NORTHEAST DOCUMENT CONSERVATION CENTER

THE ENVIRONMENT

2.2 Monitoring Temperature and Relative Humidity

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INTRODUCTION

Collection materials are vulnerable to damage from their environment whether they are paper, wood, film, leather, parchment, or metal. While we cannot eliminate all of the causes for decay of our cultural records, we can significantly slow deterioration by managing the storage environment. Yet, managing fundamentals of the storage environment such as temperature and relative humidity is a challenging task, in part because day-to-day needs often take precedence over longer-term climate control activities. In reconciling various institutional needs, environmental monitoring is a necessity.

Monitoring the environment is a foundational element of an overall preservation program and provides the baseline for managing the storage environment. The development of a monitoring program involves gathering information about the institution's building and systems, determining the priority collections to the institution's mission, and analyzing the needs and vulnerabilities of collections. This process will involve both collections care staff and facilities staff to formulate the best plan for managing the needs of storage spaces.

THE ENVIRONMENTAL MONITORING PROGRAM

In order to have an accurate record of existing environmental conditions throughout a building, temperature and RH must be measured *and recorded* with instruments designed for that purpose. The focus of most monitoring programs is on storage spaces, but keeping track of public and staff spaces will provide a better overall picture of conditions in the entire building. Concrete, accurate data will help demonstrate the capability of current climate control systems from which practical temperature and RH goals can be set—particularly in terms of the limitations of existing equipment. Under the best circumstances, monitoring will indicate that available climate control equipment is operating at its ideal capacity. When the environment is not ideal, a program can be very useful in:

- providing data showing that current climate control equipment is inadequate;
- documenting the severity of existing problems and supporting the need to add or change machinery;
- evaluating the effect of changes that have already been made to existing climate control equipment; and
- guarding against any environmental extremes that might occur during normal operations.

MONITORING THE ENVIRONMENT

Computerized building management systems (BMS) are often used by facilities staff to monitor climate conditions and control HVAC equipment in large buildings or groups of buildings. While these systems can be used to provide temperature and relative humidity data for analysis, there are a few important considerations:

- The system's sensors must be recalibrated periodically to ensure accuracy.
- Sensors must be located properly to ensure that they reflect the climate conditions the collection is experiencing.
- Some sensors should be located in return air ducts to measure air from the controlled space.
- The computerized management system must contain correct locations for the sensors.

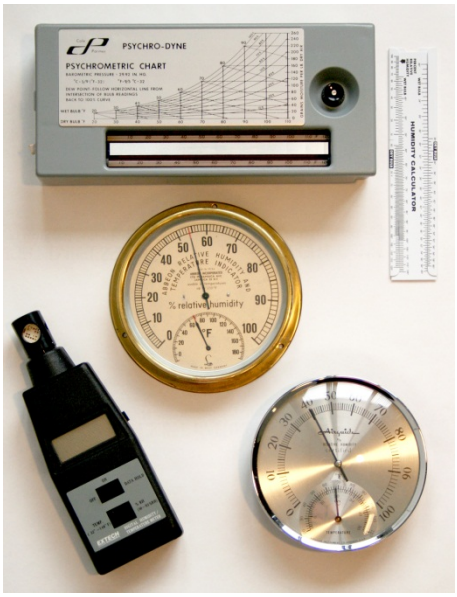
There are various instruments available to measure temperature and RH independently of a BMS. These instruments fall into two categories: those that provide "snapshot" measurements (i.e., a record of conditions at a specific moment) and those that provide a continuous record of climate conditions. Answering questions regarding cost, output, precision, durability, and ease of use will help determine which type of device is best.

Recommended "Snapshot" Monitoring Devices

"Snapshot" type instruments provide only a rough picture of the environment and are dependent on human participation (participation that may not be available after hours or on holidays). Because monitoring by spot readings is so labor intensive and human dependent, independent monitoring using continuous recording instruments is recommended.

- **Thermometers** can provide accurate temperature information. A standard thermometer that measures the entire range of foreseeable conditions in a building is satisfactory.

- **Humidity indicator strips or color cards** are an inexpensive humidity-monitoring device. Some are reversible and thus can be reused, while others are for one-time use. Humidity indicator strips provide only approximate readings, but can be useful for indicating extreme conditions.
- **Battery-operated (motor-blower) psychrometer** is a hand-held instrument that measures relative humidity. These are moderately priced and can be moved conveniently to monitor a wide variety of spaces. Replacement batteries should always be on hand. It should be noted that they can be complicated to read and require pre-treated water to operate. The non-battery equivalent, the sling psychrometer, is not recommended because of the difficulty in getting accurate readings.
- An **electronic temperature/humidity meter** is another hand-held instrument that uses a calibrated sensor to measure RH at a known temperature. While they are easy to use, many of the models may be accurate only to ±3-5% and may take several minutes to react to humidity changes. These instruments need to be recalibrated periodically (as recommended by the manufacturer).
- **Min/max digital hygrothermographs** keep a record of the highest and lowest temperature and humidity since the instrument was last reset manually; this can be done at any desired time interval (e.g., once a day, every morning and evening, once a week). Humidity measurements tend to be accurate only to about ±5% (at mid-range temperatures, accuracy may be less at temperature extremes), but these instruments can provide an initial broad outline of climate conditions.



Snapshot monitoring devices including a psychrometer, a digital humidity/temperature meter, and thermometers with humidity indicators.

Continuous Monitoring Devices

Data loggers are the most commonly used continuous recording devices in institutions. Recording hygrothermographs were the standard for many years, but they are being replaced with digital data loggers. Data loggers are easy to use, with the ability to create useful graphs that allow for more robust data analysis.

Data loggers are battery-powered instruments that use electronic sensors and a computer chip to record temperature and RH at intervals determined by the user. Data is downloaded to a computer and associated data logger software allows the user to produce customized charts and graphs that illustrate conditions over time. This is a significant advantage over hygrothermographs: data from paper charts must be replotted in a graph or strung together by hand for annual analysis. Data loggers can be moved easily to monitor different locations with a single monitor, provided the data logger's memory is erased before the logger is moved to a new location.

Purchasing data loggers is an investment. Consider some of the following questions when deciding on what type of data logger to purchase:

- **What is the building structure like?** Some data loggers use wireless radio signals to send data to a main computer, a function which may not be possible in all buildings.
- **What type of building management system is used?** The information recorded by some data loggers can easily be incorporated into a building management system (BMS), so that the data can be meshed with data collected from the BMS as well.
- **What is the software like?** Some data loggers come with software that can do most of the analysis for you. Others provide only simple graphs.
- **How is the space used?** Some data loggers are small and unobtrusive; others are quite large. Depending on where you plan on placing your loggers, you might want to consider how they will be seen—or if you want them to be seen.
- **What is the required frequency of measurements and downloads?** Data loggers have different memory capacities and, depending on how frequently measurements are taken, will require downloads.
- **How accurate do the readings need to be?** Some loggers use sensors that are temperature-compensated—meaning the logger can provide about 3% accuracy for RH over a wide range of temperature and humidity—while others do not. Also, some sensors may have a "time-lag" of 4 or 5 minutes if the humidity is falling. This would be a disadvantage if frequent sampling is required.

Recording hygrothermographs are still in use in many institutions, but are expensive to replace. When looking to purchase a new (or reconditioning an old) hygrothermograph for monitoring in a library, archive, or museum, be sure the device uses a human hair bundle to measure RH and a bimetallic device to measure temperature. Ideally, the hygrothermograph will have sensors attached to pens that record changes continually on a simple graph—these pens should be an easily replaceable cartridge type. Hygrothermographs are available with circular charts, but linear charts (also called drum charts)

are preferred since they are easier to string together and read for annual reviews.

Recording hygrothermograph

Regular maintenance is essential. The instrument should be kept clean and free of dust. Hygrothermographs also require periodic calibration, preferably quarterly. For information on calibration, see the National Park Service's Conserve-O-Gram 3.2, *Calibration of Hygrometers and Hygrothermographs* at http://www.nps.gov/history/museum/publications/conserveogram/03-02.pdf. For all other maintenance, follow the manufacturer's recommendations in the manual.

Deciding What Equipment to Buy

Cost, complexity, and time all play roles in determining what sort of device to purchase. Look at options from a number of suppliers and compare the features and prices of their equipment. If the supplier does not provide all the information you need, ask questions. The National Park Service and The Image Permanence Institute have both done comparisons (http://www.nps.gov/museum/publications/conserveogram/03-03.pdf and https://www.imagepermanenceinstitute.org/resources/newsletter-archive/v14/pem2-vs-other-dataloggers) on different types of loggers to help make informed purchasing decisions. Finally, talk to colleagues who have developed climate-monitoring programs for their input on how well their devices are working.

The following questions are important to ask in making an informed decision:

1. What do you want the information for? Are you documenting the effect of the operating changes of your climate-control equipment or do you want to record that conditions in your collection regularly fall outside acceptable limits?
2. What are the extremes of temperature and RH the instrument needs to measure? Will your instrument record the entire predictable range?
3. How precise do your measurements need to be?
4. Do you need to record information when the building is unoccupied?
5. How easy do calibration, operation, and maintenance need to be? Who will be responsible for these tasks, and what skills do they have? Can you afford both a recording instrument and a calibration instrument?
6. How many spaces to you need to monitor and for how long? How many units will you need?

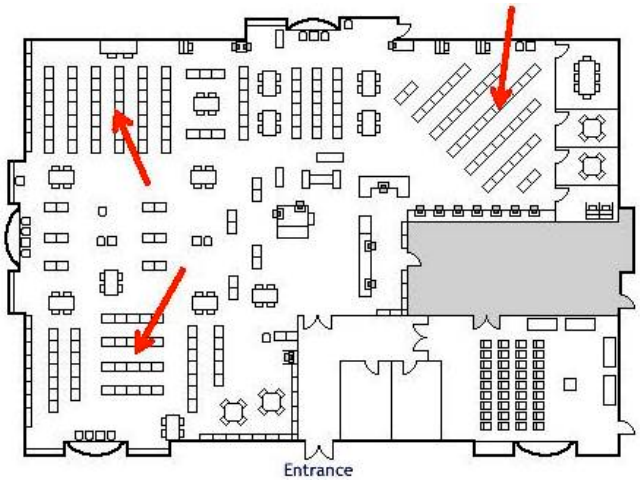
THE MONITORING PROGRAM IN PRACTICE

A good environmental monitoring program will include a written plan for the placement of recording instruments, how to collect information, when to collect information, how to present information, and how to maintain instruments. Monitoring should be the assigned responsibility of a specific person within the institution (with a designated back-up person to cover during absences and vacations). If monitoring depends on a manual—rather than an automatic—recording instrument, the plan should lay out when and how often to take measurements to reflect the widest variation in conditions.

Records of historical weather conditions and special events (exhibit openings, for example) can help to explain variations in monitoring data. For example, a special event where an unusual numbers of visitors are in a space can alter temperature and RH levels, causing a spike on the data printout. Regional weather records are available from the National Oceanic and Atmospheric Administration's (NOAA), National Climatic Data Center (www.ncdc.noaa.gov). They are also usually available from a college weather station or local airport. Users of The Image Permanence Institute's eClimateNotebook™ (https://www.eclimatenotebook.com/index.php) will automatically have access to information for their closest weather station.

Placement of Monitoring Equipment

The position of monitoring instruments is not an easy decision to make. Placement of instruments can impact the accuracy of the measurements or may raise concerns among staff and users as to their purpose. In the simplest locations, equipment should be placed above floor level, away from the direct flow of air vents, not on or near heating, cooling, or humidity control equipment, and not adjacent to doors and windows (unless you want to record the impact they have).



Map showing placement options for monitors

For example, in the above library—for general monitoring—place the monitoring device in any of the locations marked by an arrow at about mid-shelf height and concealed as well as possible to prevent the monitor from being disturbed or going missing. The monitor should be away from the entrance as this is a variable area for readings.

If a limited number of monitoring instruments are available, or you only have short-term loan of equipment, a reasonably accurate profile of conditions in several spaces can be developed by leaving an instrument in each area for at least 3 months. The most important information to look at in these snapshot views will be the extremes of temperature and humidity and the speed and extent of changes. In all cases, it is important to collect at least a year's worth of monitoring data in any one location before making any substantial changes to building systems or collection locations, since climate conditions in a single space can differ greatly during the different seasons.

Environmental monitoring data serves no purpose unless it is part of an ongoing environmental management process. Whether it is downloaded and analyzed using a computer program or plotted on graphs and analyzed by hand, data will be most useful if recorded on a regular basis. When recording information manually, or if using a recording hygrothermograph, label each chart or form with the location, date, initials of monitor's name, and recalibration information (date, time, how altered). Any data gathered can be kept in a physical or digital folder in an easily accessible location so anyone in the institution can reference it when needed for reporting, maintenance, or budgeting.

EVALUATING CLIMATE AND COLLECTION NEEDS

Regularly gathered data can be used to improve climate conditions for collections, people, and the building. When determining equipment settings, there is no right or wrong set point for all collections and, often, institutional energy requirements will necessitate changing or negotiating desired settings. The manager of the monitoring program, and the institution, can use the accumulated data to determine the actual conditions in each monitored area, assess the effect of those conditions on the collections, evaluate the capabilities of the current climate control system(s), and make changes or redistribute collections accordingly.

The Image Permanence Institute's online software program, eClimateNotebook, ties in with their preservation environment monitors, PEM2™, as well as other dataloggers.

Every building and environmental control system will have certain limitations and it is important to recognize these limits when making climate-control decisions. Climate control ranges from completely uncontrolled to sophisticated systems that can provide accurate control for heating, cooling, and humidification or dehumidification. Knowing what systems exist and what impact existing systems or new systems may have on the building envelope is important. Un-insulated, historic buildings can be damaged simply by the installation of a central heating or humidification system. Such buildings may need major alterations to be compatible with the needs of their contents. In these cases, it may even be necessary to relocate collections to provide conditions suitable for preservation.

The variety of collections materials in any given institution have different vulnerabilities and require different storage conditions. For more information on the recommended storage environments for various collection materials, see NEDCC leaflet 2.1, *Basic Guidelines for Preservation: Temperature, Relative Humidity, Light, and Air Quality*, http://nedcc.org/resources/leaflets/2The_Environment/01BasicGuidelines.php.

It is also very important to understand the value and relative importance of collections to your institution. Some materials may require stricter climate control by virtue of their relevance to the institution's mission, their research value in their original state, their importance to the collection, or their monetary value.

Facilities staff should be encouraged to participate as partners in the monitoring and decision-making processes. Facilities staff are in a position to consider long-term environmental trends in relation to day-to-day needs. They can also be knowledgeable about the building and how it and the existing systems work and react to one another. It is worth noting that HVAC systems are seldom optimally used, even when all the components are in place. A building maintenance engineer or the contractor responsible for the HVAC system can often improve its performance if data is available. Simple actions such as resetting thermostats, replacing filters, or even rearranging furniture to unblock vents can help to improve the environment and cut down on costs.

HOW TO IMPROVE THE CLIMATE

Once collection needs, current climate conditions, and system capabilities have been determined, measures to improve environmental conditions for museum, library, and archival collections might include:

- removal of collections from attics, which tend to be hot, or basements, which can be damp;
- ensuring windows and doors are well sealed against the outdoors with caulk, window coverings, weatherstripping, etc.;
- creation of storage spaces segregated by type of material (determined by material environmental needs);
- improvements in insulation and building seals;
- use of portable air conditioners, humidifiers, and/or dehumidifiers. It is critical to remember that temperature and RH are intimately related and the correction of one factor may alter the balance of other important factors (e.g., a dehumidifier may generate enough heat to require additional cooling); and/or
- installation of central environmental controls.

Common solutions to frequently encountered climate problems include:

- adjusting settings to accommodate for winter and summer conditions (for example, cold and dry or hot and humid);
- moving collections off of walls and into the centers of rooms to combat problems with condensation for institutions that close in the winter months; and
- sealing windows with plastic in the winter and using weatherstripping on doors.

If climate-control equipment was designed to produce the desired conditions, but problems cannot be solved by simple adjustments and routine maintenance, it may be necessary to have the system professionally rebalanced. Balancing is a process that measures airflow and other characteristics of HVAC systems and may require the expertise of a professional HVAC or environmental control engineer. For best results, select an engineer with experience in collections-holding institutions. If no one with this specific experience is available in your region, seek an engineer with experience in climate-control of computer facilities, which can have similar requirements. A design that works well for a hotel or shopping mall will not work for library and archival collections, a historic building, or a museum. Ask for references from clients whose needs may have been similar to your own and talk to those clients about the success or failure of the system designed for them. Make sure your consultant understands what your ideal conditions and minimum requirements will be.

CONCLUSION

As experts study and understand the interaction of all storage factors, managing the environment has come to mean more than simply setting climate targets and checking for deviation from them. The needs and vulnerabilities of collections must be taken into account, as well as the capabilities and limitations of an institution's building and systems. Accurate climate monitoring data is one of the most important tools in determining whether existing conditions meet the needs of collections throughout a facility. A properly conducted systematic climate monitoring program will enable an institution to accurately assess current success and future needs, as well as maximizing the advantages of current resources.

RESOURCES

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