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Solar energy — Collector components and materials —

Part 2:
Heat-pipes for solar thermal application — Durability and performance

Énergie solaire — Composants et matériaux du collecteur —

Partie 2: Caloduc pour application thermique solaire — Durabilité et performance

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Foreword

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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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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 tube — 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 specifies test methods for durability and performance of heat-pipes for solar thermal application.

This part of ISO 22975 is applicable to all heat-pipes for use with both evacuated tubes and flat plate collectors.

For each durability and performance test, its objective, principle, test condition, apparatus, procedure and test results are specified.

For all the tests specified in this part of ISO 22975, a complete heat-pipe is required.

Solar energy — Collector components and materials —

Part 2: Heat-pipes for solar thermal application — Durability and performance

1 Scope

This part of ISO 22975 specifies definitions and test methods for durability and performance of heat-pipes for solar thermal application.

This part of ISO 22975 is applicable to heat-pipes for use with evacuated tubes, including glass-metal sealed evacuated tubes and double-glass evacuated tubes, as well as with flat plate collectors.

This part of ISO 22975 provides test methods for determining durability of the heat-pipe, including high temperature resistance and freeze resistance.

This part of ISO 22975 also provides test methods for measuring performance of the heat-pipe, including starting temperature, temperature uniformity and heat transfer power of the heat-pipe.

This part of ISO 22975 is only applicable to gravity heat-pipes.

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

3 Terms and definitions

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

3.1
heat-pipe
heat transfer element, utilizing latent heat of phase-change for heat transfer

3.2
gravity heat-pipe
heat-pipe (3.1) without a capillary wick inside, in which the liquefied *working fluid* (3.6) returns from *condenser* (3.4) to *evaporator* (3.3) due to its own weight

3.3
evaporator
part of a *heat-pipe* (3.1), where the liquefied *working fluid* (3.6) absorbs heat, vaporizes and becomes the vaporized working fluid

3.4
condenser
part of a *heat-pipe* (3.1), where the vaporized *working fluid* (3.6) releases heat, condenses and becomes the liquefied working fluid

3.5
adiabatic section
part of a *heat-pipe* (3.1), located between *evaporator* (3.3) and *condenser* (3.4), where *working fluid* (3.6) has minimal heat exchange with the surroundings

3.6
working fluid
medium used for heat transfer in a *heat-pipe* (3.1)

3.7
tilt angle (of heat-pipe)
angle between the horizontal plane and a *heat-pipe* (3.1)

3.8
starting temperature of heat-pipe
minimum temperature required for a *heat-pipe* (3.1) to start operating

3.9
temperature uniformity of heat-pipe
temperature difference between *evaporator* (3.3) and *condenser* (3.4) when a *heat-pipe* (3.1) operates under normal conditions

3.10
heat transfer power of heat-pipe
thermal power transferred to the cooling liquid from a *heat-pipe* (3.1) when using the cooling liquid to remove heat

3.11
stable conditions
conditions in performance tests of a *heat-pipe* (3.1), in which the temperature variation is less than ±1 K over a period depending on the performance test item

4 Test overview

Durability tests and performance tests for heat-pipes are specified in Clause 5 and Clause 6, respectively. The tests shall be performed in the sequence according to Table 1.

All these tests shall be performed on the same heat-pipes.

Table 1 — Test list

Clause	Test
5.1	High temperature resistance test
5.2	Freeze resistance test[a]
6.1	Starting temperature of heat-pipes
6.2	Temperature uniformity of heat-pipes
6.3	Heat transfer power of heat-pipes[b]

[a] The freeze resistance test shall be carried out only for heat-pipes claimed to be freeze resistant.

[b] The heat transfer power test shall be performed after the high temperature resistance test.

5 Durability

5.1 High temperature resistance test

5.1.1 Objective

This test is intended to assess the capability of a heat-pipe to withstand high temperature without failure.

5.1.2 Test conditions

The test shall be carried out under the following conditions:

a) test environment: indoors;

b) ambient temperature: 15 °C to 35 °C;

c) test temperature in heating chamber: 180 °C ± 5 °C or 230 °C ± 5 °C or 280 °C ± 5 °C depending on specific application and manufacturer's declaration;

d) tilt angle of heat-pipe: 90° ± 1°.

The test may be conducted at any higher heating chamber temperature, if requested.

5.1.3 Apparatus

The test apparatus consists of a heating chamber and a thermometric system.

Measuring instruments shall meet the following requirements:

a) heating chamber temperature controller, with an accuracy of ±0,5 K;

b) ambient temperature sensor; standard uncertainty shall not be more than ±0,5 K;

c) digital clock/data acquisition system; standard uncertainty shall not be more than ±10 s/d.

5.1.4 Procedure

The test shall be carried out for a batch of at least 10 sample heat-pipes of the same product.

The procedure shall be as follows.

a) Place all sample heat-pipes into the heating chamber at the specified tilt angle.

b) Increase the temperature in the heating chamber slowly (maximum 20 K/min) up to the selected test temperature.

c) Maintain the test temperature for 30 h.

d) After the heat-pipes have cooled to room temperature, visually inspect for damage, such as leakage, breakage, distortion or deformation.

5.1.5 Results

The product will be qualified if there is no visual evidence of damage to the heat-pipes.

Results of the inspection shall be reported together with ambient temperature, test temperature in heating chamber and test duration.

5.2 Freeze resistance test

5.2.1 Objective

This test is intended to assess the extent to which a heat-pipe, which is claimed to be freeze resistant, can withstand freezing.

5.2.2 Test conditions

The test shall be carried out under the following conditions:

a) test environment: indoors;

b) ambient temperature: 20 °C to 30 °C;

c) freezing temperature: −20 °C ± 1 °C;

d) thawing temperature: 20 °C ± 1 °C;

e) tilt angle of heat-pipe: 90° ± 1°.

5.2.3 Apparatus

The test apparatus consists of an appropriate freezing device and a thawing device.

Measuring instruments shall meet the following requirements:

a) temperature controllers used for the freezing device and thawing device, with an accuracy of ±0,5 K;

b) surface temperature sensor; standard uncertainty shall not be more than ±0,5 K;

c) ambient temperature sensor; standard uncertainty shall not be more than ±0,5 K;

d) digital clock/data acquisition system; standard uncertainty shall not be more than ±10 s/d.

5.2.4 Procedure

The test shall be carried out for a batch of at least 10 sample heat-pipes of the same product.

The procedure shall be as follows.

a) Place all sample heat-pipes into the freezing device at the specified freezing temperature for 60 min, at the specified tilt angle.

b) Remove samples from freezing device, and within 30 s, insert them into the thawing device at the specified thawing temperature, keeping the evaporator in lower position, to a depth not less than 1/9 of the total length of the heat-pipe.

c) After heat-pipes are inserted into the thawing device, measure and record the temperature on the condenser surface at a point between 18 mm and 22 mm from top of the condenser. Wait for 5 min after the temperature difference between the thawing device and the condenser surface is not larger than 9 K.

NOTE If the temperature difference falls below 9 K, this indicates that the heat-pipe has started to operate again.

d) Repeat Steps a) to c) 20 times.

e) After the heat-pipes have been removed from the thawing device, visually inspect for damage, such as leakage, breakage, distortion or deformation.

5.2.5 Results

The product will be qualified if there is no visual evidence of damage to the heat-pipes.

Results of the inspection shall be reported together with ambient temperature, freezing temperature, thawing temperature, tilt angle of the heat-pipe, insertion depth in thawing device, as well as number of freeze-thaw cycles.

6 Performance

6.1 Starting temperature of heat-pipes

6.1.1 Principle

This test is intended to determine the minimum temperature required for a heat-pipe to start operating.

6.1.2 Test conditions

The test shall meet the following conditions:

a) test environment: indoors;

b) ambient temperature: 15 °C to 20 °C;

c) cold water bath temperature: 10 °C ± 0,5 °C;

d) hot water bath temperature: 25 °C ± 0,5 °C or 30 °C ± 0,5 °C or 40 °C ± 0,5 °C, depending on specific application for different working temperature of the heat-pipe, and 40 °C ± 0,5 °C is the maximum test temperature;

e) tilt angle of the heat-pipe: 90° ± 1°.

6.1.3 Apparatus

Two thermostatic water baths are used for the test. The cold water bath is maintained at the specified cold water bath temperature, and the hot water bath is maintained at the selected hot water bath temperature.

Measuring instruments shall meet the following requirements:

a) temperature controllers used for the cold water bath and hot water bath, with an accuracy ±0,5 K;

b) temperature sensors used for measuring surface and ambient temperature; standard uncertainty shall not be more than ±0,5 K;

c) digital clock/data acquisition system; standard uncertainty shall not be more than ±10 s/d.

6.1.4 Procedure

The procedure shall be as follows.

a) Fit a surface temperature sensor to the condenser of the heat-pipe, at a point between 18 mm and 22 mm from top of the condenser. Thermally insulate the heat-pipe, except for 1/6 of its length at the evaporator end.

b) Immerse the lower end of the heat pipe in the cold water bath to a depth of 1/6 of the total length of the heat-pipe, at the specified tilt angle. Wait for at least 3 min after stable conditions have been reached.

c) Remove the heat pipe from the cold water bath and immerse its lower end in the hot water bath to a depth of 1/6 of the total length of the heat-pipe, at the specified tilt angle.

d) Measure and record the temperature on the condenser surface every 10 s until at least 120 s after stable conditions have been reached.

6.1.5 Results

The condenser surface temperature of the heat-pipe shall be recorded.

The results of the measurement shall be reported together with ambient temperature, cold water bath temperature, hot water bath temperature, insertion depth of the heat-pipe, distance of measuring point from top of condenser and variation of condenser surface temperature.

6.2 Temperature uniformity of heat-pipes

6.2.1 Principle

This test is intended to measure the temperature difference between evaporator and condenser when a heat-pipe operates under normal conditions.

6.2.2 Test conditions

The test shall meet following conditions:

a) test environment: indoors;

b) ambient temperature: 25 °C ± 5 °C;

c) test temperature in hot water bath: 90 °C ± 0,5 °C;

d) tilt angle of heat-pipe: 90° ± 1°.

6.2.3 Apparatus

A thermostatic hot water bath is used for the test, maintained at the specified test temperature.

Measuring instruments shall meet the following requirements:

a) temperature controller used for the hot water bath, with an accuracy ±0,5 K;

b) temperature sensors used for measuring ambient, surface and hot water temperature; standard uncertainty shall not be more than ±0,5 K;

c) digital clock/data acquisition system; standard uncertainty shall not be more than ±10 s/d.

6.2.4 Procedure

The procedure shall be as follows.

a) Fit a surface temperature sensor to the condenser of the heat-pipe, at a point between 18 mm and 22 mm from top of the condenser.

b) Insert the heat-pipe into the water of the thermostatic hot water bath to a depth of 3/5 to 2/3 of the total length of the heat-pipe, at the specified tilt angle.

c) Measure and record the temperature on the condenser surface every 10 s until at least 60 s after stable conditions have been reached.

