SLOVENSKI STANDARD
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Ohranjanje kulturne dediščine - Postopki in instrumenti za merjenje vlažnosti v zraku in izmenjave vlage med zrakom in kulturno dediščino

Conservation of cultural property - Procedures and instruments for measuring humidity in the air and moisture exchanges between air and cultural property

Erhaltung des kulturellen Erbes - Verfahren und Geräte zur Messung der Luftfeuchte und des Feuchtigkeitsaustausches zwischen Luft und Kulturgut

Conservation des biens culturels - Modes opératoires et instruments de mesure de l'humidité de l'air et des échanges d'humidité entre l'air et les biens culturels

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Conservation of cultural property - Procedures and instruments for measuring humidity in the air and moisture exchanges between air and cultural property

Conservation des biens culturels - Modes opératoires et instruments de mesure de l'humidité de l'air et des échanges d'humidité entre l'air et les biens culturels

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If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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Foreword

This document (prEN 16242:2011) has been prepared by Technical Committee CEN/TC 346 “Conservation of cultural property”, the secretariat of which is held by UNI.

This document is currently submitted to the CEN Enquiry.

Introduction

Humidity plays a key role in the conservation of cultural heritage because most materials and/or deterioration mechanisms are directly or indirectly affected by humidity levels or changes. This European Standard is a guide intended to assist in providing an acceptable environment to cultural heritage objects. Humidity in air, expressed in a number of ways, is an important aspect of that environment. Therefore, the control of levels and variability of humidity reduces the risk of deterioration and is an important preventive measure, minimising the need for future conservation interventions.

This European Standard is a guide to specifying adequate procedures for measuring humidity in air and the minimum characteristics of instruments for such measurements so that they are carried out to an appropriate level of accuracy. Although standards exist for measuring humidity in air in other fields like meteorology or ergonomics of thermal environments, this standard focuses on the specific requirements of cultural objects.

This document is one of the series of European Standards intended for use in the study of environments for cultural property.

1 Scope

This Standard specifies procedures and instruments for the measurement of relative humidity (RH) in air in outdoor or indoor environments. It indicates how RH can be directly measured or how it can be calculated from air temperature, wet-bulb temperature and dew-point temperature. This standard contains recommendations for accurate measurements of ambient conditions and moisture exchanges between air and artworks. It is addressed to anyone in charge of environmental diagnostics, preservation, conservation or maintenance of buildings, collections or single objects.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 15757, *Conservation of Cultural Property — Specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic materials*

EN 15758, *Conservation of Cultural Property — Procedures and instruments for measuring temperatures of the air and the surfaces of objects*

EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 4677-1, *Atmospheres for conditioning and testing — Determination of relative humidity — Part 1: Aspirated psychrometer method*

ISO 7726, *Ergonomics of the thermal environment — Instruments for measuring physical quantities*

ISO/IEC Guide 1998, *Guide to the expression of uncertainty in measurement (GUM)*

ASTM D4230-02, *Standard Test Method of Measuring Humidity with Cooled-Surface Condensation (Dew-Point) Hygrometer*

ASTM E337-02, *Standard Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)*

DIN 50012-1, *Climates and their technical application — Methods of measuring humidity — General*

DIN 50012-2, *Climates and their technical application — Methods of measuring humidity — Psychrometers*

NF X15-117, *Measurement of air moisture — Mechanical hygrometers*

NF X15-119, *Measurement of air moisture — Salt solution humid air generators for the calibration of hygrometers*

NF X20-521, *Gas analysis. Determination of the water dew point of natural gas — Cooled surface condensation hygrometers*

3 Terms and definitions

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

3.1
absolute humidity
AH

volume density of water vapour, i.e. the mass of vapour contained in the unit volume of moist $AH = \frac{m_v}{V}$, expressed in g/m^3

3.2
atmospheric (or barometric) pressure
p
pressure of the air column above the measuring point, expressed in hPa (hectopascal)

3.3
barometer
instrument measuring atmospheric pressure

3.4
dew-point hygrometer
instrument measuring the temperature at which a cooled parcel of air becomes saturated with water vapour

3.5
dew-point temperature
DP
temperature to which a parcel of moist air must be cooled at constant pressure and constant water vapour content, in order to become saturated with water vapour in equilibrium with water i.e. at which water vapour begins to condensate, expressed in degrees Celsius (°C)

3.6
dry air
atmospheric air without water vapour

3.7
dry-bulb temperature
T, t
actual air temperature. In a *psychrometer*, the temperature reached by the thermometer having the dry bulb

NOTE Capital T is used when the measurement is expressed in Kelvin (K); lowercase *t* when expressed in degrees Celsius (°C).

3.8
equilibrium moisture content
EMC
moisture content at which a material neither loses nor gains moisture from the surrounding atmosphere at given relative humidity and temperature levels, expressed in g/kg as the ratio of the mass of water m_{fw} contained in the material the dry mass of the same material m_{dm}, *i.e.:* $w = \frac{m_{fw}}{m_{dm}}$

3.9
frost-point temperature
temperature to which a parcel of moist air must be cooled at constant pressure and constant water vapour content, in order to become saturated with water vapour in equilibrium with ice i.e. at which water vapour begins to freeze forming ice crystals, expressed in degrees Celsius (°C)

3.10
hygrograph
instrument measuring relative humidity (see hygrometer) but providing an apparatus to record humidity over time. Generally, a mechanically- or electrically-driven drum supporting a strip chart with RH graduation where an ink pen traces a time plot of the ambient humidity

3.11
hygrometer
instrument measuring relative humidity. It generally comprises a sensor, which is set in equilibrium with the air, and a system which transforms the signal from the sensor into an output reading expressed in percent (%rh)

3.12
mixing ratio or humidity mixing ratio
MR

ratio of the mass of water vapour m_v to the mass of dry air m_a, i.e. $MR = \frac{m_v}{m_a}$, expressed in g/kg

3.13
moist air
actual mixture of dry air and water vapour

3.14
psychrometer
instrument measuring the dry- and wet-bulb temperatures and calculating the relative humidity. It consists of two identical thermometers, one of which is sheathed in wet wicking, and a fan to ensure their ventilation at a constant velocity in order to reach equilibrium with air. The reading output is expressed in degrees Celsius (°C)

3.15
relative humidity
RH

ratio of the actual water vapour partial pressure to the saturation vapour pressure $RH = \frac{e}{e_{sat}(t)} \times 100$,

expressed in percent (%rh)

3.16
measuring range
interval of values that are intended to be measured, or that are potentially measurable, or that have been measured, specified by their upper and lower limits

3.17
repeatability
ability of the measuring instrument to reproduce the same output when successively measuring the same value of the measure and under the same conditions

3.18
resolution
smallest difference between indications of a displaying device that can be meaningfully distinguished

3.19
response time
time interval between the instant when the measure is subjected to a specified abrupt change and the instant when the response of the measuring instrument reaches and remains within specific limits around its final steady value. The response time of RH sensors is typically expressed as the time needed to reach 63.2% of the final values and in this case is called the time constant

3.20
saturation vapour pressure
$e_{sat}(t)$
maximum pressure of the water vapour in equilibrium with plane surface of pure water. Expressed in hPa (hectopascal)

3.21
sensor
device that senses either an absolute value or a change in a physical quantity and converts them into a useful signal for an information-gathering system

3.22
thermometer
instrument for measuring temperature. *It comprises: a sensor which is placed in thermal equilibrium with air (if it measures air temperature) or the surface, sometimes a probe that contains and protects the sensor, and a system that transforms the input from the sensor into an output expressed in °C*

3.23
time constant
time needed to reach 1/e = 63.2% of the final output value when the air, or the surface temperature, is subjected to a specified abrupt change to a final steady value. *See also response time.*

3.24
time stability
ability to keep constant the characteristics in the course of time. It is often expressed in terms of a percent change of the response per year (%/yr)

3.25
surface temperature
t_s
temperature of a given surface of an object. It can be measured with contact thermometers, total radiation thermometers or infrared thermometers. Surface temperature is generally different from air temperature, expressed in degrees Celsius (°C)

3.26
uncertainty (of measurement)
parameter that characterizes the dispersion of the values that could reasonably be attributed to the measure

3.27
wet-bulb temperature
t_w
in a psychrometer, the temperature reached by a thermometer sheathed in wet wicking, expressed in degrees Celsius (°C)

4 Symbols and abbreviations

No symbols and abbreviations apply to this European standard.

5 Quantities characterising humidity in air

Air humidity is expressed in a number of ways. In this Standard we refer to four key quantities characterising humidity in air for the purposes of environmental diagnostics to preserve cultural heritage: relative humidity, humidity mixing ratio, absolute humidity and dew-point temperature.

Relative humidity (RH) is the ratio of the actual partial pressure of water vapour to the saturation vapour pressure at the same temperature, and represents the degree of saturation the water vapour has reached.

Relative humidity is responsible for, or related to, many deterioration mechanisms affecting cultural property preservation. Dry environments become dusty and electrostatic deposition is enhanced. Humid environments increase chemical reactivity of gaseous pollutants. Hygroscopic materials, such as wood, paper, textiles, leather or bone, absorb and release moisture in response to changes in RH, reaching eventually at a given temperature and RH a constant level of moisture termed Equilibrium Moisture Content (EMC). The variations in EMC produce dimensional changes of the materials, i.e. expansion when EMC is increasing and shrinkage when decreasing, which may lead to high levels of stress and physical damage as fracture and deformation. High EMC favours mould growth, as well as hydrolysis, oxidation, corrosion or other chemical reactions.

In the case of photosensitive surfaces, RH has a synergic effect with light, temperature, pollution and other environmental factors in accelerating fading, discoloration and embitterment.

The humidity mixing ratio (MR) is the ratio of the mass of water vapour to the mass of dry air. It is independent of air temperature, volume and pressure and represents how much air is rich in vapour. The parameter is used to distinguish if water molecules are added to or removed from the atmosphere, e.g. to monitor evaporation, condensation, or mixing of two air masses. It is useful for environmental diagnostic purposes, to provide evidence of the action of HVAC systems or air-surface interactions. By measuring this parameter along a horizontal cross- section of a room, it is possible to reveal external air penetrating through openings, or moisture released by visitors, or when and where masonry is evaporating (higher MR close to the wall) or adsorbing moisture (lower MR to the wall).

Absolute humidity (AH) is the amount (mass) of water vapour contained in a given volume, e.g. a building, a room or a showcase. It depends on air pressure and temperature and it is useful in assessing the maximum quantity of water vapour that a given volume can contain at specified temperature conditions. When AH exceeds the air saturation level, the excess will condense. From the knowledge of the volume of a closed space, it is possible to calculate how much water will condense on objects and masonry. Such information can be used to determine, e.g., the maximum allowable number of visitors in a closed room, in order to avoid high humidity levels.

Dew-point temperature (DP) is the temperature to which moist air must be cooled at constant pressure and constant water vapour content, in order for saturation to occur. When the parameter is compared with the surface temperature (TS) of a structure or an object, the potential risk of water vapour condensation on that surface can be evaluated, i.e. condensation will occurs if TS is below DP and does not occur if T is above DP.

Equations to calculate the above quantities are reported in Annex A. Examples of environmental diagnostics using these quantities are reported in Annex B.

6 Recommendations relating to measuring methods

An accurate determination of relative humidity (RH) requires particular care because the measurement depends on the temperatures of the air and the instrument, which should be in equilibrium with each other and the equilibrium content of water vapour in the air.

The measurement of air humidity for the conservation of cultural property (EN 15757) must be conceived in the frame of a specific monitoring campaign that considers not only the value of this quantity but also the thermal field in the surrounding environment as well as close to the artefact.

The locations of the measuring points must be selected in such a way that they are representative of the environment under investigation. Each room generally shows variations of temperature and RH from point to point, therefore temperature and RH of the air that interacts with the object should be measured at a close distance to the target surface. RH should be measured also in free air, i.e. in a location not affected by the target (preferably, at a one metre distance or in the middle of the room). From these two measurements it is possible to establish whether the surface is exchanging moisture with air or not.

If the target surface temperature is different from the air temperature, the air layer in contact with the surface reaches a different RH which is difficult to measure. The actual RH at the interface between air and surface should be calculated from the actual surface temperature and the humidity mixing ratio of the air in the proximity, the latter to be derived from the values of air temperature and RH or wet-bulb or dew-point temperatures.

Measurements in locations affected by disturbing factors like heaters, ventilation grilles, windows or doors, or surfaces having a different temperature should be avoided. The measuring instruments should be placed at the level of the object if air stratification is present.

The effect of temperature on relative humidity is particularly important and must be taken into account in order to avoid measurement errors equal to or larger than the estimated measurement uncertainty. A source of error in humidity measurements can be the temperature difference between the air and the instrument.

The response time of an RH hygrometer must be considered. Meaningful results can be obtained after the sensor attains the equilibrium with the given temperature and relative humidity, which requires a time period of approximately twice the response time. If the probe is likely to be exposed to solar radiation, intense light illumination or infrared radiation from heaters, it should be shielded.

Relative humidity can be measured both directly, by means of sensors whose output is proportional to this quantity, and indirectly, through the measurement of the air temperature and the dew-point or wet-bulb temperatures. In the latter case, one has to take atmospheric pressure into account, in particular for measurements performed at high altitudes in the mountains.

7 Recommendations relating to measuring instruments

Measuring ranges, uncertainty, repeatability, stability, resolution, uncertainty and response time of the instruments for measuring air humidity are summarised in Table 1. Please note that the following characteristic should apply to the instruments, not to sensors considered separately. These characteristics should be considered as minimum requirements. The description or listing of certain instruments only means that they are recommended. Any measuring system which meets or exceeds the requirements of this European Standard can be used. It is up to users to analyze the performance of instruments available on the market and verify if they conform to this Standard.

Table 1 — Characteristics of measuring instruments

	Dew-point hygrometer	**Electronic psychrometer**	**Capacitive electronic hygrometer**	**Resistive electronic hygrometer**
Measuring range	-20 °C – 50 °C	5 % - 95 % (10 °C ≤ t ≤ 50 °C)	5 % - 95 % (-10 °C≤ t ≤ 50 °C)	5 % - 95 % (-10 °C≤ t ≤ 50 °C)
Uncertainty (*)	0.5 °C	3 %	3 %	3 %
Repeatability	0.1 °C	0.1 °C	0.2%	0.2%
Resolution	0.1 °C	0.1 °C	1%	1%
Response time	Not relevant	required: ≤2 min desirable: ≤1 min	required: ≤5 min desirable: ≤2 min	required: ≤5 min desirable: ≤2 min
Stability	≤ 0.2 °C/year	≤ 2 %/year	≤ 2 %/year	≤ 2 %/year

(*) including display resolution and short-term repeatability.

The ‘desirable’ response time would be of a considerable benefit for spot readings or continuous monitoring of short-term effects.