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Foreword

This European Standard (EN 12975-2:2006) has been prepared by Technical Committee CEN/TC 312 “Thermal solar systems and components”, the secretariat of which is held by ELOT.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2006, and conflicting national standards shall be withdrawn at the latest by September 2006.

This European Standard supersedes EN 12975-2:2001.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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Introduction

This standard specifies test methods for determining the ability of a fluid heating solar collector to resist the influence of degrading agents. It defines procedures for testing collectors under well-defined and repeatable conditions.

This standard also provides test methods and calculation procedures for determining the steady-state and quasi-dynamic thermal performance of glazed fluid heating solar collectors. It contains 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.

This standard also provides methods for determining the thermal performance of unglazed fluid heating solar collectors. Unglazed collectors are in most cases used for heating swimming pools or other low temperature consumers. In general the collectors are put together on-site, connecting absorber strips with manifolds. Real absorber areas are mostly between ten to one hundred square meters. For unglazed absorbers, readily fabricated modules with a specific size are seldom used. Therefore, during the test, it should be checked that a realistic flow pattern and flow velocity is used.

This standard also provides test methods and calculation procedures for determining the steady-state as well as the all-day thermal performance parameters for fluid heating solar collectors, under changing weather conditions. It contains methods for conducting tests outdoors during whole days and under stationary inlet temperature conditions and natural solar irradiance and natural and/or simulated wind conditions. Important effects for the all-day performance of the collector, as the dependence on incident angle, wind speed, diffuse fraction of solar irradiance, thermal sky radiation and thermal capacity are taken into account. Dependence on flow rate is not included in this standard.

Some of the advantages of the proposed extension of the present steady-state test methods of all-day testing are:

– shorter and less expensive outdoor test, suitable for European climate conditions.

– much wider range of collectors can be tested with the same method.

– at the same time, a much more complete characterisation of the collector is achieved.

– collector model is still directly compatible with that of the present basic test standards, and only correction terms are applied in this extended approach.

– all additions are based on long agreed collector theory.

– at any time, full backwards comparability to steady-state can be established by evaluating only periods of the test days that correspond to steady-state test requirements.

– same test equipment can be used as for stationary testing with only minor changes, which will also improve the accuracy of steady-state testing.

– commonly available standard PC software can be used for the parameter identification, such as spreadsheets or more advanced statistical packages that have Multiple Linear Regression (MLR) as an option.

1 Scope

This European Standard specifies test methods for validating the durability, reliability and safety requirements for fluid heating collectors as specified in EN 12975-1. This standard also includes three test methods for the thermal performance characterisation for fluid heating collectors.

It 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.

Collectors that are custom built (built in; e.g. roof integrated collectors that do not compose of factory made modules and are assembled directly on the place of installation) cannot be tested in their actual form for durability, reliability and thermal performance according to this standard. Instead, a module with the same structure as the ready collector may be tested. The module gross area should be at least 2 m^2. The test is valid only for larger collectors than the tested module.

2 Normative references

The following referenced documents are indispensable for the application of this European Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1991 (all parts), *Eurocode 1: Actions on structures*

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

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

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

DIN 1946-1,2,6 Raumlufttechnik

DIN/EN 13779 Lüftung von Nicht-Wohngebäuden – Anforderungen an Lüftungs- und Klimaanlagen

DIN/EN/ISO 140 Akustik

DIN 4100/ 4109 Schallschutz

VDI 6022 Hygiene

Im Allgemeinen sind die Raumlufttechnischen Normen einzuhalten

VDI 4670 Calculation of fluid Capacity

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3 Terms and definitions

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

Acceptance angle

The angular zone within which radiation is accepted by the receiver of a concentrating collector.

Note: Radiation is said to be accepted because radiation incident within this angle reaches the absorber after passing through the aperture.

Note: See also field-of-view angle from ISO 9488 4.8. In this case, it applies not only to pyrheliometers but also to concentrating collectors

Cleanliness factor

The cleanliness factor is defined by the ratio of optical efficiency in certain dirty conditions and the optical efficiency with the same optical element in unsoiled, clean condition. This factor can be applied to single components (reflector, receiver), or to the whole collector.

Collector optical axis

For line-focus collectors, symmetry line orthogonal to focal line and aperture plane.

Collector rotation axis or tracking axis

{concentrating collector} Pivot axis of a line-focus collector, in most cases parallel to the focal line.

Collector useful power

Thermal power gained by the heat transfer fluid in the collector.

Combined assembly

A component part configuration that is not geometrically fixed or physically connected together for normal operation. A combined assembly would generally be comprised of components with individual nameplates and serial numbers.

Note: A heliostat array is an example of a combined assembly.

Concentrator

The concentrator is that part of the concentrating collector which directs radiation onto the receiver.

Concentrator axis

In line-focus collectors, symmetry line orthogonal to the collector aperture normal.

Cosine loss

The fact that the projected collector area visible from the Sun’s direction is smaller than the collector aperture. This loss is given by the cosine of the angle of incidence.

End effects

In line-focus collectors, the loss of collected energy at the ends of the linear absorber when the direct solar rays incident on the collector make a non-zero angle with respect to a plane perpendicular to the axis of the collector

Fail-safe

An operating condition of a collector, where collector protection functions will continue under specified collector and system failure modes.

Incident angle modifier

The ratio of the efficiency at off normal angles to the efficiency at normal incidence

Intercept factor

{concentrating collector} Fraction of reflected radiation which is intercepted by the receiver, (also capture fraction)

Longitudinal angle of incidence

Angle between collector aperture normal and incident sun beam projected into the longitudinal plane.

Note: not applicable to point-focus collectors and central receivers.

Longitudinal plane

Plane defined by the normal to the collector aperture and the concentrator axis (or the largest symmetry line for flat biaxial geometries).

Maximum operating temperature

{concentrating collector} Maximum temperature reached during collector or system normal operation, usually stated by the manufacturer

Minimum acceptance angle

The smallest angle of incidence for which the incident angle modifier is less than 0.7

Module

The smallest unit that would function as a solar energy collection device

Nominal collector power

Collector output thermal power, which can be achieved at design irradiance, normal incidence of solar radiation and design operation temperature.

Near-normal incidence

Angular range from exact normal incidence within which the deviations in thermal performance measured at ambient temperature do not exceed 62 %, such that the errors caused by testing at angles other than exact normal incidence cannot be distinguished from errors caused by other inaccuracies (that is, instrumentation errors, etc.)

Nonconcentrating collector

A solar collector without any reflector, lens or other optical element to redirect and concentrate solar irradiance.

No-Flow condition

The 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.

Outgassing

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

Optical efficiency or zero loss efficiency

Theoretical efficiency of the collector without thermal losses.

Passive

{concentrating collector} An operating condition where no human or mechanical intervention is required for operation as intended.

Peak efficiency

Ratio of peak power to the incident radiant power under design ambient and operating conditions.

Peak optical efficiency

Optical efficiency at zero angle of incidence.

Note: It consists in the product of mirror reflectivity, envelope transmittance, absorber absorptance, and intercept factor, all evaluated with an incidence angle equal to zero.

Peak power

Collector output thermal power, which can be achieved under design ambient and operating conditions.

Quasi-dynamic test

Determination of the optical efficiency and the heat loss factors of the collector from a relatively short testing period, with no requirement for steady state climatic conditions. Correction terms are introduced for beam and diffuse incidence angle modifiers, thermal capacitance, wind speed and sky temperature.

Rated Performance

The thermal output characteristics of solar equipment as determined by the tests.

Receiver aperture

{concentrating collector} Maximum projected area defined by physical elements through which concentrated solar radiation enters the receiver.

Receiver efficiency

{concentrating collector} The ratio of the thermal power absorbed by the receiver working fluid to the solar radiant power intercepted by the receiver.

Reconcentrator

{concentrating collector} Reflectors used near the receiver for the purpose of increasing the concentration of sunlight on the receiver.

Reflector or Reflective Surface

{concentrating collector} A surface intended for the primary function of reflecting radiant energy.

Note: It includes also the optional reconcentrator.

Rim angle

{concentrating collector} In a cross section, the maximum angle between the normal to the aperture plane and the line connecting the focus and the edge of the reflector.

Note: this definition is not applicable to an array of heliostats with central receiver

Shadowing

Effect that radiation does not reach the primary reflector due to structural obstacles or neighbouring collectors

Site assembled collector

A collector assembled on site

Specular reflectance

The reflectance measured within an acceptance angle of 25 mrad.

Spillage

The radiation which is reflected from the concentrator subsystem, but which misses the receiver's absorber surface.

Sunshape

A distribution describing the angular distribution of light rays from the Sun.

Thermal performance

Instantaneous thermal efficiency

Tracking angle

Rotation angle required to reach a zero angular deviation between the collector actual position and the desired position relative to the sun, measured in a plane perpendicular to the rotation axis.

Note: Definition applicable only to line-focus collectors.

Transversal angle of incidence

Angle between collector aperture normal and incident sun beam projected into the transversal plane.

Note: not applicable to point-focus collectors and central receivers.

Transversal plane

Plane defined by the normal to the collector aperture and the line orthogonal to the concentrator axis (or the shortest symmetry line for flat biaxial geometries).

Trigger or safety activation temperature,

{concentrating collector} Temperature value at which the safety controls are activated for fail safe operating condition.

4 Symbols and units

a_1	heat loss coefficient at $(T_m - T_a)=0$	$Wm^{-2}K^{-1}$
a_2	temperature dependence of the heat loss coefficient	$Wm^{-2}K^{-2}$
A_A	absorber area of collector	m^2
A_a	aperture area of collector	m^2
A_G	gross area of collector	m^2
AM	optical air mass	
b_u	collector efficiency coefficient (wind dependence)	m^{-1} s
b_o	constant for the calculation of the incident angle modifier	
b_1	heat loss coefficient at $(T_m - T_a)=0$	$Wm^{-2}K^{-1}$
b_2	wind dependence of the heat loss coefficient	$Wsm^{-3}K^{-1}$
c_1	heat loss coefficient at $(T_m - T_a)=0$	$Wm^{-2}K^{-1}$
c_2	temperature dependence of the heat loss coefficient	$Wm^{-2}K^{-2}$
c_3	wind speed dependence of the heat loss coefficient	$Jm^{-3}K^{-1}$
c_4	sky temperature dependence of the heat loss coefficient	-
c_5	effective thermal capacity	$J\ m^{-2}K^{-1}$
c_6	wind dependence in the zero loss efficiency	sm^{-1}
c_f	specific heat capacity of heat transfer fluid	$Jkg^{-1}K^{-1}$
C	effective thermal capacity of collector	JK^{-1}
D	date	YYMMDD
E_L	longwave irradiance (λ >3µm)	Wm^{-2}
E_β	longwave irradiance on an inclined surface outdoors	Wm^{-2}
E_s	longwave irradiance	Wm^{-2}
F	radiation view factor	
F´	collector efficiency factor	
G	hemispherical solar irradiance	Wm^{-2}
*G**	global hemispherical solar irradiance	Wm^{-2}

G''	net irradiance	Wm^{-2}
G_b	direct solar irradiance (beam irradiance)	Wm^{-2}
G_d	diffuse solar irradiance	Wm^{-2}
LT	local time	h
K_θ	incidence angle modifier	
$K_{\theta b}$	incidence angle modifier for direct radiation	
$K_{\theta d}$	incidence angle modifier for diffuse radiation	
m	thermally active mass of the collector	kg
$\dot{m}$	mass flowrate of heat transfer fluid	kgs^{-1}
$\dot{Q}$	useful power extracted from collector	W
$\dot{Q}_L$	power loss of collector	W
SF	safety factor	
t	time	s
t_a	ambient or surrounding air temperature	°C
t_{dp}	atmospheric dew point temperature	°C
t_e	collector outlet (exit) temperature	°C
t_{in}	collector inlet temperature	°C
t_m	mean temperature of heat transfer fluid	°C
t_s	atmospheric or sky temperature	°C
t_{stg}	stagnation temperature	°C
T	absolute temperature	K
T_a	ambient or surrounding air temperature	°C
T^*_m	reduced temperature difference (= $(t_m - t_a)/G^*$)	m^2KW^{-1}
T_{max_op}	maximum operating temperature	°C
T_s	atmospheric or equivalent sky radiation temperature	K
$T_{trigger}$	trigger temperature for safety activation	°C
U	measured overall heat loss coefficient of collector,	

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	with reference to T^*_m	$Wm^{-2}K^{-1}$
U_L	overall heat loss coefficient of a collector with uni-	
	form absorber temperature t_m	$Wm^{-2}K^{-1}$
u	surrounding air speed	ms^{-1}
V_f	fluid capacity of the collector	m^3
Δp	pressure difference between fluid inlet and outlet	Pa
Δt	time interval	s
ΔT	temperature difference between fluid outlet and inlet (t_e - t_{in})	K
α	solar absorptance	
β	tilt angle of a plane with respect to horizontal	degrees
γ	azimuth angle	degrees
γ_{if}	intercept factor	
Γ	end effects	
χ	cleanliness factor	
ε	hemispherical emittance	
ω	solar hour angle	degrees
θ	angle of incidence	degrees
$\theta_{//}$ or θ_L	longitudinal angle of incidence	degrees
$\theta_{\perp}$ or θ_T	transversal angle of incidence	degrees
θ_C	half acceptance angle	degrees
Φ	latitude	degrees
ϕ_r	rim angle	degrees
λ	wavelength	µm
η	collector efficiency, with reference to T^*_m	
η_o	zero-loss collector efficiency (η at T^*_m = 0), reference to T^*_m	
$\eta_{0,en}$	*zero-loss collector efficiency at normal incidence*	-
$\eta_{0,b,en}$	*zero-loss collector efficiency for beam irradiance at normal incidence*	-

σ	Stefan-Boltzmann constant	$Wm^{-2}K^{-4}$
ρ	density of heat transfer fluid	kgm^{-3}
ρ_s	specular reflectance	
τ_c	collector time constant	s
τ	*transmittance*	
$(\tau\alpha)e$	*effective transmittance-absorptance product*	-
$(\tau\alpha)ed$	*effective transmittance-absorptance product for diffuse solar irradiance*	-
$(\tau\alpha)en$	*effective transmittance-absorptance product for direct solar radiation at normal incidence*	-
$(\tau\alpha)e\theta$	*effective transmittance-absorptance product for direct solar radiation at angle of incidence* θ	-
hf,a	*enthalpy of the air-water vapor mixture of the ambient air*	*J/kg*
hf,e	*enthalpy of the air-water vapor mixture at the outlet of the air collector*	*J/kg*
hf,i	*enthalpy of the air-water vapor mixture at the inlet of the air collector*	*J/kg*
hL	*enthalpy of the leaking air-water vapour mixture*	*J/kg*
mpe	*downstream air mass flow rate,*	*kg/s*
mpi	*upstream air mass flow rate,*	*kg/s*
mpl	*leakage air mass flow rate*	*kg/s*
pf,e	*static pressure of the heat transfer fluid (air) at the outlet to the solar collector*	*Pa*
pf,i	*static pressure of the heat transfer fluid (air) at the inlet to the solar collector*	*Pa*
Pabs	*absolute pressureof the ambient air*	*Pa*
RD	*gas constant for water vapour*	*461,4 J/kgK*
rHamb	*(relative)Humidity of the ambient air*	*%*
rHe	*(relative)Humidity of the fluid (air) at the outlet of the solar collector*	*%*
rHi	*(relative)Humidity of the fluid (air) at the inlet of the solar collector*	*%*
RL	*gas constant for air*	*287,1 J/kgK*
Tm,th	*volume flow weighted mean temperature*	*°C*

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$t_{max,start}$	*maximum starting temperature*	*°C*
$t_{mp,e}$	*fluid temperate at the downstream air mass flowmeter*	*°C*
$t_{mp,i}$	*fluid temperate at the upstream air mass flowmeter*	*°C*
$V_{p,e}$	*volumetric flow at the outnlet of the solar collector*	m^3/s
$V_{p,i}$	*volumetric flow at the inlet of the solar collector*	m^3/s
$V_{p,L}$	*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 at the inlet 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*
ρ_l	*density of air*	kg/m^3

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 **Error! Reference source not found.**)

NOTE 3 For more information about thermal performance coefficients (parameters) c_1 to c_6, see **Error! Reference source not found.**.