



BSI Standards Publication

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

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

Conservation des biens culturels - Spécifications applicables à la température et à l'humidité relative pour limiter les dommages mécaniques causés par le climat aux matériaux organiques hygroscopiques

Erhaltung des kulturellen Erbes - Festlegungen für Temperatur und relative Luftfeuchte zur Begrenzung klimabedingter mechanischer Beschädigungen an organischen hygroscopischen Materialien

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Foreword

This document (EN 15757:2010) has been prepared by Technical Committee CEN/TC 346 “Conservation of Cultural Property”, the secretariat of which is held by UNI.

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Introduction

This European Standard is a guide specifying temperature and relative humidity (RH) to preserve cultural property by limiting physical damage induced by strain-stress cycles in objects containing organic hygroscopic materials. This category of objects includes wooden items and structural elements such as floors, doors, panelling and roof timbers, paintings, books, graphic documents, textiles, objects made of bone, ivory or leather. Objects can consist of several hygroscopic materials and different kinds of materials can be used together. To a varying degree, they are vulnerable to changes and fluctuations in ambient RH that produce changes in equilibrium moisture content (EMC) in the materials as they adsorb and release moisture to adapt themselves to the continually changing environmental conditions. The variations in EMC produce dimensional changes of the materials which may lead to high levels of stress and physical damage such as fracture and deformation.

Objects containing organic hygroscopic materials need individually determined levels and ranges of temperature and RH as generally they have become acclimatised to the environments in which they have been exposed for significant periods of time. Over time, as temperature and RH fluctuations cause sufficient internal stress to create fractures, these fractures will open and close as expansion joints enabling a wider range of acceptable temperature and RH fluctuations. The material is said to have "*acclimatised*" as it now responds differently to atmospheric conditions, though this acclimatisation should not be given a positive connotation because it is due to internal fracturing and results in a form of damage. The associated loss of historical value, aesthetic value and also monetary depends on the size and location of the crack.

The determination of the temperature and RH ranges, which are optimal for preservation, is not simple due to the variety and complexity of the materials the objects comprise. Temperature has a direct effect on preservation but also an indirect effect as it controls RH of the air. The changes and fluctuations in temperature and RH should be considered from a static point of view of allowable levels or ranges and from a dynamic point of view, i.e. rate of change, duration of cycles and frequency at which cycles are repeated should be taken into account.

Deterioration is often of a cumulative nature and may be exacerbated by the number and the intensity of the individual environmental hazards. Changes and fluctuations of temperature and RH cause non-recoverable physical changes in materials although this is not always perceptible to the human eye. Vulnerability to deterioration mechanisms may increase with ageing. The same temperature and RH fluctuations may generate different effects depending on the type of object and its age.

Given the extreme complexity of the response of materials found in cultural property to variations of temperature and RH, this standard proposes a methodology leading to general specifications to limit climate-induced physical damage of organic hygroscopic materials. Therefore the standard deals with a selected category of damage and does not cover other important deterioration processes affecting other materials influenced by microclimatic factors such as oxidation, acid hydrolysis, biodeterioration, corrosion reactions and dissolution of associated materials due to deliquescence, salt crystallisation among others.

The proposed methodology is based on an analysis of a particular historical climate environment and a condition survey of the most vulnerable and/or valuable objects. The decision therefore is made on the harmlessness (or otherwise) of the existing climatic conditions. This approach usually allows for target temperatures and RH ranges that are more flexible than the single target values that are commonly accepted as ideal conditions for preservation of cultural property. This in turns allows a reduction in the environmental control needed to ensure good preservation of objects. Less and simpler equipment is required and investment, maintenance costs can be reduced. The control of temperature and RH can be further minimised by enhancing the passive control capacity of the building. High standards of preservation in historical buildings can be maintained through the use of affordable and efficient low energy solutions despite increase in the cost of energy.

Any change affecting (or concerning) the environment of an object or a collection have to be decided upon by a team of relevant professionals, which always includes a suitably qualified conservator, experienced in assessing the condition of collections and an expert in environmental control.

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1 Scope

This European Standard is a guide specifying temperature and relative humidity levels to limit climate-induced physical damage of hygroscopic, organic materials, kept in long-term storage or exhibition (more than one per year) in indoor environments of museums, galleries, storage areas, archives, libraries, churches and modern or historical buildings.

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.

prEN 15898:2010, *Conservation of cultural property — Main general terms and definitions concerning conservation of cultural property*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in prEN 15898:2010 and the following apply.

3.1 active control

use of devices able to force exchanges of heat, moisture or air, integrated with real-time processing sensors and controllers

3.2 air temperature

T

temperature read on a thermometer which is exposed to air in a position sheltered from direct solar radiation or other energy sources

NOTE If objects are exposed to direct radiation black globe or black strip thermometers should be used. For definition see also EN 15758.

3.3 equilibrium moisture content EMC

moisture content at which a hygroscopic material neither loses nor gains moisture from the surrounding atmosphere at given relative humidity and temperature levels

3.4 Heating, Ventilating or Air Conditioning Systems HVAC

active systems operated to control air temperature (heating), air temperature and humidity (air conditioning), or ventilation in a building

3.5 historical climate

climatic conditions in a microenvironment where a cultural heritage object has always been kept, or has been kept for a long period of time (at least one year) and to which it has become acclimatized

3.6

hygroscopic material

material which adsorbs moisture when the environmental relative humidity rises, and loses moisture when relative humidity drops

3.7

indoor environment

area within a building where cultural heritage objects are preserved

3.8

microclimate

climate on a small spatial scale

NOTE Typically refers to the microenvironment that interacts with the objects under consideration.

3.9

Relative Humidity

RH

ratio of the actual water vapour pressure to the saturation vapour pressure

3.10

target level

RH level that should be maintained to best ensure preservation

NOTE Determined by the historical climate of a given environment that has been proved not to be harmful to the preservation of objects. Otherwise, it should be specified by a qualified conservation professional.

3.11

target range

range of RH fluctuations that should not be exceeded to best ensure preservation

NOTE Determined by the historical climate of a given environment that has been proved not to be harmful to the preservation of objects. Otherwise, it should be specified by a qualified conservation professional.

4 General recommendations for organic hygroscopic materials

In general, organic hygroscopic materials require a mid RH range as the extremes (high and low RH ranges), affecting the EMC, can result in structural damage, deformation and cracking.

However, a material that has been stored for significant periods of time even in a poor quality environment will have become acclimatised to the conditions. Careful analysis of the material's needs is required to ensure that specified standard levels do not generate further damage.

Any change from a particular historical climatic environment may be problematic, even though the new conditions appear better for long-term preservation. If the change is sudden, the strain-stress may generate a climatic 'shock' leading to more intense levels of damage. Even if the change is slow, it may still generate stress and result in damage.

Therefore, the strategy of this standard focuses on maintaining the microclimate in terms of levels, seasonal cycles and fluctuations of temperature and RH, to which the materials have become acclimatized for a long time if this microclimate has been proved not to be harmful. Before a decision is made on the harmfulness or otherwise of pre-existing climatic conditions, the professional conservator involved in the project should carry out a condition report on the most vulnerable and/or valuable objects to be subjected to any environmental control proposal.

If the material has to be moved to a different climatic environment, then a careful, frequent monitoring of the condition of the material is necessary to detect symptoms of deterioration allowing stabilisation of environmental conditions which are appropriate for the needs of the materials.

When dealing with composite objects or when objects made of different materials occupy the same location, an evaluation of potential interaction between materials or parts of objects made of similar materials is necessary, as this situation is more complex. If there is synergy in the behaviour of the materials, the object as a whole may be more vulnerable than the most vulnerable of its component parts. However, the specifications concerning stability of temperature and RH and the importance of a careful consideration of the historical climate generally remain valid.

5 Approach to specifying temperature and RH for organic hygroscopic materials

5.1 Determination of priorities

Changes in EMC of organic hygroscopic materials induce dimensional changes, with possible internal stress cycles and related risk of deformation or cracking depending on issues of construction and materials. The risk is higher for anisotropic materials than for isotropic ones.

If the EMC and the resulting dimensional change of hydroscopic materials is affected more by changes in RH than in temperature, then RH should be maintained at historical climatic levels as closely as possible.

If, however, objects can be significantly affected by temperature change, the requirements for stability of both RH and temperature should be taken into account and adjusted accordingly.

5.2 Maintaining stable environmental conditions

When a stable RH is the priority, variations in RH should be avoided while taking into account reasonable parameters of cost, risk and benefits to the object, and spatially consistent; sharp variations in gradients and areas or devices that absorb or dissipate heat and moisture should be avoided.

Stabilising RH within a target range around average values or seasonal cycles typical of the climate history of the room will reduce the risk of physical damage. The most appropriate target range should not exceed the historical variability to which the artefact has become acclimatized, and should be based on all available past climate records covering a period of one or more calendar years. Only entire multiples of a calendar year should be used, and not fractions of it, to avoid bias due to an unbalanced number of different seasons. The method for determining the target range for RH is given in informative Annex A.

The objective of the preservation/preventive measures against physical damage is to avoid short-term fluctuations and cycles and to reduce steep and/or frequent variations in both temperature and RH which lead to physical damage of objects. Appropriate monitoring protocols should ensure that daily cycles be avoided or mitigated i.e. RH should remain constant during both day and night.

An analysis of data on the external, ambient conditions should be conducted in parallel with the regular monitoring of the internal environment. These conditions are influenced by the seasons, diurnal changes and weather extremes. The range of seasonal cycles should be narrowed and balanced the need for sustainable control. The insulating capacity of the building and the materials from which it is constructed are important factors for the maintenance of internal environmental stability.

If RH and temperature have the same priority, the above specifications hold also for temperature.

Stable RH can be obtained in one of the following ways:

- if the moisture content in air is constant, maintaining the temperature as constant as possible;
- if the moisture content in air is variable, vary the temperature in order to maintain a constant RH (when changes in temperature have no relevant impact on objects);
- if the moisture content in air is variable, add or remove moisture to the air, without altering temperature (if changes in temperature have relevant impact on objects);

- if the moisture content in air is variable, combine the two above methods (if temperature changes have not relevant impact on objects).

5.3 Priority of historical climate

When the condition of objects made of organic hygroscopic materials that have been kept in a specific microclimate for a prolonged period (at least one year) has been found satisfactory by qualified specialists in indoor climate and conservation; the historical climate in the room, including average RH levels, the range of variability of the natural cycles (seasonal or daily) and the rates of change should be kept unchanged. The only acceptable changes are improvements that reduce fluctuations in the climatic conditions.

When an object is moved for restoration or exhibition, the historical climate should be maintained as closely as possible. This holds also for transport or storage.

5.4 Further specifications

If, for whatever reason, the indoor microclimate is to be changed from the historical conditions, or if an object made of organic hygroscopic materials is to be moved into a new microclimate, research should be undertaken to evaluate the adaptation of the object to the new temperature and RH conditions, taking into account the storage history and the response of the object. Unfortunately, artefacts may appear to be adapting to microclimate changes without damage, but then fail suddenly and catastrophically (e.g. by cracking) in order to release accumulated stresses.

If for whatever reason, the historical climate is to be modified; the temperature and RH should be changed at a rate which is sufficiently low to allow a gradual adaptation. A slow rate of RH change reduces both gradients of moisture contents inside materials and related differential dimensional response leading to stress. Furthermore, stress relaxation occurs if the time period of the RH change is equivalent to the relaxation time constants of an object. A thorough investigation of the situation and the material should be carried out in order to determine this rate. It is also necessary to continually monitor the object during the period of change. Provided the object has been carefully assessed and the RH and temperature variations appropriately controlled, no change should be distinguishable in an object. Needless to say, if any deterioration is observed, the ongoing changes in RH and temperature should be halted immediately and the situation re-evaluated immediately.

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Annex A (informative)

Determination of the RH targets

A.1 Rationale

Indoor climate is defined by average levels and variability of temperature and RH. These are statistically represented in terms of:

- a) Average level over a selected period, e.g. one year
- b) Seasonal cycles
- c) Short-term fluctuations

This standard recommends that the historical climate be maintained, especially as far as RH is concerned if the object has been found to be stable. The above-mentioned statistical values (i.e. levels, ranges, cycles and fluctuations) should be used to verify if the climate has undergone any change and if so to what extent. The same values should be used as targets when heating, ventilating or air-conditioning (HVAC) systems are planned.

A.2 Environmental monitoring – data set

Evidence of for historical climate or the study confirming that there has been no change should be based on a programme of environmental monitoring conducted over a period of at least one year. If long term records are available only whole multiples of the calendar year should be used. These statistics constitute the data set on which calculations should be based.

Sampling intervals should be one hour or less, in order to respond to the time scale and the dynamics of the phenomena under investigation; so that the shortest fluctuation of interest is well documented.

The analysis proposed can be universally applied to both natural climates in buildings with no HVAC and to artificial climates in buildings where HVAC are operated. If, however, any influence has been documented to disturb excessively the climate, the target climate should be derived from the records for the periods without this influence.

A.3 Calculation of the target values

A.3.1 Average level

This level is determined as the arithmetic mean of the RH readings, i.e. sum of all observed levels divided by the number of observations. The first useful reference is the yearly average. The second is the series of monthly averages. The seasonal cycle (see below) interpolates the series of monthly averages.

A.3.2 Seasonal cycle

This cycle is obtained by calculating, for each reading, the central moving average (MA) which is the arithmetic mean of all the RH readings taken in a 30 day period composed of 15 days before and 15 days after the time at which the average is computed. For this reason, the 15 first and the 15 last days in the

sampling have not a sufficient set of data around them for such calculation. Therefore, if a moving average is requested for a whole calendar year, the sampling period should be extended by $15 + 15 = 30$ days and monitoring should cover a 395 day period in total. For example, if RH readings are recorded at an hourly interval, there are $24 \times 15 = 360$ values recorded during two 15-day periods before and after the current reading. In addition to them, we should add the current reading. In total we obtain $360 \times 2 + 1 = 721$. The MA for that reading is:

$$MA_{\text{current}} = (RH_{\text{current}} + RH_{\text{current}-1} + \dots + RH_{\text{current}-360} + RH_{\text{current}+1} + \dots + RH_{\text{current}+360})/721$$

where

RH_{current} , $RH_{\text{current}-1}$ etc are the current RH reading, the previous one, etc;

MA smooths out the short-term fluctuations and highlights longer-term trends or cycles.

A.3.3 Short-term fluctuations

A fluctuation is calculated as a difference between a current RH reading and a 30-day MA calculated for that reading as described above. Thus it takes into account both the natural seasonal variability and the stress relaxation time constant of the materials.

A.4 Determination of the target range

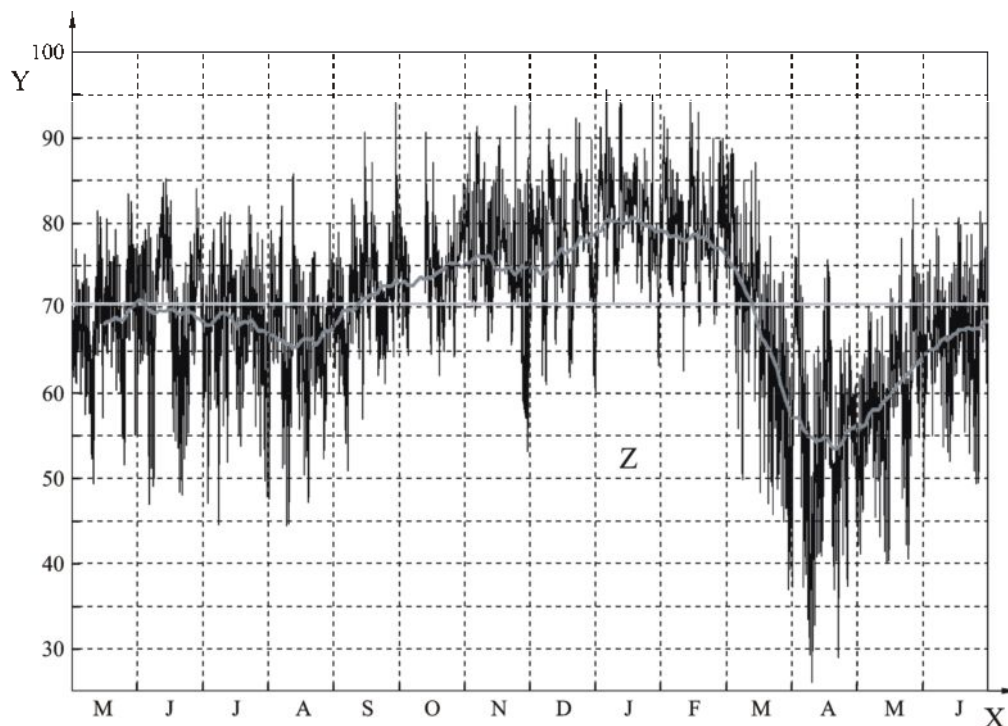
When the RH is stable there is no need to change the environment. If RH is unstable, the lower and upper limits of the target range of RH fluctuations are determined as the 7th and 93rd percentiles of the fluctuations recorded in the monitoring period, respectively. If the fluctuations follow a Gaussian distribution, these limits correspond to $-1,5$ and $+1,5$ Standard Deviation, respectively. For any distribution, the 7th or 93rd percentiles are obtained by ordering the fluctuations from the lowest negative value to the highest positive one and selecting the values below which 7th or 93rd percent of observations are found, respectively. In this way 14 % of the largest, most risky fluctuations are excluded, the cuts being equally applied to peaks and drops in RH, yielding excessively moist or dry environments.

However, if the above procedure determines that RH fluctuations depart by less than 10 % from the seasonal RH level, the calculated limit is considered unnecessarily strict and can be disregarded. The 10 % RH threshold can be accepted instead under responsibility of a qualified conservation professional.

This procedure should be used once. Iterated use will narrow the target range unnecessarily.

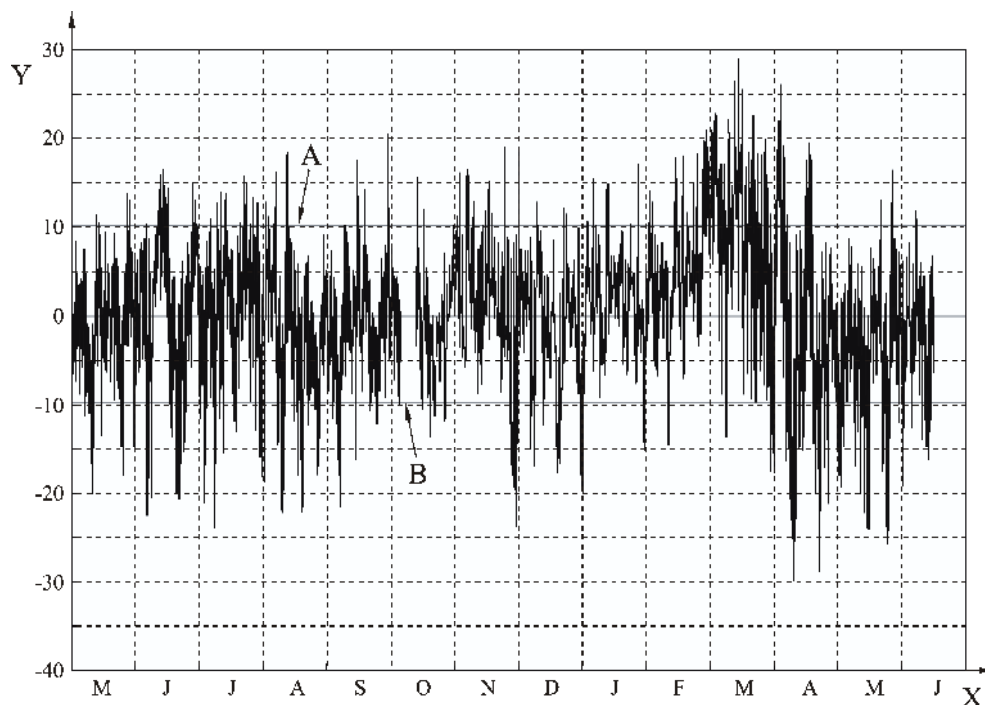
A.5 Example

A practical example, from a real case-study, is reported below to elucidate the procedure. Figures A.1 to A.3 show sample plots obtained with the described procedure. The figures are for information purposes only and the specific characteristics of the historical climate shown are not assessed.



NOTE The yearly RH average is marked by a horizontal line.

Figure A.1 — RH readings measured during one year (the jagged black line) and a seasonal RH cycle (smooth grey line) obtained by calculating the 30-day central moving average of the readings.



NOTE Lower and upper limits of the range are calculated as the 7th and the 93rd percentiles of the fluctuation magnitudes, respectively

Figure A.2 — Target range of RH fluctuations

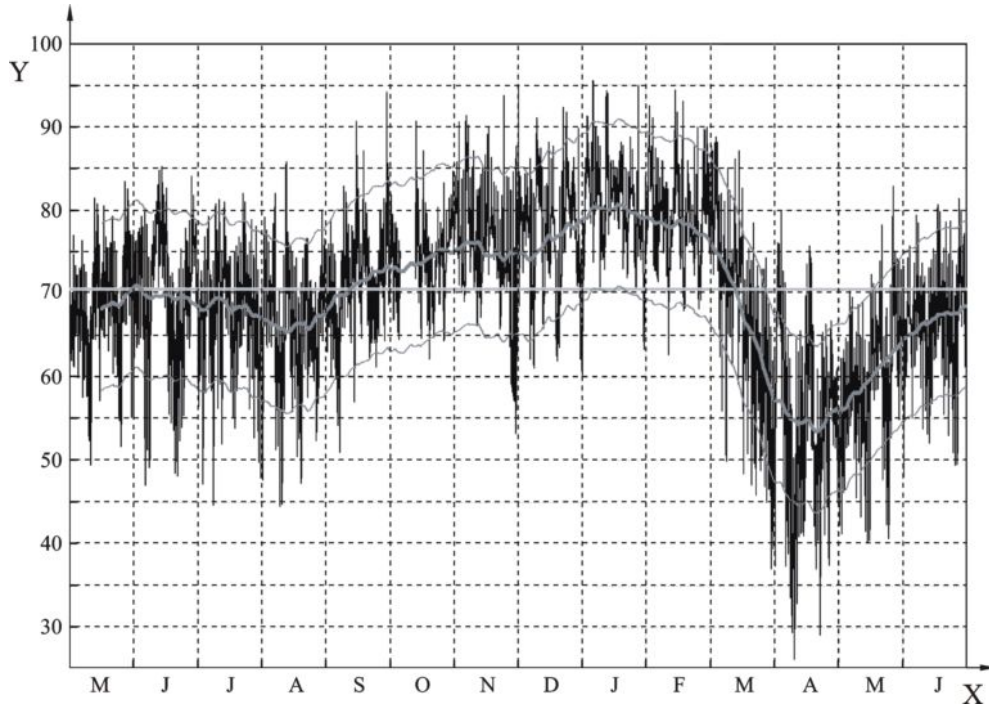


Figure A.3 — Target RH values for this sample set of RH readings

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