
**Solar energy — Collector components
and materials —**

**Part 1:
Evacuated tubes — Durability and
performance**

iTeh STANDARD PREVIEW
*Énergie solaire — Composants et matériaux du collecteur —
Partie 1: Tubes sous vide — Durabilité et performance*
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Contents

	Page
Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Classification and test list	2
5 Testing of material	3
5.1 Inspection for stones and knots	3
5.1.1 General	3
5.1.2 Test conditions	3
5.1.3 Apparatus	3
5.1.4 Procedure	3
5.1.5 Results	4
5.2 Inspection for scratches	4
5.2.1 General	4
5.2.2 Test conditions	4
5.2.3 Apparatus	4
5.2.4 Procedure	4
5.2.5 Results	5
5.3 Testing of solar transmittance	5
5.3.1 General	5
5.3.2 Test conditions and apparatus	5
5.3.3 Procedure	5
5.3.4 Results	5
5.4 Testing of solar absorptance	5
5.4.1 General	5
5.4.2 Test conditions and apparatus	5
5.4.3 Procedure	5
5.4.4 Results	6
5.5 Testing of hemispherical emittance	6
5.5.1 General	6
5.5.2 Test conditions	6
5.5.3 Apparatus and procedure	6
5.5.4 Results	7
6 Durability testing of evacuated tube	7
6.1 Vacuum performance	7
6.1.1 General	7
6.1.2 Test conditions and apparatus	7
6.1.3 Procedure	8
6.1.4 Results	8
6.2 Resistance to thermal shock	8
6.2.1 General	8
6.2.2 Test conditions and apparatus	9
6.2.3 Procedure	9
6.2.4 Results	9
6.3 Resistance to impact	9
6.3.1 General	9
6.3.2 Principle	9
6.3.3 Procedure	9
6.3.4 Results	9
6.4 Resistance to internal pressure	10
6.4.1 General	10

6.4.2	Test conditions and apparatus.....	10
6.4.3	Procedure.....	10
6.4.4	Results.....	10
7	Performance testing of evacuated tube.....	10
7.1	Tests for determination the exposure parameter.....	10
7.1.1	General.....	10
7.1.2	Test conditions.....	11
7.1.3	Apparatus.....	11
7.1.4	Procedure.....	12
7.1.5	Results.....	13
7.2	Tests for determination of sum of solar irradiation for temperature increase of double-glass evacuated tube.....	13
7.2.1	General.....	13
7.2.2	Test conditions.....	13
7.2.3	Apparatus.....	13
7.2.4	Procedure and results.....	13
7.3	Tests to determine the average heat loss coefficient of a double-glass evacuated tube.....	13
7.3.1	General.....	13
7.3.2	Test conditions.....	14
7.3.3	Apparatus.....	14
7.3.4	Procedure.....	14
7.3.5	Results.....	15
Annex A (informative)	Configuration schemes of evacuated tubes.....	16
Annex B (normative)	Test report.....	18
Annex C (normative)	Determination of the external surface area of absorber tube for double-glass evacuated tubes.....	25
Bibliography	27

ISO 22975-1:2016
<https://standards.iteh.ai/catalog/standards/sist/380aad8d-592d-41be-a7cf-3f133813aa05/iso-22975-1-2016>

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 180, *Solar energy*.

ISO 22975 consists of the following parts, under the general title *Solar energy — Collector components and materials*:

- Part 1: *Evacuated tubes — Durability and performance*
- Part 2: *Heat-pipes for solar thermal application — Durability and performance*
- Part 3: *Absorber surface durability*

The following parts are under preparation:

- Part 5: *Insulation material durability and performance*

Introduction

This part of ISO 22975 is applicable to all categories of evacuated tubes, including double-glass evacuated tubes and glass-metal sealed evacuated tubes.

This part of ISO 22975 provides test methods for inspecting stones and knots in envelope glass tubes.

This part of ISO 22975 also provides test methods for determining durability of evacuated tubes, including vacuum performance, thermal shock resistance, external impact resistance and internal pressure resistance. For each durability test, this part of ISO 22975 specifies general, apparatus, procedure and results of the test.

This part of ISO 22975 also provides test methods for measuring performance of evacuated tubes, including exposure parameter, solar irradiation for temperature increase of double-glass evacuated tube and average heat loss coefficient. For each performance test, principle, test conditions, apparatus, procedure and results of the test are specified.

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Solar energy — Collector components and materials —

Part 1:

Evacuated tubes — Durability and performance

1 Scope

This part of ISO 22975 specifies definitions and test methods for materials, durability and performance of evacuated tubes.

This part of ISO 22975 is applicable to all types of evacuated tubes.

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 9488, *Solar energy — Vocabulary*

ISO 9845-1, *Solar energy — Reference solar spectral irradiance at the ground at different receiving conditions — Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5*

3 Terms and definitions

3.1

double-glass evacuated tube

component of an evacuated tube solar collector, of which both the inner tube and the envelope tube are made of glass

3.2

glass-metal sealed evacuated tube

component of an evacuated tube solar collector, in which the absorber is affixed to a metal fluid channel, that is sealed into the envelope glass tube through a specific glass-metal sealing process

3.3

stone

opaque inclusions in the glass of the evacuated tube

3.4

knot

transparent inclusions in the glass of the evacuated tube

3.5

scratch

abraded area where the surface of the glass is torn or worn off

3.6

vacuum jacket

space between envelope glass tube and absorber in an evacuated tube, wherein air pressure is sufficiently low that thermal conduction and convection of air can be ignored

3.7 stagnation

state where no working fluid passes through the evacuated tube and the temperature of the evacuated tube is determined by the solar irradiance

3.8 exposure temperature

maximum temperature at an accessible part of an evacuated tube with specified irradiance under *stagnation* (3.7) conditions

Note 1 to entry: For double glass evacuated tubes, the temperature with only air in the tube is measured. For direct flow tubes, the measurement is done in the air-filled flow channel within the vacuum tube. For glass-metal sealed tubes with heat pipe, the well-insulated condenser surface temperature is measured.

3.9 exposure parameter

ratio of the difference between *exposure temperature* (3.8) and ambient temperature to the solar irradiance

3.10 sum of solar irradiation for temperature increase

sum of solar irradiation for a certain preset temperature rise range of the water in a *double-glass evacuated tube* (3.1)

Note 1 to entry: This term applies only to double-glass evacuated tubes.

3.11 average heat loss coefficient

ratio of heat loss per m² defined external surface area of absorber tube, without irradiance, to temperature difference between water content of vacuum tube and ambient air

Note 1 to entry: This term applies only to *double-glass evacuated tubes* (3.1).

4 Classification and test list

According to material category of absorber, evacuated tubes can be substantially classified into two types:

- a) double-glass evacuated tube, see [Figure A.1](#);
- b) glass-metal sealed evacuated tube, see [Figure A.2](#).

Tests for the two categories of evacuated tubes are summarized in [Table 1](#).

Table 1 — Test list

Category of evacuated tube	Test
Double-glass, Glass-metal sealed	5.1 Inspection for stones and knots
Double-glass, Glass-metal sealed	5.2 Inspection for scratches
Double-glass, Glass-metal sealed	5.3 Testing of solar transmittance
Double-glass	5.4 Testing of solar absorptance
Double-glass	5.5 Testing of hemispherical emittance
Double-glass	6.1 Vacuum performance
Double-glass	6.2 Resistance to thermal shock
Double-glass, Glass-metal sealed	6.3 Resistance to Impact
Double-glass, Glass-metal sealed direct flow	6.4 Resistance to internal pressure

Table 1 (continued)

Category of evacuated tube	Test
Double-glass, Glass-metal sealed	5.1 Inspection for stones and knots
Double-glass, Glass-metal sealed	7.1 Tests for determination of exposure parameter
Double-glass	7.2 Tests for determination of sum of solar irradiation for temperature increase of double-glass evacuated tube
Double-glass	7.3 Tests for determination the average heat loss coefficient of double-glass evacuated tube

5 Testing of material

5.1 Inspection for stones and knots

5.1.1 General

This test is intended to check the uniformity of the tube glass by visual inspection.

5.1.2 Test conditions

The test room/table for taking observations shall have a minimum illuminance of 1 500 lx.

5.1.3 Apparatus

The dimension measurement instrument shall have an accuracy of $\pm 0,1$ mm.

5.1.4 Procedure

- a) Draw two lines with permanent marker or other non-invasive marking method with thickness no more than 0,5 mm on the surface of tube along the axial direction, such that the surface is split into two equal parts.
- b) With one part upward, count and separately record for this part the numbers of the following:
 - stones with size not over 1 mm;
 - stones with size over 1 mm;
 - knots with size not over 1,0 mm;
 - knots with size between 1,5 mm and 2,0 mm;
 - knots with size over 2,0 mm;
 - cracks around the stones and knots.
- c) Turn the other part of the tube upward and repeat Step b).
- d) Sum the values from Steps b) and c) for each category of stone, knot or crack.
- e) Draw another pair of lines parallel with the first pair of lines, ensuring that the distance between lines is 1/4 of the perimeter. Erase the first pair of lines and count and record the stones, knots and cracks again as in Steps b) to d).
- f) For each category of stone, knot or crack, take the larger of the values recorded in Steps d) and e) as the result.

5.1.5 Results

Report the following values:

- a) the number of stones with size not over 1 mm, per unit area of the tube;
- b) the number of stones with size over 1 mm on the whole tube;
- c) the total number of stones on the whole tube;
- d) the number of knots with size not over 1,0 mm, per unit area of the tube;
- e) the number of knots with size between 1,5 mm and 2,0 mm on the whole tube;
- f) the number of knots with size over 2,0 mm on the whole tube;
- g) the number of cracks on the whole tube.

5.2 Inspection for scratches

5.2.1 General

This test will check and record the scratches on the tube by visual inspection.

NOTE The presence of scratches is one of the main reasons for tubes being broken.

5.2.2 Test conditions

The test room/table for taking observations shall have a minimum illuminance of 1 500 lx.

5.2.3 Apparatus

The dimension measurement instrument shall have an accuracy of $\pm 0,1$ mm.

5.2.4 Procedure

- a) Draw two lines with permanent marker or other non-invasive marking method with the thickness no more than 0,5 mm on the surface of tube along the axial direction, such that the surface is split into two equal parts.
- b) With one part upward, count and separately record for this part:
 - the number of scratches not longer than 100 mm;
 - the number of scratches longer than 100 mm;
 - the total length of all scratches.
- c) Turn the other part of the tube upward and repeat Step b).
- d) Sum the respective values from Steps b) and c).
- e) Draw another pair of lines parallel with the first pair of lines, ensuring that the distance between lines is 1/4 of the perimeter. Erase the first pair of lines, count and record the scratches again as in Steps b) to d).
- f) Take the larger value of each of the quantities recorded in Steps d) and e) as the results.

5.2.5 Results

Report the following values:

- a) the number of scratches not longer than 100 mm on the whole tube;
- b) the number of scratches longer than 100 mm on the whole tube;
- c) the total length of all scratches on the whole tube.

5.3 Testing of solar transmittance

5.3.1 General

This test will determine the solar transmittance (AM1.5) of the envelope glass tube.

5.3.2 Test conditions and apparatus

This test shall use a spectrophotometer with a wavelength accuracy of ± 1 nm, resolution of 0,1 nm, range of 0,3 μm to 2,5 μm and an integrating-sphere unit. The measuring spot of the spectrophotometer and the opening of the integrating sphere shall be sized to ensure that the curvature of the tube has no influence on the result.

5.3.3 Procedure

The solar transmittance of a sample piece of the envelope tube is tested twice. In the first test, place the sample into the measuring spot with the light incident on the concave surface and measure the transmittance of the sample with the spectrophotometer for solar spectral irradiance according to ISO 9845-1. In the second test, place the sample into the measuring spot with the light incident on the convex surface and measure the transmittance of the sample with the spectrophotometer for solar spectral irradiance according to ISO 9845-1.

5.3.4 Results

The transmittance for solar spectral irradiance according to ISO 9845-1 shall be reported for both measurements and the mean value of the two measurements.

5.4 Testing of solar absorptance

5.4.1 General

This test will determine the solar absorptance (AM1.5) of selective absorbing coating of a double-glass evacuated tube. This test is applicable for double glass evacuated tubes only.

5.4.2 Test conditions and apparatus

This test shall use a spectrophotometer with a wavelength accuracy of ± 1 nm, resolution of 0,1 nm, range of 0,3 μm to 2,5 μm and an integrating-sphere unit. The measuring spot of the spectrophotometer and the opening of the integrating sphere shall be sized to ensure that the curvature of the tube has no influence on the result.

5.4.3 Procedure

Two samples of the solar selective surface shall be taken; one from a position 150 mm distant from the open end of the tube and one from the middle of the tube. For each sample, position the sample into the measuring spot with the light incident on the convex surface and measure the reflectance for solar spectral irradiance according to ISO 9845-1.

5.4.4 Results

Calculate and report the solar absorptance for each sample from the measured reflectance and the mean of these two absorptance results.

5.5 Testing of hemispherical emittance

5.5.1 General

This test will determine the hemispherical emittance of selective absorbing coating of a double-glass evacuated tube.

5.5.2 Test conditions

The hemispherical emittance of the selective absorbing coating on the outside of the inner glass tube of an double-glass evacuated tube is determined by steady state calorimetry at a temperature of $80\text{ °C} \pm 5\text{ °C}$.

NOTE The gas pressure in the vacuum jacket is typically around 5×10^{-2} Pa, so the conduction of gas molecules can be ignored.

The hemispherical emittance of the selective surface ε_h is as given in [Formula \(1\)](#):

$$\varepsilon_h = \frac{IU}{\sigma A_1 (T_1^4 - T_2^4)} = \frac{q_s}{q_b} \quad (1)$$

where

- I is the current of heater, A; [ISO 22975-1:2016](https://standards.iteh.ai/catalog/standards/sist/380aad8d-592d-41be-a7cf-3f133813aa05/iso-22975-1-2016)
- U is the voltage of heater, V; <https://standards.iteh.ai/catalog/standards/sist/380aad8d-592d-41be-a7cf-3f133813aa05/iso-22975-1-2016>
- A_1 is the reference area of the outside of inner glass tube, m^2 ;
- σ is the Stefan-Boltzmann constant, $5,67 \times 10^{-8} \text{ W} \cdot \text{m}^{-2} \text{ K}^{-4}$;
- T_1 is the temperature of heater at steady state, K;
- T_2 is the temperature of cooling water, K;
- q_s is the emissive power density of selective absorbing surface, $\text{W} \cdot \text{m}^{-2}$;
- q_b is the emissive power density of black body, $\text{W} \cdot \text{m}^{-2}$.

5.5.3 Apparatus and procedure

A double-glass evacuated tube is placed into a water-cooled jacket and heating elements are inserted into the tube. The heating elements consist of the central main heater and the compensating heaters at the ends of the main heater.

The heater elements are contained within three segments of ceramic tube which fit within the inner glass absorber tube. Temperature sensors are attached to each ceramic element allowing the temperature of each to be measured and controlled independently. The temperature sensor in the inner tubes shall be recorded to a standard uncertainty of 0,2 K. The power dissipated in the central heater required to maintain the absorber tube at a chosen constant temperature is used to evaluate average heat loss of the heater. The outer segments are maintained at the same temperature as the central segment by means of independent power inputs, to prevent longitudinal heat flow. Consequently, only radial dissipation of the power need to be considered. The glass envelope is enclosed in a water cooled jacket and its temperature is thus maintained at 20 °C .