3.2.6. *Time Constant.* The time constant of the instruments used to measure the inlet and outlet water temperatures shall be no greater than 5 seconds.

3.3 *Liquid Flow Measurements.* The accuracy of the liquid flow rate measurement, using the calibration if furnished, shall be equal to or less than ± 1% of the measured value in mass units per unit time.

3.4. *Electric Energy.* The electrical energy used shall be measured with an instrument and associated readout device that are accurate within ± 1% of the reading.

3.5. *Fossil Fuels.* The quantity of fuel used by the water heater shall be measured with an instrument and associated readout device that is accurate within ± 1% of the reading.

3.6. *Mass Measurements.* Mass measurements shall be made measured with instruments that are accurate within ± 1% of the reading or 0.1 lbm, whichever is greater.

3.7. *Heating Value.* The higher heating value of the natural gas, propane, or fuel oil shall be measured with an instrument and associated readout device that is accurate within ± 1% of the reading. The heating value of natural gas and propane must be corrected for local temperature and pressure conditions.

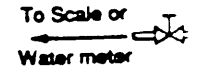
3.8. *Time.* The elapsed time measurements shall be measured with an instrument that is accurate within ± 0.5 seconds per hour.

4. Installation

4.1. *Water Heating Mounting.* A water heater designed to be free standing shall be installed according to the manufacturer's directions on a ¾ inch thick plywood platform supported by three 2 × 4 inch runners. If the water heater is not approved for installation on combustible flooring, suitable noncombustible material shall be placed between it and the platform. For heat pump water heaters without a storage tank supplied by the manufacturer, connections shall be made with a storage tank as described in section 4.9.3 and in accordance with manufacturer-published installation instructions. The storage tank and heat pump section shall be placed on platform(s) constructed as previously described. If installation materials are not provided by the heat pump manufacturer, use uninsulated 8 foot long connecting hoses, having an inside diameter of ⅝ inch. Wall mounted water heaters shall be installed in accordance with manufacturer-published installation instructions on a simulated wall section made from ¾ inch plywood and 2 × 4 inch studs. Placement in the test room shall be in an area protected from drafts.

4.2. *Water Supply.* The water supply shall be capable of delivering water at conditions as specified in section 2.

4.3. *Water Inlet and Outlet Configuration.* Inlet and outlet piping connections shall be configured as illustrated in Figures 1, 2, or 3 except a water heater 36 inches high or less, (commonly referred to as an under counter or table top model) intended for installation either beneath, adjacent to or in conjunction with a counter shall have the inlet and outlet connections configured as illustrated in Figures 4a and 4b. Type "L" hard copper tubing, the same size as the connections on the water heater shall be connected to the tank and extend 24 inches in length. If a water heater 36 inches high or less is not factory equipped with pipe to extend the field connection point of the water heater lines to outside of the jacket or cabinet, type "L" hard copper tubing shall be used to extend the water line horizontally to the exterior of the jacket or cabinet. Unions may be utilized to facilitate installation and removal of the piping arrangements. A pressure gauge and diaphragm expansion tank shall be installed in the supply water piping at a location upstream of the 24 inch cold water inlet pipe. An appropriately rated pressure and temperature relief valve shall be installed on all water heaters at the port specified by the manufacturer. Discharge piping for the relief valve shall be non-metallic. If heat traps and/or piping insulation and/or pressure relief valve insulation are supplied with the water heater, then they shall be installed for testing. Clearance shall be provided such that none of the piping contacts other surfaces in the test room.



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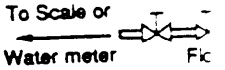

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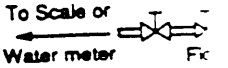

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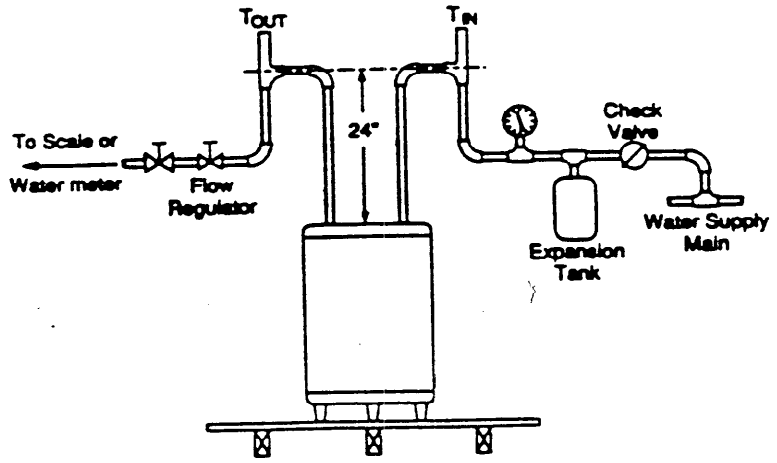

Figure 1

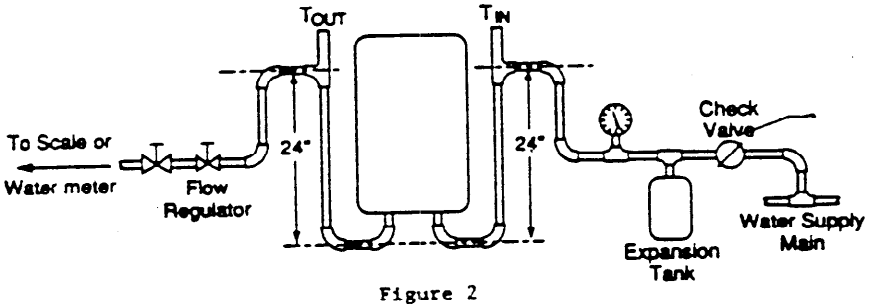

Figure 2

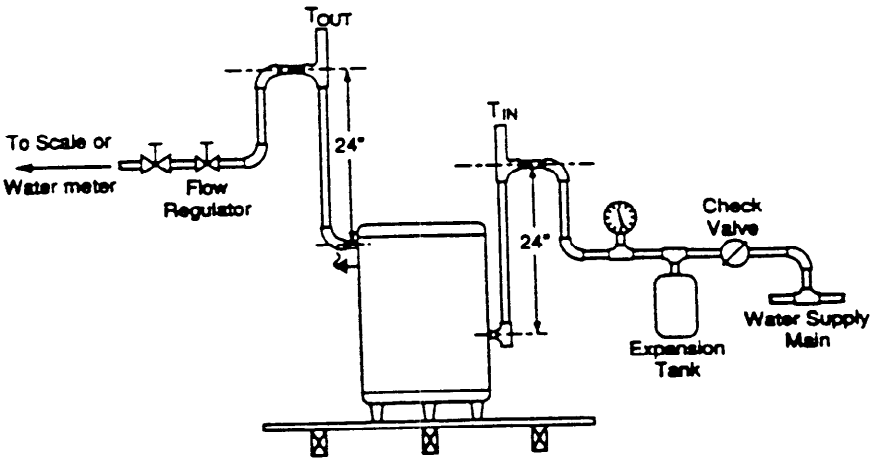

Figure 3

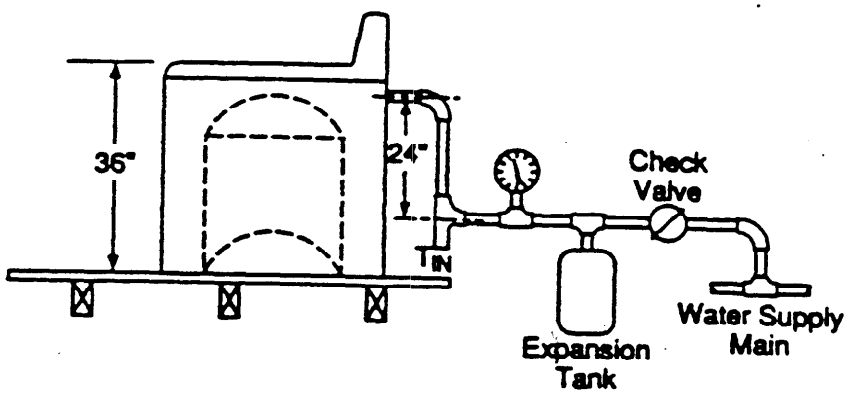

Figure 4a.

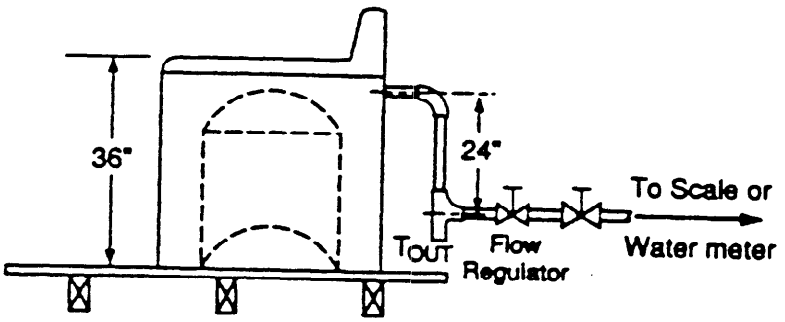

Figure 4b.

4.4. *Fuel and/or Ele Energy Consumption.* I instruments which meas the quantity and rate and/or fossil fuel cons ance with section 3.

4.5. *Internal Storage Measurements.* Install measurement sensors heater tank with a ver least four inches betwee A temperature sensor s the vertical midpoint equal volume nodes wi designate the equal volu partition the total volu much as is possible, the should be positioned aw elements, anodic prote walls, and flue pipe wall accommodate six temp meet the installation re above, install the maxi sors which comply wit quirements. The tempe be installed either thro device opening; (2) the or (3) the hot water through the relief valv water outlet, a tee fitt as applicable, shall be possible to its original water outlet includes a trap shall be installed ting. Added fittings sh thermal insulation ha hr·ft²·°F/Btu.

4.6. *Ambient Temper* air temperature shall b mately at the vertica heater and approxima surface of the water shall be shielded agains

4.7. *Inlet and Outlet Measurements.* Install in the cold-water inle outlet pipe as shown i applicable.

4.8. *Flow Control.* shall be installed to p fied within section 5.

4.9. *Flue Requiremen*

4.9.1. *Oil-Fired Wate* draft at the flue coll manufacturer's litera draft by using a suff pipe connected to th outlet and directed v an oil-fired water hea tally discharging dra degree elbow having a largest flue collar si shall be connected to A length of vent pipe the draft shall be co fitting and oriented upward. Direct vent

4.4. *Fuel and/or Electrical Power and Energy Consumption.* Install one or more instruments which measure, as appropriate, the quantity and rate of electrical energy and/or fossil fuel consumption in accordance with section 3.

4.5. *Internal Storage Tank Temperature Measurements.* Install six temperature measurement sensors inside the water heater tank with a vertical distance of at least four inches between successive sensors. A temperature sensor shall be positioned at the vertical midpoint of each of the six equal volume nodes with the tank. Nodes designate the equal volumes used to evenly partition the total volume of the tank. As much as is possible, the temperature sensor should be positioned away from any heating elements, anodic protective devices, tank walls, and flue pipe walls. If the tank cannot accommodate six temperature sensors and meet the installation requirements specified above, install the maximum number of sensors which comply with the installation requirements. The temperature sensors shall be installed either through: (1) The anodic device opening; (2) the relief valve opening; or (3) the hot water outlet. If installed through the relief valve opening or the hot water outlet, a tee fitting or outlet piping, as applicable, shall be installed as close as possible to its original location. If the hot water outlet includes a heat trap, the heat trap shall be installed on top of the tee fitting. Added fittings shall be covered with thermal insulation having an R value of 4 $hr{\cdot}ft^2{\cdot}°F/Btu$.

4.6. *Ambient Temperature.* The ambient air temperature shall be measured approximately at the vertical mid-point of the heater and approximately 2 feet from the surface of the water heater. The sensor shall be shielded against radiation.

4.7. *Inlet and Outlet Water Temperature Measurements.* Install temperature sensors in the cold-water inlet pipe and hot-water outlet pipe as shown in Figures 1, 2, or 3, as applicable.

4.8. *Flow Control.* A flow control valve shall be installed to provide flow as specified within section 5.

4.9. *Flue Requirements.*

4.9.1. *Oil-Fired Water Heaters.* Establish a draft at the flue collar as specified in the manufacturer's literature. Establish the draft by using a sufficient length of vent pipe connected to the water heater flue outlet and directed vertically upward. For an oil-fired water heater having a horizontally discharging draft hood outlet, a 90 degree elbow having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. A length of vent pipe sufficient to establish the draft shall be connected to the elbow fitting and oriented to discharge vertically upward. Direct vent oil-fired water heaters should be installed with venting equipment as specified in the manufacturer's instructions, using the minimum vertical and horizontal lengths of vent pipe recommended by the manufacturer.

4.9.2. *Gas-Fired Water Heaters.* Establish a natural draft in the following manner. For gas-fired water heaters having a vertically discharging draft hood outlet, a 5 foot vertical vent pipe extension having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. For gas-fired water heaters having a horizontally discharging draft hood outlet, a 90 degree elbow having a diameter equal to the largest flue collar size of the draft hood shall be connected to the draft hood outlet. A 5 foot length of vent pipe shall be connected to the elbow and oriented to discharge vertically upward.

Direct vent gas-fired water heaters shall be installed wth venting equipment specified in the manufacturer's instructions using the minimum vertical and horizontal lengths of vent pipe recommended by the manufacturer.

4.9.3. *Heat Pump Water Heater Storage Tank.* The tank to be used for testing a heat pump water heater without a tank supplied by the manufacturer shall be an electric storage type water heater having a volume of 47.0 gallons ± 1 gallon with an Energy Factor of 0.87 ± .01 as determined in accordance with section 6.1.7 with two 4.5 kW heating elements controlled in such a manner as to prevent both elements from operating simultaneously.

5. Test Procedures

5.1. *Storage Tank and Heat Pump Water Heaters.*

5.1.1. *Determination of Storage Tank Volume.* Determine the storage capacity, V_u, of the water heater under test, in gallons, by subtracting the tare weight—measured while the tank is empty—from the gross weight of the storage tank completely filled with water with all air eliminated and line pressure applied as described in section 2.5, and dividing the resulting net weight by the density of water at the appropriate temperature.

5.1.2. *Setting the Thermostat for a Thermostatically Operated Water Heater.* Starting with a tank of supply water, initiate normal operation of the water heater. After cutout, observe the mean tank temperature (based on the six temperature sensors) every minute until the maximum value is observed. Determine whether this maximum value of the mean tank temperature is within the range of 135°F ±5°F. If not, turn off the water heater, adjust the thermostat, and refill the tank with supply water. Then, initiate normal operation of the water heater, and once again determine the maxi-

mum mean tank temperature after cut-out. Repeat this sequence until the maximum mean tank temperature after cut-out is within the range of 135°F ±5°F. If a water heater has two thermostats, the thermostat which controls the upper heating element shall be set first to yield a maximum water temperature of 135°F ±5°F as measured by the temperature tank sensors above the upper heating element. The thermostat which controls the lower heating element shall then be set to yield a maximum mean tank temperature of 135°F ±5°F. For heat pump water heaters, which control an auxiliary resistance element, the thermostat shall be set in accordance with the manufacturer's installation instructions.

5.1.3. *Power Input Determination.* For all water heaters except electric types having immersed heating elements and initiate normal operation and determine the power input, P, to the main burners (including pilot light power, if any) after 15 minutes of operation. If the water heater is equipped with a gas appliance pressure regulator, the regulator outlet pressure shall be set within ±10% of that recommended by the manufacturer. For oil fired water heaters the fuel pump pressure shall be within ±10% of the manufacturer's specified pump pressure. All burners shall be adjusted to achieve an hourly Btu rating that is within ±2% of the value specified by the manufacturer. For an oil-fired water heater, adjust the burner to give a CO_2 reading recommended by the manufacturer and an hourly Btu rating that is within ±2% of that specified by the manufacturer. Smoke in the flue may not exceed No. 1 smoke as measured by the procedure in ASTM-D-2156-80. Gas- and oil-fired water instantaneous water heaters shall have the burners adjusted to the manufacture's maximum firing rate value.

5.1.4. *First Hour Rating Test.* Establish normal water heater operation with the maximum mean tank temperature within the range specified in section 2.1.4. Begin the first hour rating test after the thermostat has acted to reduce the electrical power or fuel input to the water heater and the maximum storage tank temperature has been achieved. If the water heater incorporates a heat-pump, wait until both the heat pump and electrical heating element(s) have ceased to supply energy to the storage tank. Record the time, oil, gas and/or electrical meter readings as appropriate. Do not interrupt electrical power and/or fuel to the water heater. The rate of water withdrawal shall be 3.00±0.25 gallons per minute. Draw and collect water withdrawn from the water heater in a suitable container for the purpose of determining its weight at the conclusion of the test. During the draw record the inlet and outlet fluid temperature beginning 15 seconds after the start and at every subsequent 5 second interval throughout the duration of each draw. Alternatively, a water meter may be used to directly measure the volume of water withdrawn. Record the maximum outlet temperature which occurs during the draw as T_{max}. The withdrawal of water shall continue until the outlet temperature drops to a value 25°F below T_{max}, defined as T_{min} at which time the draw shall be terminated. Record the average outlet temperature and mass removed as $T_{out,1}$ and M_1, respectively. If the thermostat acts to reduce the supply of fuel to the main burner or electrical input to the upper heating element of a multiple element electric water heater, or electrical input to a water heater having a single element or multiple elements which operate simultaneously, before one hour has elapsed, initiate a second draw. During the draw record the outlet fluid temperatures beginning 15 seconds after initiating the draw and at every subsequent 5 second interval throughout the duration of each draw until the outlet temperature drops to T_{min}, at which time the draw is terminated. Record the average outlet temperatures as well as the mass removed. Continue this sequence of events until one hour has elapsed. If a draw is currently taking place, continue the draw until the outlet temperature reaches T_{min}, and record the elasped time between the previously recorded time, at the beginning of the first draw, and the termination of this final draw as τ_{fin}. If a draw is not taking place at the end of one hour, wait until the thermostat acts to reduce the supply of fuel to the main burner or electrical input to the upper heating element of a multiple element electric water heater, or electrical input to a water heater having a single element or multiple elements which operate simultaneously, to initiate the final draw. During the final draw, record the outlet fluid temperature beginning 15 seconds after initiating the draw and at every subsequent 5 second intervals throughout the duration of the draw until the outlet temperature drops to T_{min}, at which time the draw is terminated. Record the elasped time between the previously recorded time, at the beginning of the first draw, and the termination of the final draw as τ_{fin}. In either case, record the outlet temperatures and the mass removed during the final draw.

5.1.5. *24 Hour Simulated Use Test.* During the simulated use test, a total of 64.3 gallons are removed. With the water heater turned off, fill the water heater with supply water and apply pressure as described in section 2.1.5. Turn on the water heater and associated heat pump unit, if present. Wait until cutout occurs at 135°F ±5°F, as specified in section 2.1.4. After the cutout occurs, measure the mean tank temperature using the temperature sensors described in section 4.5

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perature shall be determine
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record the maximum mea
ture observed after cut-out
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For heat pump water heate
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standby mode until 24 ho
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to the main burner at an
hours. If a recovery is ta

minute until the maximum mean storage tank temperature is achieved. The water heater may be operated through up to three successive cycles of drawing 10 gallons per draw, permitting recovery between each draw, prior to the start of the test. Record at this time (designated as $\tau=0$), the mean tank temperature ($\bar{T}_s$), and the oil, gas and electrical energy measurements as appropriate. Begin the 24 hour simulated use test by drawing an amount of water out of the water heater equivalent to one-sixth of the daily hot water usage, 64.3 gallons. Record the average storage tank and ambient temperature every 15 minutes throughout the 24 hour simulated use test unless recovery or a draw is occurring. At elapsed time intervals of one, two, three, four and five hours from $\tau=0$, initiate additional draws removing an amount of water equivalent to one-sixth of 64.3 gallons, with the maximum allowable deviation for any single draw being ±0.5 gallons. The quantity of water drawn during the sixth draw shall be increased or decreased as necessary such that the total volume of water withdrawn shall be equal to 64.3±1.0 gallons.

All draws during the simulated use test are to be made at flow rates of 3.0±3.0 gallons per minute. Measurements of the inlet and outlet temperatures shall be made beginning 15 seconds after the draw is initiated and at every subsequent 5 second interval throughout the duration of each draw. The arithmetic mean of the hot water discharge temperature and the cold water inlet temperature shall be determined for each draw. Record the scale or meter reading, as appropriate, after each draw. At the end of the recovery period following the first draw, record the maximum mean tank temperature observed after cut-out, $T_{max.1}$, and the energy consumed, Q, for oil, gas, and heat pump water heaters including auxiliary energy such as pilot lights, pumps, fans, etc. For heat pump water heaters Q_u is the sum of the energy consumed by the heat pump and the electrical heating elements(s).

At the end of the recovery period following the sixth draw, record the total electric and/or fuel energy consumption, Q_{su}, and the scale reading or the meter reading, as appropriate. If a water scale is used, determine the net weight of the water withdrawn, M_{FHR} in pounds. Record the maximum value of the mean tank temperature after cutout as $\bar{T}_{su}$. Except as noted below, allow the water heater to remain in the standby mode until 24 hours have elapsed from the start of the test, $\tau=0$. Prevent the water heater from beginning a recovery cycle during the last hour of the test by turning off the electric power to the electrical heating elements and heat pump, if present, or by turning down the fuel supply to the main burner at an elapsed time of 23 hours. If a recovery is taking place at an elapsed time of 23 hours, wait until the recovery is complete before reducing the electrical and/or fuel supply to the water heater. At 24 hours, record the mean tank temperature, $\bar{T}_{24}$, and the electric and/or fuel instrument readings. Determine the total energy consumption during the entire 24 hour simulated use test, Q. Record the time interval between the time at which the maximum mean tank temperature is observed after the sixth draw and the end of the 24 hour test as $\tau_{rec.1}$. Record the time during which water was not being withdrawn from the water heater during the entire 24 hour period as $\tau_{rec.2}$.

5.2 *Instantaneous Water Heaters*

5.2.1. *Setting the Outlet Discharge Temperature.* Initiate normal operation of the water heater at the full input rating. Monitor the discharge water temperature and set to a value of 135°F ± 5°F in accordance with the manufacturer's instructions. If the water heater is not capable of providing 3.00 ± 0.25 gallons per minute then adjust the flow rate as necessary to achieve the specified discharge water temperature. Record the corresponding flow rate as V_{max}. If the instantaneous water heater incorporates a controller which permits continous burner operation at a reduced input rate, adjust the flow rate as necessary to achieve a discharge water temperature of 135° ± 5°F while maintaining the minimum input rate. Record the corresponding flow rate, V_{min}. If an outlet temperature of 135° ± 5°F cannot be achieved at the minimum allowable flow rate permitted by the instantaneous water heater, record the flow rate as V_{min} and the outlet temperature as T_{min}.

5.2.2. *Power Input Determination.* For oil and gas flow actuated water heaters, adjust the burners to the maximum firing rate value specified by the manufacturer.

5.2.3. *First Hour Rating Test for Instantaneous Water Heaters.* Establish normal heater operation at the maximum input rate with the discharge water temperature set in accordance with section 5.2.1. Record the time, oil, and/or gas meters as appropriate. Do not interrupt electrical or fuel to the water heater. Draw and collect water withdrawn from the water heater, while recording the inlet and outlet fluid temperatures beginning 15 seconds after the draw is initiated and at every subsequent 5 second interval throughout the duration of the draw in a suitable container for the purpose of determining its weight at the conclusion of the test. Alternatively, a water meter may be used to directly measure the value of water withdrawn. At the end of one hour terminate the draw. Determine the mass of water withdrawn, M_{FHR}, in pounds, or the volume of water withdrawn, V_{FHR}, in gallons with an error no greater than 2 percent.

5.2.4. 24 Hour Simulated Use Test

5.2.4.1. *Fixed Input Instantaneous Water Heaters.* Establish normal operation with the discharge water temperature and flow rate set to values of 135°F ± 5°F and V_{max}, respectively. Record the oil, gas, and electrical energy measurements, as appropriate. Begin the 24 hour simulated use test by drawing an amount of water out of the water heater equivalent to one-sixth of the daily hot water usage, 64.3 gallons. At elapsed time intervals of one, two, three, four, and five hours from $\tau = 0$, initiate additional draws removing an amount of water equivalent to one-sixth of 64.3 gallons, with the maximum allowable deviation for any single draw being ± 0.5 gallons. The quantity of water drawn during the sixth draw shall be increased or decreased as necessary such that the total volume of water withdrawn shall be equal to 64.3±1.0 gallons. Measurements of the inlet and outlet water temperatures shall be made beginning 15 seconds after the draw is initiated and at every 5 second interval throughout the duration of the draw. The arithmetic mean of the hot water discharge temperature and the cold water inlet temperature shall be determined for each draw. Record the scale or meter reading, as appropriate, after each draw. At the end of the recovery period following the first draw, record the energy consumed, Q_r. Allow the water heater to remain in the standby mode until exactly 24 hours have elapsed from the start of the test, $\tau = 0$. At 24 hours, record the electric and/or fuel instrument readings. Determine the energy consumption during the entire 24 hour simulated use test, Q.

5.2.4.2. *Variable Input Instantaneous Water Heaters.* If the instantaneous water heater incorporates a controller which permits continuous burner operation at a reduced input rate, the first three draws shall be conducted using the maximum flow rate, V_{max}, while removing an amount of water equivalent to one-sixth of 64.3 gallons, with the maximum allowable deviation for any one of the three draws being ± 0.5 gallons. The second three draws shall be conducted at V_{min}. If an outlet temperature of 135° ± 5°F could not be achieved at the minimum flow rate permitted by the instantaneous water heater, the last three draws should be lengthened such that the volume removed is equivalent to

$$V_{3,6} = \frac{64.3}{6} \cdot \left[\frac{77°F}{T_{min} - 58°F} \right]$$

with the maximun allowable definition for any one of the three draws being ± 0.5 gallons. The quantity of water drawn during the sixth draw shall be increased or decreased as necessary such that the total volume of water withdrawn shall be equal to $32.15 + 3°V_{3,6} \pm 1.0$ gallons. Measurements of the inlet and outlet water temperatures shall be made beginning 15 seconds after the draw is initiated and at every 5 second interval throughout the duration of the draw. Determine the arithmetic mean of the hot water discharge temperature and the cold water inlet temperature for each draw. Record the scale or meter reading, as appropriate, after each draw. At the end of the recovery period following the first draw, record the energy consumption, $Q_{r,max}$. Record the energy consumed prior to the fourth draw and at the end of the recovery period following the fourth draw, $Q_{r,min}$.

Allow the water heater to remain in the standby mode until exactly 24 hours have elapsed from the start of the test, $\tau = 0$. At 24 hours, record the electric and/or fuel instrument readings. Determine the energy consumption during the entire 24 hours simulated use test, Q.

6. Computations

6.1 *Storage Tank Water Heaters.*

6.1.1. *Storage Tank Capacity.* The storage tank capacity is computed using the following—

$$V_{st} = (W_f - W_t)/\rho$$

where V_{st} is the storage capacity of the water heater, gallons

W_f is the weight of the storage tank completely filled with water, lbm

W_t is the tare weight of the empty storage tank, lbm

ρ is the density of water at the appropriate temperature, lbm/gal.

6.1.2. First Hour Rating Computation. Compute the first hour rating as

$$F_{hr} = \frac{60}{\tau_{hr}} \sum_{i=1}^{n} \frac{M_i(T_{del,i} - T_{in,i})}{\rho(135°F - 58°F)}$$

Which may be expressed as

$$F_{hr} = \frac{60}{\tau_{hr}} \sum_{i=1}^{n} \frac{M_i(T_{del,i} - T_{in,i})}{\rho(77°F)}$$

where M_i represents the mass removed during the ith draw of the first hour rating test, lbm

$T_{del,i}$ is the average delivery temperature for the ith draw which occurred during the first hour rating test, °F

τ_{hr} represents the ela
during the first ho
utes

$T_{in,i}$ is the average inle
ith draw which occ
hour rating test, °F

ρ represents the densit
erage delivery temp

and n represents th
which occur during
meter is used in lie
hour rating is

$$F_{hr} = \frac{60}{\tau_{hr}} \sum_{i=1}^{n} -$$

where V_i represents
during the ith dr
rating test, gal

6.1.3 *Recovery Effici*
ficiency for gas, oil, ar
type water heaters is c

$$\eta_r = \frac{M_i C_{p,i}(}{}$$

$$+ \frac{V_{st}\rho C_{p2}(}{}$$

where M_i is the mass
first draw, lbm

$C_{p,i}$ is the specific hea
age temperature (
°F

$T_{del,i}$ is the average de
the first draw, °F

$T_{in,i}$ is the average ini
first draw, °F

V_{st} is the storage tank

ρ is the density of wa
perature ($T_{max,i}$ +T

C_{p2} is the specific hea
age temperature
°F

$T_{max,i}$ is the maximun
ture recorded afte
first draw, °F

T_r is the maximum m
recorded prior to t

and Q_r is the total en
heater between c
draw and cutou
draw, including a
pilot lights, pump
trical auxiliary er
ed to thermal ene
conversion: 1kWh

τ_{hr} represents the elasped time recorded during the first hour rating test, minutes

$\bar{T}_{in,i}$ is the average inlet temperature for the ith draw which occurred during the first hour rating test, °F

ρ represents the density of water at the average delivery temperature, lbm/gal

and n represents the number of draws which occur during the test If a water meter is used in lieu of a scale, the first hour rating is

$$F_{hr} = \frac{60}{\tau_{hr}} \sum_{i=1}^{n} \frac{V_i(\bar{T}_{del,i} - \bar{T}_{in,i})}{77°F}$$

where V_i represents the volume removed during the ith draw of the first hour rating test, gal

6.1.3 *Recovery Efficiency.* The recovery efficiency for gas, oil, and heat pump storage type water heaters is computed as

$$\eta_r = \frac{M_1 C_{p1}(\bar{T}_{del,1} - \bar{T}_{in,1})}{Q_r} + \frac{V_{st}\rho C_{p2}(T_{max,1} - \bar{T}_s)}{Q_r}$$

where M_1 is the mass withdrawn during the first draw, lbm

C_{p1} is the specific heat of water at the average temperature $(\bar{T}_{del,1} + T_{in,1})/2$, btu/lbm °F

$\bar{T}_{del,1}$ is the average delivery temperature for the first draw, °F

$\bar{T}_{in,1}$ is the average inlet temperature for the first draw, °F

V_{st} is the storage tank capacity, gal

ρ is the density of water at the average temperature $(T_{max,1} + \bar{T}_s)/2$, lbm/gal

C_{p2} is the specific heat of water at the average temperature $(T_{max,1} + \bar{T}_s)/2$, Btu/lbm °F

$T_{max,1}$ is the maximum mean tank temperature recorded after cutout following the first draw, °F

$\bar{T}_s$ is the maximum mean tank temperature recorded prior to the first draw, °F

and Q_r is the total energy used by the water heater between cutout prior to the first draw and cutout following the first draw, including auxiliary energy such as pilot lights, pumps, fans, etc., Btu. (Electrical auxiliary energy shall be converted to thermal energy using the following conversion: 1kWh = 3412.76 Btu.)

The recovery efficiency for electric water heaters with immersed heating elements is assumed to be 98 percent.

6.1.4. *Hourly Standby Losses.* The hourly standby losses are computed as

$$Q_{hr} = \left[Q_{stby} - \frac{MC_p(\bar{T}_{24} - \bar{T}_m)}{\eta_r} \right] \Big/ \tau_{stby,1}$$

where Q_{hr} is the hourly standby energy losses of the water heater, Btu/hr

Q_{stby} is the total energy consumer by the water heater between the time at which the maximum mean tank temperature is observed after the sixth draw and the end of the 24 hour test period, Btu

M is the mass of the water within the storage tank, lbm

C_p is the specific heat of water at the average temperature $(\bar{T}_{24} + \bar{T}_m)/2$, Btu/lbm °F

$\bar{T}_{24}$ is the mean tank temperature at the end of the 24 hour test period, °F

$\bar{T}_m$ is the maximum mean tank temperature observed after the sixth draw, °F

and $\tau_{stby,1}$ is the elapsed time between the time at which the maximum mean tank temperature is observed after the sixth draw and the end of the 24 hour test period, hours

The standby heat loss coefficient for the tank is computed as—

$$UA = \frac{Q_{hr}}{\bar{T}_{t,stby} - \bar{T}_{a,stby}}$$

where $\bar{T}_{t,stby}$ is the average storage tank temperature between the time at which the maximum mean tank temperature is observed after the sixth draw and the end of the 24 hour test period, °F

$\bar{T}_{a,stby}$ is the average ambient temperature between the time at which the maximum mean tank temperature is observed after the sixth draw and the end of the 24 hour test period, °F

and UA is the standby heat loss coefficient of the storage tank,

$$\frac{BTU}{hr\ °F}$$

6.1.5. *Daily Water Heating Energy Consumption.* The daily water heating energy consumption, Q_d is computed as

$$Q_s = Q - \frac{C_p M(T_{2s} - T_s)}{\eta_r}$$

where Q is the total energy used by the water heater during the 24 hours simulated use test including auxiliary energy such as pilot lights, pumps, fans, etc., Btu

C_p is the specific heat of water at the average temperature $(T_{2s}+T_s)/2$, Btu/lbm °F

M is the mass of water within the storge tank, lbm

T_{2s} is the average tank temperature at the conclusion of the 24 hours simulated use test, °F

T_s is the average tank temperature at the beginning of the 24 hours simulated use test, recorded one minute before the first draw is initiated °F

and η_r is the recovery efficiency of the hot water heater, dimensionless.

6.1.6. *Adjusted Daily Water Heating Energy Consumption.* The adjusted daily water heating energy consumption, Q_{da} takes into account that the temperature difference between the storage tank and surrounding ambient temperature may not be the nominal value of 67.5°F (135°F − 67.5°F) due to the 10°F allowable variation in storage tank temperature, 135 ± 5°F, and the 5°F allowable variation in surrounding ambient temperature 65°F to 70°F. The adjusted daily water heating energy consumption is computed as

$$Q_{da} = Q_d - [(T_{stby} - T_{a\text{-}stby}] - (135°F - 67.5°F)]UA\tau_{stby,2}$$

where Q_{da} is the adjusted daily water heating consumption, Btu

T_{stby} is the mean tank temperature during the total standby portion, $\tau_{stby,2}$, of the 24 hour test, °F

$T_{a\text{-}stby}$ is the average ambient temperature during the total standby portion, $\tau_{stby,2}$, of the 24 hour test, °F

UA is the standby heat loss coefficient for the storage tank, Btu/hr°F

and $\tau_{stby,2}$ is the number of hours during the 24 hour simulated test when water was not being withdrawn from the water heater

A modification is also needed to take into account that the temperature difference between the outlet water temperature and supply water temperature may not be equivalent to the nominal value of 77°F (135°F−58°F). The following equations adjust the experimental data to a nominal 77°F temperature rise.

The energy used to heat water, Btu per day, may be computed as—

$$Q_{HW} = \sum_{i=1}^{6} \frac{M_i C_{pi}(T_{del,i} - T_{in,i})}{\eta_r}$$

where M_i is the mass withdrawn for the ith draw (i=1 to 6), lbm

C_{pi} is the specific heat of water, Btu/lbm °F

The energy required to heat the same quantity of water over a 77 °F temperature rise, Btu per day, is

$$Q_{HW,77} = \sum_{i=1}^{6} \frac{M_i C_{pi}(135°F - 58°F)}{\eta_r}$$

The difference between these two values is—

$$Q_{HWD} = Q_{HW,77} - Q_{HW}$$

which must be added to the adjusted daily water heating energy consumption value. Thus, the daily energy consumption value which takes into account that the temperature difference between the storage tank and ambient temperature may not be 67.5°F and the temperature rise across the storage tank may not be 77°F is—

$$Q_{dm} = Q_{da} + Q_{HWD}$$

6.1.7. *Energy Factor.* The energy factor, E_f, is computed as—

$$E_f = \sum_{i=1}^{6} \frac{M_i C_{pi}(135°F - 58°F)}{Q_{dm}}$$

where Q_{dm} is the modified daily water heating energy consumption as computed in accordance with Section 6.1.6, Btu

6.1.8. Annual Energy Consumption

The annual energy consumption for storage type and heat pump water heaters is computed as—

$$E_{annual} = Q_{dm} \cdot 365$$

where Q_{dm} is the modified daily energy consumption value, Btu per day and 365 is the number of days within a year, days

6.2. Instantaneous Hot Water Heaters.

6.2.1. *First Hour Rating Computation.* Compute the first hour rating as

$$F_{hr} = \frac{M(T_{del} - T_{in})}{\rho(135°F - 58°F)}$$

which may be expressed:

$$F_{hr} = \frac{M(T_{del} - T_{in})}{\rho(T$$

where M represents the during the one hour lbm

T_{del} is the average deliver

T_{in} is the average inlet tem

and ρ represents the dens average delivery tempe

If a water meter is used the first hour rating is con

$$F_{hr} = \frac{V(T_{del} - T_{in})}{T$$

where V represents the v moved during the on draw, gal

6.2.2. Recovery E

6.2.2.1. *Fixed Input Ins Heaters.* The recovery eff ed as

$$\eta_r = \frac{M_1 C_{p1}(T_{del,1} - T_{in,1}) + Q_s}{Q}$$

where M_1 is the mass with first draw, lbm

C_{p1} is the specific heat of age temperature ($T_{del,1}$ lbm°F

$T_{del,1}$ is the average deliver the first draw, °F

$T_{in,1}$ is the average inlet t first draw, °F

and Q, is the total energy heater between cutou draw and cutout fo draw, including auxili pilot lights, pumps, fa

6.2.2.2. Variable Input In Heater

For instantaneous wa have a variable firing ra ficiency values are com maximum input rate an mum input rate. The used in subsequent comp the average of these tw mum recovery efficiency

which may be expressed as—

$$F_{hr} = \frac{M(T_{del} - T_{in})}{\rho(77°F)}$$

where M represents the mass removed during the one hour continuous draw, lbm

T_{del} is the average delivery temperature, °F

T_{in} is the average inlet temperature, °F

and ρ represents the density of water at the average delivery temperature, lbm/gal

If a water meter is used in lieu of a scale the first hour rating is computed as—

$$F_{hr} = \frac{V(T_{del} - T_{in})}{77°F}$$

where V represents the volume of water removed during the one hour continuous draw, gal

6.2.2. Recovery Efficiency

6.2.2.1. *Fixed Input Instantaneous Water Heaters.* The recovery efficiency is computed as

$$\eta_r = \frac{M_1 C_{p1}(T_{del.1} - T_{in.1})}{Q_r}$$

where M_1 is the mass withdrawn during the first draw, lbm

C_{p1} is the specific heat of water at the average temperature $(T_{del.1} + T_{in.1})/2$, Btu/lbm°F

$T_{del.1}$ is the average delivery temperature for the first draw, °F

$T_{in.1}$ is the average inlet temperature for the first draw, °F

and Q_r is the total energy used by the water heater between cutout prior to the first draw and cutout following the first draw, including auxiliary energy such as pilot lights, pumps, fans, etc., Btu

6.2.2.2. Variable Input Instantaneous Water Heaters

For instantaneous water heaters which have a variable firing rate, two recovery efficiency values are computed, one at the maximum input rate and one at the minimum input rate. The recovery efficiency used in subsequent computations is taken as the average of these two values. The maximum recovery efficiency is computed as

$$\eta_{r.max} = \frac{M_1 C_{p1}(T_{del.1} - T_{in.1})}{Q_{r.max}}$$

where M_1 is the mass withdrawn during the first draw, lbm

C_{p1} is the specific heat of water at the average temperature $(T_{del.1} + T_{in.1})/2$, Btu/lbm °F

$T_{del.1}$ is the average delivery temperature for the first draw, °F

$T_{in.1}$ is the average inlet temperature for the first draw, °F

and $Q_{r.max}$ is the total energy used by the water heater between cutout prior to the first draw and cutout following the first draw, including auxiliary energy such as pilot light, Btu

The minimum recovery efficiency is computed as—

$$\eta_{r.min} = \frac{M_4 C_{p4}(T_{del.4} - T_{in.4})}{Q_{r.min}}$$

where M_4 is the mass withdrawn during the fourth draw, lbm

C_{p4} is the specific heat of water, Btu/lbm °F

$T_{del.4}$ is the average delivery temperature for the fourth draw, °F

$T_{in.4}$ is the average inlet temperature for the first draw, °F

and $Q_{r.min}$ is the total energy consumed immediately prior to the fourth draw and cutout following the fourth draw, including auxiliary energy such as pilot lights, Btu

The recovery efficiency is computed as—

$$\eta_r = \frac{\eta_{r.max} + \eta_{r.min}}{2}$$

6.2.3. *Daily Water Heating Energy Consumption.* The daily water heating energy consumption, Q_d is computed as—

$$Q_d = Q$$

where Q is the energy used by the flow actuated water heater during the 24 hour simulated use test

A modification is needed to take into account that the temperature difference between the outlet water temperature and supply water temperature may not be equivalent to the nominal value of 77 °F (135 °F−58 °F). The following equations adjust the experimental data to a nominal 77 °F temperature rise.

The energy used to heat water may be computed as—

ITEM 8.
Z21/CGA Joint Water Heater
Subcommittee Meeting,
September 23-24, 1993

RECOMMENDATIONS FROM GAMA REGARDING DEVELOPMENT OF "CATEGORY DETERMINATION" COVERAGE FOR WATER HEATER STANDARDS

Action Requested

Consider adopting for distribution for review and comment suggested revisions to the water heater and pool heater standards addressing "Categorization" and other related coverage.

History

At its November 13-14, 1991 meeting, the Z21 water heater subcommittee was informed by the American Gas Association Laboratories (AGAL) that the AGAL had certified gas water heaters which produce condensation in the flue gases as part of normal operation. The AGAL reported that it had conducted additional tests to certify such appliances to the requirements of ANSI Z21.10.3. The additional tests were similar to those specified in the Z21 boiler standard, ANSI Z21.13 (e.g, "condensate disposal systems"). In light of this, the AGAL provided the subcommittee with suggested coverage to address such appliances, similar to coverage in the Z21.13 boiler standard.

After discussion, the subcommittee endorsed the concept of developing "Categorization" coverage for the water heater standards. The subcommittee agreed to have the appropriate GAMA technical committee develop such coverage for the subcommittee's consideration at its next meeting.

In addition, at its November 1991 meeting, the subcommittee reviewed proposed revisions to Z21.10.1, Z21.10.3, and Z21.56, in light of comments received. Some of the proposals (dated June 1991) addressed (1) water heaters/pool heaters operating under forced or induced draft venting systems, and (2) fan-assisted water heaters/pool heaters, installed indoors and vented horizontally through an outside wall. In addition, the subcommittee reviewed comments in response to the June 1991 revisions to 2.29.2, under 2.29, Wind Test, which proposed the following sentence be added:

> *"If the water heater is designed to prevent the main burner from operating under this wind condition [40 mph], the wind shall be reduced to the highest value that will allow the main burner to operate."*

(8-1)

After discussion, the subcommittee agreed not to recommend the above noted proposals to the Z21 Committee. Instead, the subcommittee recommended that the GAMA Water Heater Division's Technical Committee review these proposals during its development of draft "Categorization" coverage for the water heater standards. Moreover, the subcommittee requested GAMA to include in its consideration all comments and record of discussion on the above proposals from the subcommittee's November 1991 meeting. The subcommittee then recommended the remaining June 1991 proposals to the Z21 Committee.

At its September 21-22, 1993 meeting, Mr. Frank Stanonik (GAMA) reported that suggested coverage on this subject was not available, since the Technical Committee of GAMA's Water Heater Division had not yet completed its assignment. He noted that the technical committee had discussed the "Categorization" task and had identified some issues relative to applying the current central furnace/boiler criteria to water heaters. One issue identified was that the current criteria is based on a "70 percent flue loss test." This raises the issue of whether such a flue loss test should be adopted applicable to water heaters.

Mr. Stanonik commented that the GAMA technical committee needed to address the issues involved with applying the existing criteria to water heaters, before drafting and recommending suggested coverage to the subcommittee.

In addition, Mr. Stanonik noted that the "Categorization" assignment impacts the completion of the other tasks noted above, referred to the technical committee by the subcommittee at its November 1991 meeting. After review, the subcommittee tabled this subject pending recommendations from the GAMA Water Heater Division's Technical Committee.

Background

It is anticipated that a report from the GAMA technical committee on the above subjects will be made available at this meeting.

June 1991 Proposals Held in Abeyance

Attached are proposed revisions to Z21.10.1, which were dated 1991 and were held in abeyance at the subcommittee's November 1991 meeting. Similar proposals to the Z21.10.3 and Z21.56 standards were also held in abeyance at that time, pending further consideration and recommendations from the GAMA technical committee.

Attachment
Z21/CGA Joint Water Heater Subcommittee
Meeting, September 23-24, 1993

The following draft revisions were adopted for distribution for review and comment by the Subcommittee on Standards for Gas Water Heaters at its June 19, 1990 meeting, and were held in abeyance at the subcommittee's November 13-14, 1991 meeting. These revisions were based on the Standard for Gas Water Heaters, Volume I, Storage Water Heaters With Input Ratings of 75,000 Btu Per Hour or Less, ANSI Z21.10.1-1990, and Addenda, Z21.10.1a-1991, and Z21.10.1b-1992. The revisions were held in abeyance based on comments received and the discussions recorded under the minutes of the November 1991 meeting. These revisions were referred to the GAMA Water Heater Division's Technical Committee for further consideration and recommendations.

Additions and changes are "redlined" (shaded) and "strike-out" is used to show deletions (e.g., ~~proposed deletion~~).

PART I

CONSTRUCTION

1.2 GENERAL CONSTRUCTION AND ASSEMBLY

1.2.24 A water heater for indoor installation designed to vent the flue gases horizontally through an outside wall shall be provided with the means for venting the flue gases to the outdoors unless the necessary parts to accomplish this are of specific types listed by a nationally recognized testing agency and the water heater manufacturer's instructions identify and specify the use of such specific parts (see 1.31.9 and 1.32.33).

(Present 1.2.24 through 1.2.27 become 1.2.25 through 1.2.28 respectively, unchanged.)

RATIONALE: *Construction and performance coverage is proposed to address water heaters that horizontally vent the flue gases through an outside wall. The proposals correlate with proposed and existing coverage in the Z21 central furnace standard (ANSI Z21.47).*

1.31 INSTRUCTIONS

1.31.9 In addition to the information specified in 1.31.1, a water heater for indoor installation designed to vent the flue gases horizontally through an outside wall shall also be accompanied by instructions covering the installation of properly identified parts to provide for the venting of the flue gases to the outdoors, including instructions which specify that the draft hood, when applicable, shall be installed so as to be in the same

atmospheric pressure zone as the combustion air inlet of the water heater. When the parts for venting the flue gases are not provided by the water heater manufacturer and they are specific types listed by a nationally recognized testing agency, these instructions shall clearly identify and specify the use of the specific parts (see 1.2.24 and 1.32.33).

RATIONALE: *See "Rationale" following 1.2.24.*

1.32 MARKING

1.32.33 A water heater for indoor installation designed to vent the flue gases horizontally through an outside wall shall bear on Class III marking material (unless otherwise noted) the following, as applicable:

a. The water heater manufacturer's part number(s) of the means to provide for venting of the flue gases to the outdoors. When venting system components are listed by a nationally recognized testing agency, the listing identification by manufacturer and specific part number may be used in lieu of the water heater manufacturer's part number. When parts of special design and listing are involved, the vent manufacturer is also to be identified.

b. On parts supplied by the water heater manufacturer (see 1.2.24) for venting flue gases from the water heater to the outdoors, identification in accordance with "a" above.

c. A Class V marking in a location conspicuous prior to installation clearly indicating the minimum and maximum vent length from the water heater.

(Present 1.32.35 through 1.32.43 become 1.32.34 through 1.32.42 respectively, unchanged.)

RATIONALE: *See "Rationale" following 1.2.24.*

PART II

PERFORMANCE

2.1 GENERAL

2.1.7 A water heater for indoor installation designed to vent the flue gases horizontally through an outside wall shall comply with all of the applicable performance provisions specified in this standard with the water heater installed with the minimum vent length specified by the manufacturer. In addition, the tests specified in 2.4 through 2.7 and 2.21.1-b shall be conducted with the water heater equipped with the maximum vent length specified by the manufacturer. The vent terminal or cap supplied or specified