

AS/NZS 1056.4:1997

Australian/New Zealand Standard[®]

Storage water heaters

**Part 4: Daily energy consumption
calculations for electric types**

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 Australian Gas Association
 Australian Stainless Steel Development Association
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 Electrical Development Association of New Zealand
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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL/20, Electric Water Heating Appliances, to supersede AS 1056.4—1990, *Storage water heaters, Part 4: Calculations of energy consumption*.

The previous edition of this Standard was prepared in response to proposals by the N.S.W. Office of Energy to introduce energy labelling for electric storage water heaters. It attempted to estimate the energy consumption of electric storage off-peak systems, which are lower than continuously boosted systems, by the use of a single off-peak adjustment factor of 0.90. Although this factor was a reasonable estimate for some then currently available off-peak tanks, for a delivered energy of 37.7 MJ per day, it was clearly inaccurate for larger or smaller tank sizes, for larger or smaller energy deliveries, or for those with higher levels of insulation (i.e. lower daily heat losses).

In response to these inadequacies, a simple water energy model was developed by the State Electricity Commission of Victoria, which estimated the actual in-use heat losses for off-peak systems for a wide range of conditions and delivered energies. In order to contain costs, the calculations are based on already-known performance characteristics (standing heat losses of electrical heaters, dimensions, maintenance gas consumption and thermal efficiency of gas heaters). This model has been further refined and used to prepare the graphs in Appendix A, which estimate in-use heat losses for a range of typical off-peak tanks and energy deliveries.

The term 'normative' has been used in this Standard to define the application of the appendix to which it applies. A 'normative' appendix is an integral part of a Standard.

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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard**Storage water heaters****Part 4: Daily energy consumption calculations for electric types**

1 SCOPE This Standard sets out a method for calculating the energy consumption of electric storage water heaters fitted with electric resistance heating units.

The Standard is not applicable to gas water heaters, solar water heaters, heat-exchangers or heat-pumps.

NOTES:

- 1 This Standard is based on known performance characteristics of electric storage water heaters under static conditions (i.e. standing heat losses with no delivery) and using an energy delivery of 37.7 MJ per day (equivalent to a volume of 200 L of water raised in temperature by 45°C).
- 2 The values of 37.7 MJ per day, 200 L and 45°C were chosen in order to align with AG 102.
- 3 For gas heaters, refer to AG 102.

2 APPLICATION This Standard is intended to be used in conjunction with AS 1056.1.

3 REFERENCED DOCUMENTS The following documents are referred to in this Standard:

AS

1056 Storage water heaters

1056.1 Part 1: General requirements

2984 Solar water heaters—Methods of test for thermal performance—Outdoor test method

4234 Solar water heaters—Domestic and heat pump—Calculation of energy consumption

AG

102 Approval requirements for gas water heaters

NOTE: AG 102 is available from the Australian Gas Association, 1136 Nepean Highway, Highett, Vic. 3190.

4 DEFINITIONS For the purpose of this Standard, the definitions below apply.

4.1 Continuous energization—electric energization available without interruption (i.e. 24 hours per day).

4.2 Extended off-peak energization—electric energization available for typically 14 hours per day to 20 hours per day (usually within a range of 13 hours per day to 23 hours per day) on an intermediate electricity tariff.

4.3 Restricted off-peak energization—electric energization available for typically 8 hours per day (usually within a range of 6 hours per day to 12 hours per day) on a low electricity tariff (e.g. a night rate, generally within the period from 10 p.m. to 7 a.m.).

NOTE: The actual pattern of energization will vary between electricity distributors and may even vary from day to day. Energy consumption estimates for extended off-peak systems in this Standard are only approximate. The calculations for losses are based on an energization of 8 hours per day, which are then adjusted pro-rata to the actual energization period.

5 NOTATION The quantity symbols used in this Standard are listed in Table 1.

TABLE 1
NOTATIONS

Quantity symbol	Quantity	Unit symbol*
A	Area of sides plus top ($A_S + A_T$)	m^2
A_S	Area of sides	m^2
A_T	Area of top	m^2
d	Tank diameter (or width if square)	m
E_D	Energy delivered	MJ per day
E_T	Total energy consumption ($E_D + 3.6 Q_I$)	MJ per day
F_E	Expansion loss factor to allow for losses due to the thermal expansion of water being heated	—
h	Tank height	m
n	Hour number in Table C3	—
P_E	Recharge period	hours per day
Q_I	Actual in-use heat loss as determined in accordance with Appendix A	kWh per day
Q_O	Off-peak in-use standing heat loss as determined in Appendix A of this Standard	kWh per day
Q_S	Rated standing heat loss as determined in accordance with AS 1056.1	kWh per day
t_A	Ambient-air temperature for energy consumption measurement	$^{\circ}\text{C}$
t_C	Cold-water temperature for energy consumption measurement	$^{\circ}\text{C}$
t_H	Hot-water temperature for energy consumption measurement	$^{\circ}\text{C}$
t_M	Maximum recommended thermostat setting (t_S) or 75°C , whichever is greater, as specified in Appendix B of AS 1056.1	$^{\circ}\text{C}$
t_N	Ambient air temperature for heat-loss measurement (20°C is used in Appendix B of AS 1056.1)	$^{\circ}\text{C}$
t_S	Maximum recommended thermostat setting (hot-water temperature) for water heater as specified in Appendix B of AS 1056.1	$^{\circ}\text{C}$
ΔT_A	Difference between hot-water temperature and ambient-air temperature for determination of energy consumption ($t_H - t_A$)	$^{\circ}\text{C}$
ΔT_C	Difference between hot-water temperature and cold-water temperature for determination of energy consumption ($t_H - t_C$)	$^{\circ}\text{C}$
ΔT_N	Difference between maximum thermostat setting and ambient-air temperature for determination of standing heat loss (see Appendix B of AS 1056.1) ($t_M - t_N$)	$^{\circ}\text{C}$
V_R	Storage water-heater rated hot-water delivery capacity as specified in Appendix C of AS 1056.1	L
	NOTE: Appendix A herein gives values for tank sizes of 160 L, 250 L, 315 L and 400 L.	
V_T	Total equivalent hot-water delivery for selected energy delivery and heat loss conditions	L
W_O	Off-peak element size	kW

* For conversions between the units of energy and heat loss, the exact relationship is $1 \text{ kWh} = 3.6 \text{ MJ}$.

6 CALCULATIONS

6.1 Principle The energy consumption of an electric storage water heater is the sum of the energy required to heat the cold water that is replacing the hot water used plus the heat losses due to conduction, convection and radiation.

Energy consumption is based on a given water energy delivery. This is in contrast to some countries, which specify a standardized delivered volume of water rather than a standardized quantity of energy added to the delivered water.

The actual in-use heat loss is dependent on a wide range of variables, including energization profile, rated delivery capacity, hot-water temperature, air temperature, rated standing heat loss and hot-water draw-off profile.

In some cases, a factor is applied to account for the loss of hot water that is discharged as water expands on being heated.

The determination of in-use heat losses shall be in accordance with Appendix A.

6.2 Normal daily energy consumption Calculate the daily energy consumption required for a water energy delivery of 37.7 MJ per day with a cold-water inlet temperature (t_C) of 15°C, a hot-water temperature (t_H) of 60°C and an ambient temperature (t_N) of 20°C as specified in Clause 6.3 or Clause 6.4, whichever applies, in accordance with Appendix B.

Where daily energy consumption calculations for electric water heaters are required for energy deliveries other than 37.7 MJ per day, ambient temperatures other than 20°C or hot-water temperatures other than 60°C, Equation B1 of Appendix B shall be used, with the appropriate values for F_E and Q_I being obtained from Table 2 and Appendix A respectively.

6.3 Where $t_S \leq 75^\circ\text{C}$ Where $t_S \leq 75^\circ\text{C}$, calculate the daily energy consumption (E_T) from Equation B1 of Appendix B under the conditions specified in Clause 6.2, as follows:

$$E_T = F_E \times 37.7 + \left(\frac{60 - 20}{75 - 20} \right) \times 3.6 \times Q_I$$

$$= F_E \times 37.7 + 2.618 \times Q_I \quad \dots 1$$

where

- $F_E = 1.0$ for side-fed and falling level water heaters
- $= 1.0$ for unvented water heaters with a cold-water expansion relief valve
- $= 1.016$ for other types of water heaters (derived from Table 2, where t_C is 15°C and t_H is 60°C)

$Q_I =$ that specified in Equation A1 of Appendix A

NOTES:

- 1 The factor F_E is the ratio of the volume of water at a particular hot temperature to the volume of that water at a particular cold temperature as given in Table 2. It allows for water lost through a hot-water relief valve and is therefore applicable only to water heaters having a hot-water relief valve. For other types of water heater, $F_E = 1$.
- 2 The value Q_I is determined from Equation A1 and Figures A1.1 to A1.4 in Appendix A, which are based on the rated standing heat loss (Q_S) and the rated hot-water delivery capacity (V_R) for a standard flat draw-off profile.
- 3 Expansion (typically 2 percent) occurs as cold water in the bottom of the tank is heated. Water that is expelled is generally hot (the hot-water pressure/expansion relief valve is located at the top of the tank). The expansion loss factor (F_E) should only be applied to the delivered energy (E_D). It was incorrectly applied to the total energy consumption in the previous edition of this Standard. While hot water remaining in a tank over a 24 h period will cool slightly in tanks with off-peak energization (up to as much as 7°C for higher heat

loss tanks), the loss of heat due to the expansion of this water as it heats is negligible. As an indication, the resulting heat loss from the expansion of this water will be typically less than 0.3 percent of the in-use heat loss (Q_I , which is typically less than 0.01 kWh per day).

6.4 Where $t_S > 75^\circ\text{C}$ Where $t_S > 75^\circ\text{C}$, calculate the daily energy consumption from Equation B1 of Appendix B under the conditions specified in Clause 6.2, as follows:

$$E_T = F_E \times 37.7 + \left(\frac{60 - 20}{t_M - 20} \right) \times 3.6 \times Q_I \qquad \dots 2$$

where

- $F_E = 1.0$ for side-fed and falling level water heaters
- $= 1.0$ for unvented water heaters with a cold-water expansion relief valve
- $= 1.016$ for other types of water heaters (derived from Table 2, where t_C is 15°C and t_H is 60°C)

$Q_I =$ that specified in Equation A1 of Appendix A

6.5 Validity of draw-off for off-peak systems For Equations 1 and 2 to remain valid for systems with off-peak energization, the total equivalent hot-water delivery (V_T) must be less than the rated hot-water delivery capacity (V_R) of the tank (i.e. $V_T \leq V_R$), where—

$$V_T = \frac{E_T \times 238.9}{\Delta T_C} \qquad \dots 3$$

NOTES:

- 1 Tanks with extended off-peak or continuous energization (more than 12 hours per day) do not have to meet this requirement, as they will generally be energized during some of the draw-off period. Therefore, delivered volume may exceed the rated hot-water delivery capacity.
- 2 Tanks with off-peak energization and with a second element (located in the top of the tank and having continuous energization) will be able to deliver more energy than is contained in the rated hot-water delivery capacity of the tank. However, where total equivalent hot-water delivery (V_T) is greater than the rated hot-water delivery capacity (V_R), values of Q_I from Appendix A may not be valid for these tanks as a significant amount of energy may be delivered by the top element with a low loss of heat.
- 3 The factor of 238.9 is derived from 1000 calories per litre per degree Celsius and 4.186 J per calorie.
- 4 Where the measured rated capacity is known accurately, it may be used in Equation 3 to check on the validity of draw-off for off-peak systems.

TABLE 2
EXPANSION LOSS FACTORS

Cold-water temperature (t_C) °C	Expansion loss factor (F_E)									
	Hot-water temperature (t_H), °C									
	50	55	60	65	70	75	80	85	90	95
5	1.012	1.014	1.017	1.020	1.023	1.026	1.029	1.032	1.036	1.040
10	1.012	1.014	1.017	1.020	1.022	1.025	1.029	1.032	1.036	1.039
15	1.011	1.014	1.016	1.019	1.022	1.025	1.028	1.031	1.035	1.039
20	1.010	1.013	1.015	1.018	1.021	1.024	1.027	1.031	1.034	1.038
25	1.009	1.012	1.014	1.017	1.020	1.023	1.026	1.029	1.033	1.037
30	1.008	1.010	1.013	1.015	1.018	1.021	1.025	1.028	1.031	1.035

APPENDIX A

DETERMINATION OF IN-USE HEAT LOSSES

(Normative)

A1 TANKS WITH CONTINUOUS ENERGIZATION For electric storage water heaters with continuous energization (24 hours per day), the in-use heat loss (Q_I) is equal to the rated standing heat loss (Q_S).

A2 TANKS WITHOUT CONTINUOUS ENERGIZATION The following procedure is used to determine in-use heat losses for electric storage water heaters without continuous energization (i.e. for restricted off-peak or extended off-peak energization):

- (a) Select the required draw-off profile (the relevant profile provided in the graphs in Appendix A), the tank rated delivery capacity (V_R), the energy delivery (E_D) and the standing heat loss (Q_S) for analysis.
- (b) Determine the off-peak heat loss (Q_O) from the relevant graph in Appendix A that is appropriate for the values selected for (a) above.
- (c) Determine Q_I from the following equation:

$$Q_I = Q_O + \left[(Q_S - Q_O) \times \frac{P_E - 8}{16} \right] \quad \dots A1$$

This equation is valid for the range of 6 hours per day $\leq P_E \leq 24$ hours per day.

NOTES:

- 1 Equation A1 sets Q_I equal to Q_S for continuous energization (i.e. P_E is 24 hours per day) and sets Q_I equal to Q_O if P_E is 8 hours per day, with intermediate values for P_E being linearly interpolated. The use of 6 hours per day off-peak energization in Victoria (Y6 and YT) is also valid (through extrapolation by Equation A1).
- 2 Q_O may be determined for intermediate values of energy delivery (E_D) by interpolation, if required. Heat losses for off-peak energization have been calculated for zero draw-off as a base point. Maximum allowable delivered energy is shown on each figure (limited by tank size). Extrapolation beyond maximum allowable delivered energy is not permitted. Validity of draw-off should still be checked as required by Clause 6.5 for off-peak systems.
- 3 The method used to calculate off-peak heat losses (Q_O) and to derive the graphs in Appendix A is documented in Appendix C.

A3 ASSUMED VARIABLES FOR DERIVATION OF GRAPHS The following conditions have been assumed to derive the graphs in Appendix A:

- (a) *Temperature* Neutral temperature conditions are assumed (i.e. $\Delta T_N = \Delta T_A$). Where necessary, these temperatures can be adjusted in Equation B1 for actual conditions.
- (b) *Off-peak energization profile* Off-peak energization is assumed to be available each day from 11 p.m. until 7 a.m. (i.e. a total of 8 hours per day). These values can be scaled according to actual energization.
- (c) *Electrical element size* The electrical element is assumed to have a power of 3.6 kW with an efficiency of more than 98 percent.

NOTE: For continuous water heaters, the size of the element has a negligible effect on the total energy consumption and the heat losses.

For off-peak water heaters, the size of the element has a small effect on the heat losses (which will increase with an increase of element size, but the effect is generally very small).

- (d) *Draw-off profiles* The three draw-off profiles provided (i.e. flat, morning and evening peak) are detailed in Table A1.

TABLE A1
SELECTED DRAW-OFF PROFILES USED TO DEVELOP
THE GRAPHS IN APPENDIX A

Clock time of day	Total daily delivered energy by clock time, percent		
	Figures A1.1 to A1.4 for a typical flat load (AS 2984)	Figures A2.1 to A2.4 for a morning peak load	Figures A3.1 to A3.4 for an evening peak load
7	15	35	15
8	15	25	
11	10	15	
13	10		
15	12.5		
16	12.5		
17	12.5		10
18	12.5	15	15
19		10	20
20			20
21			20
Total	100	100	100

NOTES:

- 1 The typical draw-off profile is specified in AS 2984 and is considered to be reasonably representative of Australian households for energy consumption comparison purposes, as it has a slight evening bias. Note that individual households may be quite different from this assumed profile.
- 2 Evening and morning draw-off profiles were developed by SECV after reviewing a range of draw-off data, including Lacey (1971)¹, Guthrie and Kimpton (1987)², Pacific Power (1988)³ and unpublished SECV data (there is only very limited metered data for hot-water draw-off profiles in Australia). Morning and evening draw-off profiles are intended to be representative of the more extreme ends of the range encountered in the field and provide qualification of the impact of different draw-off profiles for applications where this may be important.
- 3 The draw-off profile may significantly affect the energy consumption of off-peak systems for tanks with larger heat losses (see the example in Clause B3.5). The draw-off profile for electric systems with continuous energization will be unaffected by the draw-off profile. The impact of the draw-off profile on in-use heat losses is generally small, but can be significant for energy deliveries close to the rated hot-water delivery capacity of a tank with off-peak energization. The impact of a draw-off profile can be much more significant in solar water heaters.
- 4 Energy losses are assumed to be largely proportional to tank surface areas. The dimensional ratios are only used to apportion losses through the top (fixed) and the sides (variable) for off-peak system heat losses. Assumed tank configurations, which are based on commonly available mains pressure systems, are given in Table A2. Modelling has shown that deviations from these dimensions has only a small effect on the final results.