DRAFT STANDARD
C191-04
Performance of electric storage tank water heaters for domestic hot water service

Note: *This* draft is under development and subject to change; it should not be used for reference purposes.

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Preface

This is the fourth edition of CSA C191, *Performance of electric storage tank water heaters for domestic hot water service*. It supersedes the previous edition, published in 2000 under the title *Performance of Electric Storage Tank Water Heaters for Household Service*. The 2000 edition superseded the previous editions of the CAN/CSA-C191 Series, which consisted of CAN/CSA-C191.0, *Performance and Energy Efficiency of Electric Storage Tank Water Heaters*, and CAN/CSA-C191.1, *Performance Options for Electric Storage Tank Water Heaters*. Those editions of CAN/CSA-C191 Series were published in 1990 and 1983.

Technological changes since the publication of the previous edition of this Standard have led to the updating of clauses dealing with element watts densities, test procedures, and standby loss levels.

This Standard was prepared by the Subcommittee on Water Heaters, under the jurisdiction of the Technical Committee on Residential Equipment and the Strategic Steering Committee on Performance, Energy Efficiency, and Renewables, and has been formally approved by the Technical Committee. It will be submitted to the Standards Council of Canada for approval as a National Standard of Canada.

June 2004

Notes:

(1) Use of the singular does not exclude the plural (and vice versa) when the sense allows.

(2) Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

(3) This publication was developed by consensus, which is defined by CSA Policy governing standardization — Code of good practice for standardization *as "substantial agreement. Consensus implies much more than a simple majority, but not necessarily unanimity". It is consistent with this definition that a member may be included in the Technical Committee list and yet not be in full agreement with all clauses of this publication.*

(4) CSA Standards are subject to periodic review, and suggestions for their improvement will be referred to the appropriate committee.

(5) All enquiries regarding this Standard, including requests for interpretation, should be addressed to Canadian Standards Association, 5060 Spectrum Way, Suite 100, Mississauga, Ontario, Canada L4W 5N6.

Requests for interpretation should

(a) define the problem, making reference to the specific clause, and, where appropriate, include an illustrative sketch;

(b) provide an explanation of circumstances surrounding the actual field condition; and

(c) be phrased where possible to permit a specific "yes" or "no" answer.

Committee interpretations are processed in accordance with the CSA Directives and guidelines governing standardization *and are published in CSA's periodical* Info Update*, which is available on the CSA Web site at www.csa.ca.*

Foreword

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Testing techniques, test procedures, and instrumentation frequently must be prescribed by CSA International in addition to the technical requirements contained in Standards of CSA. In addition to markings specified in the Standard, CSA International may require special cautions, markings, and instructions that are not specified by the Standard.

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C191-04
Performance of electric storage tank water heaters for domestic hot water service

1 Scope

1.1 General
This Standard specifies requirements related to delivery, minimum standby performance, heater element ratings, and marking of electric storage tank water heaters.

1.2 Tank capacity
This Standard applies to stationary storage tank water heaters that have a rated capacity of 184 or 284 L (40 or 60 gal) and are intended for use with pressure systems in residential premises and similar locations. For convenience, the term “water heater” is used in this Standard to refer to such heaters.

In addition, the standby loss test and its associated calculation (see Clause 4.8) may be applied to stationary storage tank water heaters that have a rated capacity of 50 to 454 L (11 to 100 gal).

1.3 Mandatory language
In CSA Standards, “shall” is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard; “should” is used to express a recommendation or that which is advised but not required; and “may” is used to express an option or that which is permissible within the limits of the standard. Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material. Notes to tables and figures are considered part of the table or figure and may be written as requirements. Legends to equations and figures are considered requirements.

1.4 Units of measurement
The values given in SI (metric) units are the standard. The values given in parentheses are for information only. All measurements in gallons refer to imperial gallons.

2 Reference publications
This Standard refers to the following publications, and where such reference is made, it shall be to the edition listed below, including all amendments published thereto.

CSA (Canadian Standards Association)
CAN/CSA-B125-01
Plumbing Fittings

CAN/CSA-C22.2 No. 110-94 (R1999)
Construction and Test of Electric Storage-Tank Water Heaters

CAN/CSA-C309-M90 (R2003)
Performance Requirements for Glass-Lined Storage Tanks for Household Hot Water Service

3 Definitions

Note: *Some of the defined terms listed in this Clause do not appear elsewhere in this Standard but are defined here for informational purposes.*

The following definitions apply in this Standard:

Average water temperature — the average of the water temperature obtained through the use of six thermocouples, each located so as to sense the centre point of six approximately equal volumes of water from the top to the bottom of the tank.

Bottom inlet — a type of storage tank water heater whose cold water supply pipe is external to the tank and whose connection is on or near the bottom of the tank.

Controlled temperature differential — the difference between the water temperatures in degrees Celsius at the level of the temperature-sensing element of the thermostat at cut-in and cut-out under standby conditions.

Cut-in — the time or minimum temperature at which a water heater thermostat has acted to start the application of heat to the water.

Cut-in temperature — the minimum water temperature obtained in the top-of-tank for any particular setting of the thermostat.

Cut-out — the time or maximum temperature at which a water heater thermostat has acted to stop the application of heat to the water.

Cut-out temperature — the maximum water temperature obtained in the top-of-tank for any particular setting of the thermostat.

Diffusion ratio — the ratio of the volume of water withdrawn to the actual tank capacity.

Electric storage tank water heater — an automatically controlled, thermally insulated, electrically heated water tank with a rated storage capacity of at least 50 L.

Heater element — a complete or partial assembly consisting of a heating element, electrical insulation (e.g., mica, magnesium oxide), thermal insulation or air space, metal sheath or plate, and flange, heater block, or other mounting means.

Idling period — the period of time following the first cut-out of the lower thermostat after an adjustment of the thermostat setting or the elimination of accumulated air during which no water is withdrawn and all other test conditions remain unchanged.

Immersion heater element — a heater element mounted with the heating surface completely within the tank.

Interlock — that operation of the upper thermostat whereby the power supply to the upper heater element is closed while that to the lower heater element is simultaneously opened and vice versa. This is frequently referred to as “flip-flop” operation.

Jacket or **casing** — the outer shell surrounding the thermal insulation.

Lower heater element — the element so positioned as to heat the entire quantity of water within the tank.

Lower thermostat — the thermostat that controls the lower heater element.

Maximum operating temperature — the highest water temperature attainable in the top-of-tank at the highest setting of the thermostats.

Rated tank capacity — the marked or nominal capacity of the storage tank in litres.

Rated voltage — the voltage or range of voltages that appears on the nameplate designating the nominal voltage of the supply circuit on which the water heater is designed to be used.

Rated watts input — the power input in watts marked on the element and the nameplate of the water heater at the rated voltage.

Shipping container — the complete package when the water heater is shipped.

Standby — the condition of operation when no water is withdrawn from the tank and the water temperature is regulated by the thermostats.

Storage tank — the water container. For convenience, the term “tank” is used in this Standard.

Tank capacity — the measured or actual tank capacity in litres.

Thermal insulation — the material provided to reduce the rate of heat loss from the tank and heater elements.

Thermocouple probe — a test device inserted in the tank and provided with thermocouples to measure water temperatures at various levels.

Thermostat — a temperature-sensitive device that automatically opens and closes an electric circuit to regulate the temperature of the water in the tank.

Thermostat calibration — the relation of the cut-out temperature of water in top-of-tank to the thermostat setting indicated.

Top-of-tank — the top-sixth portion of the total tank volume.

Top-of-tank temperature — the temperature of the water at the centre point of the top-sixth portion of the total tank volume.

Upper heater element — any element supplementing the lower heater element.

Upper thermostat — the thermostat that controls the upper heater element or elements and interlocks the operation of the upper and lower heater elements.

Upper zone — the percentage of the actual tank capacity effectively heated by the upper heater element.

Working pressure — the pressure above which the tank is not to be operated.

4 Construction

4.1 General

4.1.1 Safety
Water heaters shall comply with the safety requirements of CAN/CSA-C22.2 No. 110.

4.1.2 Odours
A completely assembled water heater shall not emit objectionable odours after the initial 30 min of operation.

4.1.3 Defects and damage
A completely assembled water heater shall show no defects or signs of damage when tested in accordance with Clause 6.3.

4.1.4 Rated capacity
The rated tank capacity shall be the applicable capacity specified in Table 3.

4.1.5 Tolerance
The actual capacity of the tank shall be within ± 5% of the rated capacity and shall be determined in accordance with Clause 6.4.

4.1.6 Diffusion
Water heaters shall be provided with a device to minimize mixing of the inlet water with the water stored in the tank. The diffusion ratio of this device shall be determined by the diffusion test specified in Clause 6.7. At least 90% of the tank capacity shall be delivered before the water temperature drops more than 17 ºC (30.6ºF).

4.2 Tank

4.2.1 Convertibility
A storage tank intended for use with one or two electric heating elements shall be capable of accepting the watts density combinations applicable to the maximum element rating of the unit specified in Table 1.

4.2.2 Durability
The tank interior shall be protected from the corrosive effects of water in accordance with CAN/CSA-C309. For materials not covered by CAN/CSA-C309, evidence of the durability of the tank interior shall be provided by the manufacturer.

4.2.3 Wiring
Colour coding and interconnections for dual-element water heaters shall be as shown in Figure 1, except that when the heater element leads are integral with the element, the heater element leads may be any colour but green or green with yellow stripes. Colouring may be continuous or only the wire ends may be coloured, provided that both ends of each wire are identified. Wire whose entire length is visible shall require colouring in one place only.

4.3 Heater elements

4.3.1 Interlock
Heater elements shall be interlocked by the thermostats.

4.3.2 Watts density

The watts density of heater elements shall not exceed the values specified in Table 1 and determined in accordance with the method specified in Clause 6.9. Higher watts densities may be used, provided that evidence of equivalent or longer life expectancy of the element is provided for water quality conditions that the element could be exposed to during its expected use.

Note: *Elements with lower watts densities typically have longer life expectancies under most normally experienced water conditions.*

4.3.3 Location

The upper heater element shall be located in accordance with the upper zone capacity requirements specified in Table 2 and determined by the test specified in Clause 6.10.

4.3.4 Rating

The heater element rating shall be designated as specified in Table 3.

4.3.5 Tolerance

The heater element input shall be within ± 5% of the rated watts as determined by the test specified in Clause 6.5.

4.3.6 Rated voltage

Water heaters shall comply with the rated voltage requirements of CAN/CSA-C22.2 No. 110.

4.3.7 Immersion elements

Immersion heater elements for use in tanks that require cathodic protection shall be

(a) copper-sheathed or nickel-alloy-sheathed Series 800 or 825; and

(b) grounded to the tank through a 560 Ω ± 10% resistor rated at least 1/4 W. However, other types of anode current control may be used if this does not result in a greater anode current when the tank is tested using the most adverse water supplies that could be present at destination. Evidence of the durability of the means to control the anode current shall be provided by the manufacturer.

4.4 Thermostats

4.4.1 Range of adjustment

Thermostats shall be provided with a range of adjustment such that the lowest cut-out temperature shall be not greater than 45 °C (113°F) and the highest cut-out temperature for household use shall be 77 °C (170.6ºF).

4.4.2 Calibration

Thermostat calibration at 60 °C (140°F) and the highest settings shall be such that the top-of-tank temperature of the water is within ± 3 °C (5.4°F) of the thermostat setting determined in accordance with Clause 6.8.

4.4.3 Differential

The controlled temperature differential, as determined in accordance with Clause 6.8.2, shall be as follows:

(a) lower thermostat: 3 to 8 °C (5.4 to 14.4°F);

(b) upper thermostat: 8 to 17 °C (14.4 to 30.6°F); and

(c) single element: 3 to 8 °C (5.4 to 14.4°F).

4.4.4 Mounting

Thermostats shall be mounted in a way that permits easy replacement without affecting calibration. After a thermostat is mounted, its markings shall be legible and right side up.

4.5 Thermal insulation

4.5.1 Withstand temperature

Thermal insulation shall not be adversely affected up to a temperature increase of 56 ± 3 °C (100.8 ± 5.4°F) above the temperature of the hottest surface with which the insulation will be in contact under normal operating conditions.

4.5.2 Vibration resistance

The effectiveness of thermal insulation shall not be impaired (as would be indicated by displacement of insulation) when its water heater is tested in accordance with Clause 6.3.

4.6 Jacket

4.6.1 Exposed edges

Exposed edges of sheet metal or other metal parts shall be finished to prevent injury to persons or damage to clothing during normal use.

4.6.2 Base

The base or supporting legs shall have no sharp edges that could scratch or damage the floor on which the water heater might rest.

4.6.3 Finish

4.6.3.1 Subsurface preparation

Metal shall be cleaned to remove all traces of grease, oil, rust, and any other contamination and shall be painted only while clean.

4.6.3.2 Paint finish

Paint defects such as sagging, wrinkling, noticeable dirt entrapment, more than normal orange peel, non-uniform colour, solvent blistering, or excessive overspray shall not be evident in the overall appearance.

4.6.3.3 Integrity of the finish

Integrity of the finish shall be determined in accordance with the film build, flexibility, impact, water resistance, hardness, and adhesion tests specified in Clause 6.12.

4.7 Plumbing connections

4.7.1 Fittings

Plumbing connections, excluding drain valves, shall be NPS-3/4 or NPS-1 trade size pipe. Male and female fittings shall terminate at a distance outside the heater casing sufficient to enable piping to be connected to the water heater by conventional means without damage to the unit.

4.7.2 Drainage

Drainage shall be provided by a readily accessible hose connection valve that complies with CAN/CSA-B125. In a tank designed to accommodate an immersion heater, the water level in the tank, after drainage, shall be below the lower immersion element opening.

4.8 Standby loss

The standby energy loss of water heaters ranging in size from 50 to 454 L rated tank capacity shall not exceed the standby loss calculated in accordance with the following formulas when the heaters are tested in accordance with Clause 6.6:

(a) 50 to 284 L rated tank capacity:
  (i) $W \leq 35 + (0.20\ V_R)$ (tank without bottom inlet); and
  (ii) $W \leq 40 + (0.20\ V_R)$ (tank with bottom inlet); and

(b) 285 to 454 L rated tank capacity:
  (i) $W \leq (0.472\ V_R) - 38.5$ (tank without bottom inlet); and
  (ii) $W \leq (0.472\ V_R) - 33.5$ (tank with bottom inlet)

where

W = standby loss, W

V_R = rated tank capacity, L

Where the tolerance exceeds ± 3%, the unit shall be subject to re-examination.

4.9 Cathodic protection

Cathodic protection of the water tank, if required, shall comply with the applicable requirements of CAN/CSA-C309.

5 Markings

Note: *In this Clause, the term "manufacturer" includes the proprietor of a registered trademark.*

5.1 Hot water connection

The hot water connection shall be identified in a legible and permanent manner.

5.2 Heater elements

In addition to the markings required by CAN/CSA-C22.2 No. 110, heater element markings shall include the name of the manufacturer, catalogue or type number, rated voltage, and rated input in watts.

5.3 Thermostats

In addition to the markings required by CAN/CSA-C22.2 No. 110, thermostat markings shall include the following:

(a) name of the manufacturer;
(b) catalogue or type number;
(c) a graduated scale indicating the cut-out temperature obtainable within the range of adjustment. The lowest indicated setting shall be not more than 45 °C (113°F) and the highest indicated setting shall be 77 °C (170.6°F); and
(d) the 60 °C (140°F) point.

The "off" position shall not be marked.

5.4 Temperature-limiting control

The temperature-limiting control shall be marked with the name of the manufacturer and catalogue or type number.

5.5 Nameplate

In addition to the markings required by CAN/CSA-C22.2 No. 110, a nameplate shall be marked with the following:

(a) manufacturer's name and factory location;
(b) serial number;
(c) rated tank capacity in litres;

(d) total maximum wattage rating;
(e) standby loss level; and
(f) any additional information that the manufacturer wishes to include.

5.6 Published ratings
The published standby loss level shall be expressed to the nearest watt.

6 Tests
Note: *See Annex A for information on sample size.*

6.1 Test conditions

6.1.1 Test room

6.1.1.1 Environment
Air circulation in the test room shall provide reasonably uniform temperatures without direct drafts on the water heater. The water heater shall be placed or shielded so as not to be affected by radiation to or from the cooling or heating equipment, walls, or windows.

6.1.1.2 Ambient temperature
The air temperature of the room shall be maintained at 21 ± 5 °C (70 ± 9°F). It shall be measured and recorded to an accuracy of ± 1 °C (1.8°F). The temperature-sensitive element shall be placed approximately 1200 mm (47.2 in) from the floor and not closer than 1500 mm (59 in) to the water heater.

6.1.1.3 Accuracy and precision
The test instruments shall have the accuracy and precision specified in Table 5.

6.1.2 Services

6.1.2.1 Inlet water temperature
The supply water shall be provided at 10 °C (50°F). However, when this is not practicable, tests may be run with available inlet water temperatures, with appropriate adjustments to achieve the specified temperature differences. During testing, the supply water temperature shall not vary by more than ± 1 °C (± 1.8°F).

6.1.2.2 Water supply pressure
Water shall be supplied at a gauge pressure of between 275 kPa (40 psi) and the maximum pressure specified by the manufacturer for the water heater being tested. If the water pressure varies outside these limits during testing, the heater shall be isolated by a pressure-reducing valve in the supply line, with an expansion tank installed in the supply line downstream of the pressure-reducing valve. There shall be no shut-off means between the expansion tank and the water heater inlet.

6.1.2.3 Supply voltage
The supply voltage to the water heater shall be maintained within ± 2% of rated voltage.

6.1.3 Measurement

6.1.3.1 Water delivery

Water withdrawn during tests shall be measured by weight within ± 250 g (± 8.8 oz) or by volume within ± 250 mL (± 15.25 in^3).

6.1.3.2 Electrical consumption

Electrical consumption shall be measured with wattmeters and watt-hour meters calibrated to provide an accuracy of ± 0.5%.

Note: *A recording ammeter or other suitable instrument may be used to indicate thermostat operation.*

6.1.3.3 Water temperatures

Water temperatures shall be measured by thermometers or thermocouples connected to temperature indicators or recorders of the potentiometer type providing a minimum accuracy of ± 1 °C (± 1.8°F).

6.1.3.4 Thermocouple installation

Eight thermocouples shall be installed inside the water heater tank, two at the thermostat-sensing element level and six located so as to sense the centre point of six approximately equal volumes of water from the top to the bottom of the tank. The anodic protective device may be removed in order to install the thermocouple probe, and all testing may be performed with the device removed.

A thermocouple shall be installed in the hot water outlet pipe not more than 150 mm (6 in) from the connection to the water heater. Another thermocouple shall be installed in the cold water inlet pipe not less than 2 m (7 ft) from the connection to the water heater.

6.1.4 Test installation

The water heater shall be installed on a 19 mm (3/4 in) thick plywood platform supported by not more than four 5 × 10 cm (2 × 4 in nominal) runners.

The water piping shall be connected to the inlet of the water heater using an NPS-3/4 union or coupling and a minimum of 1.5 m (5 ft) of rubber test hose suitable for the pressure rating of the water heater. The outlet pipe shall be provided with a thermocouple as specified in Clause 6.1.3.4, a shut-off valve located immediately downstream of the outlet thermocouple, and a minimum of 1.5 m (5 ft) of rubber test hose. The water heater inlet and outlet piping shall be insulated for a length of 1.2 m (4 ft) with a material having a thermal resistance (R) value of 1.4 m^2•K/W (8 h•ft^2•°F/Btu).

Notes:

(1) An (R) value of 8 is equivalent to 8 h•ft^2•°F/Btu.

(2) Connections for a water heater with a bottom inlet and top outlet are shown in Figure 2 and connections for a water heater with a top inlet and top outlet are shown in Figure 3.

6.2 Order of tests

The sturdiness specified in Clause 6.3 shall be the first test performed. The remaining tests, beginning with Clause 6.4, should be performed in the order in which they appear in this Standard.

6.3 Sturdiness test

The water heater in its original shipping container shall be placed in an upright position on a solid floor and rocked back and forth 25 times on its shorter edges, the raised edge being lifted about 150 mm (6 in) off the floor. After this procedure, the heater shall be examined for any defects, signs of damage, or displacement of insulation.

6.4 Tank capacity test

Tank capacity shall be determined by weighing the water heater when full and when empty and computing the volume, or by measuring the volume of water necessary to fill the tank.

6.5 Heater element input test

The heater element input shall be measured with the element installed on a cold tank, 5 min after application of the rated voltage.

6.6 Standby loss test

6.6.1 Idling

The thermostats shall initially be set at 68 °C (154.4°F). The water heater shall be energized and operated without any water being withdrawn. After the lower thermostat has cut out for the first time (which starts the idling period), its setting shall be adjusted to give a top-of-tank temperature of 68 ± 3 °C (154.4 ± 5°F) and the accumulated air shall be eliminated. The water heater shall be operated under these idling conditions for the duration of the test. Water temperatures indicated by the thermocouple probe shall be recorded continuously, and at intervals not greater than 15 min.

6.6.2 Consumption measurement

At the first thermostat cut-out that occurs approximately 24 h after the start of the idling period, the water temperatures and the readings of the watt-hour meter shall be recorded. This information shall be recorded again at the first thermostat cut-out following an additional period of at least 48 h.

6.6.3 Standby loss calculation

The average standby loss in watts for a 44 °C (79°F) rise above room temperature shall be calculated as follows:

$$\text{Standby loss, } W = \left[\frac{1.161 V_T (T_1 - T_n) + E}{N}\right] \times \left[\frac{44}{(T_T - T_R)}\right]$$

where

1.161 = an approximate value for

$$\frac{\text{Density of water, kg/L} \times \text{Specific heat capacity of water, kJ°C/kg}}{3.6}$$

V_T = actual tank capacity, L

T_1 = average water temperature (see Clause 3) at start of test, °C

T_n = average water temperature (see Clause 3) at end of test, °C

E = measured energy consumption, W•h

N = length of test, i.e., interval between watt-hour meter readings, h

44 = temperature difference between nominal tank water and ambient air, °C

T_T = average of the average water temperatures (see Clause 3) recorded during the test at intervals not greater than 15 min, using the six thermocouples for measuring the six approximately equal volumes of water specified in Clause 6.1.3.4

$$= \frac{\left(\sum_1^n T_{avg}\right)}{n}$$

where

n = number of measurements made during the test

T_{avg} = average water temperature (see Clause 3)

T_R = average of the room temperatures recorded during the test at intervals not greater than 15 min

6.7 Diffusion test

With the tank full of cold water, the heater elements shall be energized. The lower thermostat shall be set to give a 56 ± 3 °C (100.8 ± 5.4°F) rise of top-of-tank temperature above the supply water temperature. Following at least 24 h of idling, and 10 min after the lower thermostat cuts out, the power supply to the water heater shall be disconnected and simultaneously water shall begin to be withdrawn. Water shall be continuously withdrawn from the tank at a rate of approximately 18 L/min (3.96 gal/min). The volume of water withdrawn before the outlet water temperature drops 17 °C (30.6°F) shall be determined.

Note: *The ratio of the volume of water withdrawn to the actual tank capacity, multiplied by 100, is the percentage of actual tank capacity withdrawn.*

6.8 Thermostat tests

6.8.1 Range of adjustment and calibration tests

6.8.1.1 Calibration of the upper thermostat

With the lower thermostat blocked open, the upper thermostat shall be set at 60 °C (140°F) and the water heater operated under the control of the upper thermostat. After three or more cycles, the temperature of the water in the top-of-tank shall be measured at cut-out. This temperature shall determine the upper thermostat calibration at that setting. This test shall be repeated at the 50 °C (122°F) and 77 °C (170.6°F) settings of the thermostat.

6.8.1.2 Calibration of the lower thermostat

With the upper thermostat disconnected, the water heater shall be operated under the control of the lower thermostat, which shall be set at 60 °C (140°F). After three or more cycles, the temperature of the water in the top-of-tank shall be measured at cut-out. This temperature shall determine the lower thermostat calibration at that setting. This test shall be repeated for 50 °C (122°F) and 77 °C (170.6°F) settings of the thermostat.

6.8.2 Controlled temperature differential tests

6.8.2.1 Controlled temperature differential of upper thermostat

With the lower thermostat disconnected, the upper thermostat shall be set at 60 °C (140°F) and the water heater operated under the control of the upper thermostat. After three or more cycles, the temperature of the water at the level of the temperature-sensing element of the upper thermostat shall be measured at both cut-out and cut-in. The difference between these two temperatures shall be the controlled temperature differential of the upper thermostat.

6.8.2.2 Controlled temperature differential of lower thermostat

With the upper thermostat disconnected, the lower thermostat shall be set at 60 °C (140°F) and the water heater operated under the control of the lower thermostat. After three or more cycles, the temperature of the water at the level of the temperature-sensing element of the lower thermostat shall be measured at both cut-out and cut-in. The difference between these two temperatures shall be the controlled temperature differential of the lower thermostat.

6.9 Watts density test

The immersion element watts density shall be the ratio of the rated watts input to the area of the outside heated surface of the element sheath.

Note: *The length of the heated surface is the length of the sheath between the attachment points of the resistance wire.*

6.10 Upper zone test

With the tank full of cold water, the lower thermostat shall be blocked open. The upper thermostat shall be set to give a 56 ± 3 °C (100.8 ± 5.4°F) rise of top-of-tank temperature above the supply water temperature. Following at least 24 h of idling, and 10 min after the upper thermostat cuts out, the power supply to the water heater shall be disconnected and simultaneously water shall begin to be withdrawn. Water shall be continuously withdrawn from the tank at a rate of approximately 18 L/min (3.96 gal/min). The volume of water withdrawn before the outlet water temperature drops 17 °C (30.6°F) shall be determined.

Note: *The upper zone is the ratio of the amount of water withdrawn to the actual tank capacity, multiplied by 100, and is the percentage of actual tank capacity effectively heated by the upper heater element.*

6.11 Delivery test

6.11.1 General

The water heater shall be capable of delivery as specified in Table 4 when tested in accordance with Clause 6.11.2.

6.11.2 Test method

Starting with a completely recovered tank with its upper and lower thermostats set at 56 ± 3 °C (100.8 ± 5.4°F) above the supply water temperature, the water heater shall be subjected to a delivery test in accordance with the appropriate schedule in Table 4. The average temperature of any withdrawal shall be not less than 44 °C (79°F) above the supply water temperature, except that the average temperature of one withdrawal may be less than 44 °C (79°F) but not less than 39 °C (70°F) above the supply water temperature. Water heaters shall be considered to have passed the delivery test if the first six withdrawals meet the requirements of this Clause.

6.11.3 Withdrawal

The first withdrawal shall be made approximately 0.5 h after cut-out of the lower thermostat. Water shall be withdrawn at a rate of approximately 18 L/min (3.96 gal/min).

6.12 Tests for jacket finish (steel painted jackets)

6.12.1 Test conditions

All tests shall be performed on a complete jacket or sections from a jacket that have been processed in accordance with the manufacturer's system for production units. The jacket or jacket sections shall be aged at least 24 h before tests are performed. Unless otherwise specified in this Standard, conditioning, aging, and testing shall be performed under standard conditions of temperature and humidity. Conditioning shall require a temperature of 22.7 ± 2 °C (73 ± 3.6°F) and a relative humidity of 50 ± 2%. The jacket finish shall meet the test requirements of Clauses 6.12.2 to 6.12.7.

6.12.2 Film build

The dry film thickness in any area shall be 0.0254 mm (0.001 in). Optionally, jackets may be tested with a range of film thicknesses. The process and paint used shall be reported for each jacket. The thinnest film thickness for each type of paint that passes all of the requirements specified in Clause 6.12 shall be established as the minimum acceptable film thickness at any point for that type of paint and its associated process only.

6.12.3 Flexibility

The finish shall withstand a 180° bend over a 12.7 mm (2 in) diameter mandrel without cracking, flaking, or loss of adhesion visible to normal or corrected-to-normal vision.

6.12.4 Impact

The finish shall withstand a direct impact of at least 2.04 J on the Gardner impact tester, or equivalent, without cracking or flaking visible to normal or corrected-to-normal vision. The blow shall be delivered to the finished surface.

The test apparatus and procedure shall be as follows:

(a) the baseplate shall be a 12.7 mm (1/2 in) thick steel plate with a 19 mm (3/4 in) diameter hole drilled through it at a right angle to the plate surface (with a corner radius on hole of 0.13 to 0.26 mm [1/2 to 1 in]);

(b) the mass for delivering the blow shall weigh 900 g (1.98 lb) and have a hemispherical striker of hardened steel; and

(c) there shall be a tube or other mechanism to align the striker with the hole in the baseplate so that the striker enters the hole when the mass is in free fall.

The test panel shall be laid flat on the baseplate, painted side up, and the mass dropped freely through a distance of 230 mm (9 in). The mass shall strike the panel at a point at least 25 mm (1 in) from the edge of the panel.

6.12.5 Water resistance

A painted section cut from the water heater jacket shall be half-immersed in distilled water at room temperature for 72 h. At the completion of this test, there shall be no blistering, rusting, or other film defects on the exterior finish more than 6 mm (1/4 in) from the cut edges.

6.12.6 Hardness

The film shall be demonstrated to have a minimum scratch resistance of F hardness when an Eberhard Faber microtomic drawing pencil is used as follows:

(a) Hold the pencil vertically and rub its lead on No. 400 grit abrasive paper until it is worn to a flat circular cross-section to the full diameter of the lead.

(b) With the edge of the lead placed against the paint film and the pencil held at an angle of 45° to the surface being tested (i.e., in a normal writing position), attempt to remove the film along a continuous length of 6 mm (1/4 in) by applying firm pressure while moving the pencil in the direction in which it points.

(c) Test the film in accordance with Item (b) in at least five locations on the film.

If the film can be removed along a length of at least 6 mm (1/4 in) in any of the locations specified in Item (c), the film shall be considered to have failed the test.

6.12.7 Adhesion

Adhesion shall be tested as follows:

(a) Scratch the finish through to the base metal using a sharp instrument (e.g., a razor blade or exacto-type knife) held normal to the finish.

(b) Apply a strip of adhesive tape conforming, e.g., to CAN/CGSB 43-GP-3Ma, Type II, Grade A or B, across the scratch.

(c) Remove the tape with a rapid pull parallel to the surface.

The test shall be successful if the finish is not removed by the tape.

Table 1
Watts density of water heater elements for 184 and 284 L units
(See Clauses 4.2.1 and 4.3.2.)

	Immersion elements watts density, W/cm^2 (W/in^2)	
Element rating, W	**Upper**	**Lower**
Copper-sheathed		
1500	—	4.2 (27)
3000, 3800, 4500	12.4 (80)	7.8 (50)
Nickel-alloy-sheathed C Series 800 and 825		
3000, 3800, 4500	12.4 (80)	12.4 (80)

Note: *Elements with lower watts densities typically have longer life expectancies under most normally experienced water conditions.*

Table 2
Upper zone capacity
(See Clause 4.3.3.)

Rated tank capacity, L	**Upper zone, % of actual**	**Tolerance, % of rated tank capacity**
184	25	± 2.5
284	33	± 2.5

Table 3
Type, designation, and description of 184 and 284 L units
(See Clauses 4.1.4 and 4.3.4 and Table 4.)

Type of unit*	Rated tank capacity, L (gal)	Heater element rating, W	
		Upper	Lower
184 EE	184 (40)	3000	3000
284 HB	284 (62)	4500	1500
284 HH	284 (62)	4500	4500
184 FF	184 (40)	3800	3800
284 FF	284 (62)	3800	3800

**The numbers refer to the capacity in litres, and the letters refer to the upper and lower element ratings in watts, as follows:*

Letter	*Element rating,* W
B	*1500*
E	*3000*
F	*3800*
H	*4500*

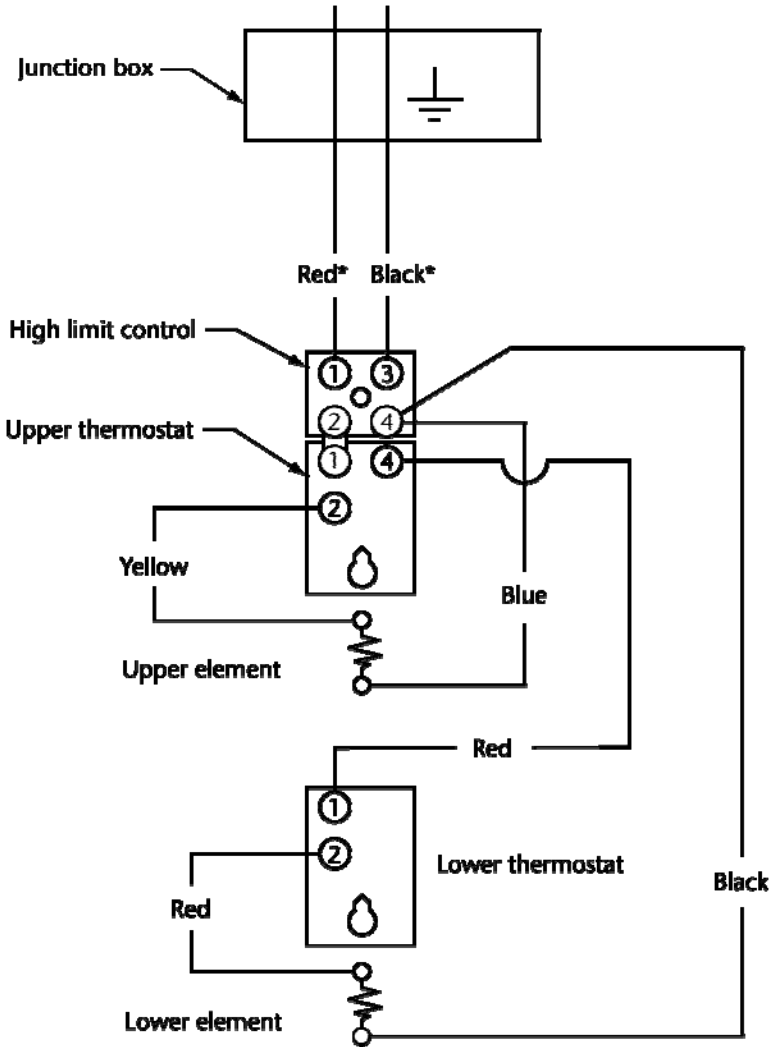
Table 4
Delivery schedule of 184 and 284 L units
(See Clauses 6.11.1 and 6.11.2.)

Withdrawal no.	Elapsed time, h	Withdrawal, L		
		184 EE* and 184 FF*	284 HB* and 284 FF*	284 HH*
1	0	40.5	40.5	57.0
2	1.0	40.5	40.5	57.0
3	2.0	46.0	46.0	63.5
4	3.0	90.0	91.0	127.5
5	3.5	81.0	82.0	114.5
6	4.0	50.0	50.0	70.0
7	5.0	14.0	14.0	19.0
8	6.0	14.0	14.0	19.0
9	7.0	14.0	14.0	19.0
10	8.0	4.5	4.5	6.5
11	9.0	14.0	14.0	19.0
12	10.0	9.0	9.0	12.5
13	11.0	9.0	9.0	12.5
14	12.0	14.0	13.0	19.0
15	13.0	9.0	9.0	12.5
16	14.0	4.5	4.5	6.5
Total	—	454.0	455.0	635.0

**The letters refer to the upper and lower element ratings. See the Note to Table 3.*

Table 5
Accuracy and precision of test instruments
for water heater tests
(See Clause 6.1.1.3.)

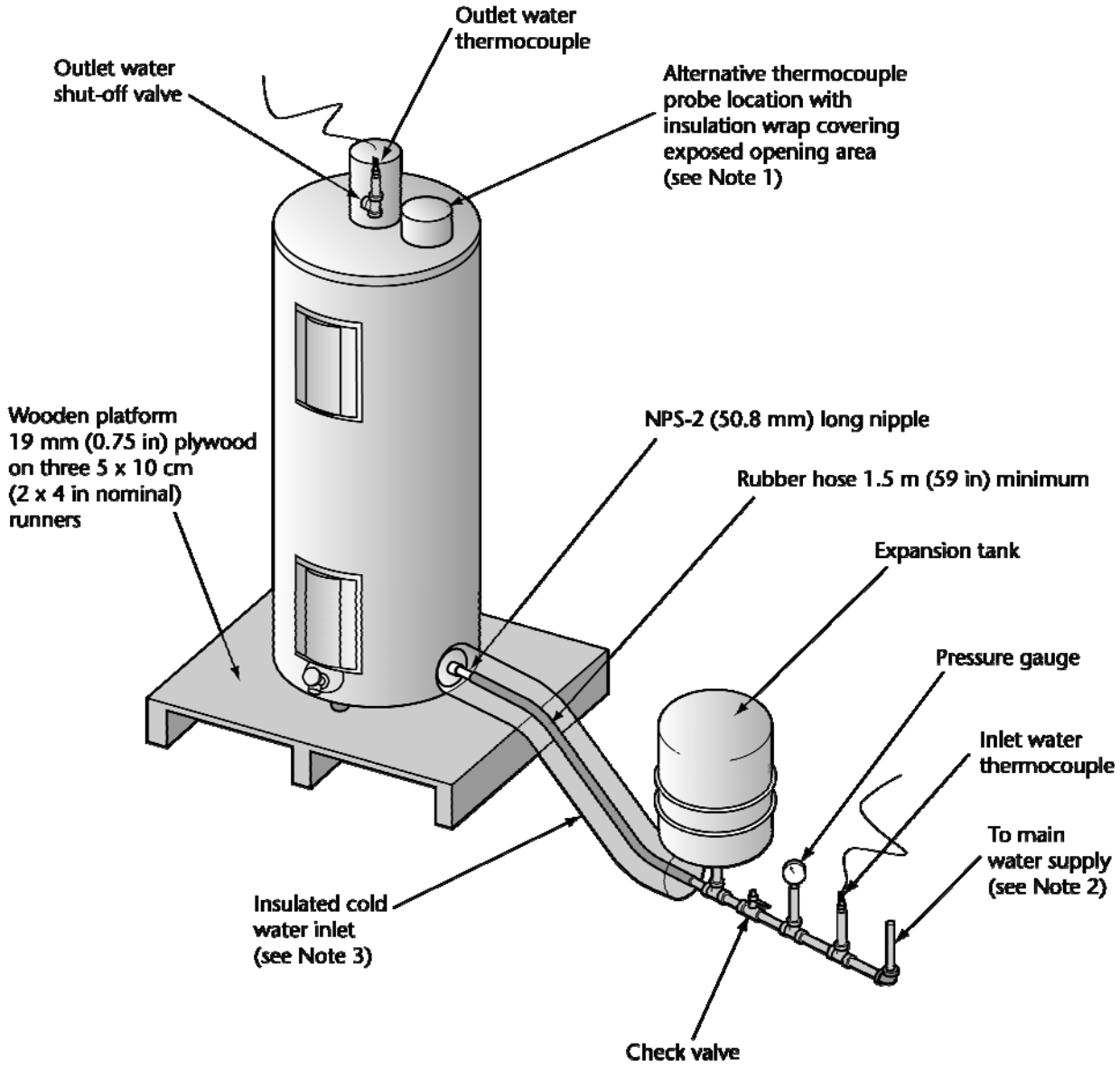
Measurement	Instrument accuracy	Instrument precision
Electric energy	± 0.5%	—
Liquid flow	± 1%	—
Mass	± 0.05 kg (± 0.1 lbm)	—
Storage tank temperature	± 0.3 °C (± 0.5°F)	± 0.14 °C (0.25°F)
Time	± 0.5 s/h	—
Water pressure	± 6.9 kPa (± 1 psig)	± 3.45 kPa (± 0.50 psig)
Water temperature at the inlet or outlet	± 0.1 °C (± 0.2°F)	± 0.06 °C (± 0.1°F)
Air dry bulb temperature	± 0.1 °C (± 0.2°F)	± 0.06 °C (± 0.1°F)
Air wet bulb temperature	± 0.1 °C (± 0.2°F)	± 0.06 °C (± 0.1°F)



**For 208 or 240 V systems, one of the two incoming supply conductors shall be red and the other shall be black. For 120 V systems, one of the two incoming supply conductors shall be white and the other shall be black.*

Note: *The configuration shown is for thermostats commonly available in the marketplace. If the manufacturer's instructions specify another configuration, that configuration shall be used.*

Figure 1
Typical dual-element water heater wiring diagram
(See Clause 4.2.3.)



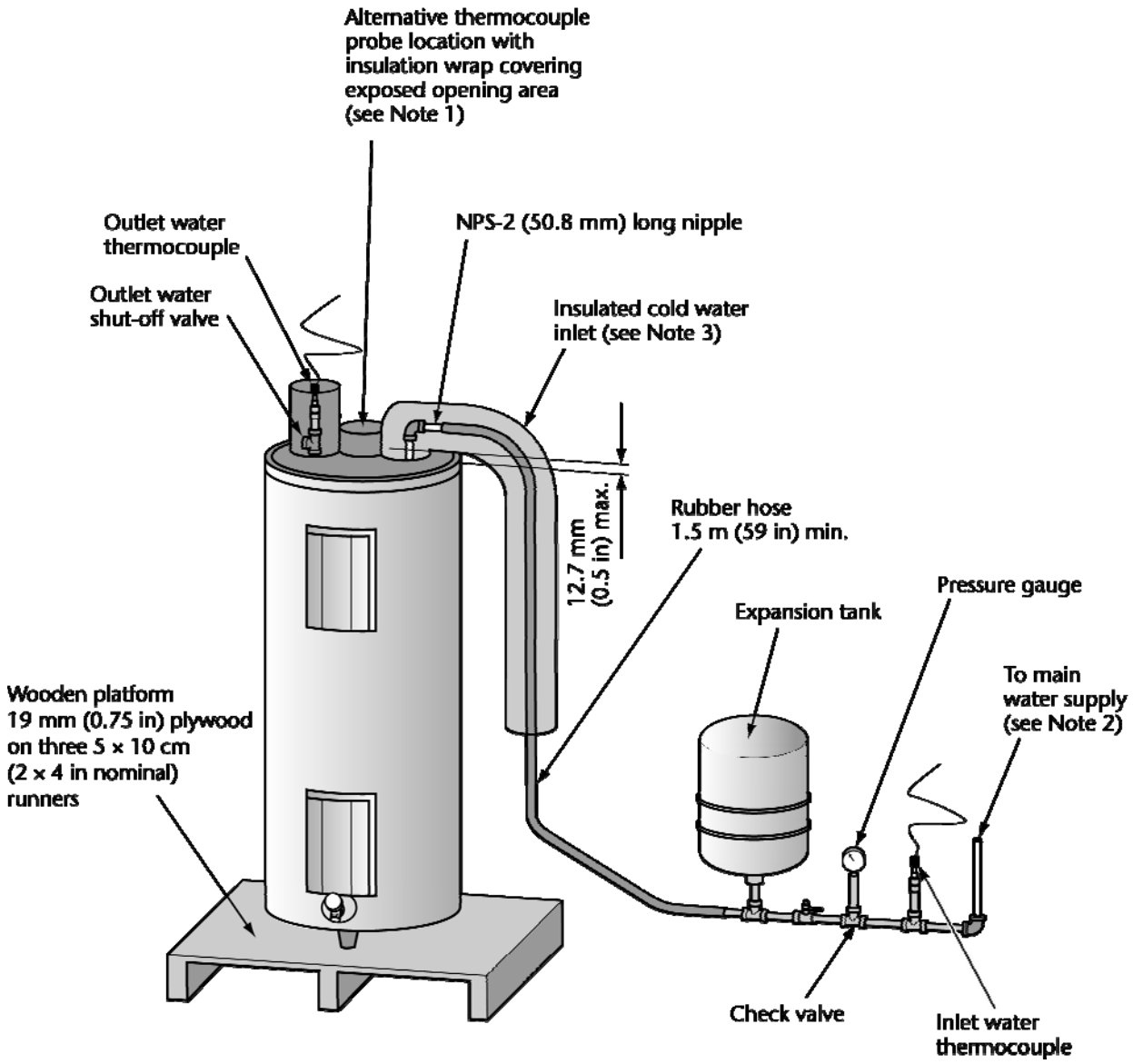
Notes:

(1) *Alternative location for thermocouple in anode rod tank coupling (anode rod may be removed for the standby loss test).*

(2) *For water pressure exceeding* 552 kPa *(80 psi), a pressure-reducing valve and an expansion tank may be used on the inlet waterline.*

(3) *Inlet and outlet waterlines shall be insulated for a length of* 1.2 m *(4 ft) from the water heater with insulation with an (R) value of at least 8.*

Figure 2
Water heater piping connections — Bottom inlet and top outlet
(See Clause 6.1.4.)



Notes:

(1) Alternative location for thermocouple in anode rod tank coupling (anode rod may be removed for the standby loss test).

(2) For water pressure in excess of 552 kPa *(80 psi), a pressure-reducing valve and an expansion tank may be used on the inlet waterline.*

(3) Inlet and outlet waterlines shall be insulated for a length of 1.2 m *(4 ft) from the water heater with insulation with an (R) value of at least 8.*

Figure 3
Water heater piping connections — Top inlet and top outlet
(See Clause 6.1.4.)

Annex A (informative)
Sample size

Note: *This informative (non-mandatory) Annex has been written in normative (mandatory) language to facilitate adoption where users of the Standard or regulatory authorities wish to adopt it formally as additional requirements to this Standard.*

A.1

A sample of sufficient size shall be tested to ensure that the reported or represented value of a water heater's performance characteristic is statistically valid. For an hourly standby watts loss or any other measure of energy consumption where a consumer would favour a lower value, the value reported or represented shall be not less than the greater of

(a) the mean of the sample; or

(b) the upper 95.0% confidence limit of the true mean divided by 1.10.