INTERNATIONAL STANDARD

# ISO 9806

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# Solar energy — Solar thermal collectors — Test methods

*Énergie solaire — Capteurs thermiques solaires — Méthodes d'essai*



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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 (ϑm - ϑa) = 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 (ϑm - ϑa) = 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 (ϑm - ϑa) = 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/(m²·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 ($\lambda > 3$ µm) | W/m² |
| $E\beta$ | long wave irradiance on an inclined surface outdoors | W/m² |
| $E_s$ | long wave irradiance | W/m² |
| $F$ | radiation view factor | |
| $F'$ | collector efficiency factor | |
| $G$ | hemispherical solar irradiance | W/m² |
| $G''$ | net irradiance | W/m² |
| $G_b$ | direct solar irradiance (beam irradiance) | W/m² |
| $G_d$ | diffuse solar irradiance | W/m² |
| $H$ | hemispherical irradiation on the collector plane | MJ/m² |
| $h_{f,a}$ | 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 |
| $K_{hem}(\theta_L,\theta_T)$ | 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 |
| $p_{f,e}$ | static pressure of the heat transfer fluid (air) at the outlet to the solar collector | Pa |
| $p_{f,i}$ | 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 W/m² and $\vartheta_m$-$\vartheta_a$ = 0 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/m² |
| $Q_{module}$ | 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 |
| $T^*_{\mathrm{m}}$ | reduced temperature difference ( = $(\vartheta_{\mathrm{m}} - \vartheta_{\mathrm{a}})/G$) | $\mathrm{m^2K/W}$ |
| $\vartheta_{\mathrm{m,max}}$ | maximum operating temperature as stated by the manufacturer | |
| $T_{\mathrm{s}}$ | atmospheric or equivalent sky radiation temperature | K |
| $t$ | time | s |
| $U$ | measured overall heat loss coefficient of collector with reference to $T^*_{\mathrm{m}}$ | $\mathrm{W/(m^2K)}$ |
| $U_{\mathrm{L}}$ | overall heat loss coefficient of a collector with uniform absorber temperature $\vartheta_{\mathrm{m}}$ | $\mathrm{W/(m^2K)}$ |
| $u$ | surrounding air speed | m/s |
| $V_{\mathrm{f}}$ | fluid capacity of the collector | $\mathrm{m^3}$ |
| $\dot{V}_p$ | volumetric flow | $\mathrm{m^3/s}$ |
| $\dot{V}_{p,e}$ | volumetric flow at the outlet of the solar collector | $\mathrm{m^3/s}$ |
| $\dot{V}_{p,i}$ | volumetric flow at the inlet of the solar collector | $\mathrm{m^3/s}$ |
| $\dot{V}_{p,L}$ | volumetric leakage flow rate | $\mathrm{m^3/s}$ |
| $X_{W,a}$ | water content of the ambient air | kg $H_2O$/kg dry *air* |
| $X_{W,e}$ | water content at the exit of the solar collector | kg $H_2O$/kg dry air |
| $X_{W,i}$ | water content at the inlet of the solar collector | kg $H_2O$/kg dry air |
| $\alpha$ | solar absorptance | % |
| $\alpha_{\mathrm{s}}$ | solar altitude angle | degrees |
| $\beta$ | tilt angle of a plane with respect to horizontal | degrees |
| $\gamma$ | collector azimuth angle (0 = south, east negative) | degrees |

| | | |
|---|---|---|
| $\gamma_s$ | solar azimuth angle (0 = south, east negative) | degrees |
| $\Delta p$ | pressure difference between fluid inlet and outlet | Pa |
| $\Delta t$ | time interval | s |
| $\Delta T$ | temperature difference between fluid outlet and inlet ($\vartheta_e$ - $\vartheta_{in}$) | K |
| $\delta$ | solar declination | degrees |
| $\varepsilon$ | hemispherical emittance | % |
| $\eta$ | collector efficiency, with reference to $T^*_m$ | - |
| $\eta_b$ | collector efficiency, with reference to $T^*_m$, based on beam irradiance $G_b$ | - |
| $\eta_{hem}$ | collector efficiency, with reference to $T^*_m$, based on hemispherical irradiance G | - |
| $\eta_{0,b}$ | peak collector efficiency ($\eta_b$ at T*m = 0), reference to T*m, based on beam irradiance Gb | - |
| $\eta_{0,hem}$ | peak collector efficiency ($\eta_{hem}$ 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) | - |
| $\eta_m$ | collector efficiency, with reference to $\eta_{max}$, 0 m/s | - |
| $\theta$ | 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 |
| $\theta_Z$ | solar zenith angle ( = 90 - θH) | degrees |
| $\theta_{II}$ or $\theta_L$ | longitudinal angle of incidence | degrees |
| $\theta_{\perp}$ or $\theta_T$ | transversal angle of incidence | degrees |
| $\vartheta_a$ | ambient or surrounding air temperature | °C |
| $\vartheta_{dp}$ | atmospheric dew point temperature | °C |
| $\vartheta_e$ | collector outlet (exit) temperature | °C |
| $\vartheta_{in}$ | collector inlet temperature | °C |