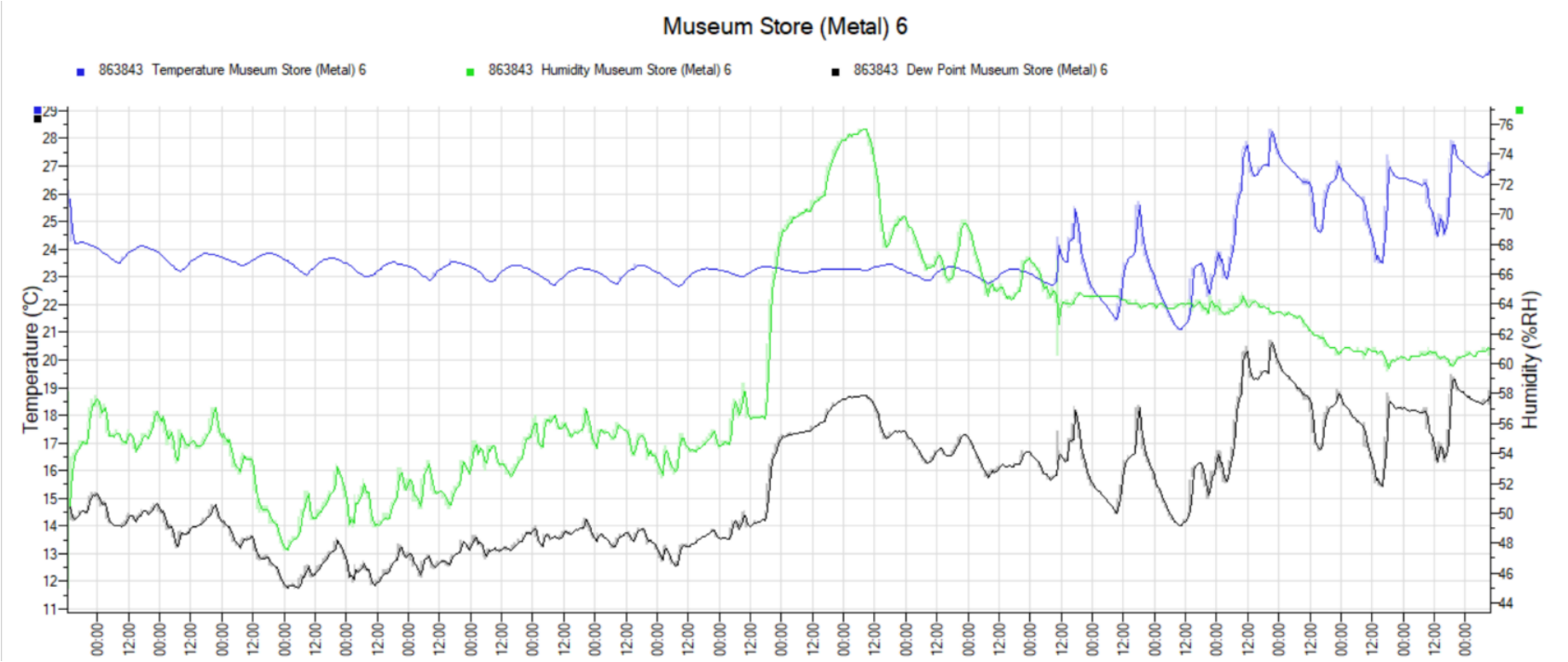


Understanding relative humidity and temperature for sustainable collection care

Norges Museumforbund

Jane Henderson Cardiff University

CONSERVATION AND SUSTAINABILITY NOT IN CONFLICT

Sometimes poor decision making about humidity and temperature targets for conservation have impacted on the **way that conservators are perceived**, on the **care of collections** and on the **sustainability of organisations** attempting to implement those decisions.

INORGANIC

ORGANIC

Humidity from first principles

TEMPERATURE FIRST PRINCIPLES:

Heat from people

Visitors 100-120 W

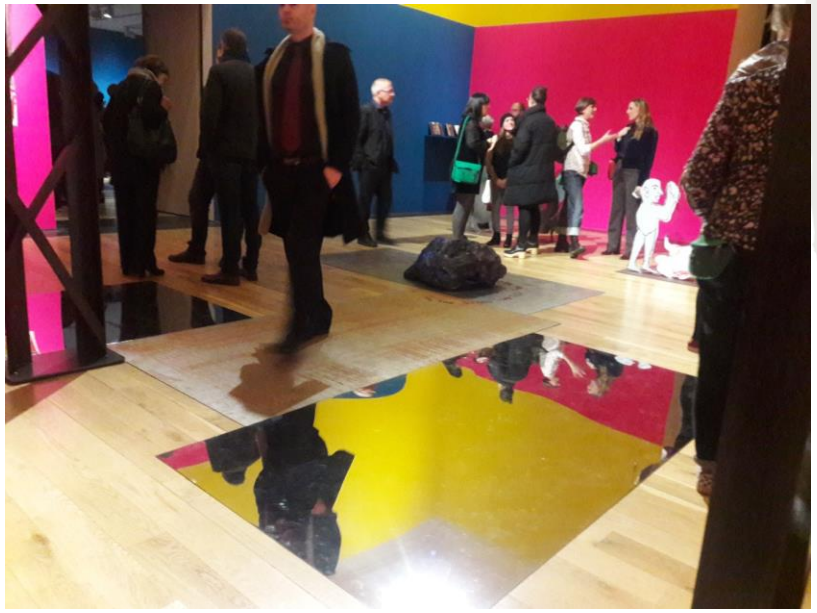
Heat from equipment

Smaller notebooks to computers approx. 100 W

Solar gain

Lights

- Example data for same amount of visible light (lumen)
  - Incandescent lamp: 60W (95% heat) = 57W Heat output
  - LED: 6W · (65% heat) = 3.9W Heat output



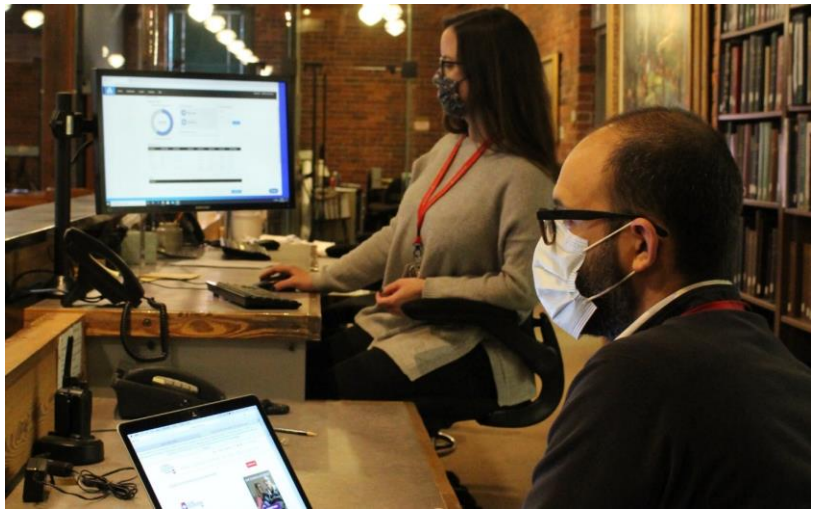


Photo by Claire Moclock / Senator John Heinz History Center
www.archive-it.org

WHY DOES HEAT MATTER? THE ARRHENIUS EQUATION

- The higher the temperature, the faster a given chemical reaction will proceed.
- At higher temperatures, the probability that two molecules will collide is higher. This higher collision rate results in a higher kinetic energy, which has an effect on the activation energy of the reaction.
- The activation energy is the amount of energy required to ensure that a reaction happens.
- The relationship between the rate a reaction proceeds and its temperature is determined by the Arrhenius Equation.

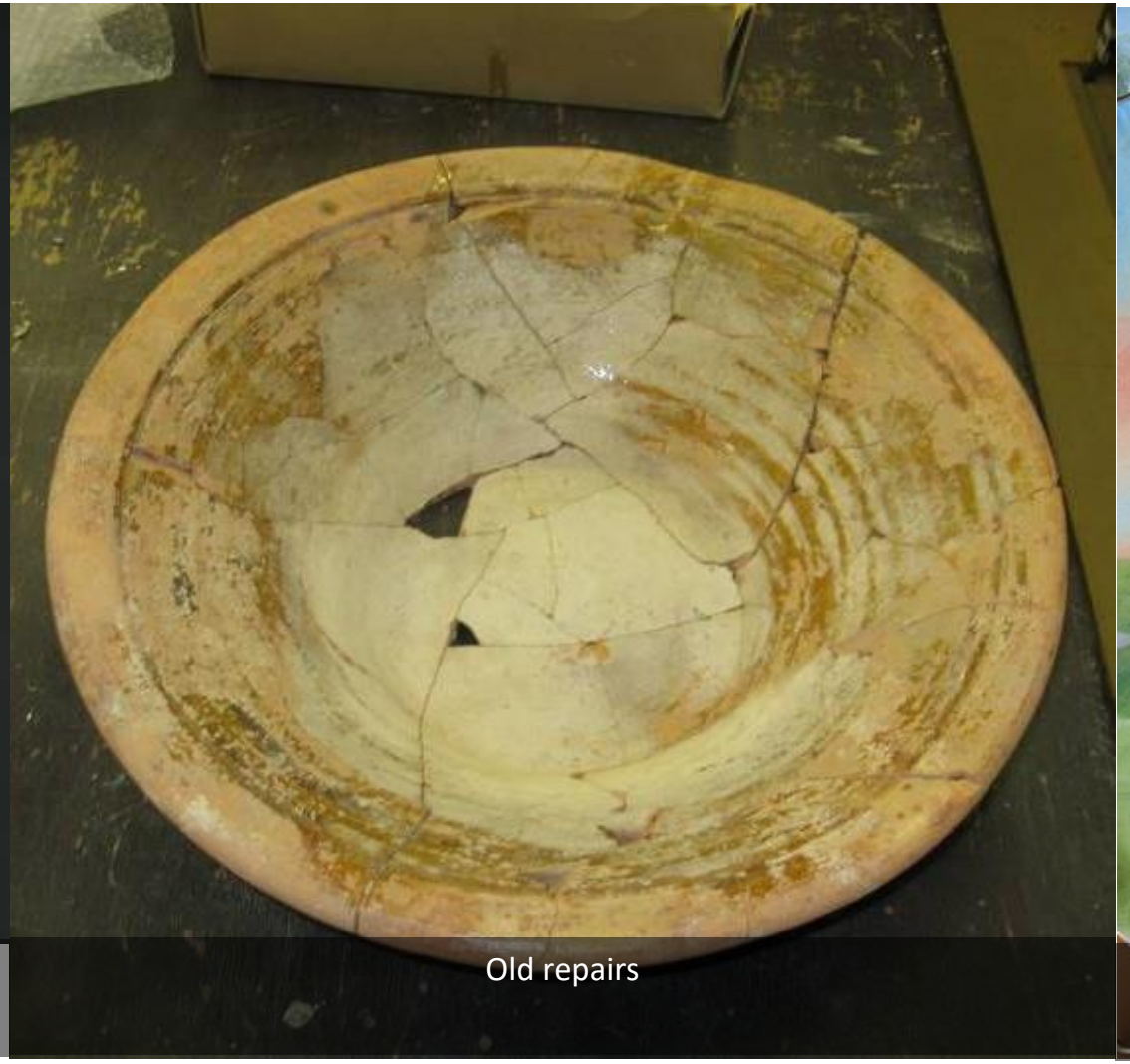
$$k=A*\exp^{(-E_a/R*T)}$$

- where k is the rate coefficient, A is a constant, Ea is the activation energy, R is the universal gas constant, and T is the temperature (in degrees Kelvin).

TEMPERATURE & THE RATE OF DECAY

Temperature has an impact on collections if it affects humidity, accelerates chemical decay, softens plastic materials or encourages the breeding of pests. We aim to manage temperature not avoid it.

Wax Seal NMW



Old repairs

Limoges

UNDERSTANDING THE RELATIONSHIP OF HUMIDITY & TEMPERATURE - TERMINOLOGY

Relative humidity (RH)

- Relative humidity is a term used to describe the **amount of moisture (water vapour) in the air**, relative to the capacity of the air to hold water at a specific temperature. If no water is added to the air as the temperature rises, relative humidity falls, because warm air has the potential to hold more moisture. Relative humidity is expressed as a percentage. For example, 50% RH indicates that the air is holding half the amount of water vapour it could hold.

Absolute Humidity

- The **amount of water vapour** contained in a quantity of air measured as a weight / volume

Moisture content

- The term used to describe the amount of **water within organic material**. Water can be found in the substrate of the material of an object; removal of water can lead to physical and chemical changes and damage. High moisture content will lead to swelling and encourage biological decay of the object.

WHAT IS HUMIDITY?

Absolute Humidity

The amount of water vapour contained in a quantity of air measured as a weight / volume

WHAT IS HUMIDITY

Relative Humidity

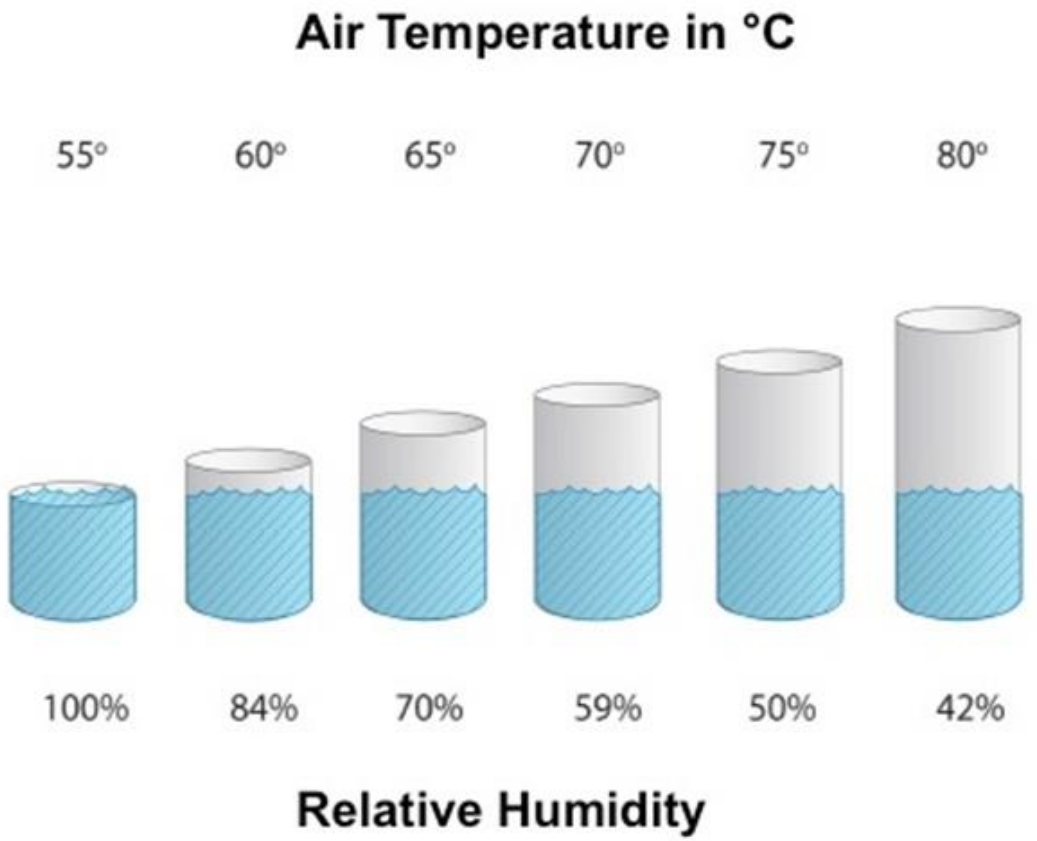
The percentage ratio of the weight of water vapour in the air to the weight that could be contained by the same volume of saturated air at the same temperature

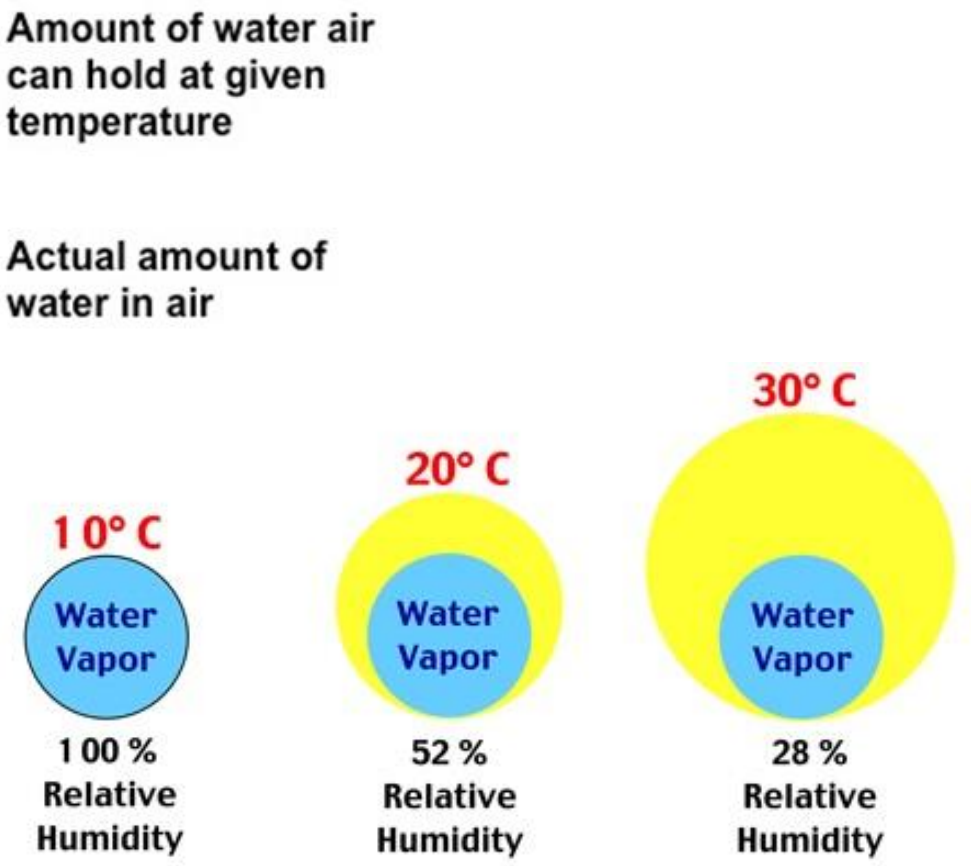



AT ANY GIVEN TEMPERATURE

$$\%\ RH = \frac{\text{Amount of water in a given quantity of air}}{\text{Maximum amount of water that air can hold}} \times 100\%$$

http://www.coffinworks.org/collections-care-its-not-just-cleaning/#!prettyPhoto





http://www.ecoloblueblog.com/2015/02/08/why-does-my-water-production-vary-relative-humidity-absolute-humidity-and-dew-point/

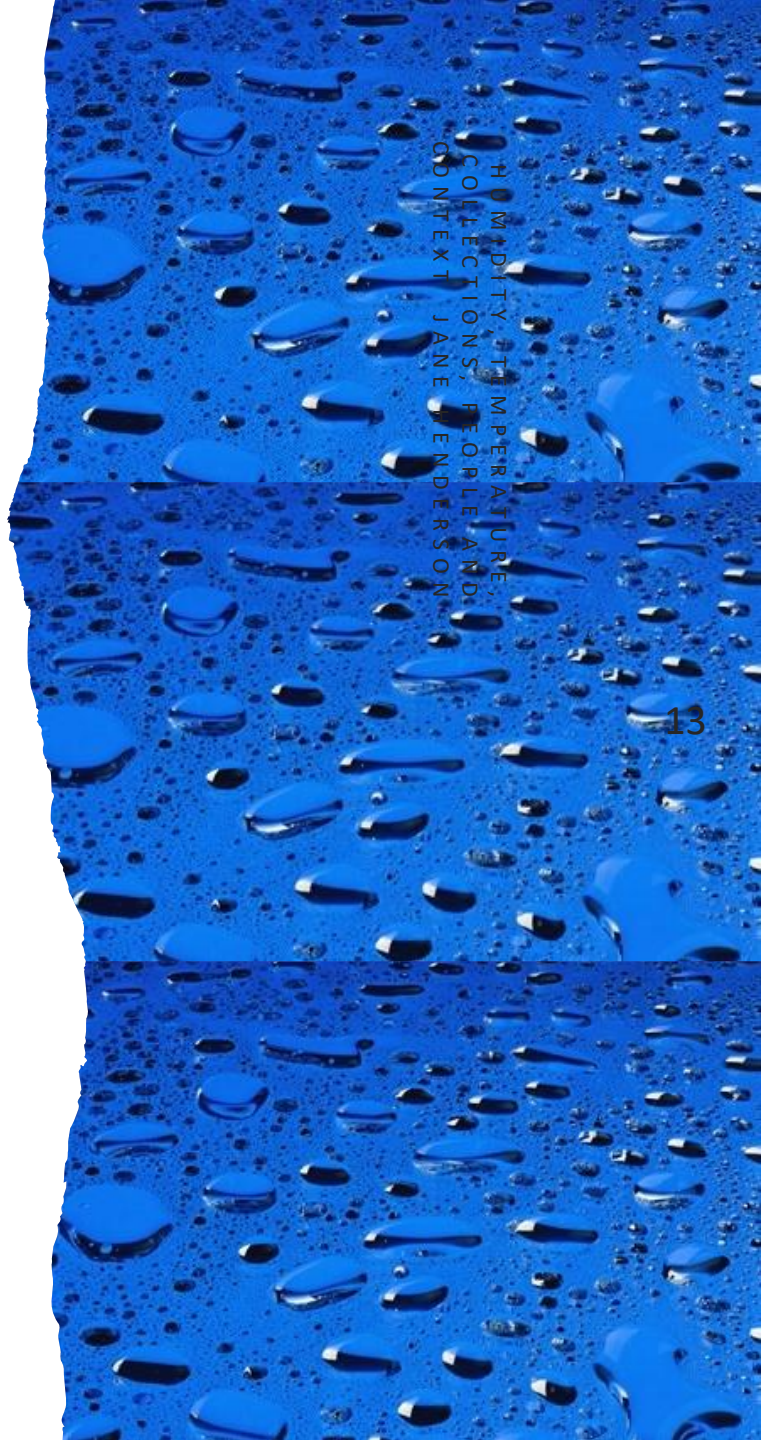
Absolute Units

Absolute humidity

- either mass of water vapor per volume of moist air (in grams per cubic metre g/m^3)
- or mass of water vapor per mass of dry air (grams per kilogram g/kg or kg/kg).

Relative humidity

- a percentage of absolute humidity relative to a maximum humidity given the same temperature
- 100% = saturation or dew point



HUMIDITY&ORGANICS

HUMIDITY, TEMPERATURE, COLLECTIONS, PEOPLE AND CONTEXT JANE HENDERSON

HUMIDITY&ORGANICS
VENEER AND INLAY

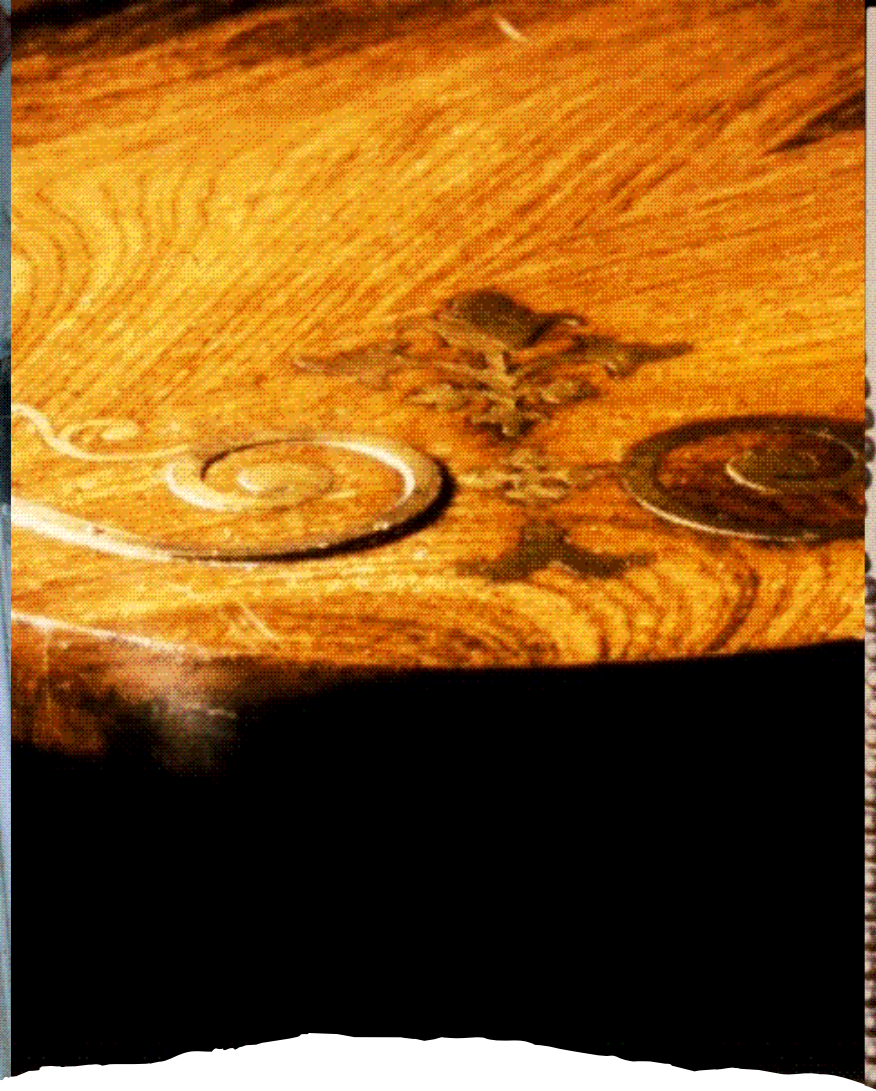
HUMIDITY&ORGANICS

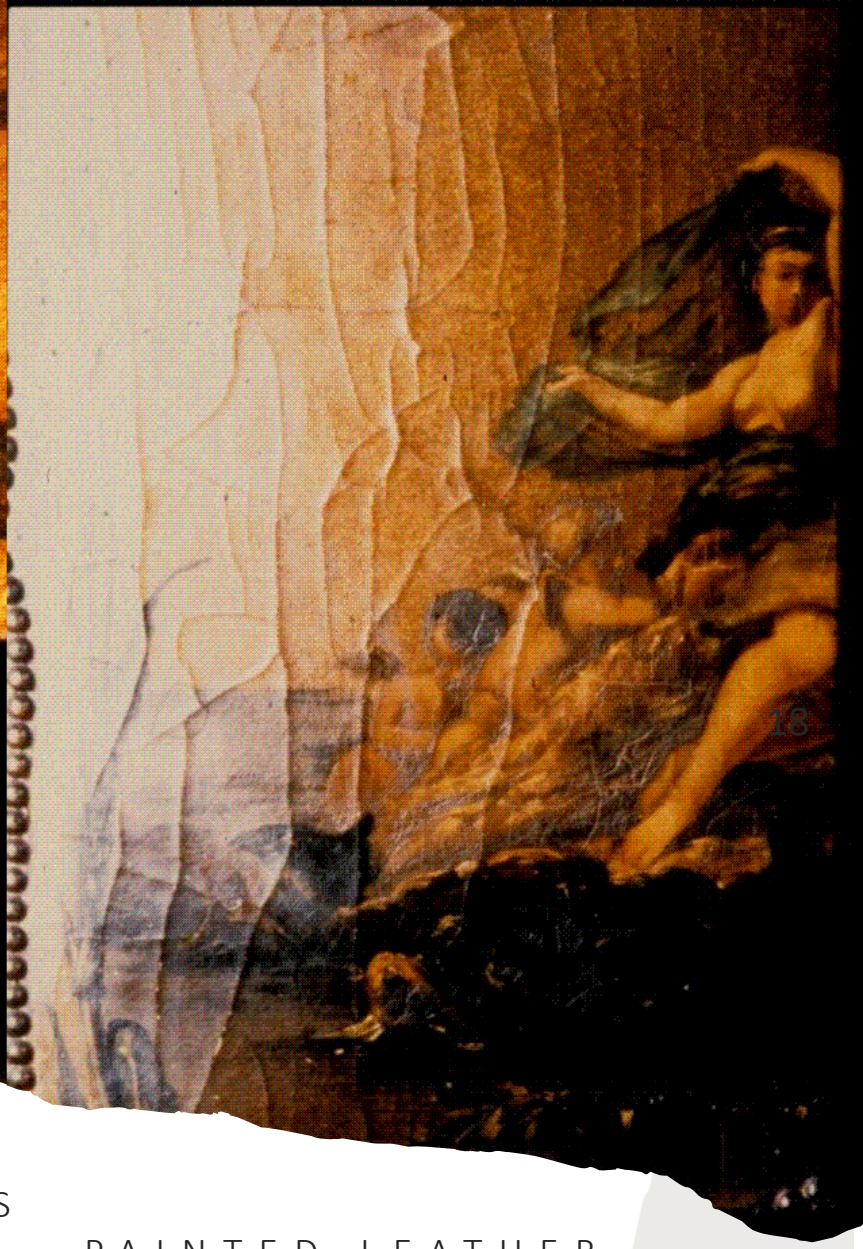
PARCHMENT

(Images: Free Library of Philadelphia Lewis O 21 from OPenn)
Severe cockling in a writ from the New York Supreme Court of Judicature, 1817. (Courtey of Geoff Huth) SAA archivists.org

HUMIDITY &ORGANICS

TWO DIFFERENT ORGANICS (Image: Kelly Tuttle)





HUMIDITY &MIXED MATERIALS

PAINTED WOOD

METAL INLAY

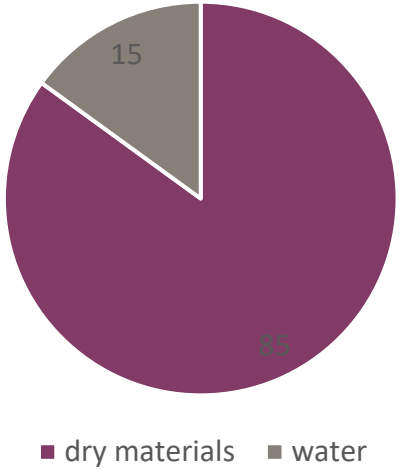
PAINTED LEATHER

UNDERSTANDING THE RELATIONSHIP OF HUMIDITY, TEMPERATURE & COLLECTIONS

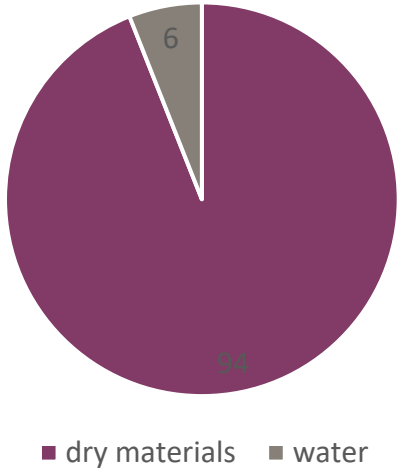
Moisture content

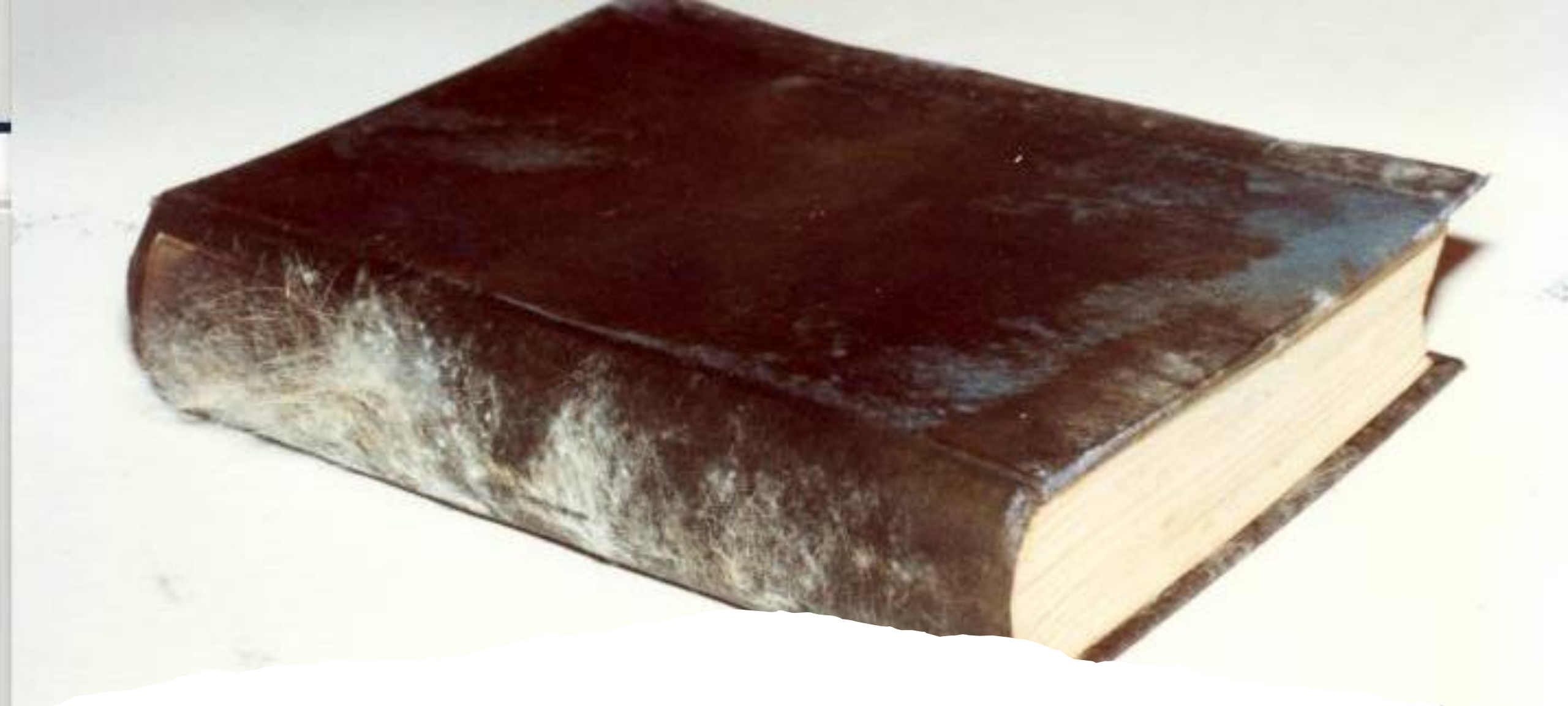
- The term used to describe the amount of **water within organic material**.
- Water can be found in the substrate of the material of an object (surface, **absorbed** or bound).
- Removal of water can lead to physical and chemical changes and damage.
- High moisture content will lead to swelling and encourage biological decay of the object.

Moisture content of wood



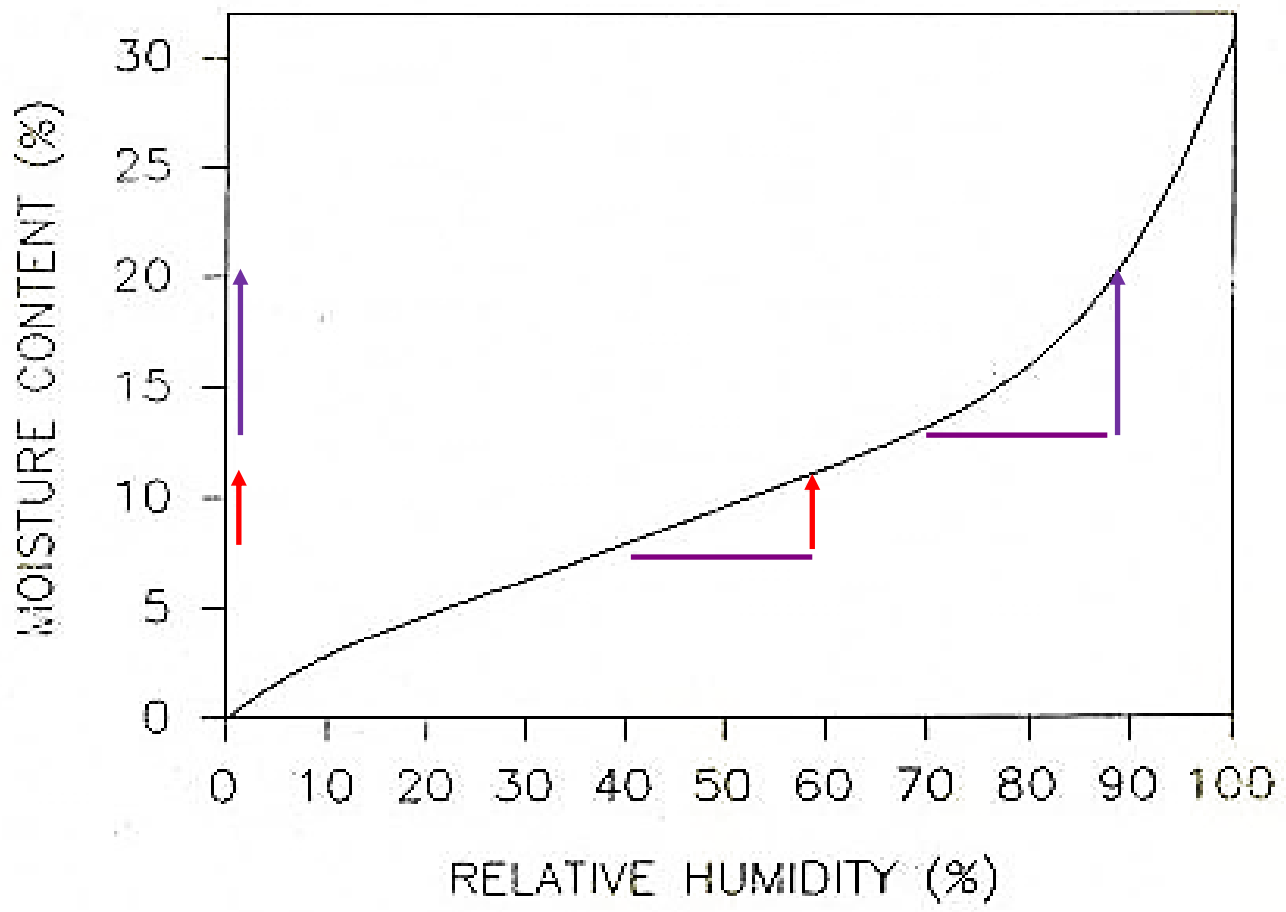
Moisture content of paper





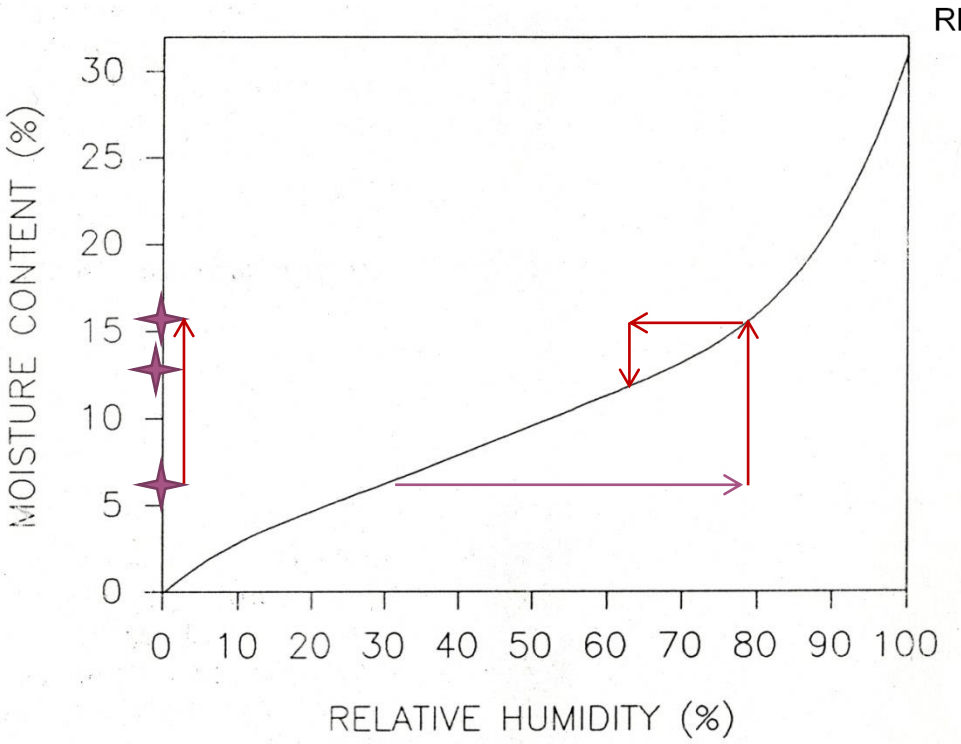
EXCESS HUMIDITY: MOULD

MOISTURE CONTENT AND RH



BUFFERING

Dimensional change

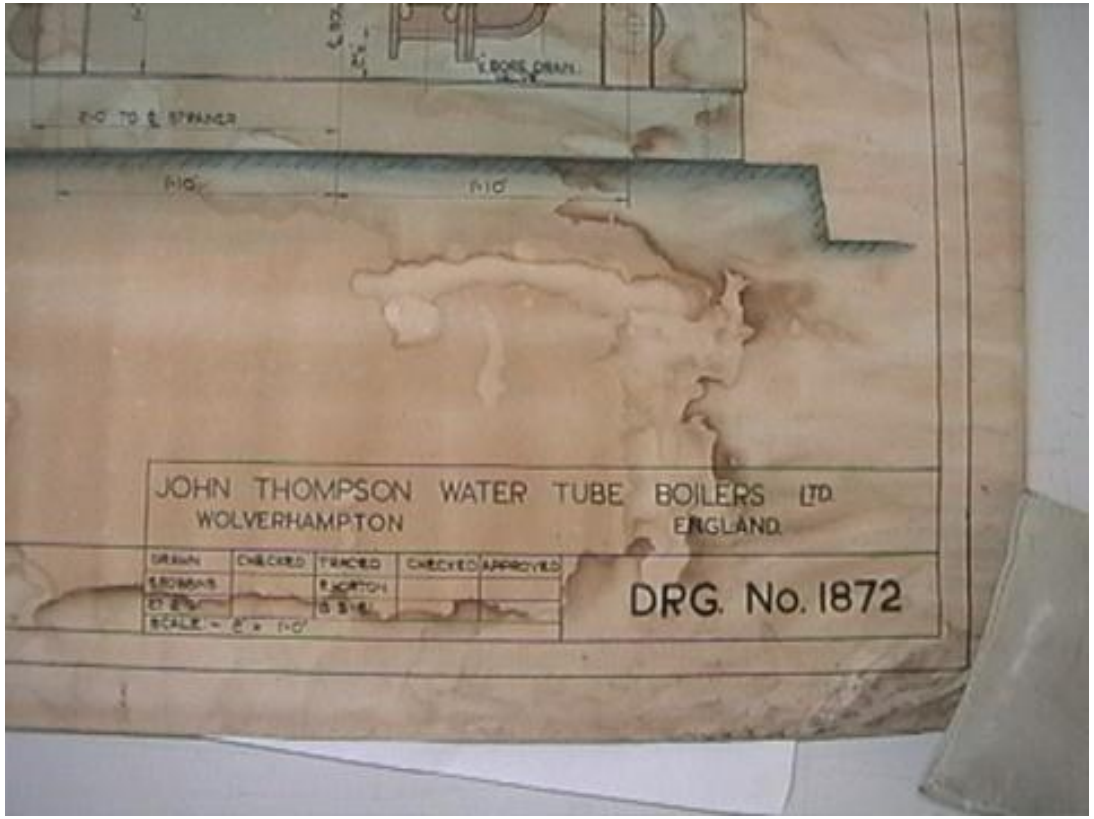


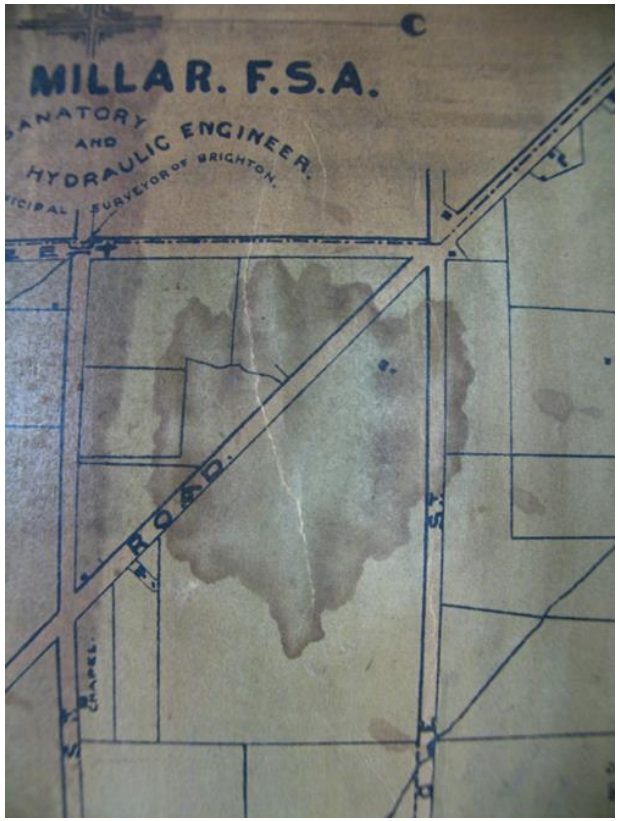
RH = $\frac{\text{Amount of water in a given quantity of air}}{\text{Maximum amount of water that air can hold}} \times 100\%$

HYSTERESIS

GETS WET MORE QUICKLY THAT IT GETS DRY

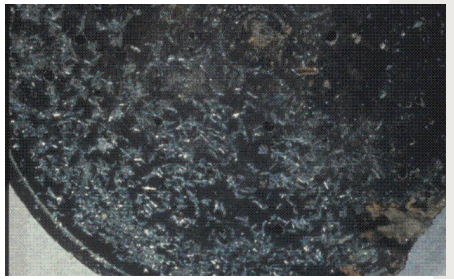
LIQUID WATER: TIDEMARKS





https://aiccm.org.au/visual-glossary/tidemark/

INORGANICS



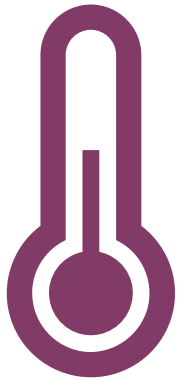
- Corrosion
- Salt

Enameled clasp on a book owned by Alfonso of Aragon. Pressmark: MSL 1910/2387 V&A

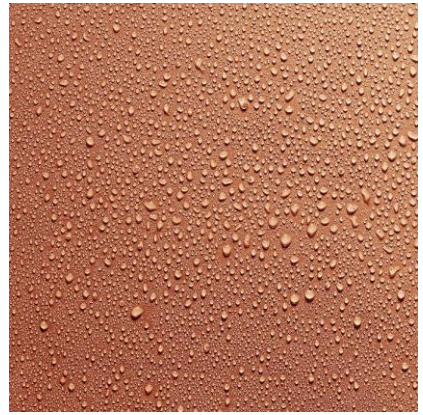
If no moisture added or removed

Temperature down

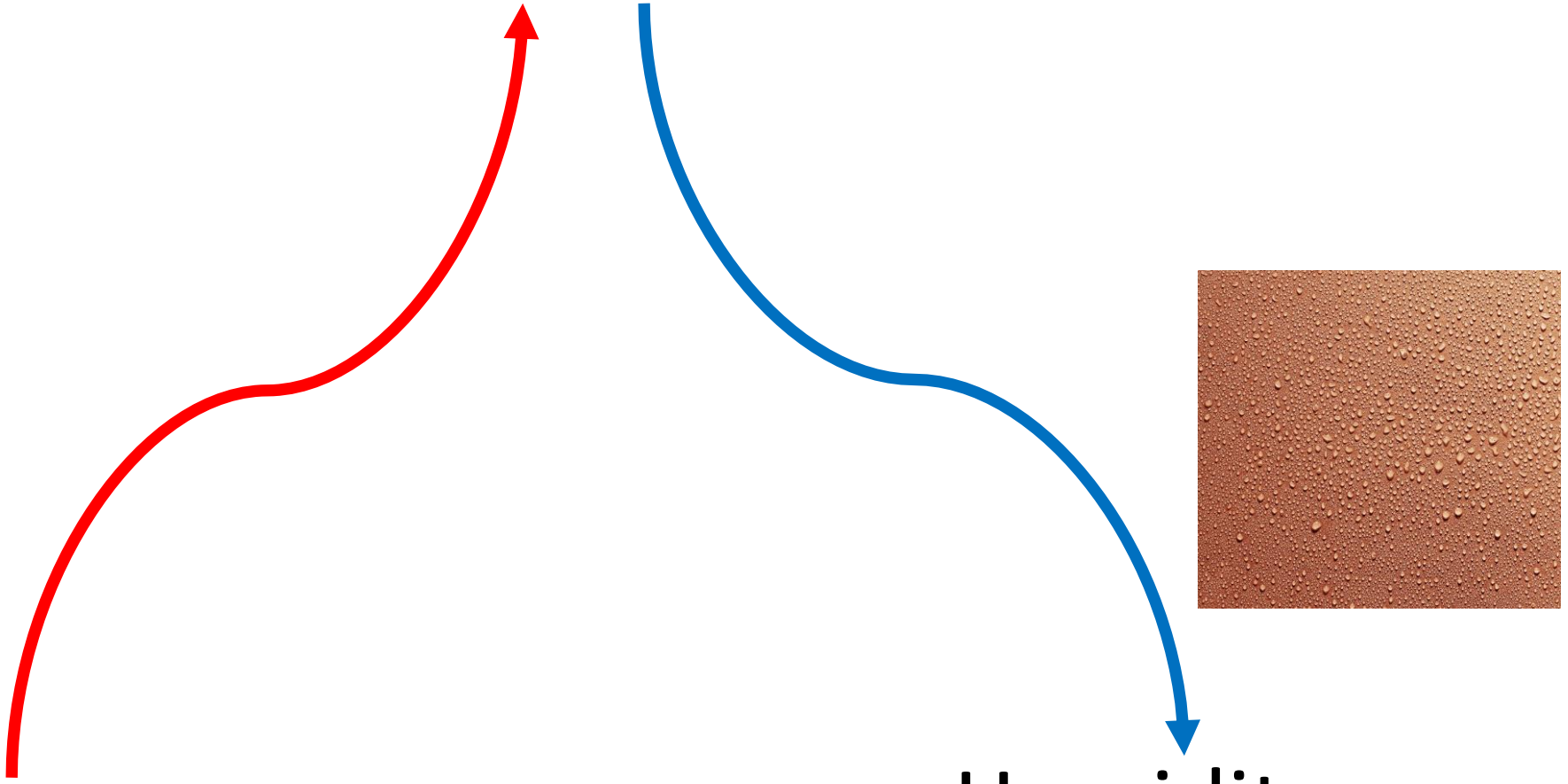
Humidity up



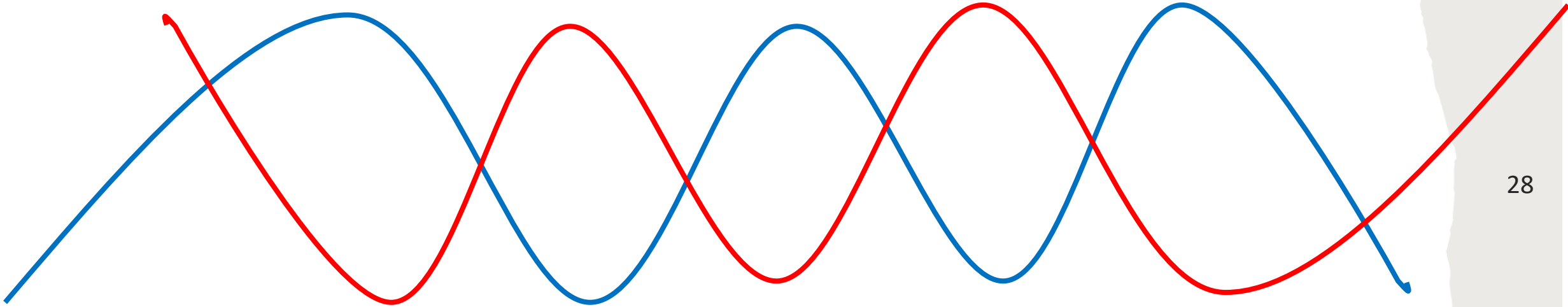
Temperature



Humidity

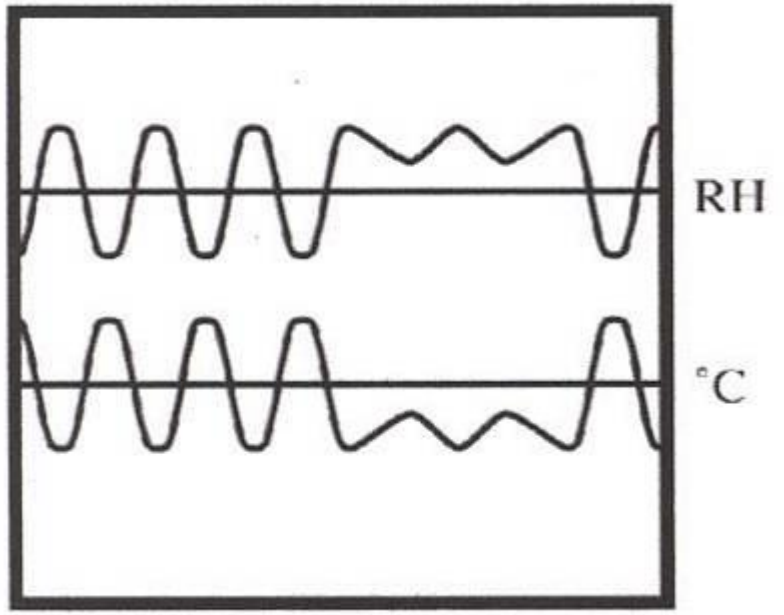

Temperature
Humidity

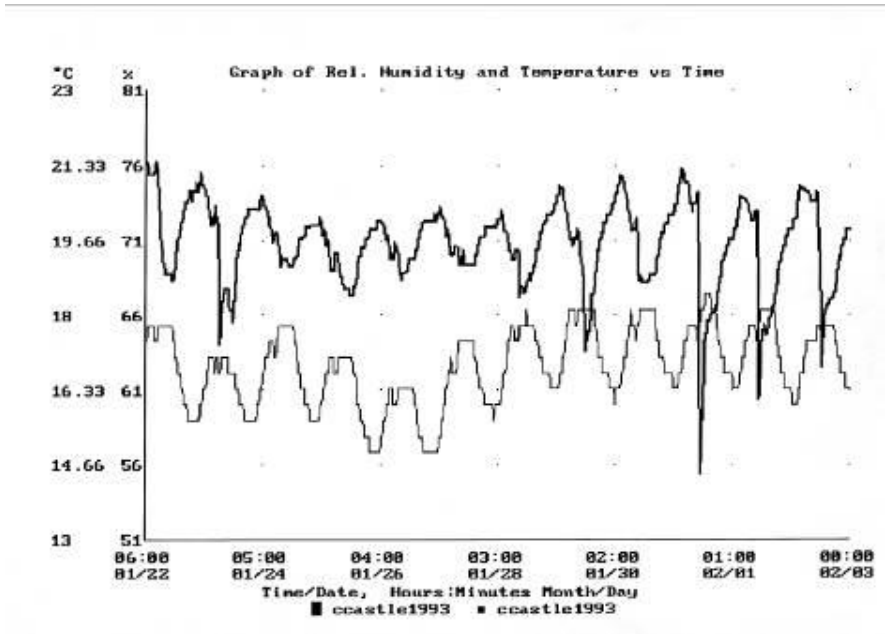
Temperature



Humidity

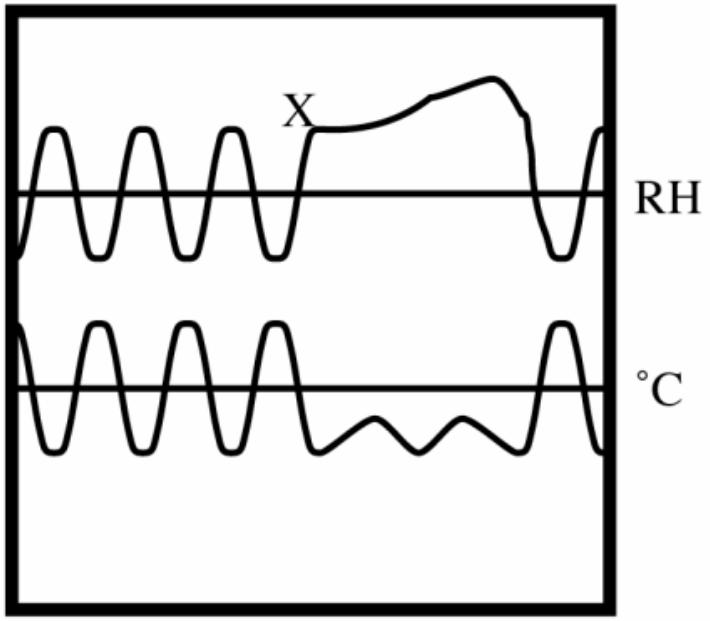
INTERPRETING DATA: SIMPLE RULES

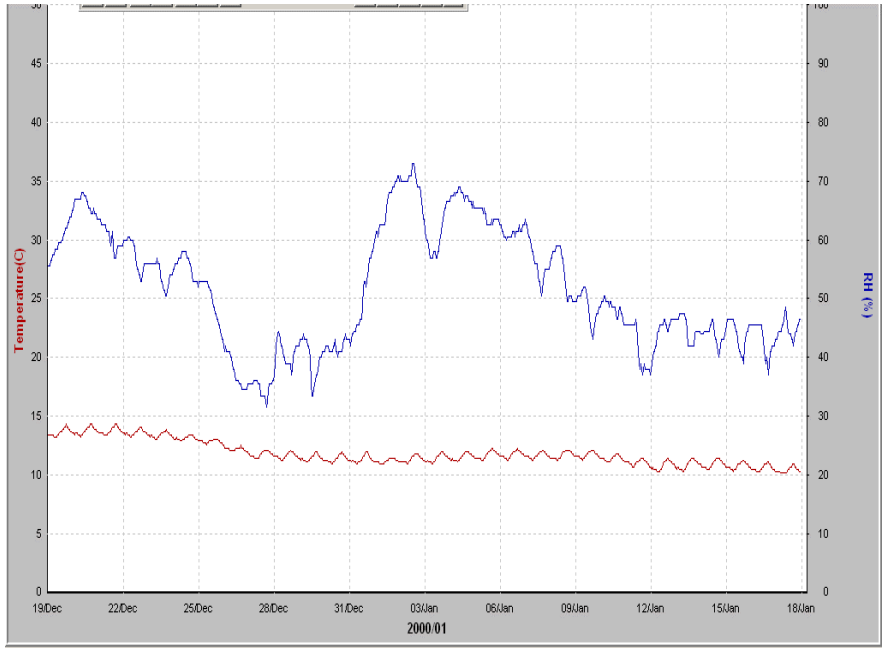




Temperature & Humidity mirroring each other

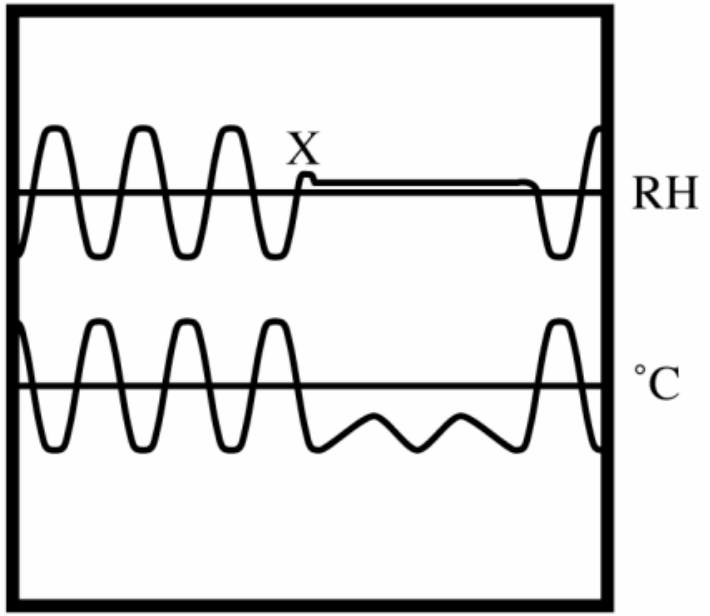
INTERPRETING DATA: SIMPLE RULES

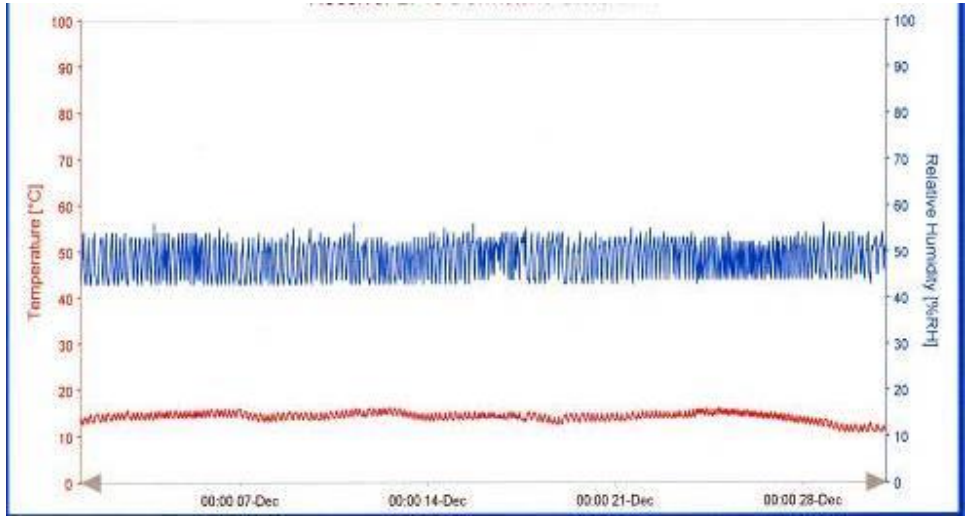




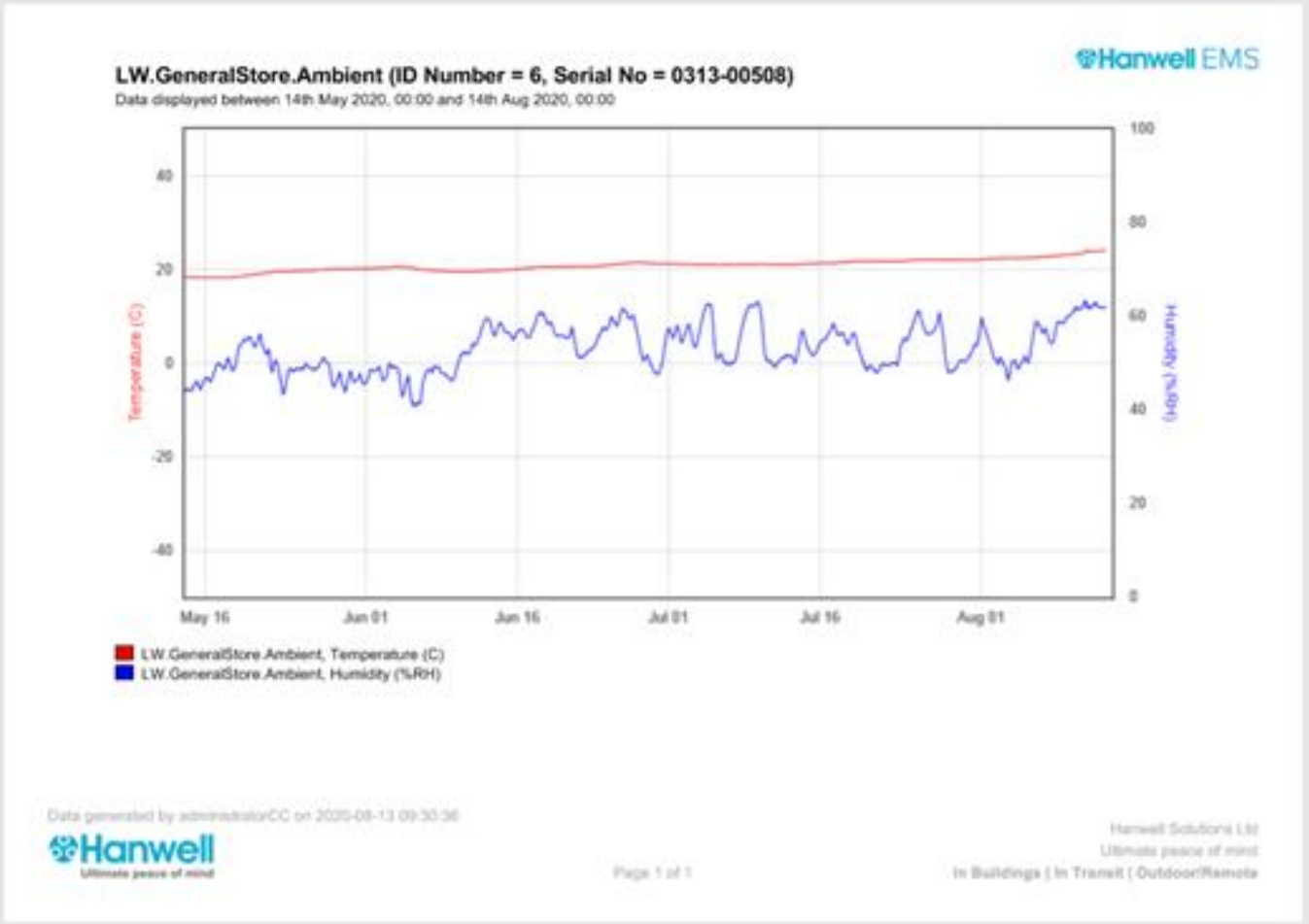
Extra water into chart at point X- perhaps wet weather

INTERPRETING DATA: SIMPLE RULES





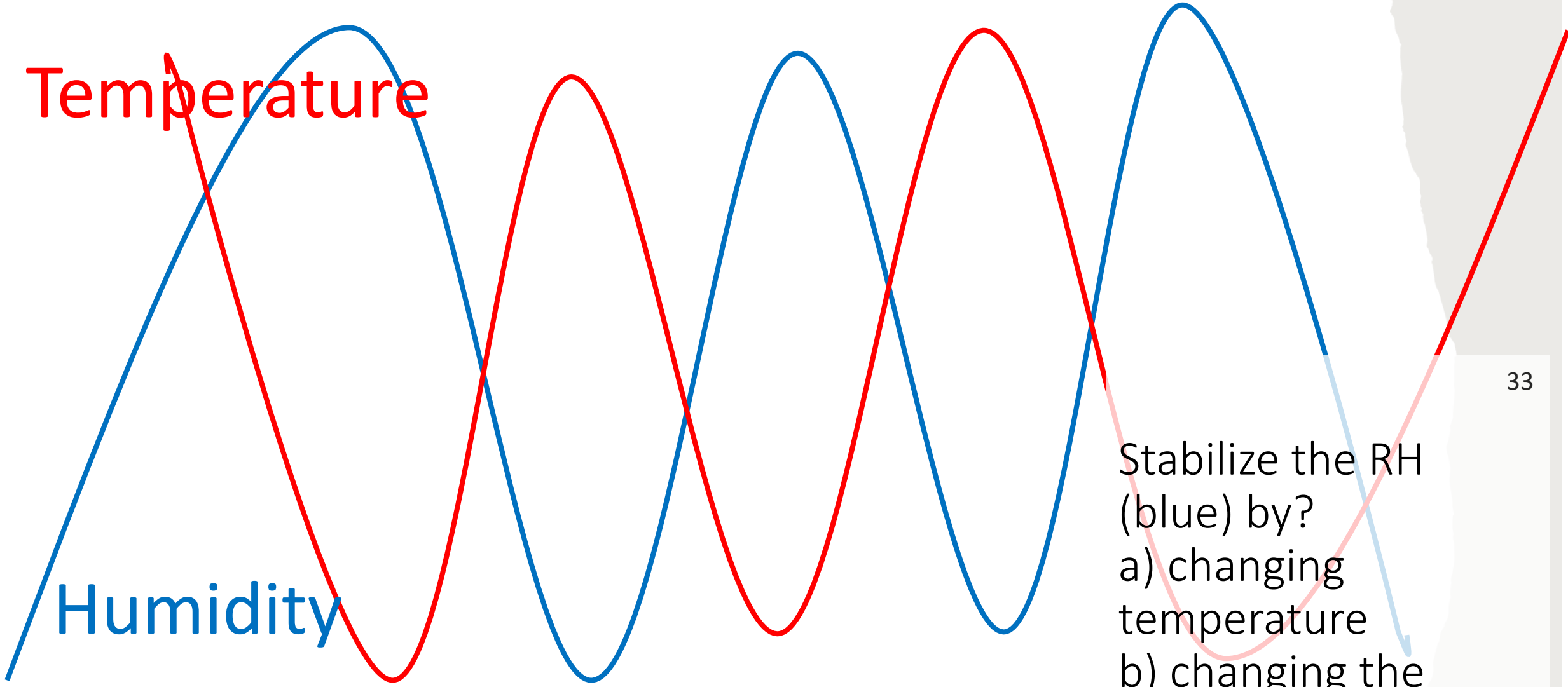
De-humidifier takes water out of the air at point X



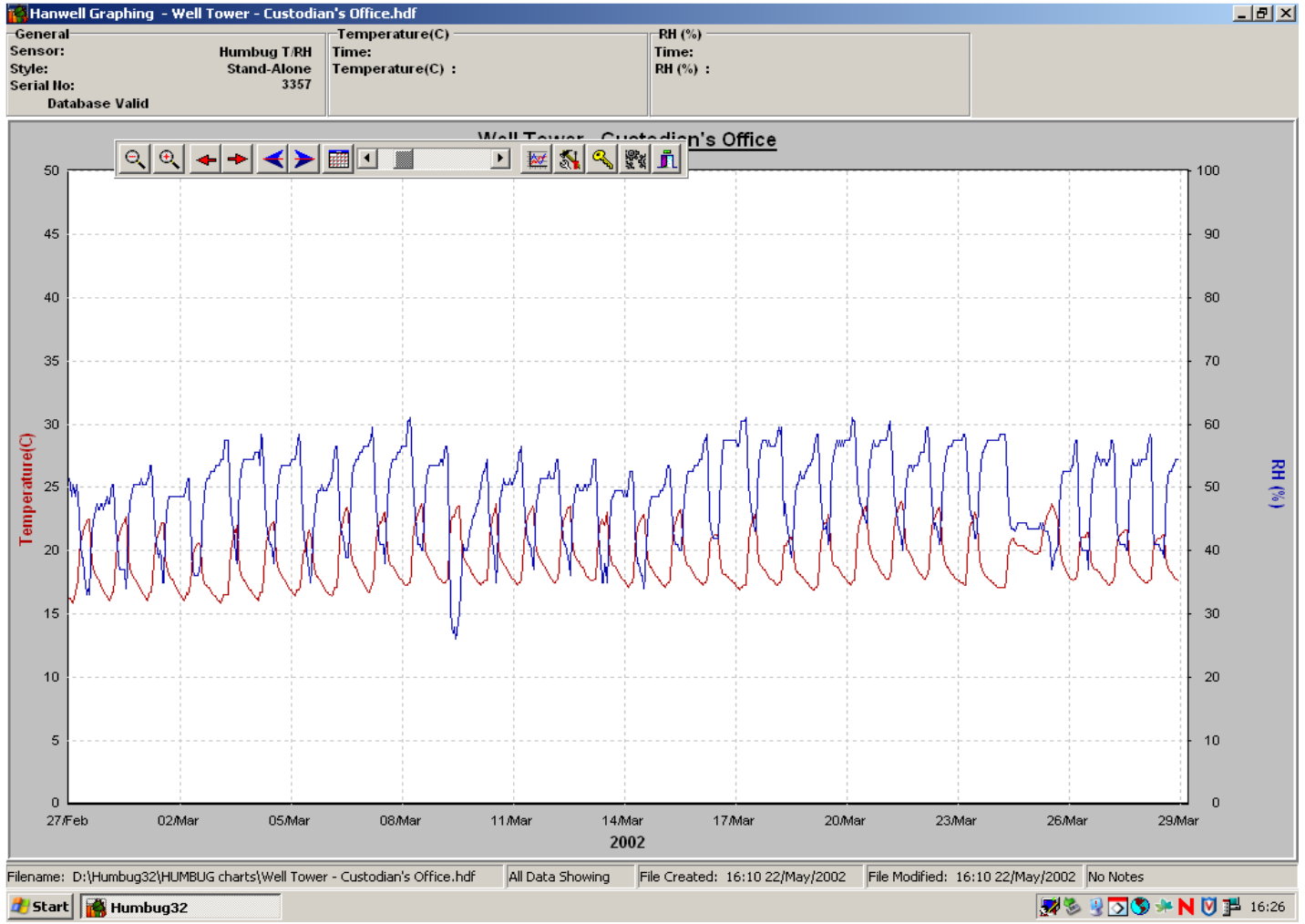
STABILIZE THE RH (BLUE) BY?

A) CHANGING TEMPERATURE

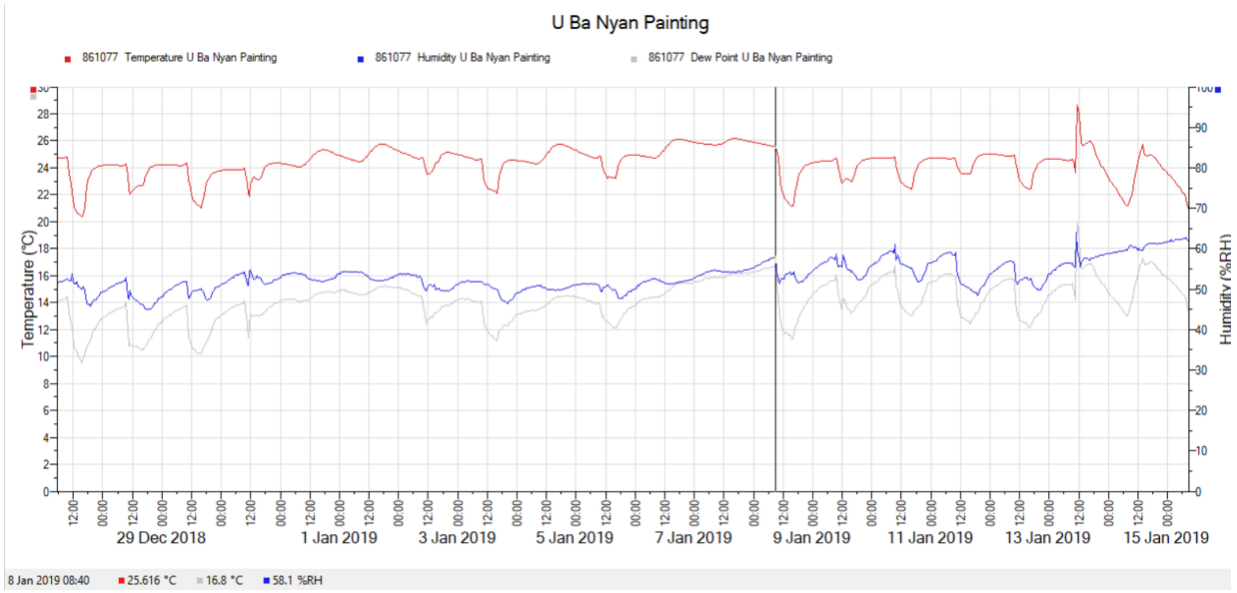
B) CHANGING THE AMOUNT OF WATER

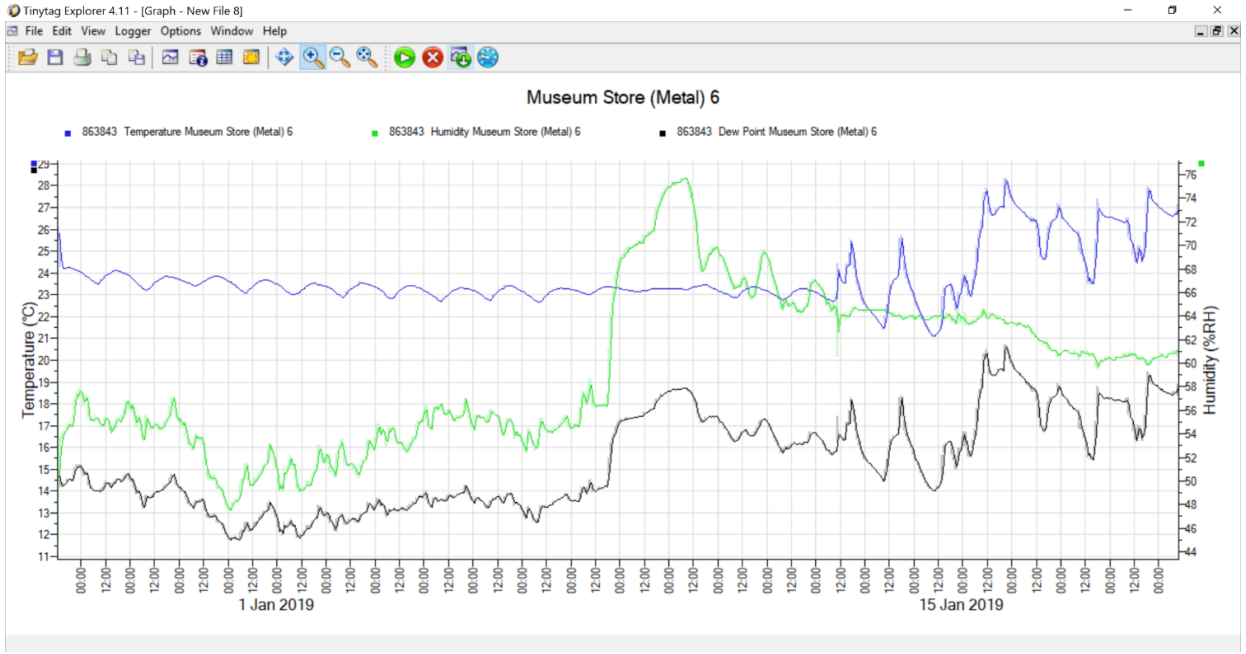


Stabilize the RH (blue) by?
a) changing temperature
b) changing the amount of water



Stabilize the RH (blue) by?
a) changing temperature
b) changing the amount of water

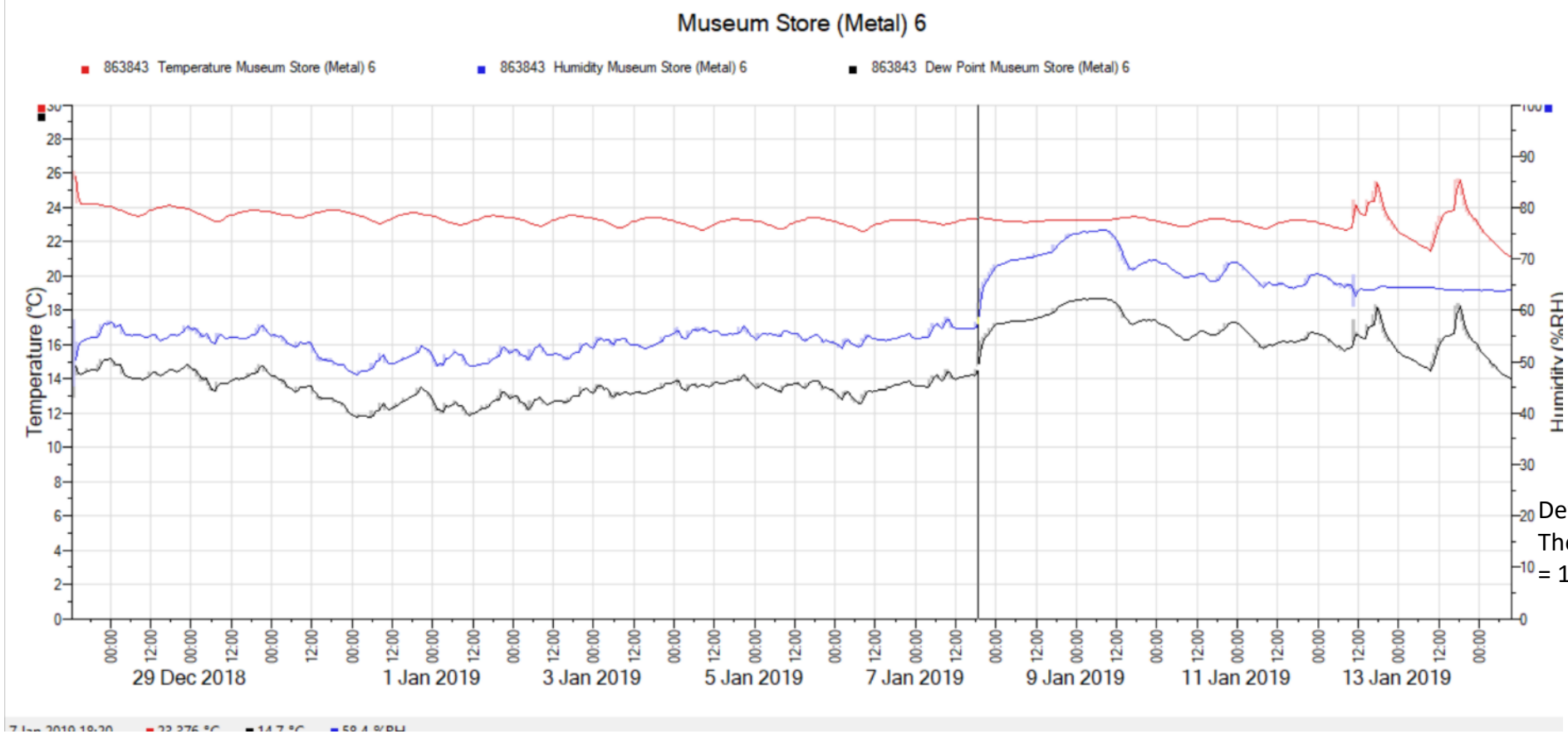




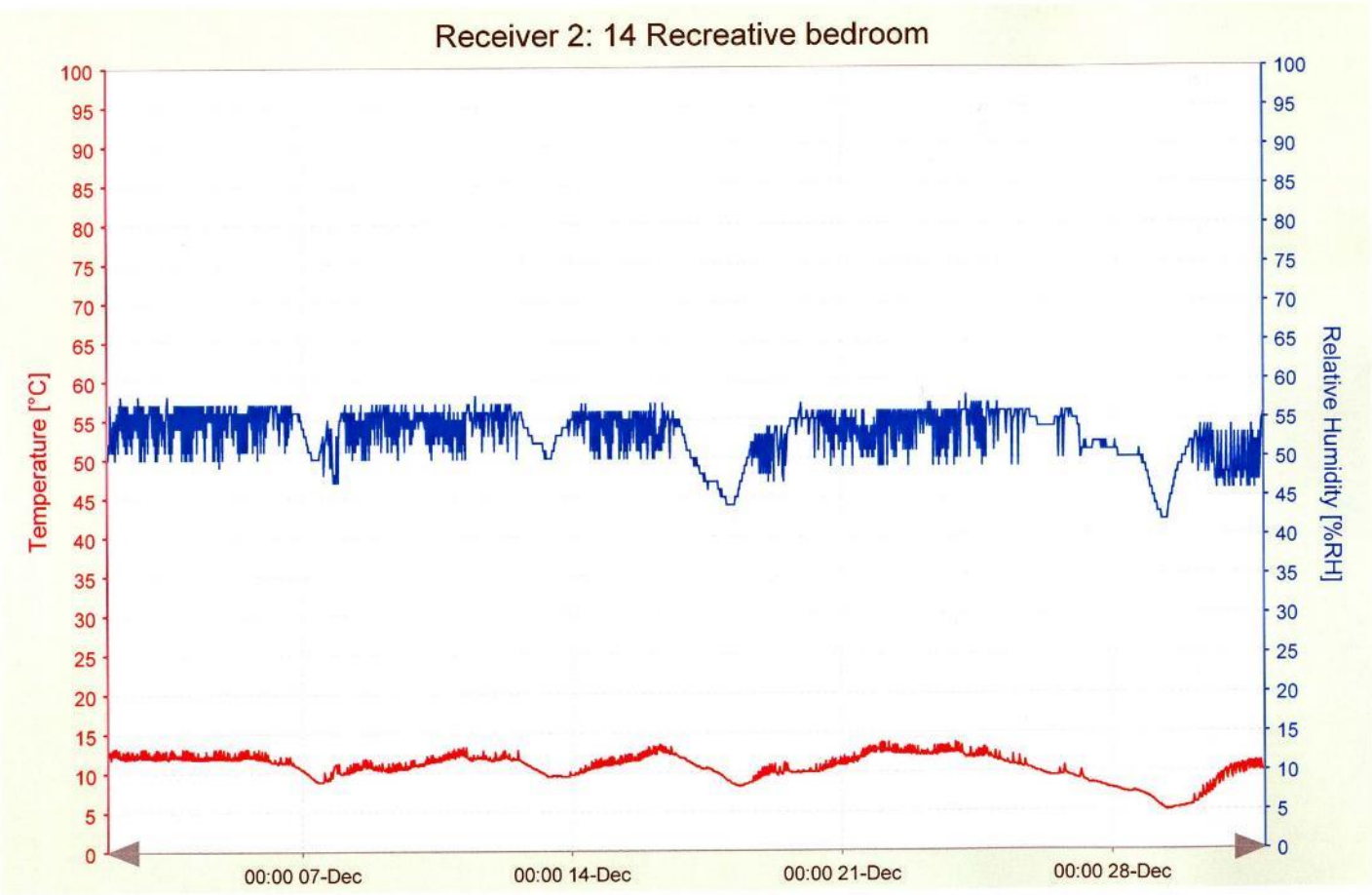
THINGS CHANGE. FIND OUT WHAT!

ARCHAEOLOGICAL MUSEUM

What changed?
2 days of rain

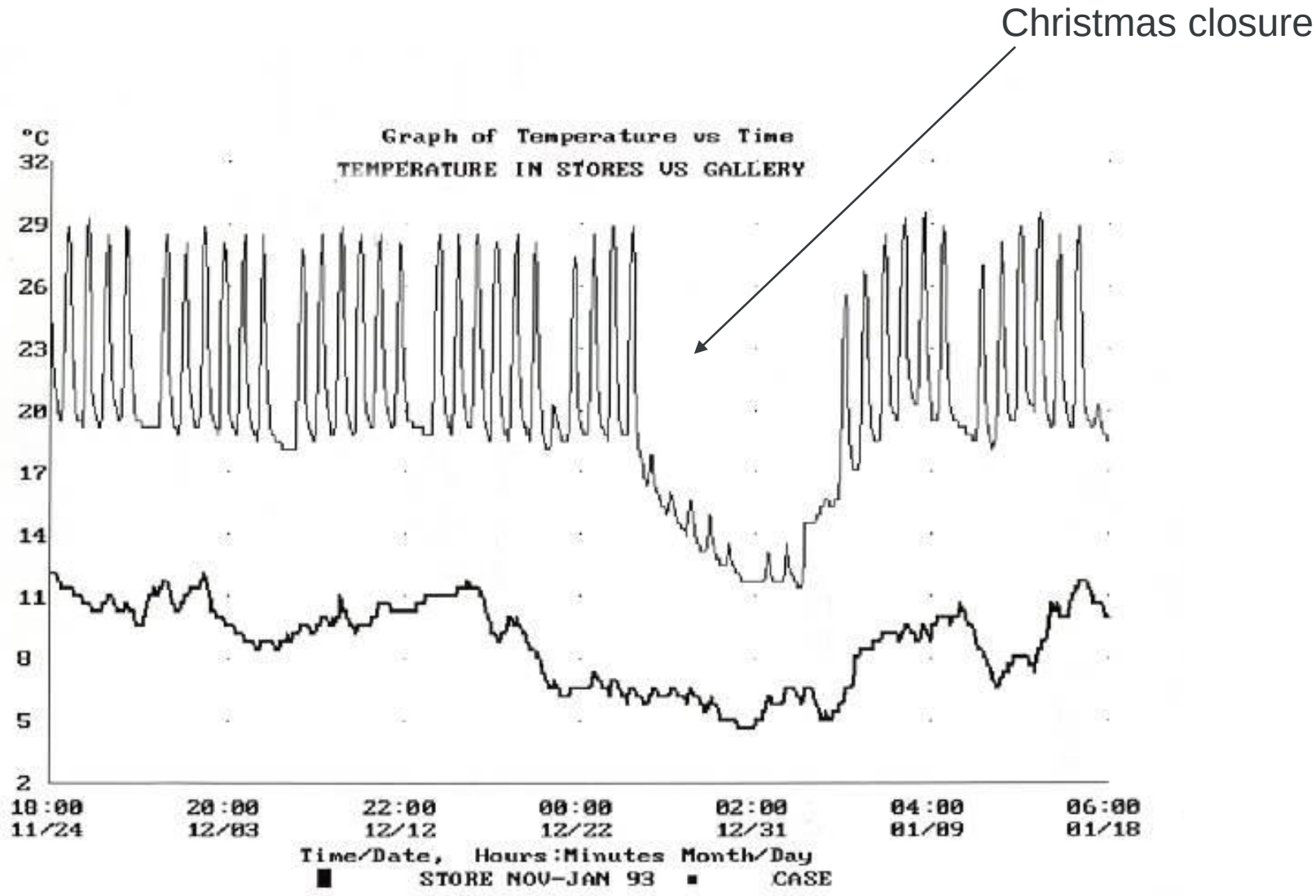


Dew Point
The temperature at which humidity = 100% (condensation)

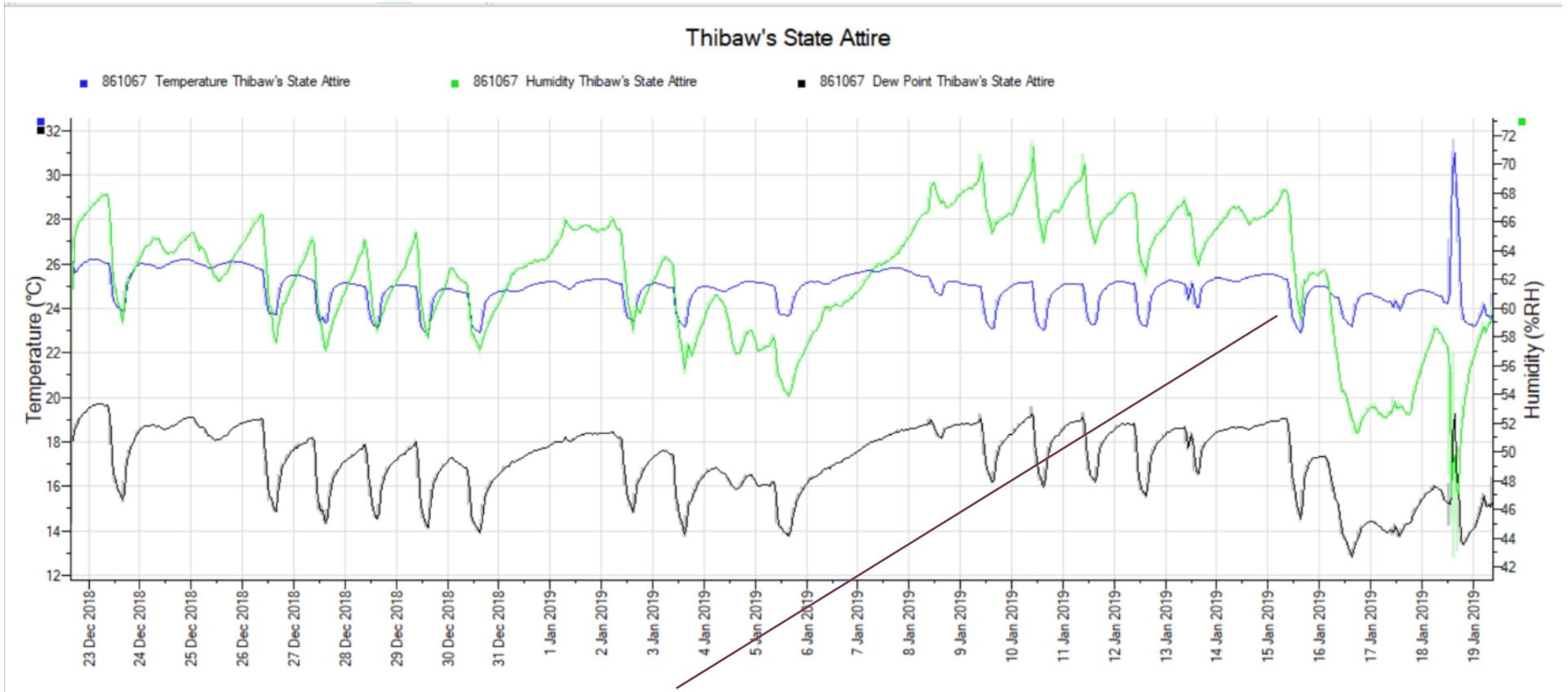


WHAT IS PLUGGED IN?

SIMPLE CLUES



NATIONAL MUSEUM YANGON



Unusual Data?
Logger moved so irrelevant
You need the supporting records

NS EN 16893:2018 MONITORING

- Provide and use monitoring devices in collection space.
- Monitor temperature &RH continuously (typically).
- Use independent monitoring devices to verify operation of building management system (BMS)
- Place monitors to collect readings that represent the typical conditions. Account should also be taken of extreme / abnormal conditions.
- For comparative purposes, the outdoor temperature and RH shall be monitored
- Information derived from monitoring shall be reviewed and interpreted regularity

MONITORING IS NOT CONTROL

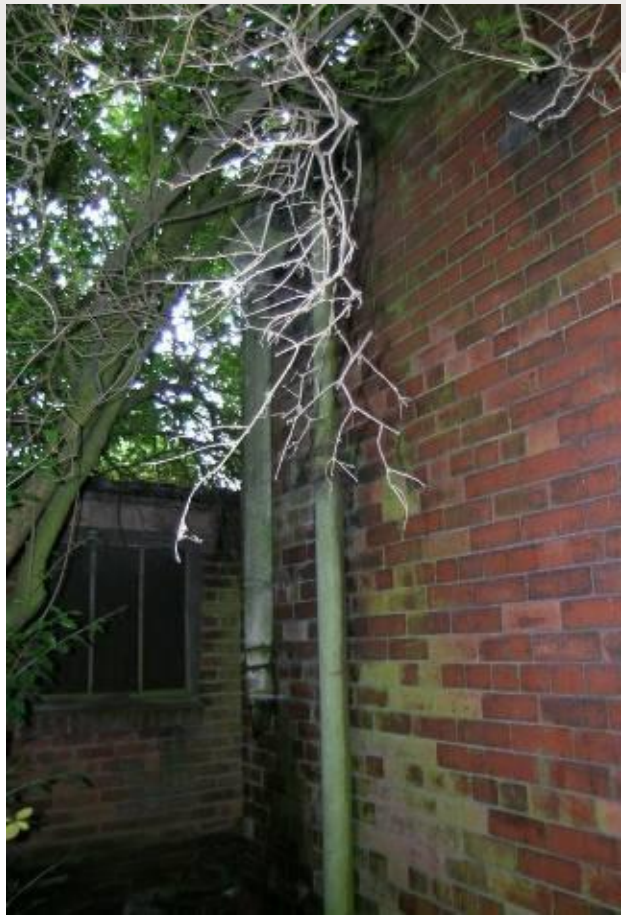
Monitoring does nothing to improve preservation conditions.

ENVIRONMENTAL CONTROL

1. building design
2. building improvements
3. packaging
4. display cases / frames.

5. collections that require specific environments that cannot be achieved by building structure alone mechanical control equipment can be installed.

NS EN 16893:2018



Sources of damp, excess air infiltration or weaknesses in insulation in an existing structure shall be identified and remedied first before considering the use of mechanical means of control.

CONTROL EQUIPMENT

Add Humidity

- Humidifiers (steam spray ultrasonic)

Remove Humidity

- De humidifiers
  - Refrigerant
  - Desiccant
- Heating (conservation heating)
- Desiccants / buffers

- Plug-in units, can increase the risk of fire or flood.

NS EN 16893:2018

- 4.3 Environmental strategy, 4.3.1 General
  An **environmental management strategy for the collection shall be develope**d, based on an assessment of the needs of the collections. … taking into account the sensitivity, significance and use of individual collection items.

- The strategy shall make clear the balance the organization intends to aim for between conservation requirements, collection use and energy economy.

TEMPERATURE TARGETS

- Building safety
- Impact on RH rise from low temperature
- Usage temperature / flexibility
- Comfort conditions for people

TEMPERATURE SPECIFIC COLLECTIONS

Wax Seal
National Museum of Wales

Incendiary igniter ‘Molotov Cocktail’ utilising a strip of nitrate film
© Imperial War Museum

Health and Safety Executive: The dangers of cellulose nitrate film HTTPS://www.HSE.Gov.UK/pubns/indg469.Pdf https://www.filmpreservation.org/preservation-basics/nitrate-degradation

	15% RH Survival years	**30 % RH** Survival years	**50% RH** Survival years
Warm 25ºC	75-250	30-100	15-50
Moderate 20ºC	150-500	60-200	30-100
Cool 10ºC	600-2000	240-800	120-400
Cold 0ºC		1200-4000	600-2000

TEMPERATURE AND APPROXIMATE LIFETIME
LOW STABILITY RECORDS MICHALSKI 2000

RELATIVE HUMIDITY TARGETS

1) Damp / high

2) RH above or below a critical value

3) RH above 0%

4) RH fluctuations

https://rachaelsmitherconservation.com/the-great-parchment-book/

1) DAMP / HIGH

Mould growth depends on moisture content and the presence of food sources

Mould grows if the moisture content is above a critical level for several days.

Rate of growth is dependant on RH.

60 – 75% is caution

Over 75 is danger

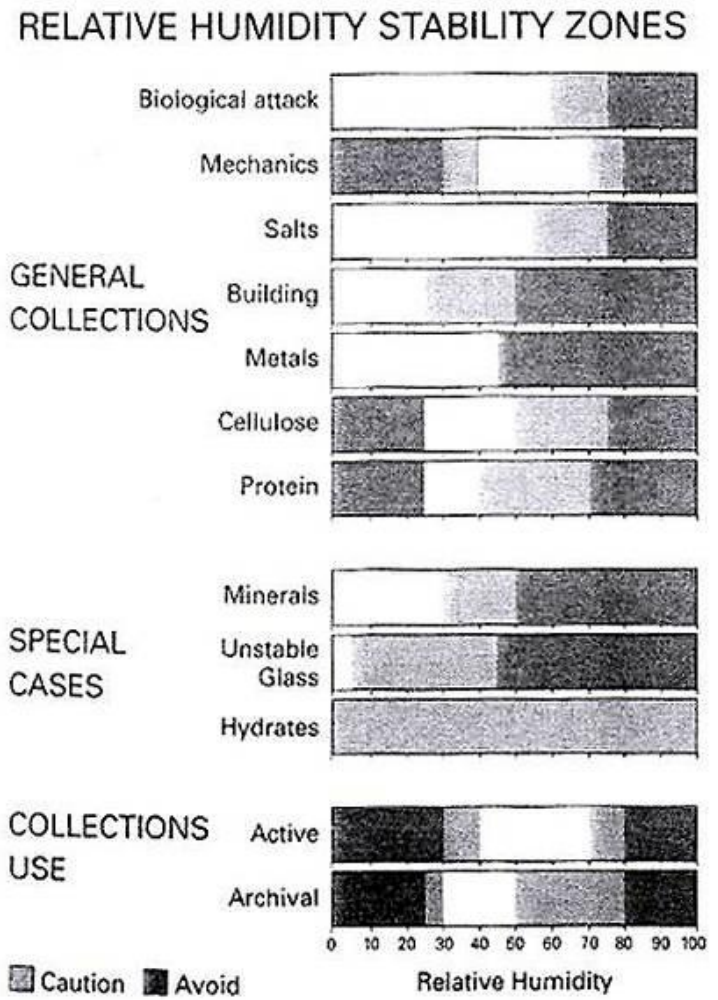
NO EASY ANSWERS

Relative Humidity

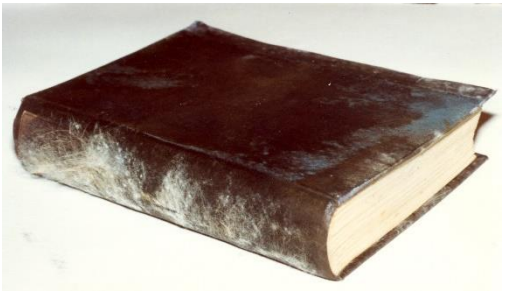
Re–examined by

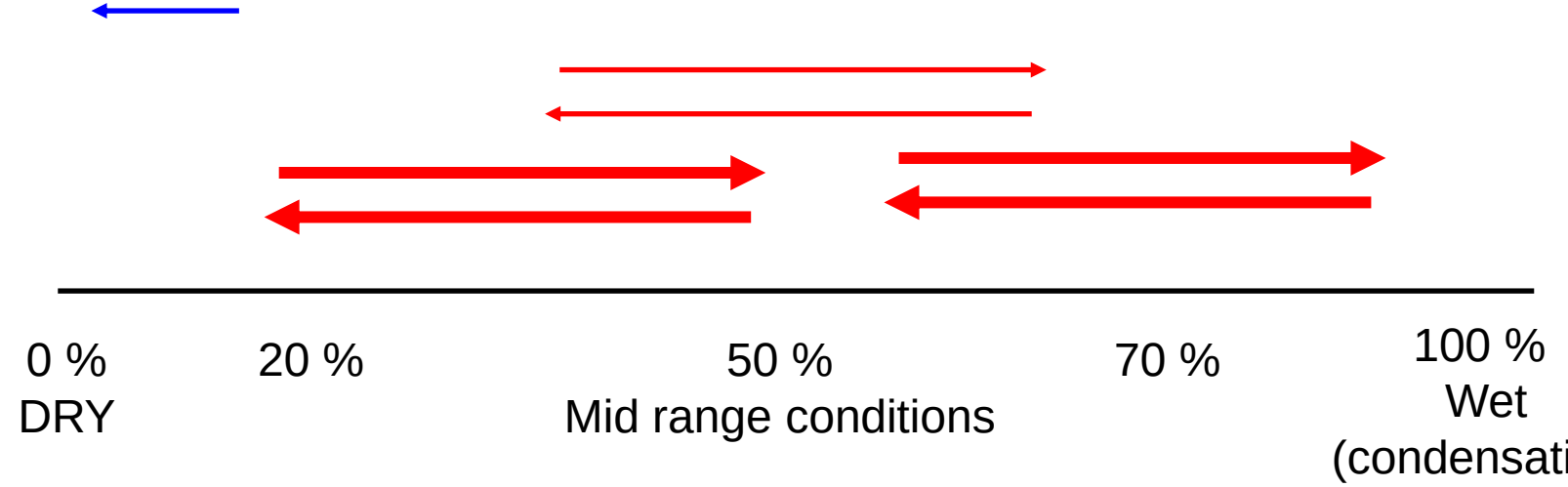
Erhardt and Mecklenburg

(IIC 1994)

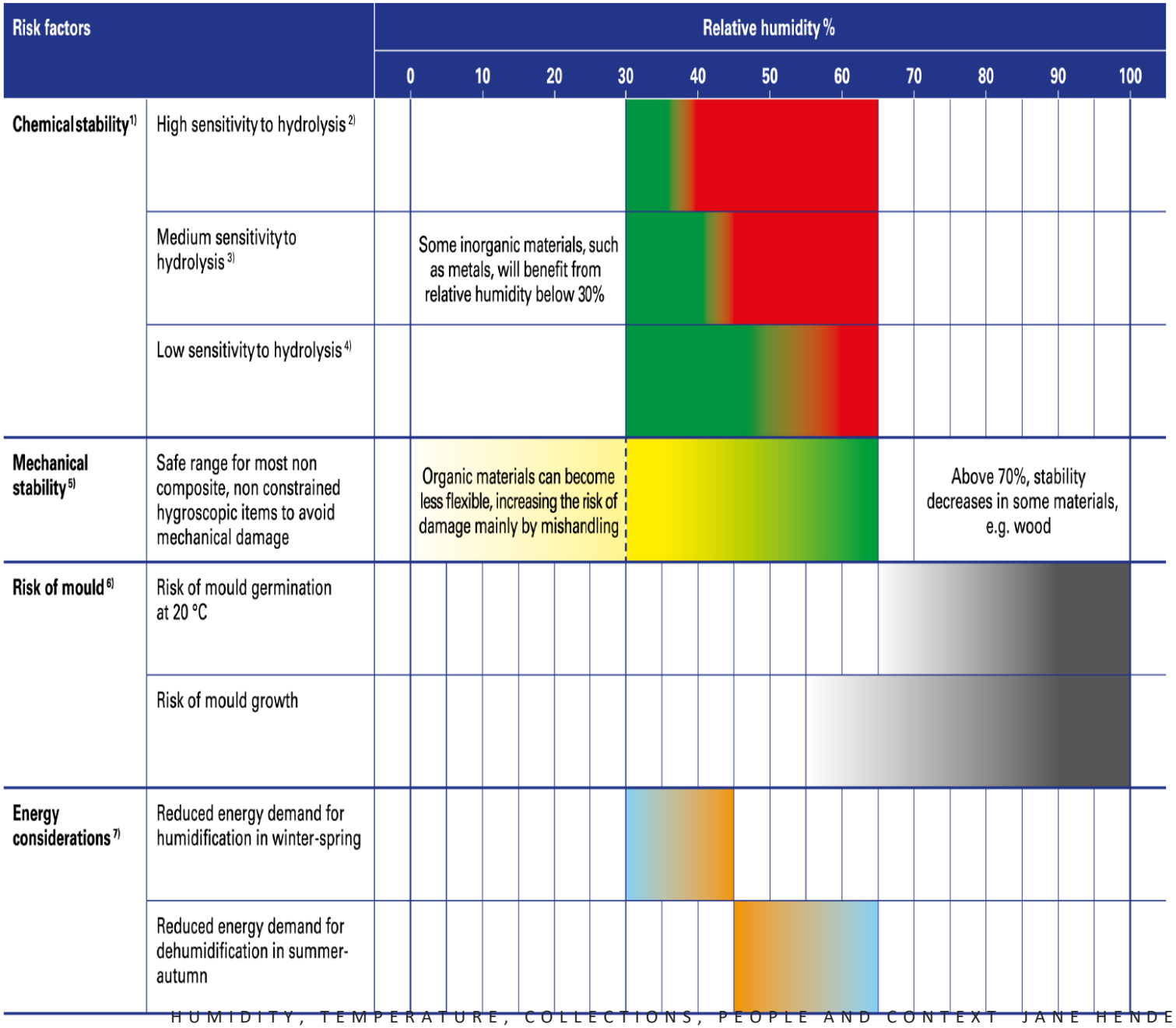


Relative Humidity Targets





Relative risk of damage and deterioration due to relative humidity
EN 16893.2018 BSI 2018



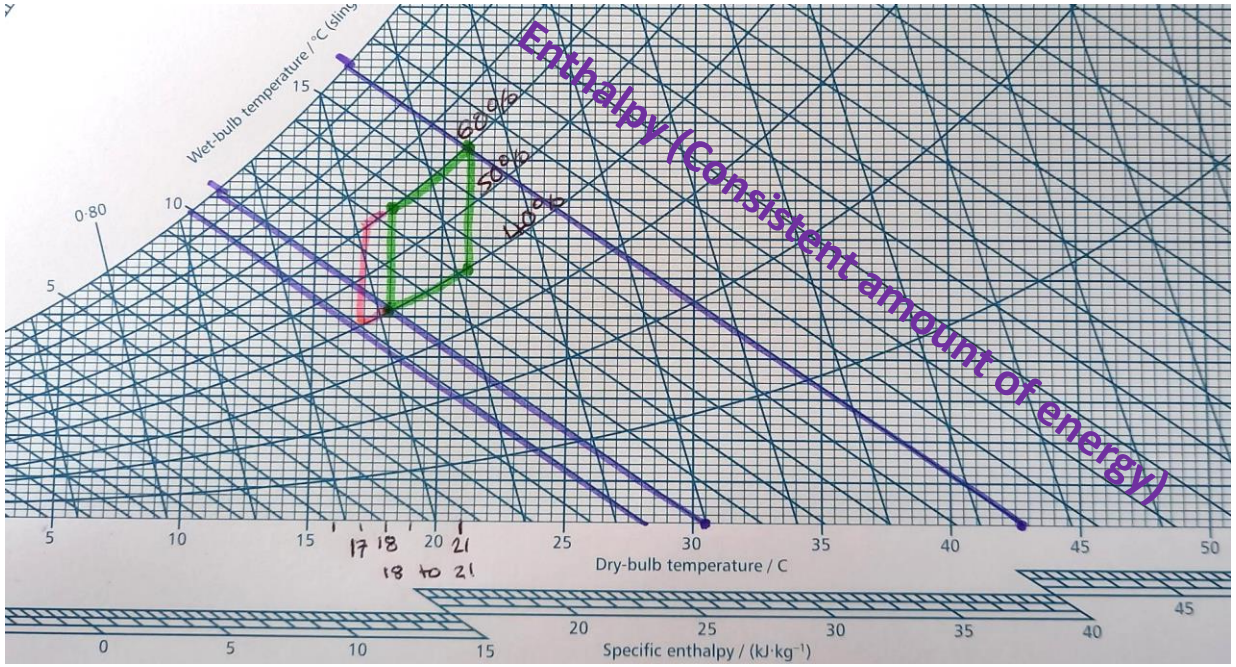
SET YOURSELF A TARGET!

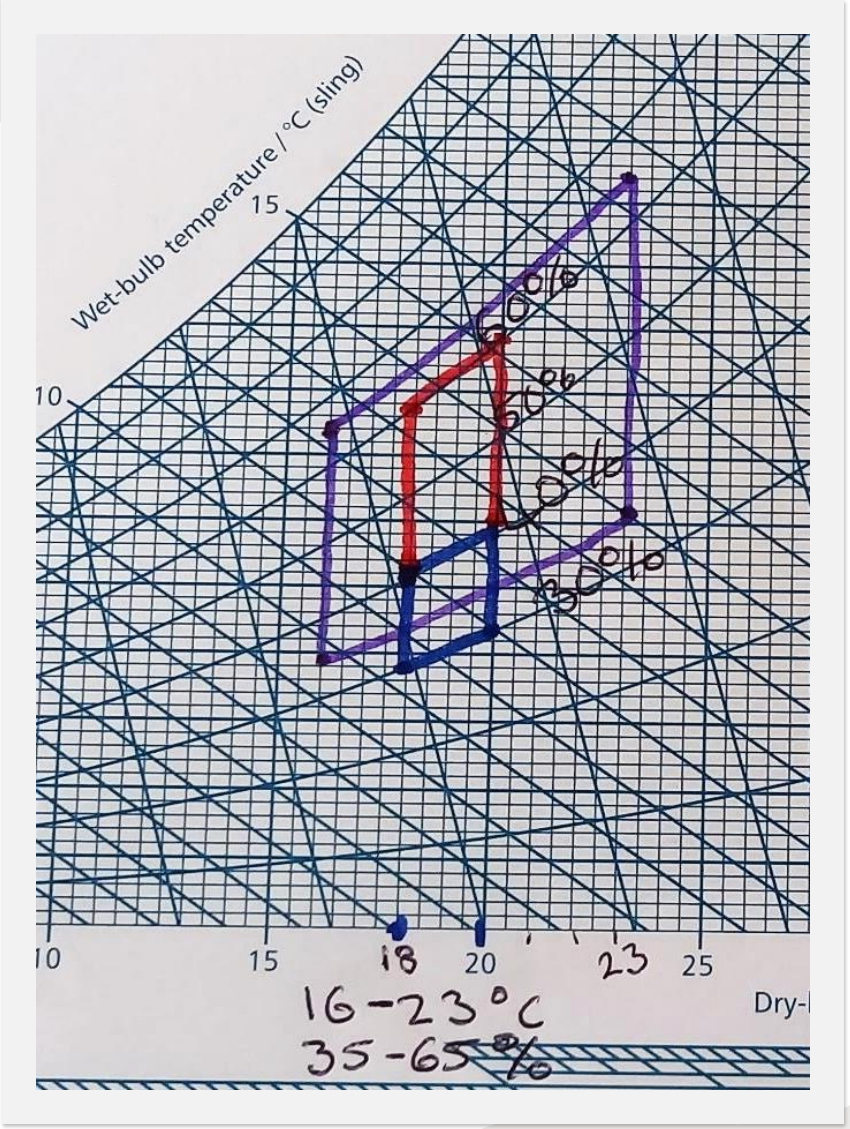
NS EN 16893:2018

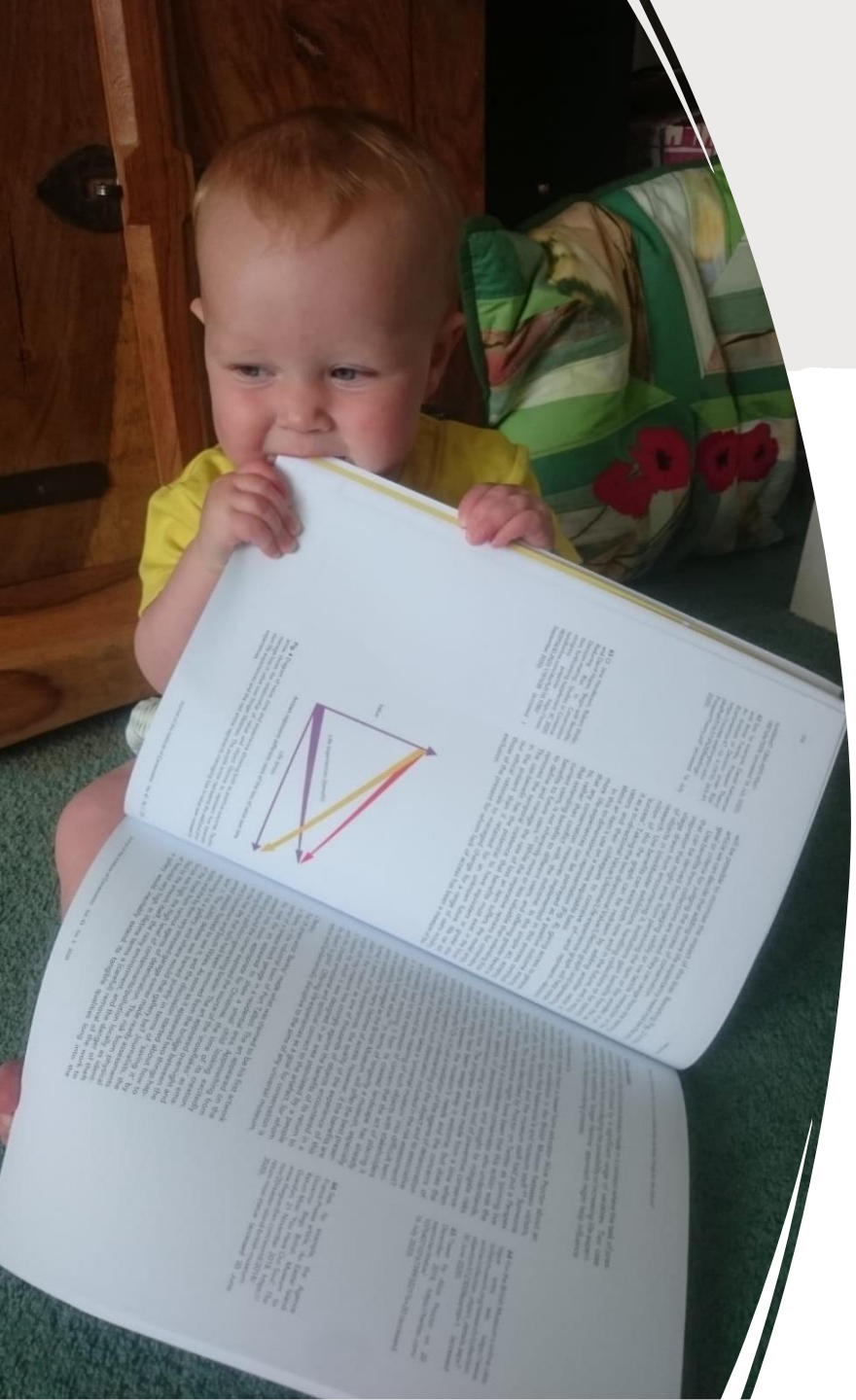
Environmental specifications for collections shall include:

1) the permissible upper and lower limits for RH and temperature & a desired seasonal average;

THE BIGGER THE TARGET THE EASIER IT IS TO HIT!







Decision factors
Benefits to institutions
Specific user needs • Safety • Cultural requirements • Access needs
Stakeholder priority
Understanding Materials & decay • Scientific testing • Observed to be safe • Tolerance limits • Combinations and vulnerability
Attitude to risk • Personal risk and responsibility • Organisation's appetite for risk • Consequence of risk

Decision factors
Distribution of benefits • Equally through time • Restoration of past inequality • Compensate current inequality
History and acclimatisation
Sustainability
Resources • Budgets • Technology • Staff skills
Authentic practice and embodied wisdom

NS EN 16893:2018
5.3.4.2STORAGE SPACES

Environmental stability in a storage space shall be achieved by a location and construction that

- ensures that the temperature inside the space is not rapidly or substantially influenced by the temperature outside,
- has low air infiltration rates,
- has a barrier to prevent moisture penetration from outside and
- incorporates hygroscopic materials on the inside to moderate internal RH fluctuations.

- Heating infrastructure that is not intended for the storage space shall not pass through or under the space.
- A new storage building or space shall be built to maximise air tightness.

NS EN 16893:2018 5.3.4 PASSIVE OR LOW-ENERGY ENVIRONMENT STRUCTURES

- Most collection types can be stored and used in an environment that changes gradually over an annual seasonal cycle, achieved through passive means.
- Determine the annual max /min by the collection type.
- If a new building or the renovation of an existing room is being planned, it **shall not be** assumed that mechanical environmental control systems are required

Key Past and Projected Impacts and Effects on Sectors and Biogeographical Regions. European Environment Agency, 2017.

Arctic region
Temperature rise much larger than global average
Decrease in Arctic sea ice coverage
Decrease in Greenland ice sheet
Decrease in permafrost areas
Increasing risk of biodiversity loss
Some new opportunities for the exploitation of natural resources and for sea transportation
Risks to the livelihoods of indigenous peoples

Atlantic region
Increase in heavy precipitation events
Increase in river flow
Increasing risk of river and coastal flooding
Increasing damage risk from winter storms
Decrease in energy demand for heating
Increase in multiple climatic hazards

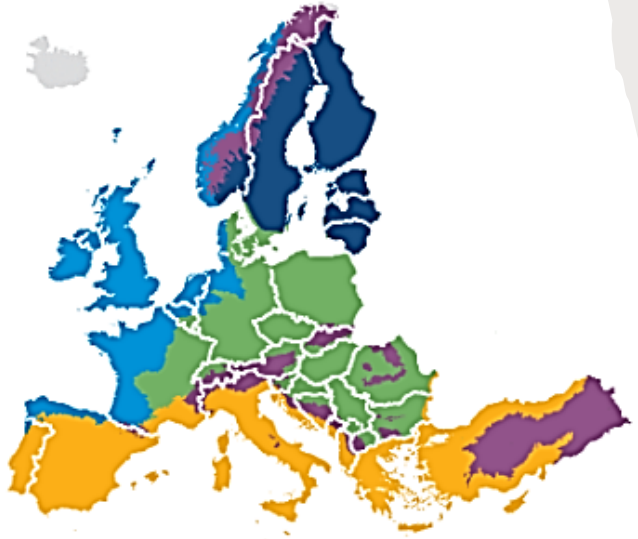
Mountain regions
Temperature rise larger than European average
Decrease in glacier extent and volume
Upward shift of plant and animal species
High risk of species extinctions
Increasing risk of forest pests
Increasing risk from rock falls and landslides
Changes in hydropower potential
Decrease in ski tourism

Coastal zones and regional seas
Sea level rise
Increase in sea surface temperatures
Increase in ocean acidity
Northward migration of marine species
Risks and some opportunities for fisheries
Changes in phytoplankton communities
Increasing number of marine dead zones
Increasing risk of water-borne diseases

Boreal region
Increase in heavy precipitation events
Decrease in snow, lake and river ice cover
Increase in precipitation and river flows
Increasing potential for forest growth and increasing risk of forest pests
Increasing damage risk from winter storms
Increase in crop yields
Decrease in energy demand for heating
Increase in hydropower potential
Increase in summer tourism

Continental region
Increase in heat extremes
Decrease in summer precipitation
Increasing risk of river floods
Increasing risk of forest fires
Decrease in economic value of fore
Increase in energy demand for cooli

Mediterranean region
Large increase in heat extremes
Decrease in precipitation and river flow
Increasing risk of droughts
Increasing risk of biodiversity loss
Increasing risk of forest fires
Increased competition between different water users
Increasing water demand for agriculture
Decrease in crop yields
Increasing risks for livestock production
Increase in mortality from heat waves
Expansion of habitats for southern disease vectors
Decreasing potential for energy production
Increase in energy demand for cooling
Decrease in summer tourism and potential increase in other seasons
Increase in multiple climatic hazards
Most economic sectors negatively affected
High vulnerability to spillover effects of climate change from outside Europe



WE SHOULD ALSO ADAPT TO THE IMPACTS OF CLIMATE CHANGE

/ADAPTING-OUR-CULTURE-TOOLKIT.PDF

- https://www.culturaladaptations.com/wp-content/uploads/2021/03

	Staff involvement
Basic	✓ Staff are encouraged to think about sustainability.
Good	✓ Staff are trained, educated and encouraged to work in an environmentally responsible manner.
	✓ Routine decisions are made taking sustainability into account.
	✓ An individual or group is responsible for encouraging sustainability improvements.
Best	✓ Staff are encouraged to use sustainable modes of transport.
	✓ Environmental policies have been adopted by management.
	✓ An individual or group is responsible for implementing sustainability policies and monitoring progress.
	✓ Environmental sustainability efforts are introduced to all new staff on induction.

	Review of the success of sustainability efforts
Basic	✓ Sustainability efforts are regularly reviewed and updated.
Good	✓ Targets for environmental sustainability progress have been set and are measured against benchmarks.
	✓ Performance is compared with other similar organizations.
Best	✓ Targets for key areas of procurement, travel, waste and energy management are incorporated into annual operational plans.

Megan de Silva & Jane Henderson (2011) Sustainability in conservation practice, Journal of the Institute of Conservation, 34:1, 5-15, DOI: 10.1080/19455224.2011.566013

#1 Maintain your building.

Everyone can inspect their own buildings and look for signs of trouble. Go outside in the rain and take pictures to help you think about what you are seeing. Put someone in charge of building maintenance and ask them to report on this. Buildings work sometimes does cost a lot but the longer you leave it the more it will cost and the more harm it will do to your collection. Damp air is more expensive (and energy intense) to heat.

#2 Clear the rainwater goods

We don't want any of you falling off ladders but make sure the gutters are emptied of leaves, especially in autumn. If you don't have a good way of accessing your guttering, consider installing fixing points to make safe ladder access. Don't forget you can also compost your leaf mulch.

#3 Shut that door

We don't need to have the door open to show the museum is open. Be creative, positive and inviting: is there a sign that you can put out that also acts as a selfie point? Can you hang signs that provide access information in multiple languages, admission charges, location of level access point and whether you have accessible toilets?

#4 Lights out

If no one is in the space don't have the lights on. This will reduce the total fade damage to your collections and your energy bills. Good quality LED lighting will provide an efficient lighting solution.

#5 Manage the entrance

People bring moisture, dirt, and pests, especially on rainy days, and we have plenty of these in Wales! Do what you can to stop these things from travelling around your museum. This might look like an umbrella stand, a really big door mat, and / or a buggy and trolley park. If you have a foyer, think about how people can comfortably adjust themselves from outside to in. Text Welsh Museums Federation STEPS TO SUSTAINABLE COLLECTION CARE

THANK YOU AND QUESTIONS

HENDERSONLJ@CARDIFF.AC.UK