Humidity and Temperature

Objectives

At the end of this chapter you should:

- know some of the adverse effects that extremes and fluctuations in relative humidity and temperature have on objects;
- understand the relationship between relative humidity and temperature; and
- be able to take steps to limit damage to collections caused by fluctuations in relative humidity and temperature.

Introduction

Relative humidity and temperature are essential components of a comfortable working environment. However, there can be some conflict between the needs of people and the requirements for the care of collections.

Relative humidity—RH—is the amount of water vapour contained in the air at a particular temperature compared with the total amount of water vapour the air can contain at that temperature. Relative humidity is expressed as a percentage. Various materials respond differently over a range of humidity levels and there is an optimum level of RH suitable for the display and storage of mixed materials.

Extremes of relative humidity and temperature can adversely affect the condition of objects, particularly those made of organic materials. But it is important to remember that many materials will stabilise in a particular climate, even though conditions are extreme. Once stabilised and conditioned to the climate, these materials will not necessarily be adversely affected by the constant, extreme conditions.

If the climate changes or objects are moved to a different climate, problems can arise. Changes in relative humidity and temperature—particularly rapid changes—are potentially far more damaging to most materials than are constant extremes. These changes can occur easily with sudden changes in the local weather, when air-conditioning units break down, and when objects are moved from storage boxes to open display or from one region of the country to another.

Steps can be taken to minimise fluctuations in relative humidity and temperature, and to protect valuable collections from the adverse effects of extremes of relative humidity and temperature. To do this, it is useful to understand how relative humidity and temperature are related, what causes relative humidity to fluctuate, and to know what effects they have on different types of materials.

What is relative humidity?

Heat really needs no explanation. You may have difficulty defining it, but you're certainly familiar with the experience of it. Relative humidity, on the other hand, does need explanation.

Water is an extremely pervasive substance and can be found everywhere on the planet—including in the air, where it's held as vapour.

The capacity of air to hold water-vapour varies according to the temperature of the air.

The warmer the air, the more water-vapour it can hold. As the air cools down, its capacity to hold water will decrease.

Relative humidity is a measure of the amount of the amount of water-vapour contained in air at a particular temperature. It is basically a comparison between:

- the amount of water-vapour held in the air at any one time and at a particular temperature; and
- the total amount of water-vapour which the air **can** hold at the same temperature, that is, the amount of water which will saturate the air at that temperature.

Relative humidity is expressed as a percentage. This can be written as an equation:

$$RH = \frac{\text{water-vapour present in the air}}{\text{water-vapour required to saturate air at that temperature}} \times 100\%$$

As the temperature of air increases, its capacity to contain water-vapour increases. For example:

- At 0°C the air can hold about 6 grams of water for each cubic metre of air, that is, 6g/m^3.

- At 10°C this increases to 10g/m^3
- At 20°C it increases to 17g/m^3
- And at 30°C it increases to 30g/m^3

So, if air at 20°C contains 8.5g/m^3 of water-vapour:

$$RH = \frac{8.5}{17} \times 100\%$$

$$= 50\%$$

Thus the relative humidity would by 50%.

How does relative humidity change?

Relative humidity is a measure of the amount of water-vapour contained in air at a particular temperature. The capacity of air to hold water-vapour varies according to the air temperature.

However, although raising the temperature increases the capacity of air to hold water, there is not always water available to move into the air to fill that increased capacity. So changes in temperature often lead to quite significant alterations to the relative humidity.

For example, in an empty, sealed box containing a fixed amount of water-vapour, raising the temperature will lower the relative humidity. This is because the capacity of the air to contain water has increased but the actual amount of water has remained the same. Using our previous example of air at 20°C with 8.5g/m^3 of water-vapour, if the temperature is raised to 30°C and no additional water is available:

at 20°C $RH = \frac{8.5}{17} \times 100\% = 50\%$ BUT at 30°C $RH = \frac{8.5}{30} \times 100\% = 28.3\%$

The reverse is also true. If the temperature in a sealed box continuing a fixed amount of water-vapour is lowered, the relative humidity will increase. The capacity of the air to hold water has decreased but the amount of water has remained the same.

This is an important concept, because display cases and sealed storage areas in some ways behave like sealed boxes; and the relative humidity can vary because the temperature varies.

This principle can also be applied to some extent to museums, galleries and libraries. But they are generally far more complex.

They have doors which admit moisture-containing air from the outside, where the temperature and relative humidity is usually different from the inside conditions.

People come into these areas. They raise the temperature, especially when they are in large groups; and they take in and give out moisture as they breathe.

Museums, galleries and libraries contain objects which take up water and give out water, according to the temperature of the surrounding air.

There may also be heating and cooling devices and/or air-conditioning in the building.

Why worry about relative humidity and temperature?

Relative humidity and temperature are two of the environmental factors which can contribute to the deterioration of our valued collections.

A bark painting—split after drying out in a low relative humidity environment.

Photograph courtesy of Artlab Australia, reproduced with permission of the Museum of Victoria

Extremes of temperature and relative humidity—and rapid fluctuations in these—can lead to a range of problems. The risks of physical damage, such as warping, cracking and splitting, chemical deterioration, and insect or mould attack are all increased when temperature and relative humidity are too high or too low.

The discolouration of the cotton proceeded much more rapidly in a damp environment.

Photograph courtesy of Artlab Australia

Insects generally like a warm damp environment.

Photograph courtesy of Artlab Australia

For more information

For more information about insects and mould, please see the chapter on Biological Pests in this volume.

The effects of extremes and fluctuations in temperature

Extremes and fluctuations in temperature are potentially less harmful than extremes or fluctuations in relative humidity; but it is difficult to separate the two because they are closely interrelated. Some independent effects of high temperature include:

- increased biological activity. Most insects and moulds thrive and reproduce readily in warmer conditions; and
- acceleration of chemical deterioration processes. Temperature affects the rate at which chemical reactions take place. For example, a temperature rise from 20–30ºC may double the rate of some degradation reactions. And this worsens if light, water or pollution also contribute to these chemical reactions.

For more information

For more information about how light and pollutants can affect chemical deterioration, please see the chapters on Light & UV Radiation and on Dust and Pollutants in this volume.

Fluctuations in temperature cause:

- expansion and contraction. If this is uneven and/or rapid, it can cause physical damage and distortion. This can be hazardous for objects made of composite materials; and
- some types of plastic, for example, vinyl records, shrink and warp in high temperatures.

The most important effect of temperature is the effect it has on altering relative humidity levels.

The effects of extremes and fluctuations in relative humidity

In high relative humidity conditions insects and moulds thrive and reproduce readily, metals corrode, dyes and textiles fade and deteriorate more quickly, organic materials such as wood and leather swell or change shape, and gelatine emulsions and adhesives become sticky.

High relative humidity conditions promote the corrosion of metals.

Photograph courtesy of Sarah Jane Rennie

The bolts are corroding in high relative humidity conditions. The corrosion products are staining the wood, and will eventually cause splitting.

Photograph courtesy of Sarah Jane Rennie

Organic materials absorb water. This is particularly noticeable in thinner materials, such as paper, vellum and parchment, textiles, leather and bark paintings. As materials absorb water, they swell and change shape, for example, stretched vellums and mounted textiles sag.

The effects of humidity on organic materials are not always immediately noticeable. But after a while, extensive damage eventually occurs.

For example, a large block of wood may take weeks or even months to transfer water from its surface into its bulk, leading to different parts of the wood having different water-contents. The consequence this has on the wood is to make it swell by different amounts, which will have the effect of splitting and warping the material.

Wood also swells more across the grain than along the grain; and by an amount which varies according to the type of wood. This makes life complicated when caring for furniture.

Textiles can display what seems to be the opposite response to changes in relative humidity. A multi-strand thread shortens in length when the relative humidity goes up. This is because the individual threads expand in diameter more than they expand in length. The result is that the strands wrap around each other more tightly, which causes the overall length to decrease. Often this process does not reverse when the relative humidity drops again.

A canvas responds in the same way as textiles; however, the paint layer on the canvas does not contract. Rather, it will compress, leading to cracking or separation between canvas and paint layer.

Different components of single objects absorb moisture at different rates and swell by different amounts. This can cause problems, such as paint layers splitting and separating from timber panels.

Composites of metal and wood are affected also. As the metal corrodes, the wood starts to split in order to accommodate the corrosion products.

Adhesives that absorb water become sticky and are an attractive food source for moulds and insects.

Gelatine emulsions on photographs also swell in humid conditions and can readily stick to the glass in their frames or, if they are stacked, they can stick together.

As for papers which are stuck down at the edges, they will increase in size in humid conditions and thus expand in the middle as their edges are restricted. This can lead to creasing.

In very low relative humidity conditions, such as in arid areas:

- insects can still survive;
- organic materials give out the moisture they contain. This can cause materials to dry out and become brittle or to distort and split;
- thicker materials lose moisture much more rapidly from their surface. This can cause warping;
- different components of single objects release moisture at different rates, which can cause the bonds between them to loosen; and
- adhesives dry out and crack, and can fail as a result.

If fluctuations are occurring constantly, the materials are being subjected to constant movement which is usually not uniform and often results in cracking, splitting and warping. Some examples of extreme damage caused by fluctuations are:

- bark paintings expand and contract as they absorb water and release it. This leads to the bark warping and splitting, and they can lose paint;
- bone and ivory are very susceptible to damage caused by fluctuations; and they warp

and split. This is especially a problem for very thin ivory sheets, such as those used for miniature painting;

- furniture with veneers can be damaged severely, because the thin, veneer layer is likely to curl and pop off the surface of the furniture if it repeatedly expands and contracts; and
- fluctuations in relative humidity can also alter the chemical composition of some minerals, so that they become another mineral.

What happens in extreme, but stable environments?

When conditions are extreme but constant, damage can still occur. Experience shows, however, that many materials become conditioned to an extreme environment.

An object in constantly high or low relative humidity does not absorb and lose water repeatedly; and it is not subject to the enormous stresses of the cycles which affect objects in fluctuating environments. Such an object is likely to be preserved longer and in better condition than a similar object in a fluctuating environment.

Remember, the emphasis should be on stability.

Can the damage be prevented?

Damage to objects and collections cannot always be prevented totally; but it can certainly be limited and slowed by controlling the relative humidity and temperature.

The most significant effect temperature can have in a museum, gallery or library environment is the way it can alter relative humidity levels.

Relative humidity and temperature are closely linked; and it is helpful to understand this link when setting out to control the environment where collections and items of value are stored.

Remember that for a fixed quantity of moisture in a given air space, as temperature rises, the relative humidity drops and, as the temperature drops, the relative humidity rises.

Identifying the source of the problem

Extremes and fluctuations in relative humidity and temperature which damage collections are experienced in many museums, galleries and libraries. These changes can be caused by:

- the regional climate;
- the climate within buildings;
- localised climates with buildings;
- microclimates; and
- visitors.

Australia is a large country with three very different climates—tropical, arid and temperate. Regional climates are particularly significant for objects which are displayed outside.

Because buildings are not fully sealed, outside conditions have a significant influence on the climate inside the building. The building's style, the materials used, the state of repair of the building and whether the building is insulated, air-conditioned or without either, all influence the impact outside conditions have on the climate inside the building.

Although buildings are not fully sealed from the outside weather, they act as barriers to the free flow of heat and moisture. This is why air-conditioning and heating are effective in providing a comfortable climate.

Within buildings there are localised climates and microclimates where conditions vary greatly from conditions in other parts of the building. For example, there would be greater variations in temperature and humidity in a small tea room with a toaster and a kettle than there would be in a closed-off storage area.

Cupboards, display cases, boxes and frames act as barriers to air and moisture circulation and can develop their own microclimate. The materials used to make the display cases, boxes and frames, combined with what's stored in them, also influence the microclimate.

People are important to the museums, galleries and libraries. The effect they have on the local climate depends on:

- how many visitors there are and whether they arrive individually or in groups;
- whether they have wet or damp umbrellas and coats;
- how long they stay; and
- their ages—school groups are potentially more disruptive to a controlled environment than adult tour groups or individuals.

All of these factors can contribute to fluctuations in, and problems with, relative humidity. Careful manipulation of these factors helps create a stable environment where the risk of damage is minimised.

What can be done to minimise damage?

The potential for damage to collections from the effects of relative humidity and heat is greatest when relative humidity and temperature fluctuate rapidly, or are extremely low or extremely high.

The damage can be minimised by modifying the conditions, if possible, and creating buffer zones between your objects and the extreme or fluctuating conditions.

There are many ways of controlling temperature and relative humidity. Some methods are better than others and their advantages and disadvantages will be discussed.

The measures you use to improve your building's environment should be selected so that you can monitor their effects and, if necessary, modify them.

Modifying the conditions in buildings

Airconditioning

Airconditioning is the most obvious, but not necessarily the best, method of controlling temperature and relative humidity. The method involves taking air—either fresh air from the outside or recycled air from the inside—and changing its temperature and moisture content.

There are two basic types of cooling airconditioners available.

An evaporative airconditioner works by passing air over a moist surface and increasing the moisture content of the air, raising the relative humidity. This type of airconditioner should not be used unless there is a dehumidifier to remove the moisture from the cool air.

Cooling coil airconditioners work on the refrigerator principle of keeping the air cool and dry. This type of airconditioner should be used with caution, and preferably with a humidifier to add moisture to the air. Monitoring the effectiveness of such equipment is crucial.

If you have airconditioning or you are considering installing it, you should be aware of the following important points:

- the cost of purchasing, operating and maintaining an airconditioning plant is high. If such a financial commitment is possible, seriously consider getting a system which not only regulates temperature but is capable of controlling the relative humidity as well;
- if airconditioning is used to control the environment, it should operate continuously. For example, it is tempting to turn off the airconditioner because of the high operating costs. But the cyclic process of turning it on and off is likely to be more damaging to collections than no air-conditioning at all;
- airconditioning systems have a limited life. They will operate at greatest efficiency for 10 to 15 years; and
- airconditioning systems should be well maintained, otherwise you could experience fluctuations in the environment.

Heating

It is sometimes necessary to heat whole buildings or individual rooms. Generally, heating is used to make people comfortable. This is an important consideration; but you should be aware also that raising the temperature affects the objects in the building.

Heating affects relative humidity. Remember:

- heating a building in an already dry environment could be disastrous, because it will lower the relative humidity;

- heating a building when there is an additional source of water will evaporate more of the water. The relative humidity may remain unchanged or it may alter, depending on the amount of water available and the amount of heat applied. This may not be the effect you're hoping to achieve; and

- if you want to raise the temperature without lowering the relative humidity, you need additional water. Additional water sources could include mechanical devices such as humidifiers or, more simply, dishes or trays of water left to evaporate.

Altering the relative humidity

It is possible to vary the humidity without markedly changing the temperature. Relative humidity can be reduced using a dehumidifier. This is a remedial measure which adjusts a dangerously wet environment.

Dehumidifiers.

Photograph courtesy of Artlab Australia

Moisture can be introduced to the air using either a steam generator or an ultrasonic humidifier. These are remedial measures which adjust a dangerously dry environment.

These machines should not be seen as permanent solutions to your environmental problems. They can be costly to run, they need fairly constant attention and can be bulky and noisy.

The building as a buffer zone

Don't despair if your building is not air-conditioned and you can't afford airconditioning. A well-maintained building of solid construction provides a very reasonable environment for collections.

A building made of thick stone walls or cavity-brick construction with high ceilings provides good insulation against climatic changes. In hot weather, these buildings take a few days to heat up; and then, as the outside temperature drops, they lose heat slowly. Fluctuations occur, but they occur gradually.

Make sure your building is well-maintained, so that it provides the maximum possible seal against fluctuations in the outside environment. This is particularly important if the building is made of light building materials and is in a fairly extreme environment.

Clean out gutters, repair cracks in walls and ceilings, and have leaky roofs checked. This improves the stability of the temperature and humidity inside.

If you are considering upgrading the buildings, remember to insulate walls and ceilings—especially if the building is constructed from light-weight or heat-conductive materials such as fibro and corrugated iron. By so doing, it can not only help to modify the internal environment, but also ensure better preservation of the collection as well as making people feel more comfortable inside.

Use the features of the building

Improved conditions for the storage and display of collections can be achieved by choosing good storage and display sites within the building, and using the features of the building to modify conditions.

The most stable area of a non-airconditioned building is an internal room on the ground floor—because it is buffered against climatic changes.

There are other areas one could choose. Basements are acceptable as they provide a cool temperature. However, they are likely to be damp. On the other hand, an attic would often not be insulated, but would be dry.

If there is an optimum choice, the most sensitive objects should be displayed in an internal room, or at least against an internal wall in preference to an external one.

In warm, humid conditions, such as in tropical areas:

- air flow and good ventilation are important if you want to minimise damage to collections;
- use oscillating fans, with doors open to improve air movement; and
- consider other ways of cooling the inside of the building. For example, install interior blinds on windows to limit the amount of heat coming into the building, install exterior shutters or awnings, or put up shade-cloth. If possible, plant trees around the building, but not too close because this gives insects easy access to the building.

If you are building a museum or modifying an existing building in the tropics, remember that non-airconditioned buildings should have breezeways, if possible.

In arid or temperate zones, when the temperature is extreme outside the building, you can limit temperature fluctuations inside your building by:

- keeping doors and windows closed;
- keeping self-closing doors well oiled, so that they shut quickly and fully;
- installing interior blinds on windows, to buffer against outside conditions;
- installing exterior shutters or awnings, or putting up shade-cloth; and
- planting trees around the building—but not too close because this gives insects easy access to the building.

Encourage people to leave wet umbrellas and coats at the front door—by providing umbrella basins and coat hooks. This will prevent the introduction of excess moisture.

Local climates and microclimates

In the same way that you use the features of a building to modify the conditions within the building, you can use doors, windows, blinds and awnings—to modify conditions within individual rooms.

There are a number of other steps which can be taken to create and modify microclimates within the building.

Layers of storage

When storing important objects, give them their own microclimate by providing layers of storage as this provides some protection against climatic extremes and fluctuations, even when conditions in the room or building are difficult to control.

Microclimates also exists within glazed frames, display cases and boxes.

For more information

There is information about conservation framing in the chapters on Textiles, Photographs and Paper in *Caring for Cultural Material 1* and *2*.

A display case is a box with transparent sides into which an object is placed. The walls of the box isolate the object to some extent. Passive control systems can also be set up within the box.

Silica gel is the most common material used to control relative humidity in display cases. It can be pre-conditioned to achieve a desired humidity level; the quantity placed in the case depends on the volume of the case.

For more information

Silica gel is not particularly easy to use. For more information about its use refer to the section on the use of silica gel later in this chapter.

Other materials, such as Nikka pellets and Artsorb, operate on the same principles as silica gel.

Cheaper alternatives which can be used include clean, cotton scraps and shredded, acid-free paper. These absorb excess moisture, but do little to correct a dry environment.

These documents are well protected from environmental fluctuations by layers of storage—individual sleeves plus a storage box.

Photograph courtesy of Artlab Australia

Acid-free wrappers, interleaving, mounting and framing when used individually or in combinations, create layers of protection from extremes of, and fluctuations in, relative humidity. They create small, isolated microclimates in which the relative humidity fluctuates slowly.

CAUTION

Avoid sealing objects in plastic in tropical conditions—it will not allow them to breathe, creating a risk of mould growth.

The layers of mounting and framing materials buffer these items against environmental extremes and fluctuations.

Photograph courtesy of Artlab Australia

A word of caution about travelling exhibitions and loans

Remember that your collections may be subject to a changing environment within and outside a museum. Of particular concern is if items are lent to other organisations, or are transported for other reasons. They should be well packed and sealed, to ensure that they are not subjected to unacceptable fluctuations in transit.

On arrival at the destination of transported items, the local climate within the crate should be allowed to gradually adjust to the conditions of the new environment. The crates should remain unopened at the destination for a full 24 hours. This should also be done on the return journey.

If the objects are travelling from one extreme to another, for example, from a tropical to an arid climate, it may be advisable to allow more than 24 hours for conditioning at each end.

The hand on this polychrome sculpture split after getting very damp and then drying out quickly. Mould has grown on the sculpture as well. The sculpture became very damp when it was shipped from Europe to Australia.

Photograph courtesy of Artlab Australia

In an ideal world...

The levels of relative humidity—RH—recommended for the safe-keeping of collections in museums, galleries and libraries are:

- 50% ± 5%;
- this is a compromise which has been arrived at by assessing the average requirement of an average collection in an average climate;
- it is almost impossible to achieve a constant relative humidity of 50%; so a margin of 5 per cent either side of this has been permitted, that is, between 45% and 55%;
- the danger zones for relative humidity are over 65%, when mould grows and metal corrosion is common; and below 35%, when some materials dry out and become brittle;
- in tropical areas, 60% ± 5% is more realistic.

For the safe-keeping of collections in museums, galleries and libraries, the temperature should be kept constant—in the range 18–22°C.

These recommended levels are ideal. However, in some areas of Australia it is extremely difficult to come close to achieving these recommended levels. It is not always practical to put all our efforts into achieving these levels within a building, when there are many others ways of providing protection.

CAUTION

We're not in an ideal world, so it is important to remember that many objects become conditioned to their environments—even though these may be extreme. A lot of damage can be done by attempting to place an object, which is stable in an extreme climate, into an environment that conforms to the recommended levels.

Australia's climatic zones

ARID

An arid climate is generally very dry.

For example:

	Av. Min RH	Av. Max RH	Av. Min Temp	Av. Max Temp
Broken Hill	25%	75%	12.1°C	23.7°C
Kalgoorlie	23%	74%	11.5°C	25.1°C
Alice Springs	17%	65%	16.3°C	33°C

In arid areas, it is often very hot during the day and very cold at night. This wide fluctuation is matched by wide fluctuations in relative humidity. Take Alice Springs for example:

- temperatures have been known to range from 42°C to 20°C in summer;
- and in winter from 18°C to -5°C; and
- relative humidity can range from 75%–20%.

TEMPERATE

A temperate climate is considered a moderate climate.

For example:

	Av. Min RH	Av. Max RH	Av. Min Temp	Av. Max Temp
Launceston	44%	90%	6.2°C	16.8°C
Adelaide	34%	79%	12°C	22.1°C
Ballarat	40%	91%	7.3°C	17.4°C

However extreme and fluctuations can be experienced in temperate areas. Take Adelaide for example:

- temperatures have been known to range from 40°C to 15°C in a day;
- relative humidity can range from 100%–30%; and
- when it is hot in Adelaide it is often quite dry.

Temperate climates tend to have a greater range of temperatures than tropical climates and may include extreme climatic variations.

TROPICAL

Tropical climates occur north of the Tropic of Capricorn. They are characterised by heavy rainfall, high humidity and high temperatures.

For example:

	Av. Min RH	Av. Max RH	Av. Min Temp	Av. Max Temp
Darwin	43%	85%	23.8°C	31.6°C
Townsville	51%	75%	19.5°C	28.6°C

Average readings do not give a very good indication of the extremes that can be experienced. In Darwin, for example:

- temperatures can range from 35°C to 20°C in a day;
- relative humidity can range from 100%–50%; and
- high temperature and relative humidity tend to coincide.

Note: Townsville may not be considered tropical—it may be more accurately classified as sub-tropical. It must be remembered that these categories are only a guide. Climates change gradually and there are many areas in Australia that would be difficult to place in these very broad categories.

MORE ABOUT RELATIVE HUMIDITY AND TEMPERATURE

Measuring relative humidity

Being able to measure relative humidity is not absolutely necessary when controlling fluctuations or extremes; but it is helpful in identifying problems.

If the environment is very dry or very damp, you can generally feel it—your skin responds to these conditions. We feel dry and sometimes a bit itchy in very dry conditions, and clammy in humid conditions. But feeling the extremes doesn't tell us how extreme the conditions are; and it gives us no indication of how rapidly the conditions are fluctuating.

To gather information about the levels, you need to measure the relative humidity and temperature; and to get information about the rate of fluctuation, you need to monitor the environment.

Measuring the conditions involves taking readings at a specific time—a snapshot of the conditions.

Monitoring conditions involves continuous or repeated measurement, so that you get a changing picture or series of snapshots over a period of time.

There are a number of devices which can be used to measure relative humidity.

Whirling hygrometer

A whirling hygrometer—also called a sling psychrometer—measures relative humidity and temperature directly.

It has two matched thermometers. One thermometer is called the dry bulb and the other the wet bulb. The wet bulb thermometer has a cotton sleeve wrapped around its base. Distilled water from a small reservoir is used to keep the sleeve wet.

The hygrometer is whirled around in the air. While this happens, water from the sleeve of the wet bulb thermometer evaporates, and the wet-bulb temperature shown by the thermometer goes down.

A whirling hygrometer or sling psychrometer.
Photograph courtesy of Artlab Australia

The amount of water which evaporates depends on the capacity of the air to contain water. The decrease in temperature shows how much water has gone into the air; this shows the capacity of the air to contain water.

The dry bulb gives the temperature of the air.

By comparing the two temperatures after the instrument has been whirled, the relative humidity can be calculated. This is made easier by using published tables listing the relative humidity against the dry and wet-bulb temperatures. These tables should be provided with the hygrometer.

The advantages of using a whirling hygrometer are:

- they are relatively cheap;
- they don't require ongoing maintenance; and
- if you purchase another measuring device, you will still need a whirling hygrometer, as a reference device to calibrate the other device.

The disadvantages of using a whirling hygrometer are:

- they provide a snapshot only. They do not continuously monitor the environment;
- to monitor the environment with a whirling hygrometer, you need to take readings in the same places at regular intervals, and record when and where you took the readings; and
- whirling a manually-operated hygrometer can make your arm tired. Battery-operated whirling hygrometers are available.

Thermohygrograph

A thermohygrograph allows for continuous measurement of relative humidity and temperature over a period of time. It monitors the environmental changes.

Thermohygrographs work on the principle that organic materials expand and contract as the relative humidity changes. In this case, the organic material is human hair.

The hairs are bundled together and stretched between a fixed pin and a moveable pin. The moveable pin is attached to a series of levers, which amplify the movement of the hairs.

A pen is attached to the end lever; and this pen plots the movement of the lever on a chart, which is mounted on a rotating cylinder. The rate of rotation can be altered, so that the relative humidity is plotted over a day, a week or a month.

A thermohygrograph also has a temperature sensor—which records the temperature on the same chart.

The chart should be changed at the end of each recording period. When you change the chart, set the pen on the correct time, and you will have a record of the times when changes occur.

The advantages of using a thermohygrograph are:

- the thermohygrograph chart contains information about temperature and humidity, as well as the relationship between the two; and
- the chart also shows when fluctuations occurred, so you can relate fluctuations to events in the area being monitored, for example, the arrival of a bus-load of tourists on a wet day!

A thermohygrograph.

Photograph courtesy of Artlab Australia

The disadvantages of using a thermohygrograph are:

- they require ongoing maintenance, to ensure they are recording accurately and to ensure that the cylinder is rotating at the right rate;
- they need to be calibrated periodically, and the hairs need to be re-conditioned; and
- thermohygrographs give you information only if you look at the charts. Most people look at the charts only at the end of the recording period, so they don't respond immediately to problems as they arise.

Dial hygrometers

Dial hygrometers work on the same principle as the thermohygrograph—using human hair to operate a lever which moves a dial.

A dial hygrometer.

Photograph courtesy of Artlab Australia

The advantages of using a dial hygrometer are that it is small and can be placed in display cases and on shelves.

The disadvantages of using a dial hygrometer are:

- they measure relative humidity, but not the temperature; and
- they measure continuously, but don't record the information—you have to look at them continuously if you want to use them to monitor changes.

Electronic hygrometers

Electronic hygrometers are generally used to provide a snapshot of conditions. They measure relative humidity and temperature, and need to be calibrated periodically. Before they are used, they need to be allowed to acclimatise to the area they will be monitoring.

Data loggers

Systems which monitor relative humidity and temperature, and download data to computers are now available—they are called data loggers.

The advantages of using data loggers are:

- they can be linked to alarms so that when conditions move outside the recommended levels, action can be taken; and
- the remote sensors can be placed in display cases, storage boxes and crates.

The disadvantages of using data loggers are:

- you need a computer to access the information; and
- they are expensive—although they are likely to become cheaper as time goes by.

Humidity indicator cards

Humidity indicator cards are also available. These use moisture-sensitive salts which change colour as the relative humidity alters. They can be very useful for low-cost monitoring—especially within display cases and storage boxes—provided you check them regularly.

Separate temperature cards are needed if you want to check temperature variations.

Calibration

Thermohygrographs and dial and electronic hygrometers do not remain accurate. Ideally, they should be calibrated against an instrument such as a whirling hygrometer once a month and if they have slipped out of calibration, they should be recalibrated. The hairs in thermohygrographs and dial hygrometers must also be reconditioned regularly.

We will not give detailed instructions for the calibration of individual instruments because there will be slight variations, depending on the type of instrument you have—whether a thermohygrograph or a dial hygrometer. The instrument will come with instructions. If it does not, ask the supplier for clear instructions. If you don't follow the instructions, your readings won't be accurate and can't be relied on.

If you buy a thermohygrograph, you will need to buy a whirling hygrometer as well. If funds are limited, the whirling hygrometer would be a wiser investment.

Dehumidifiers

A dehumidifier is basically a cooling coil airconditioner. Instead of conducting the compressor heat out of the building, the heat is retained inside the building—and so the temperature does not change, except when the dehumidifier is in a small room. In this case, the temperature in the room can be raised by the operation of the dehumidifier.

Moisture from the air, however, is still condensed on the cooling coils, and taken away by a hose or collected in a bucket. Dehumidifiers are a remedial measure to adjust a dangerously wet environment.

If using a dehumidifier to dry an area of your building, remember to empty the catchment bucket—the buckets are not very big.

Humidifiers and steam generators

Moisture can be introduced into the air by using either a steam generator or an ultrasonic humidifier.

A steam generator uses heat to create steam. The steam is then cooled to form a water-vapour, which can be introduced into the museum.

An ultrasonic humidifier uses a small crystal—vibrating at very high frequency—to smash liquid-water into tiny droplets. The droplets are small enough to be suspended in air as a cold vapour.

Both devices are remedial measures to adjust a dangerously dry environment.

NB. The water in humidifiers and steam generators needs to be topped up regularly. If this is not done, the steam generator or ultrasonic humidifier could be severely damaged.

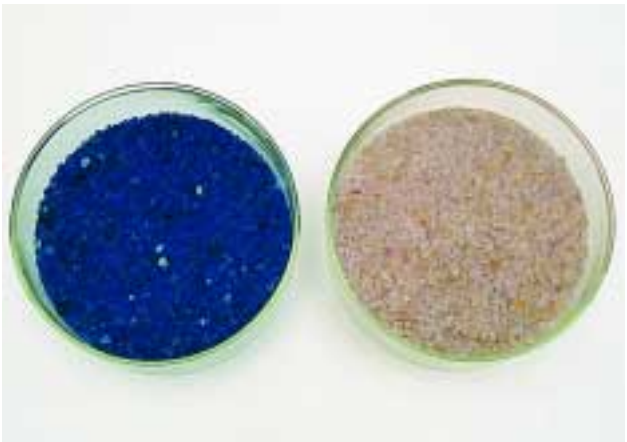
The use of silica gel

Individual display cases can act as buffer zones, and maintain humidity at reasonably constant levels—provided the temperature does not vary greatly. However, fluctuations can occur and it is sometimes necessary to use buffering materials: silica gel, for example.

Silica gel is often seen as a simple solution to environmental problems. In some museums and galleries, small bags of silica gel are placed in display cases and left there permanently. Unfortunately, this has almost no effect.

Using silica gel is not simple. The calculation used to determine the amount of silica gel required is complex. It involves a knowledge of the daily rate of air-changes in the case, the local humidity conditions and the volume of the case.

The amount of silica gel required is far more than most people imagine. The amount required can range from approximately 7kg/m^3 to about 20kg/m^3, depending on conditions. This is a lot of silica gel.



The dish of blue silica gel is ready for use. It will absorb moisture and so remove water from the atmosphere. When silica gel has absorbed all the water it can, it turns pink. When the silica gel is pink, it needs to be reconditioned.

Photograph courtesy of Artlab Australia

Silica gel also needs to be reconditioned, because it absorbs water and retains it. The silica gel has to be removed from the case and reconditioned—usually by heating in an oven—and then put back in the case. You may need two batches of silica gel, so that when you are reconditioning one, the other is in the case.

Display cases that are to contain silica gel should ideally have separate compartments: one for the object and one for the silica gel; and there should be air flow between these compartments.

CAUTION

If you use silica gel in its granulated form, it is advisable to wear a dust mask.

If you have a problem relating to temperature and humidity and how to manage it correctly for the preservation of your important objects, contact a conservator. Conservators can offer advice and practical solutions.

For further reading

Stolow, Nathan, 1987, *Conservation and Exhibitions: Packing, Transport, Storage and Environmental Considerations*, Butterworth and Co., London.

Thomson, Garry, 1994, *The Museum Environment*, 3rd edn, Butterworth-Heinemann, Oxford.

Self-evaluation quiz

Question 1.

Which of the following statements are false?

a) Extremes of temperature and relative humidity can cause damage to objects in museums, galleries and libraries.

b) Most insects and mould thrive in warmer conditions.

c) Relative humidity and temperature are closely related.

d) Relative humidity can affect the comfort of people in museums, galleries and libraries, but won't affect the collections.

Question 2.

In high relative humidity conditions:

a) bark paintings dry out and crack;

b) dyes and textiles fade and deteriorate quickly;

c) moulds become too wet to grow;

d) mounted vellums become taut.

Question 3.

Rapid fluctuations of relative humidity:

a) subject materials to constant movement as they absorb moisture and give it out again;

b) can cause extreme damage;

c) can alter the chemical composition of some minerals;

d) should be avoided;

e) all of the above.

Question 4.

If a collection has become conditioned to an extreme environment, you should:

a) alter the environment to meet the recommended ideal conditions because this will be better for the collection;

b) concentrate your efforts on maintaining a stable environment;

c) send the collection to a more moderate climate;

d) none of the above.

Question 5.

Relative humidity is a comparison between:

a) water in the air and temperature;

b) the amount of water-vapour in the air at different temperatures;

c) the amount of water-vapour in the air and the total amount of water-vapour that the air can hold at a particular temperature;

d) the humidity inside relative to the humidity outside.

Question 6.

Which of the following statements are true?

a) Changes in temperature can often lead to significant alterations in relative humidity.

b) People have no effect on relative humidity and temperature levels in museums, galleries and libraries.

c) If the temperature inside a sealed box drops, the relative humidity inside the box will be raised.

d) Display cases have 0% relative humidity.

Question 7.

The climates which are relevant to objects in museums, galleries and libraries are:

a) microclimates;

b) the climates within their storage and display areas;

c) the regional climate;

d) the climate in the building in which they are stored;

e) all of the above.

Question 8.

In warm, humid conditions:

a) good ventilation and air flow help to prevent mould outbreaks;

b) you should shut all doors and windows to prevent mould spores entering the building;

c) dehumidifiers should be used to dry the air;

d) seal your objects in plastic.

Question 9.

To protect important objects from fluctuations in relative humidity and temperature, you should:

a) provide them with layers of storage;

b) ensure the building is well maintained;

c) get air-conditioning installed;

d) buy a steam generator.

Question 10.

Layers of storage to protect against fluctuations and extremes of relative humidity can be created by:

a) placing items in storage boxes;

b) interleaving or wrapping objects;

c) placing items in display cases for exhibition;

d) mounting and framing;

e) all of the above;

f) combinations of the above.

Answers to self-evaluation quiz

Question 1.

Answer: d) is false.

Question 2.

Answer: b) is correct. a), c) and d) are incorrect. Bark paintings and vellums absorb moisture. This can cause changes in shape and distortion. Mounted vellums sag. Moulds thrive.

Question 3.

Answer: e).

Question 4.

Answer: b). The emphasis should be on stability.

Question 5.

Answer: c).

Question 6.

Answer: a) and c) are true.

Question 7.

Answer: e).

Question 8.

Answer: a) is correct. b), c) and d) are not correct. It is no use shutting doors and windows to keep mould spores out because they are everywhere anyway. Dehumidifiers should be used only as a remedial measure to adjust a dangerously wet environment. In warm, humid conditions, you should avoid sealing objects in plastic, because it will not allow them to breathe, creating a risk of mould growth.

Question 9.

Answer: a) and b). You could install airconditioning; but it's not completely necessary if you are able to create suitable microclimates. Steam generators should only ever be used to adjust a dangerously dry environment.

Question 10.

Answer: e) and f). The methods used will depend on the object type.