BS EN 12977-2:2012

BSI Standards Publication

Thermal solar systems and components — Custom built systems

Part 2: Test methods for solar water heaters and combisystems

bsi.

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 12977-2:2012. It supersedes DD CEN/TS 12977-2:2010 which is withdrawn.

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

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 75647 4

ICS 27.160; 97.100.99

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2012.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 12977-2

April 2012

ICS 27.160

Supersedes CEN/TS 12977-2:2010

English Version

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

Installations solaires thermiques et leurs composants - Installations assemblées à façon - Partie 2: Méthodes d'essai pour chauffe-eau solaires et installations solaires combinées

Thermische Solaranlagen und ihre Bauteile - Kundenspezifisch gefertigte Anlagen - Teil 2: Prüfverfahren für solar betriebene Warmwasserbereiter und Kombinationssysteme

This European Standard was approved by CEN on 19 February 2012.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, 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, Turkey and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 12977-2:2012: E

Contents

Page

Figures

Tables

Foreword

This document (EN 12977-2:2012) 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.

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

This document supersedes CEN/TS 12977-2:2010.

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, Croatia, 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, Turkey and the United Kingdom.

Introduction

a) Drinking water quality

In respect of potential adverse effects on the quality of drinking water intended for human consumption caused by the product covered by this document, it should be noted that

1) this document provides no information as to whether the product may be used without restriction in any of the Member States of the EU or EFTA,

2) while awaiting the adoption of verifiable European criteria, existing national regulations concerning the use and/or the characteristics of this product remain in force.

b) Factory made and custom built solar heating systems

EN 12976-1, EN 12976-2, EN 12977-1, EN 12977-2, EN 12977-3, EN 12977-4 and EN 12977-5 distinguish two categories of solar heating systems:

1) factory made solar heating systems; and

2) custom built solar heating systems.

The classification of a system as factory made or custom built is a choice of the final supplier, in accordance to the following definitions.

1) Factory made solar heating systems are batch products with one trade name, sold as complete and ready to install kits, with fixed configurations. Systems of this category are considered as a single product and assessed as a whole.

   If a factory made solar heating system is modified by changing its configuration or by changing one or more of its components, the modified system is considered as a new system. Requirements and test methods for factory made solar heating systems are given in EN 12976-1 and EN 12976-2.

2) Custom built solar heating systems are either uniquely built or assembled by choosing from an assortment of components. Systems of this category are regarded as a set of components. The components are separately tested and test results are integrated to an assessment of the whole system. Requirements for custom built solar heating systems are given in EN 12977-1, test methods are specified in EN 12977-2, EN 12977-3, EN 12977-4 and EN 12977-5. Custom built solar heating systems are subdivided into two categories:

   i) large custom built systems are uniquely designed for a specific situation. In general, they are designed by HVAC engineers, manufacturers or other experts;

   ii) small custom built systems offered by a company are described in a so-called assortment file, in which all components and possible system configurations, marketed by the company, are specified. Each possible combination of a system configuration with components from the assortment is considered as one custom built system.

Table 1 shows the division for different system types.

Table 1 — Division for factory made and custom built solar heating systems

Factory made solar heating systems (EN 12976-1 and EN 12976-2)	Custom built solar heating systems (EN 12977-1, EN 12977-2, EN 12977-3, EN 12977-4 and EN 12977-5)
Integral collector-storage systems for domestic hot water preparation	Forced circulation systems for hot water preparation and/or space heating/cooling, assembled using components and configurations described in a documentation file (mostly small systems)
Thermosiphon systems for domestic hot water preparation	
Forced circulation systems as batch product with fixed configuration for domestic hot water preparation	Uniquely designed and assembled systems for hot water preparation and/or space heating/cooling (mostly large systems)

NOTE 1 Forced circulation systems can be classified either as factory made or as custom built, depending on the market approach chosen by the final supplier.

NOTE 2 Both factory made and custom built systems are performance tested under the same set of basic reference conditions as specified in EN 12976-2:2006, Annex B and in EN 12977-2:2012, Annex A. In practice, the installation conditions may differ from these reference conditions.

c) Test methods and procedures for the analysis of large custom built solar heating systems

Quality assurance is of primary importance for large custom built systems. The total investment cost for such systems is higher than for smaller ones, although the specific investment cost (i.e., per m² collector area) is lower. In several European countries, the potential of large custom built systems from the point of view of conventional energy savings is much larger than for smaller ones. Moreover, the return on investment is in many cases more favourable for large systems than for small ones. Hence, both the purchasers of large custom built systems and the governments are interested in efficient, reliable and durable systems, the thermal performance of which may be accurately predicted, checked and supervised.

The test methods in this document provide a means of verifying the compliance of large custom built systems with the requirements in EN 12977-1.

NOTE 3 Within the framework of the EU ALTENER Programme the project "Guaranteed Solar Results" (GSR) was addressing similar objectives in respect of quality assurance (see [7], [8]). Similar procedures and monitoring equipment were used as described in Annexes C and D. It might be necessary to update Annexes C and D at a later stage during a revision of this document when more expertise is available.

As large custom built systems are by definition unique systems, only general procedures on how to check and supervise them may be given. An additional difficulty in the formulation of procedures is the fact that they have to be adapted to the dimension of the large custom built system considered, which may vary from typically 30 m² to 30 000 m² of collector area. Therefore, several possible levels of analysis are included (Annexes C and D).

The objective of the two short-term system tests presented in Annex C is the characterization of system performance and/or the estimation of the ability of the system to deliver the energy claimed by the designer. In principle, two approaches for short-term system testing are referred to in this European Standard:

1) a simplified check of short-term system performance, carried out by intercomparison of the measured thermal solar system heat gain with the one predicted by simulation, using the actual weather and operating conditions as measured during the short-term test;

2) a short-term test for long-term system performance prediction. The performance of the most relevant components of the solar heating system is measured for a certain time period while the system is in normal operation. More detailed measurements encompass

   i) energy gain of collector array(s) and

   ii) energy balance over storage vessel(s).

   Inter-comparison of the observed and simulated energy quantities provides the indirect validation of collector and storage design parameters. The measured data within the collector array are also used for direct identification of the collector array parameters. As far the component parameters are verified, the long-term prediction of the system gain as well as the detection of possible sources of system malfunctioning are possible.

Annex D describes a procedure for long-term monitoring as a part of the supervision of a large custom built solar heating system. The objectives of supervision may be:

3) the early recognition of possible failures of system components, in order to get the maximum benefit from the initial solar investment as well as to minimize the consumption of non-solar energy and the resulting environmental impact,

4) the measurement of system performance (solar gains or other system indicators), if requested by a contractual clause, e.g. guaranteed results.

The long-term monitoring in Annex D is limited to the solar energy specific aspects, especially to the determination of the solar contribution to the total heat load. Instrumentation used in the long-term monitoring should be an integrating part of the system, a part included from the very beginning of the design process. If adequately foreseen, it may also be used for system adjustment at start time.

1 Scope

This European Standard applies to small and large custom built solar heating systems with liquid heat transfer medium for residential buildings and similar applications, and gives test methods for verification of the requirements specified in EN 12977-1.

This document also includes a method for thermal performance characterization and system performance prediction of small custom built systems by means of component testing and system simulation.

Furthermore, this document contains methods for thermal performance characterization and system performance prediction of large custom built systems.

This document applies to the following types of small custom built solar heating systems:

— systems for domestic hot water preparation only;

— systems for space heating only;

— systems for domestic hot water preparation and space heating;

— others (e.g. including cooling).

This document applies to large custom built solar heating systems, primarily to solar preheat systems, with one or more storage vessels, heat exchangers, piping and automatic controls and with collector array(s) with forced circulation of fluid in the collector loop.

This document does not apply to

— systems with a store medium other than water (e.g. phase- change materials),

— thermosiphon systems,

— integral collector-storage (ICS) systems.

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

EN 806-1, *Specifications for installations inside buildings conveying water for human consumption — Part 1: General*

EN 809, *Pumps and pump units for liquids — Common safety requirements*

EN 1151-1, *Pumps — Rotodynamic pumps — Circulation pumps having a rated power input not exceeding 200 W for heating installations and domestic hot water installations — Part 1: Non-automatic circulation pumps, requirements, testing, marking*

EN 1991-1-3, *Eurocode 1 — Actions on structures — Part 1-3: General actions — Snow loads*

EN 1991-1-4, *Eurocode 1: Actions on structures — Part 1-4: General actions — Wind actions*

EN 12975-1:2006, *Thermal solar systems and components — Solar collectors — Part 1: General requirements*

EN 12975-2:2006, *Thermal solar systems and components — Solar collectors — Part 2: Test methods*

EN 12976-1:2006, *Thermal solar systems and components — Factory made systems — Part 1: General requirements*

EN 12976-2:2006, *Thermal solar systems and components — Factory made systems — Part 2: Test methods*

EN 12977-1:2012, *Thermal solar systems and components — Custom built systems — Part 1: General requirements for solar water heaters and combisystems*

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

EN 12977-4:2012, *Thermal solar systems and components — Custom built systems — Part 4: Performance test methods for solar combistores*

EN 12977-5:2012, *Thermal solar systems and components — Custom built systems — Part 5: Performance test methods for control equipment*

EN 60335-1, *Household and similar electrical appliances — Safety — Part 1: General requirements (IEC 60335-1)*

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

ISO 9459-5:2007, *Solar heating — Domestic water heating systems — Part 5: System performance characterization by means of whole-system tests and computer simulation*

ISO/TR 10217, *Solar energy — Water heating systems — Guide to material selection with regard to internal corrosion*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12975-1:2006, EN 12976-1:2006, EN 12977-1:2012, EN 12977-3:2012, EN 12977-5:2012, ISO 9459-5:2007 and EN ISO 9488:1999 apply.

4 Symbols and abbreviations

Table 2 — Symbols, definition and unit (1 of 2)

Symbol	Definition	Unit
a_1	heat loss coefficient at ($\vartheta_m - \vartheta_a$) = 0	W/(m² × K)
A_c	reference area of collector	m²
C_c	effective thermal capacity of collector or collector array	J/K
Day	day number of the year	
D_s	shift term for the calculation of mains water temperature at reference location	
f_{sav}	fractional energy savings	%
f_{sol}	solar fraction	%
G_d	diffuse solar irradiance on tilted plane	W/m²
G_g	global solar irradiance (on horizontal plane)	W/m²
G_h	hemispherical solar irradiance on tilted plane	W/m²
H_c	hemispherical solar irradiation on collector plane	MJ/m²
$K_{\alpha\tau}$	incidence angle modifier	
Q_{aux}	gross auxiliary energy demand of the solar heating system	MJ
$Q_{aux,net}$	net auxiliary energy demand of the solar heating system delivered by the auxiliary heater to the store or directly to the heat distribution system	MJ
Q_{conv}	gross energy demand of the conventional heating system	MJ
$Q_{conv,net}$	net energy demand of the conventional heating system	MJ
Q_d	heat demand	MJ
Q_L	energy delivered at the outlet of the solar heating system	MJ
Q_l	store heat losses of the solar heating system	MJ
$Q_{l,a}$	store heat losses of the store heated by auxiliary energy (in case of a two-store-solar-plus-supplementary system)	MJ
$Q_{l,s}$	store heat losses of the store heated by solar energy (in case of a two-store-solar-plus-supplementary system)	MJ
$Q_{l,conv}$	store heat losses of the conventional heating system	MJ
Q_{ohp}	heat diverted from the store as active overheating protection, if any	MJ
Q_{par}	parasitic energy (electricity) for the collector loop pump(s) and control unit	MJ
Q_{sav}	energy savings due to the solar heating system	MJ
Q_{sol}	energy delivered by the collector loop to the store	MJ
T^*	reduced temperature difference; $T^* = (\vartheta_m - \vartheta_a)/G_h$	m² × K/W
$(UA)_{hx}$	heat transfer capacity rate of a heat exchanger	W/K
$(UA)_S$	heat loss capacity rate of the store of the solar heating system	W/K

Table 2 — Symbols, definition and unit (2 of 2)

$(UA)_{\mathrm{S,conv}}$	heat loss capacity rate of the store of the conventional heating system	W/K
U_{L}	overall heat loss coefficient of a collector or collector array	W/(m² × K)
$\dot{V}_{\mathrm{c}}$	volume flow rate in collector loop	l/h
V_{d}	demanded (daily) load volume	l/d
$\dot{V}_{\mathrm{rc}}$	volume flow rate in circulation loop	l/h
$\dot{V}_{\mathrm{s}}$	volume draw-off flow rate from storage	l/h
$V_{\mathrm{S,conv}}$	store volume of the conventional heating system	l
v	surrounding air speed	m/s
$\Delta\vartheta$	average temperature difference induced by a heat exchanger	K
$\Delta\vartheta_{\mathrm{amplit}}$	average amplitude of seasonal mains water temperature variations on reference location	K
$\Delta\eta$	drop in system efficiency induced by a heat exchanger	%
ϑ_{a}	collector ambient or surrounding air temperature	°C
$\vartheta_{\mathrm{average}}$	yearly average mains water temperature on reference location	°C
$\vartheta_{\mathrm{ci/co}}$	collector or collector array inlet/outlet fluid temperature	°C
ϑ_{cw}	mains water temperature	°C
ϑ_{d}	desired hot water temperature	°C
ϑ_{m}	mean collector fluid temperature; $\vartheta_{\mathrm{m}} = (\vartheta_{\mathrm{ci}} + \vartheta_{\mathrm{co}})/2$	°C
ϑ_{rce}	fluid temperature at circulation loop outlet	°C
ϑ_{rci}	fluid temperature at circulation loop inlet	°C
ϑ_{S}	storage draw-off temperature	°C
$\vartheta_{\mathrm{S,amb}}$	store ambient air temperature	°C
$\vartheta_{\mathrm{start/stop}}$	temperature for which controller operation starts/stops	°C
$\vartheta_{\mathrm{tank}}$	temperature of the storage tank	°C
η_0	zero-loss collector efficiency (efficiency at $T^* = 0$)	
η_{aux}	overall generation efficiency of the auxiliary heater of the solar heating system	
η_{conv}	overall generation efficiency of the heater of the conventional heating system	
θ_{req}	required temperature for sensor high-temperature resistance	°C
θ_{sens}	sensor temperature	°C

5 System classification

See EN 12977-1:2012, Clause 5.

6 Test methods

6.1 Introduction

Subsequent test methods refer to the requirements given in EN 12977-1.

6.2 General

6.2.1 Suitability for drinking water

See EN 806-1.

6.2.2 Water contamination

Check the design of all circuits to avoid water contamination for backflow from all circuits to drinking main supplies.

6.2.3 Freeze resistance

See EN 12976-2:2006, 5.1.

6.2.4 High-temperature protection

6.2.4.1 Scald protection

If the temperature of the domestic hot water in the system can exceed 60 °C, check the design plan or the system documentation to see whether the system is provided with an automatic cold water mixing device or any other device to limit the maximum tapping temperature to 60 °C.

6.2.4.2 High-temperature protection of materials

Ensure by checking the hydraulic scheme and/or by calculation and taking into account the most adverse conditions for the materials of all parts of the system, that the maximum temperatures which may occur do not exceed the maximum permissible temperatures for the respective materials, taking into account also pressure conditions and/or mechanical stress if relevant.

NOTE Both transients (high temperature peaks of short duration) and stagnation of longer duration may create adverse conditions for the respective material.

6.2.5 Reverse circulation prevention

Check the hydraulic scheme included in the documentation (see 6.8) to ensure that no unintentional reverse circulation will occur in any hydraulic loop of the system.

6.2.6 Pressure resistance

In case that it is not documented that the store(s) and the heat exchanger(s) withstand at least 1,5 times the manufacturer's stated maximum individual working pressures, the procedures specified in EN 12976-2:2006, 5.3 should be applied on the store(s) and the heat exchanger(s).

NOTE EN 12976-2:2006, 5.3 specifies a pressure resistance test method for a complete solar thermal system. For the purpose of this subclause, this method should be principally applied on the store(s) and heat exchanger(s).

Check if the system documentation for the installer describes a pressure resistance test procedure for the collector loop of the system.

6.2.7 Electrical safety

See EN 60335-1.

6.3 Materials

Check if the documentation for the installer includes information about the durability of the materials exposed to weathering with regard to UV radiation and other weather conditions.

Check if the materials used in the collector loop comply with ISO/TR 10217 concerning internal corrosion.

6.4 Components and pipework

6.4.1 Collector and collector array

The collector should be tested according to EN 12975-2.

The design of the collector array should be checked with regard to flow distribution.

6.4.2 Supporting frame

Check the calculation proving the resistance of the frame to snow and wind loads in accordance with EN 1991-1-3 and EN 1991-1-4 where applicable.

6.4.3 Collector and other loops

With regard to the collector loop, check if the requirements listed in EN 12977-5:2012, Table 10, are fulfilled.

6.4.4 Circulation pump

See EN 809, EN 1151-1 and EN 12977-5.

6.4.5 Expansion vessels

6.4.5.1 General

For systems without a separate expansion vessel (e.g. drain-back systems) check both by calculation and the hydraulic scheme to see whether the integrated expansion facility is able to fulfil its task.

6.4.5.2 Open expansion vessels

Check the volume and design of the open expansion vessel by calculation and by checking the hydraulic scheme.

In addition, check the connection of the vessel to the atmosphere, the spill line and the expansion lines on the hydraulic scheme.

6.4.5.3 Closed expansion vessels

For small custom built systems only: Check the fulfilment of the requirements given in EN 12977-1:2012, 6.4.5.3, by calculation and by visual check of the hydraulic scheme and operating instruction.

6.4.6 Heat exchangers

Apart from the tests in compliance with EN 307, check the design of the heat exchanger(s) with respect to scaling or the availability of cleaning facilities.

In addition, the drop in system efficiency $\Delta\eta$ induced by a heat exchanger in the collector loop of a small custom built system should be estimated by Formula (1):

$$\Delta\eta = \frac{\eta_0 \; A_\mathrm{c} \; a_1}{(UA)_\mathrm{hx}} \times 100\ \% \qquad (1)$$

For small systems, $(UA)_\mathrm{hx}$ is delivered by the store performance test of EN 12977-3 or EN 12977-4 ($(UA)_\mathrm{hx}$ to be chosen for store temperatures of 20 °C, an average temperature difference of 10 K and a flow rate similar to the one used for the determination of the collector parameters). For large systems, $(UA)_\mathrm{hx}$ is taken from the heat exchanger performance data sheet provided by the manufacturer.

NOTE 1 In the latter case, since performance data of external heat exchangers (which are mostly used in large custom built systems) are generally quite reliable, no additional measurements are needed.

For heat exchangers in other loops (e.g. a load side heat exchanger), the average temperature difference on the primary side $\Delta\vartheta$ which is induced by the presence of the heat exchanger should be estimated by calculation. The drop in efficiency may then be estimated by Formula (2):

$$\Delta\eta = \left(a_1 \Delta\vartheta / G_\mathrm{ref}\right) \times 100\ \% \qquad (2)$$

where the reference solar irradiance G_ref is set to 1 000 W/m^2.

NOTE 2 More accurate calculation methods are given in [1]. In special cases, the thermal stratification in the store should be taken into account, to obtain an accurate figure for the efficiency drop.

6.4.7 Store

For small custom built systems only:

— the performance of their stores should be tested according to EN 12977-3, in the case of a solar water heater, or EN 12977-4, in the case of a solar combisystem;

— the heat loss capacity rate of these hot water stores, obtained from performance tests according to EN 12977-3 and EN 12977-4, respectively, should be compared with the requirements given in EN 12977-1:2012, 6.4.7.

6.4.8 Pipework

Check the design plan and system documentation in respect of design and material of pipes and fittings.

For the pipework in the collector loop, check its compliance with ISO/TR 10217.

6.4.9 Thermal insulation

Check the design plans and system documentation.

6.4.10 Control equipment

See EN 12977-5.

6.5 Safety equipment and indicators

6.5.1 Safety valves

Check the design plan and the system documentation to verify that each collector or each section of collector array which can be shut off is fitted with at least one suitable safety valve.

Check the specification of the safety valves, whether the materials fulfil the requirements given in EN 12977-1:2012, 6.5.1.

Check whether the size of the safety valve is correct, in compliance with the requirements given in EN 12977-1:2012, 6.5.1.

Additionally, for large custom built systems: For testing the system behaviour after release of one or more safety valves according to the requirements given in EN 12977-1:2012, 6.5.1, check the electric and hydraulic schemes or any other part of the documentation according to EN 12977-1:2012, 6.8.3.

6.5.2 Safety lines and expansion lines

Check the hydraulic scheme and system documentation to verify that safety and expansion lines cannot be shut off.

Check the internal diameter of the safety and the expansion line with respect to the requirements given in EN 12977-1:2012, 6.4.2.

Check the hydraulic scheme and system documentation to verify that the expansion line and the safety line are connected and laid in such a way that any accumulation of dirt, scale or similar impurities is avoided.

6.5.3 Blow-off lines

Check the hydraulic scheme and system documentation to verify that the blow-off lines fulfil the requirements given in EN 12977-1:2012, 6.5.3.

6.5.4 Store isolation valve

For large systems only: Verify the existence of a shut-off valve by checking the system documentation in accordance with EN 12977-1:2012, 6.5.4.

6.5.5 Indicators

6.5.5.1 Indicators for collector loop flow

Check the hydraulic scheme and system documentation in respect of the position and installation of the recommended indicators for the collector loop flow.

6.5.5.2 Pressure gauge

Check the hydraulic scheme and system documentation in respect of the position and the installation of the pressure gauge or, in the case of some drain-back systems without pressure gauge, of the other means provided for checking drain-back and the fluid level in the collector loop.

6.5.5.3 Heat meter

If large custom built systems are equipped with heat meters (see EN 12977-1:2012, 6.5.5.3), this should be mentioned in the system documentation.

6.6 Installation

6.6.1 Roof tightness

Check the design plans and the system documentation to see whether the leak tightness of the roof may be affected by the installation of the collector.

6.6.2 Lightning

For small custom built systems see EN 12976-2:2006, Annexes E and F.

For large custom built systems verify the compliance with the requirements given in EN 12977-1:2012, 6.6.2 by checking the documentation included in EN 12977-1:2012, 6.8.4.

6.6.3 Snow and wind loads

See EN 1991-1-3 and EN 1991-1-4 where applicable. Moreover, check whether the documents for the installer comply with EN 12977-1:2012, 6.6.3.

6.7 Initial operation, inspection and commissioning

This subclause applies to large systems only.

Before initial operation:

— check whether the system layout and components are as described in the documentation;

— check the record of the adjustments for the corresponding fittings. For each fitting a recorded adjustment shall exist;

— if there is a supervisor of the system, ensure that he has been sufficiently instructed.

The procedure for short-term system testing referred to in EN 12977-1:2012, 6.7 (only if needed or required) is given in Annex C.

The procedure for long-term system monitoring referred to in EN 12977-1:2012, 6.7 (only if needed or required) is given in Annex D.

6.8 Documentation

Check all documents, as to whether they fulfil the requirements given in EN 12977-1:2012, 6.8.

6.9 System performance (for small systems only)

The optional performance test methods for small custom built systems are described in Clause 7. The test results shall be presented in a test report as described in Clause 8.

6.10 Water wastage (for small systems only)

See Annex E.

7 Optional performance test of small custom built solar heating systems

7.1 General

The test method is based on component tests of the solar collector, the store(s), the controller and other components as necessary. These component tests are described in 7.2, 7.3 and 7.4. The whole system is then simulated using a validated simulation program as described in 7.6. The long-term performance of the whole system is predicted for reference conditions as described in 7.7.

If the carrying out of this performance test is required, the specification included in 7.5 and 7.6 shall be adhered to.

In general, the system does not need to be installed as a whole for testing.

For systems for hot water preparation only (class A), for systems for space heating only (class B) and for systems for combined domestic hot water preparation and space heating (class C), the full tests should be carried out including the long-term performance prediction for reference conditions.

For other systems (class D) the components should be tested and the results be stated in the test report. The long-term performance prediction is a further option. If the performance prediction is carried out, the results should be stated in the test report stating also the chosen boundary conditions for the simulation. The following remark should be added to the results of performance predictions for systems of class D:

— inter-comparison of the results of the long-term performance prediction is only possible, if validated simulation models and the same boundary conditions are used.

NOTE 1 The procedure for systems of class D as described above allows national solutions with respect to the definition of reference conditions. This is a preliminary step for the standardization of this procedure within the European countries. After enough experience has been gained on national level, the reference conditions for all European countries can be elaborated.

Before starting the performance testing, all tests specified in 6.2 to 6.8 shall be completed. In case a system fails one or more of these tests, the malfunction or defect shall be eliminated by the manufacturer prior to performance testing. If this is not possible:

— the malfunction shall be stated in the performance test report;

— the performance of the system shall be determined with the method as described in this subclause. However, the reduction of the system performance induced by the malfunction or defect shall be estimated and the results of the performance test corrected accordingly.

NOTE 2 If the system fails one of the following tests described in Clause 6, a significant reduction of the system performance can be expected:

— collector array: balanced flow (see 6.4.1);

— temperature sensors: thermal contact of the sensors to the part of which the temperature is measured (see EN 12977-5:2012, 6.3.1);

— reverse circulation prevention (see 6.2.5);

— thermal insulation (see 6.4.9).

7.2 Test of the solar collector

For the collector test according to EN 12975-2, all data for dynamic simulation of the thermal behaviour of the collector as listed below should be determined:

— standard collector efficiency parameters;

— collector heat capacity;

— incidence angle modifier for beam and diffuse irradiance (biaxial, if relevant);

— wind speed dependence of the collector heat loss coefficients, if relevant (e.g. for unglazed collectors);

— influence of flow rate, if relevant;

— influence of collector tilt angle, if relevant.

7.3 Test of the water store(s)

The store(s) should be tested in accordance with EN 12977-3 or EN 12977-4, respectively. Thereby all data for dynamic simulation of the thermal behaviour of the store(s) as described in EN 12977-3 or EN 12977-4, whichever applicable, should be determined.

7.4 Test of the control equipment

The control equipment should be tested according to the methods described in EN 12977-5. Thereby all data for dynamic simulation of the behaviour of the control equipment as described in EN 12977-5 should be determined.

7.5 Determination of the hot water comfort

See EN 12977-3:2012, Annex F and EN 12977-4, Annex E, whichever relevant.

7.6 System simulation model

The modelling of the system should be carried out using a detailed dynamic simulation programme fitted for the different system and store configurations considered, including their control strategy. The simulation programme should operate on the basis of all parameters determined in the component tests.

NOTE The level of detail needed for most system types is similar to that used in the programmes TRNSYS or equivalent.

The component models for collector and store used in the system simulation shall be respectively the same as for the characterization of the collector according to EN 12975-2, and for the characterization of the store according to EN 12977-3 or EN 12977-4, whichever applicable.

The behaviour of the control equipment determined according to EN 12977-5 shall be included in the simulation programme.

For other components, e.g. pipework or external heat exchangers, the level of detail in the simulation model shall correspond to the data used for proving the fulfilment of the specific requirements.

The following features shall be implemented in the model:

— a thermostat mixer which reduces the store outlet fluid temperature, ϑ_S, to the desired hot water temperature, ϑ_d, during draw-offs. For solar preheat systems and solar-only systems this thermostat mixer shall be located directly at the outlet of the solar part of the system;

— The collector loop operation shall be stopped when the temperature of the storage tank exceeds 95 °C if no other temperature is specified by the manufacturer.

The system simulation model shall have been previously validated.

7.7 Long-term performance prediction

7.7.1 General

The recommended long-term system performance prediction is described only for systems classes A, B and C according to EN 12977-1:2012, 5.1. However, for systems class D, the same general principles apply.

7.7.2 Calculation procedure

Use the simulation model selected according to 7.6. The component parameter values used for the simulation are those given by the component tests according to 7.2 to 7.4. Data on other components of the system, e.g. pipework or external heat exchanger, shall be those used for proving the fulfilment of the specific requirements.

The reference conditions as specified in Annex A shall be used when calculating or reporting the performance of a system by computer simulation.

For the four reference locations given in Annex A, data files providing the flow temperature, the return temperature and the mass flow rate as hourly values all over the year for a typical single-family dwelling shall be used for accounting for the space heating load.

For additional cases or locations, it is open to the interested parties to decide how to take the space heating load into account.

NOTE 1 For the four reference locations, space heating load is accounted for by using load files. Consequently, interactions between building and solar heating systems are not accounted for in this case. However, for additional cases or locations, also dynamic building simulation models that interact with the solar combisystem can be used for accounting for the space heating load.

NOTE 2 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 pipes. 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 e.g. be achieved if the pipe is directly going downwards after leaving the store or by using a siphon.

7.7.3 Prediction of yearly system performance indicators

Basic uniform reference conditions for the calculation of the performance are specified in Annex A of this document or EN 12976-2:2006, Annex B. For these conditions, the following performance indicators should be derived from the performance test results.

For solar-plus-supplementary systems:

— the net auxiliary energy demand, $Q_{\text{aux,net}}$;

— the fractional energy savings, f_{sav};

— the parasitic energy, Q_{par}.

For solar-only and preheat systems:

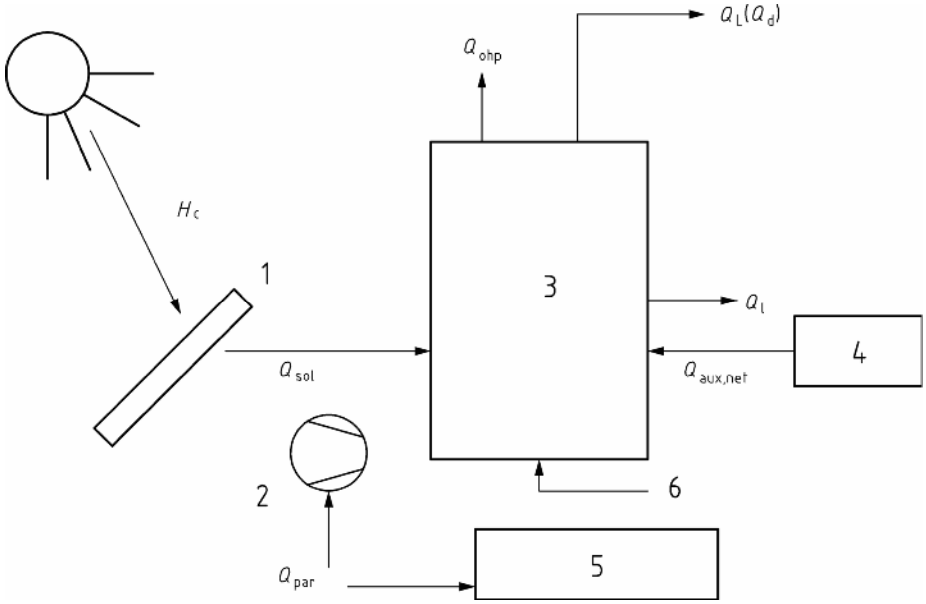
— the heat delivered by the solar heating system, Q_{L};

— the solar fraction, f_{sol};

— the parasitic energy, Q_{par}, if any is available.

7.7.4 Calculation of the net auxiliary energy demand and fractional energy savings for solar-plus-supplementary systems

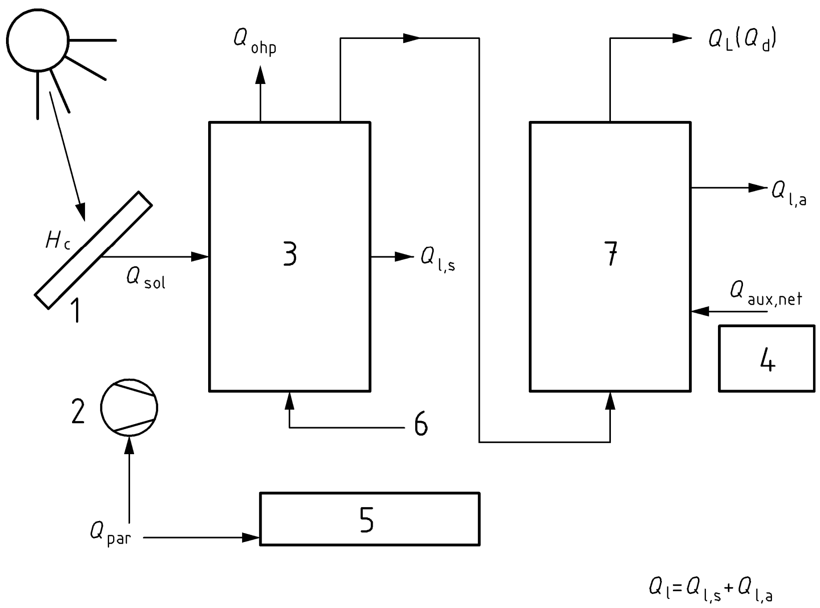
Calculate the yearly net auxiliary energy demand, $Q_{\text{aux,net}}$, directly by computer simulation (long-term performance prediction) as specified in 7.7.2 (for custom built systems) or in EN 12976-2:2006, 5.8.3.2 (for factory made systems). Additional indication to the quantities entering the energy balance of one-store and two-stores solar-plus-supplementary heating systems is given in Figure 1.



Key

1	collector	4	auxiliary heater
2	pump	5	control unit
3	store	6	mains water

a) Energy balance for one-store solar-plus-supplementary systems



Key

1	collector	4	auxiliary heater	7	auxiliary store
2	pump	5	control unit		
3	solar store	6	mains water		

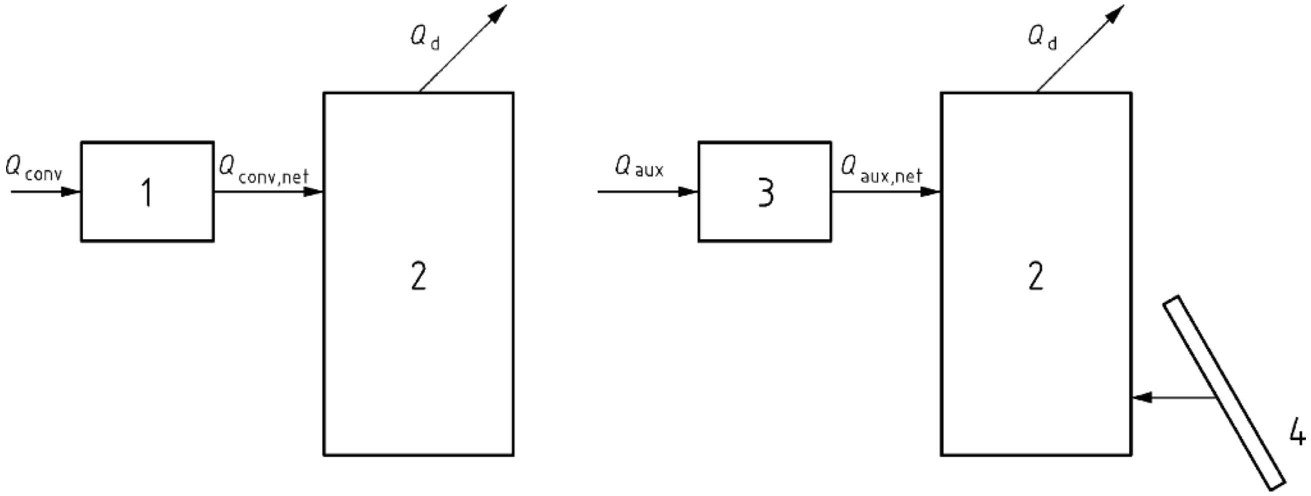
b) Energy balance for two-store solar-plus-supplementary systems

Figure 1 — Energy balance for one-store and two-store solar-plus-supplementary systems

Calculate the fractional energy savings, f_{sav}, by Formula (3) according to the definition of EN ISO 9488:

$$f_{sav} = (Q_{conv} - Q_{aux}) / Q_{conv} \quad (3)$$

The fractional energy savings is calculated on a yearly base. Figure 2 illustrates this system comparison.



a) Conventional heating system (reference system)

b) Solar heating system

Key

1 heater, η_{conv}

2 store

3 auxiliary heater, η_{aux}

4 collector

Figure 2 — Comparison of the gross auxiliary energy demand of the solar heating system, Q_{aux}, to the gross energy demand of the conventional heating system, Q_{conv}

NOTE 1 Both systems are assumed to use the same kind of conventional energy, and to supply the user with the same heat quantity giving the same thermal comfort.

The reference conditions as specified in Annex A shall be used when calculating the performance of the conventional heating system.

For the solar heating system, calculate the gross auxiliary energy demand by Formula (4):

$$Q_{aux} = Q_{aux,net} / \eta_{aux} \quad (4)$$

where

η_{aux} = 0,75

NOTE 2 The fractional energy savings are meant only to compare solar heating systems to other solar heating systems, and should not be used to compare conventional heating systems to solar heating systems.

NOTE 3 Optionally, the fractional energy savings can be derived for national conditions taking into account the efficiencies of different conventional heating systems as well as from measurements on an installed system. The procedures are described in B.2.

If a solar-plus-supplementary system cannot meet the heat demand to such a degree that the energy delivered to the user is less than 90 % of the yearly heat demand, this should be stated in the test report.

NOTE 4 The energy delivered to the user can be less than the heat demand for example when the power of the auxiliary heater is not sufficient or when strong mixing occurs in the store during draw-offs.

7.7.5 Calculation of the solar fraction for solar-only and preheat systems

Compute the system energy balance on a yearly basis. This includes the following energy quantities (see Figure 3 and Figure 4), calculated using the reference data and conditions given in Annex A or in EN 12976-2:2006, Annex B:

— Q_d heat demand;

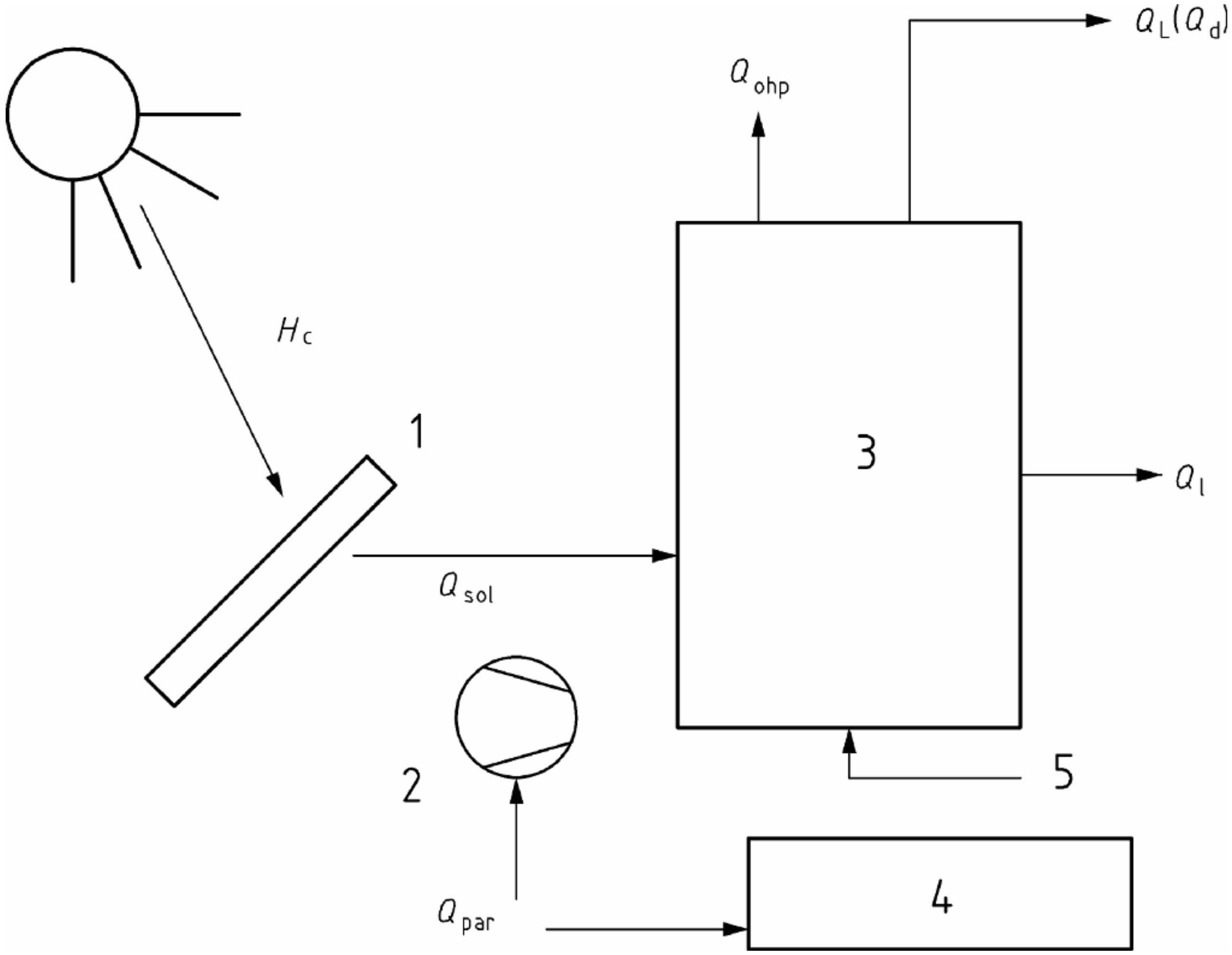
— Q_L energy delivered by the solar heating system (load);

— Q_{par} parasitic energy (electricity) for pump and controls.

The parasitic energy, Q_{par}, shall be calculated according to 7.7.6.

NOTE 1 The reference locations for calculating the load, Q_L, are the store ports or the load-side heat exchanger ports, if provided. The reference temperature for calculating the loads is the mains water temperature. Heat losses of the circulation line, if any, are not included in the loads, as the test is carried out with this line kept closed.

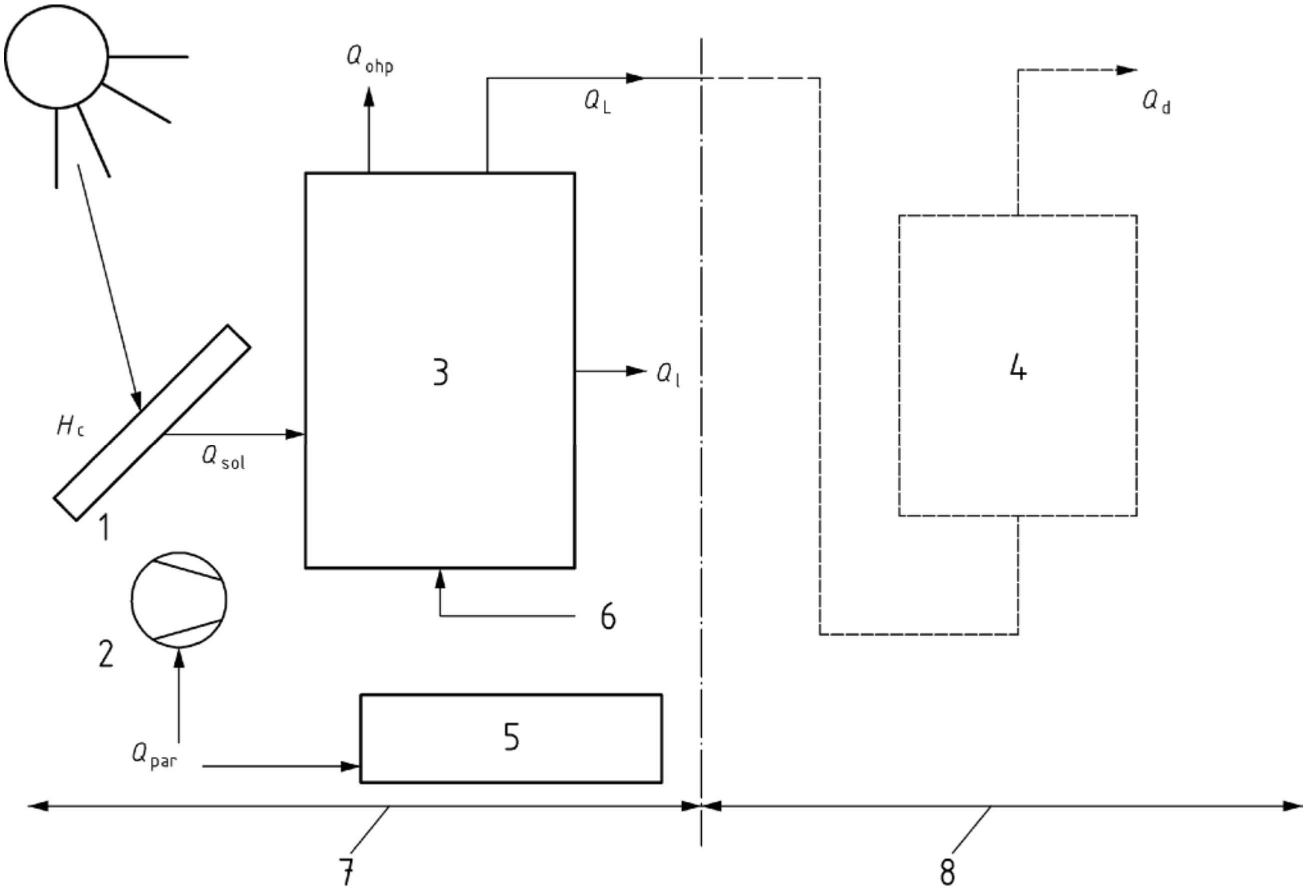
NOTE 2 According to EN ISO 9488, a solar preheat system is a solar heating system to preheat water or air prior to its entry into any other type of water or air heater. This water or air heater is not part of the solar preheat system itself. Hence, for this type of system the energy delivered by the solar heating system, Q_L, is calculated at the outlet of the solar heating system and the store heat loss, Q_l, is the heat loss of the solar store itself (see Figure 4).



Key

1	collector	4	control unit
2	pump	5	mains water
3	store		

Figure 3 — Energy balance for solar only systems



Key

1	collector	5	control unit
2	pump	6	mains water
3	solar store	7	solar preheat system
4	auxiliary heater	8	series-connected auxiliary heating system

Figure 4 — Energy balance for solar preheat systems

Calculate the solar fraction, f_{sol}, by Formula (5) according to the definition of EN ISO 9488:

$$f_{sol} = Q_L / Q_d \tag{5}$$

7.7.6 Calculation of the parasitic energy (for all system types)

Calculate the yearly parasitic energy, Q_{par}, needed by control equipment taking into account the full-load hours from the simulation and the nominal power in accordance with EN 12977-5.

7.8 Presentation of performance indicators

The results from 7.7.2 to 7.7.6 should be presented for the daily load volume(s) and space heating load(s) as specified in Annex A in the way shown in Table 3 and Table 4.

Table 3 — Presentation of system performance indicators for solar-plus-supplementary systems

Performance indicators for solar-plus-supplementary systems on annual base for a volume demand of .... l/d and a space heating load of ..... MJ/a					
Location (latitude)	$Q_{d, hw}$ MJ	$Q_{d, sh}$ MJ	$Q_{aux,net}$ MJ	Q_{par} MJ	f_{sav} %
Stockholm (59,6° N)	.....	.....			
Würzburg (49,5° N)	.....	.....			
Davos (46,8° N)	.....	.....			
Athens (38,0° N)	.....	.....			
.....[a]					

[a] For a location or a building free to choose. Detailed specifications shall be given.

Table 4 — Presentation of system performance indicators for solar-only and solar preheat systems

Performance indicators for solar-only and solar preheat systems on annual base for a volume demand of .... l/d and a space heating load of ..... MJ/a or alternatively one load taking into account both				
Location (latitude)	Q_d MJ	Q_L MJ	f_{sol} %	Q_{par} MJ
Stockholm (59,6° N)	.....			
Würzburg (49,5° N)	.....			
Davos (46,8° N)	.....			
Athens (38,0° N)	.....			
.....[a]				

[a] For a location or a building free to choose. Detailed specifications shall be given.

8 Performance test report

This clause describes the report of results from the optional tests performed according to Clause 7.

This test report applies to small custom built systems only, since the system performance test methods given in Clause 7 are applicable to small custom built systems only (see 6.9).

The test report shall include the following:

a) a detailed description of components and system configuration;

b) the prediction method used. The simulation programme shall be specified and an input file shall be enclosed;

c) the complete reference conditions used as specified in Annex A including information about the location for which the performance prediction is made and the reference weather data used;

d) for the reference conditions as specified in Annex A, the performance indicators on a yearly base as specified in 7.7.3.

Annex A
(normative)

Reference conditions for performance prediction

A.1 General

The conditions given in Table A.1 shall be used when calculating, reporting or comparing the performance of a system, either from a test or from a computer simulation.

NOTE The following reference conditions are basically identical for testing and simulating of factory made systems in EN 12976-2 and custom built systems in this document. However, some aspects related to systems considered in only one of the two standards (e.g. solar combisystems in EN 12977-2), have been deleted from the other standard.

Table A.1 — Reference conditions for performance presentation (1 of 2)

Reference condition	Value	Remarks
SYSTEM		
Collector orientation	South	
Collector tilt angle	45°	For testing, (45 ± 5) °C if not fixed for the system or specified by the manufacturer
Total length of collector circuit	20 m = 10 m + 10 m	If piping is not delivered with the system or specified by the manufacturer
Pipe diameter and insulation thickness of collector circuit	See A.2	If piping is not delivered with the system or specified by the manufacturer
Location of the collector circuit pipes	Indoors, for systems with the store located indoors; outdoors, for systems with the store located outdoors	As far as possible at the test rig
Store ambient air temperature	15 °C	For systems where the store is located outside, the ambient air temperature from the climate data shall be used.
For systems with indirect (hydraulic) auxiliary heating: Power to be applied on auxiliary heat exchanger	(100 ± 30) W per litre of store volume above the lowest end of heat exchanger	If the auxiliary heater is not delivered with the system and no restrictions have been given in the documentation The auxiliary heater shall be modelled as an ideal heat source with no heat capacity and constant heating power.
Flow rate through auxiliary heat exchanger	The flow rate through the heat exchanger shall be chosen such that the temperature difference between the inlet and outlet of the auxiliary heat exchanger is (10 ± 2) K under steady state conditions, unless specified otherwise by the manufacturer.	
For systems with electrical auxiliary heating: Power of electrical element	If an electrical element is normally delivered with the system or specified by the manufacturer, this element shall be used. Otherwise, (25 ± 8) W/l of store volume above the electrical element apply.	

Table A.1 — Reference conditions for performance presentation (2 of 2)

Reference condition	Value	Remarks
For solar-plus-supplementary systems: Status of the auxiliary heater	Permanently activated	This is for performance prediction.
Temperature of integrated auxiliary heating	52,5 °C (minimum temperature taking into account hysteresis)	Or a higher temperature, if recommended by the manufacturer
CLIMATE		
Reference locations	Stockholm, Würzburg, Davos, Athens	In the reporting form, the performance of a different location of choice may also be given.
Climate Data	For Stockholm: CEC Test Reference Year; for Davos, Würzburg and Athens: Test Reference Year	
DOMESTIC HOT WATER LOAD		
Daily load pattern	For all systems: ((*is to be adapted to the European tapping profile*)) — 100 % at 6 h after solar noon; the explicit tapping times (CET [1]) in decimal syntax for the reference locations are: Stockholm (17.80), Würzburg (18.34), Davos (18.35), Athens (18.42) (see, e.g. [17]) For testing, the load patterns shall be as specified in the test procedure.	
Mains water supply temperature	See A.3	For testing, the temperature shall be as specified in the test procedure.
Desired (mixing valve) temperature	45 °C	If the daily or yearly loads are calculated in terms of energy, this energy shall be calculated using the mains water supply temperature and the desired temperature.
Daily load volume	The load volumes in litres per day shall be chosen from the following series: 50 l/d, 80 l/d, 110 l/d, 140 l/d, 170 l/d, 200 l/d, 250 l/d, 300 l/d, 400 l/d, 600 l/d. If larger loads are required, the series may be extended by repeatedly multiplying by the square root of 2 and rounding to the nearest multiple of 10.	
	The manufacturer shall give a design load for the system. The nearest value given in the above series shall be used, as well as the next lower and higher values. It is recommended to use all lower and higher values from the series, which are between 0,5 and 1,5 times the design load. NOTE Fixed load volumes have been chosen to facilitate comparison of the performance of different systems. For testing, the load volumes shall be as specified in the test procedures.	
Draw-off flow rate	10 l/min	If the maximal design draw-off flow rate of the system is less than 10 l/min, the maximum design draw-off rate of the system shall be used.
SPACE HEATING LOAD		
Hourly values	For Stockholm, Davos, Würzburg and Athens: based on flow and return temperatures and mass flow rate of the space heating loop (see A.4)	

1) CET = Central European Time.

A.2 Pipe diameter and insulation thickness

If the pipe and insulation for the collector circuit are delivered with the system, or the pipe diameter and the insulation thickness to be used for the collector circuit are clearly specified in the installation manual for the system, the delivered hardware or the specified values shall be used.

When piping and insulation are not delivered with the system or clearly specified, the pipe diameter, the pipe thickness and the insulation thickness and thermal conductivity given in Table A.2 shall be used for forced-circulation systems.

The material for the collector circuit piping shall be copper, unless specified otherwise in the installation manual.

Table A.2 — External pipe diameter and insulation thickness for forced-circulation systems

Flow rate in collector circuit l/h	External pipe diameter [a] mm	Pipe thickness mm	Thickness of one-layer insulation [b] mm
< 90	10	1	20
90 to 140	12	1	20
140 to 235	15	1	20
235 to 405	18	1	20
405 to 565	22	1	20
565 to 880	28	1	30
880 to 1 445	35	1,5	30
1 445 to 1 500	42	1,5	39
> 1 500	Such that the flow velocity is approximately 0,5 m/s	1,5	as the internal pipe diameter

NOTE Based on a thermal conductivity of (0,04 ± 0,01) W/(m × K) for temperature at 10 °C.

[a] Tolerance 1 mm.

[b] Tolerance 2 mm.

A.3 Calculation of mains water temperature at reference location

The mains water temperature shall be calculated according to Formula (A.1):

$$\vartheta_{\text{cw}} = \vartheta_{\text{average}} + \Delta\vartheta_{\text{amplit}} \sin\left(2\pi\left(Day - D_{\text{s}}\right)/365\right) \qquad \text{(A.1)}$$

The yearly average mains water temperature ($\vartheta_{\text{average}}$), average amplitude of seasonal mains water temperature variations ($\Delta\vartheta_{\text{amplit}}$) and shift term ($D_{\text{s}}$) given in Table A.3 shall be used for the reference locations.

Table A.3 — Data for calculation of the mains water temperature at the reference locations

Reference location	$\vartheta_{average}$ °C	$\Delta\vartheta_{amplit}$ °C	D_s d
Stockholm	8,5	6,4	137
Würzburg	10,0	3,0	137
Davos	5,4	0,8	137
Athens	17,8	7,4	137

A.4 Space heating load

A.4.1 General

This clause contains information about the annual space heating load for the locations of Stockholm, Davos, Würzburg and Athens. The building related to the space heating load is described and the space heating load is specified on the basis of hourly values of the flow and return temperatures as well as the mass flow rate of the space heating loop.

For the calculation of the heat load following properties of water shall be used:

— density: 992,42 kg/m^3;

— specific heat capacity: 4,181 kJ/(kg × K).

A.4.2 Stockholm

The reference building used for the determination of the space heating load for Stockholm represents a typical Swedish single family house with a thermal insulation according to the present (year 2005) standard (Boverkets Byggregler).

The annual space heating load of the Stockholm reference building sums up to 14 960 kWh/a. Nominal indoor temperature is 20 °C and dimensioning outdoor temperature is -20 °C.

The building is characterised by the following data:

— living area: 140 m²;

— window area: 38 m²;

— windows: U-value: 1,75 W/(m² × K);

— outwall: U-value: 0,34 W/(m² × K);

— outwall area: 125 m²;

— bottom: U-value: 0,27 W/(m² × K), area: 70 m²;

— blanket: U-value: 0,24 W/(m² × K), area: 70 m²;

— air change rate: 0,5/h.

An excerpt of this space heating load file for Stockholm is given in Table A.4.

Table A.4 — Space heating load file for Stockholm

Hour of year h	Flow temperature °C	Return temperature °C	Mass flow rate kg/h
1,0	32,60	26,19	336,4
2,0	32,60	26,95	296,2
3,0	31,64	26,73	332,5
4,0	30,67	26,55	381,7
5,0	29,63	26,15	422,6
6,0	30,06	26,47	451,1
7,0	30,76	27,00	465,1
8,0	30,94	27,20	474,3
9,0	30,41	26,95	485,5
10,0	29,28	26,26	499,2
....		...	...
8 760	34,61	30,10	547,2

A.4.3 Davos

The reference building used for the determination of the space heating load for Davos represents a typical single family house with a thermal insulation according to the Swiss building code (SIA380/1:2001; "Grenzwert").

The annual space heating load of the Davos reference building sums up to 11 753 kWh/a (or 300 MJ/a per square metre net heated floor area).

The building is characterised by the following data:

— living area: 140 m²;

— window area: south 12 m², north 3,0 m², west and east 4,0 m²;

— windows: U-value: 1,4 W/(m² × K), G-value 62 %;

— outwall: U-value: 0,28 W/(m² × K);

— outwall area: south 55,0 m², north 64,0 m², west and east 44,0 m²;

— bottom: U-value: 0,27 W/(m² × K), area: 79 m²;

— air change rate: 0,4/h.

An excerpt of this space heating load file for Davos is given in Table A.5.

Table A.5 — Space heating load file for Davos

Hour of year h	Flow temperature °C	Return temperature °C	Mass flow rate kg/h
1,0	34,80	29,00	424,0
2,0	34,50	29,00	445,0
3,0	34,20	29,00	469,0
4,0	34,20	29,10	491,0
5,0	34,30	29,20	502,0
6,0	34,10	29,20	506,0
7,0	34,10	29,20	518,0
8,0	34,10	29,40	542,0
9,0	34,20	29,40	523,0
10,0	34,30	29,40	522,0
....		...	...
8 760	35,20	29,10	417,0

A.4.4 Würzburg

The reference building used for the determination of the space heating load for Würzburg represents a typical German single family house with a thermal insulation according to German building technology in 2005.

The annual space heating load of the Würzburg reference building sums up to 9 090 kWh/a.

The building is characterised by the following data:

- living area: 128 m²;
- window area: south 10 m², north 3 m², west and east 3,5 m²;
- windows: U-value: 1,4 W/(m² × K), G-value 63 %;
- outwall: U-value: 0,19 W/(m² × K);
- outwall area: south 36,1 m², north 43,1 m², west and east 31,3 m²;
- bottom: U-value: 0,41 W/(m² × K), area: 64 m²;
- blanket: U-value: 0,21 W/(m² × K), area: 64 m²;
- air change rate: 0,6/h.

An excerpt of this space heating load file for Würzburg is given in Table A.6.

Table A.6 — Space heating load file for Würzburg (1 of 2)

Hour of year h	Flow temperature °C	Return temperature °C	Mass flow rate kg/h
1,0	38,42	0,00	0,00
2,0	38,14	0,00	0,00
3,0	38,14	0,00	0,00
4,0	38,05	0,00	0,00
5,0	38,01	20,02	241,63
6,0	38,09	25,55	317,44
7,0	38,23	27,69	328,38
8,0	38,32	28,37	328,38
9,0	38,42	28,60	328,38
10,0	38,43	28,74	306,39
11,0	38,23	28,46	283,60
12,0	37,95	28,20	272,96
13,0	37,77	28,00	264,04
14,0	37,81	27,88	257,69
15,0	38,05	27,58	232,72
16,0	38,38	26,72	193,62
17,0	38,65	25,74	163,03
18,0	38,75	24,91	143,23
19,0	38,61	24,34	134,83
20,0	38,23	23,97	134,88
21,0	37,77	23,83	140,42
22,0	37,39	23,88	147,67
23,0	37,29	0,00	0,00
24,0	37,53	0,00	0,00
25,0	37,86	0,00	0,00
26,0	38,04	0,00	0,00
27,0	38,09	0,00	0,00
28,0	38,09	0,00	0,00
29,0	38,09	22,24	261,83
30,0	38,14	26,37	320,82
31,0	38,33	27,98	328,38

Table A.6 — Space heating load file for Würzburg (2 of 2)

Hour of year h	Flow temperature °C	Return temperature °C	Mass flow rate kg/h
32,0	38,66	28,57	325,73
33,0	39,03	28,71	304,52
34,0	39,31	28,67	289,45
35,0	39,40	28,59	278,59
36,0	39,32	28,50	270,61
37,0	39,13	28,39	265,09
38,0	38,94	28,24	256,30
39,0	38,75	27,55	221,77
40,0	38,61	26,61	191,73
41,0	38,57	25,83	172,55
42,0	38,57	25,27	161,93
43,0	38,57	24,96	158,76
44,0	38,61	24,76	161,02
45,0	38,75	24,78	165,56
46,0	38,98	24,90	169,82
47,0	39,36	0,00	0,00
48,0	39,88	0,00	0,00
49,0	40,44	0,00	0,00
50,0	40,95	0,00	0,00
51,0	41,32	0,00	0,00
52,0	41,55	0,00	0,00
53,0	41,83	22,41	265,23
54,0	42,25	27,69	326,07
55,0	42,67	29,56	328,38
56,0	42,99	30,18	328,38
...	...	...	...
...	...	...	...
...	...	...	...
8 760,0	37,58	0,00	0,00

A.4.5 Athens

The reference building used for the determination of the space heating load for Athens represents a typical Greek single family house also mentioned in the corresponding Greek standard (Building type L).

The annual space heating load of the Athens reference building sums up to 8 125 kWh/a.

The building is characterised by the following data:

- living area: 162,5 m²;
- window area: 34,2 m²;
- windows: U-value: 2,8 W/(m² × K);
- outwall: U-value: 0,6 W/(m² × K);
- outwall area: 161,0 m²;
- bottom: U-value: 1,6 W/(m² × K), area: 162,5 m²;
- blanket: U-value: 0,4 W/(m² × K), area: 162,5 m²;
- air change rate: 1,0/h.

An excerpt of this space heating load file for Athens is given in Table A.7.

Table A.7 — Space heating load file for Athens – Example to be updated

Hour of year h	**Flow temperature** °C	**Return temperature** °C	**Mass flow rate** kg/h
1,0	32,60	26,19	336,4
2,0	32,60	26,95	296,2
3,0	31,64	26,73	332,5
4,0	30,67	26,55	381,7
5,0	29,63	26,15	422,6
6,0	30,06	26,47	451,1
7,0	30,76	27,00	465,1
8,0	30,94	27,20	474,3
9,0	30,41	26,95	485,5
10,0	29,28	26,26	499,2
....		...	...
8 760	34,61	30,10	547,2

Annex B
(normative)

Additional information regarding the calculation of the fractional energy savings

B.1 Definition of a conventional reference water heating system

The definition of the reference system as used for the calculation of the fractional energy savings of a solar heating system (see 7.7.4) is based on following assumptions.

— The reference system is a conventional water heating system with store;

— The size of the store is 0,75 times the daily load volume:

$$V_{\mathrm{S,conv}} = 0{,}75\ V_{\mathrm{d}} \tag{B.1}$$

— The yearly heat losses of the store are

$$Q_{\mathrm{l,conv}} = (UA)_{\mathrm{S,conv}}\left(\vartheta_{\mathrm{S}} - \vartheta_{\mathrm{S,amb}}\right) 8\,760\,\mathrm{h} \tag{B.2}$$

with a heat loss capacity rate according to EN 12977-1:2012, 6.4.7

$$(UA)_{\mathrm{S,conv}} = 0{,}16\sqrt{V_{\mathrm{S,conv}}} \tag{B.3}$$

and ϑ_{S} and $\vartheta_{\mathrm{S,amb}}$ according to the reference conditions in Annex A.

— The gross energy demand Q_{conv} is derived by taking into account the overall generation efficiency of the conventional heating system η_{conv}:

$$Q_{\mathrm{conv}} = \left(Q_{\mathrm{d}} + Q_{\mathrm{l,conv}}\right) / \eta_{\mathrm{conv}} \tag{B.4}$$

where

$\eta_{\mathrm{conv}} = 0{,}75$.

B.2 Calculation of fractional energy savings for other conditions

The savings of fuel or electricity can be derived for national conditions taking into account the overall generation efficiency η_{conv} and the store losses $Q_{\mathrm{l,conv}}$ of the conventional heating system as well as the overall generation efficiency of the auxiliary heater of the solar heating system η_{aux}. Energy savings may then be calculated as follows:

$$Q_{\mathrm{sav}} = Q_{\mathrm{conv}} - Q_{\mathrm{aux}} = \left(Q_{\mathrm{d}} + Q_{\mathrm{l,conv}}\right) / \eta_{\mathrm{conv}} - Q_{\mathrm{aux,net}} / \eta_{\mathrm{aux}} \tag{B.5}$$

Values for η_{conv}, $Q_{l,conv}$ and η_{aux} can be given for many widely used types of conventional heating systems and auxiliary heating systems which are typically used in a country. This can be systems with and without store, wood-, gas- or oil-fired systems or electrical heaters. The national conventions can be taken into account when specifying these figures.

It is also possible to take into account two different overall efficiencies for the heaters during summer and winter operation.

For systems in which the auxiliary heater is integral part of the solar heating system, it is recommended to determine additionally the efficiency of the built-in heater and to calculate the fractional energy savings in terms of primary energy for national conditions.

Annex C
(informative)

Short-term system testing

C.1 General

NOTE The two test methods presented in this annex have only been validated, so far, by two laboratories, at the Danish Technological Institute DTI and at the Chalmers University of Technology Göteborg ([9], [14]). DTI is confident that the procedures are promising and very efficient. However, the full verification and a round robin test within Europe are urgently needed.

The objective of short-term system testing is to estimate the long-term system performance.

A system inspection should be performed and any error detected should be corrected before the beginning of the short-term system test (see, e.g. [6]).

In principle, two approaches for short-term system testing are referred in this document:

a) the check of short-term system performance;

b) a short-term test for long-term system performance prediction.

Both approaches are applicable to systems including auxiliary heating only in the case that heat contribution by auxiliary source can be measured with an accuracy of at least 5 %.

The first test method is a simplified one. A check of the system performance is carried out by comparing the measured solar heating system gain with the one predicted by simulation using the actual weather and operating conditions as measured during the short-term test.

By the second test method, performance of the most relevant components of the solar heating system is measured for a certain time period while the system is in normal operation. These detailed measurements include the energy gain of the collector array(s) and the energy balance of the store(s). Comparing the observed and simulated energy gives a validation of collector and storage design parameters and the measured data for the collector array are also used for direct identification of the collector array parameters. When the parameters of the components are verified, the long-term prediction of the system gain is enabled as well as a detection of possible sources of system malfunctioning.

C.2 Instrumentation, data acquisition and processing

C.2.1 General

C.2.1.1 Introduction

This clause includes instructions and recommendations on instrumentation, data acquisition and processing to be applied if any of the measurements described in this annex are carried out.

NOTE If possible, these instructions and recommendations should be reviewed already at system design time, and used to minimise the test expenses and maximise the outcome of the test.

C.2.1.2 Location of sensors

Sensors designated to take data for irradiance, surrounding air speed and ambient air temperatures should be mounted as described in C.2.1.3 to C.2.1.8.

C.2.1.3 Pyranometer for hemispherical irradiance

The pyranometer for the measurement of the hemispherical irradiance should be installed at the same geometrical plane as the collector array. It should be installed near the upper part of the collector array. If more arrays are situated on a different orientation, the test engineer has to decide whether irradiance will be measured for each array or computed on the basis of measurements on the horizontal plane.

C.2.1.4 Pyranometer for diffuse irradiance

The pyranometer for the measurement of the diffuse solar irradiance should be installed in the same geometrical plane as the collector array. It should be installed near the upper part of the collector array in the vicinity of the pyranometer measuring hemispherical irradiance.

For collector arrays situated significantly off-south (azimuth is off-south by more than 10°) the diffuse irradiance should be measured at the horizontal plane instead of the tilted plane together with an additional pyranometer used for measuring the global irradiance (i.e. on horizontal plane). The fraction of diffuse irradiance at the tilted plane is then to be computed based on the measured fraction at the horizontal plane.

C.2.1.5 Ambient air temperature

The ambient air temperature in the vicinity of the collector array should be measured, if possible, using a shaded and ventilated sensor approximately 1 m above the array, not closer than 1,5 m to the collector array and not further away than 10 m away from the array.

The sensor measuring the ambient air temperature in the vicinity of storage unit(s) should be situated in a manner to be shielded from heat radiation sources such as stores, lights, auxiliary heaters, etc.

C.2.1.6 Fluid temperatures

The sensors for measuring the fluid temperature should be located as close as possible to the inlet and outlet of the collector array and respective storage loop inlet(s)/outlet(s). Mixing devices mixing the fluid before the sensor are recommended. The piping between measurement points and the collector array or the storage respectively, should be properly insulated.

NOTE Measurement accuracy increases if the sensors are so close to the array (or to the storage) that they are thermally coupled to the array (or to the storage) even when there is no fluid circulation.

C.2.1.7 Volumetric flow meter

The volumetric flow meter should directly be installed in the loop's coldest part (e.g. mains cold water line, or for the collector loop, the collector array).

The additional pressure drop introduced by the flow meter and its connecting pipes should be negligible compared to the pressure drop in the remaining of the hydraulic loop, so that the flow rate is the same with and without the flow meter.

C.2.1.8 Anemometer

The surrounding air speed should be measured on a flat surface (minimum dimension: 1 m × 1 m) fixed in the same plane as the collector array front cover. The anemometer should be positioned at a height approximately equal to the height of the centre of the collector array. The height of vanes should be 15 cm above the surface to which the anemometer is mounted. The anemometer should be located as close as possible to the collector array, the distance should not exceed 1 m.

C.2.2 Accuracy and calibration of sensors

The requirements on sensor accuracy stated in ISO 9459-5 should be fulfilled and the calibration procedures described in that standard should be followed.

C.2.3 Data acquisition and processing

The data specified in Table C.1 and Table C.2 should be measured and recorded by the data logger. All measured data during a test sequence should be recorded with time intervals not exceeding the values specified in Table C.1 or Table C.2.

C.3 Check of short-term system performance

C.3.1 Principle

The principle of the method is indicated in Figure C.1.

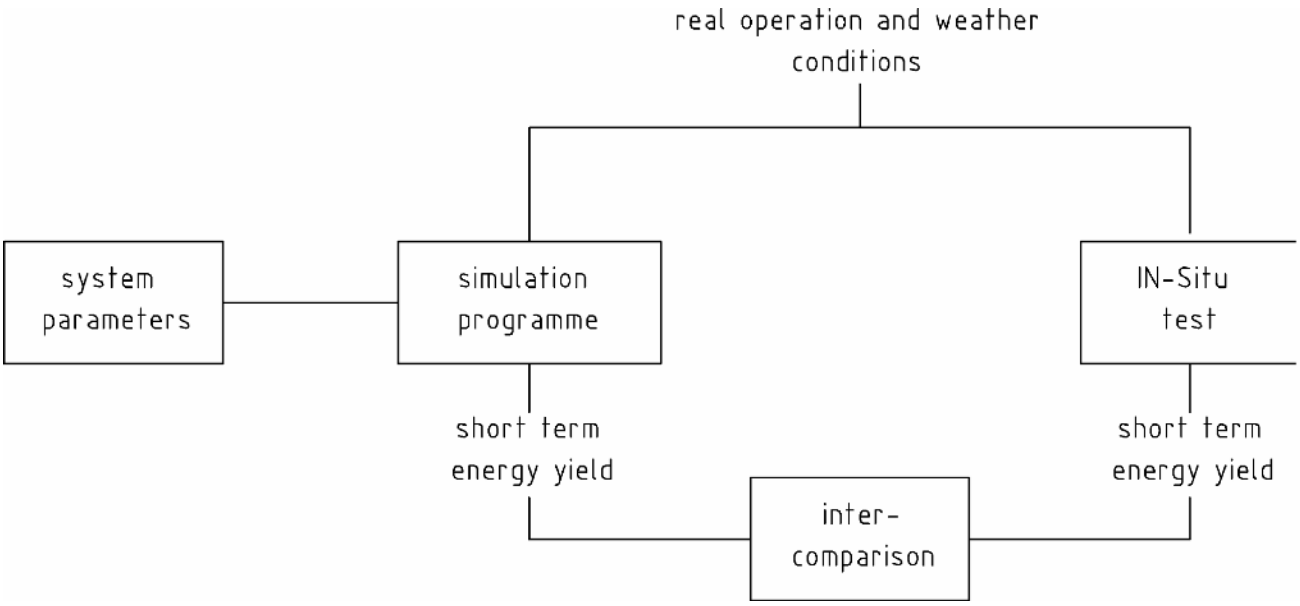


Figure C.1 — Principle of the short term system performance check: Check and intercomparison of useful energy gain

The principle of this method is to compare the measured output of the solar heating system with the output predicted by a simulation program.

The components parameters required for simulation of system performance are derived from the system documentation or the manufacturer's data. If they are not available, they can be estimated. The simulation should be carried out using weather data and solar heating system operating conditions (draw-off profile, mains water temperature, etc.) as occurred during the measuring period.

NOTE The main advantage of this method is that expensive measurements are avoided. Therefore, it is appropriate to use it for smaller systems where the cost of the test is the most critical factor.

The measurement of data as requested in C.3.2.2. should be carried out continuously until the criteria for termination of the measurement, as indicated in C.3.3, are met. The measurement should take place under "operation conditions" of the system. "Operation conditions" are defined as follows:

— for solar water heating systems: The consumer daily draw-off volume is between 50 % and 150 % of the corresponding daily draw-off volume as expected for the system and/or as predicted by the solar heating system designer;

— for solar space heating system: The solar space load is between 50 % and 150 % of the corresponding load as expected for the system under particular weather conditions and house occupancy.

This method is applicable for solar-preheat systems (e.g. systems without auxiliary energy source inside the storage) and for storage without a circulation loop.

However, the systems with auxiliary heat source and circulation loop may be treated in a similar way if the following is assured:

— the uncertainty of measurement for the auxiliary heating should be better than 2 % if immersed electrical heaters are used. For other types of auxiliary heating the uncertainty should be better than 5 %;

— the uncertainty of measurement for the heat loss power in a circulation loop should be better than 3 %;

— the circulation loop is not connected to the solar (part of the) store, hence heat from auxiliary heating cannot be transferred to the solar (part of the) store.

C.3.2 Measurement of the system energy gain

C.3.2.1 Conditioning

For the dynamic simulation of the system performance, the initial energy content of the store (i.e. the mean store temperature) is one of the required inputs. As measurements inside the store should be avoided, the initial state of the store may be found by forced store conditioning or it may be estimated on the basis of fluid temperature measurements at the collector inlet (piping leaving the lower part of the storage vessel) and the draw-off inlet/outlet (for hot water heating systems).

In order to minimise the influence of the error in determination of the initial energy content of the store(s), conditioning should be performed, whenever possible, prior to the measurement sequence.

The conditioning period encompasses the withdrawal of at least three storage volumes. The withdrawal should be carried out by night or during day periods with low hemispherical irradiance, i.e. less than 200 W/m².

NOTE Due to high water costs, conditioning should be avoided whenever the initial energy status of the store can be approximately estimated – e.g. if the daily load consumption exceeds the storage volume and after several (two to three) days of proceeding measurements the daily irradiation was lower than 5 MJ/(m² × d).

Conditioning applies only if the store volume is less than 5 m³. If conditioning is not carried out, the initial energy state of the store(s) should be estimated using the store draw-off temperature and the collector fluid inlet temperatures by means of the particular storage model (i.e. taking into account the stratification effect).

C.3.2.2 Measurements

The measurement data indicated in Table C.1 should be continuously recorded on a data logger.

Table C.1 — Variables to be measured and corresponding maximum sampling intervals

Symbol	Unit	Variable	Maximum sampling interval s
ϑ_{cw}	°C	mains water temperature	5
ϑ_S	°C	storage draw-off temperature	5
$\dot{V}_s$	m³/s	volume draw-off flow rate from storage	5
G_g, G_h	W/m²	global or hemispherical solar irradiance	5
G_d	W/m²	diffuse solar irradiance	5
ϑ_a	°C	collector ambient air temperature	30
$\vartheta_{S,amb}$	°C	store ambient air temperature	30
P_{aux}	W	auxiliary power	5
P_{rc}	W	circulation heat loss power	5
NOTE Integrating instruments should be applied for auxiliary power, circulation losses and draw-off quantities.			

C.3.3 Criteria for termination of the test

For termination of the test, the following criteria should be met:

— the irradiation integrated over the measurement sequence should be greater than 150 MJ/m²;

— at least 50 % of irradiation should occur during the time intervals with an irradiance exceeding 500 W/m².

Due to the possible error in estimation of the initial energy content of the store, the two first days of measurements should not be taken into account.

C.3.4 Simulation of the system useful energy gain using components data

The performance of the system can be predicted by means of a validated simulation program.

The store and collector parameters should be available in the system documentation.

If data for other system components such as piping, external heat exchanger, etc. are not included in the system documentation, those data given by the manufacturer should be used. If data are not available, they may be estimated.

The performance of the system, e.g. the useful energy gain, can be predicted for weather and load conditions as observed over the monitoring period.

C.3.5 Comparison of measured with simulated data

The useful energy gain delivered by the store over the test period should be compared with the observed data on daily basis.

The solar heating system under test is considered to behave as predicted by the simulation program if the difference (on the basis of daily values) between the observed and predicted system power does not exceed 10 %.

As errors in estimation of the initial energy status of the store may occur, the first three days of measurements should not be taken into account.

The comparison on a daily basis should be done only for days at which error in estimation of the initial energy status of the store at the beginning of measurement sequence may be neglected and, additionally, if the daily irradiation exceeds 15 MJ/m^2.

Finally, the difference between predicted and measured useful energy gain over the complete monitoring period (excluding the first three days as mentioned above) should not exceed 10 % in relation to the observed energy gain.

C.3.6 Test report

The test report should include the following items:

a) detailed description of components and system configuration;

b) prediction method used: the simulation program used should be specified and an input file enclosed;

c) weather data and space heating load and/or hot water demand profile: the file(s) containing data concerning monitoring of the system performance should be enclosed;

d) predicted solar energy output of the solar heating system: the daily predicted output (by the simulation program) as well as the observed one should be presented by graph and table;

e) list of the measuring equipment and sensors, with the corresponding accuracy;

f) interpretation of possible reasons for discrepancy of the predicted and observed power.

C.4 Short-term test for long-term system performance prediction

C.4.1 General

The performance of large solar hot water and/or space heating systems depends on their design parameters and on various weather and operating conditions, e.g. irradiance, ambient temperature, wind speed, and fluid inlet temperature.

In order to evaluate long-term system performance and detect sources of system malfunctioning, it is primarily necessary to

a) check the energy delivered by the collector array,

b) check the energy balance over the storage vessel(s) and, if possible,

c) identify the most important system parameters.

NOTE Ideally, both collector and storage parameters would be identified under in-situ conditions. Unfortunately, the state-of-the-art does not allow accurate and repeatable results of in-situ test of the storage vessels. Therefore, in this Standard the short-term system test is limited to the above points a) and b) and the identification of the collector array parameters only.

The storage simulation model is verified by checking the storage energy balance while the collector array parameters are identified directly. With the identified collector parameters and the validated storage model, both an accurate prediction of long-term system performance and a detection of sources of system malfunctioning are possible.

For more information, see [14].

C.4.2 Principle

The principle of the method is indicated in Figure C.2.

Measurement data should be collected under non-stationary operation. A wide range of operation conditions representative for the system being tested should be covered.

Measurement of data as requested in C.4.3.2 should take place continuously over a certain time interval until the criteria for termination of the measurement, indicated in C.4.4, are met. The measurement should be carried out under "operation conditions" of the system, according to C.3.1.

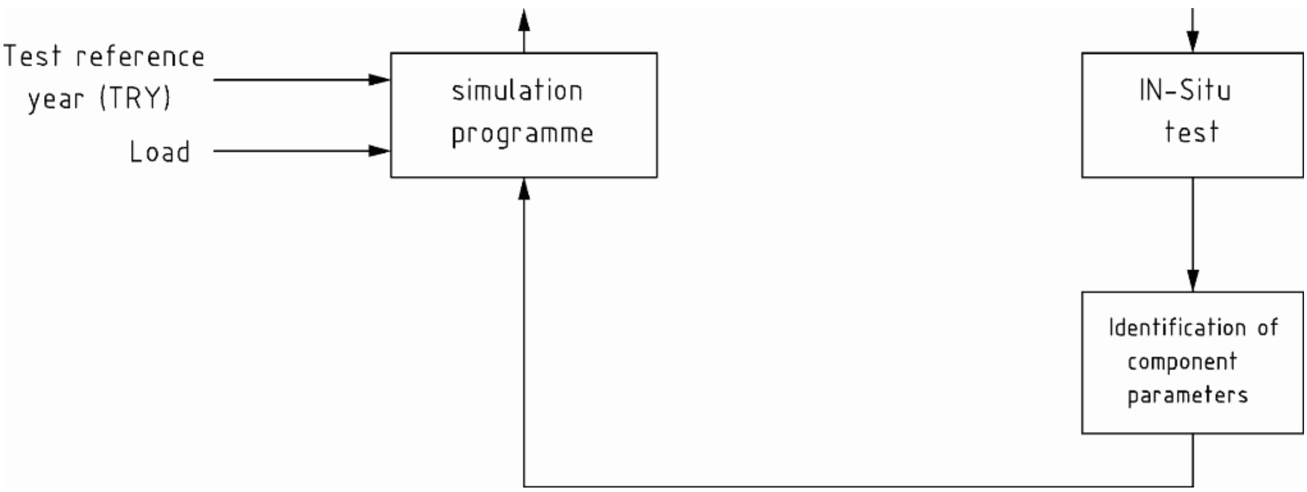


Figure C.2 — Principle of the short-term test and of the subsequent long term system performance prediction

After the criteria for termination of the test have been met, the collector array parameters should be identified. The identified parameters are thereafter used for the prediction of the long-term performance of the system. Local input data are hourly values of meteorological data, which are available, e.g. from test reference year (TRY), and the load data specific for the system being tested.

C.4.3 Measurements

C.4.3.1 Conditioning

See C.3.2.1.

C.4.3.2 Procedure

During the monitoring period, the measurement data indicated in Table C.2 should be continuously recorded.

Table C.2 — Variables to be measured during system test, and corresponding maximum sampling intervals

Symbol	Unit	Variable	Maximum sampling interval s
ϑ_{cw}	°C	mains water temperature	5
ϑ_{S}	°C	store draw-off temperature	5
ϑ_{rci}	°C	fluid temperature at circulation loop inlet	5
ϑ_{rce}	°C	fluid temperature at circulation loop outlet	5
ϑ_{ci}	°C	collector fluid inlet temperature	5
ϑ_{co}	°C	collector fluid outlet temperature	5
$\dot{V}_{c}$	m³/s	volume flow rate in collector loop	5
$\dot{V}_{rc}$	m³/s	volume flow rate in circulation loop	5
$\dot{V}_{s}$	m³/s	volume draw-off flow rate from store	5
G_{h}	W/m²	hemispherical solar irradiance on tilted plane	5
G_{g}	W/m²	global solar irradiance on horizontal plane (optional)	5
G_{d}	W/m²	diffuse solar irradiance on tilted plane	5
ϑ_{a}	°C	collector ambient air temperature	30
$\vartheta_{S,amb}$	°C	store ambient air temperature	30
v	m/s	surrounding air speed	10
P_{aux}	W	auxiliary power	1
NOTE Integrating instruments should be applied for auxiliary power and flow rates.			

The values needed for determination of the system power, such as temperature difference, volume draw-off flow rate and auxiliary power should be obtained with a period not exceeding 1 s. The data for other variables should be obtained with periods of at least 30 s for further processing.

The sampled values should be continuously integrated and averaged.

The integrated values for each variable should be computed over a recording interval and stored.

The maximum recording interval is 1 min. The data recording interval may vary during the measurement sequence.

The monitoring of the collector array and collecting of data should be continued until the criteria for termination of the test as described in C.4.4 are met.

C.4.4 Criteria for termination of the test

In order to be able to check the store energy balance and the collector array energy gain, it is necessary to collect data continuously over a certain time period with reasonably good weather conditions.

The first criterion for termination of the test applies to weather requirements during the test.

The weather conditions which should prevail during the test are the following:

a) the irradiation integrated over the test should be higher than 200 MJ/m²;

b) the total time with irradiance exceeding 500 W/m² should exceed 50 % of the total test period.

The second criterion applies to the collector operation conditions necessary for accurate identification of the collector parameters.

These general operation conditions are fully represented by four driving variables:

c) the difference between the mean collector fluid temperature, ϑ_m, and the collector ambient air temperature, ϑ_a;

d) the reduced temperature $T^* = (\vartheta_m - \vartheta_a)/G_h$;

e) the surrounding air speed;

f) the angle of incidence of the direct solar radiation on the collector plane.

The wind speed range depends on the climate where the system under test is located. The range scanned during the test should be representative for that climate.

The requested ranges of variation for other driving variables are listed in Table C.3.

Table C.3 — Range of variations of the driving variables to be scanned during a test outdoors

Driving variable	Requested range of variation
$\vartheta_m - \vartheta_a$ (while G_h > 500 W/m²)	10 K to 45 K or 65 K [a]
reduced temperature T^* (G_h > 500 W/m²)	0,02 m² × K/W to 0,12 m² × K/W or 0,2 m² × K/W [a]
angle of incidence of direct solar radiation	10° to 70°
[a] Whenever possible, the requested range of variation should be extended up to that value.	

C.4.5 Identification of collector array parameters

The theoretical model of the collector ("dynamical collector test model") should be used as defined in EN 12975-2.

The identification of the parameters of the theoretical model should be carried out by an appropriate mathematical tool for identification of parameters as defined in EN 12975-2 ("dynamical collector test model").

The collector array parameters determined by the parameter identification program should be listed together with the associate standard deviations.

C.4.6 Criteria for the acceptance of the test results

C.4.6.1 General

The main aim of the test is to enable a prediction of the long-term system performance under actual weather and load conditions.

Incorrect predictions of long-term system performance are mostly caused by

a) incorrect computation of irradiance on the tilted plane,

b) the collector array does not deliver the energy expected by the designer, and

c) the in-situ storage performance does not correspond to the designed one.

In order to eliminate these possible sources of error, the basic criteria for acceptance of the test results given in C.4.6.2 to C.4.6.4 should be fulfilled.

If one of these criteria is not met, the corresponding simulation model should be checked. If the simulation model is correct, and no error is detected in the operation of the system, the test should be prolonged for two additional days (daily irradiation exceeding 12 MJ/(m² × d)). This procedure should be repeated until the criteria are met.

C.4.6.2 Solar irradiance on the tilted plane

Only the days where the irradiation exceeds 12 MJ/(m² × d) should be considered.

C.4.6.3 Collector array

The energy delivered by the collector (on the daily basis) should not differ by more than 10 % from the energy predicted by the collector array design parameters over the operational conditions during the test period.

In addition, the identified collector parameters should be accurately determined. The identified parameters are acceptable if the standard deviations do not exceed the following values:

— 15 % for the overall heat loss coefficient of collector array U_L;

— 20 % for the incidence angle modifier $K_{\tau\alpha}$;

— 10 % for the collector array thermal capacity C_c;

— 3 % for the zero loss efficiency of collector array η_o.

If the standard deviations of any of the identified parameters listed in Table C.4 exceed their permissible values the identification procedure should be repeated using reasonable assessed values for these parameters in EN 12975-2:2006, Formula (32). Hence, the remaining parameters only should be calculated by the identification procedure.

Table C.4 — Permissible standard deviation for secondary collector parameters

Parameter	Symbol [a]	Permissible standard deviation
Temperature dependence of the overall heat loss coefficient	C_2	15 %
Wind speed dependence of the overall heat loss coefficient	C_3	15 %
Sky temperature dependence of the overall heat loss coefficient	C_4	15 %
Wind speed dependence of the zero loss collector efficiency	C_6	15 %

[a] According to EN 12975-2:2006, 6.3.4.8.2, Formula (32).

C.4.6.4 Store

Energy drawn off from store (on a daily basis) should not differ by more than 10 % from the energy predicted using the store design parameters over the particular operational conditions during the test period. Here, the energy delivered by the collector array is used as a measured input variable.

C.4.6.5 Final check

After the criteria in C.4.6.2 to C.4.6.4 are met, the complete solar heating system model should be validated comparing the measured with the predicted useful energy gain and using the following data:

— component data;

— weather data (the irradiance on the horizontal plane should be used);

— the load conditions as occurred during the validation test.

The energy predicted by simulation should not differ by more than 10 % from the measured energy output on a daily basis.

C.4.7 Test report

The test report should include

a) a detailed description of the system under test,

b) a detailed description of the test installation and instrumentation specifications (manufacturer, accuracy),

c) a graphical presentation of the measured energy gain of the collector array, as well as that predicted using the collector design parameters,

d) a graphical presentation of the measured energy delivered to the user from the storage vessel(s) as well as that predicted using the storage design parameters,

e) the identified parameters of the collector array with associate standard errors and their correlation matrix, if available. A comparison with the design collector array parameters should be stated as well,

f) data files and the file(s) resulting from the statistical data evaluation on a data storage medium (e.g. diskette, …).

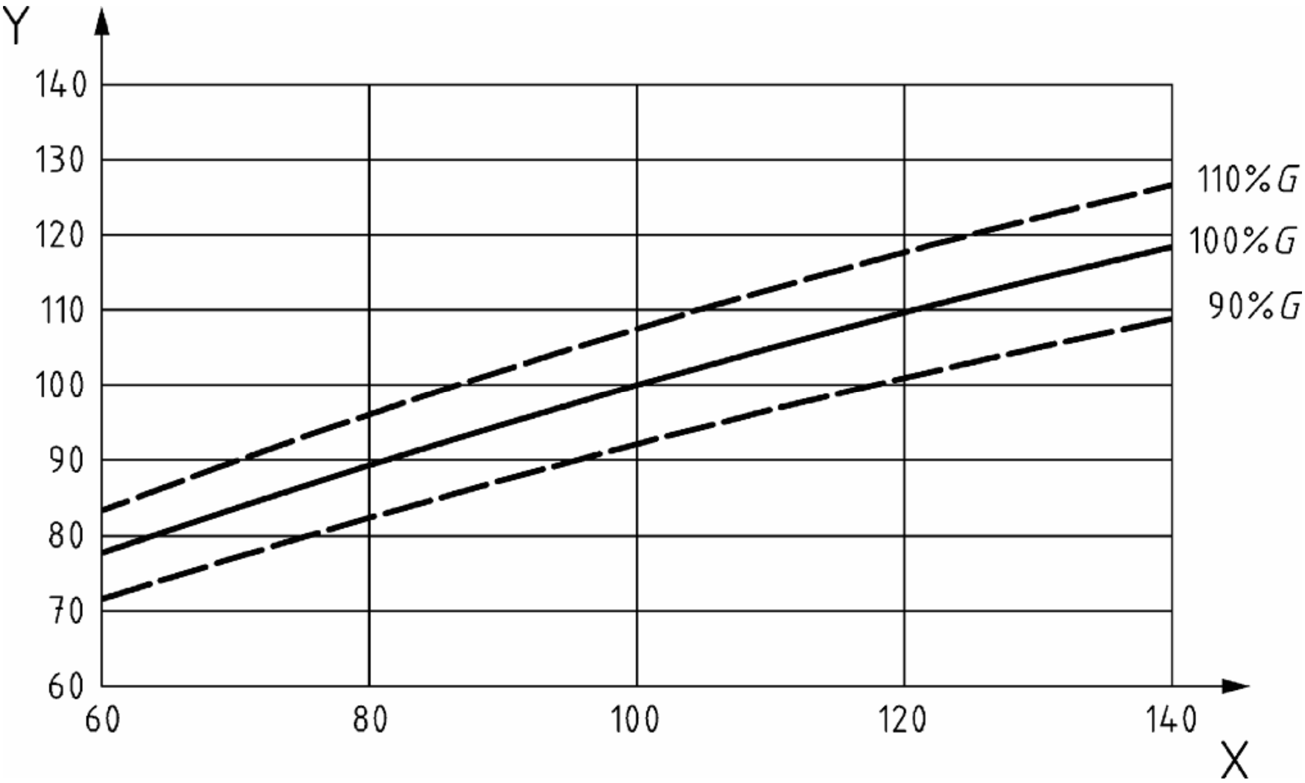
NOTE Clause 8 gives additional information on the contents of the test report.

C.4.8 Prediction of the yearly system gain

On the basis of the component data (either by in-situ measurement or manufacturer data) the detailed simulation should be performed by the same computer program as in 4.6, using actual load volume and profile and the test reference year for a particular site.

Additionally, simulation runs should be performed with the load level varying from 70 % to 120 % of the actual one and the yearly irradiation from 90 % to 110 % of that of the test reference year.

NOTE Figure C.3 gives an example of the predicted performance dependence on load level and irradiation.



Key

X-axis load scale factor in percent
Y-axis out in percent

Figure C.3 — Example of the predicted performance dependence on load level and irradiation for a solar domestic hot water heating system (see [8])

Annex D
(informative)

Long-term monitoring

D.1 General

Long-term monitoring gives the company operating the solar heating system after commissioning (referred to below as the "client") a simple supervision tool

— to determine the solar contribution to the total heat load,

— to get an indication on malfunctions or degradations of the solar heating system.

The final long-term goal is to get the maximum benefit from the initial solar investment as well as to minimize the consumption of auxiliary energy and the resulting environmental impact.

Long-term monitoring of a solar heating system is very similar to that of a common heating plant. In this annex, solar energy specific aspects are emphasized.

In order to reduce the cost of long-term monitoring as much as possible, the physical key quantities monitored should be integrated continuously, and the figures displayed by the integrators be recorded at regular time intervals (mostly in coincidence with the supervision time intervals).

The data which should be monitored includes:

— the hemispherical solar irradiance in the plane of the collector array(s);

— the total load of that part of the system to which solar energy is supplied;

— the solar contribution of the solar heating system.

The interface where the heat transferred from the solar part to the conventional part of the system (i.e. the solar contribution) is measured, should be specified individually for each system, depending on the hydraulic scheme and the control concept.

NOTE 1 It is always possible to include more physical quantities into the measuring programme, giving a higher priority to some of them according to additional supervision objectives. In that case, the additions (in comparison to this annex) should be fully documented.

Long-term monitoring starts when the expected system performance has been confirmed by the short-term system testing according to Annex C.

The monitoring procedure is described for a large custom built system with short-term storage (Class A or B according to EN 12977-1:2012, 5.2).

NOTE 2 Future updates of this European Standard may consider other system types, e.g. such with seasonal storage, when more experience on those types is available.

D.2 Evaluation chart

The evaluation chart is a diagram showing the solar contribution of the solar heating system as a function of the solar irradiation in the collector plane for different load levels. It should be used as a reference to evaluate the system performance (see D.4). The evaluation chart should be established at design time and delivered to the client with the system technical documentation. It is obtained similarly to the system energy balance and should be based on the same weather data and load assumptions (see EN 12977-1:2012, 6.8.4.2).

The evaluation chart should display different trends of solar contribution variation as a function of the load level and other possible parameters having a strong influence on the system performance.

NOTE The range of load level variation should be 70 % to 120 % of the nominal value used for dimensioning.

Weekly data are preferred in evaluation charts, as they match up to the most common time interval in use in heating plant supervision. However, daily and monthly data may also be plotted in those charts.

If monthly performance data have been obtained at design time, they may be converted to weekly average values for the corresponding months, in order to display only weekly data in the evaluation chart. Similarly, daily values may be grouped to weekly data in the evaluation chart. Finally, values from short-term testing according to Annex C, related to any time intervals, may be converted to weekly (average) values and included in the evaluation chart.

D.3 Monitoring equipment

The monitoring equipment described here is kept at the lowest possible level of instrumentation in order to minimize cost; accordingly, simple methods of evaluation have been chosen (see D.4).

More sophisticated equipment with a higher time resolution, additional physical quantities to be monitored and/or automatic data acquisition and display, is always possible. The evaluation chart should be supplemented at design time accordingly. At least all data considered in the evaluation chart should be monitored and most of the data monitored should be considered in the evaluation chart.

The simplest monitoring equipment includes

— a heat meter to measure the heat load of the system. If solar energy is supplied to a part of the system only, e.g. for hot water preparation, the load of this part should be monitored,

— a heat meter to measure the solar contribution related to the above mentioned heat load,

— an integrator of the solar irradiance in the collector plane. If different collector orientations exist within the system, the solar irradiance can be measured in the different planes and considered in evaluation charts, according to the client's wishes.

Instrumentation used in the long-term monitoring should be an integral part of the system, a part included from the very beginning of the design process. If adequately foreseen, it may also be used for adjustments at the initial operation time.

D.4 Data analysis

The monitored data should be plotted in the evaluation chart for direct visual comparison with the expected values. For their interpretation, the different load levels as well as other parameters included in the evaluation charts (see D.2) should be considered.

The system is working properly if the monitored data fit the values given by the evaluation chart within the accuracy limits agreed to by the client. If a larger discrepancy is observed, there is evidence for malfunction or degradation of the solar heating system.

Annex E
(informative)

Determination of water wastage

NOTE Currently, several procedures for the determination of water wastage are under development. A reference to an adequate procedure will be introduced in due course.

Bibliography

[1] John A. Duffie and William A. Beckman: *Solar Engineering of Thermal Processes*. Wiley-Interscience ed., 1991

[2] R. Perez, R. Stewart, C. Arbogas, R. Seals and J. Scott: *An anisotropic hourly diffuse radiation model for sloping surfaces: Description, performance validation, site dependency evaluation*. Solar energy, 36, 6, 481-497, 1986

[3] R. Perez, R. Seals, P. Ineichen, R. Stewart and D. Menicucci: *A new simplified version of the Perez Diffuse Irradiance Model for tilted surfaces*. Solar energy, 39, 3, 221-231, 1987

[4] R. Perez, P. Ineichen, R. Seals, J. Michalsky, R. Stewart: *Modelling daylight availability and irradiance components from direct and global irradiance*. Solar energy, 44, 5, 271-289, 1990

[5] R. Perez, P. Ineichen, E. Maxwell, R. Seals and A. Zelenka: *Dynamic models for hourly global-to-direct irradiance conversion*. Proc. of the ISES world congress; Vol. 2, Denver, USA, 1991

[6] U. Frei, J. Keller and R. Brunner: *Inspection Procedure for Solar Domestic Hot Water Heating Systems*. International Energy Agency, Solar Heating and Cooling Programme, Report No. T.3.E.2, edited by J.-M. Suter, April 1990 (available from the Swiss Federal Office of Energy, Bern)

[7] G. Brouwer and J.H. Liefting: *Guaranteed Solar Results for Collective Solar Hot Water Installations in the Netherlands*. EC ALTENER Project, Proceedings of the conference "EuroSun '96", 16-19.9.1996, Freiburg, Germany

[8] M. Bosanac and J.E. Nielsen: *Guaranteed Yields of Solar Hot Water Systems under Reference Conditions*. Danish Technological Institute, Final Report to ALTENER EU Project, Feb. 1996

[9] M. Bosanac and J.E. Nielsen: *In-Situ Check of Collector Array Performanc*e. Solar Energy, Vol. 59 (1997), pp. 135–142

[10] M. Bosanac, J.E. Nielsen and H.D. Stein: *Sources of the Inaccuracies of the ISO CD9459/5*. Final Report of IEA Task XIV, November 1996.

[11] DIN 43, *Elektrische Temperaturaufnehmer*, September 1987

[12] DIN IEC 751, *Industrielle Platin-Widerstandsthermometer und Platin-Messwiderstände*, December 1990

[13] BS 5918:1989, *British Standard Code of practice for Solar Heating Systems for domestic hot water*. Appendix G: "Methods of testing for differential temperature control systems"

[14] J. Dahm: *Evaluation of a Solar Heating System for a Small Residential Building Area*. Document D39:1997, Dpt. of Building Services Engineering, Chalmers University of Technology

[15] Weiss, W. (ed), Bales, Ch., Drück, H., et al.: *Solar Heating Systems for Houses, A Design Handbook for Solar Combisystems*, International Energy Agency (IEA), James & James (Science Publishes), 2003, London, ISBN: 1902916468

[16] EN 60335-2-21:2003, *Household and similar electrical appliances — Safety — Part 2-21: Particular requirements for storage water heaters (IEC 60335-2-21:2002, modified)*

[17] S. Laipple: *Influence of tapping time on system performance*. 8th Solar Keymark Network Meeting, item 17, document no. SKN N0124R0, March 2010 (available from the Solar Keymark Network)

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK