INTERNATIONAL STANDARD

ISO 9806-3

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Test methods for solar collectors —

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

Méthodes d'essai des capteurs solaires —

Partie 3: Performance thermique des capteurs non vitrés à liquide (transfert de chaleur appréciable seulement), chute de pression incluse

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Contents

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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 9806-3 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*
- *Part 4: Thermal performance of air or gas heating collectors*

Annex A forms an integral part of this part of ISO 9806. Annexes B, C, D and E are for information only.

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Test methods for solar collectors —

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

1 Scope

1.1 This part of ISO 9806 establishes methods for determining the thermal performance of unglazed liquid heating solar collectors.

1.2 This part of ISO 9806 contains methods for conducting tests outdoors under natural solar irradiance and simulated wind and for conducting tests indoors under simulated solar irradiance and wind.

1.3 This part of ISO 9806 is not applicable to those collectors in which a thermal storage unit is an integral part of the collector to such an extent that the collection process cannot be separated for the purpose of making measurements of these two processes.

1.4 This part of ISO 9806 is not applicable to collectors in which the heat transfer fluid can change phase, nor is it applicable to collectors affected by condensation of water vapour from the ambient air.

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

ISO 9845-1:1992, *Solar energy — Reference solar spectral irradiance at the ground at different receiving conditions — Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5.*

ISO 9846:1993, *Solar energy — Calibration of a pyranometer using a pyrheliometer.*

ISO 9847:1992, *Solar energy — Calibration of field pyranometers by comparison to a reference pyranometer.*

ISO/TR 9901:1990, *Solar energy — Field pyranometers — Recommended practice for use.*

WMO, *Guide to Meteorological Instruments and Methods of Observation*, 5th ed., WMO-8, Secretariat to the World Meteorological Organization, Geneva, 1983, Chapter 9.

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 irradiation: Incident energy per unit area of a surface, found by integration of irradiance over a specified time interval, often an hour or a day.

NOTES

1 Irradiation is normally expressed in megajoules per square metre (MJ/m^2) over a specified time interval.

2 Solar irradiation is often termed "radiant exposure" or "insolation". The use of these terms is deprecated.

3.2 longwave radiation; thermal radiation: Radiation at wavelengths greater than 3 μm, typically originating from sources at terrestrial temperatures (e.g. ground and other terrestrial objects).

3.3 turbulence level: Root mean square velocity fluctuation divided by the mean velocity.

3.4 unglazed solar collector: Collector without a cover over the absorber.

4 Symbols and units

The symbols and their units used in this part of ISO 9806 are given in annex A.

5 Collector mounting and location

5.1 General

Collectors tested in accordance with this part of ISO 9806 shall be mounted in accordance with 5.2 to 5.9. The mounting arrangement shall be reported with the results in the format sheets.

Full-size collector modules or collector arrays typical of full-size installations shall be tested, because the edge losses of small collectors may significantly reduce their overall performance. A minimum collector gross area of 3 m^2 is recommended.

5.2 Collector mounting frame

The collector shall be mounted in the manner specified by the manufacturer. The collector mounting frame shall in no way obstruct the aperture of the collector, and shall not significantly affect the back or side insulation, unless otherwise specified (for example, when the collector is part of an integrated roof array). The collector shall be mounted such that the lower edge is not less than 0,5 m above the local ground surface.

If mounting instructions are not specified, the collector shall be mounted on an insulated backing of conductance (2 ± 0,5) $W/(m^2\ K)$ and the upper surface painted matt white and ventilated at the back. Collectors designed to be mounted directly on standard roofing material may be mounted over a simulated roof section.

Collector arrays constructed from pipe or strip components shall be mounted with the pipes (or strips) spaced 10 mm or one diameter (width of strip) apart, whichever is smaller. If a different pipe or strip spacing is specified in the manufacturer's installation instructions, then the recommended spacing shall be used. If the collector is delivered with mounting spacers or any device fixing the spacing of the pipes (or strips), then the collector shall be tested as delivered and its geometry shall be reported in the test report.

Currents of warm air, such as those which rise up the walls of a building, shall not be allowed to pass over the collector. Where collectors are tested on the roof of a building, they shall be located at least 2 m away from the roof edge.

5.3 Collector test module size

The performance of some forms of unglazed solar collectors is a function of module size. If the collector is supplied in fixed units of area greater than 1 m^2, then sufficient of the modules shall be linked together (in series or in parallel) to give a test system absorber surface of at least 3 m^2. If the collector is supplied in the form of strips, the minimum built-up module area shall be 3 m^2 (gross area).

5.4 Tilt angle

The collector shall be tested at tilt angles such that, during the test period, the angle of incidence with direct solar radiation, θ, is less than 30° or at angles of tilt such that the incident angle modifier for the collector varies by less than $\pm$ 2 % from its value at normal incidence. Before deciding on a tilt angle, it may be necessary to check the incident angle modifier at two angles prior to commencing the tests (see annex B).

NOTE 3 For most unglazed collectors the influence of tilt angle and radiation angle of incidence on collector efficiency is small, and unglazed collectors are commonly installed at low inclinations. However, care must be taken to avoid air locks. Absorbers made of separate parallel tubes may have an angle of incidence response that increases with angle of incidence.

5.5 Collector orientation outdoors

The collector may be mounted outdoors in a fixed position facing the equator, but this will result in the time available for testing being restricted by the acceptable range of incidence angles (see 8.6). A more versatile approach is to move the collector to follow the sun in azimuth, using manual or automatic tracking.

5.6 Shading from direct solar irradiance

The location of the test stand shall be such that no shadow is cast on the collector during the test.

5.7 Diffuse and reflected solar irradiance

5.7.1 Outdoors

For the purposes of analysis of outdoor test results, solar irradiance not coming directly from the sun's disc is assumed to come isotropically from the hemispherical field of view of the collector. In order to minimize the errors resulting from this approximation, the collector shall be located where there will be no significant solar radiation reflected onto it from surrounding buildings or surfaces during the tests, and where there will be no significant obstructions in the field of view. Not more than 5 % of the collector's field of view shall be obstructed, and it is particularly important to avoid buildings or large obstructions subtending an angle of greater than 15° with the horizontal in front of the collectors.

The reflectance of most rough surface such as grass, weathered concrete or chippings is not usually high enough to cause problems during collector testing. Surfaces to be avoided in the collector's field of view include large expanses of glass, metal or water.

5.7.2 Solar irradiance simulator

In most solar simulators the simulated beam approximates direct solar irradiance only. In order to simplify the measurement of simulated irradiance, it is necessary to minimize reflected irradiance. This can be achieved by painting all surfaces in the test chamber with a dark (low reflectance) paint.

5.8 Longwave irradiance

5.8.1 Outdoors

The temperature of surfaces adjacent to the collector shall be as close as possible to that of the ambient air in order to minimize the influence of longwave radiation from surrounding surfaces. For example, the outdoor field of view of the collector should not include chimneys, cooling towers, hot roof surfaces or hot exhausts.

5.8.2 Solar irradiance simulator

For indoor testing, the collector shall be shielded from hot surfaces such as radiators, air-conditioning ducts and machinery, and from cold surfaces such as windows and external walls. Shielding is important both in front of and behind the collector. For unglazed collectors the major difference between outdoor and indoor conditions is the longwave thermal irradiance. The longwave irradiance in a simulator shall not exceed the limits specified in 9.2.

5.9 Surrounding air speed

The performance of unglazed collectors is sensitive to air speed adjacent to the collector. In order to maximize the reproducibility of results, collectors shall be mounted such that air can freely pass over the aperture, exposed back and sides of the collector. Collectors designed for integration into a roof may have their backs protected from the wind; if so, this shall be reported with the test results.

The average surrounding air speed at a distance of 100 mm above and parallel to the collector aperture shall be within the range 1,5 m/s to 4 m/s, subject to the tolerance specified in table 2 (see 8.5). An artificial wind generator shall be used to provide a turbulence level in the range 20 % to 40 % to simulate natural wind conditions. The turbulence level shall be checked at the leading edge of the collector 100 mm above the collector surface. The turbulence level shall be monitored using a linearized hot wire anemometer with a frequency response of at least 100 Hz. If the absorber is not mounted directly on a roof or a sheet of backing material, the surrounding air speed must be controlled and monitored at the front and back of the absorber.

6 Instrumentation

6.1 Solar radiation measurement

6.1.1 Pyranometer

A class I (in accordance with ISO 9060) pyranometer shall be used to measure the global shortwave radiation from both the sun and the sky. The recommended practice for use given in ISO/TR 9901 shall be observed.

6.1.2 Precautions for effects of temperature gradient

The pyranometer used during the tests shall be placed in a typical test position and allowed to equilibrate for at least 30 min before measurements commence.

6.1.3 Precautions for effects of humidity and moisture

The pyranometer shall be provided with a means of preventing accumulation of moisture that may condense on surfaces within the instrument and affect its reading. An instrument with a desiccator that can be inspected is required. The condition of the desiccator shall be observed prior to and following each collector test.

6.1.4 Precautions for infrared radiation effects on pyranometer accuracy in simulator tests

Pyranometers used to measure the irradiance of a solar irradiance simulator shall be mounted in such a way as to minimize the effects on its readings of the infrared radiation of wavelength above 3 µm from the simulator light source.

6.1.5 Mounting of pyranometer

The pyranometer shall be mounted such that its sensor is coplanar, within a tolerance of ± 1°, with the plane of the collector aperture. It shall not cast a shadow onto the collector aperture at any time during the test period. The pyranometer shall be mounted so as to receive the same levels of direct, diffuse and reflected solar radiation as are received by the collector.

For outdoor testing, the pyranometer shall be mounted at the midheight of the collector. The body of the pyranometer and the emerging leads or the connector shall be shielded to minimize solar heating of the electrical connections. Care shall also be taken to minimize energy reflected and reradiated from the solar collector onto the pyranometer. Poles that can cast a shadow on the pyranometer shall be avoided.

For indoor testing, pyranometers may be used to measure the distribution of simulated solar irradiance over the collector aperture, using a grid of maximum spacing 150 mm. The pyranometers shall be mounted and protected as for outdoors testing. Alternatively, other types of radiation detector may be used, provided that they have been calibrated for simulated solar radiation.

6.1.6 Pyranometer calibration interval

Pyranometers shall be calibrated for solar response within 12 months preceding the collector tests. Any change of more than 1 % over a 12-month period shall warrant the use of more frequent calibration or replacement of the instrument. If the instrument is damaged in any significant manner, it shall be recalibrated or replaced.

6.2 Longwave radiation measurement

6.2.1 Pyrgeometer

A pyrgeometer mounted in the plane of the collector shall be used to measure longwave irradiance.

6.2.2 Precautions for effects of temperature gradient

The pyrgeometer used during the tests shall be placed in the same plane as the collector absorber and allowed to equilibrate for at least 30 min before measurements commence.

6.2.3 Precautions for effects of humidity and moisture

The pyrgeometer shall be provided with a means of preventing accumulation of moisture that may condense on surfaces within the instrument and affect its reading. An instrument with a desiccator that can be inspected is required. The condition of the desiccator shall be observed prior to and following each collector test.

6.2.4 Precautions for effects of solar heating

The dome of the pyrgeometer used to measure longwave irradiance shall be ventilated to minimize the influence of solar heating effects.

6.2.5 Pyrgeometer calibration interval

The pyrgeometer shall be calibrated within 12 months preceding the tests. Any change of more than 5 % over a 12-month period shall warrant the use of more frequent calibration or replacement of the instrument. If the instrument is damaged in any significant manner, it shall be recalibrated or replaced.

6.3 Temperature measurements

The temperature measurements required for solar collector testing are the fluid temperature at the collector inlet, the fluid temperature difference between the outlet and inlet of the collector, and the ambient air temperature. The required accuracy and the environment for these measurements differ, and hence the transducer and associated equipment may be different.

6.3.1 Measurement of heat transfer fluid inlet temperature (t_{in})

6.3.1.1 Required accuracy

The temperature (t_{in}) of the heat transfer fluid at the collector inlet shall be measured to an accuracy of ± 0,1 °C, but in order to verify that the temperature is not drifting with time, a very much better resolution of the temperature signal to ± 0,02 °C is required.

6.3.1.2 Mounting of sensors

The transducer for temperature measurement shall be mounted at no more than 200 mm from the collector inlet and insulation shall be placed both upstream and downstream of the transducer. If it is necessary to position the transducer more than 200 mm from the collector, then a test shall be made to verify that the measurement of fluid temperature is not affected.

To ensure mixing of the fluid at the position of temperature measurement, a bend in the pipework, an orifice or a fluid-mixing device shall be placed upstream of the transducer, and the transducer probe shall point upstream in a pipe where the flow is rising (to prevent air from being trapped near the sensor), as shown in figure 1.

6.3.2 Determination of heat transfer fluid temperature difference (ΔT)

6.3.2.1 Required accuracy

The difference between the collector outlet and inlet temperatures (ΔT) shall be determined to an accuracy of ± 0,1 K. Accuracies approaching ± 0,02 K can be achieved with modern well-matched and calibrated transducers, hence it is possible to measure temperature differences down to 1 K with a reasonable accuracy. However temperature differences less than 2 K should be avoided in order to minimize errors.

Dimensions in millimetres

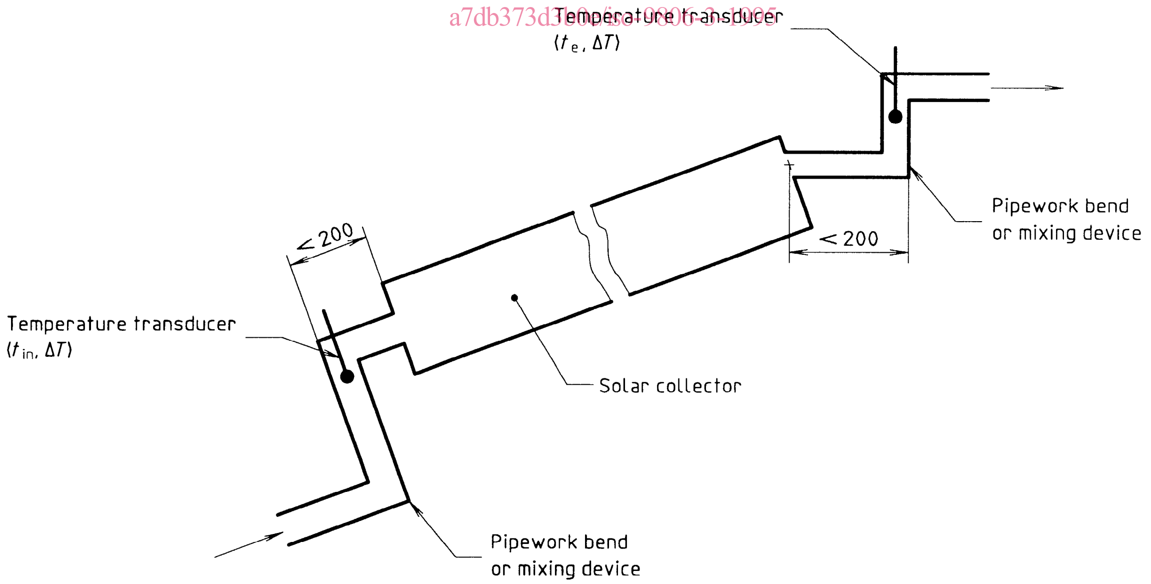

Figure 1 — Recommended transducer positions for measuring the heat transfer fluid inlet and outlet temperatures

6.3.3 Measurement of surrounding air temperature (t_a)

6.3.3.1 Required accuracy

The ambient air temperature (t_a) shall be measured to an accuracy of ± 0,1 °C. The dew point temperature t_{dp} shall be determined to an accuracy of ± 0,5 °C.

6.3.3.2 Mounting of sensors

The transducer for measuring the ambient air temperature shall be mounted in the outlet of the artificial wind generator. The transducer shall be shielded from direct and reflected solar radiation. One additional sensor should be used to measure the ambient air temperature in the back of the collector, in order to ensure that the ambient air temperature is uniform around the collector and to determine a representative average reading.

The temperature of the air flow out of the wind generator shall not deviate from the ambient air temperature more than ± 1 °C.

6.4 Collector fluid flowrate measurements

Mass flowrates may be measured directly or, alternatively, they may be determined from measurements of volumetric flowrate and temperature.

The accuracy of the liquid flowrate measurement shall be equal to or better than ± 1 % of the measured value, in mass units per unit time.

The flowmeter shall be calibrated over the range of fluid flowrates and temperatures to be used during collector testing.

NOTE 4 The temperature of the fluid in volumetric flowmeters must be known with sufficient accuracy to ensure that mass flowrates can be determined within the limits specified above.

The direction of flow through the meter should be horizontal or rising, in order to avoid air accumulation.

6.5 Surrounding air speed

The heat loss from a collector increases with increasing air speed (u) over the collector. By controlling the wind speed over the collector with an artificial wind generator as specified in 5.9, it is possible to define clearly the conditions under which the tests are performed.

6.5.1 Required accuracy

The speed of the surrounding air over the front surface of the collector shall be measured to an accuracy of ± 10 %.

Under outdoor conditions the surrounding air speed is seldom constant and gusting frequently occurs. The measurement of an average air speed is therefore required during the test period. This may be obtained either by an arithmetic average of sampled values or by a time integration over the test period.

6.5.2 Mounting of sensors

To account for air speed variations from one end of the collector to the other, a series of measurements shall be taken at a distance of 100 mm in front of the collector aperture, at nine positions equally spaced over the collector area. An average value shall then be determined. For a collector that does not have back insulation or is not mounted on a simulated roof surface, the air speed shall be measured over the front and back surfaces. The average air speed over the front and back surfaces shall be used in the data correlation.

During a test, the air speed shall be monitored at a convenient point that has been calibrated relative to the mean air speed over the collector. The anemometer shall not cast a shadow on the collector during the tests.

6.6 Pressure measurements

The heat transfer fluid pressure at the collector inlet and the pressure drop across the collector shall be measured with a device having an accuracy of ± 3,5 kPa. If the collector is supplied in modules, the pressure drop shall be specified per module. For strip absorbers, the pressure shall be specified per running metre of strip.

6.7 Elapsed time

Elapsed time shall be measured to an accuracy of ± 0,2 %.

6.8 Instrumentation/data recorders

In no case shall the smallest scale division of the instrument or instrument system exceed twice the specified accuracy. For example, if the specified accuracy is ± 0,1 °C, the smallest scale division shall not exceed ± 0,2 °C.

Analog and digital recorders shall have an accuracy equal to or better than ± 0,5 % of the full-scale reading and have a time constant of 1 s or less. The peak signal indication shall be between 50 % and 100 % of full scale.

Digital techniques and electronic integrators shall have an accuracy equal to or better than ± 1,0 % of the measured value.

The input impedance of recorders shall be greater than 1000 times the impedance of the sensors or 10 MΩ, whichever is higher.

The sampling interval shall be at most 30 s.

6.9 Collector area

The collector area (gross or absorber) shall be measured to an accuracy of ± 0,1%.

6.10 Collector fluid capacity

The fluid capacity of the collector, expressed as an equivalent mass of the heat transfer fluid used for the test, shall be measured to an accuracy of at least ± 10 %.

Measurements shall be made by weighing the collector when empty and again when filled with fluid.

7 Test installation

7.1 General consideration

Examples of test configurations for testing solar collectors employing liquid as the heat transfer fluid are shown in figures 2 and 3. These are schematic only, and are not drawn to scale.

7.2 Heat transfer fluid

The heat transfer fluid used for collector testing may be water or a fluid recommended by the collector manufacturer. The specific heat capacity and density of the fluid used shall be known to within ± 1 % over the range of fluid temperatures used during the tests. These values are given for water in annex D.

The mass flowrate of the heat transfer fluid shall be the same throughout the test sequence used to determine the thermal efficiency curve, time constant and, if any, incident angle modifiers.

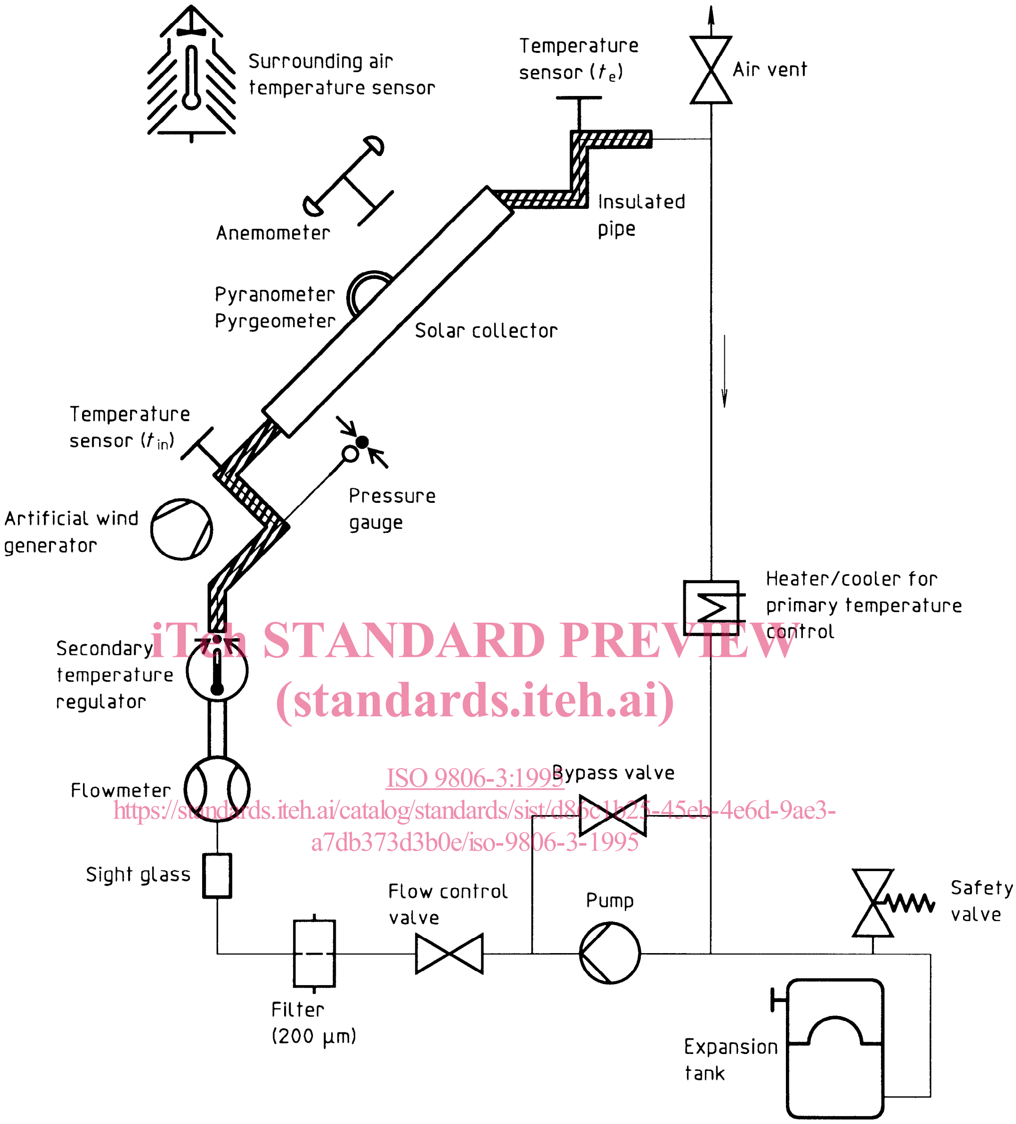

Figure 2 — Example of a closed test loop