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Foreword

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This document was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 312, *Thermal solar systems and components*, in collaboration with ISO Technical Committee TC 180, *Solar energy*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition ISO 9806:2013, which has been technically revised.

Introduction

This document defines procedures for testing fluid heating solar collectors for thermal 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 document represent a wide range of applications, e.g. glazed flat plate collectors and evacuated tube collectors for domestic water and space heating, collectors for heating swimming pools or for other low temperature systems or tracking concentrating collectors for thermal power generation and process heat applications. This document is applicable to collectors using liquids, as well as air as heat transfer fluid. Similarly, collectors using external power sources for normal operation and/or safety purposes (overheating protection, environmental hazards, etc.), as well as hybrid devices generating thermal power and electrical power are also considered.

Solar energy — Solar thermal collectors — Test methods

1 Scope

This document specifies test methods for assessing the durability, reliability, safety and thermal performance of fluid heating solar collectors. The test methods are applicable for laboratory testing and for *in situ* testing.

This document is applicable to all types of fluid heating solar collectors, air heating solar collectors, hybrid solar collectors co-generating heat and electric power, as well as to solar collectors using external power sources for normal operation and/or safety purposes. It does not cover electrical safety aspects or other specific properties directly related to electric power generation.

This document is not applicable to those devices in which a thermal storage unit is an integral part to such an extent that the collection process cannot be separated from the storage process for making the collector thermal performance measurements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 9488, *Solar energy — Vocabulary*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
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

3.2
maximum operating temperature
maximum temperature allowed during collector or system normal operation specified by the manufacturer

3.3
outgassing
process in which any material releases gases when it is exposed to elevated temperatures and/or reduced pressure

3.4
reflector
surface intended for reflecting radiant energy

3.5
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

3.6
trigger temperature
temperature value at which the safety controls are activated for fail-safe operating condition

4 Symbols

A_G	Gross area of collector as defined in the ISO 9488	m^2
a_1	Heat loss coefficient	$W/(m^2 \cdot K)$
a_2	Temperature dependence of the heat loss coefficient	$W/(m^2 \cdot K^2)$
a_3	Wind speed dependence of the heat loss coefficient	$J/(m^3 \cdot K)$
a_4	Sky temperature dependence of the heat loss coefficient	—
a_5	Effective thermal capacity	$J/(m^2 \cdot K)$
a_6	Wind speed dependence of the zero loss efficiency	s/m
a_7	Wind speed dependence of IR radiation exchange	$W/(m^2 \cdot K^4)$
a_8	Radiation losses	$W/(m^2 \cdot K^4)$
b_u	Collector efficiency coefficient (wind dependence)	s/m
C	Effective thermal capacity of collector	J/K
C_R	Geometric concentration ratio	—
c_f	Specific heat capacity of heat transfer fluid	J/(kgK)
$c_{f,i}$	Specific heat capacity of heat transfer fluid at the collector inlet	J/(kgK)
$c_{f,e}$	Specific heat capacity of heat transfer fluid at the collector outlet	J/(kgK)
$c_{f,a}$	Specific heat capacity of the ambient air	J/(kgK)
E_L	Longwave irradiance ($\lambda > 3$ µm)	W/m^2
G_{hem}	Hemispherical solar irradiance	W/m^2
G_S	Hemispherical solar irradiance for the calculation for the standard stagnation temperature	W/m^2
G_m	Average measured 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	Irradiation on collector plane for exposure test	MJ/m^2
$K_{hem}(\theta_L,\theta_T)$	Incidence angle modifier for hemispherical solar radiation	—
$K_b(\theta_L,\theta_T)$	Incidence angle modifier for direct solar irradiance	—
$K_{\theta L}$	Incidence angle modifier in the longitudinal plane	—
$K_{\theta T}$	Incidence angle modifier in the transversal plane	—
K_d	Incidence angle modifier for diffuse solar radiation	—
$\dot{m}$	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
$\dot{m}_e$	Downstream air mass flow rate	kg/s
$\dot{m}_i$	Upstream air mass flow rate	kg/s
$\dot{m}_l$	Leakage air mass flow rate	kg/s
$p_{f,e}$	Static pressure of the heat transfer fluid (air) at the outlet of the solar collector	Pa
$p_{f,i}$	Static pressure of the heat transfer fluid (air) at the inlet of the solar collector	Pa
p_{abs}	Absolute pressure of the ambient air	Pa
$\dot{Q}$	Useful power extracted from collector	W
$\dot{Q}_{Peak}$	Peak power. Power output of the collector for normal incidence, G_b = 850 W/m^2, G_d = 150 W/m^2 and ϑ_m - ϑ_a = 0 K	W
R_D	Gas constant for water vapour	461,4 J/(kgK)
R_L	Gas constant for air	287,1 J/(kgK)
T	Absolute temperature	K
t	Time	s
u	Surrounding air speed	m/s
u'	Reduced surrounding air speed $u' = u - 3$ m/s	m/s
U	Measured overall heat loss coefficient of collector with reference to $(\vartheta_m - \vartheta_a)/G_{hem}$	W/(m^{2}K)
V_f	Fluid capacity of the collector	m^3
$\dot{V}$	Volumetric flow	m^3/s

$\dot{V}_e$	Volumetric flow at the outlet of the solar collector	m^3/s
$\dot{V}_i$	Volumetric flow at the inlet of the solar collector	m^3/s
$\dot{V}_l$	Volumetric leakage flow rate	m^3/s
$X_{W,a}$	Water content of the ambient air	kg H_2O/kg dry air
$X_{W,e}$	Water content of the air at the exit of the solar collector	kg H_2O/kg dry air
$X_{W,i}$	Water content of the air at the inlet of the solar collector	kg H_2O/kg dry air
Δp	Pressure difference between fluid inlet and outlet	Pa
Δt	Time interval	s
ΔT	Temperature difference between fluid outlet and inlet (ϑ_e - ϑ_{in})	K
γ	Solar azimuth angle	°
η_b	Collector efficiency based on beam irradiance G_b	—
η_{hem}	Collector efficiency based on hemispherical irradiance G_{hem}	—
$\eta_{0,b}$	Peak collector efficiency (η_b at $\vartheta_m - \vartheta_a = 0$ K) based on beam irradiance G_b	—
$\eta_{0,hem}$	Peak collector efficiency ($\eta_{0,hem}$ at $\vartheta_m - \vartheta_a = 0$ K) based on hemispherical irradiance G_{hem}	—
$\eta_{hem,\dot{m}_i}$	Collector efficiency, with reference to mass flow $\dot{m}_i$	—
θ	Angle of incidence	°
θ_L	Longitudinal angle of incidence: angle between the normal to the plane of the collector and incident sunbeam projected into the longitudinal plane	°
θ_T	Transversal angle of incidence: angle between the normal to the plane of the collector and incident sunbeam projected into the transversal plane	°
ϑ_a	Ambient air temperature	°C
ϑ_{am}	Measured ambient air temperature	°C
ϑ_{as}	Ambient air temperature for the standard stagnation temperature	°C
ϑ_e	Collector outlet temperature	°C
ϑ_i	Collector inlet temperature	°C
ϑ_m	Mean temperature of heat transfer fluid	°C
ϑ_{max_op}	Maximum operating temperature	°C
ϑ_{stg}	Standard stagnation temperature	°C
ϑ_{sky}	Atmospheric or sky temperature	°C

$\vartheta_{trigger}$	Trigger temperature for safety activation	°C
$\vartheta_{m,th}$	Volume flow weighted mean 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
ϑ_{sm}	Average measured absorber temperature	°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	—

5 General

5.1 Test overview — Sequence of the tests

A full test sequence for solar thermal collectors including durability test and thermal performance measurements is proposed in Table 1. This test sequence may be modified or only single tests may be performed as required. For some tests, however, a certain preconditioning or a half-exposure test (see Clause 10) is mandatory. For all test sequences and single tests, the final inspection (see Clause 17) is recommended as concluding test for the proper identification and description of the test sample, as well as to identify problems or deficiencies.

Table 1 — Test list

Clause	Test
Clause 7	Air leakage rate test[f]
Clause 8	Rupture or collapse test[f]
Clause 9	Standard stagnation temperature
Clause 10	Exposure test[b]
Clause 11	External thermal shock test[b]
Clause 12	Internal thermal shock test[b,e]
Clause 13	Rain penetration test[f]
Clause 14	Freeze resistance test[c,f]
Clause 6	Internal pressure test for fluid channels[a,d,e]
Clause 15	Mechanical load test[f]
Clause 16	Impact resistance test[g]
Clause 17	Final inspection