

GAMA TESTING STANDARD



Method to Determine

PERFORMANCE OF INDIRECT-FIRED WATER HEATERS

March 2003 Edition

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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

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1.0 PURPOSE

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

- WT_t** Initial weight of weigh tank at beginning of first draw test, pounds
 ρ Density of water, pounds per gallon (see Table 3)

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 $\pm 1^\circ\text{F}$.

4.2.2 THERMOCOUPLES

Unless otherwise specified herein, thermocouples and their read out instrumentation shall have an error no greater than $\pm 0.2^\circ\text{F}$ 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 $R = 4^{\circ}\text{F h ft}^2/\text{Btu}$.

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.

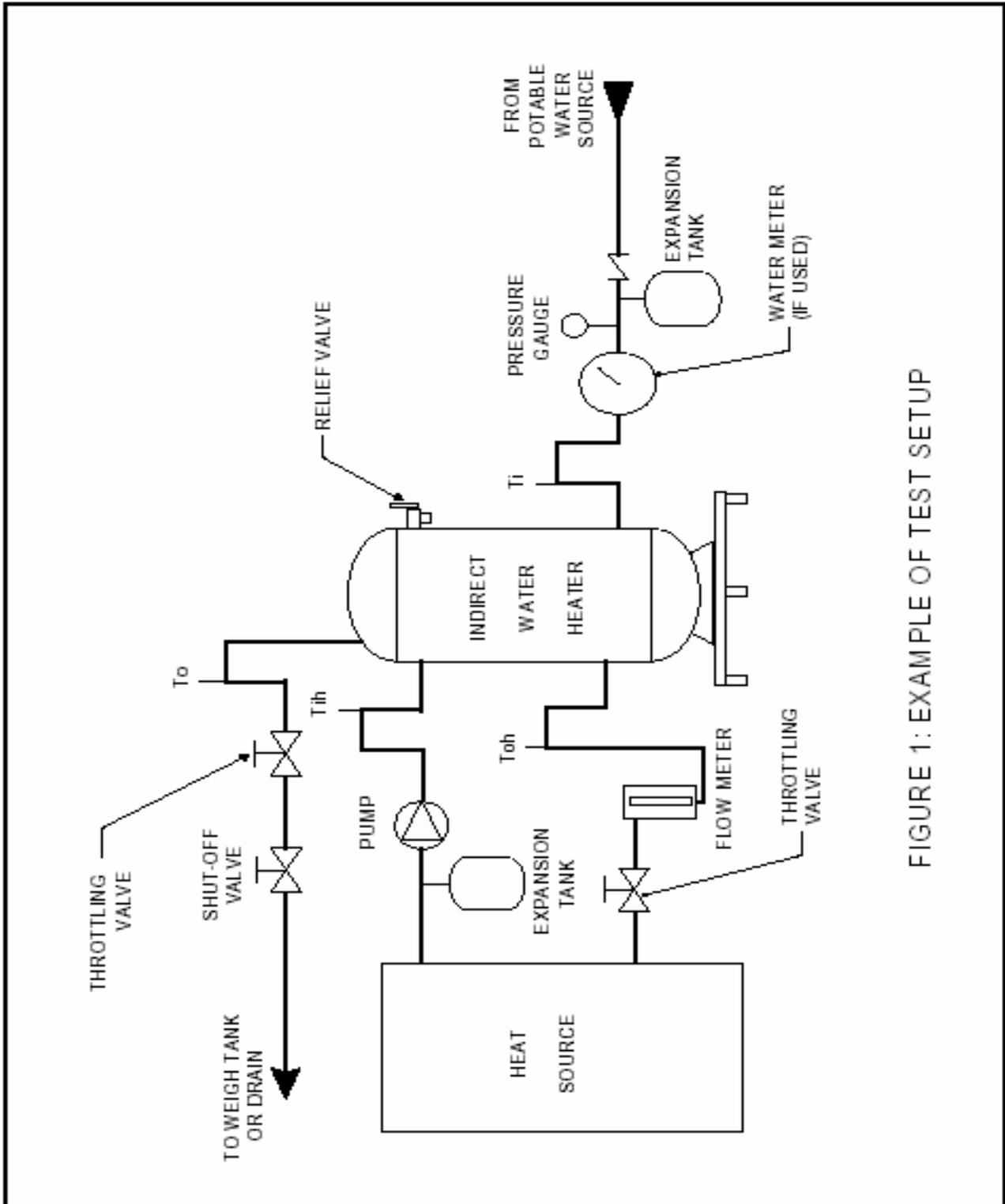


FIGURE 1: EXAMPLE OF TEST SETUP

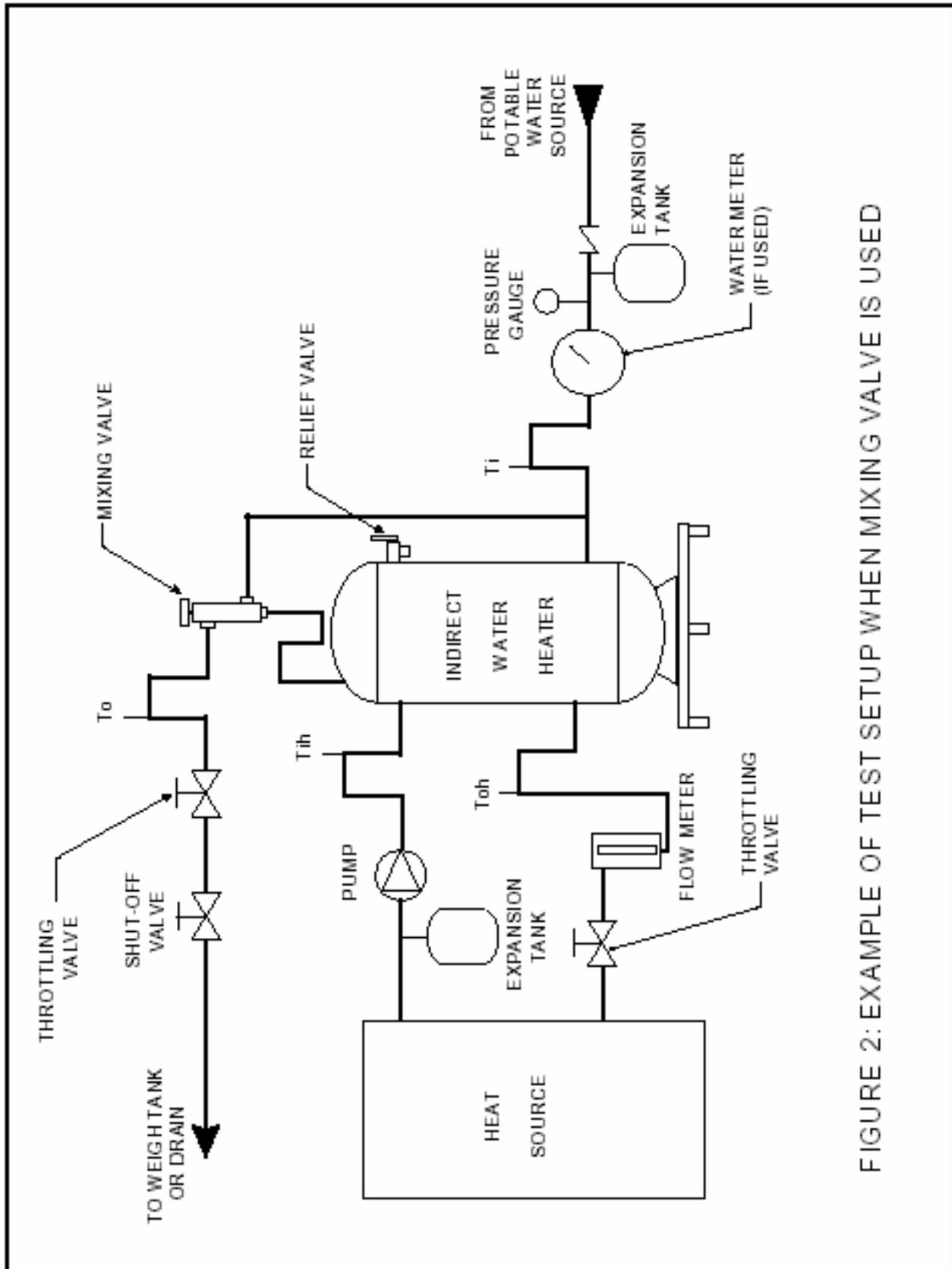


FIGURE 2: EXAMPLE OF TEST SETUP WHEN MIXING VALVE IS USED

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 ($T_c = 58^\circ\text{F} \pm 2^\circ\text{F}$) 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 $180^\circ\text{F} \pm 2.5^\circ\text{F}$.

6.2.2 WATER FLOW RATES

Maintain the required potable water flow rate, w , within ± 0.25 gpm at all times during the test (see 7.3.2). Maintain the heat source water flow rate, w_h , within ± 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	$70^\circ\text{F} \pm 5^\circ\text{F}$
Continuous Draw and First Draw Tests	$75^\circ\text{F} \pm 10^\circ\text{F}$

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_t 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 \pm 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 183F and 182F, 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 \pm 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 , \pm 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)

Nominal connection size <i>inches</i>	Flow Rate, w_h	
	<i>gpm</i>	<i>fps</i>
0.5	4	5
0.75	8	5
1.0	14	5
1.25	21	5
1.50	28	5
2.0	48	5
2.5	75	5
3.0	106	5

7.3.2 HEATED POTABLE WATER FLOW RATES

Adjust the potable water flow rate, w , to yield a nominal steady state $77^\circ\text{F } \Delta T = (T_o - T_i)$, 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 $180^\circ\text{F} \pm 2.5^\circ\text{F}$ 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 $58^\circ\text{F} \pm 2^\circ\text{F}$, and the temperature rise shall be within $77^\circ\text{F} \pm 2.5^\circ\text{F}$. 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, $T_{o(max)}$. Monitor T_o and T_i on a continuous basis and continue the draw until T_o reaches $T_{o(max)}$ minus 25°F \pm 0.5°F, at which time the draw is terminated. Measure the total weight of water drawn, W_d , pounds, or record the total potable water volume, V_d , 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° 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, $T_{o(max)}$. Monitor T_o and T_i on a continuous basis and continue the draw until T_o reaches $T_{o(max)}$ minus 65°F \pm 0.5°F or at 110°F, whichever is higher, at which time the draw is terminated. Measure the total weight of water draw, 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, $T_{o(max)}$

Minimum potable outlet water temperature:

$T_{o(max)}$ minus 25°F (*Storage Water Heaters*), or

$T_{o(max)}$ 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 $V_{(end)}$

Initial and final weight of water drawn during the test, WT_t , and $WT_{(end)}$ 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

ρ 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

ρ 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:

$$DR = DR_u \times [(135 - 70) / (135 - T_a)]$$

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:

$$DR = DR_u \times [(180 - 70) / (180 - T_a)]$$

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:

$$Q_h = (w_{h,avg}) (c_p) (T_{ih,avg} - T_{oh,avg}) \rho 60$$

where:

w_{h,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,avg}	=	average outlet water temperature from the indirect-fired water heater to the heat source, °F
T_{ih,avg}	=	average inlet water temperature to the indirect-fired water heater from the heat source, °F
ρ	=	density of the water at the average of, T_{oh,avg} and, T_{ih,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:

$$V_{cd} = 2 V_c (T_{o,avg} - T_{i,avg}) / (135 - 58)$$

or

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

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,avg}	=	average potable water outlet temperature, °F.
T_{i,avg}	=	average potable water inlet temperature, °F.
W_c	=	total weight of water drawn during continuous draw test, pounds

ρ = density of water, pounds per gallon at temperature T_c (see Table 3)

9.4 FIRST DRAW

Calculate the first draw water volume V_d

$$V_d = V_{(END)} - V_t$$

or

$$V_d = (WT_{(END)} - WT_t) / \rho$$

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
 ρ = 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

$$V_f = V_{cd} + (W_d / \rho)$$

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
 ρ = 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**

Mfr.: _____
Model No.: _____
Date: _____
Completed by: _____

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

Mfr.: _____
 Model No.: _____
 Date: _____
 Completed by: _____

INDIRECT-FIRED WATER HEATER STANDBY TEST LOG

Start Time _____ Starting Mean Tank Temp. _____ °F

TIME Min.	Mean Tank Water Temp. (Ts) °F	Ambient Air Temp. (Ta) °F		TIME	Mean Tank Water Temp. (Ts) °F	Ambient Air Temp. (Ta) °F		TIME	Mean Tank Water Temp. (Ts) °F	Ambient Air Temp. (Ta) °F
+15 Min				30				45		
30				45				9 Hours		
45				5 Hours				15		
1 Hour				15				30		
15				30				45		
30				45				10 Hours		
45				6 Hours				15		
2 Hours				15				30		
15				30				45		
30				45				11 Hours		
45				7 Hours				15		
3 Hours				15				30		
15				30				45		
30				45				12 Hours		
45				8 Hours						
4 Hours				15						
15				30						

Mfr.: _____
 Model No.: _____
 Date: _____
 Completed by: _____

INDIRECT-FIRED WATER HEATER CONTINUOUS DRAW TEST

TIME (Minutes)	POTABLE WATER				HEAT SOURCE WATER			ROOM TEMP (Ta) °F
	INLET TEMP (Ti) °F	OUTLET TEMP (To) °F	WEIGHT OR VOLUME (Wc or Vc) (lbs or gal)		INLET TEMP (Tih) °F	RETURN TEMP (Toh) °F	FLOW RATE (Wh) gal/min	
0								
5								
10								
15								
20								
25								
30								
35								
40								
45								
50								
55								
60								
65								
70								
75								
80								
85								
90								
TOTAL								

Mfr.: _____
 Model No.: _____
 Date: _____
 Completed by: _____

INDIRECT WATER HEATER FIRST DRAW TEST

Time Minutes	Mean Tank Temp.(Ts) °F	Time Minutes	Mean Tank Temp. (Ts) °F	Time Minutes	Mean Tank Temp. °F
0		25		50	
5		30		55	
10		35		60	
15		40		65	
20		45		70	

Weigh tank start weight or start gallon reading WT_t or V_t _____ lbs or gal

Start flow of potable water

Monitor T_o and T_{in} continually

Record maximum leaving potable water temperature $T_{o,max}$: _____ °F

Stop flow when $T_{o,max}$ minus $25^\circ\text{F} \pm 0.5^\circ\text{F}$ is reached for storage water heaters, or when $T_{o,max}$ minus $65^\circ\text{F} \pm 0.5^\circ\text{F}$ or 110°F , whichever is higher, is reached for instantaneous water heaters.

Record $T_{o,max}$ minus $25^\circ\text{F} \pm 0.5^\circ\text{F}$ for storage water heaters: _____ °F

OR

Record $T_{o,max}$ minus $65^\circ\text{F} \pm 0.5^\circ\text{F}$ or 110°F , whichever is higher, for instantaneous water heaters: _____ °F

Record final weight $WT_{(end)}$ or gallons reading $V_{(end)}$: _____ lbs or Gal

GAMA

IWH-R-1 Rev 3/03

Indirect-Fired Water Heater Report Sheet		
Company Name _____ Indirect-Fired Water Heater Model Number _____ Nominal Size _____ Potable Water in Tank <input type="checkbox"/> or Coil <input type="checkbox"/> , Indirect Fired Storage Heater <input type="checkbox"/> , Instantaneous Indirect Fired Heater <input type="checkbox"/> Other (e.g. material, insulation) _____		
Heat Source Manufacturer _____ Model No. _____ Btuh Output _____ Btuh Input _____ General Specifications & Description _____		
General	Test Number	
	Test Date	
Water Volume	Heater Dry Weight (W_t)	lbs
	Weight of Heater Filled with Potable Water (W^p)	lbs
	Weight of Heater Filled with Potable and Heat Source Water (W_{ph})	lbs
	Water Temperature Used to Fill Heater (T_c)	°F
	Water Density (ρ), (see table 3)	lbs/gal
	Potable Water Volume (V_p)	gal
	Heat Source Water Volume (V_h)	gal
Standby Loss	Uncorrected decay rate (DR_u)	°F/Hr
	Average Water Temperature (T_c)	° F
	Mean Tank Water Temperature Decay Rate (DR)	°F/Hr
	Heat Loss Q	Btuh
Continuous Draw	Heat Source Water Flow Rate ($w_{h,avg}$)	Gpm
	Average Outlet Water Temperature to Heat Source ($T_{oh,avg}$)	° F
	Average Inlet Water Temperature from Heat Source ($T_{ih,avg}$)	°F
	Heat Source Input (Q_h)	Btuh
	Average Potable Water Inlet Temperature (T_i)	° F
	Potable Water Outlet Temperature (T_o)	°F
	Potable start weight or volumetric meter reading	lbs or gal
	Potable final weight or volumetric meter reading	lbs or gal
	Volume or Weight of Potable Water Drawn (V_c or W_c)	gal or lbs
	Density of Water at Average Water Temperature (ρ)	lbs/gal
	Continuous Draw Rating (V_{cd})	gal/hr
First Draw	Maximum value of the mean tank temperature (T_s)	°F
	Potable outlet water maximum temperature $T_{o(max)}$	°F
	Potable outlet water stop temperature ($T_{o(max)} - 25F$ or $-65F$ or $110F$)	°F
	Potable start weight or volumetric meter reading (WT_t or V_t)	lbs or gal
	Potable final weight or volumetric meter reading ($WT_{(end)}$ or $V_{(end)}$)	lbs or gal
	Net weight divided by ρ or gallons of water drawn (W_d or V_d)	gal

First Hour Rating	First Hour Rating (V_i)	gal/hr
Laboratory Location		Test Conducted by

TABLE 3
DENSITY OF WATER

Water Temperature °F	Specific Heat Of Water (c_p) <i>Btu/lb °F</i>	Water Density (ρ) <i>lbs/gal</i>
40	1.004	8.345
50	1.002	8.343
60	1.000	8.338
70	0.999	8.329
80	0.998	8.318
90	0.998	8.304
100	0.998	8.288
110	0.999	8.270
120	0.999	8.250
130	0.999	8.228
135	0.999	8.216
140	0.999	8.205
150	1.000	8.180
160	1.001	8.154
170	1.002	8.124
180	1.003	8.097
190	1.004	8.067
200	1.005	8.035

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:

Time (hrs)	0	1	2
Temperature (°F)	137	135	133

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

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

$$b = -2$$

Therefore, the water loses 2°F per hour.