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Toplotni sončni sistemi in sestavni deli - Neserijsko izdelani sistemi - 3. del: Preskusne metode delovanja hranilnikov toplote, ogrevanih s soncem

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 : Méthodes d'essai des performances des dispositifs de stockage des installations de chauffage solaire de l'eau

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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

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

This European Standard was approved by CEN on 29 October 2017.

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European foreword

This document (EN 12977-3:2018) 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of an identical text or by endorsement, at the latest by October 2018, and conflicting national standards shall be withdrawn at the latest by October 2018.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 12977-3:2012.

This document has been prepared under the Mandate M/534 "Standardisation request to the European standardisation organisations pursuant to Article 10(1) of Regulation (EU) No 1025/2012 of the European Parliament and of the Council in support of implementation of Commission Regulation (EU) No 814/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water heaters and hot water storage tanks and Commission Delegated Regulation (EU) No 812/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of water heaters, hot water storage tanks and packages of water heater and solar device" which was given to CEN by the European Commission and the European Free Trade Association.

For relationship with EU Directive(s), see informative Annex ZA, ZB and ZC, which are integral parts of this document.

EN 12977 is currently composed with the following parts:

— *Thermal solar systems and components — Custom built systems — Part 1: General requirements for solar water heaters and combisystems*;

— *Thermal solar systems and components — Custom built systems — Part 2: Test methods for solar water heaters and combisystems*;

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

— *Thermal solar systems and components — Custom built systems — Part 4: Performance test methods for solar combistores*;

— *Thermal solar systems and components — Custom built systems — Part 5: Performance test methods for control equipment*.

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

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 12977-1:2018.

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 solar heating system.

For the determination of store parameters such as the thermal capacity and the heat loss rate, the method standardized 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 solar heating systems. This is due to the fact that the performance of solar heating 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 characterization of stores for solar heating systems is needed.

NOTE 2 For additional information about the test methods for the performance characterization 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 12977-1:2018.

Stores tested according to this document are commonly used in solar heating 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 12977-4:2018.

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. 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 (see 3.33) is within $\tilde{P}_c \pm \tilde{P}_c \times 0{,}1$

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 3.33) 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 3.33) is within $\tilde{\dot{V}} \pm \tilde{\dot{V}} \times 0{,}1$

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 circuits 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 circuit. 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 store during stand-by per K of the temperature difference between the medium store temperature and the ambient air temperature

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

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 heating 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 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; determined as described in formula (F.2)

3.31
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

3.32
predicted power
$\boldsymbol{P}_{\mathbf{xp}}$
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.

3.33
reduced charge/discharge volume
integral of a charge/discharge flow rate divided by the store volume

3.34
stand-by
state of operation in which no energy is deliberately transferred to or removed from the store

3.35
stand-by heat loss capacity rate
$\mathbf{(}\boldsymbol{UA}\mathbf{)}_{\mathbf{sb,s,a}}$
heat loss capacity rate of the store during stand-by

3.36
steady state
state of operation at which at charge or discharge during 0,5 "reduced charge/discharge volume" (see 3.33) 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.

3.37
store temperature
temperature of the store medium

3.38
stratified
state when thermal stratification is present inside the store

3.39
stratified charging
increase of thermal stratification in the store during charging

3.40
stratifier
device that enables stratified charging of the store. Commonly used stratifiers are e.g. convection chimneys or pipes with radial holes

3.41
theoretical store heat capacity
sum over all thermal capacities $m_{\mathrm{i}} \times c_{\mathrm{p,i}}$ of the entire store (fluid, store material, heat exchangers) having part of the heat store process

3.42
thermal stratification
state when the local store temperature is a function of the vertical store height, with the temperature decreasing from top to bottom

3.43
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

For the purposes of this document, the following symbols and abbreviations apply.

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
$(UA)_{s,a}$	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/m^3

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 can have one or more additional electrical auxiliary 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 circuit 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;

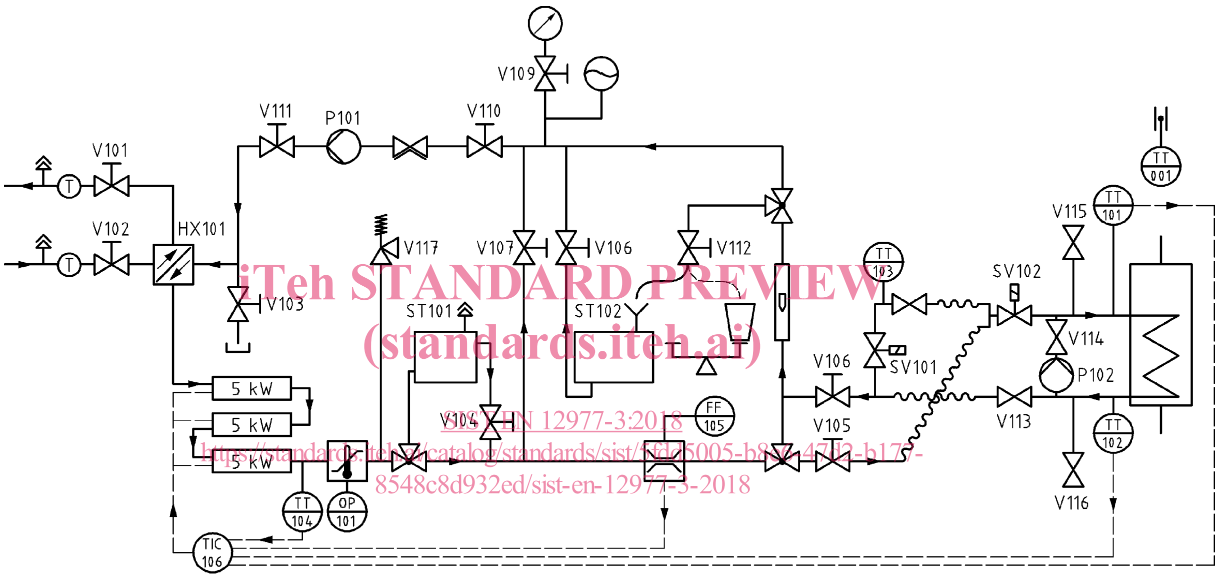
NOTE 3 A typical heating power of the discharge circuit is in the range of 25 kW.

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.

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.



Key

FF flow meter

HX heat exchanger

OP overheating protection

P pump

ST store (belonging to test facility)

SV solenoid valve

TT temperature sensor

TIC temperature indicator and controller

V valve

Figure 1 — Charge circuit of the store-testing stand

The heating medium water in the charge circuit (see Figure 1) is pumped through the cooler (HX101) and the temperature controlled heaters (TIC106) by the pump (P101). A buffer tank (ST101) is used to balance the remaining control deviations. By means of the bypass (V107) the flow through the store can be controlled, it also ensures a continuously high flow through the heating section and therefore good control characteristics. With the solenoid valve (SV101), the heating medium can bypass the store to prepare a sudden increase of the inlet temperature into the store.

The temperature sensors are placed near the inlet (TT101) and outlet (TT102) connections of the store; the connection to the store is established through insulated flexible pipes.

The charge circuit can be operated closed, under pressure (design pressure 2,5 bar, membrane pressure expansion tank and pressure relief valve (V109)) as well as open (valve (V108) open) with the store