INTERNATIONAL STANDARD

ISO 9806-2

First edition
1995-08-15

Test methods for solar collectors —

Part 2:
Qualification test procedures

Méthodes d'essai des capteurs solaires —
Partie 2: Méthodes d'essai de qualification

Reference number
ISO 9806-2:1995(E)

Contents

		Page
1	Scope	1
2	Normative references	1
3	Definitions	2
4	General	2
5	Internal pressure tests for absorbers	2
6	High-temperature resistance test	10
7	Exposure test	13
8	External thermal shock test	14
9	Internal thermal shock test for liquid-heating collectors	16
10	Rain penetration test	17
11	Freezing test	18
12	Impact resistance test (optional)	20
13	Final inspection	21
14	Test report	21

Annexes

A	Test format sheets	23
B	Stagnation temperature of liquid heating collectors	46
C	Bibliography	48

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

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.

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.

International Standard ISO 9806-2 was prepared by Technical Committee ISO/TC 180, *Solar energy*, Subcommittee SC 5, *Collectors and other components*.

ISO 9806 consists of the following parts, under the general title *Test methods for solar collectors*:

— *Part 1: Thermal performance of glazed liquid heating collectors including pressure drop*

— *Part 2: Qualification test procedures*

— *Part 3: Thermal performance of unglazed liquid heating collectors (sensible heat transfer only) including pressure drop*

Annexes A and B form an integral part of this part of ISO 9806. Annex C is for information only.

Introduction

It is widely recognized that the durability and reliability of solar collectors and solar collector systems are of great importance when the overall quality of a solar heating system is being assessed.

Collectors are required to resist a number of influences which can be clearly identified and quantified, such as high internal fluid pressures, high temperatures and rain penetration. Tests to establish the extent to which a collector is able to resist these influences are commonly called "qualification tests".

Test methods for solar collectors —

Part 2:
Qualification test procedures

1 Scope

1.1 This part of ISO 9806 establishes test methods for determining the ability of a solar collector to resist the influences of degrading agents.

1.2 This part of ISO 9806 applies to all types of solar collectors, including integral collector storage systems but excepting tracking concentrating collectors.

1.3 This part of ISO 9806 defines procedures for testing collectors under well-defined and repeatable conditions, but does not include pass/fail criteria for the test results.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9806. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9806 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 9060:1990, *Solar energy — Specification and classification of instruments for measuring hemispherical solar and direct solar radiation.*

ISO 9459-1:1993, *Solar heating — Domestic water heating systems — Part 1: Performance rating procedure using indoor test methods.*

ISO 9459-2:1995, *Solar heating — Domestic water heating systems — Part 2: Outdoor test methods for system performance characterization and yearly performance prediction of solar-only systems.*

ISO 9806-1:1994, *Test methods for solar collectors — Part 1: Thermal performance of glazed liquid heating collectors including pressure drop.*

ISO 9806-3:—[1], *Test methods for solar collectors — Part 3: Thermal performance of unglazed liquid heating collectors (sensible heat transfer only) including pressure drop.*

1) To be published.

3 Definitions

For the purposes of this part of ISO 9806, the definitions given in ISO 9806-1 and the following definitions apply.

3.1 collector, evacuated: Collector in which the space between the absorber and the cover is evacuated to a pressure < 3 kPa.

3.2 integral collector storage system: Solar heating system in which the solar collector also functions as a heat (water) storage tank.

3.3 irradiation: Incident energy per unit area of surface, found by the integration of irradiance over a specified time interval.

It is normally expressed in megajoules per square metre.

NOTE 1 The time interval specified is often an hour or a day.

3.4 stagnation conditions (in solar energy systems)**:** Conditions of temperature and pressure existing when the system has attained a quasi-steady state after the flow of the heat transfer fluid has stopped, but the absorber continues to receive significant solar radiation.

3.5 steady-state: Status of a solar collector when the heat removal rate (including losses) is equal to the solar energy input rate.

4 General

The tests in this part of ISO 9806 shall be carried out in the sequence shown in table 1, using three collectors (A, B and C) of any given type.

Tests may be omitted from the sequence upon agreement of all parties involved or at the discretion of the test laboratory. Changes in the test sequence shall be reported with the test results and the reasons for deviation shall be given.

For some qualification tests, a part of the collector may have to be tampered with in some way, for example a hole may have to be drilled in the back of the collector to attach a temperature sensor to the absorber. In these cases care should be taken to ensure that any damage caused does not affect the results of subsequent qualification tests, for example by allowing water to enter into a previously raintight collector.

NOTE 2 This sequence has been determined with a view to minimizing test costs while ensuring that the possible effects of each degrading influence are likely to be evaluated in a later test. (For example, rain penetration may result if a collector is distorted by exposure to high temperatures.)

5 Internal pressure tests for absorbers

5.1 Metallic absorbers for liquid heating collectors

5.1.1 Objective

The absorber is pressure-tested to assess the extent to which it can withstand the pressures which it might meet in service.

5.1.2 Apparatus and procedure

The apparatus, shown in figure 1, consists of a hydraulic pressure source (electrical pump or hand pump), a safety valve, an air-bleed valve and a pressure gauge with an accuracy of 5 % of the actual reading. The air-bleed valve shall be used to empty the absorber of air before pressurization.

The metallic absorber is filled with water at room temperature and pressurized to the test pressure for the test period. This pressure is maintained while the absorber is inspected for swelling, distortion or ruptures.

Table 1 — Test sequence

Sequence	Clause	Test	Collector
1	5	Internal pressure	A
2	6	High-temperature resistance1)	A
3	7	Exposure	A, B and C
4	8	External thermal shock2)	A
5	9	Internal thermal shock	A
6	10	Rain penetration	A
7	11	Freeze resistance	A
8	5	Internal pressure (retest)	A
9		Thermal performance3)	A
10	12	Impact resistance (optional)	A or B
11	13	Final inspection	A, B and C

1) For organic absorbers, the high-temperature resistance test shall be performed first in order to determine the collector stagnation temperature needed for the internal pressure test.

2) The external thermal shock test may be combined with the exposure test.

3) The thermal performance test shall be carried out in accordance with the procedures given in ISO 9806-1 or ISO 9806-3 for glazed or unglazed liquid heating collectors and ISO 9459-1 or ISO 9459-2 for integral collector storage systems.

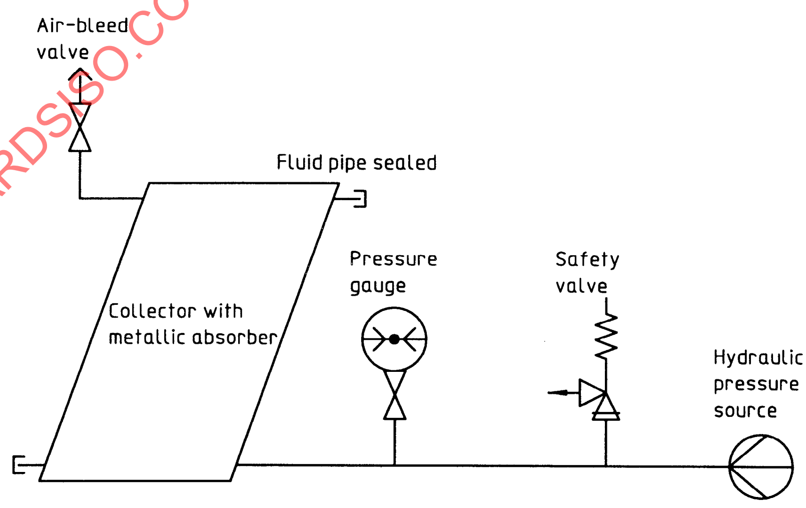

Figure 1 — Schematic for internal pressure test of metallic absorbers for liquid heating collectors

5.1.3 Test conditions

5.1.3.1 Temperature

Metallic absorbers are pressure-tested at ambient temperature within the range 5 °C to 30 °C.

5.1.3.2 Pressure

The test pressure is either the manufacturer's stated maximum test pressure or 1,5 times the maximum collector operating pressure specified by the manufacturer, whichever is lower.

The test pressure is maintained for 10 min.

5.1.4 Results

The collector shall be inspected for leakage, swelling and distortion. The results of this inspection shall be reported together with the values of pressure and temperature used and the duration of the test. If the applied test pressure was less than 1,5 times the maximum collector operating pressure specified by the manufacturer, this shall be reported.

5.2 Liquid heating absorbers made of organic materials (plastics or elastomers)

5.2.1 Objective

The absorber is pressure-tested to assess the extent to which it can withstand the pressures which it might meet in service while operating at elevated temperature. The tests are carried out at elevated temperatures, because the pressure resistance of an organic absorber may be adversely affected as its temperature is increased.

5.2.2 Apparatus and procedure

The apparatus consists of either a hydraulic or a pneumatic pressure source, and a means of heating the absorber to the required test temperature.

The characteristics of a solar irradiance simulator shall be the same as those of the simulator used for steady-state efficiency testing of liquid heating solar collectors (see ISO 9806-1).

The test conditions specified in 5.2.3 shall be maintained for at least 30 min prior to test and for the full duration of the test.

The pressure in the absorber is raised in stages as specified in 5.2.3, and the absorber is inspected for swelling, distortion or rupture after each increase in pressure. The pressure is maintained while the absorber is being inspected.

For safety reasons, the collector shall be encased in a transparent box to protect personnel in the event of explosive failure during this test.

5.2.2.1 Organic absorbers for use in unglazed collectors (test temperature < 90 °C)

Where the maximum test temperature is below 90 °C, absorbers may be submerged in a heated water bath and pressure-tested. The pressurized fluid supply to the absorber shall be fitted with a safety valve, air-bleed valve (if required) and pressure gauge having an accuracy of 5 % of the actual reading. Apparatus is shown in figure 2.

5.2.2.2 Organic absorbers for use with oil-based fluids (test temperature > 90 °C)

When the test temperature exceeds 90 °C, the absorber may be connected to a hot oil circuit. The absorber and hot oil circuit are then pressurized. The hot oil circuit shall be fitted with a safety valve, air-bleed valve and pressure gauge having an accuracy of 5 % of the actual reading.

The absorber may be heated by any of the following methods:

a) connecting a heater in the oil circuit (figure 3);

b) heating the whole collector in a solar irradiance simulator (figure 4);

c) heating the whole collector outdoors under natural solar irradiance (figure 4).

Safety measures should be taken to protect personnel from hot oil in the event of explosive failure during this test.

5.2.2.3 Organic absorbers — high-temperature pneumatic pressure test

The absorber may be pressure-tested using compressed air, when heated by either of the following methods:

a) heating the whole collector in a solar irradiance simulator (figure 5);

b) heating the whole collector outdoors under natural solar irradiance (figure 5).

The compressed air supply to the absorber shall be fitted with a safety valve and a pressure gauge having an accuracy of 5 % of the actual reading.

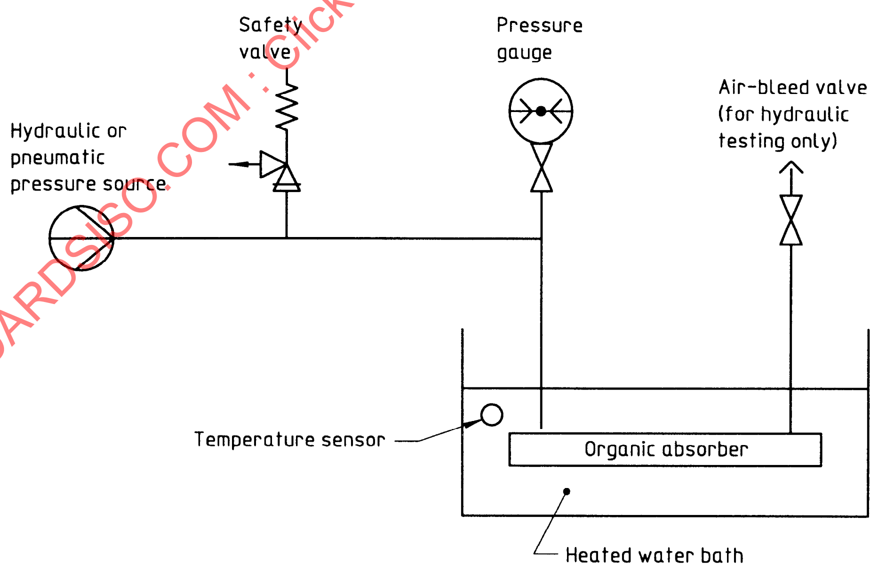

Figure 2 — Schematic for internal pressure test of organic absorbers for use in unglazed collectors

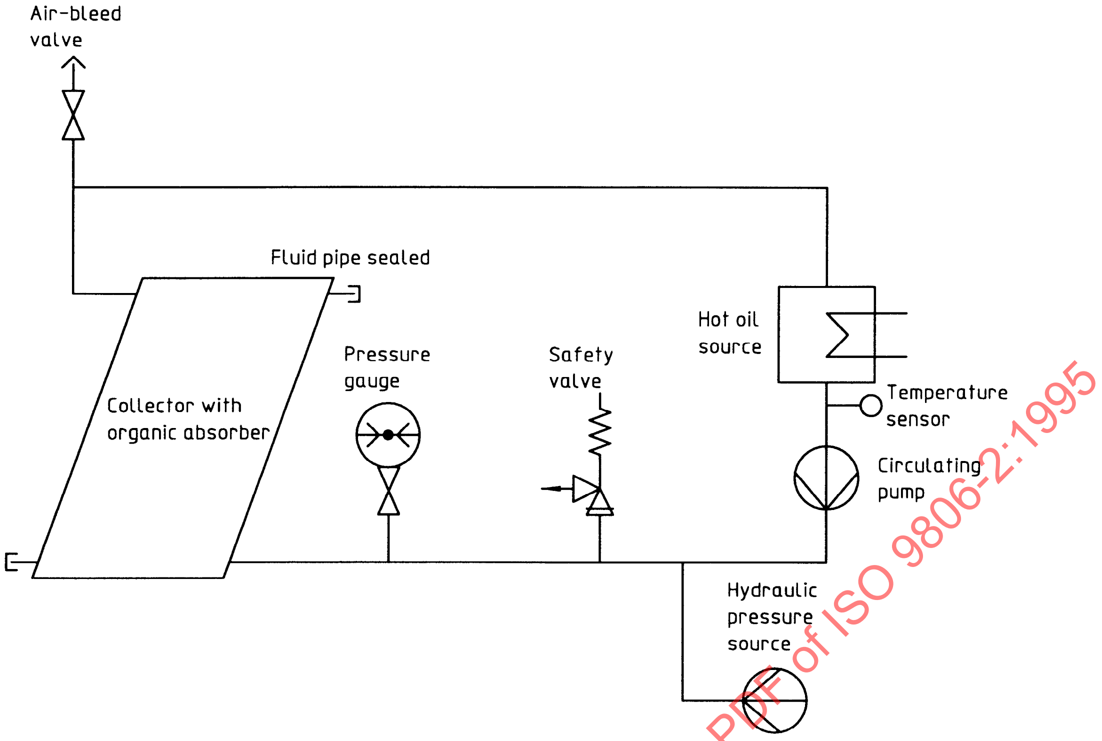

Figure 3 — Schematic for internal pressure test of organic absorbers for use with oil-based fluids (hot oil source)

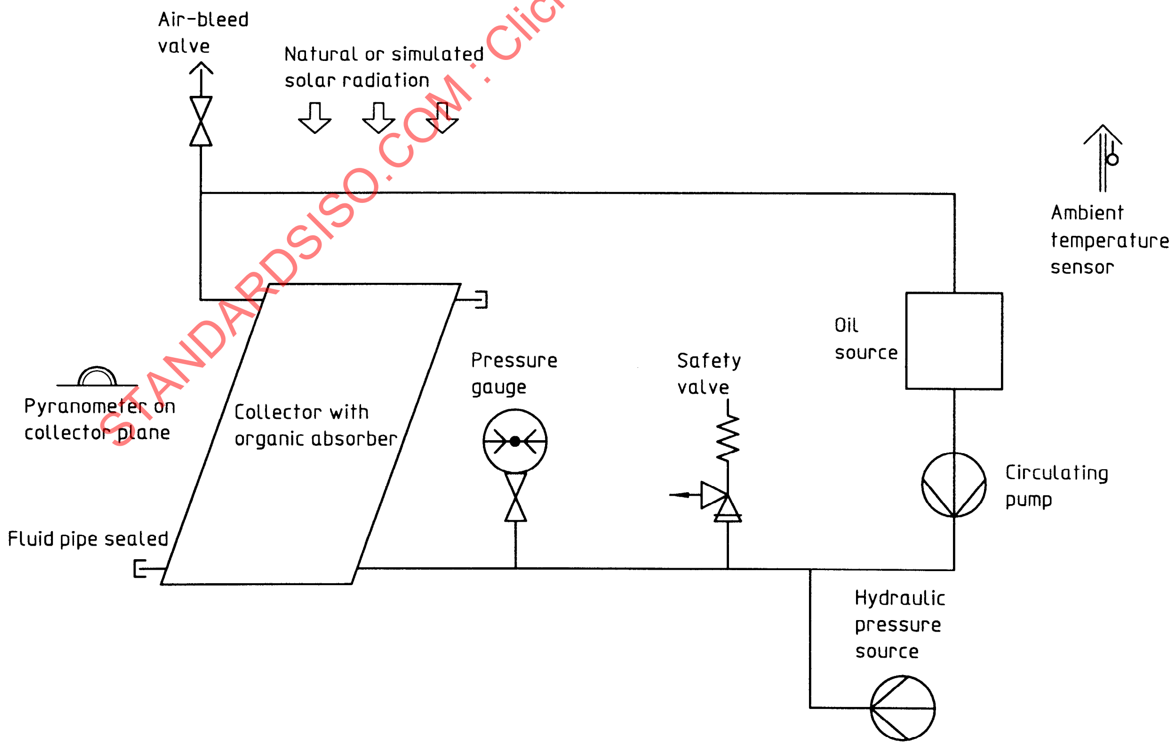

Figure 4 — Schematic for internal pressure test of organic absorbers for use with oil-based fluids (test under solar irradiance)

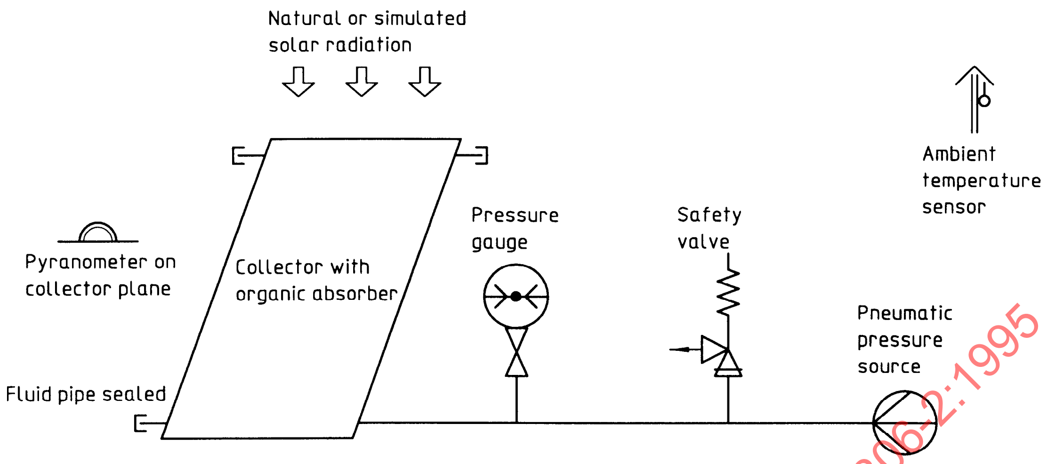

Figure 5 — Schematic for internal pressure test of organic absorbers (pneumatic test under solar irradiance)

5.2.3 Test conditions

5.2.3.1 Temperature

For absorbers made of organic materials, the test temperature is the maximum temperature which the absorber will reach under stagnation conditions.

One of the alternative sets of reference conditions given in table 2 shall be used to determine the test temperature, depending on the climate in which the collector will be used.

The calculations employed to determine the test temperature are included in annex B and shall either:

— use measured collector performance characteristics, or

— extrapolate from average values, measured in the high-temperature resistance test (6.3), of the global solar irradiance (natural or simulated) on the collector plane, the surrounding air temperature and the absorber temperature.

The test temperature for integral collector storage systems shall be 85 °C for class A and class B climate reference conditions and 100 °C for class C.

Table 2 — Climate reference conditions to determine test temperatures for internal pressure test of organic absorbers

Climate parameter	Value for climate class		
	Class A Temperate	Class B Sunny	Class C Very sunny
Global solar irradiance on collector plane, G (W/m^2)	1 000	1 100	> 1 200
Surrounding air temperature, t_a (°C)	30	40	> 40

5.2.3.2 Pressure

The test pressure shall be 1,5 times the maximum collector operating pressure specified by the manufacturer.

For absorbers made of organic materials, the pressure shall be raised to the test pressure in equal stages of 0,2 bar[2] (approximately) and maintained at each intermediate pressure for 5 min. The test pressure shall then be maintained for at least 1 h.

5.2.4 Results

The collector shall be inspected for leakage, swelling and distortion. The results of the inspection shall be reported.

Full details of the test procedure used, including the temperature, intermediate pressures and test periods used, shall be reported with the test results.

5.3 Air heating collectors with metallic absorbers

5.3.1 Objective

The collector is pressure-tested to assess the extent to which it can withstand the pressures which it might meet in service, including pressures which may arise when the airflow is blocked on the other side of the collector from the fan.

5.3.2 Apparatus and procedure

The apparatus, shown in figure 6, consists of a controllable air source or suction fan, capable of supplying the specified values of positive or negative pressure at the maximum allowable collector leakage flowrate. An airflow meter having an accuracy of 5 % is installed to measure the rate of leakage, and a pressure gauge having an accuracy of 5 % of the actual reading is installed to measure the pressure in the absorber.

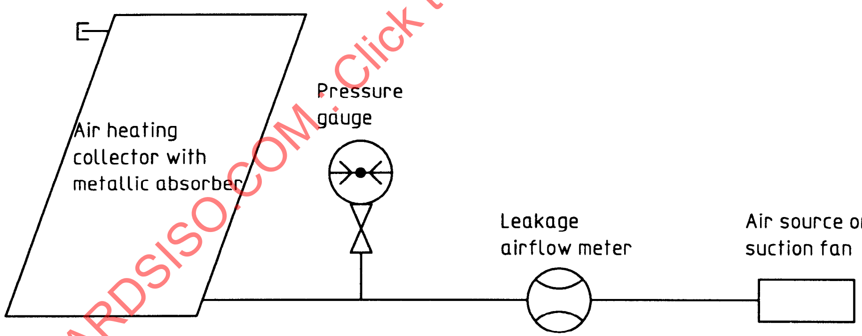

Figure 6 — Schematic for internal pressure test of air heating collectors with metallic absorbers

The air source or suction fan, airflow meter and pressure gauge are connected to the collector, and other pipe connections to the collector are sealed.

The collector is brought to the test pressure with air at ambient temperature, for the specified test period.

The collector is maintained at the test pressure while it is inspected for swelling, distortion or ruptures.

For safety reasons, the collector shall be encased in a transparent box to protect personnel in the event of explosive failure during this test.

2) 1 bar = 100 kPa.

5.3.3 Test conditions

5.3.3.1 Temperature

Air heating collectors with metallic absorbers are pressure-tested at ambient temperature.

5.3.3.2 Pressure

The test pressure is 1,2 times the maximum collector operating pressure difference above or below atmospheric pressure, as specified by the manufacturer.

The test pressure is maintained for 10 min.

5.3.4 Results

The collector shall be inspected for swelling, distortion or ruptures. The results of the inspection shall be reported together with the rate of air leakage, and the values of pressure and temperature and the test period used for the test.

5.4 Air heating absorbers made of organic materials (plastics or elastomers)

5.4.1 Objective

The collector is pressure-tested to assess the extent to which it can withstand the pressures which it might meet in service, including pressures which may arise when the airflow is blocked on the other side of the collector from the fan. Because the pressure resistance of collectors with absorbers made of organic materials is expected to be significantly reduced at higher temperatures, a pressure test at an elevated temperature shall be used.

5.4.2 Apparatus and procedure

The apparatus (see figure 7) consists of a controllable air source or suction fan, capable of supplying the specified values of positive or negative pressure at the required temperature, and at the maximum allowable collector leakage flowrate. A flowmeter having an accuracy of 5 % to measure the leakage and a pressure gauge having an accuracy of 5 % of the readings taken during the test are also required.

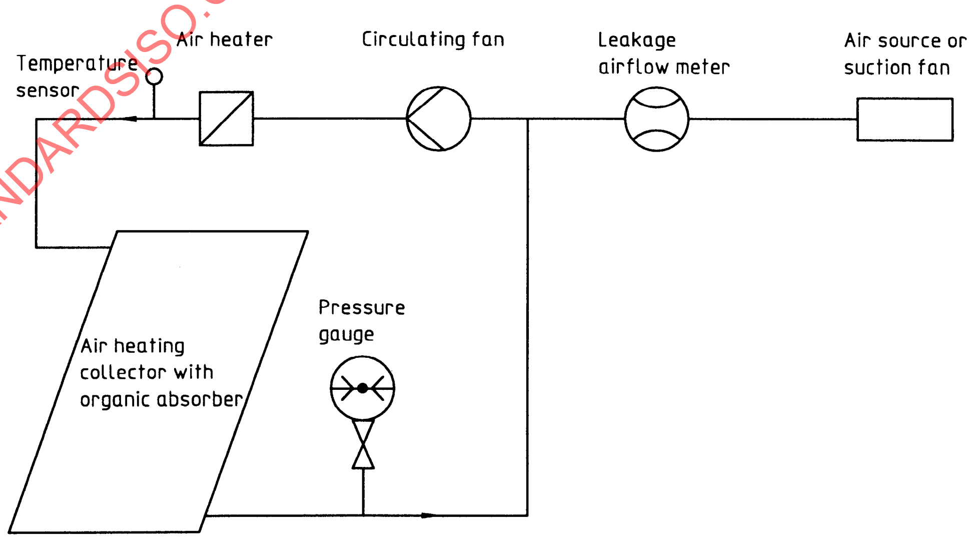

Figure 7 — Schematic for internal pressure test of air heating collectors with organic absorbers

The collector is connected to an air-heating loop in such a way that air flows downwards into the collector. The pressure gauge is connected to the collector either in a separate opening of the collector or in the heating loop close to the outlet of the collector. While circulating air through the collector, the air is heated to the test temperature and maintained there for the test period. The collector and the heating loop are pressurized or depressurized in stages to the test pressure, which is then maintained for the test period.

After the test period, the temperature and pressure are maintained while the collector is inspected for swelling, distortion or ruptures. The collector is also inspected for swelling, distortion or ruptures after each rise in pressure.

For safety reasons, the collector shall be encased in a transparent box to protect personnel in the event of explosive failure during this test.

5.4.3 Test conditions

5.4.3.1 Temperature

For absorbers made of organic materials, the test temperature is the maximum temperature which the absorber will reach under stagnation conditions.

One of the alternative sets of reference conditions given in table 2 shall be used to determine the test temperature, depending on the climate in which the collector will be used.

The test temperature shall be determined from measurements made during the high-temperature resistance test specified in clause 6, using the expression included in annex B.

5.4.3.2 Pressure

The test pressure shall be 1,2 times the maximum collector operating pressure difference above or below atmospheric pressure, as specified by the manufacturer.

For absorbers made of organic materials, the pressure shall be raised to the test pressure in equal stages of 0,2 bar (approximately) and maintained at each intermediate pressure for 5 min. The test pressure shall then be maintained for at least 1 h.

5.4.4 Results

The collector shall be inspected for leakage, swelling and distortion. The results of the inspection shall be reported. Full details of the test procedure used, including the temperature, intermediate pressures and test periods selected, shall be reported with the test results.

6 High-temperature resistance test

6.1 Objective

This test is intended to assess rapidly whether a collector can withstand high irradiance levels without failures such as glass breakage, collapse of plastic cover, melting of plastic absorber, or significant deposits on the collector cover from outgassing of collector material.

6.2 Apparatus and procedure

The collector shall be tested outdoors, or in a solar irradiance simulator, or in a hot fluid loop of the type described in 5.2.2.2. A schematic for testing outdoors or in a simulator is shown in figure 8.

The characteristics of the solar irradiance simulator to be used for the high-temperature resistance test shall be those of the solar irradiance simulator used for steady-state efficiency testing of liquid heating solar collectors in accordance with ISO 9806-1.

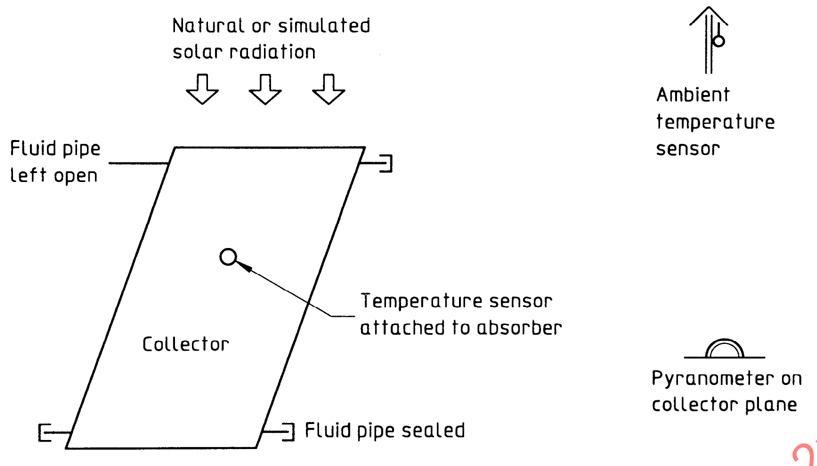

Figure 8 — Schematic for high-temperature resistance test (outdoors or in simulator)

If a hot fluid loop is used, the hot fluid shall be circulated from the bottom to the top of the collector with a constant inlet temperature, using a flowrate similar to that defined for collector efficiency testing (see ISO 9806-1).

NOTE 3 It is recognized that the thermal stresses induced by the hot fluid loop test may not be equivalent to the thermal stresses induced by heating externally using natural or simulated solar irradiance.

The collector is mounted outdoors or in a solar simulator, and it is not filled with fluid. All of its fluid pipes are sealed to prevent cooling by natural circulation of air except one, which is left open to permit free expansion of air in the absorber.

A temperature sensor is attached to the absorber to monitor its temperature during the test. The sensor shall be positioned at two-thirds of the absorber height and half the absorber width. It shall be fixed firmly in a position to ensure good thermal contact with the absorber. The sensor shall be shielded from solar radiation.

NOTES

4 When testing collectors, such as evacuated tubular collectors, for which it is not appropriate to measure the stagnation temperature at the absorber, the temperature sensor should be placed at a suitable location in the collector, and this location should be clearly described with the test results.

5 In some cases, such as evacuated absorbers, it may be difficult to attach a thermocouple to the absorber. In such cases, instead of attaching a thermocouple to the absorber, the testing laboratory may partially fill the absorber with a special fluid, seal the absorber and measure the pressure in the absorber. The relationship between the internal pressure in the absorber and its temperature should be known from the standard vapour pressure/temperature relationship for the fluid.

The test is performed for a minimum of 1 h after steady-state conditions have been established, and the collector is subsequently inspected for signs of damage as specified in 6.5.

6.3 Test conditions for testing outdoors or in a solar irradiance simulator

One of the alternative sets of reference conditions given in table 3 shall be used, depending on the climate in which the collector will be used.

Table 3 — Climate reference conditions for high-temperature resistance test

Climate parameter	Value for climate class		
	Class A **Temperate**	**Class B** **Sunny**	**Class C** **Very sunny**
Global solar irradiance on collector plane, G (W/m^2)	950 – 1 049	1 050 – 1 200	> 1 200
Surrounding air temperature, t_a (°C)	25,0 – 29,9	30 – 40	> 40
Surrounding air speed (m/s)	< 1	< 1	< 1

6.4 Test conditions for testing in a hot fluid loop

If a hot fluid loop is used, then the fluid temperature to be used in the test is the maximum temperature which the collector will reach under stagnation conditions.

One of the alternative sets of reference conditions given in table 2 shall be used to determine the test temperature, depending on the climate in which the collector will be used.

The calculations employed to determine the test temperature are included in annex B and shall either:

— use measured collector performance characteristics, or

— extrapolate from average values of solar irradiance (natural or simulated) on the collector plane, surrounding air temperature and absorber temperature, measured by exposing the collector to available climate conditions (outdoors, or in a solar simulator) under stagnation conditions for at least 1 h.

The fluid test temperature for integral collector storage systems shall be 85 °C for class A and class B climate reference conditions and 100 °C for class C.

6.5 Results

The collector shall be inspected for degradation, shrinkage, outgassing and distortion.

For tests outdoors or in a solar irradiance simulator, the results of the inspection shall be recorded together with the average values of solar irradiance (natural or simulated) on the collector plane, surrounding air temperature and speed, and absorber temperature (and the pressure of the special fluid in the absorber, if that method is used) recorded during the test.

For tests in a hot fluid loop, the results of the inspection shall be recorded together with the

— average values of the stagnation parameters (irradiance, surrounding air temperature and speed, and absorber temperature) measured under the available climate conditions;

— calculated test (stagnation) temperature determined for the climate reference conditions of table 2;

— average value of the temperature, measured during the test, of the fluid entering the collector.

7 Exposure test

7.1 Objective

The exposure test provides a low-cost indication of the ageing effects which are likely to occur during a longer period of natural ageing. In addition, it also allows the collector to "settle", such that subsequent qualification tests are more likely to give repeatable results.

7.2 Apparatus and procedure

The collector is mounted outdoors (see figure 9), but is not filled with fluid. All of its fluid pipes are sealed to prevent cooling by natural circulation of air except one, which is left open to permit free expansion of air in the absorber.

The air temperature is recorded to an accuracy of 1 K and the global irradiance on the plane of the collector recorded using a pyranometer of class I in accordance with ISO 9060. Irradiation and mean air temperature values shall be recorded every 30 min and rainfall shall be recorded daily. The collector is exposed until the test conditions have been met.

At the end of the exposure, a visual inspection shall be made for signs of damage as specified in 7.4.

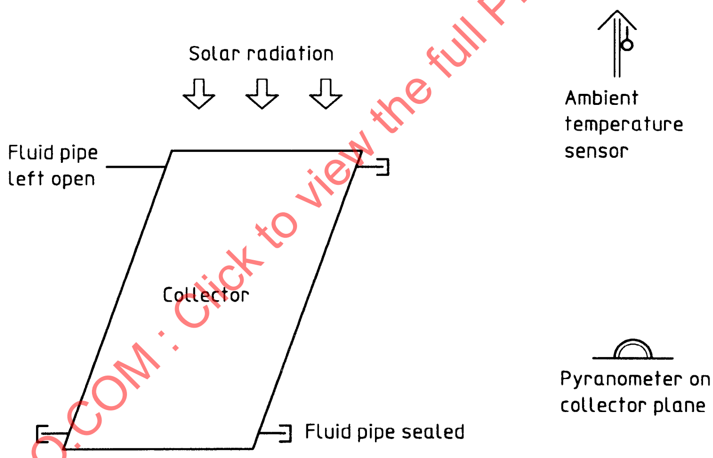

Figure 9 — Schematic for exposure test

7.3 Test conditions

One of the alternative sets of reference conditions given in table 4 shall be used, depending on the climate in which the collector will be used.

For each class of reference conditions, the collector is exposed until at least 30 days (which need not be consecutive) have passed with the minimum irradiation H shown in table 4. The irradiation is determined by recording irradiance measurements using a pyranometer.

The collector shall also be exposed (for the appropriate class of reference conditions) for at least 30 h to the minimum irradiance level G given in table 4, as recorded by a pyranometer, when the surrounding air temperature is greater than the value shown in table 4. These hours shall be made up of periods of at least 30 min.

NOTE 6 In regions where these conditions cannot be met during certain periods of the year, the 30-h exposure to high irradiance levels (table 4) can be conducted in a solar irradiance simulator having characteristics identical to those of a simulator used for steady-state efficiency testing of liquid heating solar collectors (ISO 9806-1). The 30-h exposure test is conducted after the collector has completed at least 10 days, but no more than 15 days, of the exposure to the minimum irradiation level (table 4).

If the external thermal shock test is combined with the exposure test, the first external shock shall be caused during the first 10 of the 30 h defined above, and the second during the last 10 of the 30 h.

Table 4 — Climate reference conditions for exposure test as well as for external and internal thermal shock tests

Climate parameter	Value for climate class		
	Class A Temperate	Class B Sunny	Class C Very sunny
Global solar irradiance on collector plane, G (W/m^2)	850	950	1 050
Global daily irradiation on collector plane, H (MJ/m^2)	14	18	20
Surrounding air temperature, t_a (°C)	10	15	20
NOTE — Values given are minimum values for testing.			

7.4 Results

The collector shall be inspected for damage or degradation. The results of the inspection shall be reported together with a record of the climatic conditions during the test, including daily irradiation, ambient temperature and rain.

8 External thermal shock test

8.1 Objective

Collectors may from time to time be exposed to sudden rainstorms on hot sunny days, causing a severe external thermal shock. This test is intended to assess the capability of a collector to withstand such thermal shocks without a failure.

8.2 Apparatus and procedure

The collector is mounted either outdoors or in a solar irradiance simulator, but is not filled with fluid. All of its fluid pipes are sealed to prevent cooling by natural circulation of air except one, which is left open to permit free expansion of air in the absorber (see figure 10).

A temperature sensor is attached to the absorber to monitor its temperature during the test. The sensor shall be positioned at two-thirds of the absorber height and half the absorber width. It shall be fixed firmly in a position to ensure good thermal contact with the absorber. The sensor shall be shielded from solar radiation.

NOTES

7 When testing collectors such as evacuated tubular collectors for which it is not appropriate to measure the stagnation temperature at the absorber, the temperature sensor should be placed at a suitable location in the collector, and this location should be clearly described in the test report.

8 In some cases, such as evacuated absorbers, it may be difficult to attach a thermocouple to the absorber. In such cases, instead of attaching a thermocouple to the absorber, the testing laboratory may partially fill the absorber with a special fluid, seal the absorber and measure the pressure in the absorber. The relationship between the internal pressure in the absorber and its temperature should be known from the standard vapour pressure/temperature relationship for the fluid.

An array of water jets is arranged to provide a uniform spray of water over the collector.

The collector is maintained in steady-state operating conditions under a high level of solar irradiance for a period of 1 h before the water spray is turned on. It is then cooled by the water spray for 15 min before being inspected.

The collector is subjected to two external thermal shocks.

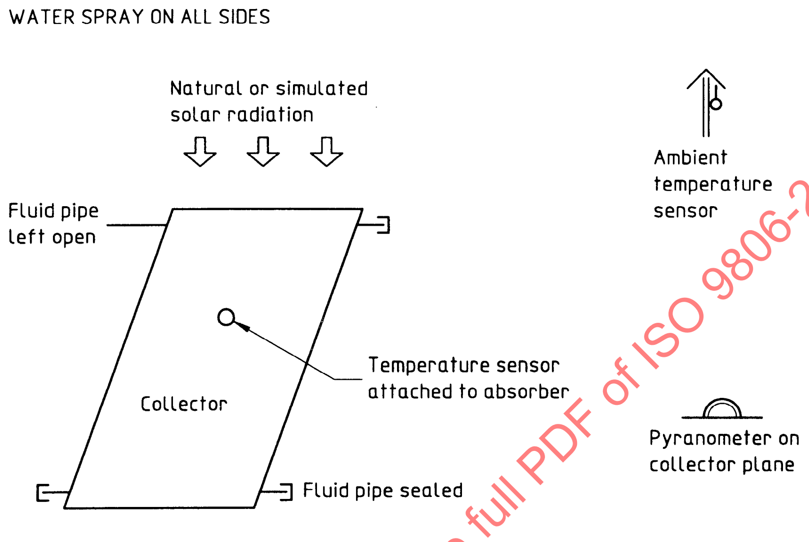

Figure 10 — Schematic for external thermal shock test

8.3 Test conditions

One of the alternative sets of reference conditions given in table 4 shall be used, depending on the climate in which the collector will be used.

For each class of reference conditions, the specified steady-state operating conditions are:

— solar (or simulated solar) irradiance G greater than the values shown in table 4;

— surrounding air temperature t_a greater than the values shown in table 4.

The water spray shall have a temperature of less than 25 °C and a flowrate in the range 0,03 l/s to 0,05 l/s per square metre of collector aperture.

If the temperature of the water which first cools the collector is likely to be at a temperature greater than 25 °C (for example if the water has been sitting in a pipe in the sun for some time), then the water shall be diverted until it has reached a temperature of less than 25 °C before being directed over the collector.

8.4 Results

The collector shall be inspected for any cracking, distortion, condensation or water penetration. The results of the inspection shall be reported. The measured values of solar irradiance, surrounding air temperature, absorber temperature, water temperature and water flowrate shall also be reported.

9 Internal thermal shock test for liquid-heating collectors

9.1 Objective

Collectors may from time to time be exposed to a sudden intake of cold heat transfer fluid on hot sunny days, causing a severe internal thermal shock, for example, after a period of shutdown, when the installation is brought back into operation while the collector is at its stagnation temperature. This test is intended to assess the capability of a collector to withstand such thermal shocks without failure.

9.2 Apparatus and procedure

The collector is mounted either outdoors or in a solar irradiance simulator (see figure 11), but it is not filled with fluid. One of its fluid pipes is connected via a shutoff valve to the heat transfer fluid source and the other (diagonally across the collector) is left open initially to permit the free expansion of air in the absorber and also to permit the heat transfer fluid to leave the absorber (and be collected).

A temperature sensor is attached to the absorber to monitor its temperature during the test. The sensor shall be positioned at two-thirds of the absorber height and half the absorber width. It shall be fixed firmly in a position to ensure good thermal contact with the absorber. The sensor shall be shielded from solar radiation.

NOTES

9 When testing collectors, such as evacuated tubular collectors, for which it is not appropriate to measure the stagnation temperature at the absorber, the temperature sensor should be placed at a suitable location in the collector, and this location should be clearly described in the test report.

10 In some cases, such as evacuated absorbers, it may be difficult to attach a thermocouple to the absorber. In such cases, instead of attaching a thermocouple to the absorber, the testing laboratory may partially fill the absorber with a special fluid, seal the absorber and measure the pressure in the absorber. The relationship between the internal pressure in the absorber and its temperature should be known from the standard vapour pressure/temperature relationship for the fluid.

The collector is maintained under a high level of solar irradiance in steady-state conditions for a period of 1 h before it is cooled by supplying it with heat transfer fluid for at least 5 min.

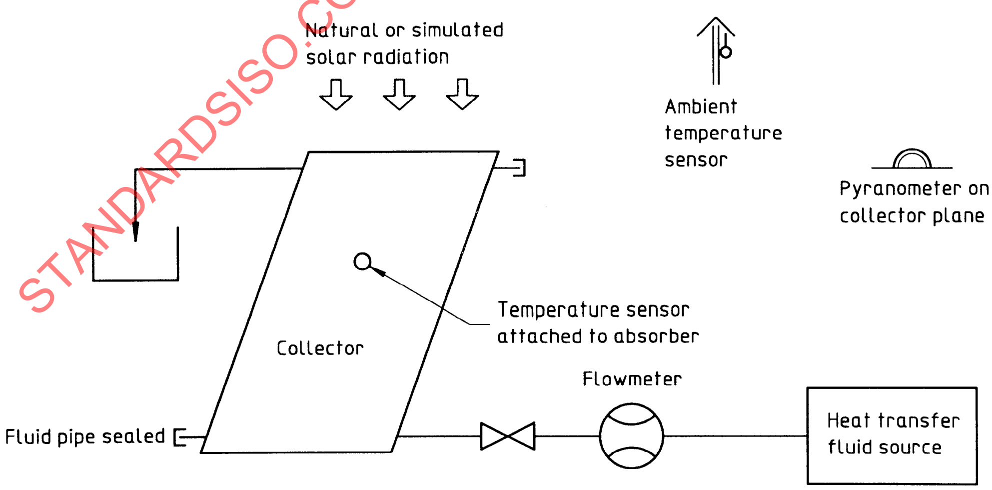

Figure 11 — Schematic for internal thermal shock test for liquid heating collectors

9.3 Test conditions

One of the alternative sets of reference conditions given in table 4 shall be used, depending on the climate in which the collector will be used.

For each class of reference conditions, the specified steady-state operating conditions are:

— solar (or simulated solar) irradiance G greater than the values shown in table 4;

— surrounding air temperature t_a greater than the values shown in table 4.

The heat transfer fluid shall have a temperature of less than 25 °C. The recommended fluid flowrate is at least 0,02 kg/s per square metre of collector aperture (unless otherwise specified by the manufacturer).

9.4 Results

The collector shall be inspected for any cracking, distortion or deformation. The results of the inspection shall be reported. The measured values of solar irradiance, surrounding air temperature, absorber temperature, heat transfer fluid temperature and heat transfer fluid flowrate shall also be reported.

10 Rain penetration test

10.1 Objective

This test is intended to assess the extent to which collectors are substantially resistant to rain penetration. They shall normally not permit the entry of either free-falling rain or driving rain. Collectors may have ventilation holes and drain holes, but these shall not permit the entry of driving rain.

10.2 Apparatus and procedure

The collector shall have its fluid inlet and outlet pipes sealed (see figure 12), and be placed in a test rig at the shallowest angle to the horizontal recommended by the manufacturer. If this angle is not specified, then the collector shall be placed at a tilt of 45° to the horizontal or less. Collectors designed to be integrated into a roof structure shall be mounted in a simulated roof and have their underside protected. Other collectors shall be mounted in a conventional manner on an open frame.

The collector shall be sprayed on all sides using spray nozzles or showers for a test period of 4 h.

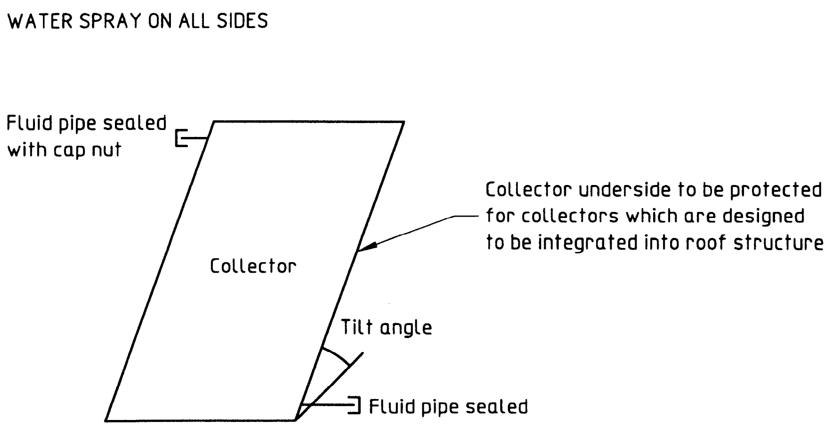

Figure 12 — Schematic for rain penetration test

10.2.1 Collectors which can be readily weighed

The collector shall be weighed before the test. After the test, external surfaces of the collector shall be wiped dry and the collector reweighed. During the wiping, transport and placement on the weighing machine, the angle of inclination of the collector shall not be changed appreciably. If the collector has drain holes, then it shall be weighed (after testing) after water has finished dripping from the drain holes.

The scales used to weigh the collector shall have an accuracy of at least 20 g.

A visual inspection of the collector shall be made after the test has been completed.

10.2.2 Collectors which cannot be readily weighed

The collector shall be mounted and sprayed as explained in 10.2, but the penetration of water into the collector shall be determined only by visual inspection.

NOTE 11 Rain penetration is more easily visible if it is made to form condensation on the cover glass. This can be done either by circulating hot water at about 50 °C through the absorber or by exposing the collector to solar radiation.

10.3 Test conditions

The collector shall be at approximately the same temperature as the surrounding air.

The water spray shall have a temperature of less than 25 °C and a flowrate in the range 0,03 l/s to 0,05 l/s per square metre of collector aperture.

10.4 Results

The collector shall be inspected for water penetration. The results of the inspection, i.e. the places where water penetrated and the approximate amount of water penetrating (either the mass of water or an estimate thereof) shall be reported. Where applicable, the mass of the collector before and after the test shall also be reported.

11 Freezing test

11.1 Objective

This test is intended to assess the extent to which water-heating collectors which are claimed to be freeze resistant can withstand freezing, and freeze/thaw cycling. This test is not intended for use with collectors which are filled with antifreeze fluids.

Two test procedures are recommended:

— one for collectors which are claimed to be freeze-resistant when filled with water, and

— one for collectors which are claimed to resist freezing after being drained.

11.2 Apparatus and procedure

11.2.1 Freeze-resistant collectors

For collectors which are claimed to be able to withstand freezing, the collector is mounted in a cold chamber (see figure 13). The collector shall be inclined at the shallowest angle to the horizontal recommended by the manufacturer. If no angle is specified by the manufacturer, then the collector shall be inclined at angle of 30° to the horizontal. Unglazed collectors shall be tested in a horizontal position unless this is excluded by the manufacturer. Next, the collector is filled with water at the operating pressure.

The cold-chamber temperature is cycled, and at the end of each cycle the collector is refilled with water at operating pressure.

The temperature of the water is monitored throughout the test.

11.2.2 Collectors with drain-down protection

For collectors which employ a drain-down system to protect them from freezing damage, the collector is mounted in a cold chamber (see figure 13). The collector is then inclined at the shallowest angle to the horizontal recommended by the manufacturer. If no angle is specified by the manufacturer, then the collector shall be inclined at an angle of 30° to the horizontal. Unglazed collectors shall be tested in a horizontal position unless this is excluded by the manufacturer. The collector is next filled with water, kept at operating pressure for 10 min and then drained using the device installed by the manufacturer.

The cold-chamber temperature is cycled.

The temperature is measured inside the absorber close to the inlet.

After the last cycle the collector is refilled with water at operating pressure.

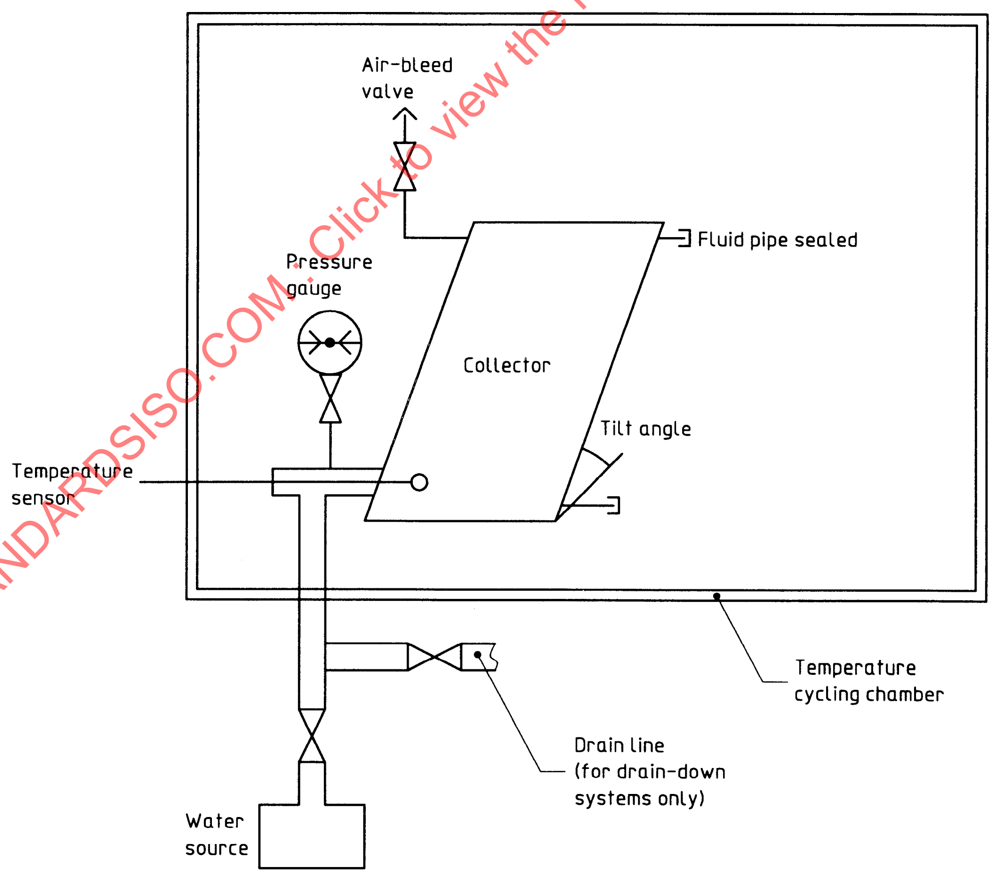

Figure 13 — Schematic for freezing test

11.3 Test conditions

The contents of the absorber are maintained at (− 20 ± 2) °C for at least 30 min during the freezing part of the cycle, and are raised to above 10 °C during the thawing part of the cycle. The duration of the thawing part of the cycle shall be at least 30 min.

The collector shall be subjected to three freeze–thaw cycles.

11.4 Results

The number of cycles carried out shall be reported. The collector shall be inspected for leakage, breakages, distortion and deformation. These shall be reported together with the absorber temperatures reached during the cycles and the times spent by the collector at the test temperatures. The tilt angle used for the test shall also be reported.

12 Impact resistance test (optional)

12.1 Objective

This test is intended to assess the extent to which a collector can withstand the effects of heavy impacts, such as those caused by petty vandalism or those likely to occur during installation. Heavy impacts may also be caused by hailstones.

12.2 Apparatus and procedure

The collector is mounted either vertically or horizontally on a support (see figure 14). The support shall be stiff enough so that there is negligible distortion or deflection at the time of impact.

Steel balls shall be used to simulate a heavy impact. If the collector is mounted horizontally then the steel balls are dropped vertically, or if it is mounted vertically then the impacts are directed horizontally by means of a pendulum. In both cases, the height of the fall is the vertical distance between the point of release and the horizontal plane containing the point of impact.

The point of impact shall be no more than 5 cm from the edge of the collector cover, and no more than 10 cm from the corner of the collector cover, but it shall be moved by several millimetres each time the steel ball is dropped.

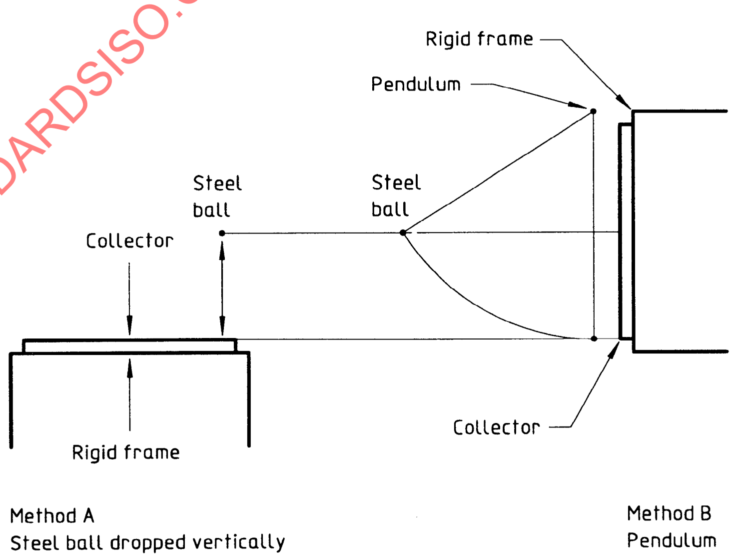

Figure 14 — Schematic for impact resistance test

A steel ball shall be dropped onto the collector 10 times from the first test height, then 10 times from the second test height etc. until the maximum test height is reached. The test is to be stopped when the collector sustains some damage or when the collector has survived the impact of 10 steel balls at the maximum test height.

12.3 Test conditions

The steel ball shall have a mass of 150 g ± 10 g.

The following series of test heights shall be used: 0,4 m, 0,6 m, 0,8 m, 1,0 m, 1,2 m, 1,4 m, 1,6 m, 1,8 m and 2,0 m.

12.4 Results

The collector shall be inspected for damage. The results of the inspection shall be reported, together with the height from which the steel ball was dropped and the number of impacts which caused the damage.

13 Final inspection

When the full test sequence has been completed, all three collectors shall be dismantled and inspected. All abnormalities shall be reported and accompanied by a photograph.

14 Test report

The format sheets given in annex A shall be completed for each test, together with the introductory format sheet (A.1) giving details of the collector.

(Blank page)

Annex A
(normative)

Test format sheets

Test Report

Collector reference No.: ....

Testing laboratory:		
....		
Address:		
....		
Tel.:	Fax:	
Accredited laboratory:	☐ Yes	☐ No
Date of issue:		

A.1 Solar collector description and test sequence

A.1.1 Solar collector description

A.1.1.1 Name of manufacturer ....

Collector model ....

and serial number ....

A.1.1.2 Collector

Type: ☐ Flat plate ☐ Evacuated tube ☐ Other (specify): ....

Gross area: .... m^2

Aperture area: .... m^2

Absorber area: .... m^2

Number of covers: ....

Cover materials: ....

Cover thickness: .... mm

Number of tubes or channels: ....

Tube diameter or channel dimensions: .... mm

Tube or channel pitch: .... mm

A.1.1.3 Heat transfer medium

Type: ☐ Water ☐ Oil ☐ Air ☐ Other (specify): ....

Specifications (additives etc.): ....

Alternative acceptable heat transfer fluids: ....

Collector reference No.: ....

A.1.1.4 Absorber

Material: ....

Surface treatment: ....

Construction type: ....

Fluid content: .... litres

Weight empty: .... kg

A.1.1.5 Thermal insulation and casing

Thermal insulation thickness: .... mm

Insulation material: ....

Casing material: ....

Total mass of collector without fluid: .... kg

Gross dimensions: .... mm

Aperture dimensions: .... mm

Sealing material: ....

A.1.1.6 Limitations

Maximum operating temperature: .... °C

Maximum operating pressure: .... kPa[3)]

Maximum pressure: .... kPa[3)]

Other limitations: ....

A.1.1.7 Climate reference conditions

Climate class: ....

A.1.1.8 Schematic diagram of solar collector (attach separate page if necessary)

A.1.1.9 Photograph of the collector (attach separate page if necessary)

A.1.1.10 Comments on collector design (attach separate page if necessary)

3) 1 bar = 100 kPa.

Collector reference No.: ....

A.1.2 Record of test sequence and summary of main results

All significant damage to the collector, including rain penetration, should be summarized in table A.1. Full details shall be given in the individual test result sheets.

Table A.1

Test		**Date**		**Summary of main test results**
		Start	**End**	
Internal pressure				
High-temperature resistance				
Exposure				
External thermal shock	First			
	Second			
Internal thermal shock				
Rain penetration				
Freezing				
Internal pressure (retest)				
Thermal performance				
Impact resistance (optional)				
Final inspection				

Remarks: ....

....

Collector reference No.: ....

A.2 Internal pressure test for metallic absorbers

NOTE 12 See A.3 for internal pressure test for absorbers made of organic materials.

A.2.1 Technical details of collector

A.2.1.1 Collector type:

☐ Liquid heating

☐ Air heating

☐ Glazed

☐ Unglazed

A.2.1.2 Maximum collector operating pressure specified by manufacturer: .... kPa

A.2.2 Test conditions

Test temperature: .... °C

Test pressure: .... kPa

Test duration: .... min

A.2.2.1 For air heating collectors only

Rate of air leakage at test pressure: .... kg/s

A.2.3 Test results

Give details of any observed or measured leakage, swelling or distortion:

....

....

....

....

....

....

Collector reference No.: ....

A.3 Internal pressure test for absorbers made of organic materials

NOTE 13 See A.2 for internal pressure test for absorbers made of metallic materials.

A.3.1 Technical details of collector

A.3.1.1 Collector type:

☐ Liquid heating
☐ Air heating
☐ Glazed
☐ Unglazed

A.3.1.2 Maximum collector operating pressure specified by manufacturer: .... kPa

A.3.1.3 Calculated collector stagnation temperature: .... °C

Calculation based on:

☐ Annex B, approach 1
☐ Annex B, approach 2

Provide details of calculation, showing input data used (attach separate page if necessary)

A.3.2 Test conditions

A.3.2.1 Fluid used to pressurize absorber:

☐ Oil
☐ Air
☐ Other (specify): ....

A.3.2.2 Method used to heat absorber:

☐ Water bath
☐ Heater in fluid loop
☐ Natural solar irradiance
☐ Simulated solar irradiance

A.3.2.3 Measured absorber test temperature: .... °C

A.3.2.4 Final test pressure: .... kPa

A.3.2.5 Duration of test at final test pressure: .... min

Collector reference No.: ....

A.3.2.6

Intermediate test pressures kPa	**Duration of test at each intermediate pressure** min

A.3.2.7 For absorbers tested under irradiance

Collector tilt angle (degrees from horizontal): .... °

Average irradiance during test: .... W/m²

Average ambient temperature during test: .... °C

Average wind speed during test: .... m/s

A.3.2.8 For air heating collectors only

Rate of air leakage at final test pressure: .... kg/s

A.3.3 Test results

Give details of any observed or measured leakage, swelling or distortion and the test pressure at which it occurred:

....

....

....

....

....

....

Collector reference No.: ....

A.4 High-temperature resistance test

A.4.1 Method used to heat collectors:

☐ Outdoor testing

☐ In solar simulator

☐ Hot oil loop

A.4.2 Conditions for testing outdoors or in a solar irradiance simulator

Collector tilt angle (degrees from horizontal): .... °

Average irradiance during test: .... W/m^2

Average surrounding air temperature: .... °C

Average surrounding air speed: .... m/s

Average absorber temperature: .... °C

Duration of test: .... min

A.4.2.1 Additional information required if an evacuated tubular collector was tested

The temperature of the collector was measured at the location shown below:

A.4.2.2 Additional information required if the absorber temperature was measured using a special fluid (as described in 6.2, note 5)

The absorber was partially filled with .... and the average pressure was .... bars, which corresponds to the average absorber temperature shown above.

A.4.3 Conditions for testing in hot fluid loop

A.4.3.1 Stagnation values under available climate conditions

Testing: ☐ outdoors ☐ in solar irradiance simulator

Collector tilt angle (degrees from horizontal): .... °

Average irradiance: .... W/m^2

Average surrounding air temperature: .... °C

Average surrounding air speed: .... m/s

Average absorber temperature: .... °C

Duration of test: .... min

Collector reference No.: ....

A.4.3.2 Hot fluid loop testing

Calculation based on:

☐ Annex B, approach 1

☐ Annex B, approach 2

Provide details of calculation, showing input data used (attach separate page if necessary)

Average fluid inlet temperature: .... °C

Duration of test: .... min

A.4.4 Test results

Give details of any observed or measured degradation, distortion, shrinkage or outgassing:

....

....

....

....

....

....

Collector reference No.: ....

A.5 Exposure test

A.5.1 Test conditions

Collector tilt angle (degrees from horizontal): .... °

In tables A.2 and A.3 full details shall be given of the climatic conditions for all days during the test, including:

— daily global irradiation, H (MJ/m^2);

— periods when the global irradiance G and the surrounding air temperature t_a have values greater than those specified for class A, class B or class C climate reference conditions of table 4;

— surrounding air temperature, t_a (°C);

— rain (mm).

A.5.2 Test results

Inspection should be conducted according to A.5.5. A full description and evaluation shall be given of any problems or failures observed, together with appropriate photographs.

....

....

....

....

....

....

....

....

....

....

....

....

Collector reference No.: ....

A.5.3 Climatic conditions for all days during the test

Table A.2

Date	H MJ/m^2	t_a °C	**Rain** mm	**Date**	H MJ/m^2	t_a °C	**Rain** mm
Total: .... days in which $H >$ .... MJ/m^2							

Collector reference No.: ....

A.5.4 Time periods in which irradiance and surrounding air temperature have values greater than those specified for class .... climate reference conditions

Table A.3

Date	G W/m^2	t_a °C	**Time periods** min
		Total:	

Collector reference No.: ....

A.5.5 Inspection results

Evaluate each potential problem according to the following scale:

0 — No problem

1 — Minor problem

2 — Severe problem

* — Inspection to establish the condition was not possible

	Collector component	Potential problem	Evaluation
a)	Collector box/fasteners	Cracking/warping/corrosion/rain penetration	....
b)	Mountings/structure	Strength/safety	....
c)	Seals/gaskets	Cracking/adhesion/elasticity	....
d)	Cover/reflector	Cracking/crazing/buckling/delamination/warping/ outgassing	....
e)	Absorber coating	Cracking/crazing/blistering	....
	Absorber tubes and headers	Deformation/corrosion/leakage/loss of bonding	....
	Absorber mountings	Deformation/corrosion	....
f)	Insulation	Water retention/outgassing/degradation	....

Collector reference No.: ....

A.6 External thermal shock test: First shock

A.6.1 Test conditions

Test performed:

☐ Outdoors ☐ In solar irradiance simulator

Test combined with short-term exposure test:

☐ Yes ☐ No

Collector tilt angle (degrees from horizontal): .... °

Average irradiance during test: .... W/m²

Minimum irradiance during test: .... W/m²

Average surrounding air temperature: .... °C

Minimum surrounding air temperature: .... °C

Period during which steady-state conditions were maintained prior to external thermal shock:

.... min

Flowrate of water spray: .... l/(s·m²)

Temperature of water spray: .... °C

Duration of water spray: .... min

Absorber temperature immediately prior to water spray: .... °C

A.6.1.1 Additional information required if an evacuated tubular collector was tested

The temperature of the collector was measured at the location shown below:

A.6.1.2 Additional information required if the absorber temperature was measured using a special fluid (as described in 6.2, note 5)

The absorber was partially filled with .... and the average pressure was .... bars, which corresponds to the absorber temperature given in A.6.1.

A.6.2 Test results

Give details of any cracking, distortion, condensation or water penetration found when examining the collector after the test.

....

....

....

....

....

....

Collector reference No.: ....

A.7 External thermal shock test: Second shock

A.7.1 Test conditions

Test performed:

☐ Outdoors ☐ In solar irradiance simulator

Test combined with short-term exposure test:

☐ Yes ☐ No

Collector tilt angle (degrees from horizontal): .... °

Average irradiance during test: .... W/m²

Minimum irradiance during test: .... W/m²

Average surrounding air temperature: .... °C

Minimum surrounding air temperature: .... °C

Period during which steady-state conditions were maintained prior to external thermal shock:
.... min

Flowrate of water spray: .... l/(s·m²)

Temperature of water spray: .... °C

Duration of water spray: .... min

Absorber temperature immediately prior to water spray: .... °C

A.7.1.1 Additional information required if an evacuated tubular collector was tested

The temperature of the collector was measured at the location shown below:

A.7.1.2 Additional information required if the absorber temperature was measured using a special fluid (as described in 6.2, note 5)

The absorber was partially filled with .... and the average pressure was .... bars, which corresponds to the absorber temperature given in A.7.1.

A.7.2 Test results

Give details of any cracking, distortion, condensation or water penetration found when examining the collector after the test.

....

....

....

....

....

....

Collector reference No.: ....

A.8 Internal thermal shock test for liquid heating collectors

A.8.1 Test conditions

Test performed:

☐ Outdoors ☐ In solar irradiance simulator

Collector tilt angle (degrees from horizontal): .... °

Average irradiance during test: .... W/m²

Minimum irradiance during test: .... W/m²

Average surrounding air temperature during test: .... °C

Minimum surrounding air temperature: .... °C

Period during which steady-state conditions were maintained prior to internal thermal shock:
.... min

Flowrate of heat transfer fluid: .... l/(s·m²)

Temperature of heat transfer fluid: .... °C

Duration of heat transfer fluid flow: .... min

Absorber temperature immediately prior to heat transfer fluid flow: .... °C

A.8.1.1 Additional information required if an evacuated tubular collector was tested

The temperature of the collector was measured at the location shown below:

A.8.1.2 Additional information required if the absorber temperature was measured using a special fluid (as described in 6.2, note 5)

The absorber was partially filled with .... and the average pressure was .... bars, which corresponds to the absorber temperature given in A.8.1.

A.8.2 Test results

Give details of any cracking, distortion, condensation or water penetration found when examining the collector after the test.

....

....

....

....

....

....

Collector reference No.: ....

A.9 Rain penetration test

A.9.1 Test conditions

A.9.1.1 Collector mounting

Collector mounted on:

☐ Open frame

☐ Simulated roof

Collector tilt angle (degrees from horizontal): .... °

A.9.1.2 Water spray

Water spray flowrate: .... l/(s·m²)

Duration of water spray: .... h

A.9.2 Test results

A.9.2.1 Collector mass

Collector mass before spraying: .... kg ± .... kg

Collector mass after spraying: .... kg ± .... kg

A.9.2.2 Give details of water penetration observed after the test

....

....

....

....

....

....

Collector reference No.: ....

A.10 Freezing test

A.10.1 Collector type:

☐ Freeze-resistant when filled with water

☐ Drain-down

A.10.2 Test conditions

A.10.2.1 Tilt angle of collector during test (degrees from horizontal): .... °

A.10.2.2 Details of freeze–thaw cycles

No. of freeze–thaw cycles	Freeze conditions		Thaw conditions	
	Test temperature °C	Duration min	Test temperature 1) °C	Duration min
1				
2				
3				

1) For freeze-resistant collectors, this is the temperature of the contents of the collector, e.g. water, ice. For drain-down collectors, this is the temperature measured inside the absorber close to the inlet.

A.10.2.3 Rate of chamber cooling: .... K/h

A.10.2.4 Rate of chamber heating: .... K/h

A.10.3 Test results

Give details of leakage, breakages, distortion or deformation.

....

....

....

....

....