Indirect-Fired Water Heater Testing Standard  IWH-TS-1 -- March 2003

TESTING STANDARD

Method to Determine
Performance of
Indirect-Fired Water Heaters

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TESTING STANDARD

Method to Determine

PERFORMANCE OF
INDIRECT-FIRED WATER HEATERS

March 2003 Edition

1.0 PURPOSE

To establish a method of test to determine the performance of Indirect-Fired Water Heaters; both Indirect-Fired Storage Waters Heaters and Indirect-Fired Instantaneous Water Heaters.

2.0 SCOPE

2.1 This test method is intended to apply to Indirect-Fired Water Heaters designed for installation with a hot water boiler or some other external source of heated water.

2.2 This standard is limited to Indirect-Fired Water Heaters having a total volume (potable plus heat source) of 120 gallons or less.

2.3 This standard does not apply to direct-fired instantaneous or storage water heaters, direct fired instantaneous water heaters, tankless water heaters, or heat pump water heaters.

3.0 DEFINITIONS

COMBINATION SPACE HEATING AND WATER HEATING APPLIANCE -
A unit designed to provide space heating and potable water heating from a single primary energy source.

HOT WATER STORAGE TANK -
A tank used to store heated, potable water.

INDIRECT-FIRED STORAGE WATER HEATER -
A water heater consisting of a potable hot water storage tank equipped with an internal or external heat exchanger used to transfer heat to the stored potable water from an external source.

INDIRECT-FIRED INSTANTANEOUS WATER HEATER -
A water heater consisting of a tank which contains hot water from an external source and a heat exchanger used to transfer heat from this stored water to the potable water.

TANKLESS WATER HEATER -
A heat exchanger for indirect heating of domestic water, designed to be used without a
domestic water storage tank. It may be attached directly to the boiler, or installed external to the boiler and connected by piping.

**THERMOSTAT, TANK**
A device which senses changes in stored water temperature, and controls by means of separate components, the flow of energy to maintain selected temperatures.

### 3.1 NOMENCLATURE

- **c_p** Specific heat of water, Btu per pound °F
- **DR** Mean tank water temperature decay rate during standby test, °F per hour
- **DR_u** Uncorrected mean tank water temperature decay rate during standby test, °F per hour
- **Q** Standby heat loss from the Indirect-Fired Water Heater tank in Btu/hr
- **Q_h** Heat exchanger heat input for indirect-fired storage water heater, Btu per hour
- **T_a** Measured ambient air temperature, °F
- **T_c** Cold water supply temperature, °F
- **T_i** Measured potable water inlet temperature, °F
- **T_i,avg** Average potable water inlet temperature, °F
- **T_ih** Inlet heat source water temperature to the Indirect-Fired Water Heater, °F
- **T_ih,avg** Average inlet heat source water temperature to the Indirect-Fired Water Heater, °F
- **T_o** Measured potable water outlet temperature, °F
- **T_o,avg** Average potable water outlet temperature, °F
- **T_oh** Outlet water temperature from Indirect-Fired Water Heater to heat source, °F
- **T_oh,avg** Average outlet water temperature from Indirect-Fired Water Heater to heat source, °F
- **T_o(max)** Maximum potable water outlet temperature, draw test, °F
- **T_s** Mean tank temperature, °F
- **V** Potable water volume for indirect-fired storage water heater, gallons
- **V_c** Volume of potable water drawn during continuous draw test, gallons per 30 minutes
- **V_cd** Continuous draw rating, gallons per hour
- **V_d** Volume of potable water drawn during the first draw test, gallons
- **V_(end)** Volume reading of potable water meter at end of first draw test, gallons
- **V_f** First hour rating, gallons per hour
- **V_h** Heat source water volume for indirect-fired storage water heater, gallons
- **V_t** Initial volume reading of potable meter reading at beginning of first draw test, gal
- **w** Water flow rate (potable) in Indirect-Fired Water Heater, gallons per minute
- **w_h** Water flow rate (heat source) for Indirect-Fired Water Heater, gallons per minute
- **w_h,avg** Average water flow rate (heat source) for Indirect-Fired Water Heater, gallons per minute
- **W_c** Total weight of potable water drawn during continuous draw test, pounds per 30 minutes
- **W_d** Total weight of potable water drawn during first draw test, pounds
- **W_p** Weight of tank when filled with potable water, pounds
- **W_ph** Weight of tank when filled with potable and heat source water, pounds
- **W_t** Dry weight of tank, pounds
- **WT_(end)** Weight of weigh tank and potable water at end of first draw test, pounds
4.0 INSTRUMENTS

4.1 GENERAL
All instruments shall be in working order and be calibrated periodically. Records of periodic calibration shall be kept and they shall contain, at a minimum, the date of calibration, method of calibration, and reference standard used.

4.2 TEMPERATURE

4.2.1 THERMOMETERS
Shall have an error no greater than ±1°F.

4.2.2 THERMOCOUPLES
Unless otherwise specified herein, thermocouples and their read out instrumentation shall have an error no greater than ±0.2°F for all readings. Thermocouples shall be the bead type having a wire size no greater than No. 24 American Wire Gauge (AWG). Water temperatures thermocouples shall be the immersion type. The meter for reading the temperature shall have 0.1°F graduations.

4.3 PRESSURE
Water pressure measuring instruments shall be calibrated so that the error is not greater than ±1 pound per square inch.

4.4 WEIGHT OR VOLUME
The error associated with the measuring instruments shall not exceed ±0.5 percent of the quantity measured.

4.5 TIME
The error associated with timing instruments shall not exceed ±0.5 seconds per hour.

4.6 WATER FLOW RATE
A flow meter, if used, shall be calibrated so that the error is no greater than 0.5 percent of the hourly rate.

5.0 APPARATUS
The apparatus described below is used in conjunction with Indirect-Fired Water Heaters during the testing.

5.1 PIPING
See Figure 1 for a conceptual piping arrangement. Provisions shall be made to assure constant supply water temperature and pressure to the unit. Figure 2 contains a conceptual piping arrangement for an Indirect-Fired Water Heater that uses a mixing valve as determined by 5.5.

5.2 WATER FLOW MEASUREMENT
Provide appropriate weigh tanks and scales, or calibrated meters, to measure water flow.

5.3 ROOM TEMPERATURE
Install a thermocouple to measure the ambient temperature with junction shielded against direct radiation from any heat source and positioned at the vertical midpoint of the unit at a perpendicular distance of approximately 24 inches from the surface of the tank jacket.

5.4 THERMOCOUPLE INSTALLATION FOR WATER TEMPERATURES

5.4.1 THERMOCOUPLE INSTALLATION
Install six or more thermocouples inside the tank. The thermocouples may be installed in the tank either through (1) the opening for the anode rod, (2) the relief valve opening, (3) the hot water outlet, or (4) other suitable location. Position each thermocouple measuring junction along a vertical line at the level of the center horizontal plane of each non-overlapping sections of approximately equal volume, from the top to the bottom of the tank; such that each thermocouple is surrounded by water and as far as possible from any heat input device, anodic protective device, tank wall, or other irregularity. The anodic protective device may be removed in order to install the thermocouples and all testing may be carried out with the device removed. If the thermocouples are installed through the hot water outlet, a nonmetallic fitting assembly shall be installed such that the outlet piping is installed as close as possible to its original location. If the hot water outlet includes a heat trap, the heat trap shall be reinstalled on top of the tee fitting. If the thermocouples are installed through the relief valve, a metallic fitting assembly shall be used outside the tank and installed as close as possible to the original location. The added exposed metal tubing shall be insulated, except the relief valve, with a thermal insulation having a value of at least R = 4°F h ft²/Btu.

Install thermocouples in both the cold water inlet pipe and the hot water outlet pipe, not more than 24 inches from the connections to the water heater; or, where those connections are inaccessible, at the closest accessible point to those connections. Install thermocouples in the pipe connecting the heat source to the heat exchanger and in the pipe returning the water to the heat source within 24 inches of the connection to the heat exchanger. Locate the thermocouples downstream of two elbows, or a turbulator, to assure good mixing.

5.4.2 MEAN TANK TEMPERATURE MEASUREMENT
Mean tank temperature of the water in the water heater tank, wherever specified, shall be the mean of the temperatures determined by using the thermocouples installed in the tank as specified in 5.4.1.

5.5 MIXING VALVES
Testing an Indirect-Fired Water Heater utilizing a mixing valve is permitted, as long as the mixing valve is supplied by the manufacturer as standard equipment. In such cases, the mixing valve used for testing shall be the same valve provided by the manufacturer, and shall be installed in accordance with the manufacturer's instructions. The outlet water temperature, \( T_o \), shall be taken using a thermocouple in a heat trap connected to the "mixed" outlet of the valve. If a water meter is used, it shall be installed upstream of the cold water connection to the mixing valve so that the total water volume drawn through both the hot and cold mixing valve connections is measured (Figure 2).

5.6 HEAT SOURCE
A laboratory source of heated water shall be provided, with sufficient capacity to adequately supply the largest unit to be tested.
6.0 TEST CONDITIONS

Indirect-Fired Storage Water Heaters and Indirect-Fired Instantaneous Water Heaters shall be equipped with the apparatus described in Section 5, and the instrumentation described in Section 4, and shall be set up for recording data. Refer to Figure 1 when equipping the test unit with the apparatus and instrumentation. The heaters shall be adjusted to the test requirements or conditions described in Sections 6 and 7.
FIGURE 2: EXAMPLE OF TEST SETUP WHEN MIXING VALVE IS USED

TO WEIGHT TANK OR DRAIN

THROTTLING VALVE

SHUT-OFF VALVE

PUMP

EXPANSION TANK

FLOW METER

THROTTLING VALVE

HEAT SOURCE

EXPANSION TANK

WATERMETER (IF USED)

PRESSURE GAUGE

FROM POTABLE WATER SOURCE

FROM TANK

RELIEF VALVE

MIXING VALVE

T_0

T_1

T_h

T_h

T_h
6.1 INSTALLATION

6.1.1 INSTALLATION
Install the water heater according to the manufacturer's installation instructions on a ¾ inch thick plywood platform elevated approximately 4 inches off the floor by three 2 X 4 inch runners. An appropriately rated pressure and temperature relief valve shall be installed in the location specified by the manufacturer.

6.1.2 HEAT SOURCE PIPING
The connecting pipe between the thermocouple and the Indirect-Fired Water Heater shall be metal pipe up to the thermocouple and the balance of the piping may be as specified by the testing laboratory (see Figure 1).

6.1.3 POTABLE WATER PIPING
The piping connecting the potable water inlet and outlet to the Indirect-Fired Water Heater shall be of the same size as the tank connections and each shall have a heat trap loop located at the closest accessible point to these connections. Provide a pressure gauge, a diaphragm type expansion tank, and a check valve in the water supply line. The piping between the potable water inlet and the inlet water thermocouple shall be threaded metal pipe and the balance of the piping may be as specified by the lab (see Figure 1).

6.2 AIR AND WATER

6.2.1 WATER SUPPLY

6.2.1.1 POTABLE WATER
During all of the draw tests, maintain the potable water supply at \( T_c = 58^\circ F \pm 2^\circ F \) and at a gauge pressure of between 40 psig and the maximum pressure specified by the manufacturer for the unit under test.

If the water supply pressure varies outside of these limits during testing, the heater shall be isolated by use of a shut-off valve in the supply line with an expansion tank installed in the supply line downstream of the shut-off valve. There shall be no shut-off means between the expansion tank and the water heater inlet.

6.2.1.2 HEAT SOURCE WATER SUPPLY
During all of the draw tests, the water supplied to the water heater’s heat exchanger inlet, \( T \), shall be \( 180^\circ F \pm 2.5^\circ F \).

6.2.2 WATER FLOW RATES
Maintain the required potable water flow rate, \( w \), within \( \pm 0.25 \) gpm at all times during the test (see 7.3.2). Maintain the heat source water flow rate, \( w_h \), within \( \pm 0.25 \) gpm.

6.2.3 AIR TEMPERATURE
Maintain the ambient air temperature, \( T_a \), of the test room, as measured according to Section 5.3., as follows:
- Standby Test: \( 70^\circ F \pm 5^\circ F \)
- Continuous Draw and First Draw Tests: \( 75^\circ F \pm 10^\circ F \)
**7.0 TEST PROCEDURE**

At the manufacturer’s discretion, an Indirect-Fired Water Heater may be operated prior to the start of the tests. This shall be accomplished by maintaining the mean potable water tank temperature, $T_s$, for a period of at least 24 hours, at the initial starting conditions specified under 7.2.

**7.1 WATER VOLUME DETERMINATION**

Install valves and any other fittings on the Indirect-Fired Water Heater that will be necessary to fill its potable and heat source portions with water. Obtain the empty weight of the Indirect-Fired Water Heater, $W_i$, in pounds with these fittings installed. Fill only the potable water portion of the Indirect-Fired Water Heater with water, ensuring that all air is removed. Record the temperature, $T_c$, of the water used. Obtain the weight of the Indirect-Fired Water Heater with only the potable water portion filled, $W_p$, in pounds.

Without draining the potable water portion, fill the heat source portion. Obtain the weight of the Indirect-Fired Water Heater with both the potable and heat source water portions filled, $W_{ph}$, in pounds. Record the temperature, $T_c$, of the water used to fill both portions.

**7.2 STANDBY TEST**

**7.2.1 INDIRECT-FIRED STORAGE WATER HEATER**

Isolate the potable water in the tank to assure that there will be no flow through the tank during this test. Heat the tank using the heat source water until the mean tank temperature reaches at least 140°F. Stop the heating process. When the mean tank temperature is between 138°F and 137°F, start recording mean tank temperature, $T_s$, and room temperature, $T_a$, at regular 15 minute intervals as the tank temperature decays. Maintain the room temperature at 70°F ±5°F. Record the final reading at a mean tank temperature below 133°F before stopping the test.

**7.2.2 INDIRECT-FIRED INSTANTANEOUS WATER HEATER**

Isolate the potable water in the heat exchanger to assure that there will be no flow through the heat exchanger during the test. Heat the tank using the heat source water until the mean tank temperature reaches at least 185°F. Stop the heating process. When the mean tank temperature is between 183°F and 182°F, start recording mean tank temperature, $T_s$, and room temperature, $T_a$, at regular 15 minute intervals as the tank temperature decays. Maintain the room temperature at 70°F ±5°F. Record the final reading at a tank temperature below 178°F before stopping the test.

**7.3 CONTINUOUS DRAW TEST**

**7.3.1 HEAT SOURCE FLOW RATE**

Adjust the heat source flow rate, $w_h$, ±0.25 gpm, according to the manufacturer’s published recommendations, but not to exceed the values shown in Table 1.
TABLE 1

Flow Rate (based on heat source connection tube size)

<table>
<thead>
<tr>
<th>Nominal connection size (inches)</th>
<th>Flow Rate, ( w_h ) (gpm)</th>
<th>( \text{fps} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>0.75</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>1.0</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>1.25</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>1.50</td>
<td>28</td>
<td>5</td>
</tr>
<tr>
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<td>48</td>
<td>5</td>
</tr>
<tr>
<td>2.5</td>
<td>75</td>
<td>5</td>
</tr>
<tr>
<td>3.0</td>
<td>106</td>
<td>5</td>
</tr>
</tbody>
</table>

7.3.2 HEATED POTABLE WATER FLOW RATES

Adjust the potable water flow rate, \( w \), to yield a nominal steady state \( \Delta T = (T_o - T_i) \), as measured over a period of 15 minutes. If an Indirect-Fired Water Heater is tested with a mixing valve as determined under 5.5, the potable water throttling valve and/or mixing valve shall be adjusted to obtain the maximum potable water flow rate, \( w \), at which the above nominal steady state temperature can be maintained. If the mixing valve does not permit the above steady state temperature to be maintained at any potable water flow rate, the heater shall be tested without the mixing valve.

7.3.3 HEAT SOURCE INPUT

The temperature of the water from the heat source to the Indirect-Fired Water Heater, \( T_{ih} \), shall be maintained at 180°F ±2.5°F at all times.

7.3.4 REQUIRED MEASUREMENTS

Once temperature and flow conditions are met, readings may be started. Readings shall be logged for the following, at least every 5 minutes from the beginning of the test.

- Time of the reading
- Potable water inlet temperature, \( T_i \)
- Potable water outlet temperature, \( T_o \)
- Heat source water temperature entering the Indirect-Fired Water Heater, \( T_{ih} \)
- Heat source water temperature leaving the Indirect-Fired Water Heater, \( T_{oh} \)
- Heat source water flow rate, \( w_h \)
- Room temperature, \( T_a \)

7.3.5 DURATION OF TEST

The readings shall continue until a 30-minute period has elapsed from the start of the test. During this time, the potable water inlet temperature, \( T_i \), shall remain within 58°F ±2°F, and the temperature rise shall be within 77°F ±2.5°F. Measure the total weight of water drawn, \( W_c \), pounds per 30 minutes, or record the total potable water flow, \( V_c \), gallons per 30 minutes, during the test.
7.4 FIRST DRAW TEST

7.4.1 INDIRECT-FIRED STORAGE WATER HEATER
Starting with a tank of cold supply water, initiate the flow of heat source water through the heat exchanger. The flow rate of this water will be the value of \( w_h \) determined in 7.3.1. Stop the flow of heat source water when the value of the mean tank temperature, \( T_s \), approaches 135°F. Continually monitor the mean tank temperature, \( T_s \). Record the maximum value of \( T_s \) after the flow of heat source water is interrupted. If the maximum value of \( T_s \) is 135°F to 140°F, proceed with the draw portion of this test. If the maximum value of \( T_s \) is outside of this range, reduce the mean tank temperature to less than 70°F with cold potable water and repeat the above process. This process shall be repeated until the maximum value of \( T_s \) after interruption of heat source water flow is 135°F to 140°F.

Record the start weight of the weigh tank or the initial reading of the volumetric water meter. Record the mean tank temperature, \( T_s \), every 5 minutes until three consecutive readings of \( T_s \) are recorded between 135°F and 140°F. (The temperature trend for, \( T_s \), is to be even or decreasing.) Initiate the potable water flow at rate \( w \), as determined in 7.3.2. Indirect-Fired Water Heaters that are tested with a mixing valve shall use the same mixing setting that was used to determine the potable water flow rate under 7.3.2. Record the maximum heated potable water outlet temperature, \( T_{ol(max)} \). Monitor \( T_o \) and \( T_i \) on a continuous basis and continue the draw until \( T_o \) reaches \( T_{ol(max)} \) minus 25°F ±0.5°F, at which time the draw is terminated. Measure the total weight of water drawn, \( W_d \), in pounds, or record the total potable water volume, \( V_d \), in gallons, drawn during the test.

7.4.2 INDIRECT-FIRED INSTANTANEOUS WATER HEATER
Starting with the tank filled with cold heat source supply water, initiate the flow of heat source water through the heat exchanger. The heat source flow rate shall be the value of \( w_h \) determined in 7.3.1. Stop the flow of heat source water when the value of the mean tank temperature, \( T_s \), approaches 175°F. Continually monitor the mean tank temperature, \( T_s \). Record the maximum value of \( T_s \) observed after the flow of heat source water is interrupted. If the maximum value of \( T_s \) is 175°F to 180°F, proceed with the draw portion of this test. If the maximum value of \( T_s \) is outside of this range reduce the mean tank temperature to less than 70°F with cold water through the heat source side of the water heater and repeat the above process. This process shall be repeated until the maximum value of \( T_s \) after interruption is 175°F to 180°F.

Record the start weight of the weigh tank or the initial reading of the volumetric water meter. Record the mean tank temperature, \( T_s \), every 5 minutes until three consecutive readings of \( T_s \) are recorded between 175°F to 180°F. (The temperature trend for, \( T_s \), is to be even or decreasing.) Initiate the potable water flow at rate \( w \), as determined in 7.3.2. Indirect-Fired Water Heaters that are tested with a mixing valve shall use the same mixing setting that was used to determine the potable water flow rate under 7.3.2. Record the maximum heated potable water outlet temperature, \( T_{ol(max)} \). Monitor \( T_o \) and \( T_i \) on a continuous basis and continue the draw until \( T_o \) reaches \( T_{ol(max)} \) minus 65°F ±0.5°F or at 110°F, whichever is higher, at which time the draw is terminated. Measure the total weight of water drawn, \( W_d \), in pounds, or record the total potable water volume, \( V_d \), in gallons, drawn during the test.

7.4.3 DATA
The following readings shall be recorded during the test:
Time of the readings
Maximum mean tank temperature
Mean tank temperature, \( T_s \) (minimum of three readings 5 minutes apart)
Maximum potable outlet water temperature, \( T_{o_{(\text{max})}} \)
Minimum potable outlet water temperature:
   \( T_{o_{(\text{max})}} \) minus 25°F (Storage Water Heaters), or
   \( T_{o_{(\text{max})}} \) minus 65°F, or at 110°F, whichever is higher (Instantaneous Water Heaters)
and final volume of water drawn during the test, \( V_t \) and \( V_{(\text{end})} \)
Initial and final weight of water drawn during the test, \( W_{T_t} \) and \( W_{T_{(\text{end})}} \) or Initial

8.0 DATA TO BE RECORDED

Water volume determination values are to be recorded on form IWH-V-1
Standby heat loss data is to be recorded on form IWH-ST-1. Data logger output may be substituted if the required data and times as shown on form IWH-ST-1 are included in the printout.
Continuous draw data is to be recorded on form IWH-CD-1.
First draw data is to be recorded on form IWH-FD-1.
The calculated values are to be recorded on the report form IWH-R-1.
The summary information is to be included on form IWH-S-1

9.0 CALCULATIONS

9.1 WATER VOLUME DETERMINATION

9.1.1 POTABLE WATER VOLUME

Calculate the potable water volume of the Indirect-Fired Water Heater in gallons, \( V \).
\[
V = (W_p - W_t) / \rho
\]

where:
- \( W_p \) weight of tank when filled with potable water, pounds
- \( W_t \) dry weight of tank, pounds
- \( \rho \) density of water, pounds per gallon at temperature \( T_c \) (see Table 3)
The volume, \( V \), shall be within \( \pm 5\% \) of the manufacturer's claimed volume.

9.1.2 HEAT SOURCE WATER VOLUME

Calculate the heat source water volume of the Indirect-Fired Water Heater in gallons, \( V_h \).
\[
V_h = (W_{ph} - W_p) / \rho
\]

where:
- \( W_{ph} \) weight of tank when filled with potable and heat source water, pounds
- \( W_p \) weight of tank when filled with potable water, pounds
- \( \rho \) density of water, pounds per gallon at temperature \( T_c \) (see Table 3)
The volume, \( V_h \), shall be within \( \pm 5\% \) of the manufacturer's claimed volume.


9.2 STANDBY HEAT LOSS

9.2.1 STANDBY TEMPERATURE DECAY RATES

9.2.1.1 INDIRECT-FIRED STORAGE WATER HEATER

Calculate the uncorrected decay rate, $DR_u$, from the points between 137°F and 133°F by the least square method described in Exhibit A.

The mean tank water temperature decay rate, $DR$, in °F/hr is defined as:

$$DR = DR_u \times \frac{135 - 70}{135 - T_a}$$

where:

$DR_u$ = Uncorrected decay rate as calculated by the least square method as shown in Exhibit A.

$T_a$ = average air temperature during the test, °F

9.2.1.2 INDIRECT-FIRED INSTANTANEOUS WATER HEATER

Calculate the uncorrected decay rate, $DR_u$, from the points between 182°F and 178°F by the least square method described in Exhibit A.

The mean tank water temperature decay rate, $DR$, in °F/hr is defined as:

$$DR = DR_u \times \frac{180 - 70}{180 - T_a}$$

where:

$DR_u$ = Uncorrected decay rate as calculated by the least square method as shown in Exhibit A.

$T_a$ = average air temperature during the test, °F

9.2.2 STANDBY HEAT LOSS

9.2.2.1 INDIRECT-FIRED STORAGE WATER HEATER

For Indirect-Fired storage tanks, the heat loss, $Q$, in Btu/hr is defined as:

$$Q = (V + V_h)(8.216)(.999)(DR)$$

where:

$V$ = measured volume of potable water, gal

$V_h$ = measured volume of heat source water, gal

8.216 = density of water at 135°F, lb/gal

.999 = specific heat of water at 135°F, Btu/lb °F

$DR$ = standby temperature decay rate at 135°F, °F/hr

9.2.2.2 INDIRECT-FIRED INSTANTANEOUS WATER HEATER

For Indirect-Fired instantaneous water heaters, the heat loss, $Q$, in Btu/hr is defined as:
\[ Q = (V + V_h)(8.097)(1.003)(DR) \]

where:
- \( V \) = measured volume of potable water, gal
- \( V_h \) = measured volume of heat source water, gal
- 8.097 = density of water at 180°F, lb/gal
- 1.003 = specific heat of water at 180°F, Btu/lb°F
- DR = standby temperature decay rate at 180°F, °F/hr

9.3 CONTINUOUS DRAW

9.3.1 HEAT EXCHANGER HEAT INPUT
The heat exchanger heat input, \( Q_h \), Btu/hr, is to be calculated as follows:

\[ Q_h = \left( \frac{w_{h,\text{avg}}}{60} \right) (c_p) (T_{ih,\text{avg}} - T_{oh,\text{avg}}) \rho \]

where:
- \( w_{h,\text{avg}} \) = heat source water flow rate, gpm
- \( c_p \) = specific heat of water at the average of \( T_{oh} \) and \( T_{ih} \) temperatures, Btu/°F/lb. (See Table 3.)
- \( T_{oh,\text{avg}} \) = average outlet water temperature from the indirect-fired water heater to the heat source, °F
- \( T_{ih,\text{avg}} \) = average inlet water temperature to the indirect-fired water heater from the heat source, °F
- \( \rho \) = density of the water at the average of \( T_{oh,\text{avg}} \) and \( T_{ih,\text{avg}} \), pounds per gallon at temperature \( T_c \) (See Table 3.)
- 60 = minutes per hour

9.3.2 CONTINUOUS DRAW RATING
Calculate the continuous draw rating, \( V_{cd} \), in gallons per hour and defined as:

\[ V_{cd} = 2 V_c (T_{o,\text{avg}} - T_{i,\text{avg}}) / (135 - 58) \]

or

\[ V_{cd} = \frac{2 (W_c) (T_{o,\text{avg}} - T_{i,\text{avg}})}{\rho (135 - 58)} \]

where:
- 2 = number of test half hours per hour
- \( V_c \) = volume of water drawn during continuous draw test, gal/30 min.
- 135-58 = nominal temperature rise, °F
- \( T_{o,\text{avg}} \) = average potable water outlet temperature, °F.
- \( T_{i,\text{avg}} \) = average potable water inlet temperature, °F.
- \( W_c \) = total weight of water drawn during continuous draw test, pounds
\[ \rho = \text{density of water, pounds per gallon at temperature } T_c \text{ (see Table 3)} \]

9.4 FIRST DRAW
Calculate the first draw water volume \( V_d \)

\[ V_d = V_{(END)} - V_t \]

or

\[ V_d = \frac{(WT_{(END)} - WT_t)}{\rho} \]

where:

- \( V_{(END)} \) = Final volume meter reading of water when test is completed, gal
- \( V_t \) = Initial volume meter reading of water when test is initiated, gal
- \( WT_{(END)} \) = Final weight of weigh tank and water, lbs
- \( WT_t \) = Tare weight of weigh tank, lbs
- \( \rho \) = Density of the water at the average water temperature in the weigh tank, lbs/gal. See Table 3

9.5 FIRST HOUR RATING
Calculate the first hour rating, \( V_f \), expressed in gallons per hour and defined as:

\[ V_f = V_{cd} + V_d \]

or

\[ V_f = V_{cd} + \left( \frac{W_d}{\rho} \right) \]

where:

- \( V_{cd} \) = continuous draw rating, gal
- \( V_d \) = total volume of water drawn during first draw test, gal
- \( W_d \) = total weight of water drawn during first draw test, pounds
- \( \rho \) = density of water, pounds per gallon at temperature \( T_c \) (see Table 3)

10.0 TEST REPORT

10.1 WATER VOLUME DETERMINATION

10.1.1 Form IWH-V-1

10.2 STANDBY TEST

10.2.1 Form IWH-ST-1

10.2.2 GRAPH
Plot of temperature vs. time, including data points at a mean tank temperature above
137°F and below 133°F for storage indirect-fired water heaters and 182°F and 178°F for instantaneous indirect-fired water heaters.

10.3. CONTINUOUS DRAW TEST

10.3.1 Log sheet Form IWH-CD-1

10.4 FIRST DRAW TEST

10.4.1 Log sheet Form IWH-FD-1

10.5 INDIRECT-FIRED WATER HEATER PERFORMANCE REPORT

10.5.1 Form IWH-R-1
INDIRECT-FIRED WATER HEATER
VOLUME LOG

Dry weight of the Indirect-Fired Water Heater (Wt) _________________ lbs.

Weight of Indirect-Fired Water Heater filled with potable water (Wp)_______________ lbs.

Weight of Indirect-Fired Water Heater filled with potable water and heat source water (Wph)_________________ lbs.

Temperature of water used to fill the Indirect-Fired Water Heater (Tc)__________________ °F
INDIRECT-FIRED WATER HEATER
STANDBY TEST LOG

Start Time ________________ Starting Mean Tank Temp. ________________ °F

<table>
<thead>
<tr>
<th>TIME Min.</th>
<th>Mean Tank Water Temp. (Ts) °F</th>
<th>Ambient Air Temp. (Ta) °F</th>
<th>TIME</th>
<th>Mean Tank Water Temp. (Ts) °F</th>
<th>Ambient Air Temp. (Ta) °F</th>
<th>TIME</th>
<th>Mean Tank Water Temp. (Ts) °F</th>
<th>Ambient Air Temp. (Ta) °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>+15 Min</td>
<td></td>
<td></td>
<td>30</td>
<td></td>
<td></td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td>45</td>
<td></td>
<td></td>
<td>9 Hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
<td>5 Hours</td>
<td></td>
<td></td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Hour</td>
<td></td>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td>30</td>
<td></td>
<td></td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td>45</td>
<td></td>
<td></td>
<td>10 Hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
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<td>6 Hours</td>
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<td></td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Hours</td>
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<td></td>
<td>30</td>
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<td>45</td>
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<td></td>
<td></td>
<td>45</td>
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<td>11 Hours</td>
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<tr>
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<td>3 Hours</td>
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<td></td>
<td>45</td>
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<td>12 Hours</td>
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<tr>
<td>45</td>
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<td></td>
<td>8 Hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4 Hours</td>
<td></td>
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</tr>
<tr>
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<td></td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**INDIRECT-FIRED WATER HEATER**  
**CONTINUOUS DRAW TEST**

<table>
<thead>
<tr>
<th>TIME (Minutes)</th>
<th>POTABLE WATER</th>
<th>HEAT SOURCE WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>INLET TEMP (T_i) °F</td>
<td>OUTLET TEMP (T_o) °F</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
</tr>
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<tr>
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<tr>
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<tr>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td></td>
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</tr>
<tr>
<td>80</td>
<td></td>
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</tr>
<tr>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
INDIRECT WATER HEATER
FIRST DRAW TEST

<table>
<thead>
<tr>
<th>Time Minutes</th>
<th>Mean Tank Temp. (Ts) °F</th>
<th>Time Minutes</th>
<th>Mean Tank Temp. (Ts) °F</th>
<th>Time Minutes</th>
<th>Mean Tank Temp. °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>25</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>55</td>
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<td></td>
<td></td>
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<tr>
<td>10</td>
<td>35</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
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<td>15</td>
<td>40</td>
<td>65</td>
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</tr>
<tr>
<td>20</td>
<td>45</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Weigh tank start weight or start gallon reading WTt or Vt __________________ lbs or gal

Start flow of potable water

Monitor To and Tin continually

Record maximum leaving potable water temperature To,max: __________________ °F

Stop flow when To,max minus 25°F ±0.5°F is reached for storage water heaters, or when To,max minus 65°F ±0.5°F or 110°F, whichever is higher, is reached for instantaneous water heaters.

Record To,max minus 25°F ±0.5°F for storage water heaters: __________________ °F

OR

Record To,max minus 65°F ±0.5°F or 110°F, whichever is higher, for instantaneous water heaters: __________________ °F

Record final weight WT(end) or gallons reading V(end): __________________ lbs or Gal
## Indirect-Fired Water Heater Report Sheet

<table>
<thead>
<tr>
<th>General</th>
<th>Test Number</th>
<th>Test Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Volume</td>
<td>Heater Dry Weight ((W_d))</td>
<td>lbs</td>
</tr>
<tr>
<td></td>
<td>Weight of Heater Filled with Potable Water ((W_p))</td>
<td>lbs</td>
</tr>
<tr>
<td></td>
<td>Weight of Heater Filled with Potable and Heat Source Water ((W_{ph}))</td>
<td>lbs</td>
</tr>
<tr>
<td></td>
<td>Water Temperature Used to Fill Heater ((T_c))</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>Water Density ((\rho)), (see table 3)</td>
<td>lbs/gal</td>
</tr>
<tr>
<td></td>
<td>Potable Water Volume ((V_p))</td>
<td>gal</td>
</tr>
<tr>
<td></td>
<td>Heat Source Water Volume ((V_h))</td>
<td>gal</td>
</tr>
<tr>
<td>Standby Loss</td>
<td>Uncorrected decay rate ((\text{DR}_u))</td>
<td>°F/HR</td>
</tr>
<tr>
<td></td>
<td>Average Water Temperature ((T_c))</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>Mean Tank Water Temperature Decay Rate ((DR))</td>
<td>°F/HR</td>
</tr>
<tr>
<td></td>
<td>Heat Loss (Q)</td>
<td>Btuh</td>
</tr>
<tr>
<td>Continuous Draw</td>
<td>Heat Source Water Flow Rate ((\text{wh}_{\text{avg}}))</td>
<td>Gpm</td>
</tr>
<tr>
<td></td>
<td>Average Outlet Water Temperature to Heat Source ((T_{oh_{\text{avg}}}))</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>Average Inlet Water Temperature from Heat Source ((T_{ih_{\text{avg}}}))</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>Heat Source Input ((Q_h))</td>
<td>Btuh</td>
</tr>
<tr>
<td></td>
<td>Average Potable Water Inlet Temperature ((T_i))</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>Potable Water Outlet Temperature ((T_o))</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>Potable start weight or volumetric meter reading</td>
<td>lbs or gal</td>
</tr>
<tr>
<td></td>
<td>Potable final weight or volumetric meter reading</td>
<td>lbs or gal</td>
</tr>
<tr>
<td></td>
<td>Volume or Weight of Potable Water Drawn ((V_c \text{ or } W_c))</td>
<td>gal or lbs</td>
</tr>
<tr>
<td></td>
<td>Density of Water at Average Water Temperature ((\rho))</td>
<td>lbs/gal</td>
</tr>
<tr>
<td></td>
<td>Continuous Draw Rating ((V_{cd}))</td>
<td>gal/hr</td>
</tr>
<tr>
<td>First Draw</td>
<td>Maximum value of the mean tank temperature ((T_s))</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>Potable outlet water maximum temperature ((T_{o(max)}))</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>Potable outlet water stop temperature ((T_{o(max)} - 25F \text{ or } -65F \text{ or } 110F))</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>Potable start weight or volumetric meter reading ((W_{T_1} \text{ or } V_1))</td>
<td>lbs or gal</td>
</tr>
<tr>
<td></td>
<td>Potable final weight or volumetric meter reading ((W_{T_1} \text{ or } V_1))</td>
<td>lbs or gal</td>
</tr>
<tr>
<td></td>
<td>Net weight divided by (\rho) or gallons of water drawn ((W_d \text{ or } V_d))</td>
<td>gal</td>
</tr>
</tbody>
</table>
**TABLE 3**

**DENSITY OF WATER**

<table>
<thead>
<tr>
<th>Water Temperature °F</th>
<th>Specific Heat Of Water (c_p) Btu/lb °F</th>
<th>Water Density (ρ) lbs/gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>1.004</td>
<td>8.345</td>
</tr>
<tr>
<td>50</td>
<td>1.002</td>
<td>8.343</td>
</tr>
<tr>
<td>60</td>
<td>1.000</td>
<td>8.338</td>
</tr>
<tr>
<td>70</td>
<td>0.999</td>
<td>8.329</td>
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<tr>
<td>80</td>
<td>0.998</td>
<td>8.318</td>
</tr>
<tr>
<td>90</td>
<td>0.998</td>
<td>8.304</td>
</tr>
<tr>
<td>100</td>
<td>0.998</td>
<td>8.288</td>
</tr>
<tr>
<td>110</td>
<td>0.999</td>
<td>8.270</td>
</tr>
<tr>
<td>120</td>
<td>0.999</td>
<td>8.250</td>
</tr>
<tr>
<td>130</td>
<td>0.999</td>
<td>8.228</td>
</tr>
<tr>
<td>135</td>
<td>0.999</td>
<td>8.216</td>
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<td>140</td>
<td>0.999</td>
<td>8.205</td>
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<td>160</td>
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<td>8.154</td>
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<tr>
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<td>1.002</td>
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<td>180</td>
<td>1.003</td>
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<td>1.004</td>
<td>8.067</td>
</tr>
<tr>
<td>200</td>
<td>1.005</td>
<td>8.035</td>
</tr>
</tbody>
</table>
EXHIBIT A

LEAST SQUARE METHOD
FOR A STRAIGHT LINE THROUGH A SERIES OF POINTS

The plot for a straight line can be calculated as:

\[ Y = a + bX \]

where:

- \( Y \) = mean tank temperature
- \( X \) = time lapse in hours
- \( b \) = the slope or decay rate of the mean tank temperature
- \( a \) = mean tank temperature at start of test

For a best fit straight line through a series of points, the least square method can be used. The slope or decay rate is defined as:

\[
b = \frac{n \sum XiYi - (\sum Xi)(\sum Yi)}{n \sum Xi^2 - (\sum Xi)^2}
\]

where “n” is the number of readings and “Xi” and “Yi” are the individual readings

Example:

**DATA:**

<table>
<thead>
<tr>
<th>Time (hrs)</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°F)</td>
<td>137</td>
<td>135</td>
<td>133</td>
</tr>
</tbody>
</table>

\[
b = \frac{n \sum XiYi - (\sum Xi)(\sum Yi)}{n \sum Xi^2 - (\sum Xi)^2}
\]

\[
b = \frac{3[(0 \times 137) + (1 \times 135) + (2 \times 133)] - (0 + 1 + 2)(137 + 135 + 133)}{3(0^2 + 1^2 + 2^2) - (0 + 1 + 2)^2}
\]

\[
b = -2
\]

Therefore, the water looses 2°F per hour.