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Expert report

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Museum and Archive Environment Monitoring:
13 Expert Tips

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Abstract

Storage in an appropriate climate – i.e. temperature and air humidity compatibility with an object – is one of the most important factors in the conservation of art and cultural assets. While other potentially damaging factors can be reduced or eliminated with some ease, heat and humidity are always present and difficult to control. Plus, depending on the composition of these artifacts and artworks, conditions that are suitable for one material may be unfavorable or even damaging for another.

While lower temperatures are preferred since they can slow natural aging and damage, the comfort of both visitors and museum staff must also be considered. In addition to temperature, sufficient light and clean air also require careful maintenance in order to guarantee enjoyment of the exhibition for visitors and provide adequate working conditions for museum staff. All these factors have the potential to damage a collection's delicate artifacts, so creating a suitable climate in which to store, display, and protect these items is of the utmost importance.

Acceptable climate ranges for these priceless works depend not only on the combination of materials that make them up, but also on how they were constructed. While there is no narrow, generally applicable climate that works for every kind of item, we do have optimal ranges for individual material groups. Despite the natural desire for simple standard values, a discerning view of the museum's indoor climate and its relationship to the collections is necessary. Therefore, compromises must be made.

Museum and Archive Environment Monitoring
13 Expert Tips

Uncontrolled temperature and humidity fluctuations have shown a potential for permanent damage to works of art. Automated, state-of-the-art and reliable museum climate monitoring is vital to your exhibits' protection. To bring better understanding to how indoor climate affects your collections, Testo has put together a 13 point overview we are presenting here. The development of the paper was supported by Cord Brune (Certified Restorer M.A.), a well-known German conservation expert with more than 20 years professional experience.

Your Testo Inc. Team

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Temperature

Temperature describes how hot or cold a substance is. Warmer temperatures accelerate chemical reactions, causing objects to age faster, while colder temperatures help substances age slower. Increased heat can also lead to softening and an alteration of shape in some materials that make up a museum's collection (example: wax).

As air temperature increases, the relative humidity of the affected area begins to decrease. As a result, the moisture content of materials can change, often leaving the material dried out. If this happens even superficially, for example due to heat from lighting, mechanical tensions in the material's structure can occur and damage the item.

Air humidity

Absolute air humidity (g/m^3) refers to the proportion of water vapor in the air. The higher the air temperature, the more water vapor the air can absorb. Absolute air humidity is the water vapor mass contained in a certain volume of air.

Relative air humidity (%RH) is the relationship of the actual mass present to the maximum possible mass of water vapor in the air. Expressed another way, it is the relationship between the absolute humidity and the maximum air humidity at a given temperature.

Material moisture

Material moisture is the quantity of free water contained in a solid substance. Hygroscopy refers to the property of substances to bind humidity from their surroundings (usually in the form of water vapor from the air humidity) and it plays an important role in material moisture. Many inorganic, solid substances melt or clump together when they take on water (example: cooking salt).

Porous inorganic and organic materials usually release the humidity again in the right conditions. After a certain time, equilibrium with the ambient air humidity is created. This equilibrium moisture is achieved at different speeds depending on the material and the structure of the surface. For example, textiles achieve this equilibrium quickly, while painted wood does so much slower.

Dew point

The dew point is the temperature at which the rate of condensation is greater than that of evaporation, which causes liquid water, or condensation, to form (100% relative humidity). This can happen when a cool object is transported into a warmer, more humid room, or when a room is ventilated with warmer outside air.

Condensation can also occur within a porous material if there is a temperature gradient in the interior – for example in an outer wall in winter. If this happens repeatedly, a building's wall can be significantly damaged. To prevent this, objects in transport must be slowly acclimatized to the temperatures at the destination. A sufficient distance of the object temperature (or wall temperature) to the dew point temperature is also mandatory.

Climate's influence

A wide range of indoor and outdoor factors can determine the climate conditions for a museum's collections and objects, and the extent and the effects stemming from these factors differ from case to case. It is not enough to simply be aware of these factors. One must emphasize exact measurement, recording, and analysis of the climate data obtained in these evaluations and use it to protect and secure their collections. This is exactly why an evaluation of the individual climate situation for a facility should be conducted on site.

Outdoor climate

Outdoor climate's influence on indoor climate depends largely on the construction of the building exterior. Nevertheless, temperature curves, solar irradiation, and precipitation remain the most potent influences on a building's temperature and differ locally from year to year, necessitating a climate control system that responds as required. Air temperature is especially important, as colder temperatures or frost in winter lead to drier air while increased air humidity stems from warm, humid periods in summer. During intermediate periods, short term/daily changes of extremes can sometimes occur as well. These constant changes in temperature and pressure clearly speak to the need for reliable, consistent climate monitoring.

Ideally, the building absorbs these fluctuations to a great extent. A large, passive building mass, good insulation, and small openings such as windows and doors help facilitate this process. In fact, the heating of large surfaces by direct solar irradiation presents a large potential for disruption. It is also important for a building to resist moisture penetration (from both precipitation and ground moisture) as much as possible. This is an especially great challenge for historical buildings, and should be met with strong awareness of air conditioning needs.

Determining parameters

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Indoor and micro-climate

With indoor climate, an exhibit's local room climate is the most important factor to consider. Every room can have differing climatic values; there can even be different climate zones within a room. For instance, a window is usually cooler and more humid than the surrounding area of the room. If such a zone is limited in size it is referred to as a micro-climate, examples of which include behind a picture or piece of furniture placed on an outer wall (usually cooler and humid), or area around a radiator (usually warmer and drier).

Showcases and frames

Sealed showcases or glass frames create a climate separate from that of the room it resides in. However, these separate climates are not necessarily suitable for the item being displayed. In order to protect especially sensitive objects, a controlled micro-climate can be constantly adjusted to suitable humidity values with the help of micro-climate appliances (for showcases), or with buffering silica gel.

Heating and room temperature control

Temperature control is intended to produce comfortable temperatures in a building for its occupants and to compensate for heat loss to the exterior. For buildings that store or display delicate art and artifacts, conventional air heating systems tend to be unsatisfactory. High radiator temperatures during a heating period can interfere considerably with air humidity level by drying localized air, leading to an inconsistent and unreliable interior climate. Newly developed systems such as displacement ventilation (example: Museum Brandhorst, Munich)[1] or building component temperature control (example: Kunstforum Ostdeutsche Galerie, Regensburg)[2] can prevent these problems and reduce costs.

Under certain circumstances, a moderate room temperature can reduce increased air humidity to some extent. This is often referred to as conservation heating.

Ventilation

Ventilation, or the necessary introduction of outside air into a space, is another major factor that affects indoor climate. For exhibition areas, one complete exchange of the air volume per hour is recommended (air exchange rate 1). While this process takes place free of artificial control through building seams or openings like windows or doors, controlled ventilation (sometimes with technical support) can reduce climatic fluctuations in many cases. In warehouses or storage facilities, where there is a lack of public traffic, exchange rates can be considerably lower (unless there is contaminant pollution).

Basics and definitions II

Air conditioning systems and portable air conditioners

Air conditioning systems contain components for heating, cooling, humidifying, dehumidifying and filtering the air to create the desired climate for an area. These systems involve a high level of technical effort, and carry the possible risk of breaking down at any time, leading to massive climatic problems. Creating a local climate for an object in a display with a centralized system is even more difficult since humidity fluctuations are usually greater than expected.

Light

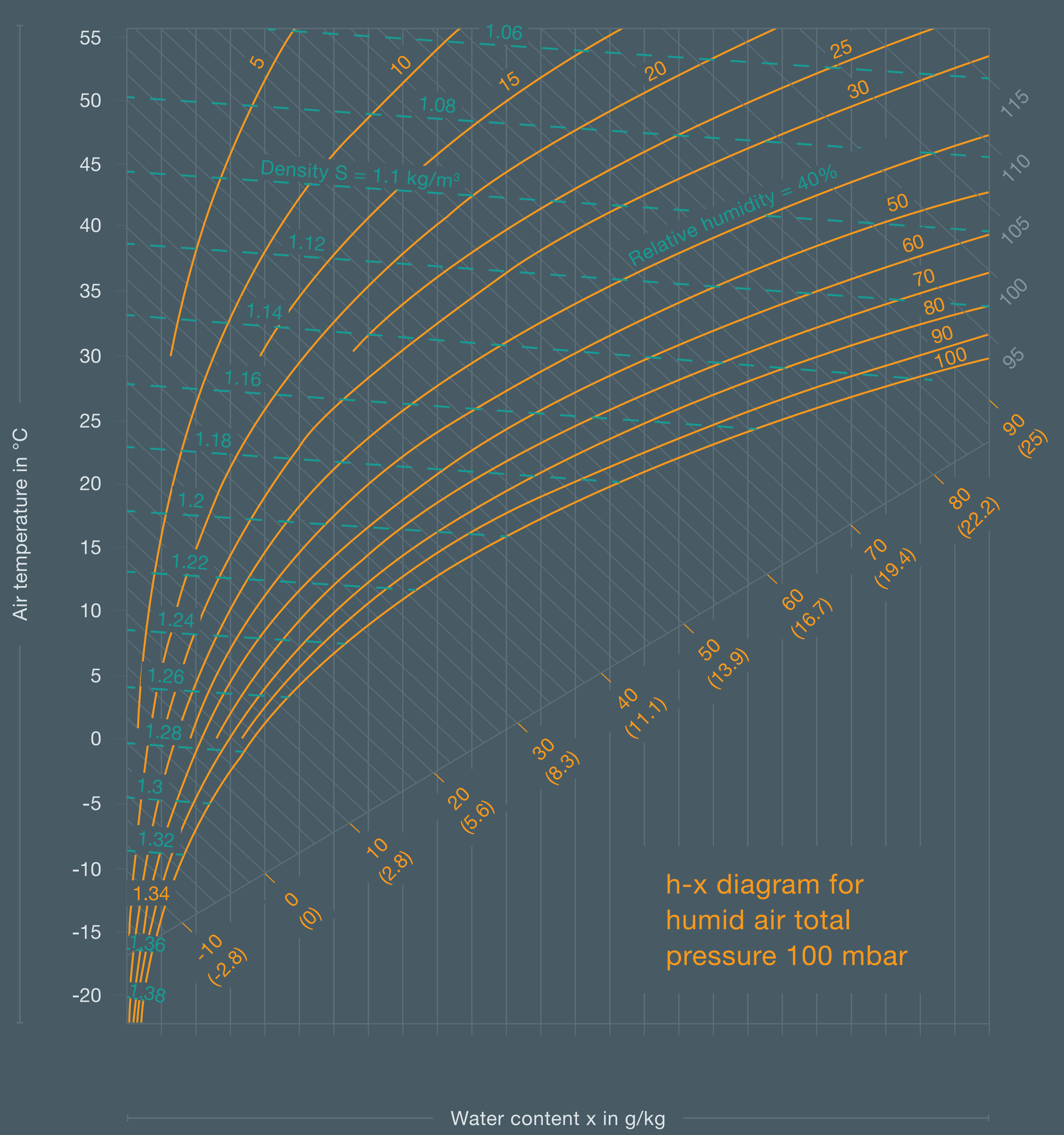
While all luminescent bodies emit heat, some produce much more than others, depending on their type and purpose. For instance, LEDs produce low amounts of heat while fluorescent tubes are considerably warmer. Halogen lamps and other light sources can become very hot as well. Light from sources like halogen bulbs and sunshine contain a high level of heat radiation, which have the potential to cause irreparable damage to items. This is especially true for objects displayed in glass cases. Light passing though glass heats the air inside, causing internal humidity to sink rapidly and damage to occur to the items located within.

Use

Finally, the way in which a collection is used and cared for has an influence on the climate at the object. In permanent exhibitions the conditions caused by visitors, lighting, air conditioning technology, and frequent cleaning measures (like floor mopping) are different than those in a storage facility. All these conditions can have a negative effect on a collection's pieces if they are not properly managed.

Objects in temporary exhibitions are exposed to additional influences, as well. Changing climate (transporting from storage to exhibition), possible lending to other facilities or museums, fresh paint, etc. can all have a serious effect on a piece of art.

Mollier-h-x diagram



The right climatic values[3]

German experts recommend an additional prioritization in the consideration of indoor climate values. At the international level too, excessive humidity is given priority over avoiding temperature increases.

Priority	Parameter	Nominal value
1	Change in rel. humidity over one hour	**≤2.5 %** The change should be as slight as possible, the frequency of fluctuations as small as possible.
2	Change in rel. humidity over one day	**≤5 %** The change should be as slight as possible, the frequency of fluctuations as small as possible.
3	Minimum and maximum rel. humidity values over one week	Wood: **50 % to 60 %** | Canvas: **50 % to 55 %** Paper: **45 % to 50 %** | Metal: **5 % to 40 %** If objects made of different materials are stored or exhibited, the values can only be a compromise between the conservation requirements of the individual materials.
4	Seasonal shift in rel. humidity over one year	**+5 %** (summer) **to -5 %** (winter) over the weekly values (priority 3) The previous history of the objects, building conditions or regional peculiarities (climate zones) can also be reasons for lowering or raising the rel. humidity.
5	Change in temperature over one hour	**≤2.5 %** The change should be a slight as possible, the frequency of fluctuations as small as possible.
6	Seasonal shift in temperature over one year	**39.2 to 82.4 °F** From the conservation point of view, lower temperatures are advantageous for the majority of materials exhibited. The indoor temperature is set accoridng to the average monthly outdoor temperature, the difference between the two being as small as possible. Increased temperatures in the range between 75.2 and 82.4 °F are permitted for a maximum of 150 hours per year.

Classes of control[4]

Data on climate regulation in museums, as currently quoted in most international publications, and based on the corresponding guidelines/recommendations.

Class of Control		Maximum Fluctuations and Gradients in Controlled Spaces	
		Short Fluctuations plus Space Gradients	Seasonal Adjustments in System Set Point
AA	Precision control, no seasonal changes, with system failure fallback	±5% rh, ±4 °F	Relative humidity no change Up 9 °F; down 9 °F
A	Precision control, some gradients or seasonal changes, not both, with system failure fallback	±5% rh, ±4 °F	Up 10% rh, down 10% rh Up 9 °F; down 18 °F
A	Precision control, some gradients or seasonal changes, not both, with system failure fallback	±10% rh, ±4 °F	rh no change Up 9 °F; down 18 °F
B	Precision control, some gradients plus winter temperature setback	±10 %rh, ±9 °F	Up 10%, down 10% rh Up 18 °F, but not above 86 °F
C	Prevent all high-risk extremes	Within 25 to 75% rh year-round Temperature rarely over 86 °F, usually below 77 °F	
D	Prevent dampness	Reliably below 75% rh	
Set Point or Annual Average: 50% rh (or historic annual average for permanent collections) **Temperature set between 59 and 77 °F**			

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Referenced expert literature

[1] BauNetz Media GmbH: Museum Brandhorst in Munich. Downloaded on November 26 2015, from http://www.baunetzwissen.de/objektartikel/Heizung-Museum-Brandhorst-in-Muenchen_778119.html

[2] Michael Kotterer, Henning Grosseschmidt: Klima in Museen und historischen Gebäuden – Vom konservatorisch richtigen Heizen und Lüften. In: Beiträge zur Erhaltung von Kunst- und Kulturgut 1 (2008), p. 98. Downloaded on November 26 2015, from http://www.kunstforum.net/doc/vdr1_2008.pdf

[3] Andreas Burmester: Die Beteiligung des Nutzers bei Museumsneubau und -sanierung oder: Welche Klimawerte sind die richtigen? In: Fachinstitut Gebäude-Klima e.V. (Hrsg.): Raumklima in Museen und historischen Gebäuden: Kongressbericht. Bietigheim 2000, p. 9-24.

[4] ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers): ASHRAE Handbook: Heating, Ventilating, and Air-Conditioning Applications, I-P Edition. Atlanta 2011, Page 23.13, Table 3.

About this publication

The original paper of the expert report written by Cord Brune has been published in March, 2016 by Testo AG under the title: “Kompaktes Klima-Wissen für Restauratoren – 13 grundlegende Faktoren” and is the basis for this publication.

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40 White Lake Rd.
Sparta, NJ 07801

Phone: 800-227-0729
Fax: 862-354-5020
E-mail: info@testo.com
Website: www.testo.com