Section 3

Archival Environments

3.1 - RATIONALE

The environment in which archives are stored, used, and displayed plays a critical role in their preservation. Recognizing that most archival collections contain a range of media with a variety of environmental vulnerabilities, the goal for archival facilities should be an environment that reduces risk to the majority of materials. Items requiring different conditions should be stored or displayed in enclosures with microclimates. Large collections may be divided into storage or display rooms with specific environments.

This chapter provides recommendations for temperature, relative humidity, and maximum pollutant levels for typical archival materials. It then outlines the way the environment can be controlled and discusses the means of monitoring the environment. The environmental and economic sustainability implications of climate-related decisions are noted throughout the chapter as well as being addressed in a dedicated section at the end.

3.2 - DEW POINT

Dew point is the temperature at which air becomes saturated with moisture (i.e., 100%) and water vapor begins to condense into liquid. Knowing the dew point is useful for several reasons.

- If a wall or floor in a collection storage room is cooler than dew point, condensation can form, leading to mold growth and water damage. Monitoring dew point in the air forewarns us if temperatures on cooler surfaces are liable to meet or descend below dewpoint.

- If the power fails when the outdoor temperature is low, at what point will the indoor temperature reach dew point and condensation occur, potentially damaging collections?

- HVAC system designers and operators often use dew point measurements in their work; understanding the relationship between temperature, relative humidity and dew point facilitates discussions around HVAC systems.

3.3 TEMPERATURE

There are four standard temperature environments in archival facilities: human comfort, cool, cold, and frozen. See the Archival Environments table in 3.5 Environmental Guidelines for details.

- Human comfort temperature is appropriate for non-permanent collections and for reading rooms and exhibition galleries.
- Cooler temperatures are good for almost all archival materials as they reduce the rate of chemical decay of organic materials and plastics and also lower the risk of biological damage. For this reason, archives storage rooms are often kept at temperatures lower than human comfort. In climates with seasonal temperature changes, lowering the temperature setpoint in the winter will result in energy savings and a reduced carbon footprint as well as extending the lifetime of the collection.
- ISO 18934:2011[1] defines a cool environment as having a temperature between 52° and 64°F (11-18°C) and a cold environment as being between 34° and 50°F (1 – 10°C). As cold storage reduces the rate of deterioration more effectively than cool storage, the choice of cold vs cool storage is primarily based on HVAC installation and operating costs.
- For certain materials such as acetate film and color prints, the rate of chemical deterioration is so rapid that frozen storage is required to achieve a reasonable lifetime. Frozen storage is not recommended for glass plates, CD's, DVD's, vinyl records, wax cylinders, and paintings.
- Specific packaging and retrieval procedures must be followed when using cold and frozen storage. For packaging items prior to cold storage, use Mark McCormick-Goodhart's Critical Moisture Indicator method.[2]
- When retrieving items from cold or frozen storage, allow time for them to acclimatize before unsealing the packages. This delay may affect immediate researcher access and organizations may wish to make digital copies of all items before they are placed in cold storage to allow for quick electronic access.
- The main risk associated with cold and frozen storage, and to a lesser extent cool storage, is the possibility of high relative humidity and condensation in the event of a power outage or equipment malfunction. Whether this risk outweighs the benefits of cold or frozen storage will depend on the reliability of the power supply and the HVAC system, the skills of the HVAC operators, the outdoor climate, and other factors. Each organization should conduct its own risk/benefit assessment.

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[1] ISO 18934:2011 Imaging materials – Multimedia archives – Storage environment

[2] McCormick-Goodhart, Mark H. "On the Cold Storage of Photographic Materials in a Conventional Freezer Using the Critical Moisture Indicator (CMI) Packaging Method". Article AaI_2007_1206_TA-02 Rev: 2007. Washington, DC: The Smithsonian Institution.

- Finally, there is no advantage to cold or frozen storage if items are retrieved frequently. Storage temperatures should be chosen considering the expected retrieval pattern.

3.4 - RELATIVE HUMIDITY

In general, archival collections are at greater risk of chemical deterioration from unsuitable temperature conditions than of physical or chemical damage from unsuitable relative humidity conditions. Nevertheless, there are certain types of relative humidity that are problematic. Detailed relative humidity recommendations are found in section 3.5 of this chapter.

- High relative humidity increases the risk of mold growth and pest activity. It may also lead to corrosion of metal elements in the collection, such as staples or daguerreotype plates, and physical damage due to expansion.
- Low relative humidity, while reducing the rate of chemical decay of organic materials, can result in physical damage if the items are handled under 30% RH. In addition, vellum and leather bindings can begin to fail at approximately 35%.
- Select a moderate relative humidity as a compromise for collections that are accessed frequently.
- Collections that are accessed infrequently benefit from lower levels of relative humidity but not below the minimum range.
- Fluctuations in relative humidity cause dimensional changes in organic materials. The degree to which these changes are damaging depends on a number of factors including the strength and frequency of the fluctuations as well as the condition of the material. Research in this area has resulted in new recommendations for maximum permissible fluctuations since it is now known that greater fluctuations are acceptable for many archival materials. The buffering effect of masses of paper records and paper-based enclosures has also been shown to reduce the impact of relative humidity fluctuations on individual records and on the storage environment as a whole.
- Where individual items or groups of items require more stable or more humid relative humidity conditions, sealed enclosures (bags, boxes, vitrines, etc.) conditioned to suitable levels can be used. These microclimates are a cost-effective and practical solution.

3.5 - AIR QUALITY

Some pollutants will damage archival materials if the pollutants are present in sufficient quantities.

Pollutant	**Form**	**Sources**	**Effects on collection materials**
Acetic acid	Gas	Indoor sources: wood products, oil-based paints, cellulose acetate in the collection	Acidification of paper; corrosion of metals
Hydrogen sulfide	Gas	Outdoor sources: pulp-and-paper industry, petroleum industry, geothermal and volcanic activity, ocean	Corrosion of metal; discoloration of silver photographic images
Nitrogen dioxide	Gas	Primarily outdoor sources including vehicle emissions, thermal power plants, smog	Deterioration of paper and leather; fading or bleeding of some inks
Ozone	Gas	Outdoor source: smog Indoor sources: electrostatic precipitators in the HVAC system, electronic air cleaners, photocopiers	Fading of some dyes and pigments; hardening of rubber
Sulphur dioxide	Gas	Outdoor sources: coal and oil power plants, industrial processes, transportation Indoor sources: proteinaceous materials (e.g. leather), sulfur-vulcanized rubber	Acidification of paper; weakening of leather; fading of some colorants
Dust and other fine particles	Particles	Outdoor sources: industry, construction, forest fires Indoor sources: workshops, carpets, clothing, renovations	Abrasion of magnetic media, vinyl records, wax cylinders; discoloration of surfaces

- Protect materials that are particularly sensitive to certain pollutants by using enclosures rather than engineering the whole storage or exhibition environment to accommodate a relatively small number of ultra-vulnerable items.
- Institutions with large numbers of vulnerable materials (e.g., 50,000 vinyl records) should consider the use of separate vaults with extra filtration for the hazardous pollutant in question (e.g., dust, in the case of vinyl).

- Standards for air quality are also dictated by human health concerns. Federal, state and provincial legislation regarding pollutant levels takes precedence over standards for collections where the former is more stringent.

3.5.1 - Outdoor-generated pollutants

- Archives should seek out local data on outdoor gaseous pollutant levels and take into account any highly localized conditions such as adjacency to freeways or pollutant-emitting factories. While these will not represent the exact levels within the facility, they provide a general indication of whether there are any such pollutants that pose risks to the collection.
- If outdoor levels of gaseous pollutants are high, the most effective means of control is to minimize outside air usage while maintaining air quality that meets relevant codes.
- If observations of collection deterioration indicate that there might be a problem with gaseous pollutants despite minimizing outside air usage, organizations may take the following steps:
- Determine whether indoor-generated pollutants are the source of the damage (see below).
- Engage an air quality consultant to measure pollutant levels.
- Protect highly vulnerable collections by placing them in air-tight enclosures with pollutant sorbents.
- As a last measure, install gas phase filters[3] in the HVAC system.

3.5.2 - Indoor-generated pollutants

- Indoors, particulate pollutants can be generated by activities (e.g., exhibition-related construction) and finishes (e.g., unfinished concrete) and gaseous pollutants can be generated by enclosures, display cases, construction materials, finishes, cleaning products, water additives in humidification systems, and collections themselves (e.g., cellulose acetate, cellulose nitrate, polyvinyl acetate).
- Wherever possible, use materials that are known to pose no risk to archival collections. For example, enclosures for photographic materials should have passed the Photographic Activity Test (PAT), an international standard test (ISO18916) for evaluating photograph storage and display products.
- See Appendix A- Prohibited Products for a list of products that should be avoided in certain contexts. See also “Choosing Materials for Storage, Exhibition & Transport” on the AIC (American Institute for Conservation) Wiki page.

[3] For a summary of the effectiveness of different gas filters, see Table 11. Gaseous Sorption Performance of Filters in Tetreault, Jean. *Airborne Pollutants in Museums, Galleries, and Archives: Risk Assessment, Control Strategies, and Preservation Management* Ottawa: Canadian Conservation Institute, 2003. p. 45.

- When new or unfamiliar products are proposed for use in exhibitions and storage, refer to Technical Data Sheets and Safety Data Sheets. If the composition of a product is unclear and it could be potentially damaging, it is standard practice to assess for harmful effects using the Oddy Test[4] or equivalent.

[4] Oddy Test Protocols, AIC Wiki, American Institute for Conservation

3.6 - ENVIRONMENTAL GUIDELINES

There is no single set of standards for archival environments. Reasons for this include:

- Standards from different countries or regions may specify environments based on local climate conditions, resulting in different ranges.
- Although different organizations produce standards with the common intent of preserving archival collections, their individual mandates may affect the details in those standards. One set of standards may reflect the needs of national institutions hosting international exhibitions while another may specify minimal requirements for small facilities.
- In the same vein, some standards speak exclusively to mixed collections while others specify different conditions for each type of material.
- Most importantly, ongoing research into the effects of the environment on archival materials continually leads to new information and revised recommendations. Many of the standards that are referenced and circulated today have been superseded by newer versions with better guidance.

3.6.1 - Recent developments

- ASHRAE Handbook: HVAC Fundamentals, Chapter 24 – Museums, Galleries, Archives and Libraries, 2019. The latest version of this publication provides primary guidance based on the most up-to-date research (as of 2019) on collections degradation and sustainable building/system design and operation.
- ISO 11799:2024 Information and documentation – Document storage requirements for archive and library materials. This new version is significantly different from older ones; prescriptive guidelines for each type of media have been replaced by statements regarding the degree of risk to collection materials at different temperatures and relative humidities.
- ISO TR 19815:2018 Information and documentation – Management of the environmental conditions for archive and library holdings. This is a significant revision where prescriptive guidelines have been replaced by a decision-making framework and the information necessary for institutions to develop environmental conditions appropriate for their collections.

3.6.2 - Environmental guidelines

The table below has been developed to assist those seeking straightforward guidance on suitable environments for their archival collections. It combines recommendations from ISO 11799:2024, ISO TR 19815:2018 and ISO 18934:2011.

With regard to air quality, the table includes MERV (Minimum Efficiency Reporting Values) ratings for particulate filtration. A MERV rating describes a filter's ability to trap fine particles. The rating system, which is based on an ASHRAE test, ranges from 1 to 16, with 1 providing the lowest level of filtration and 16 the highest.

Guidance on maximum levels of outdoor-generated gaseous pollutants has been omitted due to the relatively low risk posed by these pollutants to most archival collections and given the complexity of variables involved in assessing the threat of gaseous pollutants, both of which relate to the fact that archival materials are generally stored in enclosures. For example, limits for specific pollutants can vary by orders of magnitude (e.g., 4 ppb vs 400 ppb) amongst different published standards. For indoor-generated pollutants, see Appendix A – Prohibited Products.

SAA ENVIRONMENTAL GUIDELINES FOR ARCHIVAL FACILITIES		
	COLLECTION STORAGE	**READING ROOMS / EXHIBITION GALLERIES**
• Cooler is better for all collections. • Dryer is better for all materials except parchment and leather. • For display and reading rooms, aim for temperature and relative humidity at the lower limit of human comfort conditions. • Seasonal adjustments of setpoints are encouraged as a means to reduce energy consumption.		
Mixed archival collection[5]	T: min.2°C (36°F), max. 18°C (64°F)[6] RH: min. 30%, max. 55%[7] Air quality: min. MERV 13[8]	T: max. 26°C (79°F) or applicable regulatory maximum RH: max. 65% Air quality: min. MERV 13
Acidic paper	<u>Cool storage (second best)</u>[9] T: min. 11°C (52°F), max. 18°C (64°F) RH: 30 – 55% <u>Cold storage (best)</u>[10] T: min. 1°C (34°F), max. 10°C (50°F) RH: 30– 55%	Acclimatization[11] procedure required

[5]A mixed archival collection refers to a collection that holds more than one type of material, e.g., paper, photographic negatives and prints, vinyl records, and leather-bound books.
[6] ISO 11799:2024
[7] ISO 11799:2024
[8] ISO TR 19815:2018
[9] ISO 18934:2011
[10] ISO 18934:2011
[11] Acclimatization refers to the process used to control the rate at which collection materials adjust from one environment to another, e.g. when moved from cold storage to human comfort conditions in a reading room.

Color film and prints, acetate media, nitrate media	Cold storage (second best) T: min. 1°C (34°F), max. 10°C (50°F) RH: 30– 55% Frozen storage (best)[12] T: max 0°C (32°F) RH: 30 – 55%	Acclimatization procedure required.

[12] ISO 18934:2011

3.7 - ENVIRONMENTAL CONTROL

The regulation of the environment in an archival facility is a multi-level exercise involving the site, the building, the climate control system, and various procedures. In the sections below, a distinction is made between control mechanisms that actively adjust conditions within a space and a broader range of actions that assist in managing the environment.

3.7.1 - Temperature control mechanisms:

- Suitable heating, cooling, air circulation and ventilation equipment
- Appropriate zoning of HVAC systems
- Building envelope insulation

3.7.2 - Temperature management strategies:

- Natural ventilation processes/practices
- Drapes, shades and/or filters on windows
- Vestibules at exterior doors
- Interior doors
- Stacks without exterior walls
- Minimized solar load during cooling season
- Positive or at least neutral air pressure in repositories
- Regularly scheduled inspections and maintenance of building and environmental control systems

3.7.3 - Relative humidity control mechanisms:

- Suitable humidification, dehumidification and ventilation, air circulation equipment
- Appropriate zoning of HVAC systems
- Temperature control
- Building envelope vapor barriers

3.7.4 - Relative humidity management strategies:

- Good site drainage
- Natural ventilation processes
- Air conditioning (cooling) equipment
- Hygroscopic interior finishing materials such as gypsum board, concrete, and plaster[13]
- Vestibules at exterior doors

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[13] Padfield, Tim and Lars Aasberg Jensen. "Humidity buffering of building interiors" Conservation Physics website. https://www.conservationphysics.org/ppubs/humidity_buffering_building_interiors_nsb2011.pdf

- Positive or at least neutral air pressure in repositories
- Interior doors to stacks
- Kitchens, restrooms and utility rooms not located above or adjacent to stacks
- Keeping roof and rainwater management system in good repair
- Regularly scheduled inspections and maintenance for building, plumbing and environmental control systems
- Damp-mopping rather than wet-mopping floors

3.7.5 - Pollutant control mechanisms:

- Minimal fresh air intake (while still meeting human health requirements)
- Appropriate HVAC filtering system
- Appropriate positioning and control of outside/fresh air intakes
- Separate kitchen ventilation

3.7.6 - Pollutant management strategies:

- Careful selection of materials used inside the building
- No carpet in stacks, processing rooms and labs
- Vestibules at exterior doors
- Positive or at least neutral air pressure in repositories
- Well-sealed doors and windows
- Interior doors between storage and other building spaces
- Paved drive and parking lot
- Regular vacuuming using equipment with HEPA filters (not sweeping)

3.7.7 - HVAC

Buildings with mechanical air handling systems, commonly known as HVAC (Heating, Ventilation and Air Conditioning) systems, have one or more central units supplying conditioned air to the rest of the building via ducts.

- HVAC systems may provide heating, cooling, and humidification and/or dehumidification depending on the local climate, the needs of the collection and the limitations of the building envelope.
- A well-designed HVAC system can provide the optimal climate for an archival collection if the equipment is properly designed, installed and maintained.
- Large or multi-building HVAC systems are often controlled by computerized Building Management Systems (BMS).

- Filters used to reduce airborne particulate and gaseous pollutants influence the sizing and energy consumption of the HVAC system. Air quality requirements must be considered at the design stage along with temperature and relative humidity criteria.

3.7.5 - Non-forced air systems

Not all buildings need a central or forced-air mechanical system to achieve a preservation-quality environment. Archives may be housed in buildings with systems such as hot-water radiators, radiant floor heating, and window or wall-mounted cooling units.

- This type of equipment can control temperature to appropriate levels, but the ability to control moisture and RH is significantly limited.
- As a short-term solution, for example in emergencies, dehumidifiers and humidifiers may be used in collection rooms to mitigate RH risks. Stand-alone dehumidifiers and humidifiers are not recommended for long-term control of an environment, and their usage should always take into account the risk of flooding or electrical fire.
- Although stand-alone air filtration units are available, in practice pollutant filtration in non-ducted buildings relies primarily on actions taken at the level of the site, the building, and housekeeping.
- Historic structures where mechanical intervention is limited by either the building fabric or historic preservation requirements may still achieve temperature control and minimal moisture management through non-forced air systems but will have difficulty achieving appropriate long-term preservation conditions for archival materials.
- In temperate climates, and particularly for storage areas that are not frequently accessed, well-insulated buildings with appropriate vapor barriers can produce very stable conditions within suitable temperature and relative humidity ranges. Other means of passively achieving stable indoor climates include building entirely underground or using materials which themselves have high thermal mass, such as thick masonry.
- Computerized modeling exercises can provide a general sense of whether a given building in a particular location could reliably operate without an HVAC system while still providing a suitable environment for the collection.

3.8 - MONITORING

3.8.1 - Relative humidity and temperature

It is essential to know the facility's actual levels of temperature and relative humidity and where and when these vary from desired conditions. Evaluating environmental records allows staff to identify adjustments that will improve preservation conditions and realize energy savings. Every archival organization must therefore have a system to monitor the collection environment. There are two types of continuous monitoring systems found in archival facilities: systems using stand-alone monitoring equipment such as data loggers, and systems integrated into the Building Management System (BMS). "Snapshot" monitoring devices such as hygrometers, psychrometers and humidity strips have their uses but are not suitable as the sole means of environmental monitoring.

3.8.1.1 - Data loggers

Even if monitoring is integrated into the BMS, it is advisable to independently monitor conditions in collection rooms using dataloggers. Faulty in-duct sensors have been detected as a result of such independent monitoring. The environmental monitoring program should:

- Monitor the environment year-round
- Have a minimum of one monitoring device per collection room
- Have devices placed where they will not be subject to handling, vibration, or temperature extremes (e.g., not near a heating or cooling vent)
- Have alarms that will remotely alert staff when conditions stray into the danger zone
- Include equipment that can be used to monitor conditions within enclosures (e.g., display cases) when necessary
- Include calibration of the monitoring devices according to the manufacturer's recommended schedule
- Be understood and operable by in-house staff

Choosing data loggers:

- Use devices with the sensitivity required to meet the selected climate specifications, generally within +/- 1°F and +/- 2.5% RH.
- For most purposes, select devices that transmit data via WIFI or Bluetooth (either via a receiver or directly to a tablet or smart phone), or that are hardwired to an Ethernet port.
- Use devices with associated software that calculates dewpoint and that can format the data into useful formats such as charts showing RH, temperature and dewpoint over time.

3.8.1.2 - BMS monitoring

BMS monitoring is beneficial but is seldom designed for the special needs of archives, particularly with regard to sensor placement, data analysis and interface, and recalibration practices. BMS data supplements that from the data loggers. For the sake of preservation analysis, the BMS monitoring system should:

- Record as well as detect
- Track interior relative humidity and temperature
- Track exterior conditions
- Calculate and track dew point
- Have sensors in all collection spaces
- Have sensors in return air ducts
- Have registered the correct locations for sensors
- Send operating alarms
- Have sensors with the calibrated accuracy required to meet the selected climate specifications
- Be understood and operable by those responsible for the system, whether in-house or contractors

3.8.2 - Pollutants

- Monitoring for pollutants is usually only necessary if there is an observed deterioration of collections that is attributable to pollutants, either external or internally generated.
- As stated in 3.4.1, organizations should seek out local data on outdoor gaseous pollutant levels and take into account any highly localized conditions such as adjacency to freeways or pollutant-emitting factories. While these will not represent the exact levels within the facility, they provide a general indication of whether there are any such pollutants that pose risks to the collection.
- Should it become necessary to quantify a gaseous pollutant in an archival facility, an air quality consultant should be employed to do the testing and assist with interpretation of the results.
- Although excessive dust accumulation is usually readily apparent without the need for monitoring, it may be appropriate to monitor dust levels in areas where hypersensitive materials such as phonograph records, wax cylinders or magnetic tape are removed from their enclosures and played. Quantitative and semi-quantitative methods for dust deposition measurement are referenced in Tétreault (2003)[14].

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[14] Tétreault, Jean. *Airborne Pollutants in Museums, Galleries and Archives: Risk Assessment, Control Strategies, and Preservation Management.* Ottawa: Canadian Conservation Institute, 2003.

3.9 - SUSTAINABLE ENVIRONMENTS

In addition to switching to renewable energy sources, there are four primary areas where archives can reduce their carbon footprint: building design, HVAC design and operation, environmental targets, and lighting (including daylighting). Heating, cooling, humidifying and dehumidifying is generally the largest contributor to an institution's greenhouse gas emissions and is a significant part of an institution's budget. In addition to operating costs, there are capital costs associated with the equipment, as well as building or renovating a structure capable of maintaining an archival environment. In particular, moisture control (dehumidification and humidification) in seasonal or year-round arid or humid environments requires particularly exacting building design and construction.

Building design features promoting environmental sustainability are discussed in Chapter xx.

Should we add a section like this to the Building Construction Guidelines?

- No more than 30% of exterior walls made of glass
- Airtight construction
- Good insulation
- Natural ventilation, where appropriate
- Recycled materials
- Low carbon concrete
- In cold and temperate zones, minimizing heat loss and maximizing absorption of solar radiation in the winter, and minimizing heat gain in the summer.
- In hot zones, minimizing exposed glazing and using overhangs to shade windows.

It is possible to improve energy efficiency through HVAC design and operation while simultaneously improving preservation conditions. At the Royal British Columbia Museum, a more efficient HVAC system improved conditions from ASHRAE Class A to Class AA while reducing emissions by 500 tCO2e (tonnes of carbon dioxide equivalent) per year. An overhaul of the North Carolina Museum of Art's HVAC system improved conditions from Class C to Class AA levels while reducing energy use by 57%.

The new San Francisco Museum of Modern Art building would be expected to use more energy than the previous one given tighter environmental conditions <u>and</u> the addition of cold storage vaults, but thanks to an efficient HVAC system there has been a 37% reduction in energy use compared to the original building. Jeremy and Fiona to replace with equivalent archives examples. Lisa – LAC as an example?

Common HVAC strategies for energy efficiency:

- Analyzing mechanical system design to identify and then correct inefficiencies in delivering the desired climate.
- Shutting down HVAC systems overnight.
- Reducing outside air intake.
- Reducing fan speed, especially during milder seasons or in interior storage environments.

Studies[15] have shown that broadening the range of permissible RH and temperature and adjusting the setpoints seasonally usually reduces energy consumption. In cold climates, allow regular storage to become cool storage during winter months; this has the added benefit of reducing the rate of chemical deterioration of most materials in archival collections. Off-site storage can be a good place to try sustainable solutions such as cool wintertime temperatures and reduction of outside air, options that may be less feasible in an occupied building.

[15] Linden, Jeremy, Reilly, James M. and Herzog, Peter. "Field-tested methodology for optimizing climate management" in *Climate for Collections: Standards and Uncertainties*, Jonathan Ashley-Smith, Andreas Burmester and Melanie Eibl, eds., Postprints of the Munich Climate Conference, Doerner Institute, 2013.
Ascione F., Bellia, L., Capozzoli, A., and Minichiello, F., "Energy saving strategies in air-conditioning for museums", Applied Thermal Engineering 29 [2009] 676-686.