International Standard 4677/1

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Atmospheres for conditioning and testing — Determination of relative humidity — Part 1: Aspirated psychrometer method

Atmosphères de conditionnement et d'essai — Détermination de l'humidité relative — Partie 1: Méthode utilisant un psychromètre à aspiration

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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0 Introduction

This part of ISO 4677, dealing with the aspirated psychrometer, and ISO 4677/2, dealing with the whirling psychrometer, specify methods for the accurate measurement of humidity, but they do not specify the full details of the psychrometers required. This is to ensure that well-designed instruments which have gained acceptance in different countries are not arbitrarily excluded. Nevertheless, the methods are not necessarily suitable for all traditional designs. They could have been made so only if the lowest common performance factor had been accepted.

The course adopted, of specifying only the essential features of a few important classes of psychrometers, necessarily has some limitations. It should therefore be understood that good practice should be followed, both in implementing the requirements of the appropriate part of this International Standard and in detailing aspects of the design and the procedure which are not specified.

Neither this part of ISO 4677 nor ISO 4677/2 should be regarded as specifying requirements for psychrometers suitable for meteorological applications or other outdoor applications. Nevertheless, in both parts, humidity is measured on the scale employed almost universally for meteorological measurements at the Earth's surface and for the purposes of testing materials.

This scale has, in effect, been established by the general acceptance of particular psychrometric formulae for particular designs of psychrometers. The formula of Sprung for the Assmann psychrometer and that of Ferrel for a whirling psychrometer are representative. These formulae may be expressed in terms of the psychrometer coefficient A which appears in the psychrometer equation given in clause 7. Sprung's result corresponds to a constant value for A of $6{,}6 \times 10^{-4}\ K^{-1}$, while Ferrel's result corresponds to a value that increases from $6{,}6 \times 10^{-4}\ K^{-1}$ to $6{,}8 \times 10^{-4}\ K^{-1}$ as the wet-bulb temperature increases from 0 to 30 °C. In both cases, the uncertainty in A is about 10 %. However, it is known that the true values of A for two instruments differ by much less than 10 %. The prevailing humidity scale may therefore be regarded as defined by specifying that A is constant and equal to $6{,}7 \times 10^{-4}\ K^{-1}$ for both instruments. Since the accuracy with which A needs to be known in order to achieve a particular accuracy in the measurement of relative humidity decreases rapidly as the wet-bulb temperature rises in the range above 40°C, this definition may be regarded as applying for wet-bulb temperatures up to almost 100 °C (assuming approximately standard atmospheric pressure).

The uncertainties in relative humidity given in this International Standard relate to departures from the results that would correspond to this scale. The relationship between this scale and the true humidity scale is a question for the future. The present uncertainty in the relationship corresponds to the uncertainty in A of about 10 %. A decrease in A by this amount would, for example, result in a derived relative humidity of 50,0 % at 20 °C being changed to 51,8 %.

The aspirated psychrometer method is more accurate than that using the whirling psychrometer. In addition, it offers advantages in regard to the smaller space which it requires, the possibility of using alternative types of thermometers (for example electrical), the shielding of the thermometer bulbs from extraneous radiation and the fewer demands which it makes on the skills of the observer.

When the flow of air in the psychrometer is transverse, the instrument somewhat resembles the whirling psychrometer but, when the flow of air is axial, the radiation shield of the wet bulb plays an essential role, and additional geometrical features have to be specified.

In this International Standard, "r.h." is used as an abbreviation for "relative humidity". It does not denote a unit. Uncertainties in the relative humidity are expressed in the form $\pm u$ % r.h., the meaning of which is that the relative humidity is expected to lie in the range $(U - u)$ % to $(U + u)$ %, where U is the observed relative humidity. All uncertainties are at the 95 % confidence level.

1 Scope and field of application

1.1 Scope

This part of ISO 4677 specifies a method for the determination of the relative humidity of atmospheres for conditioning and testing having temperatures within the range from 5 to 80 °C using a psychrometer ventilated by aspiration. The property is determined with an uncertainty either not exceeding ± 3 % r.h. or not exceeding ± 2 % r.h., depending on the uncertainty in the value obtained for the wet-bulb temperature depression and on whether or not the dry-bulb temperature exceeds 40 °C.

1.2 Field of application

The method is applicable to the determination of the relative humidity of the standard atmospheres specified in ISO 554 and of most test atmospheres. It is restricted to wet-bulb temperatures not lower than 1 °C, dry-bulb temperatures not higher than 80 °C, and pressures not differing from standard atmospheric pressure by more than 30 %.

The method should not be used if the atmosphere is heavily contaminated with gases, vapours or dust.

2 References

ISO 386, *Liquid-in-glass laboratory thermometers — Principles of design, construction and use.*

ISO 554, *Standard atmospheres for conditioning and/or testing — Specifications.*

ISO 1144, *Textiles — Universal system for designating linear density (Tex System).*

3 Definitions

For the purposes of this part of ISO 4677, the following definitions apply.

3.1 thermometer: Any temperature measuring device.

3.2 psychrometer: An instrument for measuring relative humidity and consisting essentially of two thermometers the sensors of which are respectively wet and dry.

NOTE — The wet and dry sensors are termed wet and dry bulbs.

3.3 wet-bulb covering: A water-retaining covering of woven cotton material covering the wet bulb.

3.4 wick: A cotton wick which may be provided to connect the wet-bulb covering to a water reservoir so that water is fed continuously to the covering by capillarity.

3.5 ventilation: Term applied to describe a psychrometer in which there is provision for a flow of air over the bulbs.

NOTE — The flow may be either transverse or parallel to the axes of the bulbs.

3.6 aspiration: Term applied to describe a psychrometer in which there is provision for forced ventilation by drawing air over the bulbs by suction.

NOTE — The flow may be either transverse or parallel to the axes of the bulbs.

3.7 temperature depression; wet-bulb temperature depression: The difference between the temperatures of the wet and dry bulbs.

4 Principle

Wet and dry temperature sensors are exposed to a stream of air from the atmosphere. Evaporation from the surface of the wet sensor into the air-stream cools the sensor to a steady temperature such that there is a balance between the heat lost through evaporation and that gained through convection and radiation. This temperature depends on the temperature, pressure and humidity of the atmosphere. Therefore, when an approximate value is available for the pressure, the humidity can be derived from the observed temperatures of the wet and dry sensors (the observed wet- and dry-bulb temperatures).

5 Apparatus and materials

5.1 Thermometers

5.1.1 The thermometers may be of the mercury-in-glass, thermocouple, electrical resistance or other type. Mercury-in-glass thermometers may be of either the solid-stem or enclosed-scale type.

5.1.2 The thermometers (of whatever type) shall be nominally similar, and their range shall include the range from 0 to 40 °C or the range from 40 to 80 °C and may include both these ranges.

The thermometers shall be such that their readings give the value of the temperature depression with an uncertainty not greater than the appropriate value in table 1.

Table 1 — Uncertainty of temperature depression

Dry-bulb temperature	Uncertainty of temperature depression when the uncertainty in the value obtained for the relative humidity is not to exceed	
°C	± 3 % r.h.	± 2 % r.h.
< 40	± 0,2 °C	± 0,1 °C
> 40	± 0,4 °C	± 0,2 °C

Provided this requirement is met, the uncertainty in the value obtained for the dry-bulb temperature may be up to ± 0,2 °C when that temperature does not exceed 40 °C and up to ± 0,4 °C when that temperature exceeds 40 °C

NOTES

1 The uncertainty in the value which the thermometer readings give for the temperature depression means the uncertainty with which the readings give the temperature depression that actually occurs in the instrument.

2 Thermometers which give the required accuracy only when corrections (determined by calibrating the thermometers) are applied to their readings are acceptable, provided that the appropriate corrections are applied on each occasion on which the instrument is used.

5.1.3 Each thermometer shall consist of a temperature sensor of essentially cylindrical shape which is supported on a single stem, the stem being coaxial with the sensor. The free end of each sensor shall be smoothly rounded. If the diameter of the stems is small compared with that of the sensors, then both ends of each sensor shall be smoothly rounded. The sensor of a mercury-in-glass thermometer shall comprise the bulb of the thermometer and the bulb funnel.[1)]

5.1.4 In the case of transverse ventilation, the diameters of the sensors (excluding the wet-bulb covering) shall be not less than 1 mm and not greater than 4 mm.

5.1.5 In the case of axial ventilation, the diameters of the sensors (excluding the wet-bulb covering) shall be not less than 2 mm and not greater than 5 mm, and their length shall be not less than 10 mm and not greater than 30 mm.

5.1.6 The thermometers shall be mounted so that the axes of the sensors are parallel and separated by a distance of not less than three times the overall diameter of the wet sensor (including wet-bulb covering), and so that a line drawn to connect the free ends of the sensors is perpendicular to the axes.

5.1.7 Mercury-in-glass thermometers shall be graduated in 0,5 °C divisions or better and shall be capable of being read to the nearest 0,1 °C or better.

NOTE — A specification for mercury-in-glass thermometers which may be used when the uncertainty in the value obtained for the relative humidity is not to exceed ± 3 % r.h. and the dry-bulb temperature does not exceed 40 °C is given in annex A.

5.1.8 Electrical thermometers may be connected so that the readings give the temperature depression and the dry-bulb temperature directly.

5.1.9 The connecting wires of electrical thermometers shall be contained within the supporting stems and shall be isolated from the moisture in the wet-bulb covering.

5.1.10 Heat from the fan or its motor shall not affect the thermometer.

5.2 Wet-bulb covering, wick and water reservoir

5.2.1 The covering shall be made from hydrophilic undressed white cotton muslin made from thread of linear density between 10 and 25 tex (see ISO 1144) and having 20 to 25 threads per centimetre in warp and weft. A seamless sleeve is preferred, but a seam is permissible provided that it does not add appreciably to the general roughness which the weave imparts to the surface.

NOTE — If the diameter of the stem differs substantially from that of the sensor, a seamless covering cannot properly fit both the sensor and the stem (see 5.2.3).

5.2.2 After manufacture, the covering and the wick, if any, shall be boiled for approximately 15 min in an aqueous solution of approximately 5 % (*m*/*m*) of sodium carbonate decahydrate, then thoroughly rinsed in pure water (see 5.3) before being finally boiled in pure water for at least 15 min. They should not subsequently be touched with the fingers. The covering and the wick may be removed from the instrument from time to time and washed according to this procedure.

5.2.3 The covering shall cover the sensor completely and shall fit it snugly but not very tightly. It shall extend onto the stem for such a distance that the error in the observed wet-bulb temperature due to heat conduction along the stem does not exceed 0,05 °C if the dry-bulb temperature does not exceed 40 °C or 0,1 °C if the dry-bulb temperature exceeds 40 °C. A method which may be used to determine the minimum distance for which the covering shall extend onto the stem to meet this requirement is described in annex B.

NOTE — For a mercury-in-glass thermometer with a solid stem, a distance of twice the stem diameter is usually adequate.

5.2.4 The stem of each thermometer shall be clear of obstructions and freely exposed to the air-stream over a length measured from the sensor of not less than 1,5 times the length of the extension of the covering required by 5.2.3.

5.2.5 During operation of the psychrometer, the covering shall be completely permeated with water as evidenced by a glistening appearance in a beam of light.

5.2.6 When the covering is being fitted or refitted and on subsequent occasions from time to time, the covering shall be washed *in situ* with pure water, using, for example, laboratory apparatus such as a wash bottle. It shall be renewed when it shows any evidence of permanent change.

5.2.7 If a wick is provided, it shall consist of twisted threads of white cotton and shall have the minimum cross-section consistent with an adequate feed of water to the wet bulb for the highest rates of evaporation. The free length of the wick shall be at least twice the diameter of the wet bulb and at least three times the wick diameter, ensuring that water arriving at the covering is already practically at the wet-bulb temperature. The wick shall be limp.

5.2.8 If a wick is provided, air which passes over the wick other than in the close proximity of the wet bulb shall not impinge on the wet bulb. In the case of axial ventilation, the wick shall be attached to that extremity of the covering which is on the stem.

5.2.9 The water reservoir shall not obstruct the flow of air, and its contents shall not affect the humidity of the air sample.

5.2.10 The level of water in the water reservoir shall not be more than 50 mm below the level of the lowest part of the wet bulb.

1) Use of the term "bulb funnel" is consistent with ISO 386.

5.3 Water

Suitable water can be prepared using distillation or deionization techniques.

5.4 Air

5.4.1 The flow of air over both the wet and dry bulbs shall be a forced draught of flow velocity 4 ± 1 m/s for transverse ventilation and 2 ± 0,5 m/s for axial ventilation.

5.4.2 The air sample shall not pass over any obstruction or through the fan before it passes over the wet and dry bulbs.

5.4.3 In the case of axial flow, the direction of the flow shall be from the free end of each sensor towards the support end.

5.4.4 No air which has been cooled by the wet bulb or by the wick shall impinge on the dry bulb.

NOTE — This may be ensured by having two separate incoming air-streams.

Air which has been discharged from the instrument shall not locally return to the incoming air.

5.5 Radiation shields

5.5.1 Any radiation shield shall be of thin sheet metal. Surfaces required to be polished shall be of bare metal which will retain its brightness.

5.5.2 In the case of transverse ventilation, radiation shields may be provided to shield the wet and dry sensors from extraneous radiation. In addition, a shield may be provided between the sensors.

Shields shall be shaped so as to allow the air-stream to cover the whole of each sensor and the whole of that part of the supporting stem of each sensor and that part of the wick, if any, which lie within the shield.

Any shield surface which faces one or both of the sensors shall be blackened; all other shield surfaces shall be polished.

5.5.3 In the case of axial ventilation, a separate concentric cylindrical radiation shield shall be provided for each sensor and shall be polished inside and out. The shields shall be similar, and their diameter shall be not less than 1,75 d and not greater than 2,5 d, where d is the overall diameter of the wet sensor (including wet-bulb covering).

The length and positions of the shields shall be such that the extension of the shield of the wet sensor beyond each end of the wet covering is not less than d and not greater than 3 d, and such that a line drawn to connect the forward ends of the shields is perpendicular to the axes.

Unless a second pair of concentric cylindrical radiation shields is provided outside the first, the entrance of each shield shall be bell-mouthed in shape, the shield being curved outwards near the entrance so that in cross-section its form in that region approximates a quadrant of a circle of radius not less than 0,75 d and not greater than 1,5 d.

If a second pair of concentric cylindrical radiation shields is provided outside the first, they should be polished inside and out, and the inner shields shall be uniform cylinders over their whole length. The entrance of each outer shield shall be slightly forward of the entrance of the inner shield, and shall be bell-mouthed in shape, with the radius in the cross-section not less than d and not greater than 2 d. Air at a flow rate approximately the same as that of the air entering the inner shield shall enter the space between the inner and outer shields.

NOTE — Since it is polished internally, the shield around the axially ventilated wet bulb reduces the net radiative heat transfer to the wet bulb from its surroundings by a factor of about three. Therefore, unlike the internally blackened shield which may be provided in the case of transverse ventilation, the shield plays an essential role in determining the value of the psychrometer coefficient A. If the shield were blackened internally in the case of axial ventilation, the value of A would be increased to approximately 8 % greater than the value for the case of transverse ventilation (with or without an internally blackened shield). The air flow velocity for axial ventilation would have to be increased from 2 m/s to about 16 m/s to eliminate this difference. The conditions specified for the case of axial flow somewhat resemble those which occur in Assmann-type psychrometers.

6 Procedure

6.1 Location

As far as practicable, choose a location where the air constitutes a representative sample and where it is not affected by such factors as machinery and personnel.

6.2 Preparation for test

Ensure that water has permeated the whole of the wet-bulb covering. If the covering was initially dry, allow several minutes for saturation. Avoid touching the covering or the wick, if any, with the fingers. Ensure that the dry bulb is dry.

6.3 Ventilation and observation

6.3.1 Establish the flow of air and maintain it until a constant wet-bulb temperature or a steady cyclic variation of wet-bulb temperature is attained.

NOTE — With mercury-in-glass thermometers, a ventilation time of about 2 min is usually necessary.

If the measurements are being made in a relatively small enclosed space and steadily rising wet- and dry-bulb temperatures are observed, consider whether heat and moisture liberated by the instrument itself are affecting the conditions.

6.3.2 Read the thermometers with the necessary accuracy, taking into account the requirements of 5.1.2.

6.3.3 If measurements are performed in almost constant conditions, for example, when the control cycle is long compared with the measurement time, repeat the procedures specified in 6.3.1 and 6.3.2, re-wetting the covering as necessary, until, for three consecutive readings, no two temperature depressions differ by more than the appropriate amount specified in table 1.

6.3.4 If measurements are performed under conditions fluctuating rapidly under control, take a number of readings over at least two complete cycles.

NOTE — If measurements are performed while conditions are being changed under control, the readings may not be meaningful.

6.3.5 If necessary, correct the thermometer readings, and hence the temperature depression, in accordance with any prior calibration of the thermometers.

7 Expression of results

7.1 Determination from a psychrometric table or chart

Use a psychrometric table or chart in which the values are consistent with the equations and appropriate value of the psychrometer coefficient A as given in 7.2, and, from the dry-bulb temperature and the temperature depression, deduce the relative humidity and the humidity in any other desired units. To facilitate the identification of suitable tables or charts, values of relative humidity for various dry-bulb temperatures and temperature depressions are given in annex C for standard atmospheric pressure and three relevant values of A, namely $6{,}5 \times 10^{-4}\ K^{-1}$, $6{,}7 \times 10^{-4}\ K^{-1}$ and $6{,}9 \times 10^{-4}\ K^{-1}$.

7.2 Determination by calculation

7.2.1 Determine the partial pressure of water vapour in the air sample, p, from the following psychrometric equation, or from a similar equation that is equivalent for the prevailing conditions:

$$p = p_w(t_w) - A p_T (t - t_w)$$

where

$p_w(t_w)$ is the saturation vapour pressure of water at the wet-bulb temperature;

t is the dry-bulb temperature, in degrees Celsius;

t_w is the wet-bulb temperature, in degrees Celsius;

p_T is the total atmospheric pressure;

A is the psychrometer coefficient, per kelvin.

NOTE — p, $p_w(t_w)$ and p_T are to be expressed in the same units.

The value of A shall be chosen from the range from $6{,}5 \times 10^{-4}\ K^{-1}$ to $6{,}9 \times 10^{-4}\ K^{-1}$. If a value of A has been determined for the particular design of psychrometer and lies in this range, then it shall be used. If a value has been determined but lies outside this range, then the closer extreme value of the range shall be used. If no value of A has been determined, then the value $6{,}7 \times 10^{-4}\ K^{-1}$ shall be used.

NOTE — For example, at 20 °C and standard atmospheric pressure, if use of the value $6{,}5 \times 10^{-4}\ K^{-1}$ for A led to a value of 50,0 % for the relative humidity, then use of the value $6{,}9 \times 10^{-4}\ K^{-1}$ would lead to a value of 48,9 %.

7.2.2 The relative humidity, expressed as a percentage, is given by the formula

$$100\ p/p_w(t)$$

where $p_w(t)$ is the saturation partial pressure of water vapour at the dry-bulb temperature t.

7.2.3 If required, the dew-point temperature may be calculated. It is the temperature at which the saturation partial pressure is equal to p.

7.2.4 The value of the saturation vapour pressure of water for any particular temperature shall be obtained from a formula or tables consistent with the formula given in the current edition of "Technical Regulations of the World Meteorological Organization (WMO)".

NOTE — Although, in general, they will give values differing slightly from those given by the WMO formula, the formula of Goff and Gratch, given in [1], and that of Wexler, given in [2], may be regarded as consistent with the WMO formula for present purposes.

8 Accuracy

The uncertainty in the value obtained for the relative humidity is estimated either not to exceed ± 3 % r.h. or not to exceed ± 2 % r.h., depending (see table 1) on the uncertainty in the value obtained for the temperature depression and on whether or not the dry-bulb temperature exceeds 40 °C.

NOTE — The estimated limits for the uncertainty in the relative humidity take into account the contributions from all sources except the possible difference, referred to in clause 0, between the adopted humidity scale and the true scale.

9 Test report

The test report shall include the following information:

a) a reference to this part of ISO 4677;

b) identification of the instrument used;

c) the date and time of measurement;

d) the location, and any factors influencing the test conditions (see 6.1 and 6.3.1);

e) the dry-bulb temperature, the relative humidity percent and the humidity in any other desired units;

f) the uncertainty in the dry-bulb temperature (see 5.1.2) and the uncertainty in the relative humidity, expressed in the form used in this part of ISO 4677 (see clause 0).