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Standard Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)[1]

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~~ε1 NOTE—Section 20 was added editorially in April 1996.~~

1. Scope

1.1 *General*:

1.1.1 This test method covers the determination of the humidity of atmospheric air by means of wet- and dry-bulb temperature readings.

1.1.2 This test method is applicable for meteorological measurements at the earth's surface, for the purpose of the testing of materials, and for the determination of the relative humidity of most standard atmospheres and test atmospheres.

1.1.3 This test method is also applicable when the temperature of the wet bulb only is required. In this case, the instrument comprises a wet-bulb thermometer only.

1.1.4 Relative humidity ~~(rh)~~(RH) does not denote a unit. Uncertainties in the relative humidity are expressed in the form ~~*U*~~ *RH* ± ~~*u*~~*rh* ~~% rh,~~ %, which means that the relative humidity is expected to lie in the range (~~*U*~~*RH* − ~~*u*~~rh) % to (~~*U*~~ RH + ~~*u*~~rh) %, where ~~*U*~~ RH is the observed relative humidity. All uncertainties are at the 95 % confidence level.

1.2 *Method A—Psychrometer Ventilated by Aspiration:*

1.2.1 This method incorporates the psychrometer ventilated by aspiration. The aspirated psychrometer is more accurate than the sling (whirling) psychrometer (see Method B), and it offers advantages in regard to the space which it requires, the possibility of using alternative types of thermometers (for example, electrical), easier shielding of thermometer bulbs from extraneous radiation, accidental breakage, and convenience.

1.2.2 This method is applicable within the ambient temperature range 5 to 80°C, wet-bulb temperatures not lower than 1°C, and restricted to ambient pressures not differing from standard atmospheric pressure by more than 30 %.

1.3 *Method B—Psychrometer Ventilated by Whirling (Sling Psychrometer):*

1.3.1 This method incorporates the psychrometer ventilated by whirling (sling psychrometer).

1.3.2 This method is applicable within the ambient temperature range 5 to 50°C, wet-bulb temperatures not lower than 1°C and restricted to ambient pressures not differing from standard atmospheric pressure by more than 30 %.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (For more specific safety precautionary statements, see 8.1 and 15.1.)

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 861 Practice for Use of the Tex System to Designate Linear Density of Fibers, Yarn Intermediates, and Yarns
D 1193 Specification for Reagent Water
D 1356 Terminology Relating to Sampling and Analysis of Atmospheres
D 1357 Practice for Planning the Sampling of the Ambient Atmosphere
D 3631 Test Methods for Measuring Surface Atmospheric Pressure
D 4023 Terminology Relating to Humidity Measurements
D 4230 Test Method of Measuring Humidity with Cooled-Surface Condensation (Dew-Point) Hygrometer
E 1 Specification for ASTM Liquid-in-Glass Thermometers

~~[1] This test method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.11 on Meteorology.~~

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[1] This test method is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.11 on Meteorology.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* ~~, Vol 07.01.~~ volume information, refer to the standard's Document Summary page on the ASTM website.

EI380EEE/ASTM SI-10 Practice for Use of the International System of Units (SI) (the Modernized Metric System)

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of humidity terms used in this test method, refer to Terminology D 4023.

3.1.2 For definitions of other terms in this test method, refer to Terminology D 1356.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *Method A—Aspirated Psychrometer*:

3.2.1.1 *aspiration*—The wet and dry bulbs (and the psychrometer) are described as aspirated because there is provision for the forced ventilation by drawing air over the bulbs by suction. The flow may be either transverse or parallel to the axes of the bulbs.

3.2.1.2 *thermometer*— for purposes of this standard, and except where a specific type is indicated, the term thermometer means any temperature-measuring device.

3.2.1.3 *wet-bulb covering and wick* —the wet bulb is provided with a water-retaining covering of a woven-cotton material. A cotton wick which connects the covering to a water reservoir may be provided so that water is fed to the covering continuously by capillarity.

3.2.2 *Method B—Sling Psychrometer*:

3.2.2.1 *ventilation*— the wet and dry bulbs (and the psychrometer) are described as ventilated because there is provision for a flow of the air over the bulbs. The flow is transverse to the axes of the bulbs.

3.2.2.2 *wet-bulb covering*—the wet bulb is provided with a water-retaining covering of a woven-cotton material.

4. Summary of Methods

4.1 *General*:

4.1.1 The wet-bulb temperature depression, the dry-bulb temperature, and the ambient pressure provide the basis for deriving the relative humidity.

4.2 *Method A—Aspirated Psychrometer:*

4.2.1 Establish the airflow (see 7.4) and maintain it until a minimum wet-bulb temperature is attained. (With mercury-in-glass thermometers, about 2-min ventilation time is usually necessary.)

4.2.2 Read the thermometers with the necessary precision, obtaining the dry-bulb temperature with an overall uncertainty of ±0.2°C or better, and the temperature depression with an overall uncertainty of ±0.2°C or better for an uncertainty in the relative humidity of ±3 % ~~rh.~~RH. For an uncertainty in the relative humidity of ±2 % ~~rh,~~RH, obtain the dry-bulb temperature with an overall uncertainty of ±0.2°C or better and the temperature depression with an overall uncertainty of ±0.1°C or better. (Also see Section 12.)

4.3 *Method B—Sling Psychrometer:*

4.3.1 Holding the instrument well away from the body, and for outdoor measurements to windward and in the shade, whirl it at such a rate as to achieve the specified airspeed at the wet and dry bulbs, see 14.4.

4.3.2 Read the thermometers with the necessary precision, obtaining the dry-bulb temperature with an overall uncertainty of ±0.6°C or better, and the temperature depression with an overall uncertainty of ±0.3°C or better for an uncertainty in the relative humidity of ±5 % ~~rh,~~RH, also see Section 19.

5. Significance and Use

5.1 The object of this test method is to provide guidelines for the construction of a psychrometer and the techniques required for accurately measuring the humidity in the atmosphere. Only the essential features of the psychrometer are specified.

METHOD A—PSYCHROMETER VENTILATED BY ASPIRATION

6. Interferences

6.1 When an aspirated psychrometer is used for measurements in a 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.

6.2 While the thermometers are being read, keep all surfaces that are at temperatures other than the environment (such as the hands, face, and other warmer or colder objects) as far as possible from the thermometer bulbs.

6.3 This method should not be used where there is heavy contamination of the air with gases, vapors, or dust.

7. Apparatus

7.1 *Thermometers for an Aspirated Psychrometer*:

7.1.1 The range of the thermometers shall not exceed the range 0 to 80°C. This range may be achieved by providing more than a single pair of matched thermometers. When the uncertainty in the derived relative humidity is required to be not more than ±3 % ~~rh,~~RH, the thermometers shall be such that their readings give the temperature depression with an uncertainty of not more than ±0.2°C. When the uncertainty in the relative humidity is required to be not more than ±2 % ~~rh,~~RH, they shall be such that their readings give the temperature depression with an uncertainty of not more than ±0.1°C. The uncertainty in the reading of the dry-bulb temperature shall be not more than ±0.2°C.

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

7.1.3 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 be that part of the thermometer extending from the bottom of the bulb to the top of the entrance flare of the capillary.

7.1.4 With transverse ventilation, the diameters of the sensors (excluding wet covering) shall be not less than 1 mm and not greater than 4 mm.

7.1.5 With axial ventilation, the diameters of the sensors (excluding wet covering) shall be not less than 2 mm and not greater than 5 mm, and their length not less than 10 mm and not greater than 30 mm.

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

7.1.7 Mercury-in-glass shall be graduated to 0.5°C or closer and be capable of being read to the nearest 0.1°C or better. (A specification for mercury-in-glass thermometers suitable when the uncertainty in the derived relative humidity is required to be not more than ±3 % ~~rh~~RH is given in Annex A1.)

7.2 *Wet-Bulb Covering*, *Wick*, *and Water Reservoir:*

7.2.1 The covering shall be fabricated from white-cotton muslin of linear density from 1.0 to 1.2 g/m, refer to Practice D 861. 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.

7.2.2 The covering shall completely cover the sensor or bulb of the thermometer, fit snugly but not very tightly, and shall be in physical contact with the bulb over its entire surface. 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. (A method of determining the distance for which the covering must extend onto the stem is outlined in Annex A2. For mercury-in-glass thermometers with solid stems, a distance of twice the stem diameter is usually adequate.)

7.2.3 To maintain a snugly fit cover on the wet bulb, the covering may be secured with a cotton thread at the end of the covering on the stem of the thermometer, at the top of the thermometer bulb, and at the bottom of the bulb. However, whenever a wicking is used, the covering shall not be secured between the thermometer bulb and the cotton wicking which connects the covering to a water reservoir.

7.2.4 After fabrication, the covering and wick shall have been washed in a dilute solution of sodium carbonate and thoroughly rinsed with distilled water. They shall not subsequently be touched with the fingers.

7.2.5 The stem of each thermometer shall, for a length measured from the sensor and not less than 1.5× the length of the extension of the covering required by 7.2.2, be clear of obstructions and freely exposed to the airstream.

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

7.2.7 The covering shall be washed in situ with distilled water from time to time and be renewed when it shows any evidence of permanent change.

7.2.8 When a wick is provided, the free length of a 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 at practically the wet-bulb temperature. A wick shall be limp.

7.2.9 A water reservoir shall not obstruct the airflow, and its contents shall not affect the humidity of the sample air.

7.2.10 The level of the water in a water reservoir shall be between 5 and 25 mm below the level of the lowest part of the wet bulb.

7.3 *Water*—Reagent water shall be produced by distillation, or by ion exchange or reverse osmosis followed by distillation, refer to Specification D 1193.

7.4 *Airflow*:

7.4.1 The flow of air over both the wet and dry bulbs shall be a forced draught of 3 to 10 m/s for thermometers with maximum allowable diameter of the sensors.

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

7.4.3 With axial flow, the direction of the flow shall be from the free end of each sensor towards the support end.

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

7.5 *Radiation Shields*:

7.5.1 Any radiation shields shall be of metal with a thickness of 0.4 to 0.8 mm. Surfaces required to have a polished finish shall be of a bare metal which will retain its brightness.

7.5.2 With transverse ventilation, radiation shields may be provided to shield the wet and dry bulbs from extraneous radiations. The radiation shields, essentially in the form of parallel plates, can be either polished on the outside and blackened on the inside, or polished on both the inside and outside surfaces. The clearance between the wet and dry bulbs and the shields shall be not less than half the overall diameter of the wet bulb. The shields shall be liberally flared outwards at the inlet to prevent the flow separating from the shields on the inside (vena-contracta effect). The shields may form part of a duct for the airflow. A second shield, outside, is not necessary.

7.5.3 With axial ventilation, concentric radiation shields shall be provided for the wet and dry bulbs, and shall be polished inside and out. (The shield around the wet bulb plays a vital role in reducing the radiative heat transfer between that bulb and its surroundings by a factor of about three.) The diameter of the shield shall be not less than 1.8 d and not greater than 2.5 d, where d is the overall diameter of the wet bulb. Its length and position shall be such that its projection beyond each end of the wet covering is not less than d and not greater than 3 d. The entrance to the shield shall be liberally flared to form a bell-mouth to prevent the flow separating from the shield on the inside. The shield may serve also as the duct for the airflow. A second shield, outside, is not necessary.

8. Precautions

8.1 *Safety Precautions*—Mercury vapor is poisonous, even in small quantities, and prolonged exposure can produce serious physical impairment **(1)**.[3] If a mercury thermometer is accidentally broken, carefully collect, place, and seal all of the mercury in a strongly made nonmetallic container. Avoid skin contact with mercury.

8.2 *Technical Precautions*—For reliable measurement and control, strict adherence to the exacting technique is necessary. Aside from the obvious mistake of not using a psychrometric chart or table prepared for the existing barometric pressure, most errors of psychrometry tend to restrict lowering of the wet-bulb temperature and thus indicate a higher relative humidity than actually exists.

8.2.1 *Conditions which Contribute to High Wet-Bulb Temperature*:

8.2.1.1 Improper installation of wet-bulb covering (loose fitting, too short, or too long).

8.2.1.2 Dirty or contaminated covering.

8.2.1.3 Contamination of wetting water.

8.2.1.4 Insufficient air flow.

8.2.1.5 Failure to reach or read the minimum point of the wet-bath depression.

8.2.1.6 Moisture or heat generation, or both, from the operator taking readings and from the wet-bulb water reservoir.

8.2.1.7 Radiant heating effects.

8.2.2 Heat from the fan or motor shall not affect the thermometer readings.

8.2.3 Instrument shall be used in the shade and not exposed to direct sunlight.

8.2.4 Prior to a measurement, the instrument shall have been exposed long enough to the test atmosphere to have attained the ambient temperature.

8.2.5 The shield shall not be allowed to become wetted.

9. Calibration

9.1 The thermometers used in a psychrometer should be compared once a year at four or more temperatures with the covering removed from the wet-bulb thermometer. Once every three months, the thermometers should be compared, with the covering removed from the wet-bulb thermometer, at the ambient dry-bulb temperature. The readings shall conform to the requirements (see 7.1.1 and Section 12) when the instruments are totally immersed. For highest accuracy, the thermometers should be calibrated over their range of use while totally immersed. The corrections thus determined should be applied to the readings when making a measurement.

10. Procedure

10.1 *Location*—Avoid locations where proximity to machinery, direct heat from the sun, or other sources of radiation would have undue influence. Stand preferably facing the air current so that the instrument receives the air before the air has passed near you. The site or location is selected so that the air is a representative sample. (Also see Practice D 1357.)

10.2 *Preparing Psychrometer*—Moisten the covering of the wet bulb thoroughly with distilled water. (Before the start of a series of measurements, deliver an excess of clean water directly to the wet-bulb covering from the reduced tip of a clean glass or plastic tube which is a part of a small wash bottle, for example, squeeze bottle, so that drops of water fall from the covering. This flooding procedure will help to remove organic contamination which may be on the surface of the wet-bulb covering.) Wetting should be repeated before each separate measurement. A small bottle or porous porcelain cup will serve as a convenient water container. If new or dry through disuse, several minutes may be required for complete saturation of the fabric. Avoid touching the fabric with the fingers, which may deposit oil or dirt. Replace soiled covering and wick. Maintain the dry bulb absolutely dry.

10.3 *Aspirating the Psychrometer*—Operate the fan motor, thus exposing the thermometers to the action of the air until the minimum wet-bulb temperature is indicated. Continue operating the fan until the readings of the thermometers become constant.

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[3] ~~Annual Book of ASTM Standards, Vol 11.01.~~

[3] The **boldface** numbers in parentheses refer to the list of references at the end of this test method.

10.3.1 *Reading Psychrometer*—While operating the fan, read the thermometers quickly but carefully. Read the wet bulb first. Under ordinary conditions, an approximate 0.15°C error in wet-bulb depression results in a 1 % error in relative humidity. While the thermometers are being read, keep all surfaces that are at temperatures other than the environment (such as the hands, face, and either warmer or colder objects) as far as possible from the thermometer bulbs.

10.3.2 For measurements in nominally constant conditions, for example, where fluctuation period is long compared with the measurement time, repeat steps 10.3 and 10.3.1, rewetting the covering if necessary, until in three successive readings the greatest temperature depression differs from the least by not more than 0.2°C for an uncertainty of ±3 % rhRH or not more than 0.1°C for an uncertainty of ±2 % rh. RH.

10.3.3 Where measurements are being made under conditions fluctuating rapidly, take a number of readings over at least two complete cycles.

10.3.4 Where measurements are being made while conditions are changing or are being changed under control, the readings might not be meaningful.

10.4 *Check Readings*—For purposes of checking, make as many readings as necessary until three successive readings agree. If atmospheric conditions are fluctuating, it may be desirable to obtain several readings in order to secure an average (that is, if there is a definite cycling in conditions, then readings should be continued for at least two cycles). It will be necessary to rewet the covering of the wet bulb when the fabric starts to dry, as indicated by a rising wet-bulb temperature.

11. Calculation

11.1Subtract the wet-bulb reading from the dry-bulb reading. The difference is the

11.1 Subtract the wet-bulb reading from the dry-bulb reading ($T - T_w$). The difference is the *wet-bulb depression*. Knowing the dry-bulb temperature and the wet-bulb depression, the relative humidity could be calculated by using the basic psychrometric equation shown in the following section. In practice, calculations directly involving the basic equation are seldom needed. Instead, tables, charts, curves, and other calculating devices developed from the basic equation are used, such as the table in Appendix X3.

11.2 When calculating relative humidity from the psychrometric equation, use the following equation or one that for the prevailing conditions is equivalent:

$$e = e_w(t_w) - Ap(t - t_w) \quad (1)$$

$$e = e_w(T_w) - AP(T - T_w) \quad (1)$$

where:

e = the partial pressure of water vapor in the atmosphere, Pa,
$e_w(t_{(T_w)})$ = the saturation pressure of water vapor at the wet-bulb temperature t_w, Pa, see Appendix X2,
t T = the dry-bulb temperature in °C,
t_{T_w} = the wet-bulb temperature in °C,
p P = the total (atmospheric) pressure, Pa, see Test Methods D 3631,
A = the psychrometer coefficient in K^{-1}, and

where e, $e_w(t_{T_w})$ and p P are expressed in the same units, see Practice E 380.

11.2.1 The value of A shall be chosen in the range 6.2×106.2 × 10^{-4} to 6.9 × 10^{-4} kK^{-1}. The psychrometer coefficient developed by Ferrel, $A = 6.6 \times 10^{-4}(1 + 0.00115\, t_{T_w})$, falls within this range. 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 use the value developed by Ferrel. (It may be noted that if, for example, at 20°C and standard atmospheric pressure use of the value $6.5 \times 10^{-4}\ K^{-1}$ led to a derived relative humidity of 50.0 %, then use of the value $6.9 \times 10^{-4}\ K^{-1}$ would lead to a derived relative humidity of 48.9 %.)

11.3 *Saturation Vapor Pressure*—Saturation vapor pressure of pure water vapor over a plane surface of water, ew in hPa at the wet-bulb temperature, T_w in Celsius can be calculated by this exponential expression: (**6**)

$$e_w(T_w) = 6.1094 \cdot e^{[17.625T_w/(243.04 + T_w)]} \quad (2)$$

The saturation vapor pressure (e_s) for water in the temperature range between 0°C and 100°C can also be calculated by the following polynomial expression (**7, 8**):

$$e_s = 2.70102980826 \times 10^{-5}\, T^5 + 2.92123923916\, x\, 10^{-4}\, T^4 + 2.53760036868 \times 10^{-2}\, T^3 + 1.48376504190\, T^2 + 4.37196700302 \times 10^{1}\, T + 6.13141885322 \times 10^{2} \quad (3)$$

11.4 *Relative Humidity*—The psychrometric equation gives the partial pressure of the water vapor. In the meterological range of pressure and temperature, the saturation vapor pressure of the pure water phase and of the moist air will be assumed to be equal. (Water vapor and air mixture is assumed to behave as ideal gas.) This assumption will introduce an error of approximately 0.5 % or less in the calculated partial pressure of water vapor and an error of less than 0.5 % in the calculated relative humidity. (See Test Method D 4230.) If water vapor and air are assumed to behave as ideal gases, then

U=ee

$$RH = e/e_s \times 100\% \cdot 100\,\% \quad (4)$$

where:
e = the partial pressure of the water vapor and
e_s = the saturation vapor pressure of water at the dry-bulb temperature, see Appendix X2.

11.4 *Use of Psychrometric Table or Chart*:

11.4.1 Take a psychrometric table or chart, the values in which are consistent with the equations and appropriate value of the psychrometer coefficient *A* as given in 11.2, and from the dry-bulb temperature and the temperature depression obtain the relative humidity or the humidity in whatever desired measure. (To facilitate the identification of suitable tables or charts, values of relative humidity for various dry-bulb temperatures and temperature depressions are given in Appendix X1 for standard atmospheric pressure and three relevant values of *A*, namely 6.5×10^{-4}, 6.7×10^{-4}, and 6.9×10^{-4} K^{-1}.)

11.4.2 In Appendix X3, values of relative humidity for dry-bulb temperatures 2 to 50°C and various temperature depressions are given for standard atmospheric pressure (101325 Pa) and using Ferral's value for *A* $[6.60\times10^{-4}(1+0.00115\ t_w)]$.

11.4.3 In cases where the barometric pressure differs from standard atmospheric pressure, the corrections that are to be applied to the values of relative humidity listed in Appendix X3 are given in Appendix X4.

12. Precision and Bias

12.1 The uncertainty in the derived relative humidity is estimated not to exceed the values shown in Table 1 if the temperature depression and the dry-bulb temperature measurement do not exceed the uncertainty values shown in Table 1.

METHOD B—PSYCHROMETER VENTILATED BY WHIRLING (SLING PSYCHROMETER)

13. Interferences

13.1 (See 6.2 and 6.3.)

14. Apparatus

14.1 *Thermometers for Sling Psychrometers* :

14.1.1 The thermometers shall be mercury-in-glass thermometers.

14.1.2 The range of the thermometers shall not exceed the range 0 to 50°C; however, this range may be achieved by providing more than a single pair of matched thermometers. When the uncertainty in the derived relative humidity is required to be not more than ±5 % rh, RH, the thermometers shall be such that their readings give the temperature depression with an uncertainty of not more than ±0.3°C and the uncertainty in the reading of the dry-bulb temperature shall be not more than ±0.6°C. When the uncertainty in the derived relative humidity is required to be not more than ±3 % rh, RH, the thermometers shall be such that their readings given the temperature depression and the dry-bulb temperature with an uncertainty of not more than ±0.2°C.

14.1.3 The diameters of the thermometer bulbs (excluding wet covering) shall be not greater than 4 mm.

14.1.4 (See 7.1.7.)

14.2 *Wet-Bulb Covering*:

14.2.1 (See 7.2.1.)

14.2.2 The covering shall completely cover the sensor or bulb of the thermometer, fit snugly but not very tightly, and shall be in physical contact with the bulb over its entire surface. 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. For mercury-in-glass thermometers with solid stems, a distance of twice the stem diameter is usually adequate.

14.2.3 To maintain a snugly fit cover on the wet bulb, the covering may be secured with a cotton thread at the end of the covering on the stem of the thermometer, at the top of the thermometer bulb, and at the bottom of the bulb.

14.2.4 (See 7.2.4.)

14.2.5 The stem of each thermometer shall, for a length measured from the sensor and not less than 1.5 × the length of the extension of the covering required by 14.2.2, be clear of obstructions and freely exposed to the airstream.

14.2.6 (See 7.2.6 and 7.2.7.)

TABLE 1

Uncertainty in Derived Relative Humidity, %, rh RH	Uncertainty in Temperature Depression, °C	Uncertainty in Dry-bulb Temperature,° C
±4	±0.3	±0.2
±3	±0.2	±0.2
±2	±0.1	±0.2
±5	±0.3	±0.6
±4	±0.2	±0.6
±3	±0.1	±0.6

14.3 *Water*—(See 7.3.)

14.4 *Airflow*:

14.4.1 The psychrometer shall be whirled so that the flow of air over both the wet and dry bulbs is equivalent to 3 to 10 m/s for thermometers with maximum allowable diameter of the sensors.

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

14.4.3 (See 7.4.4.)

14.5 *Radiation Shields*—Radiation shields are not necessary.

15. Precautions

15.1 *Safety Precautions*:

15.1.1 Mercury vapor is poisonous, even in small quantities, and prolonged exposure can produce serious physical impairment **(1)**, see 8.1.

15.1.2 Before using a sling psychrometer, check for adequate clearance to freely sling or whirl the thermometers without hitting any solid surfaces; for example, the knee.

15.1.3 If a mercury thermometer is accidentally broken, follow the handling procedure in 8.1.

15.2 *Technical Precautions*—(See 8.2.)

15.2.1 *Conditions which Contribute to High Wet-Bulb Temperature*—(See 8.2.1.1-8.2.1.7.)

15.2.2 (See 8.2.3 and 8.2.4.)

16. Calibration

16.1 The thermometers used in a psychrometer should be compared once a year at four or more temperatures with the covering removed from the wet-bulb thermometer. Once every three months, the thermometers should be compared, with the covering removed from the wet-bulb thermometer, at the ambient dry-bulb temperature. The readings shall conform to the requirements, (see 14.1.2 and Section 19) when the instruments are totally immersed. For highest accuracy, the thermometers should be calibrated over their range of use while totally immersed. The corrections thus determined should be applied to the readings when making a measurement.

17. Procedure

17.1 *Location*—(See 10.1.)

17.2 *Preparing Psychrometer*—(See 10.2.)

17.3 *Ventilating the Psychrometer*—Holding the instrument well away from the body, and for outdoor measurements to windward and in the shade, whirl it at such a rate as to achieve the specified airspeed at the wet and dry bulbs (see 14.4) and then stop the motion after 30 s to read the thermometers. Resume whirling for an additional 10 s before stopping the motion to read the thermometers. Continue this procedure of whirling for 10 s, rewetting the covering if necessary (see 10.4), until a minimum wet-bulb temperature has been attained. (About 2-min ventilation time is usually necessary.)

17.3.1 *Reading Psychrometer*—After whirling the psychrometer, read the thermometers quickly but carefully. Read the wet bulb first. Under ordinary conditions, an approximate 0.3°C error in wet-bulb depression results in a 2 % error in relative humidity. While the thermometers are being read, keep all surfaces that are at temperatures other than the environment (such as the hands, face, and either warmer or colder objects) as far as possible from the thermometer bulbs.

17.3.2 For measurements in nominally constant conditions, for example, where a fluctuation period is long compared with the measurement time, repeat Steps 17.3 and 17.3.1, rewetting the covering if necessary, until in three successive readings the greatest temperature depression differs from the least by not more than 0.3°C for an uncertainty of ±5 % ~~rh.~~ RH.

17.3.3 (See 10.3.3 and 10.3.4.)

17.4 *Check Readings*—(See 10.4.)

18. Calculation —(See Section 11.)

19. Precision and Bias

19.1 The uncertainty in the derived relative humidity is estimated not to exceed the values shown in Table 2 if the temperature depression and the reading of the dry-bulb temperature do not exceed the uncertainty values shown in Table 2.

TABLE 2

Uncertainty in Derived Relative Humidity, %, ~~rh~~ RH	Uncertainty in Temperature Depression, °C	Uncertainty in Dry-bulb Temperature,° C
±4	±0.3	±0.2
±3	±0.2	±0.2
±5	±0.3	±0.6
±4	±0.2	±0.6

20. Keywords

20.1 aspiration; humidity; psychrometer; psychrometric table; temperature; vapor pressure; ventilation; wet-bulb temperature

ANNEXES

(Mandatory Information)

A1. MERCURY-IN-GLASS THERMOMETERS SUITABLE WHEN THE UNCERTAINTY IN THE MEASURED RELATIVE HUMIDITY IS REQUIRED NOT TO EXCEED ±3 % RH

A1.1 Mercury-in-glass thermometers conforming to the following specification are suitable when the uncertainty in the measured relative humidity is required not to exceed ±3 % ~~rh.~~ RH.

A1.1.1 *Type*—The thermometers shall be of the solid-stem type, and 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.

A1.1.2 *Temperature Scale*—The thermometers shall be graduated for total immersion and in accordance with the Celsius scale which corresponds with the International Practical Temperature Scale of 1968.

A1.1.3 *Range*—The nominal temperature range of the thermometers shall be 0 to 80°C for an aspirated psychrometer and 0 to 50°C for a sling psychrometer.

A1.1.4 *Materials*—The stem shall be made of suitable thermometer glass with an enamel back. The bulb shall be made of glass meeting the Specification E 1.

A1.1.5 *Annealing and Stabilization* —The glass shall be suitably annealed, and the thermometers shall be stabilized by a suitable heat treatment before they are filled with mercury.

A1.1.6 *Expansion Chamber*—Each thermometer shall include an expansion chamber above the highest scale line so that a temperature of at least 100°C can be sustained without the likelihood of damage.

A1.1.7 *Dimensions*:

	mm
Length from bottom of bulb to underside of button or ring top (maximum)	240
Scale length corresponding to the nominal range (minimum)	130
Bulb length[A]	10 to 30
Bulb diameter	3 to 4
Stem diameter	4 to 5
Distance of neck (if any) from top of bulb[A]	8 to 12
Distance of lowest scale line from top of bulb[A] (min)	30
Distance of expansion chamber from highest scale line (min)	10

[A] The top of the entrance flare of the capillary is taken to be the top of the bulb.

A1.1.8 *Graduation and Figuring*—The thermometers shall be graduated at each 0.5°C, with a spacing of approximately 2 mm and with a longer line at each 1°C. The graduations shall be numbered at each 5°C.

A1.1.9 *Accuracy*—Readings of each thermometer made by a knowledgeable and experienced observer with the thermometers totally immersed shall not be in error by more than 0.2°C for any temperature in the nominal range. For any two temperatures in the nominal range, readings of the two thermometers, so made, shall give the difference of the temperatures with an error not exceeding 0.2°C.

A1.1.10 *Spare Thermometer*—If a third thermometer is associated with the psychrometer, then A1.1.9 shall apply to each of the three possible combinations of two thermometers.

A2. DETERMINATION OF THE DISTANCE FOR WHICH THE WET-BULB COVERING MUST EXTEND ONTO THE THERMOMETER STEM TO LIMIT THE HEAT-CONDUCTION ERROR TO 0.05°C

A2.1 Temporarily fit the bulbs (sensors) of both thermometers with coverings similar to that to be used on the wet bulb, but allow the coverings to extend onto the stems considerably further than usual, say 1.5 ×, the usual distance.

A2.2 Operate the instrument in the usual manner but with both coverings wet, choosing a location where the conditions are steady. Observe the difference of the thermometer readings as accurately as possible. (This difference is due mainly to the errors of the thermometers themselves.)

A2.3 Progressively reduce the extension of one of the coverings onto the stem until the difference of the readings of the thermometers is estimated to have changed by 0.05°C. The extension existing at that stage is the minimum permissible.

A2.4 A more accurate determination can be made if the difference of the readings is plotted against the extension for a number of extensions both greater than and less than that corresponding to a change of 0.05°C. The minimum extension which corresponds to a change of this amount may then easily be read from the plot.

A2.5 During the procedure, as in normal operation of the psychrometer, care must be taken to preserve the cleanliness of the coverings, and in particular to avoid touching them with the fingers.

A2.6 The procedure determines the extension necessary for the conditions which prevail at the time. If it is carried out under conditions which differ substantially from those under which the psychrometer is normally used, then allowance should be made for the fact that for a given extension of the covering the temperature error due to the heat conduction is roughly proportional to the temperature depression. For example, if the present procedure is carried out under atmospheric conditions such that the temperature depression is twice the value which occurs in the normal use of the instrument, then the extension which results in a change of 0.1°C in the temperature difference is the required minimum.

APPENDIXES

(Nonmandatory Information)

X1. SKELETON TABLE OF RELATIVE HUMIDITIES

TABLE X1.1 Comparison of the Calculated Relative Humidity Using Three Different Values of the Psychrometer Coefficient *A*

	Dry-Bulb Temperature in °C									Dry-Bulb Temperature in °C							
$t - t_w$	10	20	30	40	50	60	70	80	$t - t_w$	10	20	30	40	50	60	70	80
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		...	...	...	8.5	19.0	26.0	31.0	35.5
0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	22.0	...	...	...	7.5	18.5	26.0	31.0	35.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		...	...	...	7.0	18.0	26.5	31.0	35.0
	76.5	82.5	86.0	88.0	89.5	90.5	91.0	92.0		...	...	...	3.0	14.5	22.0	27.5	31.5
2.0	76.5	82.5	86.0	88.0	89.5	90.5	91.0	92.0	24.0	...	...	...	2.5	14.0	21.5	27.0	31.5
	76.0	82.5	86.0	88.0	89.5	90.5	91.0	92.0		...	...	...	2.0	13.5	21.5	27.0	31.5
	54.5	66.5	73.0	77.0	79.5	81.5	83.0	84.5		...	...	...	...	10.5	18.0	23.5	28.0
4.0	54.0	66.0	73.0	77.0	79.5	81.5	83.0	84.5	26.0	...	...	...	...	10.0	18.0	23.5	28.0
	53.5	66.0	72.5	77.0	79.5	81.5	83.0	84.5		...	...	...	...	9.5	17.5	23.5	28.0
	34.0	51.5	61.0	67.0	70.5	73.5	75.5	77.0		...	...	...	...	6.5	14.5	20.5	25.0
6.0	33.0	51.0	60.5	66.5	70.5	73.5	75.5	77.0	28.0	...	...	...	...	6.0	14.5	20.0	24.5
	32.0	50.5	60.5	66.5	70.5	73.0	75.5	77.0		...	...	...	...	5.5	14.0	20.0	24.5
	14.5	37.5	50.0	57.5	62.0	65.5	63.5	70.5		...	...	...	...	3.0	11.5	17.5	22.0
8.0	13.5	36.5	49.5	57.0	62.0	65.5	63.5	70.5	30.0	...	...	...	...	2.5	11.0	17.0	22.0
	12.0	36.0	49.0	57.0	62.0	65.5	63.5	70.5		...	...	...	...	2.0	11.0	17.0	21.5
	...	24.5	39.5	48.5	54.5	58.5	62.0	64.5		...	...	...	...	...	8.5	14.5	19.0
10.0	...	23.5	39.0	48.5	54.5	58.5	62.0	64.5	32.0	...	...	...	...	...	8.0	14.5	19.0
	...	22.5	38.5	48.0	54.0	58.5	61.5	64.5		...	...	...	...	...	7.5	14.0	19.0
	...	12.0	30.0	40.5	47.5	52.0	55.5	58.5		...	...	...	...	...	5.5	12.0	16.5
12.0	...	11.0	29.5	40.0	47.0	52.0	55.5	58.5	34.0	...	...	...	...	...	5.5	11.5	16.5
	...	10.0	29.0	40.0	47.0	52.0	55.5	58.5		...	...	...	...	...	5.0	11.5	16.5
	...	0.5	21.0	33.0	40.5	46.0	50.0	53.5		...	...	...	...	...	3.0	9.5	14.0
14.0	...	...	20.5	32.5	40.5	46.0	50.0	53.0	36.0	...	...	...	...	...	2.5	9.0	14.0
	...	...	20.0	32.5	40.0	45.5	50.0	53.0		...	...	...	...	...	2.5	9.0	14.0
	...	...	13.0	26.0	34.5	40.5	45.0	48.5		...	...	...	...	...	0.5	7.0	12.0
16.0	...	...	12.0	25.5	34.5	40.0	44.5	48.0	38.0	...	...	...	...	...	0.5	7.0	12.0
	...	...	11.5	25.5	34.0	40.0	44.5	48.0		...	...	...	...	...	...	6.5	11.5
	...	...	5.0	20.0	29.0	35.0	40.0	43.5		...	...	...	...	...	...	5.0	10.0
18.0	...	...	4.5	19.5	28.5	35.0	40.0	43.5	40.0	...	...	...	...	...	...	5.0	10.0
	...	...	3.5	19.0	28.5	35.0	39.5	43.5		...	...	...	...	...	...	4.5	9.5
	...	...	...	14.0	23.5	30.5	35.5	39.5									
20.0	...	...	...	13.5	23.5	30.0	35.0	39.0									
	...	...	...	12.5	23.0	30.0	35.0	39.0									

X1.1 Relative humidities rounded to the nearest 0.5 % ~~rh~~RH are tabulated for various temperatures and temperature depressions and for standard atmospheric pressure and three values of the psychrometer coefficient. Table X1.1 is given so that other more detailed tables may be compared with it. The dry-bulb temperature interval of 10°C and the temperature depression interval of 2°C are too wide to allow the table to be used for routine humidity measurement. The saturation vapor pressure of water has been taken from A. Wexler, Appendix X2. Standard atmospheric pressure is 1.01325×10^5 Pa.

Values	
Upper	$A = 6.5 \times 10^{-4}$ K^{-1}
Intermediate	$A = 6.7 \times 10^{-4}$
Lower	$A = 6.9 \times 10^{-4}$

X2. SATURATION VAPOR PRESSURE OVER WATER

X2.1 The saturation vapor pressure of the pure phase over plane surface of pure water for temperatures 0 to 100°C was obtained from Wexler's 1976 formulation **(2)**. Other suitable saturation vapor pressure tables are given in the Smithsonian Meteorological Tables **(3)**, International Meteorological Tables **(4)**, and ASHRAE Handbook and Product Directory **(5)** . The following simplified equation **(2)** yields values of the saturation vapor pressure over water which differ from those given in Table X2.1 by 20 ppm or less:

$$\ln e_s = \sum_{i=1}^{4} g_i (T_{68})^{i-2} \tag{X2.1}$$

where:
g_1 = -0.63536311×10^4,
g_2 = $0.3404926034 \times 10^{2}$,
g_3 = $-0.19509874 \times 10^{-1}$,
g_4 = $0.12811805 \times 10^{-4}$,
e_s = in Pascal, and
T_{68} = $273.15 + t_{68}$, and
t_{68} = –degree Celsius (International Practical Temperature Scale of 1968).

TABLE X2.1 Saturation Vapor Pressure Over Water (IPTS—68)[A]

Temp °C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	Pa	Pa	Pa	Pa	Pa	Pa	Pa	Pa	Pa	Pa
0	611.213	615.667	620.150	624.662	629.203	633.774	638.373	643.003	647.662	652.350
1	657.069	661.819	666.598	671.408	676.249	681.121	686.024	690.958	695.923	700.920
2	705.949	711.010	716.103	721.228	726.386	731.576	736.799	742.055	747.344	752.667
3	758.023	763.412	768.836	774.294	779.786	785.312	790.873	796.469	802.100	807.766
4	813.467	819.204	824.977	830.786	836.631	842.512	848.429	854.384	860.375	866.403
5	872.469	878.572	884.713	890.892	897.109	903.364	909.658	915.991	922.362	928.773
6	935.223	941.712	948.241	954.810	961.419	968.069	974.759	981.490	988.262	995.075
7	1001.93	1008.83	1015.76	1022.74	1029.77	1036.83	1043.94	1051.09	1058.29	1065.52
8	1072.80	1080.13	1087.50	1094.91	1102.37	1109.87	1117.42	1125.01	1132.65	1140.33
9	1148.06	1155.84	1163.66	1171.53	1179.45	1187.41	1195.42	1203.48	1211.58	1219.74
10	1227.94	1236.19	1244.49	1252.84	1261.24	1269.68	1278.18	1286.73	1295.33	1303.97
11	1312.67	1321.42	1330.22	1339.08	1347.98	1356.94	1365.95	1375.01	1384.12	1393.29
12	1402.51	1411.79	1421.11	1430.50	1439.93	1449.43	1458.97	1468.58	1478.23	1487.95
13	1497.72	1507.54	1517.43	1527.36	1537.36	1547.42	1557.53	1567.70	1577.93	1588.21
14	1598.56	1608.96	1619.43	1629.95	1640.54	1651.18	1661.89	1672.65	1683.48	1694.37
15	1705.32	1716.33	1727.41	1738.54	1749.75	1761.01	1772.34	1783.73	1795.18	1806.70
16	1818.29	1829.94	1841.66	1853.44	1865.29	1877.20	1889.18	1901.23	1913.34	1925.53
17	1937.78	1950.10	1962.48	1974.94	1987.47	2000.06	2012.73	2025.46	2038.27	2051.14
18	2064.09	2077.11	2090.20	2103.37	2116.61	2129.92	2143.30	2156.75	2170.29	2183.89
19	2197.57	2211.32	2225.15	2239.06	2253.04	2267.10	2281.23	2295.44	2309.73	2324.10
20	2338.54	2353.07	2367.67	2382.35	2397.11	2411.95	2426.88	2441.88	2456.94	2472.13
21	2487.37	2502.70	2518.11	2533.61	2549.18	2564.85	2580.59	2596.42	2612.33	2628.33
22	2644.42	2660.59	2676.85	2693.19	2709.62	2726.14	2742.75	2759.45	2776.23	2793.10
23	2810.06	2827.12	2844.26	2861.49	2878.82	2896.23	2913.74	2931.34	2949.04	2966.82
24	2984.70	3002.68	3020.74	3038.91	3057.17	3075.52	3093.97	3112.52	3131.16	3149.90
25	3168.74	3187.68	3206.71	3225.85	3245.08	3264.41	3283.85	3303.38	3323.02	3342.76
26	3362.60	3382.54	3402.59	3422.73	3442.99	3463.34	3483.81	3504.37	3525.05	3545.83
27	3566.71	3857.71	3608.81	3630.02	3651.33	3672.76	3694.29	3715.94	3737.69	3759.56
28	3781.54	3803.63	3825.83	3848.14	3870.57	3893.11	3915.77	3938.54	3961.42	3984.42
29	4007.54	4030.77	4054.12	4077.59	4101.18	4124.88	4148.71	4172.65	4196.71	4220.90
30	4245.20	4269.63	4294.18	4318.85	4343.64	4368.56	4393.60	4418.77	4444.06	4469.48
31	4495.02	4520.69	4546.49	4572.42	4598.47	4624.65	4650.96	4677.41	4703.98	4730.68
32	4757.52	4784.48	4811.58	4838.81	4866.18	4893.68	4921.32	4949.09	4976.99	5005.04
33	5033.22	5061.53	5089.99	5118.58	5147.32	5176.19	5205.20	5234.36	5263.65	5293.09
34	5322.67	5352.39	5382.26	5412.27	5442.43	5472.73	5503.18	5533.78	5564.52	5595.41
35	5626.45	5657.64	5688.97	5720.46	5752.10	5783.89	5815.83	5847.93	5880.17	5912.58
36	5945.13	5977.84	6010.71	6043.73	6076.91	6110.25	6143.75	6177.40	6211.22	6245.19