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Efficiency of domestic electrical storage water heaters and testing methods

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National foreword

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Effizienz von elektrischen Warmwasserspeichern für den Hausgebrauch

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Content

European foreword

This document (EN 50440:2015) has been prepared by CLC/TC 59X "Performance of household and similar electrical appliances".

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2016-10-05
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2018-10-05

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For the relationship with EU Directives see informative Annexes ZZA and ZZB, which are integral parts of this document.

1 Scope

This European Standard specifies methods for measuring the performance of electric storage water heaters for the production of sanitary hot water for household and similar use.

The object is to state and define the principal performance characteristics of electric storage water heaters and to describe the test methods for measuring these characteristics.

NOTE 1 This standard does not apply to;

- storage water heaters that use electricity as a secondary source of heating the water;
- storage water heaters that do not use a tank to storage hot water;
- electric storage water heaters that do not meet the minimum (or maximum) output performance of the smallest (or biggest) load profile, as defined in Table 4.

NOTE 2 This standard does not specify performance or safety requirements. For safety requirements see EN 60335-1 in conjunction with EN 60335-2-21.

2 Normative references

Not applicable.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
storage water heater
water heater that uses electric heating elements as the means of heating water for long-term storage in a thermally insulated container and provided with a device to control the water temperature

3.2
primary function
to heat water for the production of hot water for household and similar needs

3.3
energized storage water heater
storage water heater that is designed to supply hot water and energised for 24 h per day

3.4
off-peak storage water heater
storage water heater that is designed to supply hot water whilst only being supplied with electrical energy at off-peak/low tariff periods

Note 1 to entry: The off-peak storage water heater is required to fulfil the requirements of the tapping pattern between 7:00h and 22:00h without external energy supply, e.g. to enable operation at off-peak/low-tariff periods and/or to operate in conditions of insecurity of energy supply. A product qualifies as “off-peak” if it is only energized for a maximum of 8 consecutive hours anywhere between 22:00h and 7:00h during the test with the 24h tapping pattern.

3.5
load profile
means the output performance (in terms of flow-rates, temperatures, tapping pattern, etc.) of a storage water heater when fulfilling its primary function under specific ambient conditions (see Tables 3 and 4), as declared by the manufacturer

3.6
energy efficiency
means the ratio between the delivered energy in the sanitary hot water for its load profile and the consumed electrical energy

3.7
storage volume
rated quantity of water stored in the appliance

Note 1 to entry: This is declared in litres.

3.8
smart control
device that automatically adapts the water heating process to individual usage conditions with the aim of reducing energy consumption

3.9
out of the box-mode
standard operating condition, setting or mode set by the manufacturer at factory level, to be active immediately after the appliance installation, suitable for normal use by the end-user according to the water tapping pattern for which the product has been designed and placed on the market

4 Symbols and Units

Table 1 – Symbols

Symbol	Unit	Description
η_{elecwh}	[%]	Energy efficiency of a storage water heater.
Q_{ref}	[kWh]	Reference energy for the 24 h tapping pattern for the load profile of the water heater.
Q_{elec}	[kWh]	Electricity consumption with the relevant 24 h tapping pattern.
θ'_{p}	[°C]	mean water temperature for the determination of θ_p, measured at the outlet
f	[l/min]	Minimum flow rate which hot water is contributing to the reference energy as specified in Table 4.
T_m	[°C]	The water temperature at which hot water starts contributing to the reference energy as specified in table 4
T_p	[°C]	Minimum water temperature to be achieved during water draw off as specified in Table 4
$Q_{testelec}$	[kWh]	Measured electricity consumption over 24 h test (step 4).
Q_{H2O}	[kWh]	Useful energy content of the hot water of n drawn-offs
$V_{water}^{full-drawing}$	[litres]	Sum of quantity of hot water totally delivered during the tapping period.
V_{40_exp}	[litres]	Measured volume delivered at the mean water temperature.
V_{40}	[litres]	Mixed water quantity delivered at 40 °C.
C_{act}	[litres]	Actual capacity of Water Heater
m_{act}	[kg]	Actual weight of water contained inside the tank of the Water Heater
smart		Presence or not of smart control (value shall be 0 or 1).
SCF		Efficiency gain by smart control function.

5 Calculation of the electrical energy efficiency (η_{elecwh})

The electrical energy efficiency (η_{elecwh}) of a storage water heater is the ratio between the delivered energy in the hot water for the tapping pattern of its load profile and the consumed energy. The consumed energy is the result of the test of the water heater with adjustments for:

– ***smart control*** that can reduce the energy consumption

The electrical energy efficiency of a storage water heater shall be calculated as Formula 1:

$$\eta_{elecwh} = \frac{Q_{ref}}{Q_{elec}(1 - SCF \cdot smart)} \quad (1)$$

where:

Q_{ref} is the delivered energy for the 24 h tapping pattern for the load profile of the water heater, in kWh;

Q_{elec} indicates the presence of **smart control** and is yes = 1, no = 0;

NOTE SCF=0 in case no **smart control** is detected during testing (9.2).

6 Measured parameters

The parameters below shall be established following the measurement methods described in following Clauses 7 and 9:

a) electricity consumption [kWh/d];

b) electrical energy efficiency [%];

c) storage volume [litre].

7 General conditions for measurements

Measurements shall be carried out with a supply of:

Table 2 – Electricity

Measured quantity	Unit	Value	Permissible deviation (average over test period)	Uncertainty of measurement (accuracy)	Notes
Electricity					
Power	W			± 2 %	
energy	kWh			± 2 %	
voltage, *test-period > 48 h*	V	230/ 400	± 4 %	± 0,5 %	
voltage, *test-period < 48 h*	V	230/ 400	± 2 %	± 0,5 %	
electric current	A			± 0,5 %	
frequency	Hz	50	± 1 %		

Table 3 gives additional test conditions and tolerances for test outputs (i.e. thermal energy).

Table 3 – Test conditions and outputs. Set values and tolerances

Measured quantity	Unit	Value	Permissible deviation (average over test period)	Permissible deviations of individual measured values	Uncertainty of measurement (accuracy)	Notes
Time						
Time	s				± 0,1 s	
Maximum interval between samples (during the deliver of hot water)	s	3				
Maximum interval between samples (during the no-deliver of hot water)	s	60				
Sanitary water						
cold water temperature	°C/ K	10 °C	+/- 1 K	+/- 1 K	+/- 0,5 K*	
cold water pressure	MPa	0,3 MPa			± 5 %	
hot water temperature	°C/ K	pattern			+/- 0,5 K*	a, b
volume flowrate	l / min	pattern			± 1 %	
volume measurements	l				± 0,5 %	
thermal energy	kWh	pattern	± 2 % (overall)	± 2 % (or ±10Wh)	± 2 % (or ±10Wh)	c
Ambient air						
Temperature	°C/ K	20 °C	± 1 K		± 1 K	

a To be measured by "rapid response thermometer", meaning an instrument that registers within 1 s. at least 90% of the final temperature rise from 15 to 100 °C when the sensor is plunged in still water.

b Thermocouple with a maximum diameter of 0,5mm, centred in stream, directly at outlet

c Apart from the maximum deviation a correction factor Qref/QH2O is applied, whereby Qref is taken from Table 4 and QH2O is the energy content of the useful water actually delivered during the test. "Useful water" is water with a temperature higher than a threshold value Tm for tappings in a profile specified in Table 4.

*Together with the publication task it should be mentioned towards the Commission that this tolerance is hard or really not to be reached in practice.

All other installation requirements are made according to the manufacturer's instructions.

8 Reference conditions

Table 4 specifies the tapping patterns for the chosen Load Profile. Parameters in the table are:

a) *Load Profile* [XXS-4XL, in header row of table];
b) *h* hour [hh:mm] starting at 0:00 h;
c) Q_{tap} [kWh] useful energy content of water withdrawal to be achieved in the draw-off;
d) *f* [l/min] minimum flow rate to be reached during tapping;
e) T_m [°C] temperature from which counting of useful energy content starts;
f) T_p [°C] minimum (peak) temperature to be achieved during tapping;
g) Q_{ref} [kWh/d] daily (24 h) useful energy content of all water draw-offs, effectively the sum of all Q_{tap}.

For all tests a cold water temperature of (10 ± 2) ºC shall be used.

As much as possible, the test method uses a 'black-box' approach, i.e. largely technology independent. This means amongst others that the laboratory uses the original appliance thermostat, in the position specified by manufacturer, and at the factory settings.

Table 4 –Load profile of water heater (reference test tapping patterns)

∞	XXS				XS				S			
	Qtap	f	Tm	Tp	Qtap	f	Tm	Tp	Qtap	f	Tm	Tp
h	kWh	l/min	°C	°C	kWh	l/min	°C	°C	kWh	l/min	°C	°C
	0,105	2	25						**0,105**	**3**	**25**	
07.05												
07.15												
07.26												
	0,105	2	25		**0,525**	**3**	**35**	-	**0,105**	**3**	**25**	
07.45												
08.01												
08.05												
08.15												
08.25												
	0,105	2	25						**0,105**	3	25	
08.45												
09.00												
	0,105	2	25						**0,105**	3	25	
10.00												
10.30												
11.00												
	0,105	2	25						**0,105**	3	25	
	0,105	2	25						**0,105**	3	25	
	0,105	2	25									
	0,105	2	25									
12.45	**0,105**	2	25		**0,525**	3	35	-	**0,315**	4	10	55
14.30												
15.00												
15.30												
16.00												
16.30												
17.00												
	0,105	2	25						**0,105**	3	25	
	0,105	2	25						**0,105**	3	40	
	0,105	2	25									
	0,105	2	25									
	0,105	2	25									
20.30					**1,050**	3	35	-	**0,420**	4	10	55
	0,105	2	25									
20.46												
	0,105	2	25									
	0,105	2	25									
21.30									**0,525**	5	45	
21.35	**0,105**	2	25									
	0,105	2	25									
Qref	**2,100**				**2,100**				**2,100**			

h	M				L				XL			
	Qtap	f	Tm	Tp	Qtap	f	Tm	Tp	Qtap	f	Tm	Tp
	kWh	l/min	°C	°C	kWh	l/min	°C	°C	kWh	l/min	°C	°C
07.00	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
07.05	**1,400**	6	40		**1,400**	6	40					
07.15									**1,820**	6	40	
07.26									**0,105**	3	25	
07.30	**0,105**	3	25		**0,105**	3	25					
07.45					**0,105**	3	25		**4,420**	10	10	40
08.01	**0,105**	3	25						**0,105**	3	25	
08.05					**3,605**	10	10	40				
08.15	**0,105**	3	25						**0,105**	3	25	
08.25					**0,105**	3	25					
08.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
08.45	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
09.00	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
09.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
10.00									**0,105**	3	25	
10.30	**0,105**	3	10	40	**0,105**	3	10	40	**0,105**	3	10	40
11.00									**0,105**	3	25	
11.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
11.45	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
12.00												
12.30												
12.45	**0,315**	4	10	55	**0,315**	4	10	55	**0,735**	4	10	55
14.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
15.00									**0,105**	3	25	
15.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
16.00									**0,105**	3	25	
16.30	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
17.00									**0,105**	3	25	
18.00	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
18.15	**0,105**	3	40		**0,105**	3	40		**0,105**	3	40	
18.30	**0,105**	3	40		**0,105**	3	40		**0,105**	3	40	
19.00	**0,105**	3	25		**0,105**	3	25		**0,105**	3	25	
19.30												
20.00												
20.30	**0,735**	4	10	55	**0,735**	4	10	55	**0,735**	4	10	55
20.45												
20.46									**4,420**	10	10	40
21.00					**3,605**	10	10	40				
21.15	**0,105**	3	25						**0,105**	3	25	
21.30	**1,400**	6	40		**0,105**	3	25		**4,420**	10	10	40
21.35												
21.45												
Qref	**5,845**				**11,655**				**19,070**			

h	XXL				3XL				4XL			
	Qtap	f	Tm	Tp	Qtap	f	Tm	Tp	Qtap	f	Tm	Tp
	kWh	l/min	°C	°C	kWh	l/min	°C	°C	kWh	l/min	°C	°C
07.00	**0,105**	3	25		**11,2**	48	40		**22,4**	96	40	
07.05												
07.15	**1,820**	6	40									
07.26	**0,105**	3	25									
07.30												
07.45	**6,240**	16	10	40								
08.01	**0,105**	3	25		**5,04**	24	25		**10,08**	48	25	
08.05												
08.15	**0,105**	3	25									
08.25												
08.30	**0,105**	3	25									
08.45	**0,105**	3	25									
09.00	**0,105**	3	25		**1,68**	24	25		**3,36**	48	25	
09.30	**0,105**	3	25									
10.00	**0,105**	3	25									
10.30	**0,105**	3	10	40	**0,84**	24	10	40	**1,68**	48	10	40
11.00	**0,105**	3	25									
11.30	**0,105**	3	25									
11.45	**0,105**	3	25		**1,68**	24	25		**3,36**	48	25	
12.00												
12.30												
12.45	**0,735**	4	10	55	**2,52**	32	10	55	**5,04**	64	10	55
14.30	**0,105**	3	25									
15.00	**0,105**	3	25									
15.30	**0,105**	3	25		**2,52**	24	25		**5,04**	48	25	
16.00	**0,105**	3	25									
16.30	**0,105**	3	25									
17.00	**0,105**	3	25									
18.00	**0,105**	3	25									
18.15	**0,105**	3	40									
18.30	**0,105**	3	40		**3,36**	24	25		**6,72**	48	25	
19.00	**0,105**	3	25									
19.30												
20.00												
20.30	**0,735**	4	10	55	**5,88**	32	10	55	**11,76**	64	10	55
20.45												
20.46	**6,240**	16	10	40								
21.00												
21.15	**0,105**	3	25									
21.30	**6,240**	16	10	40	**12,04**	48	40		**24,08**	96	40	
21.35												
21.45												
Qref	**24,530**				**46,760**				**93,520**			

9 Test procedures

9.1 Standard Test Procedure

9.1.1 Introduction

The following subclauses describe the test procedure to establish the electricity consumption Q_{elec} during a 24 h test.

9.1.2 Installation

Install product in test environment according to manufacturer's instructions.

Designated floor-standing appliances are to be placed on a floor with low thermal leakage (e.g. 20 mm thick medium density fibreboard could be placed under the test object at a distance of 100 mm above the floor of the test room).

Wall-mounted products shall be mounted on a panel at least 150 mm from any structural wall with a free space of at least 250 mm above and below the product and at least 700 mm to the sides. Products designated to be built-in shall be mounted according to manufacturer's instructions.

Products with declared Load Profiles 3XL and/or 4XL may be tested on-site, provided test conditions are equivalent, possibly with correction factors, to the ones referenced here.

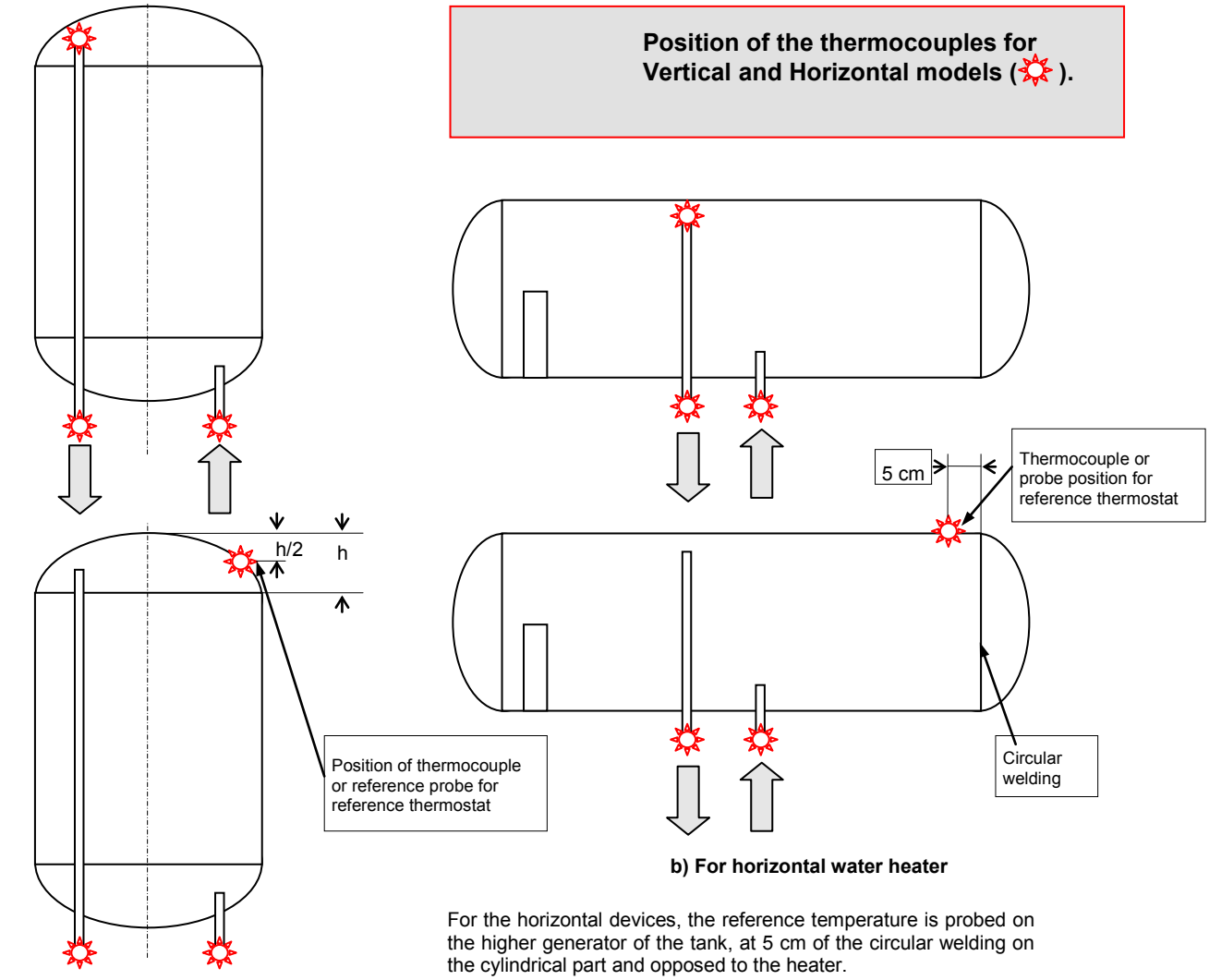
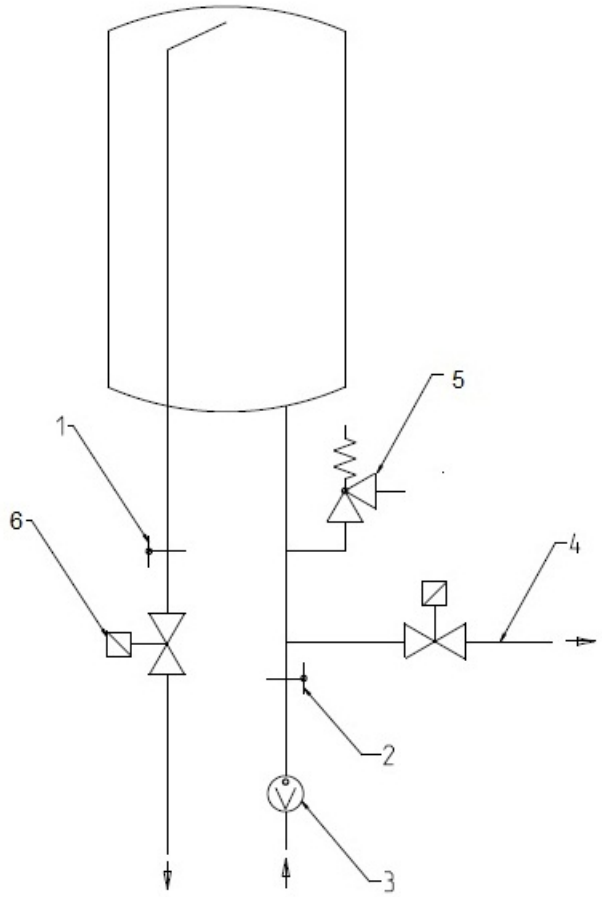


Figure 1 – Position of the thermocouples for Vertical and Horizontal models



Key

1 thermocouple outlet temperature
2 thermocouple cold water temperature
3 measurement flow rate
4 valve bypass
5 safety valve
6 valve tapping

Figure 2 – example of hydraulic connection (unvented products)

Distance between the cold water inlet of the water heater and the position of the thermocouple measuring cold water shall be lower or equal to 100 mm.

9.1.3 Stabilisation

Keep product at ambient conditions (test room) until all parts of the product have reached ambient conditions ± 5 K (at least for 24 h).

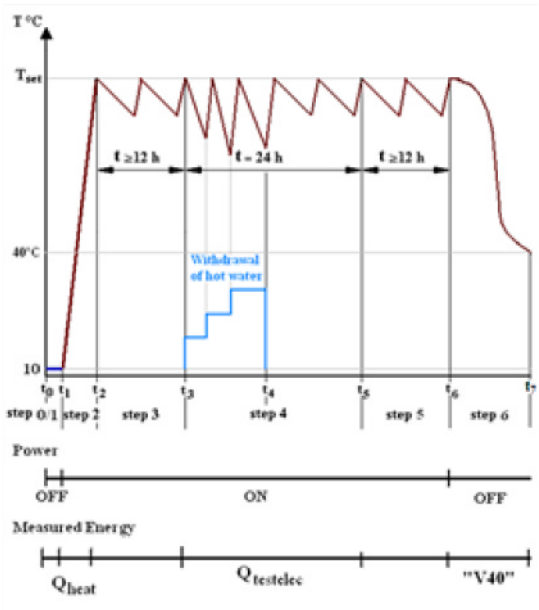


Figure 3 – Test procedure for "ENERGIZED APPLIANCES"

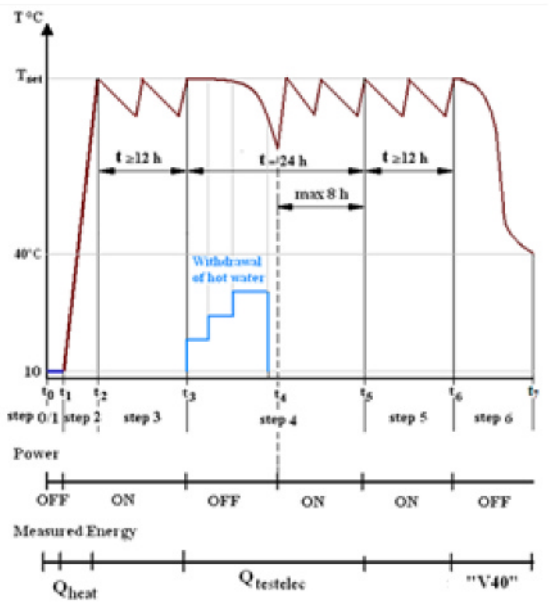


Figure 4 – Test procedure for "OFF-PEAK APPLIANCES"

9.1.4 Storage volume

STEP 0 of Figures 3 and 4: the volume of the tank in a storage electric water heater is measured as follows.

The empty water heater is to be weighted; the weight of taps on inlet and/or outlet pipes shall be considered.

Then the storage water heater is filled with cold water in accordance with the manufacturer's instruction at cold water pressure. The water supply is then cut off.

The filled water heater is to be weighted.

The difference of the two weights (m_{act}) is to be converted into the volume in litres.

$$C_{act} = \frac{m_{act}}{0.9997} \tag{2}$$

This volume is to be reported in litres to the nearest one-tenth litres. The measured value (actual value) shall not be more than 2 % lower than the rated value.

9.1.5 Filling and heat-up

STEP 1 of Figures 3 and 4: products with storage-facilities shall be filled with cold water (10 ± 2) °C. Filling stops at the applicable cold water pressure (see Table 4).

STEP 2 of Figures 3 and 4: the product is energized to reach "out-of-the-box" factory settings, e.g. for storage temperature. The product's own means of control (thermostat) shall be used. The next stage starts at thermostat cut out.

9.1.6 Stabilisation at zero-load

STEP 3 of Figures 3 and 4: keep the product at normal operating conditions as specified by the manufacturer without draw-offs during at least 12 h. This stage ends - and next stage starts - at the first thermostat cut-out after 12 h.

9.1.7 Tapping

STEP 4 of Figures 3 and 4: for the selected Load Profile, draw-offs are made in accordance with the specifications of the appropriate 24 h tapping pattern in Table 4. Tapping pattern starts directly after thermostat cut out from stabilisation part with the first tapping at 7:00h time-value as implied in Table 4. The tapping period ends 24 h later. The required useful energy content of the hot water is the total Q_{ref} [in kWh] in Table 4.

During the tapping stage technical parameters (power, temperature, etc.) are established in accordance with specifications in Table 4. During draw-offs the recommended maximum sample rate is 3 s (see Table 3). Recorded values shall be part of the technical test report.

Electricity consumption over the 24 h test $Q_{testelec}$ [kWh electricity] will be measured over 24 h (i.e. t_5-t_3).

Useful energy content of the hot water drawn-off Q_{H2O} [kWh] is determined as described below:

- follows from average in-/outlet temperature difference during the useful tapping period in [K], the tapped useful water volume in litre. and the specific heat of water c_w (1,163 x 10^{3} kWh/(litre x K)):

$$Q_{H2O}[i] = \Delta T[i] \times V[i] \times c_w \quad (3)$$

where:

$Q_{H2O}[i]$	is the "Energy content" of one draw-off in [kWh];
$\Delta T[i]$	is the average in-/outlet temperature difference during the useful tapping period in [K];
$V[i]$	is the tapped useful water volume [litres];
c_w (1,163x10^{-3} kWh/(litre x K))	is the specific heat of water.

For all the *n* draw-offs of one tapping profile the energy content is the sum:

$$Q_{H2O} = \sum Q_{H2O}[i] \quad for\ i = 1\ to\ n \quad (4)$$

This formula can have many formats, e.g. more dynamic formats using flowrate and instantaneous temperature differences, but it comes down to the same result.

Products to be classified as “Off-peak” appliances shall be energized for a maximum period of 8 consecutive hours (t_5-t_4) during 22:00h and 7:00h of the 24 h tapping pattern as specified in Table 4.

In addition $V_{water}^{full-drawing}$ [litres] will be recorded; it is the sum of quantity of hot water totally delivered during the tapping period.

9.1.8 Reporting of Q_{elec}

$Q_{testelec}$ shall be corrected for any energy surplus or deficit outside the strict 24 h tapping period, i.e. a possible energy difference before and after the tapping cycle is taken into account. Furthermore, any surplus or deficit in the delivered useful energy content of the hot water is taken into account in the following equations for Q_{elec}.

$$Q_{elec} = \left(\frac{Q_{ref}}{Q_{H2O}} \right) \times \left\{ Q_{testelec} + \frac{1{,}163 \times C_{act} \times \left(T_3(t_3) - T_5(t_5) \right)}{1000} \right\} \text{ [kWh]} \quad (5)$$

where T_3 and T_5 are water temperatures measured at the dome of water heater, respectively at t_3 and t_5.

9.1.9 Re-stabilisation at zero-load

STEP 5 of Figures 3 and 4: keep product at nominal operating conditions without draw-offs during at least 12 h. For products with storage-facilities subject to a control cycle this stage ends at the first thermostat cut-out after 12 h.

9.1.10 Mixed water quantity delivered at 40 °C

STEP 6 of Figures 3 and 4: quantity of water at 40 °C, which has the same heat content (enthalpy) as the hot water which is delivered above 40 °C at the output of the water heater.

Immediately following measurement according to “Re-stabilization at zero-load” (STEP 5), the water heater is switched off after the last cut-out of the thermostat.

Then a quantity of water equal to the rated capacity is withdrawn through the outlet at a constant rate of flow by supplying cold water; the flow of water from open outlet water-heaters is controlled by the inlet valve. The flow in any other type of water-heaters is kept constant by means of a valve fitted in the outlet or the inlet.

The rate of flow is adjusted to the maximum value showed on “Water heater load profile” chosen to perform the appliance during the tapping cycle.

T_{set} [°C] is the water temperature, without withdrawal of water, measured with a thermocouple placed inside the upper section of the tank. For metal tanks the thermocouple may be placed on the outer surface of the tank as well. This value is the water temperature measured after the last cut-out of the thermostat during the “Re-stabilization at zero-load” step.

θ_c [°C] is the average temperature of inlet cold water during the test.

θ_p [°C] is the average temperature of outlet water and its normalized value is named θ_p [°C]; it is to be calculated in according to the following formula:

$$\theta_p[°C] = \left(T_{set} - 10 \right) \times \frac{\left(\theta'_p - \theta_c \right)}{\left(T_{set} - \theta_c \right)} + 10 \quad (6)$$

NOTE Temperature readings are preferable taken continuously. Alternatively, they may be taken at equal intervals evenly spread over the discharge, for example every 5 litres (maximum). If there is a sharp drop in temperature, additional readings may be necessary in order to correctly calculate the average value θ_p.

Outlet water temperature shall always be ≥ 40 °C which is to be taken into account for the calculation of θ_p.

The volume V_{40_exp} [litres] which corresponds to the quantity of water delivered at least 40 °C is to be considered.

Quantity of hot water V_{40} [litres] delivered with a temperature of at least 40 °C will be calculated by the following equation:

$$V_{40}[litres] = V_{40\,exp} \cdot \frac{\left(\theta_p - 10 \right)}{30} \quad (7)$$

9.2 Smart Control Test procedure

9.2.1 Measurement procedure

The **Smart Control** test procedure is based on two periods of test; they are named “reference period” and “smart period”. During the first period, “reference period”, the smart control does not influence the heating procedure and the appliance uses the factory settings for the temperature; in the second period, “smart period”, which will be reached automatically, the appliance works to reduce any electricity consumption to achieve a minimum performance goal (i.e. Smart control factor: SCF) compared with the first period of test.

During both periods the chosen tapping profiles have to be fulfilled.

The total test period is called SMART CYCLE.

The whole test is made using the product thermostat.

9.2.2 Installation

STEP 0 of Figure 5: The appliance is installed following the same methodology showed in 9.1.2.

9.2.3 Stabilisation

STEP 1 of Figure 5: The appliance is stabilised following the same methodology showed in 9.1.3.

9.2.4 Filling and heat-up

STEP 2 of Figure 5: The appliance is filled and heated-up following the same methodology showed in 9.1.5.

It is heated-up at (T_{set} ± 3°C) temperature; T_{set} is the water temperature measured at the dome (Figure 1) of appliance and this value is given by the manufacturer to achieve a minimum performance goal (i.e. SCF).

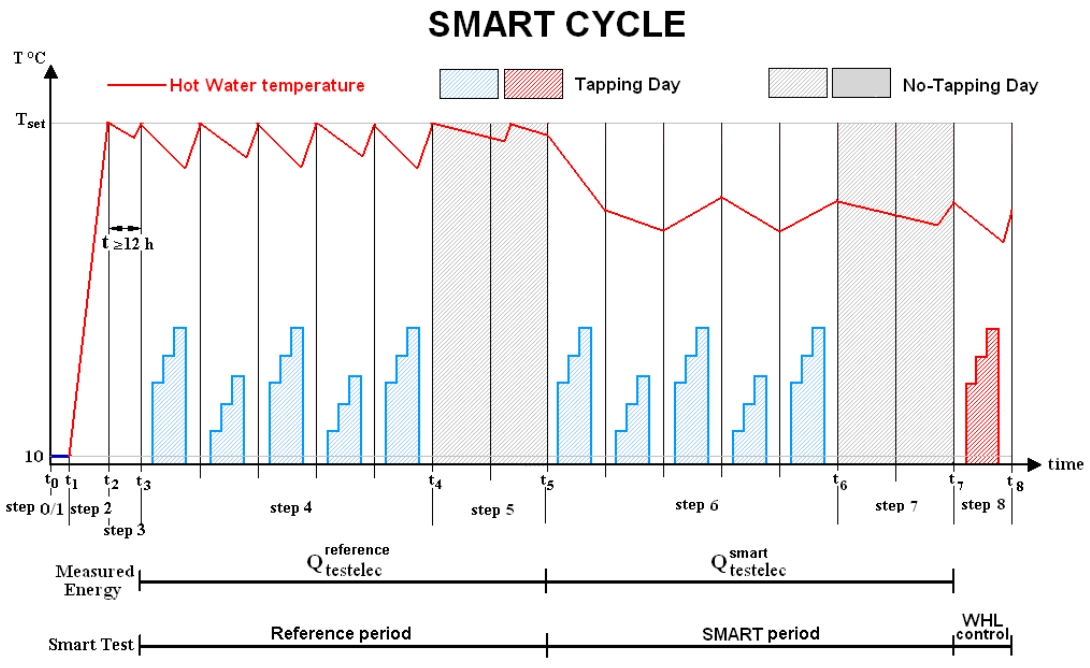


Figure 5 – Test procedure for “SMART CYCLE”

9.2.5 Stabilisation before reference period

STEP 3 of Figure 5: keep the product at normal operating conditions as specified by the manufacturer without draw-offs during at least 12 h. This stage ends - and next stage starts - at the first thermostat cut-out after 12 h.

At the end of this step, the water temperature measured at the dome shall be (T_{set} ± 3°C) at t_3.

9.2.6 Reference period

STEP 4/5 of Figure 5: This test period allows consumer behaviour learning and measuring energy consumption with **smart control** activation.

STEP 4/5 can last 7 or 14 days (1 or 2 weeks); the manufacturer will decide to use one or two weeks procedure and the product will be tested following this one.

The first 5 days of test, in terms of tapping profiles, will be chosen randomly by the lab between the Load Profile, declared by the manufacturer for the product (WHL), and the immediately lower Load Profile (WHL-1). It means five water heater loads shall be defined (i.e. three “WHL” and two “WHL-1”) and the lab can decide to use them randomly (e.g. WHL=M → MMMSS, SSMMM, MSMSM, …). In the (unlikely) case that WHL-1 is the smallest Load Profile XXS, the product shall be tested using only the Load Profile WHL (e.g. XXS) for all five days.

The 6th and 7th days of test there will be no tapping. An example is given in Table 5.

In case of a 2-weeks period the second week is identical to the first week.

Table 5 – Tapping profiles

Reference period	Smart period
Day 1: WHL	Repetition in the same order
Day 2: WHL-1	
Day 3: WHL	
Day 4: WHL-1	
Day 5: WHL	
Day 6: no tapping	
Day 7: no tapping	

If a second week in the reference period is used, it shall have the same WHL and WHL-1 sequence and order compared with the first week.. It means five water heater loads shall be defined (i.e. three “WHL” and two “WHL-1”) and the lab can decide to use them randomly during the first week (e.g. WHL=M → first week: MMMSS, second week: MMMSS …).

SMART CONTROL is manually/automatically activated, in according to the manufacturer’s instructions, at time t_3 (Figure 5), and it stays on from t_3 to t_8.

For the selected Load Profiles, draw-offs are made in accordance with the specifications of the appropriate 24 h tapping pattern in Table 4. Tapping patterns start at t_3 (7:00h) as implied in Table 4. The tapping period ends 24 h later for each day.

During the tapping step, technical parameters (power, temperature, etc.) are established in accordance with specifications in Table 3. During draw-offs the recommended sample rate is 3 s or less. Recorded values shall be part of the technical test report.

Electricity consumption over each 24h test, $Q_{testelec}^{reference}[i]$ [kWh electricity], will be measured and a total energy content will be defined for the “Reference period”.)

$$Q_{testelec}^{reference} = \sum_{i=1}^{7n} Q_{testelec}^{reference}\ [i] \tag{8}$$

where n=1 if “reference period” is based on one week or n=2 if it is based on two weeks.

During the “reference period” period, the water temperature at the dome of the appliance shall be fixed as

$$T_{set}^{reference} \leq T_{set} + 5°C \tag{9}$$

In this way, the electronic thermostat of product can be considered reliable.

Now, useful energy content of the hot water drawn-off Q_{H2O} [kWh] shall be determined as described in 9.1.7. For each day a $Q_{H2O}^{reference}\ [i]$ value shall be measured and a weekly value can be measured indeed; it can be expressed as

$$Q_{H2O}^{reference} = \sum_{i=1}^{7n} Q_{H2O}^{reference}\ [i] \tag{10}$$

where n=1 if “reference period” is based on one week or n=2 if it is based on two weeks.

Products classified as “Off-peak” appliances shall be energized for a maximum period of 8 consecutive hours during 22:00h and 7:00h of the 24 h tapping pattern as specified in Table 4.

9.2.7 Smart period

STEP 6/7 of Figure 5: Immediately after the Reference period, the test of “Smart period” is performed during one week, using the same repetition of tapping profile defined during the “reference period”; **smart control** function is activated. The energy consumption is measured during this step as well and it will be compared to the energy consumption of the “reference period” step. This percentage of saving is named “Smart control factor: SCF”.

The main parameters of this test can be expressed as: electricity consumption over each 24 h test, $Q_{testelec}^{smart}\ [i]$ [kWh electricity], will be measured and a total energy content will be defined for the “Smart period”.

$$Q_{testelec}^{smart} = \sum_{i=1}^{7n} Q_{testelec}^{smart}\ [i] \tag{11}$$

where n=1 if “reference period” was based on one week or n=2 if it was based on two weeks.

And useful energy content of the hot water drawn-off Q_{H2O} [kWh] shall be determined as described in 9.1.7. For each day a $Q_{H2O}^{smart}\ [i]$ value shall be measured and a weekly can be expressed as :

$$Q_{H2O}^{smart} = \sum_{i=1}^{7n} Q_{H2O}^{smart}\ [i] \tag{12}$$

where n=1 if “reference period” was based on one week or n=2 if it was based on two weeks.

Products to be classified as “Off-peak” appliances shall be energized for a maximum period of 8 consecutive hours during 22:00h and 7:00h of the 24h tapping pattern as specified in Table 4.

9.2.8 Reporting of "Smart Control Factor"

"SMART Control Factor" shall be corrected for any energy surplus or deficit outside the strict 24 h tapping period (and weekly period as well), i.e. a possible energy difference before and after the tapping cycle is taken into account. The difference between Q_{H2O} (after first week) and Q_{H2O} (after second week) measurement results have to be lower than 2 %. Furthermore, any surplus or deficit in the delivered useful energy content of the hot water is taken into account in the following formula:

$$SCF = \left(1 - \frac{Q^{smart}_{testelec}}{Q^{ref}_{testelec}}\right) \quad (13)$$

9.2.9 WHL control cycle

STEP 8 of Figure 5: Immediately after the "Smart period" an additional 24 h (named "WHL control" cycle) shall be performed and requirements are fulfilled; in this step the product is tested in according to the water heater load of the first day (Day 1) of "Reference period". In this step electricity consumption shall not be measured.

10 Data Report

Each test shall be accompanied by a 'Data Report' on specific performance characteristics of the product, as defined in Table 6.

Table 6 – Data report

1.	Manufacturer	X
2.	Model & ID	Y
3.	Date of test	dd-mm-yy
4.	Basic product Type	Electric
4.1	Nominal Power, in kW	N,NN
4.2	Rated capacity, in litres	NNN
4.3	Actual capacity, in litres	NNN;N
5.	Subtype	Conventional
6.	Load Profile	XXS / XS / S / M / L / XL / XXL / 3XL / 4XL
7.	Tset declared by the manufacturer, in °C	NN
7.1	Tset measured value, in °C	NN;N
8.	Electricity consumption, in kWh/d electric **(Q_{elec})**	NNN;NN
9.	smart	
9.1	Smart control factor, SCF [%]	NN;NN
9.2	Sequence of SMART tapping cycles used during the test	N / N-1 / N / N-1 / N / - / -
10.	**Off-peak**	yes/no
11	Electric Energy Efficiency % **(η_{elecwh})**	NNN,N% **999%** 999%

Annex A
(normative)

Calculation of the specific energy efficiency and of the Annual Consumption of electric energy

A.1 Symbols and Units

Table A.1 – Symbols and Units

Symbol	Unit	Description
η_{wh}	[%]	Specific energy efficiency of a storage water heater, which is the ratio between the useful energy in the delivered hot water and the consumed electrical energy converted to primary energy.
Q_{cor}	[kWh]	Ambient correction term which takes into account the fact that the place where the water heater is installed is not an isothermal place.
Q_{atot}	[kWh/y]	Annual primary energy use for the load profile.
AEC	[kWh/y]	Annual consumption of electric energy.
CC		Conversion Coefficient of electricity in primary energy. Its value is defined in Annex II, note 3 of Directive 2006/32/EC of the European Parliament, in the Council of 5 April 2006 and Council Directive 93/76/EEC. NOTE CC = 2.5 in year 2012.

A.2 Calculation of the Specific Energy Efficiency

The specific energy efficiency (η_{wh}) of a storage water heater is the ratio between the delivered energy in the hot water for the tapping pattern of its load profile and the consumed energy converted to primary energy.

The consumed energy is the result of the test of the water heater with adjustments for:

- ***smart control*** that can reduce the energy consumption;
- ***ambient correction*** that takes into consideration the fact that the installation by the consumer will not be an isothermal place.

The specific energy efficiency of a dedicated storage water heater shall be calculated as (Formula A.1):

$$\eta_{wh} = \frac{Q_{ref}}{CC \cdot Q_{elec}(1 - SCF \cdot smart) + Q_{cor}} \qquad \text{(A.1)}$$

where:

- Q_{ref} is the delivered energy for the 24 h tapping pattern for the load profile of the water heater, in kWh;
- Q_{elec} is the consumption of electric energy with the relevant 24 h tapping pattern, in kWh;
- *smart* indicates the presence of **smart control** and is yes = 1, no = 0;

NOTE SCF=0 in case no **smart control** is detected during testing (9.2).

$$Q_{cor} = -k \cdot (CC \cdot (Q_{elec} \cdot (1 - SCF \cdot smart) - Q_{ref})) \quad \text{(A.2)}$$

- Where the k-values are given in Table A.2 for each load profile :

Table A.2 – k values

	XXS	XS	S	M	L	XL	XXL	3XL	4XL
k	0,23	0,23	0,23	0,23	0,23	0,23	0,0	0,0	0,0

For electric storage water heaters the declared specific energy efficiency shall be:

$$\eta_{wh} \leq \frac{1}{CC} \quad \text{(A.3)}$$

which is a necessary condition to apply because the formula could give a higher efficiency for electric dedicated storage water heaters with **smart controls**.

A.3 Calculation of the Annual Consumption of electric energy

The Annual Consumption of electric energy (AEC), in kWh/year and rounded to the integer, to be calculated as:

$$AEC = 0.6 \cdot 366 \cdot (Q_{elec} \cdot (1 - SCF \cdot smart) + \frac{Q_{cor}}{CC}) \quad \text{(A.4)}$$

A.4 Data Report

The 'Data Report' on specific performance characteristics of the product should be supplemented with the elements in Table A.3.

Table A.3 – Complements to Data Report

12.	Conversion Coefficient to Primary Energy CC	N,NN
13.	Specific Energy Efficiency % (η_{wh})	NNN,N% 999% 999%
14.	Annual electricity consumption AEC, in kWh/y	NNNNN 999% 999%

Annex ZZA
(informative)

Relationship between this European Standard and the requirements of Commission Regulation (EC) No 812/2013

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association to provide a means of conforming to requirements of *Commission Regulation (EC) No 812/2013 of 18 February 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to energy labelling requirements for water heaters and hot water storage tanks*.

Once this standard is cited in the Official Journal of the European Union under that Commission Regulation, compliance with the clauses of this standard given in Table ZZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding requirements of that and associated EFTA regulations.

Table ZZA.1 — Correspondence between this European Standard and Commission Regulation (EC) No 812/2013

Requirements of Commission Regulation (EC) No812/2013	Clauses and subclauses of this EN
Daily electricity consumption	9.1.8 Reporting of Qelec
Annual electricity consumption	A.3.2 Calculation of the Annual Consumption of electric energy
Water heater energy efficiency	A.3.1 Calculation of the Specific Energy Efficiency
Smart control	9.2 Smart Control Test procedure
Capacity	9.1.4 storage volume

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Annex ZZB
(informative)

Relationship between this European Standard and the requirements of Commission Regulation (EC) No 814/2013

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association to provide a means of conforming to requirements of *Commission Regulation (EC) No 814/2013 of 2 August 2013 implementing Directive 2009/125/EU of the European Parliament and of the Council with regard to ecodesign requirements for water heaters and hot water storage tanks*.

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Table ZZB.1 — Correspondence between this European Standard and Commission Regulation (EC) No 814/2013

Requirements of Commission Regulation (EC) No814/2013	Clauses and subclauses of this EN
Daily electricity consumption	9.1.8 Reporting of Qelec
Annual electricity consumption	A.3.2 Calculation of the Annual Consumption of electric energy
Water heater energy efficiency	A.3.1 Calculation of the Specific Energy Efficiency
Smart control	9.2 Smart Control Test procedure
Capacity	9.1.4 storage volume
V40	9.1.10 Mixed water quantity delivered at 40°C

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Bibliography

DIRECTIVE 2009/125/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products

COMMISSION REGULATION (EU) No 814/2013 of 2 August 2013

DIRECTIVE 2010/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other recources by energy-related products

COMMISSION DELEGATED REGULATION (EU) No 812/2013 of 18 February 2013

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