximum recorded outlet temperature.

B4.3.4.5.3 Allow the test unit to recover and draw, at cut-out, as many times as possible in one hour.

B4.3.4.6 Compile data and print report.

B4.3.5 Oil-Fired Storage Water Heaters: Simulated Use Test.

Notice: Section B4.2, Test Set-up shall be followed prior to proceeding to this section.

B4.3.5.1 Install the fuel line quick connect fitting.

B4.3.5.2 Install a pressure gauge.

B4.3.5.3 Install the electrical sensing leads.

- B4.3.5.4** Connect the fuel supply line.
- B4.3.5.5** Fill the water heater and test it for leaks at a minimum pressure of 40 psi.
- B4.3.5.6** Turn the water heater on and check the entire fuel train for leaks.
- B4.3.5.7** Using the pressure gage, verify the pump is operating within the manufacturer's specifications and adjust as necessary.
- B4.3.5.8** After the burner has been on for 10 minutes, check the input rate. It must be within $\pm 2\%$ of the rated value.
- B4.3.5.9** Adjust the burner for minimum stack, or over fire draft, as outlined in the manufacturer's instructions.
- B4.3.5.10** Without exceeding a #1 smoke, the CO₂ level shall be adjusted, as outlined in the manufacturer's instructions.
- B4.3.5.11** Set the water heater thermostat for approximately 135°F. Allow the test unit to soak-in for a minimum period of 24 hours and the average tank temperature has reached a temperature of 135°F \pm 5°F. At no time shall the unit be disconnected from its energy supply for more than 1 hour.
- B4.3.5.12** After soak-in period, turn off fuel supply, disconnect fuel supply and electric connections if transferring between a warm-up and test station. At no time shall the unit be disconnected from its energy supply for more than 1 hour.
- B4.3.5.13** Install the unit in a test station, connect the fuel supply, the ambient, tank, inlet and outlet thermocouples, any current sensors, and power cords.
- B4.3.5.14** Ensure the water supply temperature is 58°F \pm 2°F and at a flow rate of 3 \pm 0.25 gpm.
- B4.3.5.15** Set thermostat to 135°F. Initiate a water draw and continue draw until cut-in.
 - B4.3.5.15.1** Monitor tank temperature and cut-out when the average tank temperature is 135°F \pm 5°F.
 - B4.3.5.15.2** Ensure the average tank temperature is 135°F \pm 5°F. If the average tank temperature is not 135°F \pm 5°F, initiate a water draw until cut-in and repeat thermostat setting procedure above.
- B4.3.5.16** Unless specified by the manufacturer in advance of the test, perform one pre-draw until cut-in. The number of pre-draws is limited to three.
- B4.3.5.17** Initiate 24-hour simulated use test and data acquisition system after burner cut-out. Conduct the test as detailed in Section 5.1.5 of 10 CFR Part 430 Subpart B Appendix E.
- B4.3.5.18** Compile data and print report.

B4.3.6 Oil-Fired Storage Water Heaters: First Hour Rating Test.

Note: Section B4.2, Test Set-up must be followed prior to proceeding to this section.

- B4.3.6.1** If the heater has just completed the 24 hr simulated use test:

B4.3.6.1.1 Initiate a water draw until cut-in.

B4.3.6.1.2 After cut-out, confirm that the average tank temperature is within the limit specified in B4.3.5.15.

B4.3.6.1.3 Initiate the "First Hour Rating" test. If heater has not just completed a 24 Hr. simulated use test, set thermostats per B4.3.5.15 above. Initiate one water draw until cut-in, then initiate first hour rating test after cut-out.

B4.3.6.2 Water shall be supplied for first hour rating test at 58°F \pm 2°F and at a rate of 3 \pm 0.25 gpm.

B4.3.6.3 Wait 60 seconds before beginning to monitor T-mean.

B4.3.6.4 Record T-mean at 60 second intervals.

B4.3.6.5 Initiate the first hour rating test and data acquisition system at T-mean max after cut-out (135°F \pm 5°F). Conduct the test as detailed in Section 5.1.4.3 of 10 CFR Part 430 Subpart B Appendix E.

B4.3.6.5.1 T-mean max is defined as the temperature at which the rolling 60 second average (of readings taken every 5 seconds) T-mean temperature drops 0.05°F from the previous rolling average reading.

B4.3.6.5.2 Record temperatures every five seconds, until the outlet water temperature drops 25°F below the maximum recorded outlet temperature.

B4.3.6.5.3 Allow the test unit to recover and draw, at cut-out, as many times as possible in one hour.

B4.3.6.6 Compile data and print report.

B4.3.7 Gas-Fired Tankless Water Heaters: Simulated Use Test.

Note: Section B4.2, Test Set-up shall be followed prior to proceeding to this section.

B4.3.7.1 Install the gas line and the manifold pressure line.

B4.3.7.2 Connect the gas meter.

B4.3.7.3 Inlet and outlet thermocouples shall be located as indicated in Figure 5.

B4.3.7.4 Fill the water heater and test for leaks at a minimum pressure of 40 psi.

B4.3.7.5 Turn on the water heater.

B4.3.7.6 Allow water to flow through the unit to allow the burner to fire at its maximum input rate.

B4.3.7.7 Check the entire gas train for leaks.

B4.3.7.8 Check the input rate. It must be within \pm 2% of its maximum rated value using the method detailed in ANSI Z21.10.3. The manifold pressure shall be within \pm 10% of that printed on the rating plate.

B4.3.7.9 If input rate is not within $\pm 2\%$ of the maximum rated value, the operator shall adjust manifold pressure, assuming he stays within the allowed $\pm 10\%$ to attempt to achieve $\pm 2\%$ of the rated input.

B4.3.7.9.1 If adjusting the manifold pressure does not achieve the rated input or it cannot be adjusted, the operator shall re-orifice the unit using (an) alternate orifice(s) supplied by the manufacturer.

Note: Manufacturers are to supply test facility with a selection of orifices for use at the test facility. When a test unit is re-orificed, the test facility will notify the manufacturer of the alternate orifice(s) used, and manufacturer shall re-supply the test facility with a replacement orifice(s).

B4.3.7.9.2 The operator shall check the entire gas train for leaks after re-orificing the water heater. Any leaks discovered shall be fixed.

B4.3.7.9.3 Combustion shall only be checked when the water heater is very clearly operating abnormally (e.g. CO alarms are going off, producing smoke (when it is not supposed to), flames are shooting out of the vent, etc.).

B4.3.7.10 Set the water heater thermostat to 135°F. If the water heater cannot be set exactly at 135°F, the unit shall be set within $\pm 5^\circ\text{F}$.

B4.3.7.11 Draw water from the unit for approximately 30 minutes. Allow the test unit to soak-in for a minimum period of 4 hours. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

B4.3.7.12 After soak-in period, turn off gas. Disconnect gas supply connections if transferring between a warm-up station and a test station. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

B4.3.7.13 Install the unit in a test station, connect the gas meter, manifold pressure line, and manifold pressure transducer. Connect the ambient, tank, inlet and outlet thermocouples, any current sensors, and power cords.

B4.3.7.14 Ensure the water supply temperature is $58^\circ\text{F} \pm 2^\circ\text{F}$.

B4.3.7.15 If the test unit has a variable input, determine the maximum flow rate that the unit can produce an outlet temperature of $135^\circ\text{F} \pm 5^\circ\text{F}$. This is V_{\max} , which shall be used for the first three draws of the SUT.

B4.3.7.15.1 If the unit has a fixed input, all six draws shall be conducted at V_{\max} .

B4.3.7.16 Determine the minimum flow rate that the unit can produce an outlet temperature of $135^\circ\text{F} \pm 5^\circ\text{F}$. This is V_{\min} , which shall be used for the last three draws of the SUT.

B4.3.7.17 Manifold pressure shall be monitored throughout the test to detect improper gas valve operation or leaks.

B4.3.7.18 Initiate 24-hour simulated use test and the data acquisition system. Conduct the test as detailed in Section 5.2.4 of 10 CFR Part 430 Subpart B Appendix E.

B4.3.7.19 Compile data and print report.

B4.3.8 Gas-Fired Tankless Water Heaters: Maximum GPM Rating Test.

Note: Section B4.2, Test Set-up shall be followed prior to proceeding to this section.

B4.3.8.1 Draw water from the test unit at a flow rate that will allow the unit to operate at its maximum firing rate. The outlet temperature must be $135^{\circ}\text{F} \pm 5^{\circ}\text{F}$.

B4.3.8.2 Initiate the "Maximum GPM Rating" test. Conduct the test as detailed in section 5.2.3 of 10 CFR Part 430 Subpart B Appendix E.

B4.3.8.3 Draw water from the test unit for 10 minutes. Using a water meter, or an alternative means, measure the amount of water drawn over the course of the test. Throughout the test, record the inlet and outlet water temperatures.

B4.3.8.4 Compile data and print report.

B4.3.9 Electric Tankless Water Heaters: Simulated Use Test.

Note: Section B4.2, Test Set-up shall be followed prior to proceeding to this section.

B4.3.9.1 Connect a power cord if one is not provided.

B4.3.9.2 Inlet and outlet thermocouples shall be located as indicated in Figure 5.

B4.3.9.3 Fill the water heater and test for leaks at a minimum pressure of 40 psi.

B4.3.9.4 Turn on the water heater.

B4.3.9.5 Allow water to flow through the unit to allow the heater to operate at its maximum input rate.

B4.3.9.6 Set the water heater thermostat to 135°F . If the water heater cannot be set exactly at 135°F , the unit shall be set within $\pm 5^{\circ}\text{F}$.

B4.3.9.7 Install the unit in a test station. Connect the ambient, tank, inlet and outlet thermocouples, any current sensors, and power cords.

B4.3.9.8 Draw water from the unit for approximately 30 minutes. Allow the test unit to soak-in for a minimum period of 24 hours. At no time shall the unit be disconnected from its energy supply for more than 1 hour.

B4.3.9.9 Ensure the water supply temperature is $58^{\circ}\text{F} \pm 2^{\circ}\text{F}$.

B4.3.9.10 If the test unit has a variable input, determine the maximum flow rate that the unit can produce an outlet temperature of $135^{\circ}\text{F} \pm 5^{\circ}\text{F}$. This is V_{max} , which shall be used for the first 3 draws of the SUT.

B4.3.9.11 If the unit has a fixed input, all six draws shall be conducted at V_{max} .

B4.3.9.12 Determine the minimum flow rate that the unit can produce an outlet temperature of $135^{\circ}\text{F} \pm 5^{\circ}\text{F}$. This is V_{min} , which shall be used for the last three draws of the SUT.

B4.3.9.13 Initiate the 24-hour simulated use test and the data acquisition system. Conduct the test as detailed in Section 5.2.4 of 10 CFR Part 430 Subpart B Appendix E.

B4.3.9.14 Compile data and print report.

B4.3.10 *Electric Tankless Water Heaters: Maximum GPM Rating Test.*

Note: Section B4.2, Test Set-up shall be followed prior to proceeding to this section.

B4.3.10.1 Draw water from the test unit at a flow rate that will allow the unit to operate at its maximum kW rate. The outlet temperature must be $135^{\circ}\text{F} \pm 5^{\circ}\text{F}$.

B4.3.10.2 Initiate the “Maximum GPM Rating” test. Conduct the test as detailed in Section 5.2.3 of 10 CFR Part 430 Subpart B Appendix E.

B4.3.10.3 Draw water from the test unit for 10 minutes. Using a water meter, or an alternative means, measure the amount of water drawn over the course of the test. Throughout the test, record the inlet and outlet water temperatures.

B4.3.10.4 Compile data and print report.

B4.4 *Calculation Methods.*

B4.4.1 *Heating Value Calculation Method for Gas-Fired Water Heaters.*

Fossil fuel Btu on gas-fired water heaters are calculated using Equation 1.

$$Q = \text{HHV} \cdot [(V \cdot \text{Corr}) \cdot (520/(460 + T)) \cdot (B + P \cdot 0.0735559) / 30] \quad 1$$

Where:

B = Barometric pressure, in Hg
 Corr = Meter correction (meter correction gets applied here because it changes depending on rate)
 HHV = Higher heating value, Btu per cubic-foot
 P = Gas pressure, in H₂O
 T = Gas temperature, °F
 V = Volume of gas, ft³

Fossil fuel Btu on gas-fired water heaters for the 24-hr simulated use test (SUT) are determined using Equation 2.

3. Q_t = Total fossil fuel Btu consumed during the entire 24-hr SUT

$$Q_t = \text{HHV}_t \cdot [(V_t \cdot \text{Corr}) \cdot (520/(460 + T_t)) \cdot (B_t + P_t \cdot 0.0735559) / 30] \quad 2$$

Where:

B_t = Average barometric pressure in Hg during entire 24-hr SUT
 Corr = Meter correction
 HHV_t = Average higher heating value during entire 24-hr SUT, Btu per cubic-foot
 P_t = Average Gas pressure in WC during entire 24-hr SUT
 T_t = Average Gas temperature °F during entire 24-hr SUT
 V_t = Volume of gas consumed during entire 24-hr SUT, cubic-feet

4. Q_r = Storage tank and fixed input instantaneous water heater fossil fuel Btu consumed between cut-out prior to the first draw and cut-out following the first draw, recovery efficiency using Equation 3.

$$Q_r = HHV_r \cdot [(V_r \cdot \text{Corr}) \cdot (520/(460 + T_r)) \cdot (B_r + P_r \cdot 0.0735559) / 30] \quad 3$$

Where:

B_r = Average barometric pressure in Hg during recovery efficiency
 Corr = Meter correction
 HHV_r = Average higher heating value during recovery efficiency, Btu per cubic foot
 P_r = Average Gas pressure in WC during recovery efficiency
 T_r = Average Gas temperature, °F during recovery efficiency
 V_r = Volume of gas consumed during recovery efficiency, cubic-feet

5. $Q_{r,\max}$ = Variable input rate instantaneous water heater fossil fuel Btu consumed between cut-out prior to the first draw and cut-out following the first draw, max recovery efficiency using Equation 4.

$$Q_{r,\max} = HHV_{r,\max} \cdot [(V_{r,\max} \cdot \text{Corr}) \cdot (520/(460 + T_{r,\max})) \cdot (B_{r,\max} + P_{r,\max} \cdot 0.0735559) / 30] \quad 4$$

Where:

$B_{r,\max}$ = Average barometric pressure in Hg during max recovery efficiency
 Corr = Meter correction
 $HHV_{r,\max}$ = Average higher heating value during max recovery efficiency, Btu per cubic-foot
 $P_{r,\max}$ = Average Gas pressure in WC during max recovery efficiency
 $T_{r,\max}$ = Average Gas temp °F during max recovery efficiency
 $V_{r,\max}$ = Volume of gas consumed during max recovery efficiency, cubic-feet

6. $Q_{r,\min}$ = Variable input rate instantaneous water heater fossil fuel Btu consumed between cut-out prior to the fourth draw and cut-out following the fourth draw, min recovery efficiency using Equation 5.

$$Q_{r,\min} = HHV_{r,\min} \cdot [(V_{r,\min} \cdot \text{Corr}) \cdot (520/(460 + T_{r,\min})) \cdot (B_{r,\min} + P_{r,\min} \cdot 0.0735559) / 30] \quad 5$$

Where:

$B_{r,\min}$ = Average barometric pressure, in Hg during min recovery efficiency
 Corr = Meter correction
 $HHV_{r,\min}$ = Average higher heating value during min recovery efficiency, Btu per cubic-foot
 $P_{r,\min}$ = Average Gas pressure, in H₂O WC during min recovery efficiency
 $T_{r,\min}$ = Average Gas temperature, °F during min recovery efficiency
 $V_{r,\min}$ = Volume of gas consumed during min recovery efficiency, cubic-feet

B4.4.2 Converting Volume (gal) to mass (lbm) using Equation 6.

$$M_i = V_i \times \rho_i \quad 6$$

Where:

M_i = Mass withdrawn for the i^{th} draw ($i = 1$ to 6), lbm
 V_i = Total volume water measured at the point where flow volume is measured, gal
 ρ_i = Density of the water based on water temperature measured at the point where the flow volume is measured, lbm/gal

Section B5. References - Normative

None.

Section B6. References - Informative

B6.1 ANSI Z21.10.1-2013/CSA 4.1-2013 - Gas water heaters - Volume I, storage water heaters with input ratings of 75,000 Btu per hour or less. CSA Group, 8501 East Pleasant Valley Road, Cleveland, Ohio 44131-5575.

B6.2 ASHRAE, Terminology. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc, 2015 <https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology>

B6.3 International Steam Tables - Properties of Water and Steam based on the Industrial Formulation IAPWS-IF97, Second Edition, Wagner and Kretzschmar, Springer, February 6, 2008.

B6.4 ISO/IEC 17025:2005 - General requirements for the competence of testing and calibration laboratories. International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

B6.5 U.S. Department of Energy (DOE) Appendix E to Subpart B of 10 CFR Part 430 - Uniform Test Method for Measuring the Energy Consumption of Water Heaters, *Federal Register*, 63 FR 25996 (May 11, 1998).

Section B7. Figures - Informative

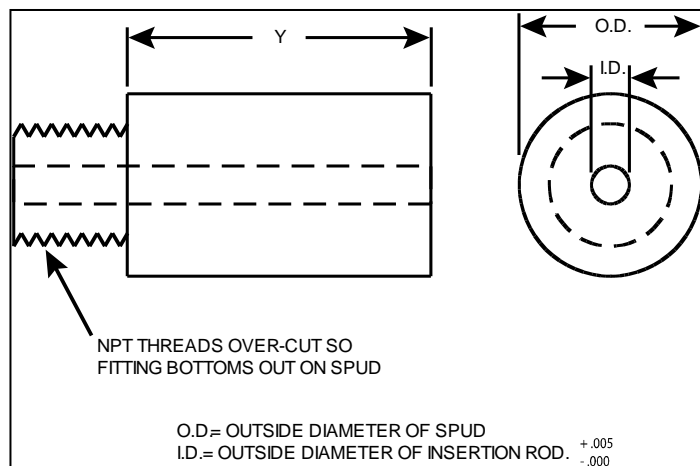


Figure B1. Tank Height Rod Fitting

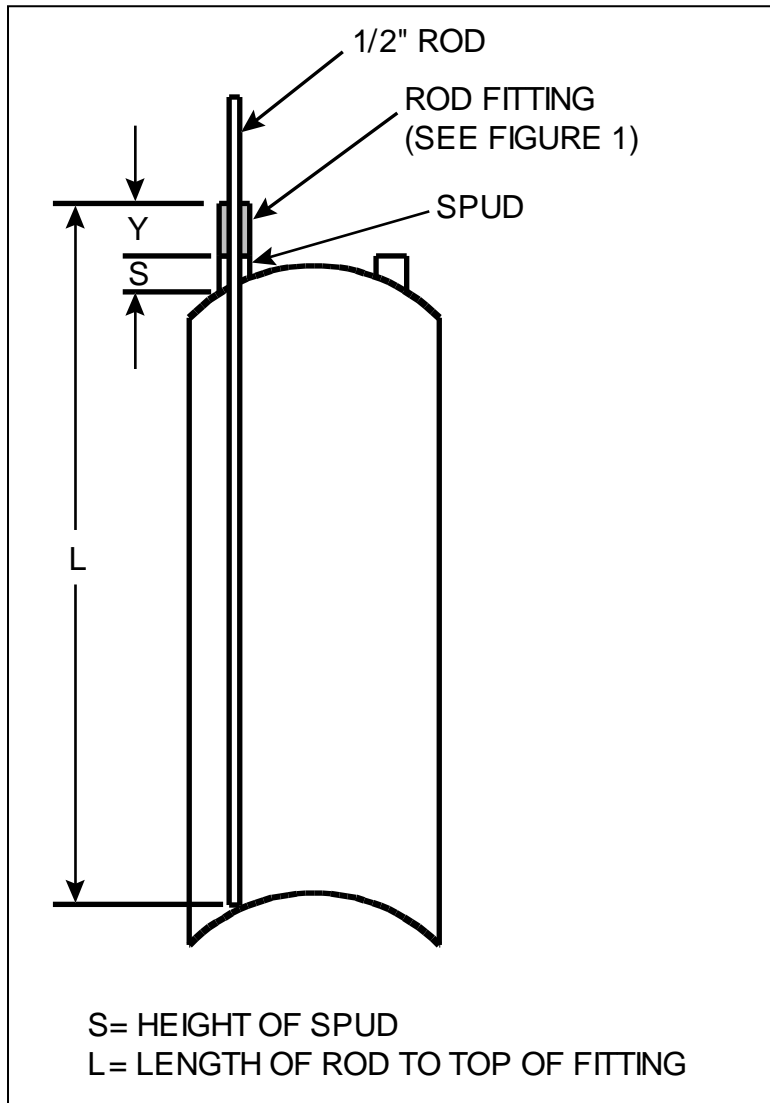
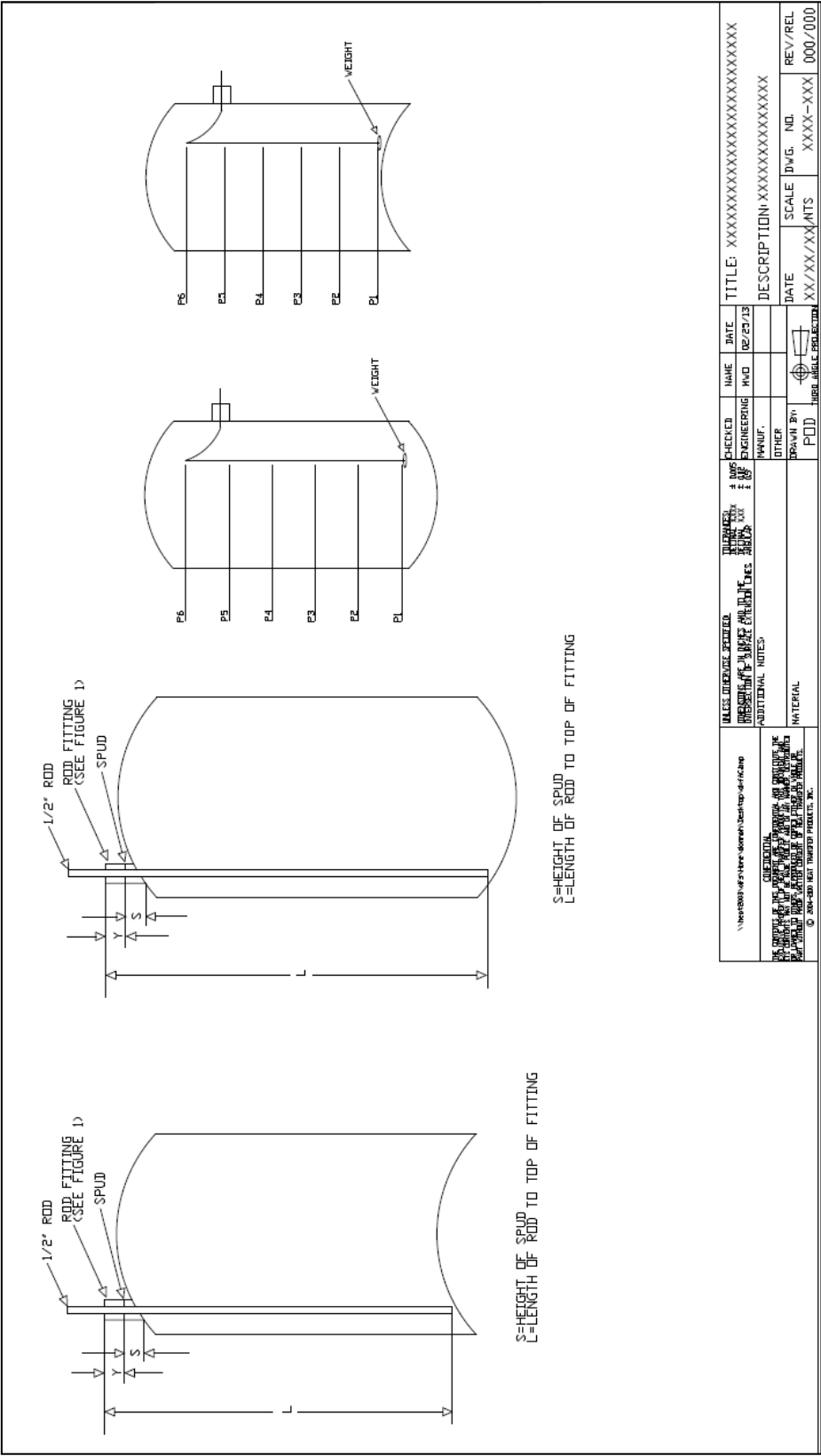


Figure B2. Tank Height Determination



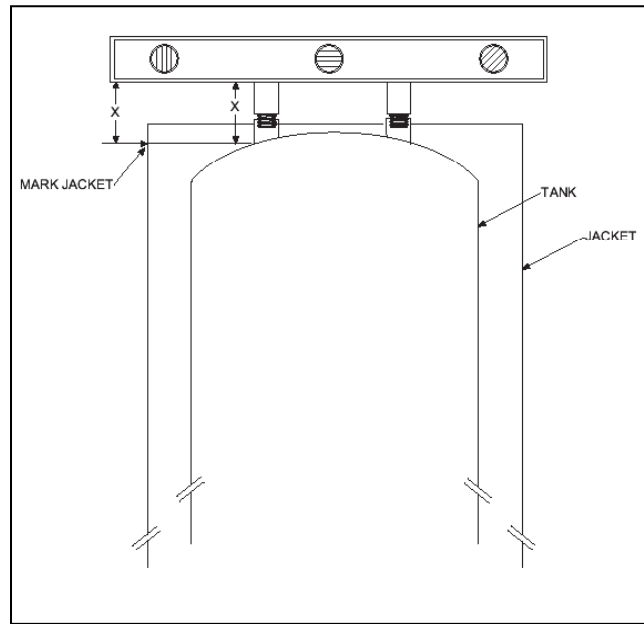


Figure B4. Marking Tank Height on Water Heater Jacket

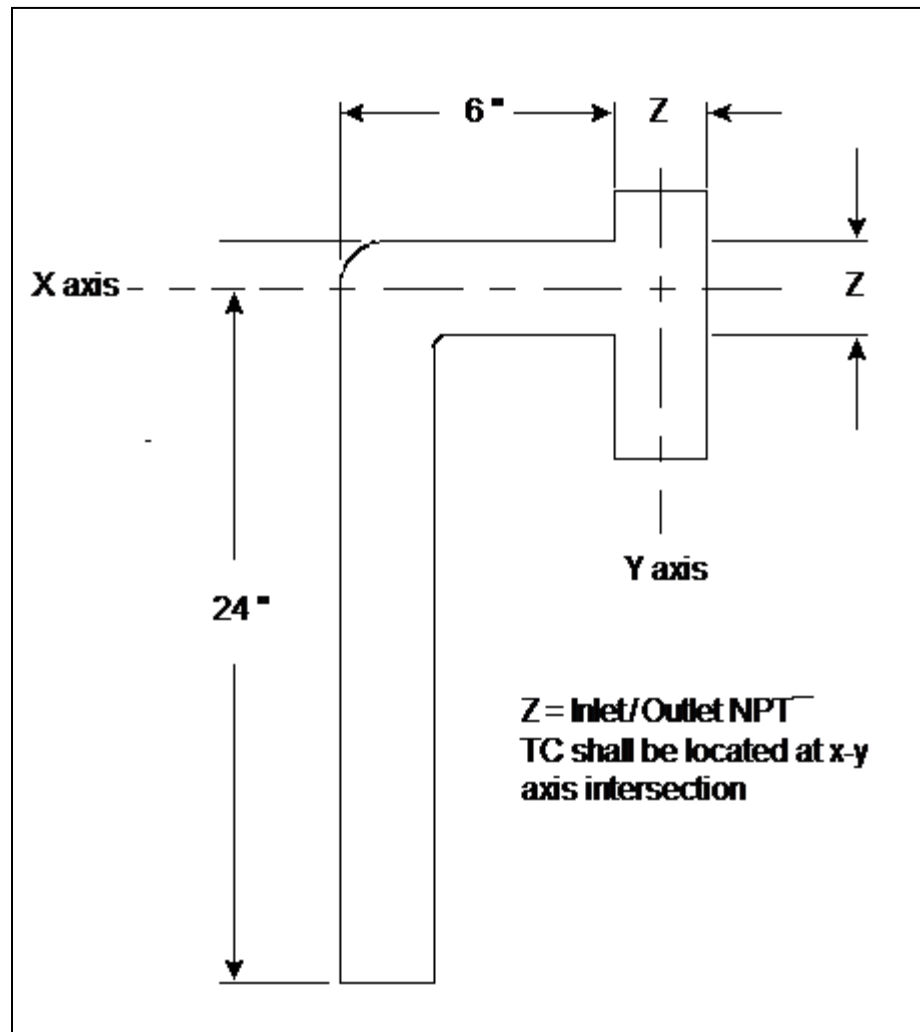


Figure B5. Inlet and Outlet Thermocouple Placement

Section B8. Suggested Fittings - Informative

Here are suggestions for fittings that address the problem of nipple engagement depth on the TC probe. They may not all be viable for every manufacturer but provide ideas on ways to solve the problem:

- 1- Use the rod fitting with a camlock fitting or a quick connect fitting at the end. Use an O-ring on the bottom thread to make a perfect seal between the spud and the rod fitting and allow the fitting to bottom out on spud. The distance "X" is known and we know that the TC probe will always be at the same position because of the camlock fitting or the quick connect fitting.
- 2- Same as No 1 but use a flange fitting with a gasket in between. Again, we know dimension "X".

This fitting would allow the TC probe to move up or down to adjust it to the right position. Position "X" would have to be measured each time and then the TC probe would have to be adjusted consequently.

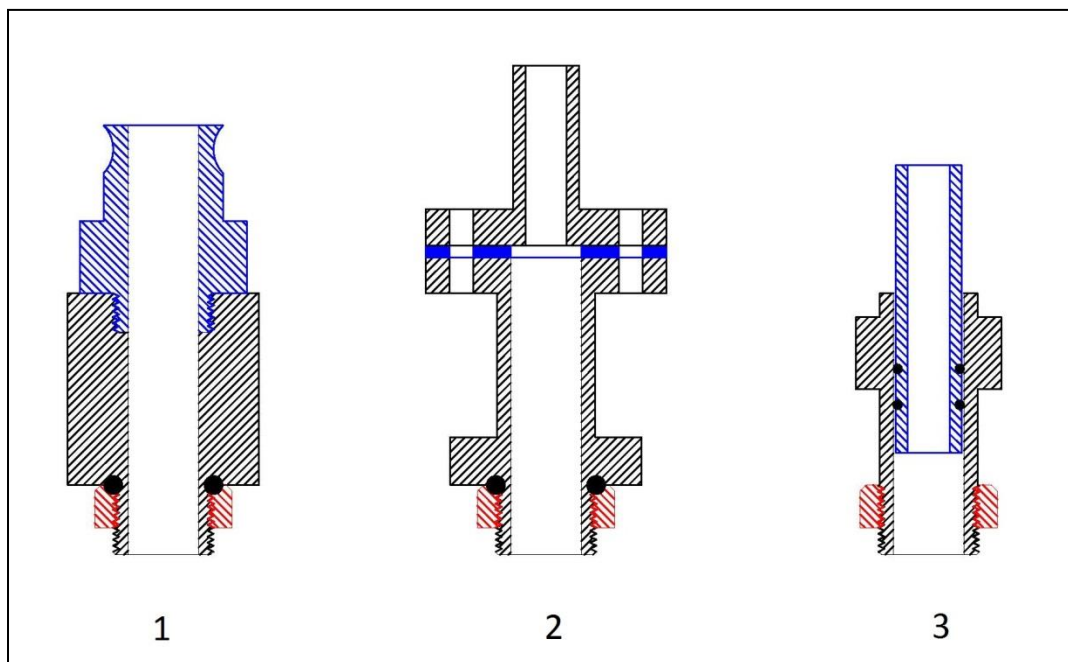


Figure B6. Thermocouple Tree Fitting Examples

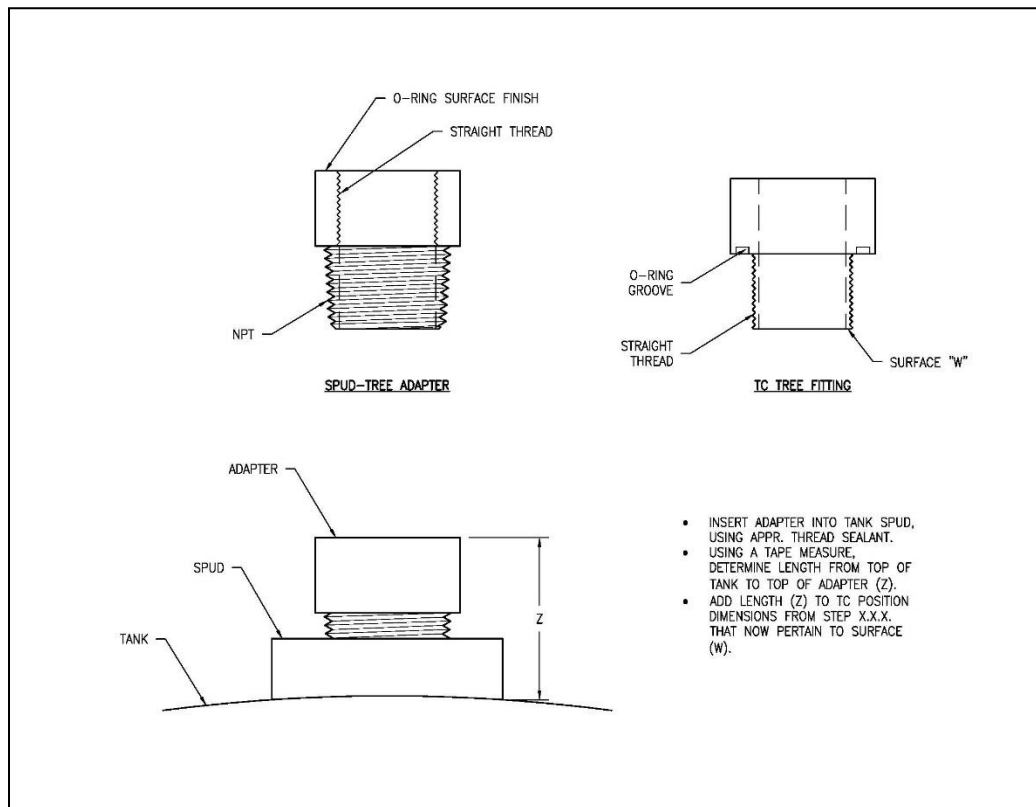


Figure B7. Thermocouple Tree Fitting and Adapter

Section B9. Standard Weights, Measures and Conversions - Informative

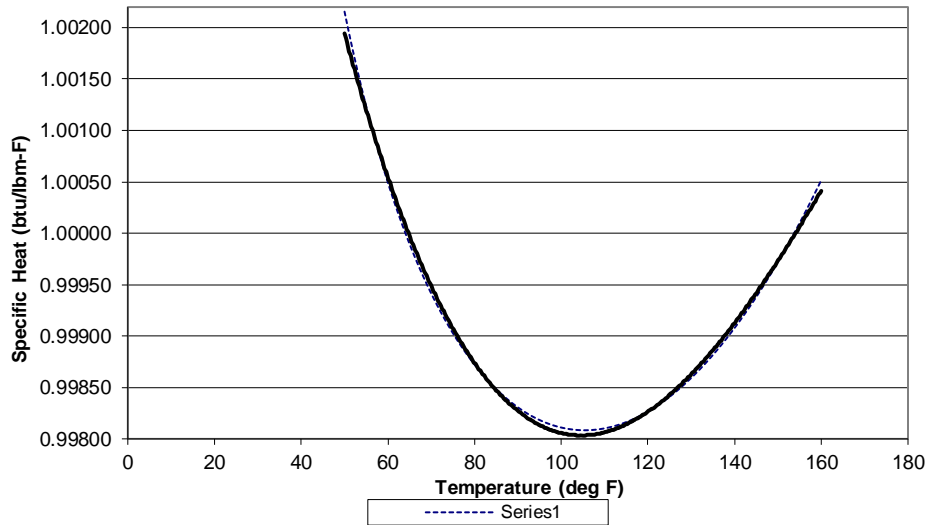
For conversion purposes, one may use either the ASME Int. Steam Tables Published in 2000 ASME Steam Tables are formulated under IAPWS-IF97 or the curve fit present below:

Curve Fit: Water Specific Heat vs. Temperature

2000 ASME Steam Tables (IAPWS-IF97)

$$C_p = -4.903944E-09T^3 + 2.584046E-06T^2 - 0.000375475T + 1.015074$$

R Squared = 0.9973



Curve Fit: Water Density vs. Temperature

2000 ASME Steam Tables (IAPWS-IF97)

$$C_p = -7.36376E-5T^2 + 0.002427088T + 62.48442$$

R Squared = 0.9999

