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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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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 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.

6.2.5 Results

The difference between the hot water bath temperature and the stable condenser surface temperature shall be recorded.

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

6.3 Heat transfer power of heat-pipes

6.3.1 Principle

This test is intended to determine the heat transfer power of a heat-pipe at different operating temperatures and tilt angles.

The heat transfer power of a heat-pipe can be calculated according to Formula (1):

$$\dot{Q} = \dot{Q}_1 - \dot{Q}_2 \tag{1}$$

where

$\dot{Q}$ is the heat transfer power of heat-pipe, W;

$\dot{Q}_1$ is the thermal power transferred to cooling liquid from heat-pipe, W;

$\dot{Q}_2$ is the thermal power transferred to cooling liquid from environment or apparatus, W; normally, $\dot{Q}_2$ is negligible if the cooling liquid jacket is well-insulated.

The thermal power received by cooling liquid, can be calculated according to Formula (2):

$$\dot{Q}_1 = \dot{m}\, C_\text{p} \left(\vartheta_2 - \vartheta_1\right) \tag{2}$$

where

$\dot{m}$ is the mass flow rate of cooling liquid, kg/s;

C_p is the specific heat capacity of cooling liquid, J/(kg · K);

ϑ_2 is the inlet temperature of cooling liquid, °C;

ϑ_1 is the outlet temperature of cooling liquid, °C;

6.3.2 Test conditions

The test conditions shall meet the following requirements:

a) test environment: indoors;

b) ambient temperature: 25 °C ± 5 °C;

c) relative humidity: not higher than 80 %;

d) inlet temperature of cooling liquid: 30 °C ± 0,5 ;

e) mass flow rate of cooling liquid: 30 kg/h ± 0,3 kg/h, to ensure a fully turbulent flow around the condenser;

f) test operating temperatures:
    1) 60 °C ± 0,5 °C;
    2) 90 °C ± 1 °C;
    3) 120 °C ± 2 °C (when the heat-pipe is claimed to be able to operate at above 100 °C);

g) tilt angle of heat-pipe for each test operating temperature:
    1) the lowest recommended angle;
    2) angle: 20° ± 1°;
    3) angle: 30° ± 1°;
    4) angle: 45° ± 1°;
    5) angle: 60° ± 1°;
    6) angle: 75° ± 1°;
    7) angle: 90° ± 1°.

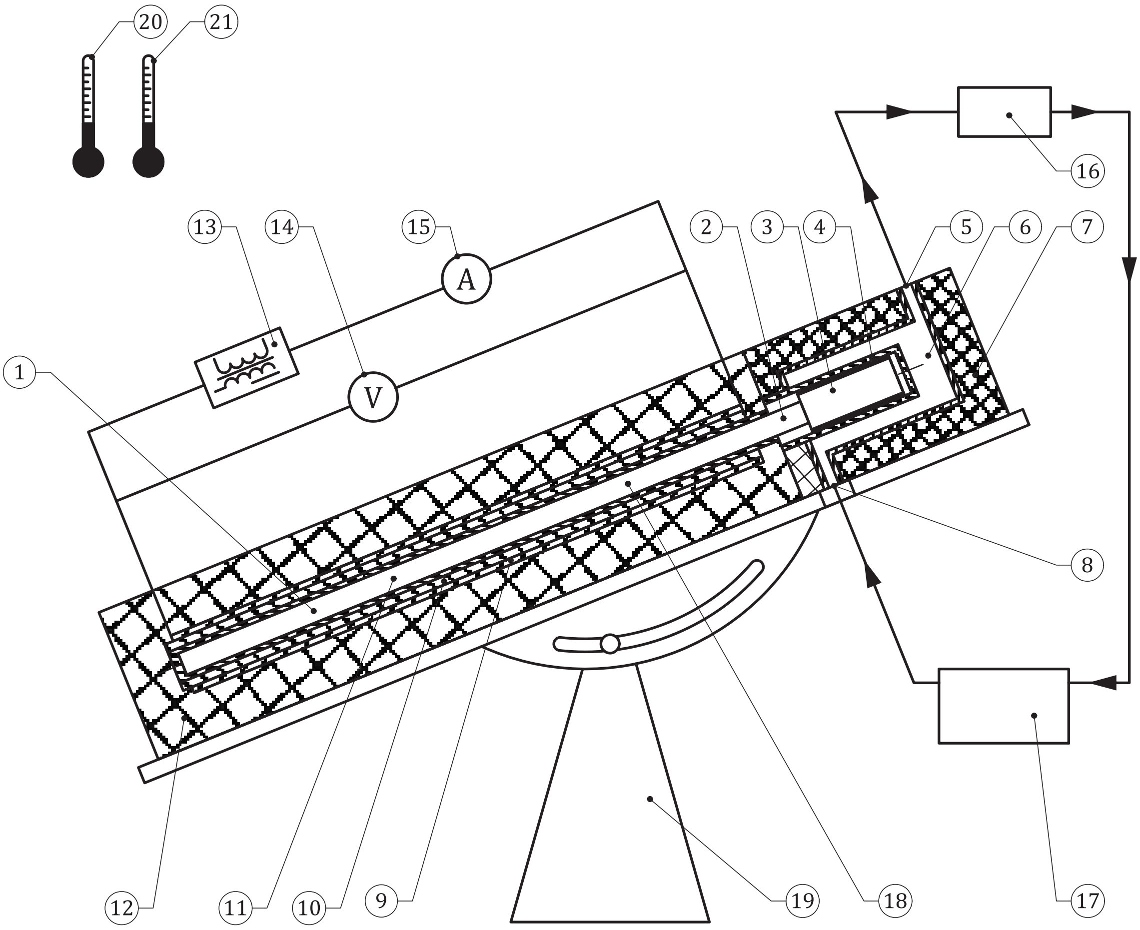
6.3.3 Apparatus

6.3.3.1 Overall description

A typical test apparatus for measuring the heat transfer power of a heat-pipe is shown in Figure 1.

The test apparatus in Figure 1 includes heat-pipe mounting support, electric heating barrel, electric power regulator, cooling liquid jacket, supply of cooling liquid at constant temperature and pressure, flow meter, and thermometric system.

An alternative test apparatus is similar to Figure 1, but with a hot liquid jacket for heating the evaporator in lieu of the electric heating barrel.



Key

1	heat-pipe evaporator
2	heat-pipe adiabatic section
3	heat-pipe condenser
4	heat transfer paste
5	temperature difference sensor
6	cooling liquid jacket
7	thermal insulation
8	inlet temperature sensor
9	electric heating barrel
10	heat-uniform tube
11	evaporator temperature sensor
12	thermal insulation
13	voltage regulator
14	volt meter
15	ampere meter
16	flow meter
17	thermostatic liquid bath
18	evaporator temperature sensor
19	tilt-angle adjustable support
20	thermometer
21	humidity meter

Figure 1 — Typical test apparatus for measuring heat transfer power

Measuring instruments shall meet the following requirements:

a) ampere meter and volt meter (or a power meter), with an accuracy class 0,5;

b) temperature controller used for thermostatic liquid bath, with an accuracy ±0,5 K;

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

d) temperature sensor used for measuring inlet liquid temperature; standard uncertainty shall not be more than ±0,1 K;

e) temperature sensor used for measuring liquid temperature between inlet and outlet; standard uncertainty shall not be more than ±0,05 K;

f) flow meter; standard uncertainty shall not be more than ±1 %;

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

6.3.3.2 Evaporator heating device

Two options for the evaporator heating device are as follows.

a) As in Figure 1, the evaporator of the heat-pipe is inserted into the sleeve of an electric heating barrel. A copper tube shall be placed between the evaporator and the electric heating elements to ensure uniform heating power distribution. The outer surface of the heating barrel shall be thermally insulated.

b) A hot liquid jacket is used for heating the evaporator. The related measuring instruments (inlet liquid temperature sensor, liquid temperature difference sensor, flow meter, etc.) shall meet the same requirements as for the cooling liquid jacket. The outer surface of the hot liquid jacket shall be thermally insulated.

Two surface temperature sensors shall be placed on the outer surface of the evaporator, at distances from the end of evaporator of 1/3 and 2/3 of the total length of the heat-pipe. The average of the temperature values measured by these sensors shall be taken as the test operating temperature of the heat-pipe.

6.3.3.3 Condenser cooling device

If the condenser of the heat-pipe is not intended for direct immersion in liquid, it shall be inserted into the sleeve of the cooling liquid jacket and surrounded with heat transfer paste that has not been used previously. The outer surface of the cooling liquid jacket shall be thermally insulated.

If the condenser of the heat-pipe is intended for direct immersion in liquid, it shall be directly inserted into the cooling liquid jacket. The outer surface of the cooling liquid jacket shall be thermally insulated.

Fluctuations of cooling liquid inlet temperature shall not exceed ±0,5 K/h. The standard uncertainty of the detected temperature difference shall not exceed ±2 %.

6.3.3.4 Heat-pipe mounting support

The heat-pipe mounting support shall provide for adjustment of tilt-angle in accordance with 6.3.2 g).

6.3.4 Procedure

6.3.4.1 Test state

During testing, the heat-pipe shall be tilted according to the requirements of 6.3.2 with the level of the evaporator below the level of the condenser.

6.3.4.2 Determination of heat transfer power at different operating temperatures and tilt angles

The procedure shall be as follows.

a) Set the cooling liquid temperature and flow rate in accordance with 6.3.2.

b) Set the tilt angle of the heat pipe to the lowest recommended angle.

c) Gradually adjust the power input to the evaporator heating device, until the test operating temperature of the heat pipe is 60 °C ± 0,5 °C. Steady-state is deemed to be achieved when the variation in test operating temperature is less than ±1 K over a period of 8 min.

d) When steady-state conditions have been achieved, begin to record the values of mass flow rate and inlet/outlet temperature difference of the cooling liquid, at intervals of 30 s for a period of 10 min.

e) Calculate the heat transfer power of the heat-pipe according to Formula (1) and Formula (2), using the averages of the recorded values for mass flow rate and inlet/outlet temperature difference of the cooling liquid.

f) Repeat Steps b) to e) with the other values of tilt angle, as specified in 6.3.2 g).

g) Repeat Steps b) to f) for test operating temperatures of 90 °C ± 1 °C and 120 °C ± 2 °C.

6.3.4.3 Determination of maximum heat transfer power

This test shall be conducted directly after carrying out the test of heat transfer power at test operating temperature 120 °C ± 2 °C and tilt angle 90° ± 1°.

The procedure shall be as follows.

a) Increase the power input to the evaporator heating device at a rate of less than 5 W/min.

b) Observe the test operating temperature of the heat pipe. Once there is an obvious sudden temperature increase, or the temperature shows obvious oscillation and instability, the heat-pipe has reached its heat transfer limit.

c) Reduce the power input to the evaporator heating device to a point just before the heat transfer limit.

d) When steady-state conditions have been achieved, begin recording the values of mass flow rate and inlet/outlet temperature difference of the cooling liquid, at intervals of 30 s for a period of 10 min.

e) Calculate the maximum heat transfer power, $\dot{Q}_{\text{max}}$, of the heat-pipe according to Formula (1) and Formula (2), using the averages of the recorded values for mass flow rate and inlet/outlet temperature difference of the cooling liquid.

6.3.5 Results

The following values shall be reported:

a) all dimensions of the heat-pipe according to Figure A.1;

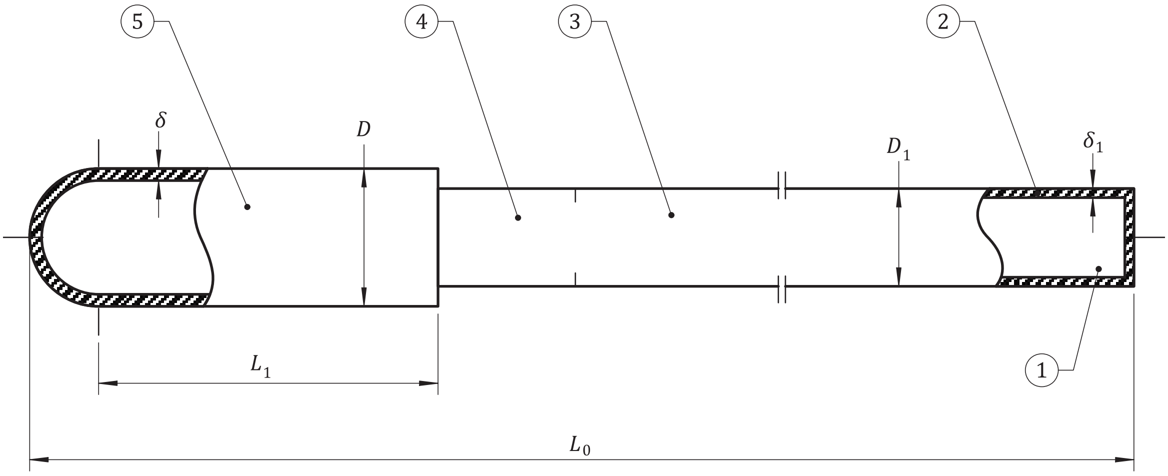
b) ambient temperature;

c) for each test condition: the tilt angle, test operating temperature and measured heat transfer power;

d) the maximum heat transfer power.

Annex A
(informative)

Typical configuration of a heat-pipe for solar thermal application



Key

1	working fluid
2	shell (container)
3	evaporator
4	adiabatic section
5	condenser
D	diameter of condenser
D_1	diameter of evaporator
δ	wall thickness of condenser
δ_1	wall thickness of evaporator
L_0	total length of the heat-pipe
L_1	apparent effective length of condenser

Figure A.1 — Typical configuration of a heat-pipe

Annex B
(normative)

Test reports on a heat-pipe for solar thermal application

Test reports shall be issued in accordance to ISO/IEC 17025.

B.1 General

Heat-pipe reference No: ....

Test performed by: ....

Address: ....

Date, Telephone, Fax: ....

B.2 Description of the heat-pipe

Name of manufacturer: ....

Name of brand: ....

Serial No: ....

Drawing document No: ....

Year of production: ....

The heat-pipe for evacuated tubes:

Type name: ....

Total length of the heat-pipe: .... mm

Apparent effective length of condenser: .... mm

Diameter of condenser: .... mm

Diameter of evaporator: .... mm

Wall thickness of condenser: .... mm

Wall thickness of evaporator: .... mm

Shell material: ....

Working fluid (inorganic/organic): ....

Configuration scheme of the heat-pipe: ....

Photograph of the heat-pipe: ....

Maximum operating temperature: .... °C

B.3 Durability

B.3.1 Summary of main results for durability test

All significant damage to the heat-pipe should be summarized in Table B.1.

Table B.1 — Summary of main results for durability test

Test	Date		Summary of test results
	Start	End	
High temperature resistance			
Freeze resistance			

Remarks: ....

....

Full details should be given in the individual test result sheet.

B.3.2 High temperature resistance test

After the high temperature resistance test specified in 5.1.4, the heat-pipe shall be inspected for damage.

Test conditions:

Test environment: indoors

Ambient temperature: .... °C

Test temperature in heating chamber: .... °C

Test duration: .... h

Test results:

Give details of leakage, breakage, distortion or deformation and any other failures.

....

....

B.3.3 Freeze resistance test

After the freeze resistance test specified in 5.2.4, the heat-pipe should be inspected for damage.

Test conditions:

Test environment: indoors

Ambient temperature: .... °C

Freezing temperature: .... °C

Thawing temperature: .... °C

Tilt angle of the heat-pipe: ....°

Inserted depth in thawing device: .... mm

Test results are given in Table B.2.

Table B.2 — Freeze resistance test results

No. of freeze-thaw cycles	**Freeze conditions**		**Thaw conditions**	
	Freezing temperature (°C)	**Duration** (min)	**Thawing temperature** (°C)	**Duration** (min)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Test results:

Give details of leakage, breakage, distortion or deformation and any other failures.

………

………

B.4 Performance

B.4.1 Starting temperature

The test method shall be chosen from 6.1.

Heat-pipe:

Total length of the heat-pipe: …………………………………………………………………… mm

Insert depth of the heat-pipe: …………………………………………………………………… mm

Measuring point from top of condenser: ………………………………………………… mm

Test conditions:

Test environment: indoors

Ambient temperature: ……………………………………………………………………………… °C

Cold water bath temperature: .... °C

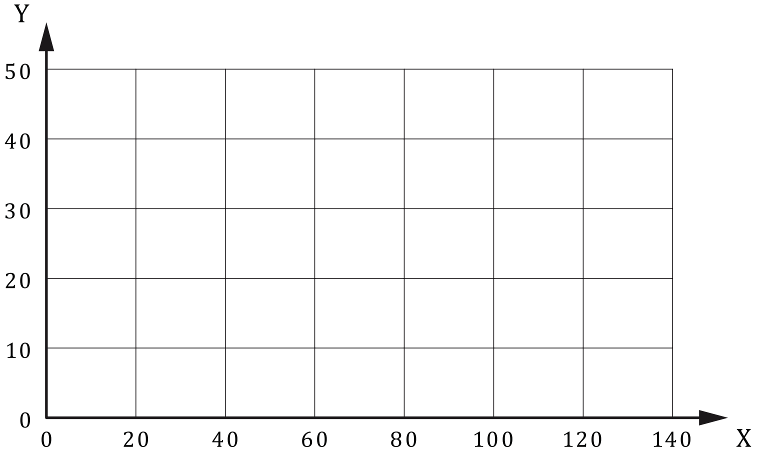
Hot water bath temperature: .... °C

Test results:

Test results are given in Table B.3 and Figure B.1.

Table B.3 — Performance rest results

Time (s)	Hot water bath temperature (°C)	Condenser surface temperature (°C)
0		
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
110		
120		



Key

X time (s)

Y condenser surface temperature (°C)

Figure B.1 — Condenser surface temperature variation with time

The condenser surface temperature is at .... °C when the heat source temperature is at .... °C.

B.4.2 Temperature uniformity

The test method shall be chosen from 6.2.

Heat-pipe:

Total length of the heat-pipe: .... mm

Insert depth of the heat-pipe: .... mm

Measuring point from top of condenser: .... mm

Test conditions:

Test environment: indoors

Ambient temperature: .... °C

Hot water bath temperature: .... °C

Test results:

Test results are given in Table B.4.

Table B.4 — Temperature uniformity test results

Time (s)	**Hot water bath temperature** (°C)	**Condenser surface temperature** (°C)	**Temperature difference** (K)
0			
10			
20			
30			
40			
50			
60			
Mean			

Temperature difference between the hot water bath and the condenser surface is .... K when the heat source temperature is at 90 °C ± 0,5 °C.

B.4.3 Heat transfer power

The test method shall be chosen from 6.3.

Heat-pipe:

Total length of the heat-pipe: .... mm

Apparent effective length of condenser: .... mm

Effective length of heated evaporator: .... mm

Diameter of condenser: .... mm

Diameter of evaporator: .... mm

Test conditions:

Test environment: indoors

Ambient temperature: .... °C

The first test operating temperature: .... °C

The second test operating temperature: .... °C

The third test operating temperature: .... °C

Test results:

Test results at 60 °C ± 0,5 °C, 90 °C ± 1 °C, 120 °C ± 2 °C are respectively given in Table B.5, Table B.6 and Table B.7.

Table B.5 — Results of the heat transfer power at 60 °C ± 0,5 °C

Time (30 s)	**Electric heating power** (W)	**Operating temperature**			**Cooling liquid**			**Heat transfer power** $\dot{Q}$ (W)
		No.1 (°C)	**No.2** (°C)	**Mean** (°C)	**Mass flow rate** $\dot{m}$ (kg/s)	**Inlet temperature** ϑ_1 (°C)	**Temperature difference** $\vartheta_2 - \vartheta_1$ (K)	
0								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Mean								

There shall be seven tables the same as Table B.5 for seven tilt angles of the lowest recommended angle, 20°, 30°, 45°, 60°, 75°, 90°, respectively.

Table B.6 — Results of the heat transfer power at 90 °C ± 1 °C

Time (30 s)	**Electric heating power** (W)	**Operating temperature**			**Cooling liquid**			**Heat transfer power** $\dot{Q}$ (W)
		No.1 (°C)	**No.2** (°C)	**Mean** (°C)	**Mass flow rate** $\dot{m}$ (kg/s)	**Inlet temperature** ϑ_1 (°C)	**Temperature difference** $\vartheta_2 - \vartheta_1$ (K)	
0								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Mean								

There shall be seven tables the same as Table B.6 for seven tilt angles of the lowest recommended angle, 20°, 30°, 45°, 60°, 75°, 90°, respectively.

Table B.7 — Results of the heat transfer power at 120 °C ± 2 °C

Time (30 s)	**Electric heating power** (W)	**Operating temperature**			**Cooling liquid**			**Heat transfer power** $\dot{Q}$ (W)
		No.1 (°C)	**No.2** (°C)	**Mean** (°C)	**Mass flow rate** $\dot{m}$ (kg/s)	**Inlet temperature** ϑ_1 (°C)	**Temperature difference** $\vartheta_2 - \vartheta_1$ (K)	
0								
1								
2								
3								
4								
5								
6								
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15								
16								
17								
18								
19								
20								
Mean								

There shall be seven tables the same as Table B.7 for seven tilt angles of the lowest recommended angle, 20°, 30°, 45°, 60°, 75°, 90°, respectively.

Maximum heat transfer power after reaching 120 °C ± 2 °C:

As soon as the heat-pipe reaches its heat transfer limit after reaching 120 °C ± 2 °C at the tilt angle 90° ± 1°, determine the maximum heat transfer power according to Formula (1) and Formula (2).

Test results after reaching 120 °C ± 2 °C at the tilt angle 90° ± 1° are given in Table B.8.

Table B.8 — Results of the maximum heat transfer power after reaching 120 °C ± 2 °C

Time (30 s)	**Electric heating power** (W)	**Operating temperature**			**Cooling liquid**			**Heat transfer power** $\dot{Q}$ (W)
		No.1 (°C)	**No.2** (°C)	**Mean** (°C)	**Mass flow rate** $\dot{m}$ (kg/s)	**Inlet temperature** ϑ_1 (°C)	**Temperature difference** $\vartheta_2 - \vartheta_1$ (K)	
0								
1								
2								
3								
4								
5								
6								
7								
8								

The maximum heat transfer power ($\dot{Q}_{\text{max}}$) is …… W.

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