SLOVENSKI STANDARD
SIST ISO 9806-1:1997

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Metode za preskus sprejemnikov sonl ne energije - 1. del: Termil ni ul inek zasteklenih sprejemnikov s kapljevino kot prenosnikom toplote, vkljul no z dolol itvijo padca tlaka v sprejemniku

Test methods for solar collectors -- Part 1: Thermal performance of glazed liquid heating collectors including pressure drop

Méthodes d'essai des capteurs solaires -- Partie 1: Performance thermique des capteurs vitrés à liquide, chute de pression incluse

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INTERNATIONAL STANDARD

ISO 9806-1

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Test methods for solar collectors —

Part 1:

Thermal performance of glazed liquid heating collectors including pressure drop

Méthodes d'essai des capteurs solaires —

Partie 1: Performance thermique des capteurs vitrés à liquide, chute de pression incluse

Reference number
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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 9806-1 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*

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

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Test methods for solar collectors —

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

1 Scope

1.1 This part of ISO 9806 establishes methods for determining the thermal performance of glazed liquid heating solar collectors. These tests are intended for use as part of the sequence of tests specified in ISO 9806-2.

1.2 This part of ISO 9806 provides test methods and calculation procedures for determining the steady-state and quasi-steady-state thermal performance of solar collectors. It contains methods for conducting tests outdoors under natural solar irradiance and for conducting tests indoors under simulated solar irradiance.

1.3 This part of ISO 9806 is not applicable to those collectors in which the 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 unglazed solar collectors nor is it applicable to tracking concentrating solar collectors. (See ISO 9806-3 for a test method for unglazed collectors.)

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 9806-2:—[1], *Test methods for solar collectors — Part 2: Qualification test procedures.*

1) To be published.

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.*

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 edn., WMO-8, Secretariat to the World Meteorological Organization, Geneva, 1983, Chapter 9.

3 Definitions

For the purposes of this part of ISO 9806, the following definitions apply.

3.1 absorber: Device within a solar collector for absorbing radiant energy and transferring this energy as heat into a fluid.

3.2 absorber area (of a nonconcentrating solar collector)**:** Maximum projected area of an absorber.

3.3 absorber area (of a concentrating solar collector)**:** Surface area of the absorber which is designed to absorb solar radiation.

3.4 angle of incidence (of direct solar radiation)**:** Angle between the line joining the centre of the solar disc to a point on an irradiated surface and the outward-drawn normal to the irradiated surface.

3.5 aperture: Opening of a solar collector, through which the unconcentrated solar radiation is admitted.

3.6 aperture area: Maximum projected area through which the unconcentrated solar radiation enters a collector.

3.7 collector area, gross: Maximum projected area of a complete solar collector, excluding any integral means of mounting and connecting fluid pipework.

For an array or assembly of flat plate collectors, evacuated tubes or concentrating collectors, the gross collector area includes the entire area of the array, i.e. also borders and frame.

3.8 collector, concentrating: Solar collector that uses reflectors, lenses or other optical elements to redirect and concentrate the solar radiation passing through the aperture onto an absorber, the surface area of which is smaller than the aperture area.

3.9 collector efficiency (of a solar thermal collector)**:** Ratio of the energy removed from a specified reference collector area (gross or absorber) by the heat transfer fluid over a specified time period, to the solar energy incident on the collector for the same period, under steady-state conditions.

3.10 collector, evacuated tube [tubular]: Solar collector employing transparent tubing (usually glass), with an evacuated space between the tube wall and the absorber.

The absorber may consist of an inner tube of another shape, with means for removal of thermal energy. The pressure in the evacuated space is usually less than 1 Pa.

3.11 collector, flat plate: Nonconcentrating solar collector in which the absorbing surface is essentially planar.

3.12 heat transfer fluid: Fluid that is used to transfer thermal energy between components in a system.

3.13 irradiance: At a point on a surface, the radiant energy flux incident on an element of the surface, divided by the area of that element.

Irradiance is normally expressed in watts per square metre.

3.14 irradiance, direct solar: Radiant energy flux, incident on a given plane receiving surface from a small solid angle centred on the sun's disc, divided by the area of that surface.

It is expressed in watts per square metre.

NOTE 1 The inclination of the surface should be specified, e.g. horizontal. If the plane is perpendicular to the axis of the solid angle, then direct normal solar irradiance is received. For appropriate radiometers of modern design, the small solid angle (field-of-view angle) is less than 6°.

3.15 irradiance, global solar: Radiant energy flux, incident on a given plane receiver surface, from a solid angle of 2π sr, divided by the area of that surface.

It is expressed in watts per square metre.

NOTE 2 The inclination of the surface should be specified, e.g. horizontal. Solar irradiance is often termed "incident solar intensity", "instantaneous insolation", "insolation" or "incident radiant flux density". The use of these terms is deprecated.

3.16 optical air mass: Measure of the length of the path traversed by light rays from the sun through the atmosphere to sea-level, expressed with reference to the normal (vertical) path length.

3.17 pyranometer: Radiometer designed for measuring the irradiance on a plane receiving surface which results from the radiant fluxes incident from the hemisphere above within the wavelength range of 0,3 µm to 3 µm.

3.18 pyrgeometer: Instrument for determining the irradiance on a plane receiving surface which results from the radiant flux incident from the hemisphere above within the wavelength range of approximately 3 µm to 50 µm.

NOTE 3 This spectral range is similar to that of atmospheric longwave radiation and is only nominal. The spectral response of a pyrgeometer depends largely on the material used for the domes which protect each receiving surface.

3.19 pyrheliometer: Instrument using a collimated detector for measuring the direct (beam) radiation received from a solid angle centred on the sun's disc, on a plane perpendicular to the axis of the solid angle.

The output of the instrument can be read as either irradiance or irradiation.

NOTE 4 The spectral response of a pyrheliometer should be approximately constant in the wavelength range of 0,3 µm to 3 µm, and its acceptance angle should be less than 6°. It is synonymous with the deprecated term "actinometer".

3.20 radiant energy: Energy emitted, transferred or received as radiation.

3.21 radiant energy flux: Power emitted, transferred or received as radiation.

3.22 radiation: Phenomenon of energy transfer in the form of electromagnetic waves.

3.23 radiometer: Instrument used for measuring radiation.

The output of the instrument can be read as either irradiance or irradiation.

3.24 solar irradiance simulator: Artificial source of radiant energy simulating solar radiation, usually an electric lamp or an array of such lamps.

3.25 solar thermal collector: Device designed to absorb solar radiation and to transfer the thermal energy so gained to a fluid passing through it.

NOTE 5 Sometimes called "panel", the use of which is deprecated to avoid potential confusion with photovoltaic panels.

3.26 time constant: Time required for a system whose performance can be approximated by a first-order differential equation, to have its output changed by 63,22 % of its final change in output following a step change in input.

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

The way in which a collector is mounted will influence the results of thermal performance tests. Collectors tested in accordance with this part of ISO 9806 shall therefore be mounted in accordance with 5.2 to 5.8.

Full-size collector modules shall be tested, because the edge losses of small collectors may significantly reduce their overall performance.

5.2 Collector mounting frame

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), an open mounting structure shall be used which allows air to circulate freely around the front and back of the collector. The collector shall be mounted such that the lower edge is not less than 0,5 m above the local ground surface.

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 Tilt angle

In order to facilitate international comparisons of test results, the collector shall be mounted such that the angle of tilt of the aperture from the horizontal is:

latitude $\pm$ 5° but not less than 30°.

Collectors may be tested at other tilt angles, as recommended by manufacturers or specified for actual installations.

NOTE 6 For many collectors, the influence of tilt angle is small, but it can be an important variable for specialized collectors such as those incorporating heat pipes.

5.4 Collector orientation

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 acceptance range of incidence angles. A more versatile approach is to move the collector to follow the sun in azimuth, using manual or automatic tracking.

5.5 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.

5.6 Diffuse and reflected solar irradiance

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. With some collector types, such as evacuated tubular collectors, it may be equally important to minimize reflections on both the back and the front fields 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 approximately 15° with the horizontal in front of the collectors.

The reflectance of most rough surfaces 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.

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.

5.7 Thermal irradiance

The performance of some collectors is particularly sensitive to the levels of thermal irradiance.

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 thermal radiation. For example, the outdoor field of view of the collector should not include chimneys, cooling towers or hot exhausts.

For indoor and simulator 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.

5.8 Wind

The performance of many collectors is sensitive to air speeds. In order to maximize the reproducibility of results, collectors shall be mounted such that air can freely pass over the aperture, back and sides of the collector. The mean wind speed, parallel to the collector aperture, should be between the limits specified in 8.3. Where necessary, artificial wind generators shall be used to achieve these wind speeds.

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.

6 Instrumentation

6.1 Solar radiation measurement

6.1.1 Pyranometer

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

6.1.1.1 Precautions for effects of temperature gradient

The pyranometer used during the test(s) shall be placed in a typical test position and allowed to equilibrate for at least 30 min before data-taking commences.

6.1.1.2 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 daily measurement sequence.

6.1.1.3 Precautions for infrared radiation effects on pyranometer accuracy

Pyranometers used to measure the irradiance of the 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.

6.1.1.4 Mounting of pyranometers outdoors

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 of 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.

6.1.1.5 Use of pyranometers in solar irradiance simulators

Pyranometers may be used to measure both the distribution of simulated solar irradiance over the collector aperture and the variation in simulated irradiance with time (see 9.6.1). The pyranometers shall be mounted and protected as for outdoor testing. Alternatively, other types of radiation detector may be used, provided that they have been calibrated for simulated solar radiation.

6.1.1.6 Calibration interval

Pyranometers shall be calibrated for solar response within 12 months preceding the collector test(s) in accordance with the procedure given in ISO 9846 or ISO 9847. Any change of more than ± 1 % over a year 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. All calibrations shall be performed with respect to the world radiometric reference (WRR) scale.

6.1.2 Measurement of the angle of incidence of direct solar radiation

A simple device for measuring the angle of incidence of direct solar radiation can be produced by mounting a pointer normal to a flat plate on which graduated concentric rings are marked. The length of the shadow cast by the pointer may be measured using the concentric rings and used to determine the angle of incidence. The device should be positioned in the collector plane and to one side of the collector.

NOTE 7 The angle of incidence of direct solar radiation (θ) may be calculated from the solar hour angle (ω), the collector tilt angle (β), the collector azimuth angle (γ) and the latitude of the test site (ϕ), using the following relations:

$$\cos\theta = (\sin\delta \sin\phi \cos\beta) - (\sin\delta \cos\phi \sin\beta \cos\gamma) + (\cos\delta \cos\phi \cos\beta \cos\omega) + (\cos\delta \sin\phi \sin\beta \cos\gamma \cos\omega) + (\cos\delta \sin\beta \sin\gamma \sin\omega)$$

where the solar declination δ for day number n of the year is given by:

$$\delta = 23{,}45 \sin [360(284 + n)/365]$$

6.2 Thermal radiation measurement

6.2.1 Measurement of thermal irradiance outdoors

The variations of thermal irradiance outdoors are not normally taken into account for collector testing. However, a pyrgeometer may be mounted in the plane of the collector aperture and to one side at midheight, to determine the thermal irradiance at the collector aperture.

6.2.2 Determination of thermal irradiance indoors and in solar simulators

6.2.2.1 Measurement

The thermal irradiance may be measured using a pyrgeometer as indicated in 6.2.1 for outdoor measurements. Pyrgeometers should be well ventilated in order to minimize the influence of solar or simulated solar irradiance.

For indoor testing, the thermal irradiance shall be determined with an accuracy of $\pm$ 10 W/m^2.

6.2.2.2 Calculation

Provided that all sources and sinks of thermal radiation in the field of view of the collector can be identified, the thermal irradiance at the collector aperture may be calculated using temperature measurements, surface emittance measurements and radiation view factors.

The thermal irradiance incident on a collector surface (designated 1), from a hotter surface (designated 2) is given by $\sigma\varepsilon_2 F_{12} T_2^4$.

Or, more usefully, the additional thermal irradiance (compared with that which would be present if surface 2 had been a perfect black body at ambient temperature) is given by:

$$\sigma F_{12} (\varepsilon_2 T_2^4 - T_a^4) \qquad \ldots (1)$$

See annex A, clause A.1 for explanation of symbols. Radiation view factors are given in textbooks on radiation heat transfer.

The thermal irradiance at the collector aperture may also be calculated from a series of measurements made for small solid angles in the field of view. Such measurements can be made using a pyrheliometer with and without a glass filter to identify the thermal component of the total irradiance.

6.3 Temperature measurements

Three temperature measurements are required for solar collector testing. These are the fluid temperature at the collector inlet, the fluid temperature at the collector outlet, 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 of the heat transfer fluid at the collector inlet shall be measured to an accuracy of ± 0,1 °C, but in order to check that the temperature is not drifting with time, a very much better resolution of the temperature signal to ± 0,02 °C is required.

NOTE 8 This resolution is needed for all temperatures used for collector testing (i.e. over the range 0 °C to 100 °C) which is a particularly demanding accuracy for recording by data logger, as it requires a resolution of one part in 4 000 or a 12-bit digital system.

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 around the pipework both upstream and downstream of the transducer. If it is necessary to position the transducer more than 200 mm away 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 and 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)

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, and hence it is possible to measure heat transfer fluid temperature differences of 1 K or 2 K with a reasonable accuracy.

Dimensions in millimetres

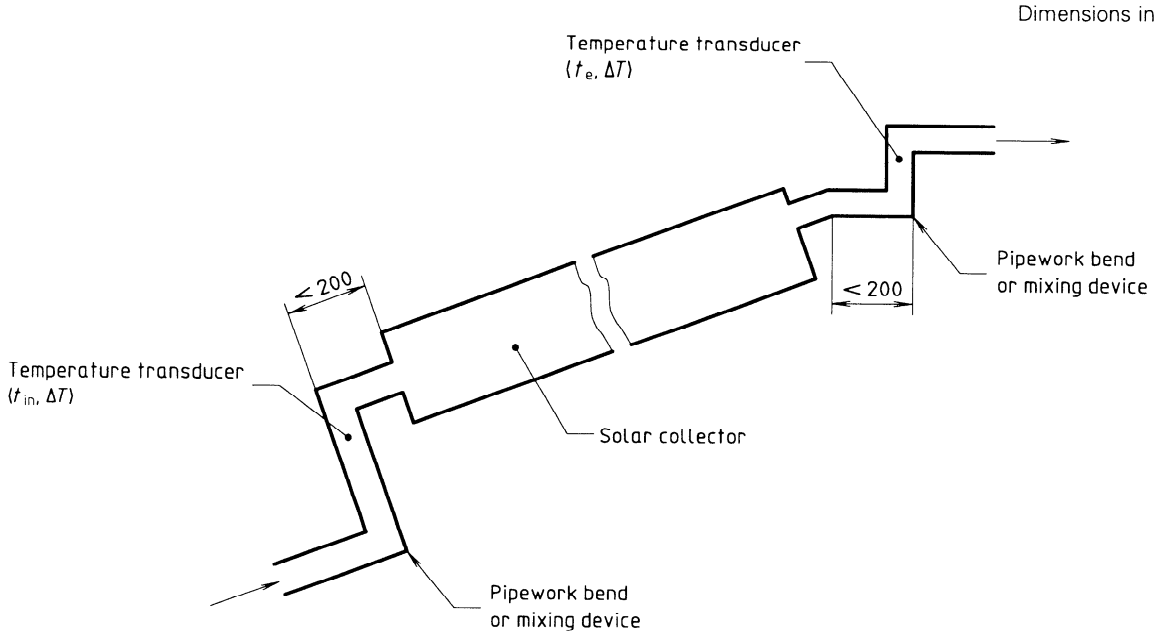

Figure 1 — Recommended transducer positions for measuring the heat transfer fluid inlet and outlet temperatures

6.3.3 Measurement of surrounding air temperature (t_a)

6.3.3.1 Required accuracy

The ambient or surrounding air temperature shall be measured to an accuracy of ± 0,50 °C.

6.3.3.2 Mounting of sensors

For outdoor measurements the transducer shall be shaded from direct and reflected solar radiation by means of a white-painted, well-ventilated shelter, preferably with forced ventilation. The shelter itself shall be shaded and placed at the midheight of the collector but at least 1 m above the local ground surface to ensure that it is removed from the influence of ground heating. The shelter shall be positioned to one side of the collector and not more than 10 m from it.

If air is forced over the collector by a wind generator, the air temperature shall be measured in the outlet of the wind generator and checks made to ensure that this temperature does not deviate from the ambient air temperature by more than ± 1 °C.

6.4 Measurement of collector liquid flowrate

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 within ± 1,0 % of the measured value, in mass per unit time.

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

NOTE 9 The temperature of the fluid in volumetric flowmeters should be known with sufficient accuracy to ensure that mass flowrates can be determined to within the limits specified.

6.5 Wind velocity

The heat losses from a collector increase with increasing air speed over the collector, but the influence of wind direction is not well understood. Measurements of wind direction are therefore not used for collector testing. The relationship between the meteorological wind speed and the air speed over the collector depends on the location of the test facility, so meteorological wind speed is not a useful parameter for collector testing. By using the wind speed measured over the collector, it is possible to define clearly the conditions in which the tests were 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 ± 0,5 m/s for both indoor and outdoor testing.

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.