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Imaging materials — Recommendations for humidity measurement and control

Matériaux pour l'image — Recommandations pour le mesurage et le contrôle de l'humidité

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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 thorugh 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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. 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 seventy-five percent of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this Technical Report may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 18931 was prepared by Technical Committee ISO/TC 42, *Photography.*

Introduction

Some tests in photographic International Standards are carried out at a specified temperature and relative humidity (RH). A typical test condition is 23 °C ± 1 °C and (50 ± 2) % RH.

Temperature is relatively easy to measure and control to within ± 1 °C. Accurate thermometers of several types, which have been calibrated by a national standards laboratory or by the vendor and traceable to a standards laboratory, are readily available.

Humidity is much more complex. Calibration by national standards laboratories can be expensive, and the relatively long turn-around time conflicts with the need for frequent recalibration of the most useful humidity sensors. Some instrument vendors are now providing calibration traceable to the National Institute of Standards and Technology (NIST) at moderate cost. In other situations, the standards user may wish to do his own calibration. It should be noted that calibration is complicated by the lack of useful reference points; relative humidities of 0 % and 100 %, for example, are not readily measurable. The accurate and precise determination of relative humidity is usually done indirectly and the results converted to relative humidity.

This Technical Report discussed devices used as hygrometers and humidistats in the measurement and control of relative humidity. The importance of relative humidity as opposed to other moisture parameters is discussed in annex A.

Imaging materials — Recommendations for humidity measurement and control

1 Scope

This Technical Report discusses devices in photographic standardization that are used as hygrometers and humidistats in the measurement and control of relative humidity (RH) in test chambers and storage areas. Special attention is given to situations where a photographic standard specifies controlling relative humidity to ± 2 % RH or better.

Electric hygrometers are recommended for their precision, low cost, and accuracy when properly calibrated. Calibration can be done either by the vendor or in-house by a dew-point measurement. Where the budget permits, dew-point combined with ambient temperature measurements (converted to relative humidity) may be the only sensor system.

2 Terms and definitions

For the purposes of this Technical Report, the following terms and definitions apply.

2.1
absolute humidity
mass of water vapour per unit volume of wet gas

NOTE It is a measure of the amount of water present as part of the chemical analysis of the space, i.e., how much water is availble for chemical activity.

2.2
accuracy
degree of conformity of a measurement to an accepted standard or ideal (true) value

2.3
desiccant
drying agent

2.4
dew-point
temperature to which moisture-laden air must be cooled to induce condensation

2.5
dry-bulb temperature
true temperature of the air at rest, i.e., the temperature as measured with ordinary instrumentation

2.6
frost-point
temperature to which moisture-laden air must be cooled for frost or ice formation

2.7
humidistat
device that senses the moisture content of the air for the purpose of controlling it

2.8
humidity
general term for the amount of water vapour in the air

2.9
hygrometer
instrument that measures the moisture content of an air specimen

2.10
mixing ratio
mass of water vapour per unit mass of dry air

2.11
mole ratio
number of moles of water vapour per mole of dry gas

2.12
percent saturation
mass of water vapour present relative to the mass at saturation

NOTE Often confused with relative humidity.

2.13
precision
measure of repeatability; the degree of closeness of a series of measurements under the same operating conditions

2.14
relative humidity
ratio, expressed as a percentage, of the existing partial vapour pressure of water to the vapour pressure at saturation

2.15
wet-bulb temperature
temperature indicated by a temperature sensor covered by a wetted wick

3 Moisture content of gases

The moisture content of a gas specimen can be expressed in a variety of ways. Details are given in the literature (see [1] in the bibliography) and are beyond the scope of this Technical Report. Some methods have been defined above and include absolute humidity, relative humidity, dew-point, etc. They are interrelated, and each has its place with scientists, engineers, meteorologists, etc.

Films and papers respond directly to relative humidity, and this justifies its specification in International Standards concerning photography (see annex A).

4 Measuring systems

Humidity devices serve one or more of the following purposes:

— measurement;

— control;

— calibration.

Of the more than ten fundamentally different ways to measure moisture content (see [2], [3], [4] in the bibliography), only the most significant for International Standards concerning photography will be discussed. Applicability to each of the above purposes will be included.

Agreement among laboratories to within ± 2 % RH is obviously not possible with instrument accuracies of only ± 5 %. This Technical Report will, therefore, stress accuracy.

4.1 **Gravimetric train** (calibration only)

In this method, technicians weigh a small amount of a powerful drying agent. A moist air specimen is then passed through so as to remove all its moisture. The drying agent is then reweighed. Equilibrium moisture content is achieved when a repeat measurement at a greater time interval shows no change. The difference in weight determines the moisture content.

Although simple in principle, the procedure is complex in practice and a single measurement can take hours, days or weeks to perform. The apparatus fills a room and is used by national standards laboratories to provide the ultimate standard of accuracy.

4.2 **Dew-point/Frost-point hygrometers;** also called condensation hygrometers (secondary calibration, measurement and control)

This is the most accurate off-the-shelf method to calibrate working humidity sensors. Dew-point is the temperature at which moisture from the carrier gas condenses on a chilled surface. When the ambient temperature is also measured, relative humidity can be calculated either off-line or by an internal microprocessor. Commercial instruments use a mirror chilled by a thermoelectric cooler together with a light-emitting diode and a photocell which receives the reflected image. Moisture condensation causes the light to scatter, at which point the feedback circuit from the photocell controls the cooling so as to maintain the mirror temperature at the dew-point.

The main disadvantages of this method are cost and a slow response at low frost-points, where the sublimation rate can be slow. Advantages include accuracy and freedom from drift as long as the mirror is kept clean. This is easily achieved by use of a maintenance kit that consists of a small bottle of alcohol and some cotton swabs. Some instruments even have a simple calibration control to cancel out day-to-day accumulations of dust. It is important that the illumination system be shielded from room light. The design should, therefore, include provision to maintain good airflow over the mirror, so that the dew-point at the mirror surface matches that in the room.

The ambient temperature measurement is as critical as the dew-point measurement. Therefore, the temperature probe should be recalibrated every few months.

Dew-point devices are often used for measurement and occassionally as humidistats for controlling relative humidity. Their accuracy can be in the range of ± 1 % RH. Users find them to be free of drift if proper precautions are taken with the mirror. A major failure of the circuitry is virtually unknown, but could conceivably occur.

An inexpensive hygrometer would then be useful to establish whether a sudden change in reading was due to the instrument or to the air-handling system. In the USA, the National Institute of Standards and Technology (NIST) provides dew-point certification of instruments used to calibrate commercial devices. Here a “two-pressure generator” is used for generating air at a controlled dew-point which is then sent to the device to be calibrated.

4.3 Wet-bulb/dry-bulb thermometers and aspirated psychrometers

This inexpensive and widely used method employs two thermometers. One is dry, while the other is wrapped in a wet-cotton wick. The cooling effect of evaporation of water from the wick causes a temperature depression. Psychrometric charts give relative humidity when the two temperatures are known. Sling psychrometers are a common example. Aspirated psychrometers mount the thermometers in a case with a battery-operated fan to draw air over them.

The literature is extensive (see [5], [6] in the bibliography) and in summary states that at dew-points above 0 °C and under ideal conditions, accuracy is seldom better than 5 % RH. This meets the requirements for storage areas, but seldom for measurements where ± 2 % RH is specified.

The cooling effect of evaporation is often not complete, and this minimizes the wet-bulb depression. The calculated relative humidity, therefore, tends to be too high. The effect is most pronounced at low humidities.

A major problem is swelling of the wick, leading to poor contact with the bulb. The wick should, therefore, be replaced frequently. Other problems include wick contamination by salt deposits and oil from the operator's fingers. Web-bulb thermometers obviously cannot be used in freezer vaults.

4.4 Electric hygrometers (measurement and control)

The sensing element changes either its resistance or capacitance with changes in relative humidity. The instrument circuitry makes the conversion to relative humidity.

These measuring devices are widely used. They respond quickly to small changes in humidity and are sensitive enough to measure changes as small as 0,3 % RH. They can be multiplexed; data from multiple locations are often sent to a data logger. The sensors themselves are inexpensive and, depending on instrument design, can be replaced if damaged by moisture condensation resulting from, for example, failure of the air-conditioning system. Many are portable. Others, including some portables, provide analog or digital data recording.

Electric sensors have largely replaced hair hygrometers in humidistats. When properly installed and maintained, they exceed the precision requirements for conformity to International Standards concerning photography and do so at a modest cost. These devices may drift with time so accuracy should be checked by periodic calibration, either by the vendor or with a dew-point measurement.

4.5 Hair hygrometers/Mechanical expansion

This type of equipment is included for the sake of completeness, but cannot be recommended for any purpose where humidity tolerances are ± 2 % RH. It is a modification of the oldest form of humidity measurement and is based on the principle that a human hair or bundle of hairs increases in length with an increase in humidity. In recent years, hair has been replaced with a ribbon of nylon or other material.

Accuracy is seldom ± 5 % RH and errors can be even greater with some instruments. The response is very slow and there are serious hysteresis effects.

4.6 Saturated salt solutions

Saturated salt solutions are obviously not measuring devices, but are utilized in many International Standards as a means to obtain controlled humidity where specimen size permits a glass laboratory desiccator jar to be used. Equilibration times should never be shortened. A frequent error is the presence of too much water. It is important that the solution be a slush with excess undissolved crystals. Too much water, as in a true solution, even with undissolved crystals in the bottom, can cause a less-than-saturated solution at the surface. The result will be a higher than expected humidity. Some undissolved crystals shall be above the level of the saturated salt solution and the surface area of the solution should be as large as practical.

If these and all other precautions are followed, good inter-laboratory agreement should be expected. Agreement to within ± 2 % RH is possible, but should not be assumed if one laboratory uses saturated salt solutions while another uses a test chamber. The literature on saturated salt solutions is also extensive (see [7] in the bibliography).

4.7 Divided flow-type humidity generator

A divided flow-type humidity generator produces a controlled humidity atmosphere which can be accurately measured with a dew-point/frost-point hygrometer (see 4.2).

Saturated humid air (100 % RH air) is generated by bubbling air several times through a water tank under controlled temperature. The divided flow method obtains the desired humidity by mixing dried air with the saturated air at the desired ratio. It is capable of establishing a humidity atmosphere between 0 % RH and 100 % RH.

5 Sensor location

The location of a humidity sensor is as least as important as its accuracy (see [8], [9] in the bibliography). The worst places are at an air intake and in a dead-air space, such as a wall. A good location may be immediately downstream of a piece of measuring or test equipment. The return air duct may be the best sensor location for a vault or storage area. Circulating fans are sometimes used in large vaults.

6 Recommendations

— Hair hygrometers should not be used.

— A large facility with many locations to monitor should consider using electronic hygrometers calibrated on a scheduled basis by the engineering department of the facility, or some other qualified group, using a dew-point instrument. A data logger may also be indicated.

— If only one measuring instrument is needed and the budget permits, a dew-point device will suffice.

— It is not easy to achieve the humidity control specified in International Standards concerning photography. If the information in this Technical Report is not sufficiently detailed, the services of a professionnal in the field should be sought.

Annex A

Importance of relative humidity

Gelatin shares with leather, wood, keratin, and indeed most natural organic materials the property of responding directly to relative humidity (RH) and not to most other moisture parameters. In the brief explanation that follows, it is important to realize that vapour-phase water is just another gas, exerting its own pressure independently of nitrogen, oxygen and other atmospheric gases.

At equilibrium, moisture enters the product at the same rate as it leaves it. In this dynamic process, the vapour pressure of the water in the air can be thought of as the inward driving force. Clause 2 defines relative humidity as the ratio, expressed as a percent, of the partial vapour pressure of the gas-phase water to its vapour pressure at saturation. Absolute humidity uses the mass of the water vapour and not its pressure. An example follows[1].

Consider a natural material that contained 8,4 % moisture by weight at 25 °C and 50 % RH. The data in Table A.1 shows the moisture content when the ambient temperature is raised or lowered and time for equilibration is allowed, but no other changes are made. Absolute humidity has not changed and clearly could not be used to establish the final moisture content of the product.

Table A.1

Temperature °C	**RH** %	**Sample moisture** %
25	50	8,4
35	28	4,8
15	93	24,0

The other major parameter, which is vapour pressure dependent, is dew-point. This makes it a fundamental method particularly suited to calibration of relative-humidity instruments. Dew-point sensors have also been used successfully as humidistats to control drier humidity in coating photographic films.

1) Quinn, F.C., Humidity, the neglected parameter. *Test Engineering*. pp. 10-15, July 1968.