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Thermal solar systems and components - Custom built systems - Part 3: Performance test methods for solar water heater stores

Thermische Solaranlagen und ihre Bauteile - Kundenspezifisch gefertigte Anlagen - Teil 3: Leistungsprüfung von Warmwasserspeichern für Solaranlagen

Installations solaires thermiques et leurs composants - Installations assemblées à façon - Partie 3 : Caractérisation des performances des dispositifs de stockage pour des installations de chauffage solaires

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Thermal solar systems and components - Custom built systems - Part 3: Performance test methods for solar water heater stores

Installations solaires thermiques et leurs composants - Installations assemblées à façon - Partie 3: Méthodes d'essai des performances des dispositifs de stockage des installations de chauffage solaire de l'eau

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Foreword

This document (EN 12977-3:2012) has been prepared by Technical Committee CEN/TC 312 “Thermal solar systems and components”, the secretariat of which is held by ELOT.

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of an identical text or by endorsement, at the latest by October 2012, and conflicting national standards shall be withdrawn at the latest by October 2012.

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Introduction

The test methods for stores of solar heating systems as described in this European Standard are required for the determination of the thermal performance of small custom built systems as specified in EN 12977-1.

The test method described in this European Standard delivers a complete set of parameters, which are needed for the simulation of the thermal behaviour of a store being part of a small custom built thermal solar system.

For the determination of store parameters such as the thermal capacity and the heat loss rate, the method standardised in EN 12897 can be used as an alternative.

NOTE 1 The already existing test methods for stores of conventional heating systems are not sufficient with regard to thermal solar systems. This is due to the fact that the performance of thermal solar systems depends much more on the thermal behaviour of the store (e.g. stratification, heat losses), than conventional systems do. Hence, this separate document for the performance characterisation of stores for solar heating systems is needed.

NOTE 2 For additional information about the test methods for the performance characterisation of stores, see [1] in Bibliography.

1 Scope

This European Standard specifies test methods for the performance characterization of stores which are intended for use in small custom built systems as specified in EN 12977-1.

Stores tested according to this document are commonly used in solar hot water systems. However, the thermal performance of all other thermal stores with water as a storage medium can also be assessed according to the test methods specified in this document.

The document applies to stores with a nominal volume between 50 l and 3 000 l.

This document does not apply to combistores. Performance test methods for solar combistores are specified in EN 12977-4.

2 Normative references

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

EN 12828, *Heating systems in buildings — Design for water-based heating systems*

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

EN ISO 9488:1999, *Solar energy — Vocabulary (ISO 9488:1999)*

ISO 9459-5, *Solar heating — Domestic water heating systems — Part 5: System performance characterization by means of whole-system tests and computer simulation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 9488:1999 and the following apply.

3.1
ambient temperature
mean value of the temperature of the air surrounding the store

3.2
charge
process of transferring energy into the store by means of a heat source

3.3
charge connection
pipe connection used for charging the storage device

3.4
combistore
one store used for both domestic hot water preparation and space heating

3.5
conditioning

process of creating a uniform temperature inside the store by discharging the store with $\tilde{\vartheta}_{D,i}$ = 20 °C until a steady state is reached

Note 1 to entry: The conditioning at the beginning of a test sequence is intended to provide a well-defined initial system state, i.e. e. a uniform temperature in the entire store.

3.6
constant charge power, $\tilde{P}_{c}$

charge power which is achieved when the mean value $\tilde{P}_{c}$ over the period of 0,5 reduced charge volumes is within $\tilde{P}_{c}$ ± $\tilde{P}_{c}$ × 0,1

Note 1 to entry: The symbol "~" above a certain value indicates that the corresponding value is a mean value.

3.7
constant inlet temperature, $\tilde{\vartheta}_{x,i}$

temperature which is achieved during charge ($x = C$) or discharge ($x = D$), if the mean value $\tilde{\vartheta}_{x,i}$ over the period of 0,5 "reduced charge/discharge volume" (see 3.34) is within ($\tilde{\vartheta}_{x,i}$ ± 1) °C

Note 1 to entry: The symbol "~" above a certain value indicates that the corresponding value is a mean value.

3.8
constant flow rate, $\tilde{\dot{V}}$

flow rate which is achieved when the mean value of $\tilde{\dot{V}}$ over the period of 0,5 "reduced charge/discharge volumes" (see 3.34) is within $\tilde{\dot{V}}$ ± $\tilde{\dot{V}}$ × 0,1

Note 1 to entry: The symbol "~" above a certain value indicates that the corresponding value is a mean value.

3.9
dead volume/dead capacity
volume/capacity of the store which is only heated due to heat conduction (e.g. below a heat exchanger)

3.10
direct charge/discharge
transfer or removal of thermal energy in or out of the store, by directly exchanging the fluid in the store

3.11
discharge
process of decreasing thermal energy inside the store caused by the hot water load

3.12
discharge connection
pipe connection used for discharging the storage device

3.13
double port
corresponding pair of inlet and outlet connections for direct charge/discharge of the store

Note 1 to entry: Often, the store is charged or discharged via closed or open loops that are connected to the store through double ports.

3.14
effective volume/effective capacity
volume/capacity which is involved in the heat storing process if the store is operated in a usual way

3.15
electrical (auxiliary) heating
electrical heating element immersed into the store

3.16
external auxiliary heating
auxiliary heating device located outside the store. The heat is transferred to the store by direct or indirect charging via a charge loop. The external auxiliary heating is not considered as part of the store under test

3.17
heat loss capacity rate, $(UA)_{s,a}$
overall heat loss of the entire storage device per K of the temperature difference between the medium store temperature and the ambient air temperature

Note 1 to entry: The heat loss capacity rate depends on the flow conditions inside the store. Hence, a stand-by heat loss capacity rate and an operating heat loss capacity rate are defined. If $(UA)_{s,a}$ is mentioned without specification, $(UA)_{s,a}$ represents the stand-by heat loss capacity rate.

3.18
heat transfer capacity rate
thermal power transferred per K of the temperature difference

3.19
immersed heat exchanger
heat exchanger which is completely surrounded with the fluid in the store tank

3.20
indirect charge/discharge
transfer or removal of thermal energy into or out of the store, via a heat exchanger

3.21
load
heat output of the store during discharge. The load is defined as the product of the mass, specific thermal capacity and temperature increase of the water as it passes the solar hot water system.

3.22
mantle heat exchanger
heat exchanger mounted to the store in such a way that it forms a layer between the fluid in the store tank and ambient

3.23
measured energy, $Q_{x,m}$
time integral of the measured power over one or more test sequences, excluding time periods used for conditioning at the beginning of the test sequences

3.24
measured power, $P_{x,m}$
power calculated from measured volume flow rate as well as measured inlet and outlet temperatures

3.25
measured store heat capacity
measured difference in energy of the store between two steady states on different temperature levels, divided by the temperature difference between these two steady states

3.26
mixed
state when the local store temperature is not a function of the vertical store height

3.27
model parameter
parameter used for quantification of a physical effect, if this physical effect is implemented in a mathematical model in a way which is not analogous to its appearance in reality, or if several physical effects are lumped in the model (e.g. a stratification number)

3.28
nominal flow rate, $\dot{V}_n$
nominal volume of the entire store divided by 1 h

3.29
nominal heating power, P_n
nominal volume of the entire store multiplied by 10 W/l

3.30
nominal volume, V_n
fluid volume of the store as specified by the manufacturer

3.31
operating heat loss capacity rate, $(UA)_{op,s,a}$
heat loss capacity rate of the store during charge or discharge

3.32
predicted energy, Q_{xp}
time integral of the predicted power over one or more test sequences, excluding time periods used for conditioning at the beginning of the test sequences

3.33
predicted power, P_{xp}
power calculated from measured volume flow rate, as well as measured inlet temperature and calculated outlet temperature

Note 1 to entry: The outlet temperature is predicted by numerical simulation.

3.34
reduced charge/discharge volume
integral of a charge/discharge flow rate divided by the store volume

3.35
stand-by
state of operation in which no energy is deliberately transferred to or removed from the store

3.36
stand-by heat loss capacity rate, $(UA)_{sb,s,a}$
heat loss capacity rate of the store during stand-by

3.37
steady state
state of operation at which at charge or discharge during 0,5 “reduced charge/discharge volume” (see 3.34) the standard deviation of the temperature difference between store inlet and store outlet temperatures of the charging/discharging circuit is lower than 0,1 K

Note 1 to entry: In cases of an isothermal charged store, constant temperature differences between the inlet and outlet temperatures of the discharge circuit may occur during the discharge of the first store volume before the outlet temperature drops rapidly. This state is not considered as steady state.

3.38
store temperature
temperature of the store medium

3.39
stratified
state when thermal stratification is present inside the store

3.40
stratified charging
increase of thermal stratification in the store during charging

3.41
stratifier
device that enables stratified charging of the store. Commonly used stratifiers are e.g. convection chimneys or pipes with radial holes

3.42
theoretical store heat capacity
sum over all thermal capacities $m_i \times c_{p,i}$ of the entire store (fluid, tank material, heat exchangers) having part of the heat store process

3.43
thermal stratification
state when the local store temperature is a function of the vertical store height, with the temperature decreasing from top to bottom

3.44
transfer time, $t_{x,f}$
time period during which energy is transferred through the connections for charge ($x = C$) or discharge ($x = D$). The transfer time is calculated over one or more test sequences, excluding time periods used for conditioning at the beginning of the test sequences

4 Symbols and abbreviations

C_s	thermal capacity of the entire store, in J/K
c_p	specific heat capacity, in J/(kg K)
P_n	nominal heating power, in W
$P_{x,m}$	measured power transferred through the charge ($x = C$) or discharge ($x = D$) circuit, in W
$P_{x,p}$	predicted power transferred through the charge ($x = C$) or discharge ($x = D$) circuit, in W
$Q_{x,m}$	measured energy transferred through the charge ($x = C$) or discharge ($x = D$) circuit, in J
$Q_{x,p}$	predicted energy transferred through the charge ($x = C$) or discharge ($x = D$) circuit, in J
t_{st}	time required to achieve a steady state, in s
$t_{x,f}$	transfer time for charging ($x = C$) or discharging ($x = D$), in s

$(UA)_{hx,s}$ heat transfer capacity rate between heat exchanger and store, in W/K

$(UA)_{op,s,a}$ operating heat loss capacity rate of the store, in W/K

$(UA)_{s,a}$ heat loss capacity rate of the store, in W/K

$(UA)_{sb,s,a}$ stand-by heat loss capacity rate of the store, in W/K

V_n nominal volume of the store, in l

$\dot{V}_n$ nominal flow rate, in l/h

$\tilde{\dot{V}}_x$ constant flow rate of the charge ($x = C$) or discharge ($x = D$) circuit, in l/h

$\Delta\vartheta_m$ mean logarithmic temperature difference, in K

ϑ_a ambient temperature, in °C

ϑ_s store temperature, in °C

$\vartheta_{x,i}$ inlet temperature of the charge ($x = C$) or discharge ($x = D$) circuit, in °C

$\tilde{\vartheta}_{x,i}$ constant inlet temperature of the charge ($x = C$) or discharge ($x = D$) circuit, in °C

$\vartheta_{x,o}$ outlet temperature of the charge ($x = C$) or discharge ($x = D$) circuit, in °C

$\varepsilon_{x,P}$ relative error in mean power transferred during charge ($x = C$) or discharge ($x = D$), in %

$\varepsilon_{x,Q}$ relative error in energy transferred during charge ($x = C$) or discharge ($x = D$), in %

ρ density, in kg/m³

5 Store classification

Hot water stores are classified by distinction between different charge and discharge modes. Five groups are defined as shown in Table 1.

Table 1 — Classification of the stores

Group	Charge mode	Discharge mode
1	direct	direct
2	indirect	direct
3	direct	indirect
4	indirect	indirect
5	stores that cannot be assigned to groups 1 to 4	

NOTE All stores may have one or more additional electrical heating elements.

6 Laboratory store testing

6.1 Requirements on the testing stand

6.1.1 General

The hot water store shall be tested separately from the whole solar system on a store-testing stand.

The testing stand configuration shall be determined by the classification of hot water stores as described in Clause 5.

An example of a representative hydraulic testing stand configuration is shown in Figure 1 and Figure 2.

The circuits are intended to simulate the charge and discharge loop of the solar system and to provide fluid flow with a constant or well-controlled temperature. The full test stand consists of one charge and one discharge circuit.

NOTE 1 If the store consists of more than one charge or discharge devices (e.g. two heat exchangers), then these are tested separately.

The testing stand shall be located in an air-conditioned room where the room temperature of 20 °C should not vary more than ± 2 K during the test.

Both circuits shall fulfil the following requirements:

— the flow rate shall be adjustable and stable within ± 5 %;

— the working temperature range shall be between 10 °C and 90 °C;

NOTE 2 A typical heating power of the charge circuit is in the range of 15 kW.

— the minimum cooling power in the discharge circuit shall be at least 25 kW at a fluid temperature of 20 °C;

NOTE 3 A typical heating power of the discharge circuit is in the range of 25 kW.

NOTE 4 If mains water at a constant pressure and a constant temperature below 20 °C is available, it is recommended to design the discharge circuit in a way, that it can be operated as closed loop or as open loop using mains water to discharge the store.

— the minimum heating up rate of the charge circuit with disconnected store shall be 3 K/min;

— the minimum available electrical heating power for electrical auxiliary heaters shall be 6,0 kW.

NOTE 5 The electrical power of the pump (P101) should be chosen in such a way that the temperature increase induced by the pump (P101) is either less than 0,6 K/h when the charge circuit is "short-circuited" and operated at room temperature (“short-circuited” means that no storage device is connected and SV102, V113, V115 and V116 are closed, see Figure 1) or an additional cooling device should be integrated in the circuit.