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Heating boilers - Energy assessment of hot water storage systems

Chaudières de chauffage - Evaluation de la performance énergétique des préparateurs d'eau chaude

Heizkessel - Energetische Bewertung von Warmwasserspeichersystemen

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This document (EN 15332:2007) has been prepared by Technical Committee CEN/TC 57 “Central heating boilers”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2008, and conflicting national standards shall be withdrawn at the latest by May 2008.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard : Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This European Standard specifies a method for the energy assessment of a domestic hot water system comprising an external heating boiler of specified minimum output indirectly heating an unvented (closed) hot water tank of up to 1 500 l. Whilst tanks intended primarily for direct heating are not covered by this European Standard, it does allow the provision of electric heating elements for auxiliary use.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12897, *Water supply — Specification for indirectly heated unvented (closed) storage water heaters*

3 Terms and definitions

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

3.1
indirectly heated un-vented (closed) hot water storage tanks
storage vessels used for heating up domestic hot water with an external heat source where the hot water side is not vented to atmosphere, including all devices delivered with it

3.2
hot water side
side of the storage tank which contains domestic hot water

NOTE If a mixing valve is delivered with the storage tank, it is considered as part of the hot water side.

3.3
heating side
side of the storage tank which contains the heating medium

3.4
temperature of the cold water
ϑ_c
temperature at the entrance of the hot water side of the storage tank in °C

3.5
temperature of the warm water
ϑ_w
temperature at the outlet of the hot water side in °C

3.6
usable hot water temperature
ϑ_u
minimum temperature for the hot water to be usable

NOTE Minimum temperature for the hot water defined here as difference between the temperature of the warm water ϑ_w = 45 °C minus the temperature of cold water ϑ_c = 10 °C ($\vartheta_u = \vartheta_w - \vartheta_c$ = 35 K).

3.7
heating medium supply temperature
ϑ_h
heating medium temperature at the entrance of the heating side of the water heater

3.8
heating medium return temperature
ϑ_r
heating medium temperature at the outlet of the heating side of the water heater

3.9
storage temperature
ϑ_s
temperature of the storage tank measured at the thermostat position, which is intended for this purpose

3.10
ambient temperature
ϑ_a
temperature in the environment of the hot water storage tank measured according to 5.4.1

3.11
storage excess temperature
$\Delta\vartheta_x$
temperature difference between the storage temperature and the ambient temperature:

$$\Delta\vartheta_x = \vartheta_s - \vartheta_a$$

3.12
tapping volume flow
V_w
flow of warm water through the hot water side in l/s

3.13
tapping mass flow
m_w
flow of warm water through the hot water side in kg/h

3.14
loading mass flow
m_l
flow of heating medium through the heating side in kg/h

3.15
rated storage capacity
C_R
capacity of the storage tank assigned by the manufacturer in l

3.16
actual storage capacity
C_A
water content of the hot water and the heating side determined by volume measuring or balancing in l

3.17
hot water capacity
C_U
quantity of hot water in litre at usable hot water temperature ϑ_u which could be tapped at one 10 min tapping at a cold water temperature of ϑ_c = 10 °C and a maximum hot water temperature of ϑ_w =65 °C ($\Delta\vartheta_w = \vartheta_w - \vartheta_c$ = 55 K) with reheating

3.18
heat exchanger performance
P_e
continuous transferable heat power from the heating side to the hot water side in kW at standard conditions of ϑ_c = 10 °C, ϑ_w = 60 °C and ϑ_h = 80 °C

3.19
standby loss
Q_B
energy loss in kWh/d at nominal storage temperature against environment with an ambient temperature of ϑ_a = 20 °C, but at least 45 K excess temperature

3.20
cold condition
condition at which the temperature in no side of the storage tank is more than 10 K over the cold water temperature ϑ_c

3.21
cycle time
$\Delta\tau$
time interval of the data acquisition in s

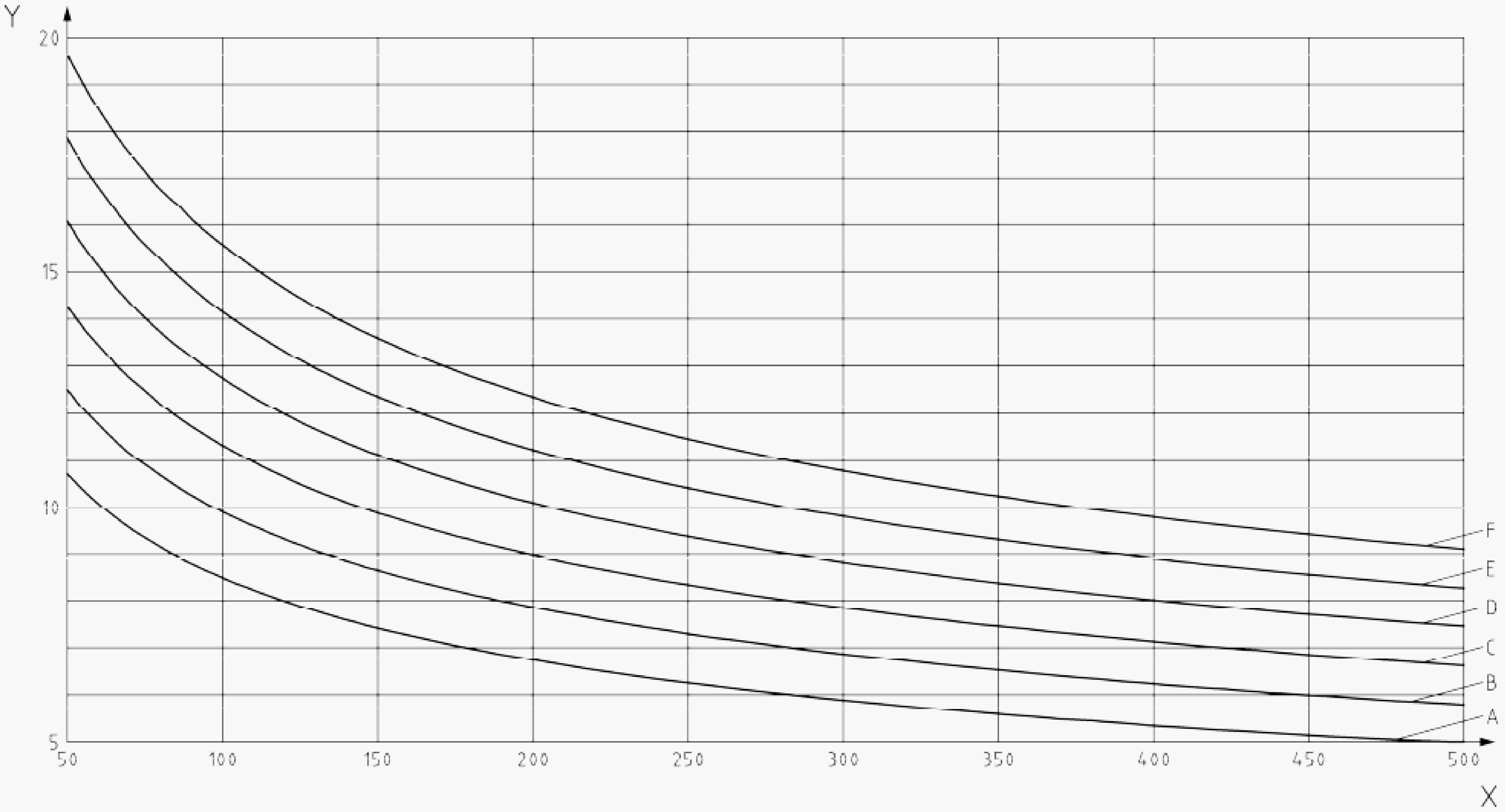
3.22
nominal operating conditions
index n
operation conditions resulting from the measurement or given by the manufacturer

3.23
nominal storage temperature
temperature of the stored water in the tank as measured by the thermostat

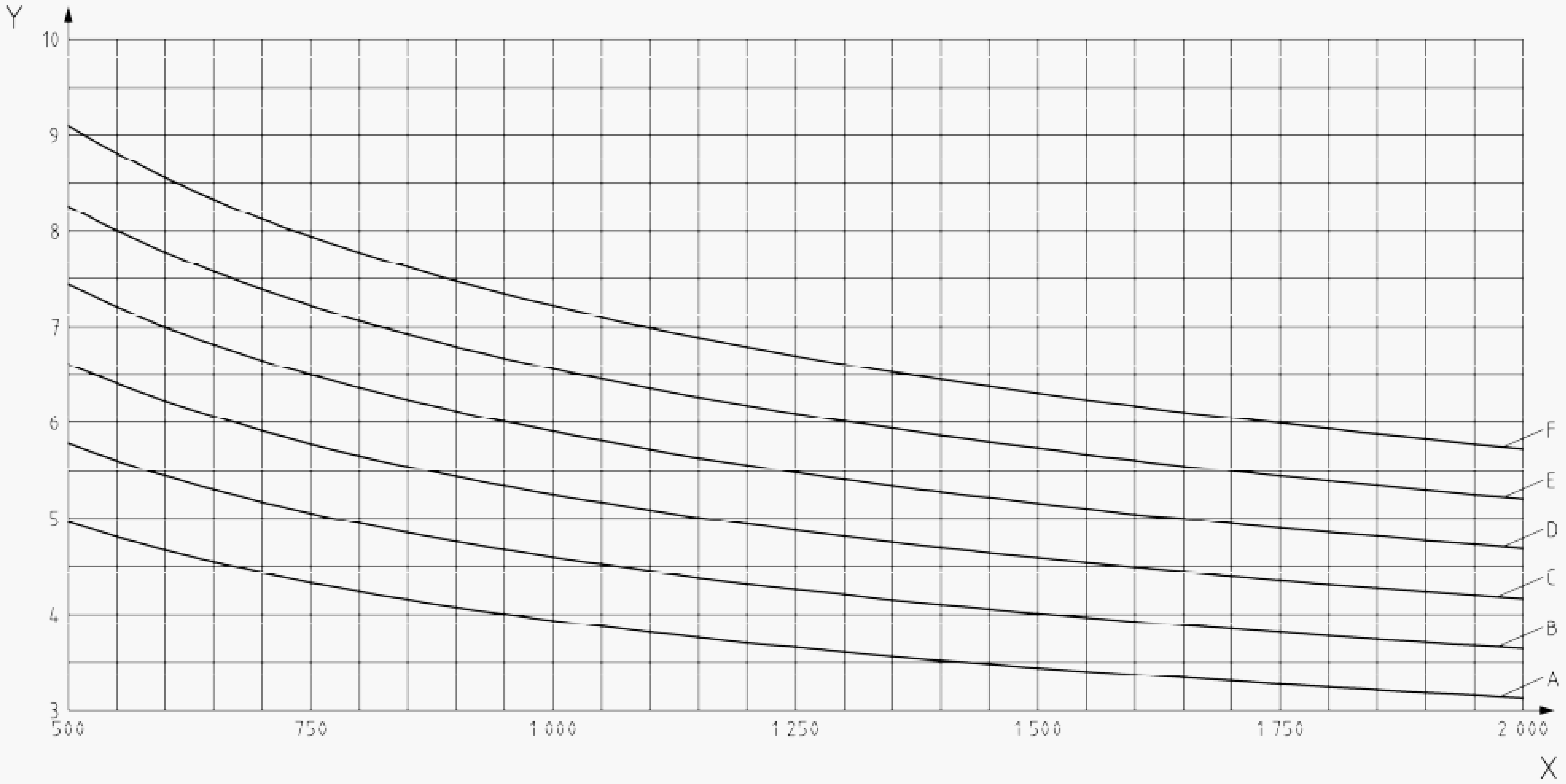
4 Requirements on the hot water storage tanks

4.1 Energy assessment

For the energy assessment of the hot water storage tank, the standby loss shall be rated against the hot water capacity according to Figure 1.



a)



b)

Key

Y standby loss related to the hot water capacity in (Wh/l)/d

X hot water capacity C_u in litres

A to F coefficient for the rational use of energy, see explanation to the Equations (1) to (3)

Figure 1 — Labelling of hot water storage tanks based on the hot water capacity

The maximal standby loss $Q_{B,max}$ for the different quality levels shall be calculated according to Equations (1) to (3) depending by the used method:

$$Q_{B,max} = QL(n) \times 52{,}5 \times C_R^{-1/3} \quad (1)$$

$$Q_{B,max} = QL(n) \times 52{,}5 \times C_A^{-1/3} \quad (2)$$

$$Q_{B,max} = QL(n) \times 52{,}5 \times C_U^{-1/3} \quad (3)$$

where

$Q_{B,max}$ is the maximal standby loss in kWh/d;

C_R is the rated storage capacity in l;

C_A is the actual storage capacity in l;

C_U is the hot water capacity in l;

$QL(n)$ is the coefficient for rational use of energy, see Figure 1

with n from A to F

$QL(A) = 0{,}75$;

$QL(B) = 0{,}875$;

$QL(C) = 1{,}0$;

$QL(D) = 1{,}125$;

$QL(E) = 1{,}25$;

$QL(F) = 1{,}375$.

The hot water capacity depends on the construction of the storage tank.

The hot water capacity could be:

— estimated with the real storage volume (4.2);

— estimated with the real storage volume and the heat exchanger performance (4.3);

— measured (4.4).

The standby loss shall be measured according to 5.4 or any other method which is proven to give the equivalent results.

4.2 Estimating the hot water capacity from the actual storage capacity

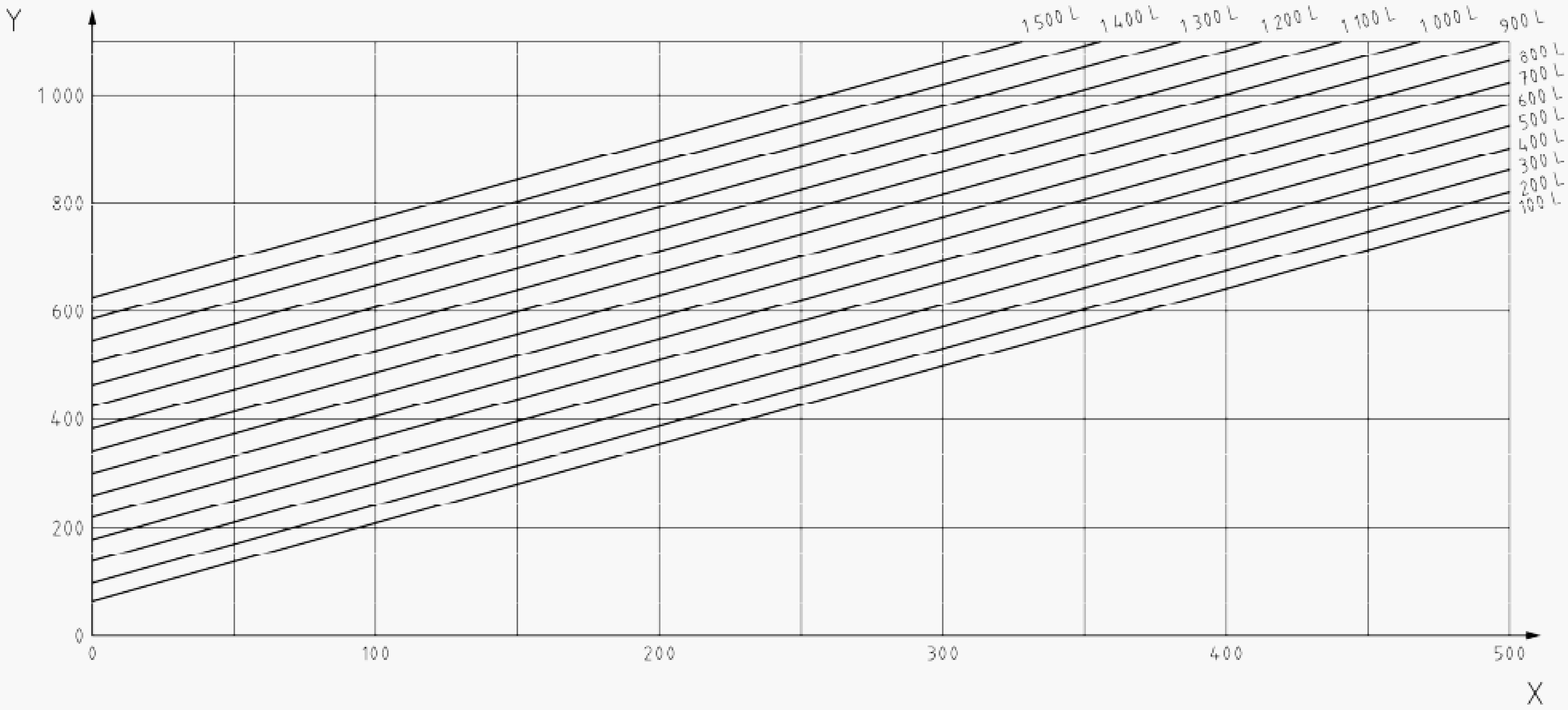
If no measurement has been taken, the behaviour of the storage tank shall be assumed to be fully mixing.

This means that under the conditions of cold water temperature ϑ_c = 10 ºC, usable hot water temperature ϑ_u = 45 ºC, storage temperature after loading ϑ_s = 65 ºC the hot water capacity C_u can only achieve 4/7 of the actual storage capacity.

If the heat exchanger performance is not known, the hot water storage capacity shall be determined as the intersection of actual storage capacity line and y-axis in Figure 2.

4.3 Estimating the hot water capacity with known heat exchanger performance

If the heat exchanger performance is measured according to 5.2 and assuming a fully mixing storage tank, the hot water capacity could be calculated with the actual storage capacity as shown in Figure 2:



Key

Y hot water capacity C_u in litres

X heat exchanger performance P_e in kW

Figure 2 — Hot water capacity calculated with actual storage capacity of up to 1 000 l and heat exchanger performance

The diagram in Figure 2 is based on Equation (4):

$$C_u = \frac{4}{7}\left(C_A + P_E \times \left(\frac{\tau_t}{c_w \times \Delta \vartheta_u} \times \rho_w\right)\right) = \frac{4}{7}\left(C_A + P_E \times 4{,}1\right) \quad (4)$$

where

c_W is the specific heat capacity of water (constant 4,18 kJ/kg K);

τ_t is the tapping time (600 s);

ρ_w is the density of water (1 kg/l).

4.4 Measuring the hot water capacity

The hot water capacity shall be measured according to 5.3 or according to EN 12897.

NOTE Other methods can be used if these methods give equivalent results.

5 Measurements

5.1 Connection of the storage tank

The storage tank shall be tested with the accessories it is delivered with. The storage tank shall be connected to the heat source as indicated by the manufacturer. If the water heater has a circulation connection, it shall be closed.

5.2 Measurement of the heat exchanger performance

The heat exchanger performance shall be measured under continuous operation.

The cold and hot water temperature, the heating medium supply and return temperature and the heating medium mass flow m_l or the warm water mass flow m_w shall be measured.

If the mass flow is not given by the manufacturer, the heat supply to the water heater and the mass flow of the warm water and the heating medium shall be regulated in such a way that the temperature difference between heating medium supply temperature and cold water temperature is $\vartheta_h - \vartheta_c$ = (70 ± 2) K, the temperature difference between heating medium supply and return temperature is $\vartheta_h - \vartheta_r$ = (20 ± 1) K and the temperature difference between warm and cold water temperature is $\vartheta_w - \vartheta_c$ = (50 ± 1) K.

The steady-state condition shall be considered as reached, if the mass flow does not vary more than ± (1 % + 1 kg/s), and the temperatures no more than ± 0,2 K around the measured average value of 10 measured values taken up within 10 min.

The heat performance P_e in kW results as product of flow of the warmed up water, rise in temperature and specific heat capacity of the water according to Equation (5):

$$P_e = m_w \times c_w \times (\vartheta_w - \vartheta_c) \times \frac{1}{3600} \text{ in kW.} \quad (5)$$

5.3 Measurement of the hot water capacity

5.3.1 General

The cold water temperature for the test can be between ϑ_c = 8 °C to 18 °C, but is not allowed to fluctuate during the test by more than ± 1 K. All given temperatures refer to a cold water temperature of ϑ_c = 10 °C. If the cold water temperature differs, the measurement has to take place with the according temperature differences which are given in brackets named with $\Delta\vartheta = \vartheta - \vartheta_c$.

The storage tank shall be regarded as loaded when the loading controller switches off. The hot water temperature shall never exceed $\vartheta_{w,max}$ = 65 °C ($\Delta \vartheta_{w,max}$ = 55 K).

The storage tank shall be regarded as empty when the hot water temperature falls below the usable hot water temperature ϑ_u = 45 °C ($\Delta \vartheta_u$ = 35 K).

5.3.2 Preparation

The storage tank shall be connected to a heat source. The heating supply temperature shall be limited to $\vartheta_h - \vartheta_c$ = (70 ± 2) K.

The supply mass flow shall be set to the value determined in 5.2. The heat generator shall be switched on and off together with the pump by a loading controller with a two point behaviour and a switching difference of max. 5 K shall be used.

The controller sensor shall be positioned in the tank thermostat pocket, which is provided for this purpose.

5.3.3 Procedure

The temperature gradient of cold and warm water and the warm water mass flow shall be logged during the measurement tapping within an interval of max. 10 s.

The measurement cycle shall consist of at least three tappings: at least two pre-tappings and one measurement tapping.

The tapping volume flow V_w for all tappings shall be set at such a level that the tank is emptied during the measurement tapping within (10 ± 1) min. The setting of the right tapping volume flow may require a number of iteration loops. The tapping volume flow shall not be changed during the measurement.

If the storage tank could not be emptied within 10 min due to temperature or volume flow restrictions (e.g. instantaneous heating of the hot water), the volume flow shall be set to the highest possible value.

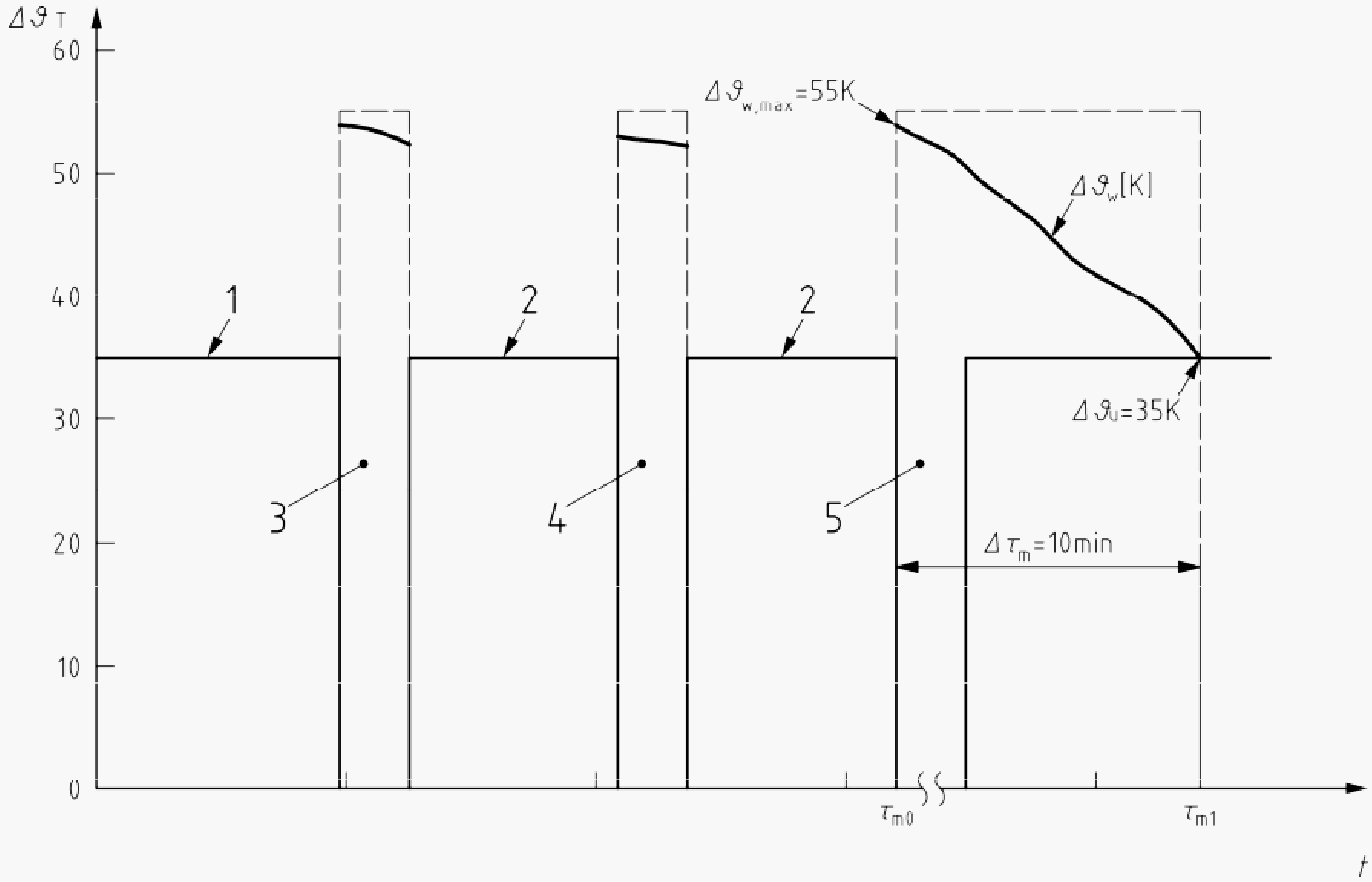
The storage tank shall be first loaded from the cold condition. The set point of the loading controller shall be set at such a level that the heat source is switched off when the nominal storage temperature is reached. As soon as the tank is loaded the first pre-tapping shall start. The tapping shall stop when the loading controller starts reloading. Immediately after ending reloading the second pre-tapping shall start. If the hot water temperature exceeds the maximum hot water temperature within this tapping, the set value of the loading controller shall be adapted and another pre-tapping is performed. This iteration is done until no further adaptation of the set point is necessary.

The measurement tapping shall start as soon as the reload of the last preliminary tapping is stopped by the controller at τ_{m0}. In this case tapping shall continue until the storage tank is empty, which means that the hot water temperature falls below the usable hot water temperature at τ_{m1}.

If the hot water temperature exceeds $\vartheta_{w,max}$ = 65 °C ($\Delta\ \vartheta_{w,max}$ = 55 K) at any time during the test, the set point of the loading controller has to be adjusted again, and the measurement cycle repeated.

The set point of the loading controller at which the measurement tapping takes place shall be noted as the nominal storage temperature ϑ_{sn}.

The diagram in Figure 3 shows the principle of the measurement cycle.



Key

1 loading

2 reloading

3 first pre-tapping

4 second pre-tapping (repeated if necessary)

5 measurement tapping

Figure 3 — Principle of the measurement cycle

5.3.4 Evaluation

The quantity of hot water that could be tapped with the usable hot water temperature within the measurement tapping shall be calculated according to Equation (6).

$$C_u = \sum_{\tau_{m0}}^{\tau_{m1}} V_w \times \Delta\tau_m \times \frac{(\vartheta_w - \vartheta_c)}{(\vartheta_u - 10\,°C)} \qquad (6)$$

where $\Delta\tau_m = (\tau_{m1} - \tau_{m0}) = (10 \pm 1)$ min.

If the storage tank could not be emptied within 10 min due to temperature or volume flow restrictions (e.g. instantaneous heating of the hot water), the measurement is evaluated for $\Delta\tau_m$ = 10 min.

5.4 Measurement of the standby-loss

5.4.1 General

The standby loss shall be measured by keeping the storage temperature constant with the help of an electrical heating and a controller. Therefore the storage tank shall be equipped with an additional electrical immersion heater within the lower third.

The average ambient temperature shall be ϑ_{amb} = (20 ± 5) °C, but shall not fluctuate more than ± 1 K.

The ambient temperature ϑ_{amb} shall be measured in the half height and 1 m distance from the storage tank. If the distance between storage tank and wall is smaller than 2 m, then it shall be measured in the middle of this distance.

The storage water temperature shall be measured at the place, which is intended by the manufacturer for it (e.g. thermostat pocket). If there is no such place, the temperature should be measured in the upper third of the storage tank.

The medium storage temperature shall be the nominal storage temperature ϑ_{sn} ± 5 K, at least 65 °C.

The medium storage excess temperature shall be the nominal storage excess temperature ϑ_{xn} ± 3 K, at least $\Delta\vartheta_x$ = 45 K.

The controller switching difference shall be lower than 0,8 K.

The standby loss corresponds to the electrical energy consumption in the steady state condition.

5.4.2 Preparation

The storage tank shall be separated during the test from any external connection. During the entire test, the storage tank shall be completely filled with water.

All water containing connections shall be insulated with an insulation material with a thermal conductivity of 0,030 W/(m K) < λ < 0,035 W/(m K). All pipework shall be insulated with an insulation of 30 mm, excepting connections not for water driving purpose (e.g. thermostat pocket).

There shall be free space of at least 70 cm around the storage tank, and at least 100 cm above the storage tank.

Wall hung storage tanks shall be mounted on a separate wall which is at least 15 cm from the room wall with the delivered mounting kit. The free space below the storage tank shall be at least 25 cm.

5.4.3 Execution of the measurement

The test remains up for at least 24 h after reaching the steady state condition and begins and ends with a switch of the temperature controller.

The consumption of electrical energy E_1 within this time t_1 shall be measured, see Figure 4.

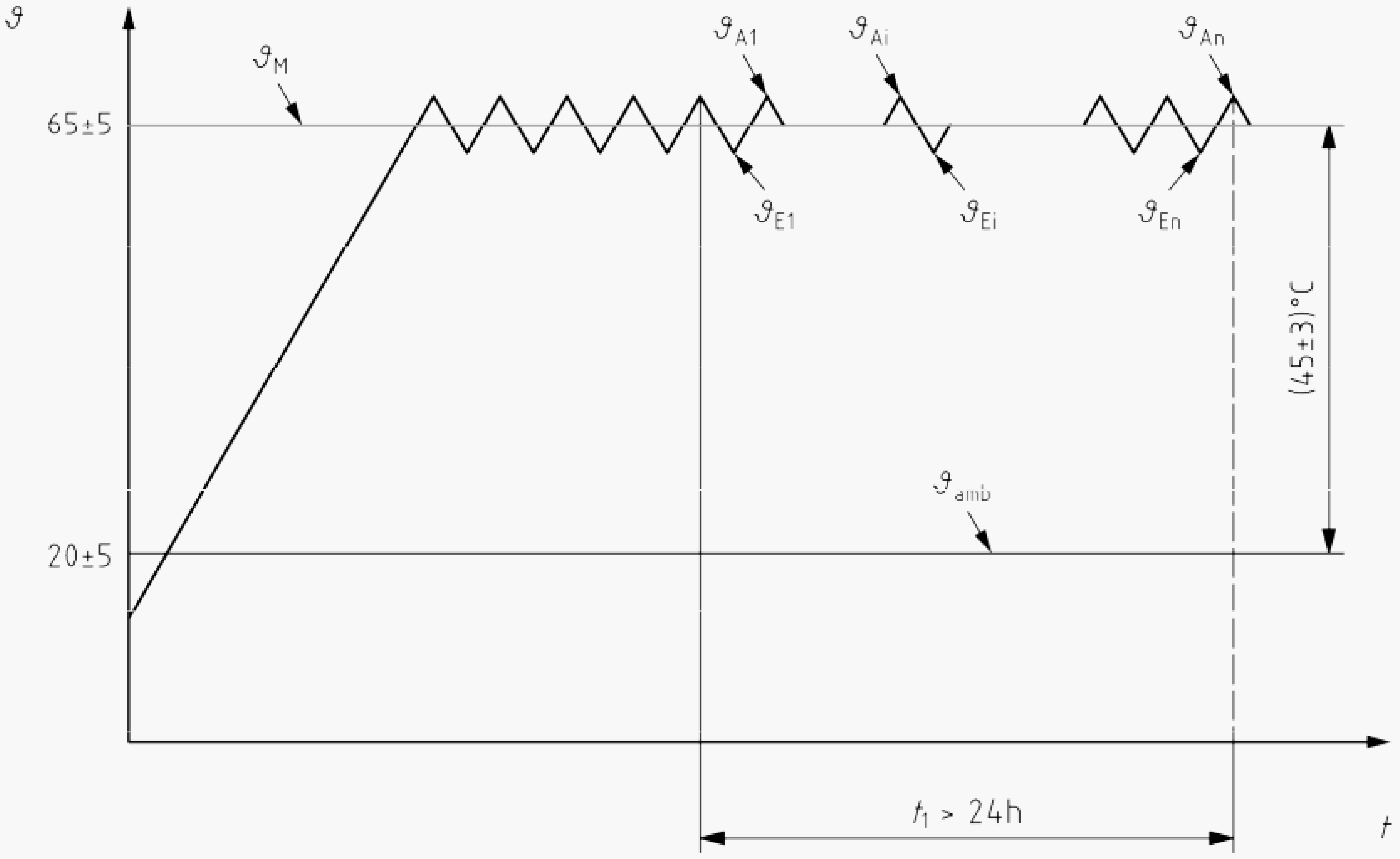


Figure 4 — Measurement of consumption of electrical energy

5.4.4 Evaluation

The energy consumption within 24 h shall be calculated according to Equation (7):

$$E = \frac{E_1 \cdot 24}{t_1} \tag{7}$$

The medium storage temperature shall be calculated according to Equation (8):

$$\vartheta_M = \frac{\vartheta_A + \vartheta_E}{2} \tag{8}$$

with

$$\vartheta_A = \frac{\sum_{i=1}^{n} \vartheta_{Ai}}{n} \text{ and } \vartheta_E = \frac{\sum_{i=1}^{n} \vartheta_{Ei}}{n}$$

The heat loss within 24 h shall be calculated according to Equation (9):

$$Q_B = \frac{\min(45K; \vartheta_{xn})}{\vartheta_M - \vartheta_{amb}} \cdot E \tag{9}$$

6 Requirements on the test rig

6.1 Environment

Ambient temperature should be between 15 ºC and 28 ºC. Air speed in the area shall not exceed 0,25 m/s.

The relative humidity shall be lower than 85 %.

The water heater shall be protected from radiation from the environment.

The cold water temperature ϑ_c shall not vary more than ± 1 K during the test, and has to be below 18 ºC and higher than 8ºC.

6.2 Measuring accuracy

6.2.1 Temperature

Temperatures shall be measured with a minimum accuracy of ± 0,1 K. It shall be guaranteed by appropriate installation of the temperature probes that on the measuring points the medium caloric temperature of the water is measured. The time constant for the temperature measurement shall not be larger than 5 s.

6.2.2 Mass and volume flow

The mass and volume flow of the water shall be measured with minimum accuracy of 1 %.

6.2.3 Time

The time shall be measured with a minimum accuracy of ± 1 s.

6.2.4 Electrical energy

Electrical energy shall be measured with a minimum accuracy of 1 %, at least ± 10 Wh.

6.2.5 Measurement cycle time

The cycle time for the measurement after 5.3 shall not be larger than 10 s.

For all other measurements according to Clause 4 the cycle time should not be larger than 60 s.

6.2.6 Volume

The actual storage capacity of the storage tank shall be measured with a minimum accuracy of 1 %.