SLOVENSKI STANDARD
SIST ENV 12977-2:2002

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Toplotni sončni sistemi in sestavni deli - Neserijsko izdelani sistemi - 2. del: Preskusne metode

Thermal solar systems and components - Custom built systems - Part 2: Test methods

Thermische Solaranlagen und ihre Bauteile - Kundenspezifisch gefertigte Anlagen - Teil 2: Prüfverfahren

Installations solaires thermiques et leurs composants - Installations assemblées a façon - Partie 2: Méthodes d'essais

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27.160	Sončna energija	Solar energy engineering
91.140.10	Sistemi centralnega ogrevanja	Central heating systems
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English version

Thermal solar systems and components - Custom built systems - Part 2: Test methods

Installations solaires thermiques et leurs composants - Installations assemblées à façon - Partie 2: Méthodes d'essais

Thermische Solaranlagen und ihre Bauteile - Kundenspezifisch gefertigte Anlagen - Teil 2: Prüfverfahren

This European Prestandard (ENV) was approved by CEN on 12 March 2001 as a prospective standard for provisional application.

The period of validity of this ENV is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the ENV can be converted into a European Standard.

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Contents

Foreword

This European Prestandard has been prepared by Technical Committee CEN/TC 312 "Thermal solar systems and components", the secretariat of which is held by ELOT.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this European Prestandard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

The annexes A and B are normative. The annexes C and D are informative.

Introduction

Drinking water quality

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

a) This Prestandard provides no information as to whether the product may be used without restriction in any of the Member States of the EU or EFTA;

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

Factory Made and Custom Built solar heating systems

The standards EN 12976-1 well as EN 12976-2 and the Prestandards ENV 12977-1 to ENV 12977-3 distinguish two categories of solar heating systems: **Factory Made** solar heating systems and **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 with the following definitions.

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 for which a new test report is necessary. Requirements and test methods for Factory Made solar heating systems are given in EN 12976-1 and EN 12976-2.

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 ENV 12977-1, test methods are specified in ENV 12977-2 and ENV 12977-3. Custom Built solar heating systems are subdivided into two categories:

- **Large Custom Built systems** are uniquely designed for a specific situation. In general HVAC engineers, manufacturers or other experts design them.
- **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, -2)	**Custom Built Solar Heating Systems (ENV 12977-1, -2, -3)**
Integral collector-storage systems for domestic hot water preparation	Forced-circulation systems for hot water preparation and/or space heating, assembled using components and configurations described in a documentation file (mostly small systems)
Thermosiphon systems for domestic hot water preparation	
Forced-circulation systems as a batch product with fixed configuration for domestic hot water preparation	Uniquely designed and assembled systems for hot water preparation and/or space heating (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 reference conditions as specified in annex B of EN 12976-2:2000 and annex A of ENV 12977-2:2001. In practice, the installation conditions may differ from these reference conditions.

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 favorable 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 Prestandard provide a means of verifying the compliance of large custom built systems with the requirements in ENV 12977-1.

NOTE 3 Within the framework of the EU ALTENER Programme the project "Guaranteed Solar Results" (GSR) is addressing similar objectives in respect of quality assurance (see [7], [8]). Similar procedures and monitoring equipment are used as described in annexes C and D. It might be necessary to update the informative annexes C and D later on in a revision of this Prestandard when more experience is available, in particular from the GSR project.

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 to 30000 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 Prestandard:

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

b) 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 a) energy gain of collector array(s) and b) energy balance over storage vessel(s). Intercomparison 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: a) 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; b) 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 Prestandard 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 ENV 12977-1.

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

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

This European Prestandard 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.

This European Prestandard 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 Prestandard does not apply to:

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

– systems for space heating with a distribution fluid other than water for the space heating subsystem (e.g. air systems);

– small custom built systems with a circulation line entering any store having a feedback on the solar heated store.

Principally, systems with circulation line may be tested in accordance to the methods described in this Prestandard, if the connecting port for the circulation line is kept closed during the tests. This should, however, stated in the test report.

– thermosiphon systems;

– integral collector-storage (ICS) systems.

The test procedure of annex C cannot be applied to solar heating systems with concentrating collectors.

NOTE The two test methods presented in annex C (”Short-term system testing”) have only been validated, so far, 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.

2 Normative references

This European Prestandard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Prestandard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 307:1998	Heat exchangers — Guidelines to prepare installation, operating and maintenance instructions required to maintain the performance of each type of heat exchanger
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	Pumps - Rotodynamic pumps - Circulation pumps having an electrical effect not exceeding 200 W for heating installations and domestic hot water installations — Requirements, testing, marking
EN 1717	Protection against pollution of potable water in drinking water installations and general requirements of devices to prevent pollution by backflow
ENV 1991-2-3	Eurocode 1- Basis of design and actions on structures – Part 2-3: Actions on structures - Snow loads
ENV 1991-2-4	Eurocode 1- Basis of design and actions on structures – Part 2-4: Actions on structures - Wind loads
prEN 12897:1997	Water supply – Specification for indirectly heated unvented (closed) hot water storage systems
EN 12975-1	Thermal solar systems and components – Solar collectors –Part 1: General requirements
EN 12975-2:2001	Thermal solar systems and components – Solar collectors –Part 2: Test

	methods
EN 12976-1:2000	Thermal solar systems and components – Factory made systems – Part 1: General requirements
EN 12976-2:2000	Thermal solar systems and components – Factory made systems – Part 2: Test methods
ENV 12977-1:2001	Thermal solar systems and components – Custom built systems – Part 1: General requirements
ENV 12977-3	Thermal solar systems and components – Custom built systems – Part 3: Performance characterization of stores for solar heating systems
EN 60335-1:1994	Safety of household and similar electrical appliances – Part 1: General requirements (IEC 60335-1:1991 modified)
EN 60335-2-21:1999	Safety of household and similar electrical appliances – Part 2: Particular requirements for storage water heaters (IEC 60335-2-21:1997 + Corrigendum 1998, modified)
ISO 9459-5	Solar heating - Domestic water heating systems - Part 5: System performance by means of whole system testing and computer simulation
EN ISO 9488:1999	Solar energy– Vocabulary (ISO 9488:1999)

3 Terms and definitions

For the purposes of this Prestandard, the terms and definitions given in EN ISO 9488 and ISO 9459-5 as well as EN 12975-1, EN 12976-1 and ENV 12977-1 apply.

4 Symbols and abbreviations

a_1	algebraic constant for the determination of the collector heat loss coefficient
A_c	collector reference area
C_c	collector array heat capacity
f_{sol}	solar fraction
G	solar irradiance
G_d	diffuse irradiance
G_g	global irradiance (i.e. horizontal)
G_h	hemispherical irradiance, e.g. on tilted plane
H_c	hemispherical solar irradiation in collector plane
$K_{\alpha\tau}$	incidence angle modifier
P_{aux}	power of the auxiliary heater
P_c	thermal power of the collector or collector array

P_{rc}	circulation heat loss power
Q_{sol}	heat delivered by the collector loop to the store
$Q_{aux,net}$	net auxiliary energy demand of a solar heating system delivered by the auxiliary heater to the store or directly to the heat distribution system (see 7.5.3)
Q_L	energy delivered at the outlet of the solar heating system
Q_d	heat demand
Q_l	store heat losses
Q_{ohp}	heat diverted from the store as active overheating protection, if any
Q_{par}	parasitic energy (electricity) for the collector loop pump(s) and control unit
$\vartheta_{average}$	yearly average cold water temperature on reference location
$\vartheta_{c,amb}$	collector ambient air temperature
$\vartheta_{S,amb}$	store ambient air temperature
$\vartheta_{ci/co}$	collector or collector array inlet/outlet fluid temperature
ϑ_{cw}	mains water temperature
ϑ_d	desired hot water temperature
ϑ_m	mean collector fluid temperature; $\vartheta_m = (\vartheta_{ci} + \vartheta_{co}) / 2$
ϑ_{rci}	fluid temperature at circulation loop inlet
ϑ_{rce}	fluid temperature at circulation loop outlet
θ_{req}	required temperature for sensor high-temperature resistance (see annex B)
ϑ_S	store outlet fluid temperature
θ_{sens}	sensor temperature (see annex B)
$\vartheta_{start/stop}$	temperature for which controller operation starts/stops (see annex B)
ϑ_{tank}	temperature of the storage tank (see annex B)
T^*	reduced temperature of collector; $T^* = (\vartheta_m - \vartheta_{c,amb}) / G_h$
$(UA)_{hx}$	heat transfer rate of a heat exchanger
$(UA)_S$	store heat loss rate
U_L	overall heat loss coefficient of collector array
V_d	demanded (daily) load volume
V_S	store volume
$\dot{V}_C$	volume flow rate in collector loop
$\dot{V}_{rc}$	volume flow rate in circulation loop
$\dot{V}_S$	volume draw-off flow rate from storage
v	surrounding air speed

$\Delta\vartheta$	temperature difference
$\Delta\vartheta_{amplit}$	average amplitude of seasonal variations on reference location
η_0	zero-loss collector efficiency (efficiency at $T^* = 0$)

5 System classification

See clause 5 of ENV 12977-1:2001.

6 Test methods

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

NOTE The numbering of the following clauses is kept in direct correspondence to the numbering in ENV 12977-1.

6.1 General

6.1.1 Suitability for drinking water

See EN 806-1.

6.1.2 Water contamination

For small custom built systems see EN 1717.

Large custom built systems: Check the hydraulic scheme or any other part of the documentation of the system according to 6.7.3 of ENV 12977-1:2001. (See also the introduction about water quality).

6.1.3 Freeze resistance

See 5.1 of EN 12976-2:2000

6.1.4 Overheating protection

6.1.4.1 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 capable for limiting the water temperature to 60 °C at most.

6.1.4.2 Overheating 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.

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

6.1.5 Reverse flow prevention

Check the hydraulic scheme included in the documentation (see 6.7) to ensure that no unintentional reverse flow will occur in any hydraulic loop of the system.

6.1.6 Pressure resistance

See prEN 12897:1997.

If any component of the system is not covered by prEN 12897:1997 or EN 12975-1, check the technical data to see whether the component for the part of the system in which it is used will withstand the lowest of the following pressures

– 1,5 times the manufacturer's stated maximum working pressure

– the manufacturer's stated maximum test pressure

In addition, for large custom built systems only:

– Regarding safety valves, check the hydraulic scheme or any other part of the documentation of the system according to 6.7.3 of ENV 12977-1:2001.

– Regarding pressure resistance, check whether the collector array can withstand short and high pressure peaks. Calculate the highest pressure that can occur in the individual loops in the system and compare it with the maximum allowed pressure of the individual loops (see also NOTE 2 in 6.1.6 of ENV 12977-1:2001). Alternatively, an experimental test with 1,3 times the maximum allowed pressure of each loop may be applied.

6.1.7 Electrical safety

See EN 60335-1:1994 and EN 60335-2-21:1999.

6.2 Materials

Check the work certificates provided by the manufacturer whether the requirements on UV radiation and weather resistance as well as on the choice of materials for the collector loop are fulfilled. For small custom built systems this check shall in any case be performed, for large ones as far as applicable.

6.3 Components and pipework

6.3.1 Collector and collector array

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

In addition, the maximum disparity of the mass flow rate in parallel collector rows should be calculated by means of the corresponding pressure drops.

6.3.2 Supporting frame

Check the calculation proving the resistance of the frame to snow and wind loads in accordance with ENV 1991-2-3 and 1991-2-4.

6.3.3 Collector and other loops

The optional collector loop test comprises the following steps:

– Determination of the nominal power needed by the collector loop pump

– Calculation of the highest heat power which can be delivered by the collector array $P_{c,max}$:

$$P_{c,max} = \eta_0 A_c G_{ref} \qquad (1)$$

where G_{ref} is the reference irradiance of 1000 W/m^2 (for other symbols see clause 4).

– Check of the values calculated by formula (1) in comparison with the values listed in Table 4 of ENV 12977-1:2001.

For other heat transfer loops, the nominal parasitic power of their pump(s) should be directly compared with the calculated highest transmitted heat power, based on Table 4 of ENV 12977-1:2001.

6.3.4 Circulation pump

See EN 809 and EN 1151.

6.3.5 Expansion vessel

For drain-back systems without a separate expansion vessel, check both by calculation and the hydraulic scheme to see whether the drain-back facility is able to fulfil its additional task as an expansion vessel.

6.3.5.1 Open expansion vessel

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.

6.3.5.2 Closed expansion vessel

For small custom built systems only: Check the fulfilment of the requirements given in 6.3.5.2 of ENV 12977-1:2001 by calculation and by visual check of the hydraulic scheme and operating instruction.

6.3.6 Heat exchangers

Apart from the tests in compliance with EN 307:1998, 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 (2):

$$\Delta\eta = \frac{\eta_0 A_c a_1}{(UA)_{hx}} 100\ \% \qquad (2)$$

where η_0 and a_1 are given from the collector performance test of EN 12975-2. For small systems $(UA)_{hx}$ is delivered by the store performance test of ENV 12977-3 ($(UA)_{hx}$ to be chosen for fluid temperatures of 20 °C). For large systems $(UA)_{hx}$ 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 mean temperature rise 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:

$$\Delta\eta = (a_1\, \Delta\vartheta / G_{ref})\ 100\% \qquad (3)$$

where the reference irradiance G_{ref} is set to 1000 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.

6.3.7 Store

With the exception of the heat loss rate, stores for drinking water shall be tested according to clause 6 of prEN 12897:1997. For small custom built systems, this test applies in any case, for large custom built systems as far as applicable.

In addition, for small custom built systems only:

- the performance of their hot water stores should be characterized according to ENV 12977-3.

- the heat loss rate of these hot water stores, obtained from performance characterization according to ENV 12977-3, should be compared with the requirements given in 6.3.7 of ENV 12977-1:2001.

6.3.8 Pipework

Check the design plan, manufacturer's works certificates and system documentation in respect of design and material of pipes and fittings.

6.3.9 Thermal Insulation

Check the design plans and system documentation.

6.3.10 Control system

6.3.10.1 Controller

For small custom built systems only: The optional controller test is described in annex B.

6.3.10.2 Temperature sensors

The design plans and components shall be visually checked in respect of location, installation and insulation of the sensors according to the requirements in 6.3.10.2 of ENV 12977-1:2001.

Additionally:

– For small custom built systems: Test the sensor resistance to high temperature as described in B.3. This test is, however, not necessary if a documentation delivered with the sensor indicates that it can withstand 100 °C or stagnation conditions (whichever the greatest) without altering by more than 1 K.

– For large custom built systems: Check the suitability of the temperature sensors in respect of stagnation conditions or maximum temperatures in connection with the quality declaration given by the supplier.

6.4 Safety equipment and indicators

6.4.1 Safety valves

Check the design plan and the system documentation to verify that each collector or group of collectors is fitted with at least one suitable safety valve.

Check the specification of the safety valves, whether the materials fulfil the requirements given in 6.4.1 of ENV 12977-1:2001.

Check whether the size of the safety valve is correct, in compliance with the requirements given in 6.4.1 of ENV 12977-1:2001.

Check whether the temperature of the heat transfer medium at the release pressure of the safety valve exceeds the maximum allowed temperature of the heat transfer medium.

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 6.4.1 of ENV 12977-1:2001, check the electric and hydraulic schemes or any other part of the documentation according to 6.7.3 of ENV 12977-1:2001.

6.4.2 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 6.4.2 of ENV 12977-1:2001.

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 are avoided.

6.4.3 Blow-off lines

Check the hydraulic scheme and system documentation to verify that the blow-off lines fulfil the requirements given in 6.4.3 of ENV 12977-1:2001.

6.4.4 Store shut-off valve

For large systems only: Verify the existence of a shut-off valve by checking the system documentation in accordance with 6.7.3 of ENV 12977-1:2001.

6.4.5 Indicators

6.4.5.1 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.