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Thermal solar systems and components — Custom built systems

Part 4: Performance test methods for solar combistores

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National foreword

This British Standard is the UK implementation of EN 12977-4:2012. It supersedes DD CEN/TS 12977-4:2010 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RHE/25, Solar Heating.

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Foreword

This document (EN 12977-4:2012) has been prepared by Technical Committee CEN/TC 312 “Thermal sorla 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of an identical text or by endorsement, at the latest by October 2012, and conflicting national standards shall be withdrawn at the latest by October 2012.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 document are required for the determination of the thermal performance of small custom built systems for combined domestic hot water preparation and space heating, so-called solar combisystems, as specified in EN 12977-1.

These test methods deliver parameters, which are needed for the simulation of the thermal behaviour of a store being part of a small custom built system.

NOTE 1 With the test methods for stores given in EN 12897 only a few parameters are determined in order to characterise the thermal behaviour of a store. These few parameters are not sufficient for the determination of the thermal performance of small custom built systems as described in EN 12977-2.

NOTE 2 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), as conventional systems do. Hence, this separate document for the performance characterisation of stores for solar heating systems is needed.

NOTE 3 For additional information about the test methods for the performance characterisation of stores see EN 12977-3 and [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 combisystems. However, the thermal performance of all other thermal stores with water as a storage medium (e.g. for heat pump systems) can be also assessed according to the test methods specified in this document.

This document applies to combistores with a nominal volume up to 3 000 l and without integrated burner.

NOTE This document is extensively based on references to EN 12977-3:2012.

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 12977-3:2012, *Thermal solar systems and components — Custom built systems — Part 3: Performance test methods for solar water heater stores*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12977-3:2012 and EN ISO 9488:1999 apply.

4 Symbols and abbreviations

For symbols and abbreviations, refer to EN 12977-3:2012.

5 Store classification

Solar combistores are classified by distinction between different charge and discharge modes. Five groups are defined as shown in Table 1.

Table 1 — Classification of combistores

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

NOTE 2 Stores that can be charged or discharged directly and indirectly (e.g. a store of a space heating system with an internal heat exchanger for the preparation of domestic hot water) can belong to more than one group. In this case, the appropriate test procedures or the assignment to one of the groups respectively, should be chosen depending on its mode of operation.

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 the combistores as described in Clause 5.

An example of a representative hydraulic testing stand configuration is shown in EN 12977-3:2012, Figure 1 and Figure 2. An appropriate test facility consists of two charge loops as shown in EN 12977-3:2012, Figure 1 and two discharge loops as shown in EN 12977-3:2012, Figure 2.

6.1.2 Measuring data and measuring procedure

The requirements specified in EN 12977-3:2012, 6.1.2 shall be fulfilled.

6.2 Installation of the store

6.2.1 Mounting

The store shall be mounted on the testing stand according to the manufacturer's instructions.

The temperature sensors used for measuring the inlet and outlet temperatures of the fluid used for charging and discharging the storage device, shall be placed as near as possible at least 200 mm to the inlet and outlet connections of the storage device. The installation of the temperature sensors inside the pipes shall be done according to approved methods of measuring temperatures.

If there is/are more than one pair of charging and/or discharging inlet or outlet connections, then only one may be connected to the testing stand (at the same time) while the other(s) shall be closed.

The pipes between the store and the temperature sensors shall be insulated according to EN 12828.

6.2.2 Connection

The way of connecting the storage device to the testing stand depends on the purpose of the thermal tests which shall be performed. Detailed instructions are given in the clauses where the thermal tests are described.

Connections of the store which do not lead to the charge or discharge circuit of the testing stand shall be closed, and not connected heat exchangers shall be filled up with water. All closed connections shall be insulated in the same way as the store.

Since fluid in closed heat exchangers expands with increasing temperature, a pressure relief valve shall be mounted.

NOTE The performance of a solar heating system depends on the individual installation and actual boundary conditions. With regard to the heat losses of the store besides deficits in the thermal insulation, badly designed connections can increase the heat loss capacity rate of the store due to natural convection that occurs internally in the pipe. In order to avoid this effect, the connections of the pipes should be designed in such a way that no natural convection inside the pipe occurs. This can be achieved if the pipe is directly going downwards after leaving the store or by using a heat trap siphon.

6.3 Test and evaluation procedures

6.3.1 General

The aim of store testing as specified in this document is to determine parameters required for the detailed description of the thermal behaviour of a hot water combistore. Therefore, a mathematical computer model for the store is necessary. The basic requirements on suitable models are specified in Annex A and Annex B.

The following parameters shall be known for the simulation of a store being part of a solar system.

a) Stored water:

   1) height;

   2) effective volume respectively effective thermal capacity;

   3) heights of the inlet and outlet connections;

   4) heat loss capacity rate of the entire store;

   5) if the insulation varies for different heights of the store, the distribution of the heat loss capacity rate should be determined for the different parts of the store;

   6) a parameter describing the degradation of thermal stratification during stand-by;

NOTE 1 One possible way to describe this effect in a store model is the use of a vertical thermal conduction. In this case, the corresponding parameter is an effective vertical thermal conductivity.

   7) a parameter describing the characteristic of thermal stratification during direct discharge;

NOTE 2 An additional parameter may be used to describe the influence of different draw-off flow rates on the thermal stratification inside the store, if this effect is relevant.

   8) positions of the temperature sensors (e.g. the sensors of the collector loop and auxiliary heater control).

b) Heat exchangers:

   1) heights of the inlet and outlet connections;

   2) volume;

   3) heat transfer capacity rate as a function of temperature;

   4) information on the capacity in respect of stratified charging;

NOTE 3 The capacity in respect of stratified charging can be determined from the design of the heat exchanger as well as from the course in time of the heat exchanger inlet and outlet temperatures.

   5) heat loss rate from the heat exchanger to the ambient (necessary only for mantled heat exchangers and external heat exchangers).

c) Electrical auxiliary heat source:

   1) position in the store;

   2) axis direction of heating element (horizontal or vertical). If the auxiliary heater is installed in a vertical way, also its length is required;

   3) effectivity that characterises the fraction of the thermal converted electric power which is actually transferred inside the store.

NOTE 4 Badly designed electrical auxiliary heaters may cause significant heat losses during operation. In this case, the electrical power supplied to the heater is not equal to the thermal energy input to the store.

The following clauses describe how the listed parameters can be determined. Therefore, specific test sequences are necessary. The test sequences indicated by letters (e.g. test CD) can be subdivided into phases indicated by a number (e.g. CD1 – conditioning). Between the end of one phase and the start of the following phase, a maximum stand-by time of 10 min is allowed. During this stand-by time, the ambient temperature only shall be measured and recorded.

NOTE 5 One essential point of the methods described is that measurements inside the store are avoided.

NOTE 6 The determination of all above listed store parameters is possible only according to the method described in 6.3.2 and the data processing of the test sequences described in 6.3.3. For further details and test sequences, see EN 12977-3.

6.3.2 Test sequences

6.3.2.1 Introduction

The store is tested on the test stand by different specific test sequences. The sequences are specified to stimulate the physical effects, which correspond to the parameter to be determined. A parameter identification program using a store model evaluates the measuring data.

Charging and discharging the entire store implies connections of the charge/discharge circuits to the uppermost and lowermost direct ports available at the tank. Full discharging is required for conditioning of the store and for the final discharge phase. Full charging is required for all discharge tests, which require that the entire store is charged.

The series of the performed tests should comprise two tests, which include stand-by periods. One test is for the entire store, to determine the heat loss capacity rate. The other test concerns only the part of the store, which is heated up (usually the auxiliary heated part). This test is used to determine the degradation of thermal stratification during stand-by. The stand-by period should be such that the losses during this period are approximately half of the stored energy. For these two tests with stand-by periods, the same test should also be performed without a stand-by period.

Flow rates and power values are given as examples only. The chosen flow rate or power should be suited to the type of component, which will be used with those connections.

6.3.2.2 General

This clause describes the thermal test sequences for the different groups of combistores. This clause is based on procedures defined in EN 12977-3, only new items are included. In EN 12977-3 mainly the determination of the thermal capacity, heat loss capacity rate of the entire store and the heat transfer capacity rate of immersed heat exchangers is defined.

The thermal test sequences described in this document shall be carried out for all groups of combistores. The storage device shall be connected to the testing stand according to 6.2.

6.3.2.3 General charge direct (Test CD)

Test CD:

- test phase CD1: conditioning until steady-state is reached;
- test phase CD2: charging through test ports until $\vartheta_{C,o}$ = 55 °C;
- test phase CD3: optional stand-by until approximately half stored energy is lost to ambient;
- test phase CD4: direct discharge of the entire store until steady state is reached.

Table 2 — Flow rates and store inlet temperatures for Test CD

Test phase	Process	Charge			Discharge		
		$\tilde{\dot{V}}_C$ l/h	$\tilde{\vartheta}_{C,i}$ °C	$\tilde{\vartheta}_{C,o}$ °C	$\tilde{\dot{V}}_D$ l/h	$\tilde{\vartheta}_{D,i}$ °C	$\tilde{\vartheta}_{D,o}$ °C
CD1	conditioning	0	-	-	$0{,}5 \times \dot{V}_n$	20,0	variable
CD2	charge	$0{,}5 \times \dot{V}_n$	60,0	variable	0	-	-
CD3	stand-by	0	-	-	0	-	-
CD4	discharge	0	-	-	$0{,}5 \times \dot{V}_n$	20,0	variable

If the ports are used with a boiler the operating temperature of which is greater than 60 °C (e.g. a wood boiler), a higher inlet temperature ($\vartheta_{C,i}$) may be used.

6.3.2.4 General charge indirect (Test CI)

Test CI:

- test phase CI1: conditioning until steady-state is reached;
- test phase CI2: charge through test heat exchanger at constant power of $\tilde{P}_C$ = 2,0 × P_n until $\vartheta_{C,o}$ = 60 °C;
- test phase CI3: optional stand-by until approximately half stored energy is lost to ambient;
- test phase CI4: direct discharge of the entire store until steady state is reached.

Table 3 — Flow rates and store inlet temperatures for Test CI

Test phase	Process	Charge			Discharge		
		$\tilde{\dot{V}}_C$ l/h	$\tilde{\vartheta}_{C,i}$ °C	$\tilde{\vartheta}_{C,o}$ °C	$\tilde{\dot{V}}_D$ l/h	$\tilde{\vartheta}_{D,i}$ °C	$\tilde{\vartheta}_{D,o}$ °C
CI1	conditioning	0	-	-	0,5 × $\dot{V}_n$	20,0	variable
CI2	charge	1,2 × $\dot{V}_n$	variable	variable	0	-	-
CI3	stand-by	0	-	-	0	-	-
CI4	discharge	0	-	-	0,5 × $\dot{V}_n$	20,0	variable

If the heat exchanger is used at different flow rates, the test should be performed four times, using, if possible, the following different charging conditions: constant power P_n at high and low flow rates, as well as constant power 0,5 × P_n at low and high flow rates.

6.3.2.5 General discharge direct (Test DD)

Test DD:

- test phase DD1: conditioning until steady-state is reached;
- test phase DD2: charging of the entire store until $\vartheta_{C,o}$ = 55 °C;
- test phase DD3: discharge through test ports until $\vartheta_{D,o}$ = 30 °C;
- test phase DD4: direct discharge of the entire store until-steady state is reached.

Table 4 — Flow rates and store inlet temperatures for Test DD

Test phase	Process	Charge			Discharge		
		$\tilde{\dot{V}}_C$ l/h	$\tilde{\vartheta}_{C,i}$ °C	$\tilde{\vartheta}_{C,o}$ °C	$\tilde{\dot{V}}_D$ l/h	$\tilde{\vartheta}_{D,i}$ °C	$\tilde{\vartheta}_{D,o}$ °C
DD1	conditioning	0	-	-	$0{,}5 \times \dot{V}_n$	20,0	variable
DD2	charge	$0{,}5 \times \dot{V}_n$	60,0	variable	0	-	-
DD3	discharge	0	-	-	$0{,}5 \times \dot{V}_n$	20,0	variable
DD4	discharge	0	-	-	$0{,}5 \times \dot{V}_n$	20,0	variable

6.3.2.6 General discharge indirect (Test DI)

Test DI:

- test phase DI1: conditioning until steady-state is reached;
- test phase DI2: charge of the entire store until $\vartheta_{C,o}$ = 55 °C;
- test phase DI3: discharge through the test heat exchanger until $\vartheta_{D,o}$ = 30 °C;
- test phase DI4: direct discharge of the entire store until steady state is reached.

Table 5 — Flow rates and store inlet temperatures for Test DI

Test phase	Process	Charge			Discharge		
		$\tilde{\dot{V}}_C$ l/h	$\tilde{\vartheta}_{C,i}$ °C	$\tilde{\vartheta}_{C,o}$ °C	$\tilde{\dot{V}}_D$ l/h	$\tilde{\vartheta}_{D,i}$ °C	$\tilde{\vartheta}_{D,o}$ °C
DI1	conditioning	0	-	-	$0{,}5 \times \dot{V}_n$	20,0	variable
DI2	charge	$0{,}5 \times \dot{V}_n$	60,0	variable	0	-	-
DI3	discharge	0	-	-	$0{,}5 \times \dot{V}_n$	20,0	variable
DI4	discharge	0	-	-	$0{,}5 \times \dot{V}_n$	20,0	variable

If the heat exchanger is intended for domestic hot water preparation, this test shall be performed three times under different discharge conditions. To each of these three discharge conditions the following two charge conditions shall apply: store fully charged and auxiliary part charged. In all, six tests shall be performed. The following discharge conditions should apply:

- low flow rate;
- high flow rate.

The test shall be repeatedly performed under following conditions: Intermittent discharge at high flow rate with 10 min discharge and 10 min stand-by. This test does not need to be performed if it can be assumed that the heat transfer capacity rate of the discharge heat exchanger will not be time dependent.

6.3.3 Data processing of the test sequences

6.3.3.1 General

NOTE The data processing of the test sequences is partly based on references to EN 12977-3:2012, only new items are included.

The evaluation of the measured data is based on parameter identification. When all necessary tests as described in 6.3.2 are performed, identification of store parameters shall be carried out using a numerical store model that fulfils the requirements given in Annex A. For information regarding an adequate parameter identification algorithm that fulfils the necessary requirements, see EN 12977-3:2012, Annex C.

The store model shall meet the requirements of the benchmark tests given in Annex A.

For the parameter identification, the measured data can be compressed and/or converted to constant time steps. In both cases, the data records shall represent mean values for the corresponding time step. During charge and discharge, the time steps should not exceed 3 min. During stand-by, a maximum time step of 15 min is allowed.

For the parameter identification ("fit"), the measured values of the inlet store temperatures, ambient temperature, flow rates and the power of the electrical heating source(s) shall be used as inputs. Since at the beginning of each test the store is always conditioned to 20 °C, no skip time is required. Hence the data used for parameter identification ("fitting"), shall start with the second test phase, and ϑ_{s} = 20 °C shall be used as initial temperature for the store model.

6.3.3.2 Determination of all store parameters (except the vertical position of the temperature sensors)

NOTE The determination of all store parameters, except of the vertical position of the temperature sensors, is partly based on references to EN 12977-3:2012, only new items are included.

All parameters, which are determined by parameter identification, shall be identified during one parameter identification process. This requirement is not relevant for the determination of the vertical positions of the temperature sensors.

For every time step during the fit for each connection "x" ($x = C$ for charge and $x = \mathrm{D}$ for discharge), the absolute difference between the transferred measured and predicted power shall be calculated by Formula (1):

$$\Delta P_{\mathrm{x}} = \left| P_{\mathrm{x,p}} - P_{\mathrm{x,m}} \right| \quad (1)$$

where the transferred predicted power, $P_{\mathrm{x,p}}$, and the measured power, $P_{\mathrm{x,m}}$, shall be calculated according to Formulas (2) and (3):

$$P_{\mathrm{x,p}} = \overline{\rho} \times \overline{c}_{\mathrm{p}} \times \dot{V} \times \left(\vartheta_{\mathrm{x,i}} - \vartheta_{\mathrm{x,o,p}} \right) \quad (2)$$

$$P_{\mathrm{x,m}} = \overline{\rho} \times \overline{c}_{\mathrm{p}} \times \dot{V} \times \left(\vartheta_{\mathrm{x,i}} - \vartheta_{\mathrm{x,o,m}} \right) \quad (3)$$

The function $f(t)$, which shall be minimised for the determination of the store parameters (except the vertical positions of the temperature sensors), is the integral of the sum over all absolute power differences calculated by Formula (4):

$$f(t) = \int_t \sum_x \Delta P_\mathrm{x} \, d\,t \tag{4}$$

6.3.3.3 Determination of the vertical position of the temperature sensors

NOTE 1 The determination of the vertical position of the temperature sensors is partly based on references to EN 12977-3:2012, only new items are included.

If all parameters of the store, except the vertical position of the temperature sensors have been determined according to 6.3.3.2, the determination of the vertical positions of the temperature sensors or their location respectively shall be performed as described in this clause. For the description of the thermal behaviour of the store by means of the numerical model, the parameters determined according to 6.3.3.2 shall be used.

For every time step during the fit for each temperature sensor "z" the absolute difference between the measured temperature at the location of the temperature sensor, $\vartheta_\mathrm{z,m}$, and the predicted temperature at the location of the temperature sensor, $\vartheta_\mathrm{z,p}$, shall be calculated by Formula (5):

$$\Delta \vartheta_\mathrm{z} = \left| \vartheta_\mathrm{z,m} - \vartheta_\mathrm{z,p} \right| \tag{5}$$

The function $f(t)$, which shall be minimised for the determination of the vertical positions of the temperature sensors, is the integral over all absolute temperature difference for the temperature sensor "z" as shown in Formula (6):

$$f(t) = \int_t \Delta \vartheta_\mathrm{z} d\,t \tag{6}$$

The determination of the vertical positions of the temperature sensors has to be performed separately for each temperature sensor "z" or vertical position respectively.

NOTE 2 The exact vertical positions of the temperature sensors as well as the upper connections of the heat exchangers above which the store is charged mixedly, have a minor influence on the thermal behaviour of the store. Hence, these vertical positions need not be determined by means of parameter identification. It is recommended to measure the corresponding positions or to determine them from the drawing of the store.

7 Test report

7.1 General

In accordance with EN 12977-3, the test report shall include:

a) a detailed description and the technical data of the tested store (based on the manufacturer's instruction);

b) the determined parameters and a description of them;

c) reference to the used store model (parameters for simulation).

7.2 Description of the store

In accordance with EN 12977-3, the description of the store shall be based on the information provided by the manufacturer. It shall include the following.

a) General data:

1) manufacturer;

2) type;

3) year of construction;

4) serial number;

5) nominal volume;

6) description and drawing of the schematic design.

b) Stored water:

1) volume;

2) material and corrosion protection (only for material in contact with drinking water);

3) maximum operation pressure;

4) maximum operation temperature;

5) thermal insulation;

6) diameter and type of connections.

c) Electrical heating source(s):

1) nominal voltage;

2) nominal heating power;

3) diameter and type of connection.

d) Heat exchanger(s):

1) volume;

2) material and corrosion protection (only for material in contact with drinking water);

3) type of pipes (with/without ribs, coil, etc.);

4) size of the area for heat transfer;

5) position inside the store;

6) maximum operation pressure;

7) maximum operation temperature;

8) diameter and type of connections.

7.3 Test results

The test results shall be presented and documented in accordance to the specifications given in EN 12977-3.

NOTE 1 Some of the parameters used for the characterisation of the thermal behaviour of the store are related to the used store model. Therefore, information on these parameters and the store model should be provided.

a) Geometrical data:

1) weight of the complete storage device (empty);

2) maximum height of the complete storage device;

3) maximum diameter of the complete storage device.

b) Volumes:

1) volume of the stored water;

2) volume of the heat exchanger(s).

c) Thermal parameters:

1) thermal capacity of the entire store;

2) thermal capacity of appropriate parts of the store (e.g. auxiliary heated part);

3) stand-by heat loss capacity rate (optional: operating heat loss capacity rate);

4) parameter describing the degradation of thermal stratification during stand-by;

5) parameter describing the quality of thermal stratification during direct discharge;

6) heat transfer capacity rate $(UA)_{hx,s}$ of the heat exchanger(s). The test conditions (fluid, temperatures, flow rate, transferred heating power) for the determination of the heat transfer capacity rate shall be mentioned in the test report.

d) Temperature sensors:

1) vertical positions of the temperature sensors.

NOTE 2 If a diagram of $(UA)_{hx,s}$ over the temperature is included in the test report, the transferred heating power at each point of the diagram should be indicated, if the transferred heating power varies for the different points of the plotted $(UA)_{hx,s}$ values.

In addition, the draw-off profiles for two different draw-off flow rates (e.g. from Test C and Test S, see EN 12977-3:2012) and the two draw-off profiles used for the determination of the parameter describing the degradation of thermal stratification during stand-by (e.g. from Test NiA and Test NiB or from Test EiA and Test EiB, see EN 12977-3:2012), should be included.

7.4 Parameters for the simulation

All parameters which are necessary to describe the thermal behaviour of the store in combination with a suitable numerical calculation model shall be recorded. In addition to the parameters listed in 7.3, the following parameters are required:

a) data of the fluid (e.g. constant values for the density and the specific heat capacity);

b) position of the

   1) inlet and outlet connection(s) for direct charge and discharge;

   2) inlet and outlet connection(s) of the heat exchangers;

c) information on the ability for stratified charging/discharging.

Annex A
(normative)

Store model benchmark tests

See EN 12977-3:2012, Annex A.

Annex B
(normative)

Verification of store test results

NOTE A verification procedure might be included at a later stage.

Annex C
(normative)

Benchmarks for the parameter identification

See EN 12977-3:2012, Annex C.

Annex D
(informative)

Requirements for the numerical store model

See EN 12977-3:2012, Annex D.

Annex E
(informative)

Determination of hot water comfort

NOTE 1 The following notes are taken from EN 12977-3:2012, Annex F.

NOTE 2 In CEN/TC 57/WG 8 "Energy efficiency requirements for warm water storage tanks", a procedure for the determination of hot water comfort provided by stores was developed, available as EN 15332. This procedure seems to be appropriate to be used here. In addition to this procedure, the parameters for auxiliary heating of the store will be specified in detail. Furthermore, the influence of the solar contribution on the hot water comfort could be considered.

NOTE 3 The test procedure will be used for determination of size class according to the Mandate M/324.

Bibliography

[1] H. Drück, E. Hahne: *Thermal Testing of Stores for Solar Domestic Hot Water Systems*, Final report from IEA Task XIV, Dynamic Component and System Testing Group - IEA Report no. T.14.DCST.1A

[2] H. Visser, H. A. L. Van Dijk: *Test Procedures for Short Term Thermal Stores*, Kluwer Academic Publishers, Dordreckt, Boston, London, 1991, ISBN 0-7923-1131-0

[3] *IEA Solar Heating and Cooling Program, Task III: Performance Testing of Solar Collectors*, Reference and Calibration Heaters, Swedish Council for Building Research, ISBN 91-540-4501-0, January 1986

[4] W. Spirkl: *Dynamic SDHW System Testing*, Program Manual, Version 2.4, InSitu Scientifc Software, Klein & Partners, Baaderstr. 80, 80469 München, 1994

[5] EN 307, *Heat exchangers — Guidelines to prepare installation, operating and maintenance instructions required to maintain the performance of each type of heat exchangers*

[6] EN 12976-2, *Thermal solar systems and components — Factory made systems — Part 2: Test methods*

[7] EN 12977-1, *Thermal solar systems and components — Custom built systems — Part 1: General requirements for solar water heaters and combisystems*

[8] EN 12977-2, *Thermal solar systems and components — Custom built systems — Part 2: Test methods for solar water heaters and combisystems*

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

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