# Factsheet:

## Temperature and Humidity

SCOTTISH MUSEUMS COUNCIL

## Introduction

Stable environmental conditions are amongst the most important factors in the preservation of museum collections. Temperature, humidity, light levels and air quality all need to be controlled. This factsheet deals with the effects of temperature and humidity. The effects of light levels and air pollution are discussed in two separate factsheets.

## Humidity

### Organic materials

Plants and animals contain a high proportion of water, and it is therefore not surprising that their products - organic materials, such as wood, paper, cotton, linen, wool, silk, parchment, leather, fur, feathers, ivory, bone and horn - also retain moisture. These materials are **hygroscopic**. They can and will absorb or give off moisture until they reach a state of equilibrium with the air that surrounds them.

When the surrounding air is very **dry**, organic materials will **give off** some of their moisture: they become brittle and may shrink, warp, split or crack.

When the surrounding air is **damp**, the materials will **absorb** some of the moisture from the air: they may swell, cockle, warp, change shape and/or lose strength. Dampness can also cause mould and fungal growth on organic materials.

### Inorganic Materials

Inorganic materials (glass, ceramics, metals and minerals) are also affected by high or low humidity. Materials that have a natural salt content may suffer from **efflorescence** when the air is dry. The salts in deteriorated glass, porous ceramics and some geological material are carried to the surface by moisture (which may have entered the pores during a period of higher humidity). The moisture evaporates and the salts crystallise on the surface.

Other inorganic materials are affected by high humidity: metals (particularly iron and copper alloys) **corrode**; dyes and pigments **fade** more readily; and geological material can suffer from **pyrite decay.**

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## Physical Damage

If the humidity of the air changes frequently, hygroscopic materials will swell and shrink repeatedly. This causes **internal stress** and **damage**, and can particularly be a problem in composite objects where the different materials have different rates of shrinkage. The expansion of one material may force changes in the dimensions of another, causing considerable tension and eventually damage (e.g. skins on drums, paintings on wooden panels).

Moisture can also start or speed up the damaging effect of air pollutants and other harmful substances on many museum items (refer to SMC factsheets *Air Pollution* and *The Effects of Storage and Display Materials on Museum Objects*).

## Temperature

Although most objects are not **directly** sensitive to temperature, there are good reasons for controlling the temperature in areas with collection items, as temperature changes do affect the items **indirectly:**

Changes in temperature cause changes in the **humidity** of the air. Objects can be very sensitive to changes in humidity, and it is therefore important to maintain humidity at a stable level. **This is the main reason for controlling the temperature.**

**Chemical processes** and **biological activity** are speeded up when the temperature increases.

Some materials **expand and contract** when the temperature changes. For composite objects whose parts expand at different rates an unusual change in temperature may be particularly damaging.

People working in, or visiting, areas with collection items require a temperature which is comfortable for them.

## How Do Temperature and Humidity Work Together?

As mentioned above, the **humidity** of the air depends on the **temperature** of the air:

- one cubic metre of air can hold 10g water at 10°C; but
- the same cubic metre can hold more than 30g water when the air is heated up to 30°C

Measuring the ***absolute*** **humidity** (the amount of moisture in grammes) would not be very useful, because 10g water makes air feel very damp at 10°C, but it leaves air still quite dry at 30°C. This is why ***relative*** **humidity** (RH) is used to measure the dampness

or dryness of the air. Relative humidity is expressed as a percentage of the maximum amount of water the air can hold at that temperature:

- at 10°C, 10g water is the maximum amount the air can hold, so the RH is 100%
- at 30°C, 10g is about one-third of the maximum amount, therefore the RH is approximately 33%

This means that a change in temperature causes a change in relative humidity. If the temperature fluctuates between day-time and night-time, the relative humidity will also fluctuate. This principle is an important factor in the control of the relative humidity (see below).

**Recommended Levels for Temperature**

In general, a moderately fluctuating temperature between 10 and 20°C is acceptable for museum objects. Below 10°C it can become more difficult to maintain recommended humidity levels, and problems with condensation may occur. Above 20°C degradation processes will take place increasingly quickly. For people's comfort a band within this range has been determined within which both objects, museum visitors and staff feel comfortable. The band lies between 16 and 20°C, therefore

***the recommended temperature for museum items is 16 to 20°C***

For areas that are not frequented by staff and/or visitors (such as stores), the temperature may be lower than 16°C, but it is important that items are allowed to acclimatise gradually when they are moved from storage to display areas and vice versa.

**Recommended Levels For Relative Humidity**

The maximum level for relative humidity is determined by the point at which mould and fungal growth starts. Mould and other fungi need a humidity of at least 70% RH, therefore

***the recommended maximum level for relative humidity is 70%***

Below 40% humidity-sensitive items can become unacceptably dry and brittle, therefore

***the recommended minimum level for relative humidity is 40%***

Within these outer limits, **some materials require more specifically controlled levels** of relative humidity. A table with desired levels for different types of collections can be found at the end of this factsheet.

## Monitoring Temperature and Humidity

Scotland is infamous for its cold and wet climate. In winter the temperature may drop to around freezing point with humidity levels between 70 and 90%. However, when this air is heated up for use inside a building, the humidity will fall considerably. Many Scottish museums therefore suffer from **low winter humidity**. In summer the temperature can rise to 17°C or more, and the humidity levels may fluctuate between 65 and 95%, giving a **high summer humidity** in museum buildings.

In a naturally ventilated building in sound condition, it can be expected that the indoor conditions will respond to the outdoor conditions. But there are many factors that can affect the temperature and humidity inside a building, in a display room, or even around one particular object.

The indoor conditions may be affected by the following **external** factors:

- **Water penetration** or **rising damp** can cause high humidity levels if the building is in poor condition or badly maintained
- **Sudden weather changes** can cause dramatic fluctuations if the building is not insulated
- **Direct sunshine** on metal roofs and glass skylights can cause considerable heat gain and day-night variations inside

(Parts of) the indoor conditions may be affected by the following **internal** factors:

- **Poor air circulation or ventilation** can cause local conditions (*micro-climates*) that differ from the ambient conditions
- **Heating systems** run for people's comfort only (e.g. on at 8am, off at 5pm) can cause day-night fluctuations.
- **Visitors** produce moisture, particularly when it rains (wet coats and umbrellas)
- **In-case lighting**, or **spot-lights** directed at objects, can create local pockets of high temperature and low RH
- **Radiators** or **heating units** underneath or near a museum item can cause very low humidity levels for that particular item
- **Display cases,** generally used to provide a more favourable environment, can also have the opposite effect: an adverse micro-climate can develop

**Continuous Monitoring**
To gain an understanding of the temperature and humidity levels in the museum, it is essential that they are **monitored continuously.** Once conditions have been monitored over a period of at least 12 months, the results give a picture of the environmental conditions within the building. They will indicate which areas are suitable for what type of items, which areas need additional control equipment to make them suitable for museum items, and which areas are not suitable at all.

**Fluctuations**
As can be seen above, there are many causes for fluctuations in temperature and humidity. These fluctuations can cause damage to museum items and should therefore be avoided or minimised.

In particular, fluctuations that occur **repeatedly** over a period between a few hours and a few days are potentially damaging. The changes take place slowly enough for the objects to adjust to them, but fast enough to cause frequent movement, stress and fatigue in the material.

**Occasional very rapid** fluctuations (within 1 or 2 hours) will have a less damaging - though by no means negligible - effect on items. **Very gradual** fluctuations will give the items enough time to acclimatise slowly.

Some types of items are more affected by fluctuations than others. In general, when transporting items to an area with different environmental conditions, it is a good idea to keep items well packed and wrapped in acid-free tissue and a box or blanket. This will ensure that acclimatisation to the new conditions can take place gradually.

## Controlling Temperature and Humidity

Stable internal conditions can only be achieved if the building is providing an effective barrier against external environmental conditions. This can be achieved by ensuring that the building is in sound condition. A building survey will indicate whether any parts of the building need maintenance or repair, and should ideally be carried out once every five years. An energy efficiency survey will indicate whether the insulating properties of the building or the building services need improvement.

To reduce the adverse effect of the external conditions on the indoor environment, the following steps can be taken:
· keep all windows closed at all times
· keep the entrance door closed as much as possible (alternatively install double doors, a vestibule or a revolving door)
· apply solar control film on windows and skylights to reduce the effect of direct sunlight

In addition, control equipment such as heaters, humidifiers or dehumidifiers may be needed to create and maintain a stable environment. To ensure that pieces of control equipment work efficiently, it is important that they complement each other, but can be made to function individually if so desired.

As a stable relative humidity is the main aim when controlling temperature and humidity, the temperature can be allowed to fluctuate moderately in favour of the stability of the relative humidity. It also means that the humidity levels can be used to control the heating, and this can be achieved by controlling the heating system with a humidistat rather than a thermostat. However, in situations with large fluctuations in humidity the

use of humidifiers or dehumidifiers can be more cost-effective.

It cannot be stressed enough that **stability** is the most important factor when determining and maintaining desired humidity levels. Preference should be given to maintaining a stable level **approximating** the desired level **all of the time**, rather than maintaining the exact desired level only part of the time.

**Micro-climates**
In some situations it can be difficult or not financially viable to control the environment of an entire building. In those situations control on a smaller scale may be more practical.

For items on display the conditions can be improved by using air tight display cases in which the environmental conditions can be controlled with silica gel, or even with humidifiers and dehumidifiers if the budget allows. They can also be used to create micro-climates for items that need different environmental conditions (e.g. very low humidity for iron objects; low oxygen levels for rubber items). If air tight display cases are used, it is important that the conditions inside the case are continuously monitored, to prevent the development of adverse micro-climates. Small display cases can be fitted with humidity-indicator strips, dial hygrometers or small electronic hygrometers. Large cases can be fitted with a thermohygrograph, or with an electronic sensor if an electronic data logging system is used.

For stored items the conditions can be improved by using enclosures. Each enclosure around an object will act as a physical buffer, and will **slow down** the damaging effects of adverse conditions. In this way conditions around individual items can be greatly improved by using acid-free tissue, Melinex sleeves or cotton covers, inside boxes or trays with lids, inside cupboards, wardrobes, plan chests, chests of drawers etc. It is also important that doors of store rooms are kept closed at all times, and that storage areas are not used as corridors.

## Further information and advice

This is one of a series of factsheets, advice sheets and guidance notes produced by SMC on common collections care and preventive conservation issues. For more details, signposting to further sources of advice or information on how to contact a conservator, see our website at: www.scottishmuseums.org.uk


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## Advice Sheet: Desired levels of Relative Humidity for Museum Collections (at normal temperatures)

**ARCHAEOLOGICAL SPECIMENS**
(not at site) Humidity-sensitive items (wood, leather, fibrous components), 40-60%. Stone, ceramics, metallic specimens, other inert materials, 20-30%, or even less - if corrosion products or salts are active.

**ARMS, ARMOUR, METALS**
15-40%, according to condition of metal and oxide formations. Wooden components need special protection. Polished metals, eg brasses and bronzes do not tarnish at 15% RH or less.

**BOTANICAL OBJECTS, DRIED PLANTS, SEEDS**
40-60%

**CERAMICS, TILES, STONE**
20-60%, depending on embedded salts being present. Susceptible to `freeze-thaw cycles' form of damage, if exposed out of doors.

**COINS, NUMISMATIC COLLECTIONS**
15-40%, depending on corrosion products, oxides and patina formations, and their degree of stability.

**COSTUMES, TEXTILES, RUGS, TAPESTRIES**
30-50%. Silk and wool are more sensitive to moisture damage than cotton or linen. Painted textiles are most sensitive to RH changes. Synthetic fabrics are less reactive, but exhibit electrostatic properties at low RH values, and readily accumulate dust at surfaces.

**ETHNOGRAPHIC BARK, CLOTH, BASKETRY, MANILLA, SISAL, MASKS, FEATHERS, LEATHER GARMENTS**
40-60% according to specific reactivity.

**FURNITURE, MARQUETRY**
40-60%, depending essentially on wood content, grain, joining, and condition of surface or barrier coatings; especially affected by seasonal RH drifts or cycles. Some woods are less sensitive than others owing to resin content, or construction.

**GEOLOGICAL MATERIAL**
45-55%. Minerals, rock and fossil material containing pyrite maximum 50%, ideally 30%.

**GLASS**
40-60%. Crizzled glass needs narrower band of controlled RH (eg 40%) to prevent advance of this condition. Other kinds of glass, RH not too critical.

**INSECTS, DRIED AND MOUNTED, AS IN ENTOMOLOGICAL COLLECTIONS**
40-60%

**IVORIES, BONE CARVINGS**
50-60%, requiring more control than anatomical collections. Dimensional responses very slow, except when in thin sheets, as in ivory miniatures.

**LACQUER WARES**
50-60%. Japanese authorities recommend higher levels to 70%.
**LEATHER, SKINS, BINDINGS**
45-60%. Variable according to tanning process.

**PARCHMENT, VELLUM**
55-60%. Narrow control required because of great hygroscopicity.

**PAPER**
40-50% (some authorities recommend less)

**STRETCHED PAPER**
45-55%. Paper screens, oriental screens, drawings on stretched frames, need narrow RH control.

**PHOTOGRAPHS, FILMS, (CINÉ, AUDIO AND VIDEO MATERIALS)**
30-45%. The gelatin is reactive, as is support paper; plastic film components less responsive.

**PAINTINGS ON CANVAS**
40-55%. Unlined paintings, or paintings lined with hygroscopic adhesives are more reactive than those lined with wax or synthetic materials.

**PAINTINGS ON WOOD, POLYCHROME SCULPTURES**
45-60% depending on thickness, wood grain, ground and method of joining sections. Some panel paintings need narrow RH levels to minimize warping. Massive wood sculptures particularly susceptible to seasonal drifts.

**PAINTED, VARNISHED WOOD, VARIOUS**
45-60%. In this category are musical instruments, models, decorative objects having painted or coated wood as the principal components.

**PLASTIC MATERIALS**
30-50%. In general, plastic materials, eg acrylic supports, sculptures, castings, have slight humidity responses, but do warp when in thin sheets and exposed to varying conditions. Electrostatic properties at low RH levels with dust accumulations.

Based on: STOLOW, N, *Conservation and exhibitions: packing, transport, storage, and environmental considerations.* London, Butterworths, 1987.