
International Standard



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**Atmospheres for conditioning and testing —
Determination of relative humidity —
Part 2: Whirling psychrometer method**

Atmosphères de conditionnement et d'essai — Détermination de l'humidité relative — Partie 2: Méthode utilisant un psychromètre fronde

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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.

International Standard ISO 4677/2 was prepared by Technical Committee ISO/TC 125, *Enclosures and conditions for testing*.

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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Atmospheres for conditioning and testing — Determination of relative humidity — Part 2: Whirling psychrometer method

0 Introduction

This part of ISO 4677, dealing with the whirling psychrometer, and ISO 4677/1, dealing with the aspirated 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 4677/1 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 $6,6 \times 10^{-4} \text{ K}^{-1}$, while Ferrel's result corresponds to a value that increases from $6,6 \times 10^{-4} \text{ K}^{-1}$ to $6,8 \times 10^{-4} \text{ K}^{-1}$ 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 the 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 $6,7 \times 10^{-4} \text{ K}^{-1}$ 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 whirling psychrometer method is not as accurate as that using the aspirated psychrometer. In addition, it requires more space, is practically restricted to the use of mercury-in-glass thermometers, does not provide for shielding of the thermometer bulbs from extraneous radiation and is more demanding on the skills of the observer. However, the whirling psychrometer is simpler in construction and less expensive than the aspirated psychrometer.

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 whirling. The property is determined with an uncertainty not exceeding ± 3 % r.h.

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: A mercury-in-glass thermometer.

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

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 — This flow is provided by whirling the instrument in the hand, and is transverse to the axes of the thermometer bulbs.

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

4 Principle

When the psychrometer is whirled, air flows over the wet and dry bulbs. Evaporation from the surface of the wet bulb into the airstream cools the wet bulb 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 bulbs (the observed wet- and dry-bulb temperatures).

5 Apparatus and materials

5.1 Thermometers

5.1.1 The thermometers may be of either the solid-stem or enclosed-scale type.

5.1.2 The thermometers 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 $\pm 0,2$ °C if the dry-bulb temperature does not exceed 40 °C and not greater than $\pm 0,4$ °C if that temperature exceeds 40 °C. Provided this requirement is met, the uncertainty in the value obtained for the dry-bulb temperature may be up to $\pm 0,2$ °C when that temperature does not exceed 40 °C and up to ± 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 The diameters of the thermometer bulbs shall be not less than 2 mm and not greater than 4 mm.

5.1.4 The thermometers shall be mounted so that their axes are parallel and separated by a distance of not less than three times the overall diameter of the wet bulb (including wet-bulb covering).

5.1.5 The thermometers shall be graduated in 0,5 °C divisions and shall be capable of being read to the nearest 0,1 °C.

NOTE — A specification for thermometers which may be used when the dry-bulb temperature does not exceed 40 °C is given in annex A.

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.

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 thermometer bulb 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 0,1 °C if the dry-bulb temperature does not exceed 40 °C or 0,2 °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 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 bulb 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.

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 be not more than 50 mm below the level of the lowest part of the wet bulb.

5.3 Water

Suitable water can be prepared using distillation or deionization techniques.

5.4 Air

5.4.1 The air flow velocity over both the wet and dry bulbs shall be 4 ± 1 m/s.

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

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

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 Whirling and observation

6.3.1 Holding the instrument windward and well away from the body, whirl it in the hand at such a rate as to achieve the specified air flow velocity at the wet and dry bulbs (see 5.4.1). Stop whirling periodically to read the thermometers. When whirling has stopped, quickly read the wet-bulb thermometer and then the dry-bulb thermometer. Continue the procedure until a constant wet-bulb temperature or a steady cyclic variation of wet-bulb temperature is attained.

NOTE — A ventilation time of about 2 min is usually necessary.

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 0,2 °C if the dry-bulb temperature does not exceed 40 °C or 0,4 °C if that temperature exceeds 40 °C.

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 $6,5 \times 10^{-4} \text{ K}^{-1}$, $6,7 \times 10^{-4} \text{ K}^{-1}$ and $6,9 \times 10^{-4} \text{ K}^{-1}$.

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:

$$p = p_w(t_w) - Ap_T(t - t_w)$$

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 $6,5 \times 10^{-4} \text{ K}^{-1}$ to $6,9 \times 10^{-4} \text{ K}^{-1}$. 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 A has been determined, then the value $6,7 \times 10^{-4} \text{ K}^{-1}$ shall be used.

NOTE — For example, at 20 °C and standard atmospheric pressure, if use of the value $6,5 \times 10^{-4} \text{ K}^{-1}$ for A led to a value of 50,0 % for the relative humidity, then use of the value $6,9 \times 10^{-4} \text{ K}^{-1}$ 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 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 not to exceed $\pm 3 \%$ r.h.

NOTE — The estimated limit for the uncertainty in the relative humidity takes 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);
- 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).

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Annex A

Specifications for thermometers which may be used when the dry-bulb temperature does not exceed 40 °C

(This annex does not form an integral part of the standard. The adoption of the specification set out in this annex is at the option of the user and has no bearing on the meaning or interpretation of the main text of the standard.)

A.1 Compliance with ISO 386

Except where the clauses of this annex require departures from the features and practices specified in ISO 386, the wet- and dry-bulb thermometers shall comply with the requirements of that International Standard.

NOTE — Because of the special requirements for thermometers for use in psychrometers, some of the following clauses are not consistent with ISO 386, and some of the specifications for dimensions in clause A.8 are not of the form required by that International Standard.

A.2 Type

The thermometers shall be of the solid-stem type and shall be nominally similar. The stem may have a slight neck near the bulb to allow the wet-bulb covering to be secured more easily by a cotton thread.

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A.3 Range

The nominal range shall be from 0 to 40 °C.

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A.4 Immersion

The thermometers shall be graduated for complete immersion.

NOTE — In the psychrometer, the wet-bulb thermometer is used under conditions of partial immersion. For thermometers which comply with the requirements of this annex, the error introduced by ignoring this fact is negligible.

A.5 Materials

The materials of construction shall comply with the requirements of ISO 386, and the bulbs shall be made of glass. Requirements for glasses for thermometer bulbs will form the subject of ISO 4795.

A.6 Annealing and stabilization

Before the thermometers are filled with mercury, the glass of the thermometers shall be suitably annealed and the glass of the bulbs stabilized by a suitable heat treatment.

A.7 Expansion chamber

An expansion chamber shall be provided above the highest scale line and shall have a volume sufficient to ensure that a temperature of at least 60 °C can be sustained by the thermometers with no significant likelihood of damage or of a consequent need for recalibration.