

BS EN ISO 9806:2013



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Solar energy — Solar thermal collectors — Test methods

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Users should be aware that BS 5918:1989, Code of practice for solar heating systems for domestic hot water, is in the process of being revised. BS 5918 covers ad hoc assemblies out of scope of the BS EN 12976 series and the BS EN 12977 series of standards.

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.

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Solarenergie - Thermische Sonnenkollektoren -
Prüfverfahren (ISO 9806:2013)

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Foreword

The text of ISO 9806:2013 has been prepared by Technical Committee ISO/TC 180 “Solar energy” of the International Organization for Standardization (ISO) and has been taken over as EN ISO 9806:2013 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of an identical text or by endorsement, at the latest by May 2014, and conflicting national standards shall be withdrawn at the latest by May 2014.

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 EN 12975-2:2006.

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Endorsement notice

The text of ISO 9806:2013 has been approved by CEN as EN ISO 9806:2013 without any modification.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 9806 was prepared by Technical Committee ISO/TC 180, *Solar energy*, and by Technical Committee CEN/TC 312, *Thermal solar systems and components* in collaboration.

This first edition cancels and replaces the first editions EN 12975-2:2006, ISO 9806-1:1994, ISO 9806-2:1995, and ISO 9806-3:1995, which have been technically revised.

Introduction

This International Standard defines procedures for testing fluid heating solar collectors for performance, reliability, durability and safety under well-defined and repeatable conditions. It contains performance test methods for conducting tests outdoors under natural solar irradiance and natural and simulated wind and for conducting tests indoors under simulated solar irradiance and wind. Outdoor tests can be performed either steady-state or as all-day measurements, under changing weather conditions.

Collectors tested according to this International Standard represent a wide range of applications, e.g. tracking concentrating collectors for thermal power generation and process heat, glazed flat plate collectors and evacuated tube collectors for domestic water and space heating, unglazed collectors for heating swimming pools or other low temperature applications. Air heating collectors have been included in the scope of this International Standard. Similarly, collectors using external power sources for normal operation and/or safety purposes (overheating protection, environmental hazards, etc.) are also considered.

Solar energy — Solar thermal collectors — Test methods

1 Scope

This International Standard specifies test methods for assessing the durability, reliability and safety for fluid heating collectors.

This International Standard also includes test methods for the thermal performance characterization of fluid heating collectors, namely steady-state and quasi-dynamic thermal performance of glazed and unglazed liquid heating solar collectors and steady-state thermal performance of glazed and unglazed air heating solar collectors (open to ambient as well as closed loop).

This International Standard is also applicable to hybrid collectors generating heat and electric power. However it does not cover electrical safety or other specific properties related to electric power generation.

This International Standard is also applicable to collectors using external power sources for normal operation and/or safety purposes.

This International Standard is not applicable to those collectors in which the thermal storage unit is an integral part of the collector to such an extent that the collection process cannot be separated from the storage process for the purpose of making measurements of these two processes.

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.

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 9060, *Solar energy — Specification and classification of instruments for measuring hemispherical solar and direct solar radiation*

ISO 9488, *Solar energy — Vocabulary*

ASTM E330-02, *Standard Test method for Structural performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference*

EN 779, *Particulate air filters for general ventilation - Determination of the filtration performance*

EN 13142, *Ventilation for buildings - Components/products for residential ventilation - Required and optional performance characteristics*

EN 13779, *Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems*

VDI 4670, *Thermodynamic properties of humid air and combustion gases*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 9488 and the following apply.

3.1
longitudinal angle of incidence

angle between the normal to the plane of the collector and incident sun beam projected into the longitudinal plane

Note 1 to entry: Not applicable to point-focus collectors and central receivers.

3.2
longitudinal plane

plane defined by the normal to the plane of the collector and the concentrator axis, or the largest symmetry line for flat biaxial geometries

3.3
maximum operating temperature

maximum temperature reached during collector or system normal operation, usually stated by the manufacturer

Note 1 to entry: Concentrating collector.

3.4
module

smallest unit that would function as a solar energy collection device

3.5
no-flow condition

condition that occurs when the heat transfer fluid does not flow through the collector array, due to shut-down or malfunction, and the collector is exposed to the same solar irradiance as under normal operating conditions

3.6
optical axis

symmetry line orthogonal to focal line and the plane of the collector in line-focus collectors

3.7
outgassing

process in which a solid material releases gases when it is exposed to elevated temperatures and/or reduced pressure

3.8
peak efficiency

efficiency of the collector at a temperature difference ($\vartheta_m - \vartheta_a = 0$) based on normal incidence of solar radiation and either hemispherical or beam irradiance

3.9
peak power

power output of the collector at a temperature difference ($\vartheta_m - \vartheta_a = 0$) based on normal incidence of solar radiation and either hemispherical or specific combinations of beam and diffuse irradiance

3.10
passive

operating condition where no human or mechanical intervention is required for operation as intended

Note 1 to entry: Concentrating collector.

3.11
reflector or reflective surface

surface intended for the primary function of reflecting radiant energy

Note 1 to entry: Concentrating collector.

Note 2 to entry: It includes also the optional reconcentrator.

3.12

Simulated Roof

construction using materials of a quality typical to that used in roofs, from roof structure to roof coverings

3.13

transversal angle of incidence

angle between collector the normal to the plane of the collector and incident sun beam projected into the transversal plane

Note 1 to entry: Not applicable to point-focus collectors and central receivers.

3.14

transversal plane

plane defined by the normal to the plane of the collector and the line orthogonal to the concentrator axis, or the shortest symmetry line for flat biaxial geometries

3.15

trigger or safety activation temperature

temperature value at which the safety controls are activated for fail safe operating condition

Note 1 to entry: Concentrating collector.

4 Symbols and abbreviated terms

A_G	gross area of collector	m^2
AM	optical air mass	-
a_1	heat loss coefficient at $(\theta_m - \theta_a) = 0$	$W/(m^2 \cdot K)$
a_2	temperature dependence of the heat loss coefficient	$W/(m^2 \cdot K^2)$
B	"earth position" around the sun during the year 0-360 deg	degrees
b_u	collector efficiency coefficient (wind dependence)	s/m
b_0	constant for the calculation of the incident angle modifier	
b_1	heat loss coefficient at $(\theta_m - \theta_a) = 0$	$W/(m^2 \cdot K)$
b_2	wind dependence of the heat loss coefficient	$Ws/(m^3 \cdot K)$
C	effective thermal capacity of collector	J/K
C_R	Concentration ration	
c_1	heat loss coefficient at $(\theta_m - \theta_a) = 0$	$W/(m^2 \cdot K)$
c_2	temperature dependence of the heat loss coefficient	$W/(m^2 \cdot K^2)$
c_3	wind speed dependence of the heat loss coefficient	$J/(m^3 \cdot K)$
c_4	sky temperature dependence of the heat loss coefficient	-

c_5	effective thermal capacity	J/(m ² ·K)
c_6	wind dependence in the zero loss efficiency	s/m
c_f	specific heat capacity of heat transfer fluid	J/(kg·K)
$C_{f,i}$	specific heat capacity of heat transfer fluid at the collector inlet	J/(kg·K)
$C_{f,e}$	specific heat capacity of heat transfer fluid at the collector outlet	J/(kg·K)
$C_{f,a}$	specific heat capacity of the ambient air	J/(kg·K)
D	date	YYMMDD
E	formula of time correcting for the eccentric path	minutes of the earth around the sun.
E_L	long wave irradiance ($\lambda > 3 \mu\text{m}$)	W/m ²
E_β	long wave irradiance on an inclined surface outdoors	W/m ²
E_s	long wave irradiance	W/m ²
F	radiation view factor	
F'	collector efficiency factor	
G	hemispherical solar irradiance	W/m ²
G''	net irradiance	W/m ²
G_b	direct solar irradiance (beam irradiance)	W/m ²
G_d	diffuse solar irradiance	W/m ²
H	hemispherical irradiation on the collector plane	MJ/m ²
$h_{f,a}$	enthalpy of the air-water vapor mixture of the ambient air	J/kg
$h_{f,e}$	enthalpy of the air-water vapor mixture at the outlet of the air collector	J/kg
$h_{f,i}$	enthalpy of the air-water vapor mixture at the inlet of the air collector	J/kg
h_L	enthalpy of the leaking air-water vapor mixture	J/kg
$K_{\text{hem}}(\theta_L, \theta_T)$	incidence angle modifier	-
$K_b(\theta_L, \theta_T)$	incidence angle modifier for direct radiation	-
$K_{\theta_L, coll}$	incidence Angle Modifier along the coll. tubes or reflectors	-

$K_{\theta T, coll}$	incidence Angle Modifier perpendicular to collector tubes or reflectors	-
K_d	incidence angle modifier for diffuse radiation	-
m	thermally active mass of the collector	kg
$\dot{m}$	mass flow rate of heat transfer fluid	kg/s
$\dot{m}_{min}$	minimum mass flow by the performance test	kg/h
$\dot{m}_{max}$	maximum mass flow by the performance test	kg/h
$\dot{m}_{pe}$	downstream air mass flow rate	kg/s
$\dot{m}_{pi}$	upstream air mass flow rate	kg/s
$\dot{m}_{pl}$	leakage air mass flow rate	kg/s
p_{fe}	static pressure of the heat transfer fluid (air) at the outlet to the solar collector	Pa
p_{fi}	static pressure of the heat transfer fluid (air) at the inlet to the solar collector	Pa
P_{abs}	absolute pressure of the ambient air	Pa
$\dot{Q}$	useful power extracted from collector	W
$\dot{Q}_{peak}$	power output of the solar collector module for normal incidence, $G = 1000 \text{ W/m}^2$ and $\vartheta_m - \vartheta_a = 0 \text{ K}$	W
$\dot{Q}_t$	mean power output during one time step	W
$\dot{Q} / A_G$	specific useful energy extracted from the collector	W/m ²
Q_{module}	useful energy extracted from the collector, annual energy gain	kWh per module
$\dot{Q}_L$	power loss of collector	W
R_D	gas constant for water vapor	461,4 J/(kgK)
rH_{amb}	(relative)humidity of the ambient air	%

rH_e	(relative)humidity of the fluid (air) at the outlet of the solar collector	%
rH_i	(relative)humidity of the fluid (air) at the inlet of the solar collector	%
R_L	gas constant for air	287,1 J/(kgK)
T	absolute temperature	K
T^*_m	reduced temperature difference (= $(\vartheta_m - \vartheta_a)/G$)	m ² K/W
$\vartheta_{m,max}$	maximum operating temperature as stated by the manufacturer	
T_s	atmospheric or equivalent sky radiation temperature	K
t	time	s
U	measured overall heat loss coefficient of collector with reference to T^*_m	W/(m ² K)
U_L	overall heat loss coefficient of a collector with uniform absorber temperature ϑ_m	W/(m ² K)
u	surrounding air speed	m/s
V_f	fluid capacity of the collector	m ³
$\dot{V}_p$	volumetric flow	m ³ /s
$\dot{V}_{p,e}$	volumetric flow at the outlet of the solar collector	m ³ /s
$\dot{V}_{p,i}$	volumetric flow at the inlet of the solar collector	m ³ /s
$\dot{V}_{p,L}$	volumetric leakage flow rate	m ³ /s
$X_{W,a}$	water content of the ambient air	kg H ₂ O/kg dry air
$X_{W,e}$	water content at the exit of the solar collector	kg H ₂ O/kg dry air
$X_{W,i}$	water content at the inlet of the solar collector	kg H ₂ O/kg dry air
α	solar absorptance	%
α_s	solar altitude angle	degrees
β	tilt angle of a plane with respect to horizontal	degrees
γ	collector azimuth angle (0 = south, east negative)	degrees

γ_s	solar azimuth angle (0 = south, east negative)	degrees
Δp	pressure difference between fluid inlet and outlet	Pa
Δt	time interval	s
ΔT	temperature difference between fluid outlet and inlet ($\vartheta_e - \vartheta_{in}$)	K
δ	solar declination	degrees
ε	hemispherical emittance	%
η	collector efficiency, with reference to T^*_m	-
η_b	collector efficiency, with reference to T^*_m , based on beam irradiance G_b	-
η_{hem}	collector efficiency, with reference to T^*_m , based on hemispherical irradiance G	-
$\eta_{0,b}$	peak collector efficiency (η_b at $T^*_m = 0$), reference to T^*_m , based on beam irradiance G_b	-
$\eta_{0,hem}$	peak collector efficiency (η_{hem} at $T^*_m = 0$), reference to T^*_m , based on hemispherical irradiance G	-
$\eta_{max,0m/s}$	maximum collector efficiency (at 0 m/s and one fixed mass flow rate)	-
η_m	collector efficiency, with reference to $\eta_{max, 0 m/s}$	-
θ	angle of incidence	degrees
$\theta_{T,def}$	reference angle in T-direction for determination of IAM. Normally = 0	degrees
$\theta_{L,def}$	reference angle in L-direction for determination of IAM. Normally = 0	degrees
θ_z	solar zenith angle ($= 90 - \theta_H$)	degrees
θ_{II} or θ_L	longitudinal angle of incidence	degrees
$\theta_{\perp}$ or θ_T	transversal angle of incidence	degrees
ϑ_a	ambient or surrounding air temperature	°C
ϑ_{dp}	atmospheric dew point temperature	°C
ϑ_e	collector outlet (exit) temperature	°C
ϑ_{in}	collector inlet temperature	°C

ϑ_m	mean temperature of heat transfer fluid	°C
$\vartheta_{max,op}$	maximum operating temperature	°C
ϑ_s	atmospheric or sky temperature	°C
ϑ_{stg}	standard stagnation temperature	°C
$\vartheta_{trigger}$	trigger temperature for safety activation	°C
$\vartheta_{m,th}$	volume flow weighted mean temperature	°C
$\vartheta_{max,start}$	maximum starting temperature	°C
$\vartheta_{mp,e}$	fluid temperate at the downstream air mass flow meter	°C
$\vartheta_{mp,i}$	fluid temperate at the upstream air mass flow meter	°C
λ	wavelength	µm
ρ	density of heat transfer fluid	kg/m ³
ρ_l	density of air	kg/m ³
σ	Stefan-Boltzmann constant	W/(m ² K ⁴)
τ_c	collector time constant	s
τ	transmittance	
$(\tau\alpha)$	effective transmittance-absorptance product	-
Φ	latitude of collector and climate data location	degrees
ω	solar hour angle	degrees

NOTE 1 In the field of solar energy the symbol G is used to denote solar irradiance, rather than the generic symbol E for irradiance.

NOTE 2 C is often denoted $(mC)_e$ in basic literature (see also [Clause 26](#))

NOTE 3 For more information about thermal performance coefficients (parameters) c_1 to c_6 , see B.1

NOTE 4 Collectors not intended for the generation of steam or super-heated water have maximum operating temperature $\vartheta_{m,max} \leq 110$ °C.

5 General

5.1 Test overview - Sequence of the tests

For some qualification tests ([Table 1](#)), a part of the collector may have to be manipulated in some way, for example a hole may have to be drilled in the back of the collector to attach a temperature sensor to the absorber. In these cases care should be taken to ensure that any damage caused does not affect the results of subsequent qualification tests, for example by allowing water to enter into a previously rain tight collector.

Table 1 — Test list

Subclause	Test
6	Internal pressure test for fluid channels ^{f, g}
7	Leakage test ^h
8	Rupture and collapse test ^h
9	High-temperature resistance ^{a, b}
11	Exposure test ^b
12	External thermal shock test ^c
13	Internal thermal shock test ^c
14	Rain penetration test ^{d, h}
15	Freeze resistance test ^{e, h}
16	Mechanical load test ^h
17	Impact resistance test ⁱ
20	Thermal performance test ^j
28	Pressure drop measurement ^{h, l}
18	Final inspection ^k
a For organic absorbers, the high-temperature resistance test shall be performed before internal pressure test in order to determine the collector standard stagnation temperature needed for the internal pressure test. b The high temperature and exposure test shall be carried out on the same collector. c The external and internal thermal shock tests may be combined with the exposure test or the high-temperature resistance test. d The rain penetration test shall be carried out only for glazed collectors. e The freeze resistance test shall be carried out only for collectors claimed to be freeze resistant. f Applicable only for liquid heating collectors. g For fluid channels made of organic materials, a full exposure is required before the test, see Clause 11. h Pre-exposure or full exposure is required before the test, see Clause 11. i Pre-exposure or full exposure is required before the test if polymer cover, see Clause 11. j Full exposure is required before the performance testing of heat pipe collectors. k Every collector tested needs to undergo the final inspection. l Mandatory only for air heating collectors.	

5.2 Particular aspects of collectors using external power sources and active or passive measures for normal operation and self-protection

Collectors shall be tested in such a way that they shall be able to demonstrate suitable performance and ability to protect themselves from common failures due to conditions that can arise in standard operation.

The collector shall be assembled (if it is necessary) and its components shall operate according to manufacturer's specifications. If the collector has active mechanisms which are intended to be functional during normal operation, those mechanisms shall be operational during testing. A tracking device, if it is present, shall be supplied by the collector manufacturer and shall be used during the tests. Concentrating collector designs which include a factory sealed container charged with refrigerant or other fluid used in the collection of heat shall be tested without the removal of this element.

The protection systems can be active, such as actuators, motors and other equipment, or passive, such as materials reacting to heat or other designs. The manufacturer shall clearly define the equipment protection features and shall specify whether or not the equipment requires an external energy source to operate.

The collector can present a combination of active and passive controls, and in that case the test sequence shall be selected to verify suitable operation of active and passive mechanisms during normal operating conditions.

6 Internal pressure tests for fluid channels

6.1 Inorganic fluid channels

6.1.1 Objective

The fluid channels shall be pressure-tested to assess the extent to which they can withstand the pressures which they might meet in service.

6.1.2 Apparatus and procedure

The apparatus consists of a hydraulic pressure source (electrical pump or hand pump), a safety valve, an air-bleed valve and a pressure gauge with a standard uncertainty better than 5 %. The air-bleed valve shall be used to empty the fluid channels of air before pressurization. The inorganic fluid channels shall be filled with water at room temperature and pressurized to the test pressure for the test period. This pressure shall be maintained while the fluid channels are inspected for swelling, distortion or ruptures.

6.1.3 Test conditions

Inorganic fluid channels shall be pressure-tested at ambient temperature within the range 5 °C to 40 °C, shielded from light. The test pressure shall be 1,5 times the maximum collector operating pressure specified by the manufacturer. The test pressure shall be maintained (± 5 %) for 15 min.

6.2 Fluid channels made of organic materials (plastics or elastomers)

6.2.1 Objective

The fluid channels shall be pressure-tested to assess the extent to which it can withstand the pressures which it might meet in service while operating at elevated temperature. The tests shall be carried out at elevated temperatures, because the pressure resistance of an organic fluid channel may be adversely affected as its temperature is increased.

6.3 Apparatus and procedure

6.3.1 General

The apparatus consists of either a hydraulic or a pneumatic pressure source and a means of heating the fluid channels to the required test temperature.

The test conditions specified in [6.3.4](#) shall be maintained for at least 30 min prior to the test and for the full duration of the test.

The pressure in the fluid channels shall be raised in stages as specified in [6.3.4](#). If possible the pressure should be maintained while the fluid channels are being inspected.

For safety reasons, the collector shall be encased in a transparent box to protect personnel in the event of explosive failure during this test.

One of the methods described in [6.3.2](#) and [6.3.3](#) shall be chosen.

6.3.2 Organic fluid channels - high temperature hydraulic pressure test

The fluid channels may be connected to a hot fluid circuit. The fluid channels and hot fluid circuit are then pressurized. Fluid channels may be heated by any of the following methods:

- a) submerging the fluid channels in a heated water bath and pressure-tested. The pressurized fluid supply to the absorber shall be fitted with a safety valve, air-bleed valve (if required) and pressure gauge having a standard uncertainty better than 5 %.
- b) connecting a heater in the liquid circuit (fluid needs to be in liquid phase);
- c) heating the whole collector in a solar irradiance simulator;
- d) heating the whole collector outdoors under natural solar irradiance.

Safety measures should be taken to protect personnel from hot fluid in the event of explosive failure during this test.

6.3.3 Organic fluid channels - high temperature pneumatic pressure test

The fluid channels may be pressure-tested using compressed air, when heated by either of the following methods:

- a) heating the whole collector in a solar irradiance simulator;
- b) heating the whole collector outdoors under natural solar irradiance.

The compressed air supply to the fluid channels shall be fitted with a safety valve and a pressure gauge having a standard uncertainty better than 5 %.

6.3.4 Test conditions

The test temperature shall be the maximum operation temperature specified by the manufacturer or the standard stagnation temperature whichever is greater, see [Clause 10](#). The test pressure shall be 1,5 times the maximum collector operating pressure specified by the manufacturer. For fluid channels made of organic materials, the pressure shall be raised to the test pressure in equal steps (approximately five) and maintained at each intermediate pressure for 5 min. The test pressure shall be maintained for at least 1 h.

6.4 Results

The collector shall be inspected for leakage¹⁾, swelling and distortion. Leakage can be assumed if pressure loss $\Delta P > 5\%$ of the test pressure or 17 kPa, whichever is greater. The results of this inspection shall be reported together with the values of pressure and temperature used and the duration of the test.

7 Leakage test (closed loop air heating collectors only)

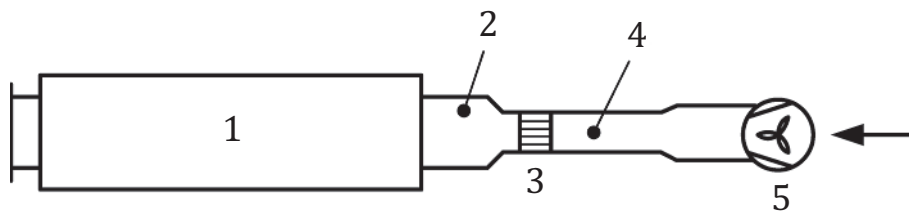
7.1 Objective

The test is intended to quantify the leakage volumetric flow rate of air heating collectors. In some cases of collector designs the leakage test is not applicable, e.g. collectors open to ambient.

7.2 Apparatus and procedure

The Leakage test can be realized with a volumetric flow meter, e.g. as shown in [Figure 1](#) — Schematic of apparatus used for measuring air leakage in air collectors. Leakages resulting from other sources other than the test object shall be quantified and deducted from the collector test results.

1) In case of an air heating collector leakage is not defined as a problem. The leakage volumetric flow rate shall be determined according to Clause 7.



Key

- 1 Solar air heater
- 2 Pressure gauge
- 3 Flow meter
- 4 Temperature sensor
- 5 Fan

Figure 1 — Schematic of apparatus used for measuring air leakage in air collectors.

The collector shall be mounted with the air outlet sealed and the inlet connected to a volumetric air flow measurement as well as a variable speed fan. The pressure difference between inlet and ambient shall be measured with a differential pressure measurement device. The test consists of two parts, a positive and a negative leakage test. The test shall be performed with positive and negative pressure. The standard uncertainty shall be better than $\pm 2\%$ for volumetric air flow measurement and better than ± 10 Pa for the differential pressure measurement.

7.3 Test conditions

The test shall be done at ambient temperature without irradiance. Ambient temperature should not vary more than ± 5 K during the test. At least four positive and four negative pressure values shall be realized. The maximum internal pressure shall be 1,5 times the maximum operating pressure specified by the manufacturer. The pressure shall be raised to the maximum test pressure in equal steps (approximately five). The test period for each step shall not be less than 10 min.

In the case of organic fluid channels it is recommended to repeat the test at maximum operation temperature specified by the manufacturer or standard stagnation temperature whichever is greater.

7.4 Results

The results shall be reported as in A.4.

8 Rupture or collapse test (air heating collectors only)

8.1 Objective

This test is intended to determine the ability of air heating solar collectors to withstand the pressure levels expected in the air duct systems with which they will be incorporated.

8.2 Apparatus and Procedure

8.2.1 General

The apparatus shall consist of a pneumatic pressure source, a means of measuring the pressure and a means of measuring the rate of air flow out of the collector. For collectors with organic materials (plastics or elastomers) in direct contact with the working fluid the tests shall be carried out at elevated temperatures and for this a means of heating the absorber to the required test temperature is also required.

The whole collector should then be heated using one of the following methods:

- a) connecting a heater in the fluid circuit, and circulating hot air through the collector before the collector outlet is sealed
- b) heating the whole collector in a solar irradiance simulator
- c) heating the whole collector outdoors under natural solar irradiance

Appropriate safety measures shall be taken to protect personnel in the event of explosive failure during this test.

The basic apparatus can be similar or identical to that used for the air collector leakage test and the measurement accuracy shall fulfil the same requirements (see [7.2](#)).

8.2.2 Closed-loop collectors

The collector shall be mounted the same as for the air collector leakage tests (see [7.2](#)). The side wall aperture introduced for the purpose of the uniform load tests shall be sealed.

The procedure shall be as follows:

- a) Seal the pressure gauge into the collector outlet port and connect the inlet port through the flow meter and pressure regulator to the air supply.
- b) Ensure that the air supply is suitable for applying the appropriate positive or negative gauge pressure.
- c) Set the pressure regulator to the ambient pressure and note the pressure gauge zero reading.
- d) If the test is conducted at a temperature other than ambient temperature, then the collector shall be heated by one of the methods stated in [8.2.1](#).
- e) Activate the air supply and open the regulator valve until a gauge pressure of 1,5 times the maximum (positive and/ or negative) collector operating pressure specified by the manufacturer is reached and maintain it for 10 min.
- f) Inspect the collector and record any evidence of structural damage.
- g) Note the flow rate meter indicator.
- h) Allow the pressure to return to ambient.
- i) Note the final reading of the pressure gauge.

8.2.3 Open to ambient collectors

The procedure shall be as follows:

- a) Connect the outlet port of the collector to a suitable air extraction system. Provide a pressure tap at the outlet port of the collector to measure pressure at the collector outlet relative to atmospheric pressure. The outlet pressure tap shall be located as shown in [Figure 8](#) Example of an open test loop of [23.2.3](#).
- b) Ensure that the air supply is suitable for applying the required test flow rate.

- c) If the test is conducted at a temperature other than ambient temperature, then the collector shall be heated by one of the methods stated in [8.2.1](#).
- d) With no air flow through the collector, note the pressure gauge zero reading.
- e) Activate the air supply and increase it until 1,5 times the maximum flow rate specified by the manufacturer is reached over a period of not less than 15 s. The collector will be tested in the normal use configuration, with air at atmospheric pressure being drawn into the collector.
- f) The air flow shall be maintained for no less than 10 min. At the end of 10 min, while maintaining air flow rate, inspect the collector and record any evidence of distortion or collapse.
- g) Allow the air flow to return to zero.
- h) Note the final reading of the pressure gauge.
- i) Inspect the collector for collapse, distortion, and permanent displacement of the collector components.

8.3 Test conditions

8.3.1 Temperature

Collectors with organic materials (plastics or elastomers) in direct contact with the working fluid shall be tested at the maximum temperature that the absorber reaches under the following conditions:

- a) the solar collector manufacturer's recommended minimum air flow rate;
- b) 1 000 W/m²; and
- c) 30 °C ambient air temperature.

All other air heating solar collectors shall be tested at ambient temperature.

8.4 Results and reporting

The results shall be reported as required in [A.5](#).

9 High-temperature resistance test

9.1 Objective

This test is intended to assess rapidly whether a collector can withstand high temperature and irradiance levels without failures such as glass breakage, collapse of plastic cover, melting of plastic absorber, or significant deposits on the collector cover from outgassing of collector material or any other effect that possibly could lead to reduced performance, lifetime, safety or distorted visual appearance of the collector.

Direct heating solar air collectors should respect the requirements concerning components for ventilation in EN 13779 and EN 13142.

9.2 Apparatus and procedure

The collector shall be tested outdoors, or in a solar irradiance simulator.

The characteristics of the solar irradiance simulator to be used for the high-temperature resistance test shall be those of the solar irradiance simulator used for efficiency testing of fluid heating solar collectors.

The collector shall be mounted outdoors or in a solar simulator. Liquid heating collectors shall not be filled with fluid. In case of liquid heating collectors all of the fluid pipes except for one shall be sealed to prevent cooling by natural circulation of air.

A temperature sensor shall be attached to the absorber to monitor its temperature during the test. The sensor shall be positioned in the hottest region of the absorber. The location shall be reported with the results. In case of liquid flat plate collectors the hottest region can be assumed at two-thirds of the absorber height and half the absorber width. It shall be fixed firmly in a position to ensure good thermal contact with the absorber. The sensor shall be shielded from solar radiation.

In case of collectors using external power sources and active or passive measures for normal operation and self-protection, high temperature resistance test shall be carried out during the exposure test. If controls are present to manage both a no-flow and high temperature condition, the collector shall be filled with heat transfer fluid according to the procedure described in 28.3 and operated as intended. If the function is ok, it should not be able to reach stagnation conditions. In that case the controls shall be checked and the collector shall operate close to the maximum operating temperature defined by the manufacturer (below control system trigger temperature). In the test report specifications must be given for the flow rate, fluid temperature, and duration of flow.

When testing collectors, such as evacuated tubular collectors, for which it is not appropriate to measure the standard stagnation temperature at the absorber, the temperature sensor should be placed at a suitable location in the collector, and this location should be clearly described with the test results.

In some cases, such as evacuated collectors, it may be difficult to attach a temperature sensor to the absorber. In such cases, instead of attaching a temperature sensor to the absorber, the testing laboratory may partially fill the absorber with a suitable fluid, seal the absorber and measure the temperature of the fluid directly or measure the pressure in the absorber. The relationship between the internal pressure in the absorber and its temperature should be known from the standard vapor pressure/temperature relationship for the fluid. Alternatively the absorber temperature of a heat pipe tubular collector may reasonably be measured by affixing a temperature sensor to the condenser during assembly.

It is recommended to perform the determination of the standard stagnation temperature together with the high-temperature resistance test.

In case of a solar air heating collector, the mass flow rate for the measurement of the maximum starting temperature shall be same as the smallest one applied in the collector thermal efficiency test.

The test shall be performed for a minimum of 1 h after steady-state conditions have been established (steady-state conditions can be assumed for absorber temperatures changes of less than ± 5 K), and the collector shall be subsequently inspected for signs of damage as specified in Clause 18.

9.3 Test conditions

The set of reference conditions given in Table 2 or conditions resulting in the same or higher collector temperature than standard stagnation temperature according to Clause 10 shall be used for all climate classes (see Table 4).

Table 2 — Climate reference conditions for high-temperature resistance test

Climate parameter	Value for all climate classes
Hemispherical solar irradiance on collector plane, G in W/m^2	> 1000
Surrounding air temperature, θ_a in $^{\circ}\text{C}$	$20 - 40$
Surrounding air speed in m/s	< 1

When testing unglazed collectors without backside insulation, the collector shall be mounted onto a dark surface ($\alpha > 80\%$) to rise maximum temperatures as worst case condition.

9.4 Results

The collector shall be inspected for degradation, shrinkage, outgassing and distortion.

The results of the inspection shall be recorded as in A.6 together with the average values of solar irradiance (natural or simulated) on the collector plane, surrounding air temperature and speed and

absorber temperature (and the pressure of the suitable fluid in the absorber, if that method is used) recorded during the test. Control functions which have been verified shall be described and reported with the test results.

For solar air heating collectors, the maximum start temperature at the collector outlet shall be measured and reported.

10 Standard stagnation temperature of liquid heating collectors

10.1 General

This Clause provides methods for determining the standard stagnation temperature of a collector, i.e. the temperature of the collector during periods of no useful heat removal from the collector with high solar radiation and ambient surrounding temperatures. These methods are used to check, that standard stagnation temperature at collector label and in installer instruction manual is higher than determined standard stagnation temperature.

Standard stagnation temperature given by the manufacturer should be given in an up-rounded 10° resolution

The standard stagnation temperature should be determined for a selected solar irradiance G_s and a selected ambient temperature ϑ_{as} .

The determined standard stagnation temperature is used in the following tests:

- internal pressure testing of collectors with organic absorbers (see [6.2](#));
- high-temperature resistance test using a hot fluid loop (see [9.2](#)).

For different kind of collectors different methods for determination of standard stagnation temperature are appropriate. [Table 3](#) gives an overview:

Table 3 — Guide to standard stagnation temperature determination method

Collector type		10.2	10.3
Flat plate collector	Inorganic absorber	X	X
	Organic absorber	X	X
Evacuated tube collector	Heat pipe	X	X
	Direct flow	X	X

For collectors with organic absorbers the internal pressure test is done at standard stagnation temperature.

10.2 Measurement and extrapolation of standard stagnation temperature

The standard stagnation temperature ϑ_{stg} , for the selected values of solar irradiance G_s and ambient temperature ϑ_{as} , is calculated by extrapolating from measured steady-state values of:

- solar irradiance G_m (natural or simulated) on the collector plane;
- surrounding air temperature ϑ_{am} ;
- absorber temperature ϑ_{sm} .

while the collector is exposed to the available solar irradiance and ambient temperature (outdoors, or in a solar irradiance simulator) under steady-state conditions without heat extraction from the collector (stagnation conditions).

The expression for determining the standard stagnation temperature for the selected parameters (G_s and ϑ_{as}) is:

$$\vartheta_{stg} = \vartheta_{as} + \frac{G_s}{G_m} (\vartheta_{sm} - \vartheta_{am}) \quad (1)$$

It is based on the approximation that the ratio $(\vartheta_{sm} - \vartheta_{am})/G_m$ remains constant under steady-state collector stagnation conditions.

This approximation is acceptable only if the irradiance level (G_m) used during the test is within 10 % of the irradiance specified for the stagnation conditions (G_s).

For flat plate collectors the temperature sensor shall be positioned at two-thirds of the absorber height and half the absorber width. It shall be fixed firmly in a position to ensure good thermal contact with the absorber. The sensor shall be shielded from solar radiation.

For evacuated tubular collectors the temperature sensor should be placed at a suitable location in the collector i.e. where the highest temperature relevant to the heat transfer fluid is to be found.

10.3 Determining standard stagnation temperature using efficiency parameters

The thermal performance of the liquid heating collector is used in order to calculate its standard stagnation temperature. If the thermal performance of the collector is not known, it shall be determined by testing the collector accordingly.

The second-order formula for the instantaneous thermal efficiency of the collector should be used for determining the standard stagnation temperature:

$$\eta = \eta_0 - a_1 T_m^* - a_2 G (T_m^*)^2 \quad (2)$$

It should be noted that the reduced temperature difference T_m^* is defined by the mean temperature of the heat transfer fluid (t_m). The instantaneous efficiency is based the gross area A . Two different sets of constants η_0 , a_1 and a_2 may be available to express the instantaneous efficiency of the collector.

The standard stagnation temperature for the selected irradiance G_s and ambient temperature ϑ_{as} is calculated by the following formula:

$$\vartheta_{stg} = \vartheta_{as} + \frac{-a_1 + (a_1^2 + 4 \eta_0 a_2 G_s)^{1/2}}{2 a_2} + 20^\circ\text{C} \quad (3)$$

where any available set of constants η_0 , a_1 and a_2 can be used.

This approach involves extrapolating the collector efficiency formula to the stagnation condition. Hence it is essential that the efficiency formula is valid up to η approximately 0. To ensure this, the collector efficiency formula evaluation should include test data at T_m^* values approaching $T_m^*_{stagnation}$. If all the efficiency test data were evaluated at T_m^* values less than $T_m^*_{stagnation}/2$, then [10.2](#) should be used to determine ϑ_{stg} .

NOTE Measurements of performance are done at higher wind speed than in stagnation conditions. 20 °C are added to compensate the higher wind speed.

10.4 Results

The results of the stagnation measurement shall be reported as required in A.6.4.

11 Exposure and pre-exposure test

11.1 Objective

The exposure test provides a low-cost reliability test sequence, indicating (or simulating) operating conditions which are likely to occur during real service and also allows the collector to “settle”, such that subsequent qualification tests are more likely to give repeatable results. For the latter purpose a pre-exposure test sequence with approximately half the duration of the full exposure test is defined. Which of these two sequences that shall or can be applied prior to a specific qualification test is explained in [Table 1](#).

11.2 Apparatus and procedure

The collector shall be mounted outdoors, but not filled with fluid (in case of liquid heating collector), unless controls are used to manage both a no-flow and high temperature condition according to the manufacturer's instructions. In that case, collectors shall be filled with the heat transfer fluid and such controls shall be verified. Collector designs which include a factory sealed container charged with refrigerants or other fluid used in the collection of heat shall be tested without heat transfer fluid flowing through them unless controls are used for over temperature protection. In case of liquid heating collectors all of the fluid pipes shall be sealed to prevent cooling by natural circulation of air. In case of solar air heaters all fluid pipes shall be sealed. One shall be left open to permit free expansion of air in the absorber. All components and subsystems, as they have been designed by the manufacturer and described in the operation manual, shall be validated to be functional during the exposure period. If the collector includes active systems to protect itself, these protections shall be active and operational during the exposure test.

The ambient air temperature shall be recorded to a standard uncertainty of 1 K and the global irradiance on the plane of the collector recorded using a pyranometer of class I or better in accordance with ISO 9060. Irradiation and mean air temperature values shall be recorded at least every 5 min. The collector shall be exposed until the test conditions have been met.

At least once a week, collectors shall be subjected to visual inspection and any signs of damage as specified in [11.4](#) or change in the physical appearance shall be registered and reported with the test results.

When testing unglazed collectors without backside insulation, the collector shall be mounted onto a dark surface ($\alpha > 80\%$) in order to rise maximum temperatures as during worst case conditions.

11.3 Test conditions

The set of reference conditions given in [Table 4](#) shall be used. The class according to which the collector is to be tested is defined by the collector manufacturer.

The collector shall be exposed until at least 30 days (or 15 days for pre-exposure) have passed and the minimum irradiation H shown in [Table 4](#) is reached. The irradiation is determined by recording irradiance measurements using a pyranometer.

The collector shall also be exposed for at least 30 h (15 h for pre-exposure) to the minimum irradiance level G given in [Table 4](#), as recorded by a pyranometer, when the ambient air temperature is greater than the value shown in [Table 4](#) or conditions resulting in the same collector temperature according to [Clause 10](#). These hours shall be made up of periods of at least 30 min.

Table 4 — Climate reference conditions for exposure test as well as for external and internal thermal shock tests

Climate condition	Value for climate class		
	Class C Temperate	Class B Sunny	Class A Very Sunny
Hemispherical solar irradiance on collector plane during minimum 30 hours (or 15 hours in case of pre-exposure), G in W/m ² /minimum ambient temperature, θ_a in °C	800/10	900/15	1000/20
Irradiation on collector plane for exposure test during minimum 30 days, H in MJ/m ²	420	540	600
Irradiation on collector plane for pre-exposure sequence during minimum 15 days, H in MJ/m ²	210	270	300
Values given are minimum values for testing. The same class shall be applied for irradiance and for irradiation values respectively.			

Indoor exposure using a solar simulator may be applied to reach the 30 or 15 hours and/or the irradiation once the 30 or 15 outdoor days have been reached. It should not consist of cycles of more than 8 h. If a cycle takes more than 8 h, just 8 h are counted. A minimum of 4 h shall be passed in between each cycle to cool down the collector to close to ambient temperature.

11.3.1 Additional test conditions for active and passive controls

The manufacturer shall identify all active and passive controls which are present in the collector for protection purposes such as controls, motors, actuators or other elements. The manufacturer shall submit to the laboratories their control set points and parameters in order to verify their suitable operation during normal working conditions in which events as over temperature, wind, etc. can affect the collector lifetime and its performance.

The laboratory shall establish a test cycle in which all active and/or passive controls (if they are present) which are necessary to keep the collector in working order can be verified during the exposure period. Their operation shall be validated to be functional, in such a way that any failure can be detected. The test cycle shall include as events, the loss of electrical supply and the blockage of tracking mechanism (if it is present). The laboratory shall check the collector response and its ability to overcome (or not) such events.

In the test report specifications must be given for flow rate, fluid temperature, and duration of flow if a fluid flow is applied in the test.

11.4 Results

The results of the inspection shall be reported as required in A.7.

12 External thermal shock test

12.1 Objective

Collectors may from time to time be exposed to sudden rainstorms on hot sunny days, causing a severe external thermal shock. This test is intended to assess the capability of a collector to withstand such thermal shocks without a failure.

12.2 Apparatus and procedure

The collector shall be mounted either outdoors or in a solar irradiance simulator. Liquid heating collectors shall not be filled with fluid. In case of liquid heating collectors all of the fluid pipes shall be sealed to prevent cooling by natural circulation of air. In case of solar air heaters all fluid pipes shall be

sealed. One shall be left open to permit free expansion of air in the absorber. In case of an air heating collector the inlet and outlet shall resist water penetration.

An array of water jets shall be arranged to provide a uniform spray of water over the front of the collector.

The collector shall be exposed to climatic conditions as described in [Table 4](#) (class specified by the manufacturer) for a period of 1 h before the water spray. It is then cooled by the water spray for 15 min before being inspected.

The collector shall be subjected to two external thermal shocks.

12.3 Test conditions

The set of reference conditions given in [Table 4](#) shall be used. The specified operating conditions shall be:

- solar (or simulated solar) irradiance G greater than the value shown in [Table 4](#).
- surrounding air temperature θ_a greater than the value shown in [Table 4](#).

Or conditions resulting in the same collector temperature according to [Clause 10](#).

The water spray shall have a temperature of less than 25 °C and a flow rate in the range 0,03 kg/s to 0,05 kg/s per square meter of collector gross area.

If the temperature of the water which first cools the collector is likely to be greater than 25 °C (for example if the water has been sitting in a pipe in the sun for some time), then the water shall be diverted until it has reached a temperature of less than 25 °C before being directed over the collector.

12.4 Results

The results shall be reported as required in A.8.

13 Internal thermal shock test

13.1 Objective

Collectors may from time to time be exposed to a sudden intake of cold heat transfer fluid on hot sunny days, causing a severe internal thermal shock, for example, after a period of shutdown, when the installation is brought back into operation while the collector is at its stagnation temperature. This test is intended to assess the capability of a collector to withstand such thermal shocks without failure.

13.2 Apparatus and procedure

The collector shall be mounted either outdoors or in a solar irradiance simulator. Liquid heating collectors shall not be filled with fluid. One of its fluid pipes shall be connected via a shutoff valve to the heat transfer fluid source and the other shall be left open initially to permit the free expansion of air in the absorber and also to permit the heat transfer fluid to leave the absorber (and be collected). If the collector has more than two fluid pipes, the remaining openings shall be sealed in a way that ensures the designed flow pattern within the collector.

The collector shall be exposed to climatic conditions as described in [Table 4](#) (class specified by the manufacturer) for a period of 1 h before it is cooled by supplying it with heat transfer fluid for at least 5 min.

The collector shall be subjected to two internal thermal shocks.

This test is not applicable to those parts of the collector which are factory sealed. It is not applicable to those collectors in which heat transfer fluid is continuously flowing for protection purposes. In that case control(s) used to manage a no-flow condition shall be validated to be functional in such a way that any failure can be detected.

13.3 Test conditions

[Table 4](#) shall be used.

The specified operating conditions shall be:

- solar (or simulated solar) irradiance G greater than the value shown in [Table 4](#) - ambient air temperature ϑ_a greater than the value shown in [Table 4](#).

or conditions resulting in the same collector temperature according to [Clause 10](#).

In case of a liquid heating collector the heat transfer fluid shall have a temperature of less than 25 °C. The fluid flow rate shall be the maximum flow rate of the thermal performance test, at least 0,02 kg/s per square meter of collector gross area (unless otherwise specified by the manufacturer). In case of an air heating collector the heat transfer fluid shall be at ambient temperature or less. The flow rate shall be the maximum recommended flow rate specified by the manufacturer.

13.4 Results

The results shall be reported as required in A.9.

14 Rain penetration test

14.1 Objective

This test is applicable only for glazed collectors and is intended to assess the extent to which glazed collectors are substantially resistant to rain penetration. They shall normally not permit the entry of either free-falling rain or driving rain. Collectors may have ventilation holes and drain holes, but these shall not permit the entry of drifting rain.

When testing a concentrating collector a procedure comparable to this should be followed.

14.2 Apparatus and procedure

The collector shall be installed in a test rig at the shallowest angle to the horizontal recommended by the manufacturer. If this angle is not specified, then the collector shall be placed at a tilt of 30° to the horizontal (see [Figure 2](#) — Positioning of collector and spray nozzles for rain penetration test). Collectors designed to be integrated into a roof structure shall be mounted in a simulated roof and have their underside protected. Other collectors shall be mounted in a conventional manner on an open frame or a simulated roof.

The collector shall be sprayed with water at a temperature lower than 30 °C. The duration of the spraying process shall be at least 4 h. During the spraying process the absorber shall be kept warm. This shall be done by circulating hot fluid at 55 °C (± 5 K) through the absorber.

If the detection of ingress of water by final inspection is chosen ([Clause 18](#)), the collector shall be left at the test rig for rain penetration for at least 4 h after the end of spraying, without heating the absorber. After that the collector shall be stored in such a way that the results are not influenced until the detection of ingress of water has been carried out. The detection of ingress of water by final inspection shall be done within at least 4 h and at most 48 h after the end of spraying. If the weighing method is chosen, the collector shall be weighted between 4 – 5 h after the spraying process. Unnecessary transportation of the collector should be avoided.

In case of rain penetration test outdoor the collector should be shaded to keep temperature of absorber at about 55 °C.

The penetration of water into the collector shall be determined by final inspection or by weighing the collector.

If the weighing method results in failure judgment, the final inspection shall be done for final assessment of the result.

If the weighing method is chosen, the collector shall be put on the scale before the start of the test on three consecutive occasions. The three weights shall not vary by more than $\pm 5 \text{ g/m}^2$ collector gross area. After the spraying process the collector shall be weighted again on three consecutive occasions. Again the three weights shall not vary by more than $\pm 5 \text{ g/m}^2$ collector gross area. The determined water quantity shall be less than 30 g/m^2 collector gross area. The standard uncertainty of the scale shall be better than 5 g/m^2 collector gross area.

During final inspection (according to [Clause 18](#)) the collector shall be inspected with focus on the following criteria:

- Water inside the casing
- Wet insulation (more than 10 ml coming out by squeezing insulation)
- Visible trace of water drops running down (cover, absorber, casing)

When testing evacuated tubular collectors the fixing devices of evacuated tubes should be checked if they are designed for draining of water.

For the weighing method it is essential to dry and clean the outside of the collector before and after the spraying process. If a compressor is used this should be done in a way not to move water into or out of collector casing.

14.3 Test conditions

The water pressure shall be maintained at 300 kPa ($\pm 50 \text{ kPa}$). The spray heads required are specified as followed:

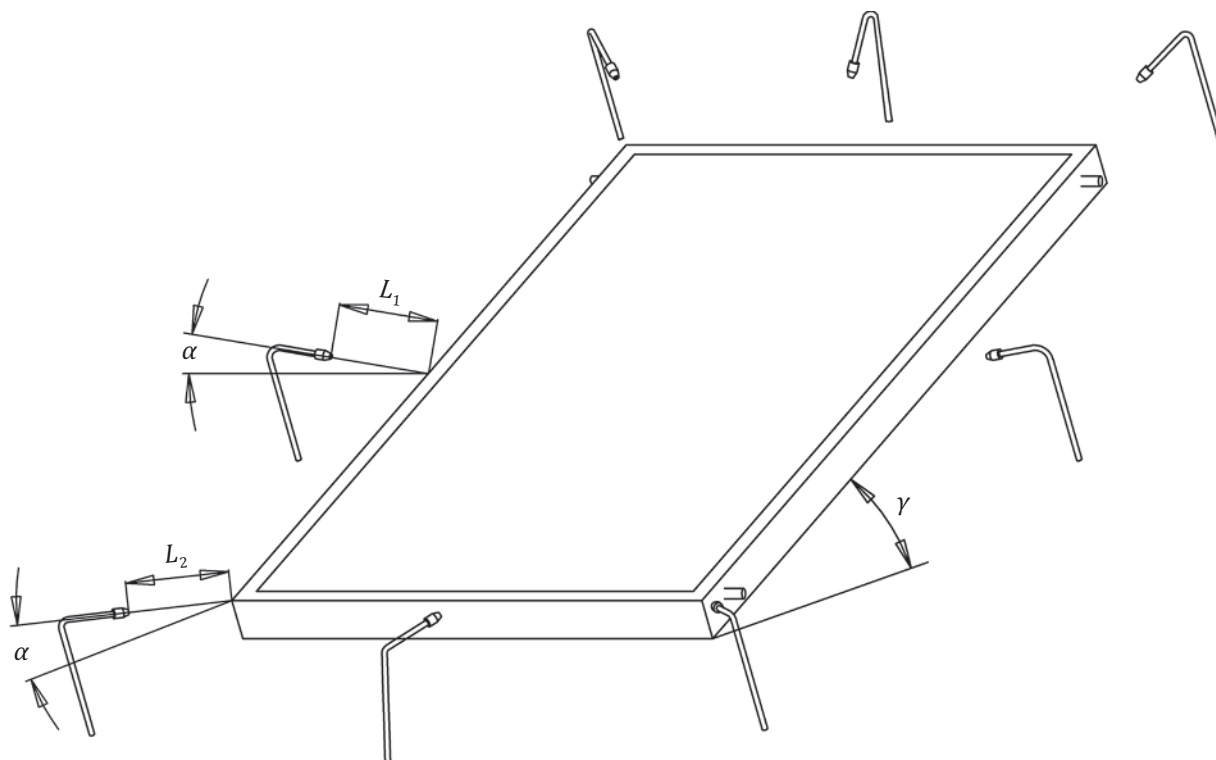
- full cone spray nozzles
- mass flow of 2 kg/min ($\pm 0,5 \text{ kg/min}$) per nozzle,
- spray angle of $60^\circ \pm 5^\circ$.

If drop size is defined in data sheets of spray nozzle it should be at least $150 \mu\text{m}$.

The positioning of the spray nozzles shall be done according to [Figure 2](#) — Positioning of collector and spray nozzles for rain penetration test, i.e.:

- every corner of the casing shall be sprayed directly
- every area shown in [Figure 3](#) — Spraying areas of flat plate collectors (including middle bar) and [Figure 4](#) — Spraying areas of evacuated tube collectors and should be sprayed.
- spray heads shall also be positioned at the side of the collector if the corner nozzles are further apart than the maximum distance of 150 cm.
- the spray nozzles shall be directed at an angle of $30^\circ (\pm 5^\circ)$ onto the plane of the collector
- the spray heads shall be located at a distance of 250 mm ($\pm 50 \text{ mm}$) from the corners and 250 – 400 mm from the sides of the collector (see [Figure 2](#) — Positioning of collector and spray nozzles for rain penetration test).
- the maximum distance between two spraying nozzles shall be 150 cm

Middle bars should be sprayed from spraying heads above with a distance of 400 to 600 mm, the angle of 30° is not required.



Key

L_1 250 – 400 mm

L_2 250 mm

α 30° angle of spray nozzle with respect to the collector surface

γ smallest tilt angle to the horizontal recommended by the manufacturer, if this angle is not specified use 30°

Figure 2 — Positioning of collector and spray nozzles for rain penetration test

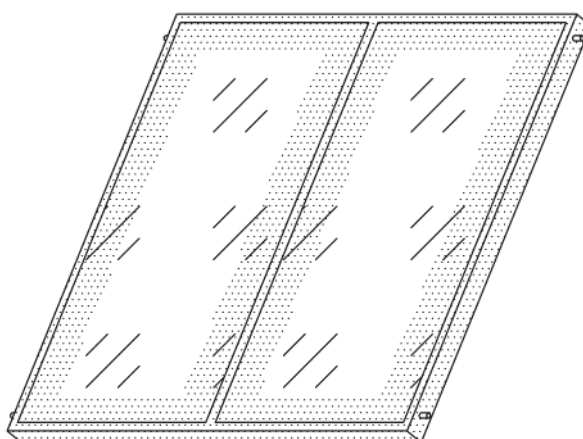


Figure 3 — Spraying areas of flat plate collectors (including middle bar)

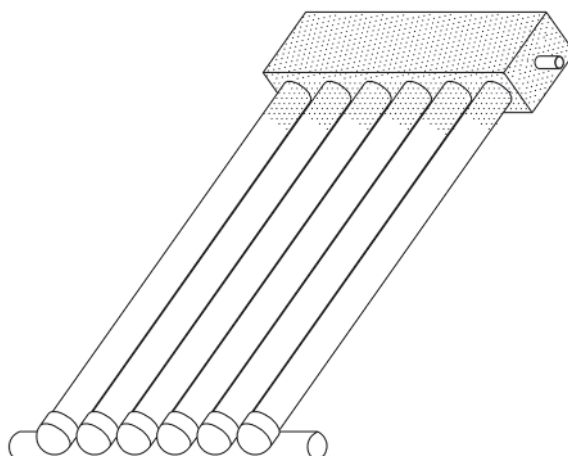


Figure 4 — Spraying areas of evacuated tube collectors

14.4 Results

The results shall be reported as required in A.10.

15 Freeze resistance test

15.1 Objective

This test is not applicable to collectors for which it is clearly stated in the installation manual that they may only be used with an antifreeze fluid or air. Neither is it to be used where special means are used to prevent water in a permanently filled collector loop from freezing e.g. by antifreeze algorithm unless additional liquids with the risk of freezing are used as e.g. in many heat pipes.

Two test procedures are recommended:

- one for collectors which are claimed to be freeze-resistant when filled with water, and
- one for collectors which are claimed to resist freezing after being drained.

15.2 Apparatus and procedure

15.2.1 General

The collector shall be mounted in a cold chamber. The collector shall be fitted correctly, shut completely and inclined at the smallest tilt angle to the horizontal recommended by the manufacturer. If no angle is specified by the manufacturer, the collector shall be inclined at an angle of 30° to the horizontal. Unglazed collectors shall be tested in a horizontal position unless this is excluded by the manufacturer.

15.2.2 Freeze-resistant collectors

The collector shall be filled with water at the operating pressure. The cold-chamber temperature shall be cycled, and at the end of each cycle the collector shall be refilled with water at operating pressure. The temperature of the water shall be monitored throughout the test.

15.2.3 Collectors with drain-down protection

The collector shall be filled with water, kept at operating pressure for 10 min and then drained using the device installed by the manufacturer. If, 5 min after the start of the drain process, the collector is

drained water from the collector corresponds to approximately 95 % of the total water which filled that collector, no test in cold chamber is required. The temperature shall be measured inside the absorber close to the inlet. After the last cycle the collector shall be refilled with water at operating pressure.

15.3 Test conditions

The water contents of the absorber or the heat pipe shall be maintained at $(-20 \pm 2) ^\circ\text{C}$ for at least 30 min during the freezing part of the cycle, and are raised to above $10 ^\circ\text{C}$ during the thawing part of the cycle. The duration of the thawing part of the cycle shall be at least 30 min.

The collector shall be subjected to three freeze–thaw cycles.

15.4 Results

The results shall be reported as required in A.11.

16 Mechanical load test with positive or negative pressure

16.1 Objectives

The mechanical load test with positive pressure is intended to assess the extent to which the transparent cover of the collector, the collector box and the fixings are able to resist the positive pressure load due to the effect of wind and snow.

The mechanical load test with negative pressure is intended to assess the deformation and the extent to which the collector box and the fixings between the collector cover, collector box and collector mounting are able to resist uplift forces caused by the wind.

16.2 Apparatus and procedure

16.2.1 Mechanical load test with positive pressure

For the mechanical load test with positive pressure the collector shall be fixed on a stiff even ground using the manufacturers original equipment for mounting. Different methodologies may be used to apply load to the collector. If weight of material is used the collector shall be placed horizontally.

NOTE The collector mounting comprises the equipment to connect the collector fixings with the supporting framework (e.g. roof anchor, roof hook). The collector fixing comprises the equipment to connect the collector box/frame with the collector mounting equipment (e.g. clamps, bolts).

- Using a foil and gravel or water:

On the collector a foil shall be laid and on the collector frame a wooden or metallic frame shall be placed, high enough to contain the required amount of gravel or similar material. The gravel, preferably type 2-32 mm, shall be weighed in portions and distributed in the frame so that everywhere the same load is created (pay attention to the bending of the glass), until the desired height is reached.

- Using suction cups:

The test can also be carried out using suction cups. The suction cups shall be distributed as even as possible on the collectors surface. The suction cups shall not hinder the movement of the collector cover caused by the mechanical load.

- Using air pressure on the collector cover:

If sealing towards the ambient is necessary, the sealing shall not hinder the movement induced by the load in any way.

16.2.2 Mechanical load test with negative pressure

For the mechanical load test with negative pressure the collector can be placed horizontally and the manufacturers' original equipment for mounting shall be used. Different methodologies may be used to apply load to the collector.

A lifting force which is equivalent to the specified negative pressure load shall be applied evenly over the cover or the tubes. If the cover has not been loosened, or any other failure which could be defined as major, at the final pressure, then the pressure may be stepped up until failure occurs. The time between each pressure step shall be the time needed for the pressure to stabilize.

- Method (a): The load may be applied to the collector cover by means of a uniformly distributed set of suction cups.
- Method (b): For collectors which have an almost airtight collector box, the following procedure may be used to create a negative pressure on the cover. Two holes are made through the collector box into the air gap between the collector cover and absorber, and an air source and pressure gauge are connected to the collector air gap through these holes. A negative pressure on the cover is created by pressurizing the collector box. For safety reasons the collector shall be encased in a transparent box to protect personnel in the event of failure during this test.
- Method (c): For evacuated tubular collectors ropes, belts or other appropriate equipment to distribute the forces along the tubes can be used.
- Method (d): For evacuated tubular and flat plate collectors the method according to ASTM E330-02 using air pressure can be applied.

Where flashings or sealing kits that are an integral part of the collector provide any uplift resistance, they should be included in the test.

16.2.3 Particular specifications for concentrating collectors

As concentrating collectors have different geometries, the laboratory may design specific and suitable procedures to test resistance against mechanical load. This circumstance and the procedure carried out shall be clearly described with the test results. When according to the manufacturer's instructions, controls are present to protect the collectors against wind or snow load, the control functions shall be checked, if it is possible, and they shall demonstrate resistance to failures associated with normal collector operation.

16.3 Test conditions

The test pressure shall be 2400 Pa (positive and negative) or as specified by the manufacturer. The reference area to be used is the gross area of the collector.

A permanent deformation should be assigned to a load value, while it is completely relieved after every load increment and the distortion is measured compared to the beginning of the test sequence.

16.4 Results

The results shall be reported as required in A.12.

17 Impact resistance test

17.1 Objective

This test is intended to assess the extent to which a collector can withstand the effects of impacts caused by hailstones.

17.2 Test procedure

Two test methods are available. The first one uses ice balls, the second one steel balls. The test method to be applied shall be chosen by the manufacturer.

The test procedure consists in a succession of shot series on the collector. Each shot series consists in 4 shots of the same impact strength. For ice balls the impact strength of a shot is determined by the ball diameter and velocity according to [Table 5](#). For steel balls the impact strength of the shot is determined by the height of drop according to [17.5](#).

Balls of increasing impact strength shall be used in the successive shot series.

For the first shot series the smallest ice ball diameter specified by the manufacturer or the lowest height of drop specified by the manufacturer for the steel ball shall be used.

The last shot series shall be the one with the ice ball diameter or the steel ball height of drop specified by the manufacturer, unless the collector has to be considered as destroyed before this shot series could be performed.

Impact locations shall be selected according to [17.3](#). For each impact location the point of impact shall be moved by a few millimetres from all previous points of impact, while maintaining the shot direction normal to the collector surface at this location.

For evacuated tube collectors the following rule applies: If one tube breaks the test shall be repeated with a second tube. If also this tube breaks the test is considered as failed.

17.3 Impact location

a) Glazed flat plate collectors:

The points of impact shall be located 75 mm from each of two intersecting edges of the glazing, or absorber surface, as appropriate. For each shot of one specific ice ball diameter or test height a different corner shall be chosen.

b) Unglazed flat plate collectors:

For the selection of the points of impact the same rules as for glazed flat plate collectors applies. Unglazed collectors shall be filled with a fluid at atmospheric pressure.

c) Evacuated tube collectors:

For each ice ball diameter or height of drop, one randomly chosen tube of the collector shall be tested. The points of impact shall be located at 75 mm from each end and the shot direction shall be normal to the tube axis. The tube shall be hit twice at the upper end and twice at the lower end.

d) Collectors that cannot be clearly classified into the category a), b) or c):

Two representative impact locations shall be defined by the testing laboratory. Both impact locations shall be shot twice. The coordinates of the points of impact shall be defined before the shots.

17.4 Method 1: Impact resistance test using ice balls

17.4.1 Apparatus

- a) A storage container for storing the ice balls at a temperature of $-4\text{ °C} \pm 2\text{ °C}$.
- b) A rigid frame for supporting the collector, with the impact surface perpendicular to the path of the projected ice ball; the support shall be stiff enough so that there is negligible distortion or deflection at the time of impact.
- c) A balance to determine the mass of an ice ball to a standard uncertainty of $\pm 2\%$.

- d) A launcher capable of propelling an ice ball as defined in [17.4.2](#).
- e) An instrument for measuring the velocity of the ice ball to a standard uncertainty of ± 2 m/s. The distance of the velocity sensor to the collector surface shall be at maximum 1 m.

17.4.2 Ice balls

The ice balls shall be made of demineralized water without any additive. They shall consist in clear ice entirely free of air bubbles and shall not have any crack visible to an unaided eye. The ball diameter shall be one of those listed in [Table 5](#). The ice balls used for the shots shall have a temperature of $-4\text{ °C} \pm 2\text{ °C}$.

Table 5 — Ice ball masses and test velocities

Diameter [mm $\pm 5\%$]	Mass [g $\pm 5\%$]	Test velocity [m/s $\pm 5\%$]
15	1,63	17,8
25	7,53	23,0
35	20,7	27,2
45	43,9	30,7

17.4.3 Specific aspects of the test procedure using ice balls

- a) Place the balls in the storage container and leave them there for at least 1 h before use.
- b) Ensure that all surfaces of the launcher likely to be in contact with the ice balls are near room temperature.
- c) Fire a number of trial shots at a simulated target in accordance with step e) below and adjust the launcher until the velocity of the ice ball, as measured with the velocity sensor in the prescribed position, is within $\pm 5\%$ of the relevant hailstone test velocity given in [Table 5](#).
- d) Install the collector at room temperature on the rigid frame.
- e) The time between the removal of the ice ball from the container and its impact on the collector shall not exceed 60 s.
- f) Fire the shot series on the collector as required. Inspect the collector at the points of impact and take notice of any sign of damage and visible effect of the shots.

17.5 Method 2: Impact resistance test using steel balls

The collector shall be mounted either vertically or horizontally on a support. The support shall be stiff enough so that there is negligible distortion or deflection at the time of impact.

Steel balls shall be used to simulate a hail impact. If the collector is mounted horizontally then the steel balls are dropped vertically, or if it is mounted vertically then the impacts are directed horizontally by means of a pendulum. In both cases, the height of drop is the vertical distance between the point of release and the horizontal plane containing the point of impact.

If the test is conducted according to this method, the steel ball shall have a mass of $150\text{ g} \pm 10\text{ g}$ and the following heights of drop shall be considered: 0,4 m, 0,6 m, 0,8 m, 1,0 m, 1,2 m, 1,4 m, 1,6 m, 1,8 m and 2,0 m.

17.6 Results

The results shall be reported as required in A.13.

18 Final inspection (related to [Clauses 5 to 17](#))

When the tests have been completed, and the same collector is not going to be used for the performance test, the collector used for the test shall be dismantled and inspected. All abnormalities shall be documented and accompanied by photographs. The collector and all of its components shall be described and should be photographed (glazing, absorber, absorber coating, insulation, housing, inlet and outlet ports, glazing supports and retainers, seals, gaskets, back sheet, etc.).

Specific assessment criteria for each of the tests listed in [Table 1](#) of [5.1](#) are listed in the respective test paragraphs. The term “no major failure”, denotes that none of the following occurs:

- Fluid channel leakage (in case of liquid heating collectors only) or such deformation that permanent contact between absorber and cover is established;
- Breaking or permanent deformation of cover or cover fixing;
- Breaking or permanent deformation of collector fixing points or collector box;
- Vacuum loss, such that vacuum or sub atmospheric collectors shall be classified according to the definition in ISO 9488 (only applicable for vacuum and sub atmospheric collectors);
- Accumulation of humidity in form of condensate on the inside of the transparent cover of the collector exceeding 10 % of the visible transparent cover area. In case of an open loop air heating collector for limited periods of time this criterion maybe exceeded.
- Any other abnormality resulting in a significant reduction of performance or service life time.

The evaluation of accumulation of humidity for application of the pass criteria should be applied only on the following test:

- External Thermal Shock
- Rain Penetration Test

19 Test report (related to [Clauses 5 to 18](#))

The format sheets given in [Annex A](#) shall be completed for each test, together with the introductory format sheet A.2 reporting a summary of main results, including the test methods.

20 Performance testing of fluid heating collectors

20.1 General

Performance testing includes the assessment of the heat power delivered by the collector under various operating conditions as well as the assessment of additional collector parameters (pressure drop, incident angle modifier, heat capacity, time constant) required for the calculation of the collector heat output.

For hybrid collectors generating heat and electric power, the operation mode of the electricity generator (MPP tracked, open or short circuit) could have a major influence on the thermal performance and need to be mentioned within the report. If the absorber of the hybrid collector is close connected to the electricity generator and if there is no extra glazing in front, this collector shall be treated as unglazed. During thermal performance testing, the electricity generator shall be maintained within 15 % of the module's maximum power point (MPP) if operated in MPP mode.