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PRESERVATION LEAFLET

THE ENVIRONMENT

02-01 Temperature, Relative Humidity, Light, and Air Quality: Preservation Basics

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INTRODUCTION

One of the most effective ways to protect and preserve a cultural heritage collection is to control the environment in the spaces where it is stored. When we speak of environmental control in this context, we focus on four factors: temperature, relative humidity (RH), light, and air quality. Managing these factors and minimizing their impact on materials is the goal of environmental control.

Environmental factors interact with one another, contributing to the overall storage climate. In addition, different *combinations* of factors have different impacts. For example, warm temperatures and *high* relative humidity can lead to mold growth, whereas warm temperatures and *low* relative humidity can make wood-and paper-based collection materials more brittle. In addition, wide *fluctuations* in temperature and relative humidity can cause damage to collections.

Like temperature and RH, air quality and light contribute to the deterioration of collections. Visible light will fade colors, and ultraviolet light speeds the embrittlement of paper. Dust, volatile organic compounds (VOC's), and pollution affect the air quality in a collection space and act as catalysts that accelerate the rate of deterioration of collections.

THE BASICS

Environmental Monitoring

Monitoring the storage environment is a foundational element of an overall preservation program. By monitoring and controlling the environment, you can minimize the impact of agents of deterioration – the chemical, biological, and physical forces that accelerate the breakdown of collection materials. The monitoring process requires the participation of both collections care staff and facilities staff to formulate the best plan. See NEDCC Preservation Leaflet 02-02 Monitoring Temperature and Relative Humidity for more information on setting up an environmental monitoring program.

Maintenance of Systems

Installing—and maintaining—climate control equipment will greatly enhance the ability of an institution to ensure a safe and stable storage environment. Collections care staff and facilities staff should agree on a schedule for regular maintenance and inspection of heating, cooling, and humidification equipment and systems. Changing filters and clearing condensate lines are examples of simple tasks that will promote the proper operation of your equipment over time.

Set Points

Guidelines exist for the "ideal" temperature and RH for a building *occupied by workers or residents*, but in a cultural heritage institution, it is important to also consider the needs of the collection. Different formats and types of materials require different environments for optimal preservation. (See Chart 1, below.)

In a mixed-used space (e.g. offices and collection storage in the same room), human comfort must be

maintained without unduly hastening the deterioration of the most valuable collections. In a space that is used exclusively for storage but that contains mixed formats, there is no single, ideal set point.

Many climate systems are designed for normal home and office use and struggle to maintain the cooler, drier set points previously recommended by the preservation community. This effort can result in damaging fluctuations in environmental conditions, reduce the efficiency and cost-effectiveness of the system, and shorten the life span of equipment. **For these reasons, the concept of ideal set points has been revised to account for building age and construction, human comfort, format needs, and energy usage.** See the following sections of this leaflet for more detailed discussions of the impact of temperature, humidity, light, and air quality on collections.

TEMPERATURE

Of all the components combined under the umbrella of the environment, temperature and relative humidity are the easiest to understand and control.

Temperature in its most familiar sense means the degree of warmth or coldness on a standard scale. Temperature is also a measure of the vibration of molecules in collection materials. The molecules in materials are constantly vibrating: when the temperature increases, the molecules vibrate more quickly and begin to spread out. When the temperature falls, the molecule vibrations slow down and the molecules contract.

What impact does this have on collection materials? At higher temperatures, the increased vibration of molecules increases the energy available for chemical reactions, and the materials deteriorate more quickly. For example, newsprint stored at high temperatures deteriorates because the lignin molecules will break down more quickly, cleaving and bonding again and again with the cellulose, thus weakening and embrittling the paper. (Lignin is a common component of paper that leads to the formation of acid.)

Protecting collections from high temperature

Studies completed by the Image Permanence Institute show that "material response to changes in temperature (thermal equilibration) is fast, taking only hours, as compared to the response to changes in humidity (moisture equilibration), which may take days, weeks, or months" (IPI, eClimateNotebook). In areas dedicated to storage and not intended as workspace, the temperature can and should be kept lower to conform to best practices for material type. Temperature settings for public and staff spaces, including those that also double as collection storage or display, should aim for a setting that is as low as possible while still being comfortable for people. Typically, this means a temperature between 64°F and 72°F and not exceeding 75°F. However, you must consider the age and construction of the building as well as the effectiveness of the climate control system.

RELATIVE HUMIDITY

Relative humidity and temperature are directly related and cannot easily be separated. When the temperature changes, relative humidity does, too. Relative humidity (RH) is given as a percentage. For example, when the relative humidity is 50% at 70°F, the air being measured is holding half of the water vapor it can hold at that temperature.

It is important to note that the temperature determines how much water vapor the air can hold before it becomes saturated. Warmer air can hold more water vapor than colder. This is why iced tea glasses "sweat" in the summer; the cold air immediately around the icy glass cannot hold as much moisture, and that excess moisture condenses on the glass. Thus, even relatively small changes in temperature can mean real changes in RH.
What does this mean for collection materials? For one, materials stored close to exterior walls will be impacted by the temperature outside. Most organic collection materials (paper, leather, parchment, textiles, etc.) will absorb and release water easily,

meaning they are hygroscopic. When the humidity is high, they will absorb moisture and expand, and when the humidity is low, they will release moisture and shrink. If this occurs rapidly, this movement can lead to distortion in paper, bindings, and other collection materials. Of greater concern is pest activity and mold, which are more likely at a higher relative humidity.

Very low relative humidity can be problematic too, leading to stiffening of binding materials, flaking of emulsion layers from film, and the loss of flexibility in paper, leading to breakage similar to brittleness.

CHART 1	Space	Temperature	Relative Humidity
Paper/Books/Textiles	Combined use areas (collection storage and public/work space)	**68°F ± 4°F**	**30% - 60%**
	Collections Storage accessed regularly	**55°- 65°F**	**30% - 60%**
	Collections Storage accessed infrequently	**40° - 50°F**	**30% - 60%**
Film (Cellulose Nitrate)	Storage Only	Not recommended	
	Cold Storage	**0° - 36°F**	**20% - 30%**
Film (Cellulose Acetate) (motion picture, photographic, or microfilm; black and white and color)	Storage Only	**41° - 45°F**	**30% (at 45°F) - 40% (at 41 °F)**
	Cold Storage (recommended for color)	**14° - 36°F**	**30% (at 36°F) - 50% (at 14 °F)**
Film (Polyester) (motion picture, photographic, or microfilm; black and white and color)	Storage Only	**55° - 70°F**	**30% - 50%**
	Cold Storage (recommended for color)	**14° - 36°F**	**30% (at 36°F) - 50% (at 14°F)**
Glass Negatives/Lantern Slides	Storage Only	**55° - 64°F**	**30% - 40%**
Photographs	Storage	**55° - 61°F**	**30% - 50%**
	Cold Storage (recommended for color)	**14° - 41°F**	**40% (at 41°F) - 50% (at 14°F)**
Magnetic Media (Acetate or Polyester) (e.g. VHS, floppy disk)	Storage	**52° - 73°F**	**20% (at 73°) - 50% (at 52°)**
Grooved Media	Storage	**46°F ± 4°F**	**30% - 40%**
Optical Media (e.g. CDs)	Storage	**68°F ± 4°F**	**30% - 50%**
Paintings	Storage	**68°F ± 4°F**	**45% - 55%**

LIGHT

Light is damaging to collection materials. Intense light levels and/or long exposure times can lead to fading or changes in dyes and colorants. Ultraviolet radiation will lead to weakening, bleaching, and yellowing of paper and other organic materials. All of these changes can diminish readability, affect the aesthetic appreciation of artwork, and reduce access to the information contained therein. Unfortunately, light damage is cumulative and irreversible.

Sunlight and some types of electric lighting generate heat, and this is a factor in managing the temperature within a space. See NEDCC Preservation Leaflet 02-04 Protection from Light Damage for more information on this topic.

Protecting collections from light

To protect **stored** collections from light damage, keep the lights off when the storage space is not in use and consider putting the most sensitive items into boxes.

For **combined** storage and work or public spaces:

- Cover windows and skylights with UV blocking film and shades. These should be closed during

the most intense light of the day and replaced when their effectiveness declines.
- Filter fluorescent lights with UV blocking sleeves
- Keep collections off of top shelves and away from direct contact with windows
- Protect any materials that may be particularly susceptible to light damage, such as framed color photographs or watercolors, by displaying away from any direct light (sunlight and spotlights) and glazing with UV blocking glass or Plexiglas.

While collections are on **exhibit** they are at their most vulnerable. Care should be taken to protect these materials from light damage. Items should not be displayed near windows or doors to reduce the exposure to intense sunlight. Depending on the sensitivity of materials on exhibit, the gallery should be lit between 50 and 150 lux and very fragile materials should not be on permanent display. See NEDCC Preservation Leaflet 02-05 Protecting Paper and Book Collections During Exhibition for more information on this topic.

AIR QUALITY

Pollutants originate both outside and inside of the institution and contribute to the deterioration of library and archival materials. Airborne pollutants can be divided into two types: particulates and gaseous. Particulates, which include dust, soot, and mold, can abrade, soil, and disfigure materials. Soot in particular is very damaging because of its greasy and sometimes toxic nature. Gaseous pollutants include sulfur dioxide, nitrogen oxides, ozone, and formaldehyde. These act as catalysts for harmful chemical reactions that lead to the formation of destructive acid in collection materials

Airborne particulates come from dust, dirt, mold, pollen, and skin cells, but other materials can be present depending on geographic location. Particulates are measured in microns – 1/1,000,000 of a meter and labeled µ. Knowing the particulate size is important for determining the appropriately-sized air filter for your climate control system. Particulate size can vary widely: pollen ranges in size from 10 to 1000µ, mold from 10-30µ, and dust from .001 to 30µ.

Particulates are important to filter for the following reasons:

- Silica in dirt can be very abrasive.
- Pollen, mold, and skin cells attract insect pests (and dead insect pests attract other insects and rodents).
- Mold will become active when the environment becomes warm and damp.
- Pollen, mold, and skin cells can attract and retain moisture and gaseous pollutants on the surface of collection materials.

Gaseous pollutants refer predominantly to outdoor pollutants but also include pollutants generated from inside. Outdoor pollutants are brought indoors by open windows, window air conditioning units, forced air furnaces, and full HVAC systems. The three major outdoor pollutants are:

- Sulfur dioxide (SO_2) – produced by burning fossil fuels and coal
- Nitrogen oxide (NO) and nitrogen dioxide (NO_2) – produced by car exhaust and deteriorating nitrate film
- Ozone (O_3)– produced by sunlight reacting with pollutants outdoors or by electric equipment such as copy machines, computers, printers, and air filters

When sulfur and nitrogen compounds come into a humid atmosphere, there is a chemical reaction resulting in the production of sulfuric and nitric acids. These acids cause considerable damage to paper, leather, and other organic collection materials even though they are not produced in enough volume to be harmful to humans. (This is the same reaction that causes acid rain.) The extra oxygen in ozone is not strongly bonded and will break down easily, which causes materials to deteriorate through oxidation.

Indoor gaseous air pollutants originate from building materials and deteriorating collections. Often referred to as volatile organic compounds (VOC's), sources include wood, plywood, particle board,

paints and varnishes, carpeting and upholstery, construction adhesives, plastics, cellulose nitrate and acetate films, and pyroxylin-impregnated book cloth. Even degrading paper releases acetic acid.

VOC's released by these sources include organic acids, formaldehyde, and plasticizers, all of which contribute to and increase the speed of chemical reactions in collection materials and lead to the powdering and weakening of leather, the fading of colors, and the weakening and embrittlement of cloth and paper. With the right filter, gaseous particulates, like particulates in general, can be reduced or removed from the air.

Protecting collections from pollutants

Although it is not as easy to protect collections from pollutants, there are some basic steps to follow that will minimize exposure. When storing collections, put items into acid-free, lignin-free, buffered boxes and folders where appropriate.

Exhibit cases and exhibit mounts should be constructed of chemically stable materials. Materials for cases should avoid:

- Wood (wooden exhibit case decks can be covered in a true vapor barrier such as Marvelseal® or even archival quality board)
- Polyurethane foams
- Polyvinylchloride (PVC) plastics of any kind
- Rubber gasketing (which contains sulfur)
- Animal fibers, silk, or dyed fabrics
- Collections in direct contact with foam core, rubber cement, pressure-sensitive adhesives

See NEDCC Preservation Leaflet 02-05 Protecting Paper and Book Collections During Exhibition for more information on this topic.

CLIMATE CONTROL

The installation and maintenance of climate control systems can help to create more stable environmental conditions for the long-term storage of collections. This equipment can range from simple (ceiling fans, window air conditioners) to the complex – a building-wide system that controls temperature and RH, while filtering and circulating the air. Any equipment selected to control the environment needs to be suited to the needs of the building, the institution, and its geographic location. When in doubt, consult with a reliable vendor for the desired equipment. Controlling the indoor environment requires an understanding of the external environment to determine system limitations and adjust settings to be able to maintain the indoor environment within a safe range. See NEDCC Preservation Leaflet 02-02 Monitoring Temperature and Relative Humidity for more information on setting up a formal environmental monitoring program to determine the effectiveness of the climate control system.

Additional measures can be taken by the institution to control temperature and relative humidity. A first step is to purchase a simple thermohygrometer (available in hardware stores) to monitor temperature and humidity and determine if further measures need to be taken.

Building maintenance can be as critical to sustaining a stable and safe environment as having a climate control system. Low-cost measures to improve the building and lower energy costs include:

- Sealing foundation cracks
- Caulking windows and using storm windows
- Weather-stripping and adding door sweeps to external doors to reduce drafts
- Blinds or draperies can be used on south and west facing windows (north and east facing in the Southern hemisphere) during the warmer months
- Cleaning gutters regularly
- Having the downspouts and sump pump drain well away from the building to minimize water infiltration
- Changing HVAC, furnace, or air conditioner filters according to manufacturers' recommendations to reduce particulates and help the climate control system work more efficiently

In addition, there are low-cost strategies to help control air quality:

- Keep exterior windows closed

- Store sensitive materials in custom protective enclosures or boxes of acid-free, lignin-free, buffered paper or board
- Eliminate or minimize exposure to some of the causes to the pollutants such as copy machines (ozone), wood, and cleaning agents
- Allow newly constructed or renovated spaces time to off-gas their harmful VOCs before moving collections in. This period can vary depending on the nature of construction or renovation; consult with those doing the construction and a preservation specialist to determine an appropriate timeline.
- When possible, ensure the air intake for the HVAC system is not located near the loading dock or on a busy thoroughfare

CONCLUSION

The basic guidelines in this leaflet will help to prolong the lives of collections for generations to come. An understanding of all the elements of a safe environment—temperature, relative humidity (RH), light, and airborne pollutants—will help ensure collections will be accessible to future researchers. Collections with a variety of formats and materials will require a balancing of factors rather than one simple setting for temperature and relative humidity. This understanding is key to an informed strategy of environmental control, which is one of the best and most comprehensive ways to protect and preserve collections.

FOR FURTHER READING

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