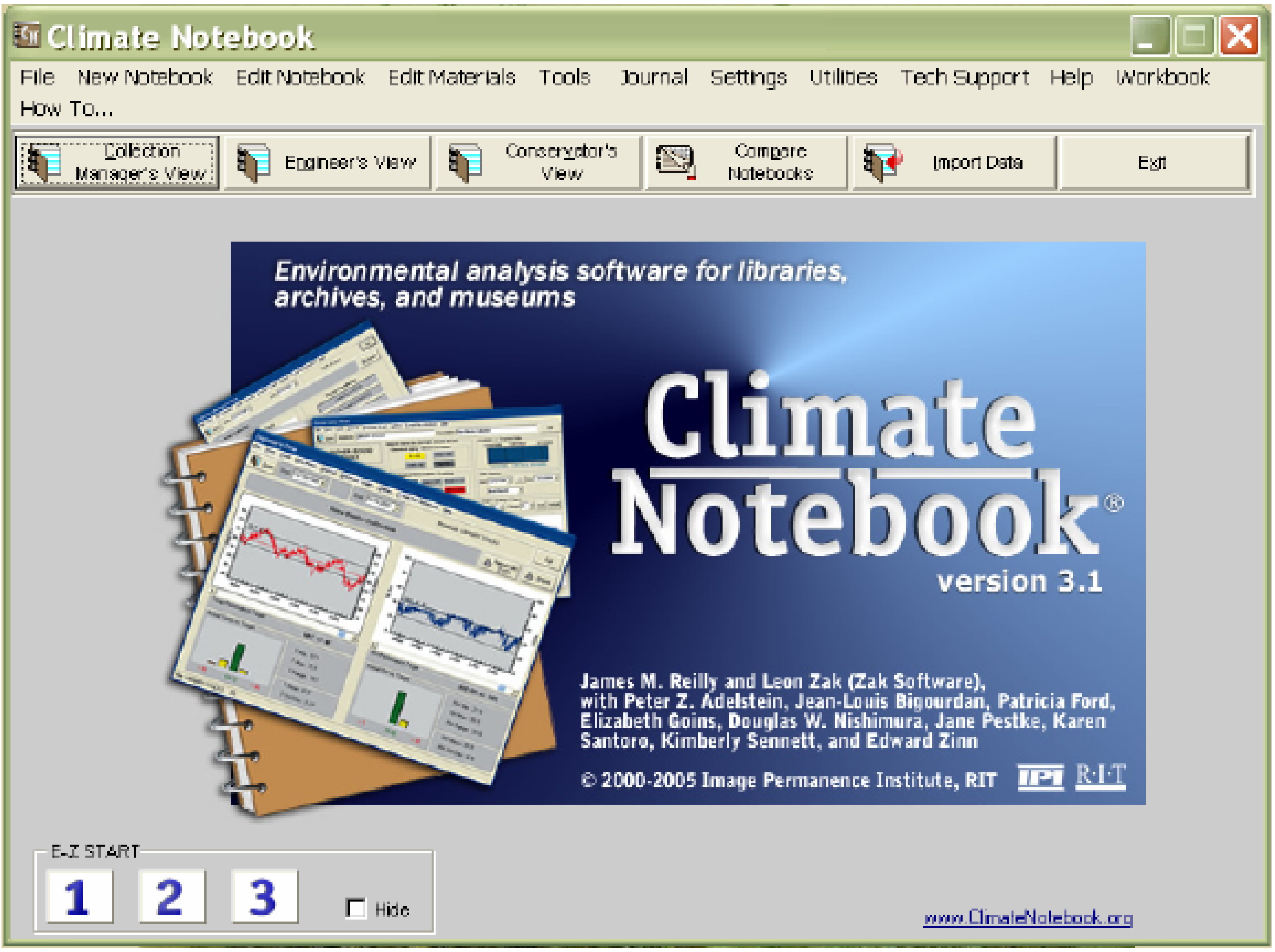
Step-by-Step Workbook: Achieving a Preservation Environment for Collections



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Step-by-Step: Achieving a Preservation Environment for Collections

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Workbook Contents

Ch.1 IPI and the Role of Environmental Monitoring and Analysis in Collection Preservation ...….. 2 - 3

- Development and Testing of Tools for Environmental Analysis

Ch.2 Environmental Monitoring ………………………………………………………………. 4 – 8

- Why Environmental Monitoring is Important
- A Broader Approach to Monitoring the Environment
- The Preservation Management Process
- Questions

Ch.3 The Effect of the Environment on Natural Aging and the Rate of Decay ………...………… 9 – 15

- Temperature, RH and Dewpoint: Three Inter-related Quantities
- IPI's Dewpoint Calculator
- Questions

Ch.4 Development of Preservation Quality Metrics …………………………………….…….. 16 – 22

- Preservation Index – A New Measure of the Storage Environment
- Time-Weighted Preservation Index – A Cumulative Measurement
- Mold Risk Factor – Identifying Favorable Conditions
- Dimensional Change Metrics – Reaching Equilibration with the Environment

Ch. 5 Understand Your Building and its Climate Control System ……………………………..… 23 - 35

- The Evolution of Climate Control
- What HVAC Systems are Designed to Do
- Understand Your Mechanical System
- Activities to Help You Understand Your Mechanical System
- Questions and HVAC System Documentation Forms

Ch.6 Collection Materials and their Response to the Environment …………………………..... 36 - 41

Ch. 7 Analyze the Preservation Quality of Your Storage Environment ………………………….. 42 – 50

- Step-by-Step Evaluation
- Questions

Ch.8 Take Action to Improve the Preservation Quality of Your Environment ………………….. 51 – 55

- Create a Process for Managing the Environment
- Preservation Environment Management Process
- Questions

Ch.9 Keeping the Data Organized ………………………………………………………….……. 56 – 58

- File Organization and Management
- Location Profile

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Chapter One IPI and the Role of Environmental Monitoring and Analysis in Collection Preservation

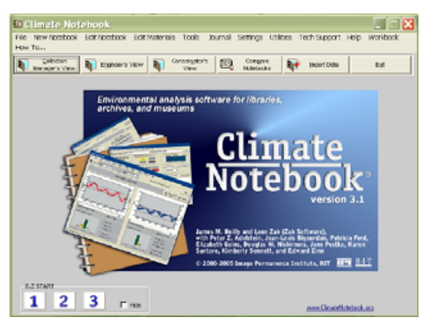
The Image Permanence Institute (IPI) is a university-based, non-profit research laboratory founded in 1985 as a department of the College of Imaging Arts and Sciences at Rochester Institute of Technology (RIT) in Rochester, New York. Devoted to scientific research in preservation technology, IPI supports the preservation field through research, publication, educational activities, products and services.

Initially focused on the preservation of photography, microfilm, cinema and other forms of recorded information, IPI has broadened its mission in the last decade to include a wide range of materials found in cultural institutions. Recent developments include important tools for assessing and managing collection storage and display environments in museums, libraries, and archives. With funding from the National Endowment for the Humanities (NEH), the Institute for Museum and Library Services (IMLS) and the Andrew W. Mellon Foundation, separate projects have resulted in new hardware for environmental monitoring, and new software for data analysis.

> ***The storage environment is recognized as the greatest cause of collection decay, and the most effective means of preventing it.***

- **Development and Testing of Tools for Environmental Analysis**

The ***Preservation Environment Monitor® (PEM)*** is a datalogger that developed out of a general quantitative model of organic decay for environmental analysis called the ***Time-Weighted Preservation Index (TWPI)***. TWPI values are computed internally and displayed along with temperature and humidity. Funded by NEH, the PEM was designed to make data gathering in cultural institutions simple and accurate.



Another major development in environmental research at IPI was ***Climate Notebook® software (CNB)*** for environmental monitoring. With funding from the Mellon Foundation, a simple utility to retrieve data from the PEM and calculate TWPI values evolved into a sophisticated software application for organizing, analyzing, and reporting on environmental conditions.

The Mellon Foundation also funded ***"Optimizing Collection Life and Energy Costs in Cultural Institutions."*** IPI, along with the energy-efficiency consulting firm of Herzog/Wheeler & Associates, worked with the Library of Congress and the New York Public Library to measure storage conditions, evaluate

HVAC systems and make improvements to provide a better environment for the collections at the same or lower operating costs. Based on lessons learned in this project, IPI made plans to test the hardware and software in a wide range of cultural institutions.

In 2000, ***"Creating a Computerized System to Document the Effects of Environmental Conditions on the Preservation of Collections,"*** was funded by NEH, IMLS and the Mellon Foundation. This testing in the field ***(Field Trial I)*** of both the PEM datalogger and Climate Notebook software was undertaken in order to improve both the technology and the understanding of environmental assessment. Nearly 200 libraries, archives and museums of all types and sizes throughout the U.S. participated. A survey of participants found that 96% of users described the tools as easy to use and helpful, and would recommend them to other institutions.

Field Trial participants were particularly pleased with the way that CNB promoted and simplified communication among staff in different departments. The software helped them learn more about the effects of the environment on their collections, and determine what changes to make to extend the life and preserve the value of their collections. Several participants were able to use the data-based reports to acquire funding to improve collection storage conditions.

Based on the success of the Field Trial, NEH granted additional funding for IPI's ***"Training and Implementation for Effective Use of Environment in Collections Preservation"*** grant (2004 – 2006). This project ***(Field Trial II)***, allowed IPI to provide training and information to preservation field service providers in every region of the United States, provide advanced training for a large group of Field Trial I participants, and develop a service model for institutions that lack the time or expertise to conduct environmental monitoring and analysis themselves. One participant, Laurie Booth, President of Midwest Conservation Services, Inc. stated "Frankly, I think the Climate Notebook software with its powerful mathematical modeling, has the potential of revolutionizing the way the conservation field approaches 'ideal' climate control."

IPI remains focused on the effective management of storage environments in cultural institutions. Our goals are based on strong scientific evidence that heat and moisture are the primary rate-controlling factors in almost every mode of decay. Control of these factors in the storage environment is of fundamental importance in preservation and is more broadly effective than other, more limited, preservation actions. It is also much cheaper to implement. We want to see institutions use storage conditions as efficiently and effectively as their local climate and existing mechanical systems will allow. Few currently do. Even some institutions who have attempted to achieve an optimum preservation environment are not reaching that goal. Standing in the way are some serious technical and organizational obstacles that IPI is working with institutional staff to remove.

Chapter Two Environmental Monitoring

- **Why Environmental Monitoring is Important**

Cultural institutions have been entrusted to provide stewardship to the collections in their care. Stewardship requires a long-term vision – longer than an individual, or even an institutional lifespan. This is a difficult concept for many people, and difficult to manage when the demands on resources are often immediate. However, institutions have a responsibility to extend the life of the collection materials they hold by providing the best care possible.

While there are a number of factors that can be included in a broad concept of storage environment, this workbook deals only with temperature and relative humidity. Light, air pollution, radiation, and vibration – when they are present – are important and deserving of attention. However, it is understood that temperature and RH are the most fundamental factors to consider in environmental management. They are always present, have the broadest effect on the largest number of items in the collection, and they act as enablers (or inhibitors) of damage by other factors such as light or pollutants. Managing the environment also has an effect on the fiscal health and everyday working life of the institution. The capital expense, staff salaries, and increasing energy and other operating costs associated with mechanical systems are a huge portion of institutional budgets. IPI's experience shows that most places can do better both for the collections and for the bottom line when staff "stakeholders" work together to understand, evaluate, and improve the environment in their institution.

Environmental monitoring has come a long way from weekly collecting of hygrothermograph charts, calibrating of equipment and changing of pens and paper. Advancements in datalogger technology have allowed preservation staff to gather and view years of data electronically. As technology has advanced, and the amount of data available for review has increased, the time and staff expertise available to do something with the data has decreased.

Through our research and testing at IPI, as well as collaborative work with a number of organizations, we have developed a new approach to environmental analysis that is best described as a ***Preservation Management Process.*** There are three essential elements to this approach:

- ***UNDERSTAND*** Know why, how and what to monitor. Bring the knowledge of collections care and facilities staff together.
- ***EVALUATE*** Use appropriate metrics to quantify and analyze the "Preservation Quality" of the environment.
- ***TAKE ACTION*** Develop an institutional action plan based on your definition of the optimal preservation environment.

The chapters in this workbook detail the ***step-by-step process needed to achieve a preservation environment for collections***, and give you the tools you need to understand, evaluate and take action.

- **A Broader Approach to Monitoring the Environment**

Basic analysis of environmental data deals with the raw temperature and RH readings. It may involve tables of raw data, visualization using graphs, and descriptive statistics such as mean, minimum, maximum, range, and standard deviation. Climate Notebook software offers advanced capabilities for basic data analysis, and incorporates a number of customizable features and a powerful interface for manipulating time scales. The value of basic analysis is greatest in circumstances where there is a very clear and well-established sense of what the environmental conditions *should* be. Basic analysis is typically all that is needed for building operators and facilities managers. They have been given target values, and graphs and statistics tell them whether the targets are being met. When the targets are not met, they will have to adjust operating parameters or obtain new equipment.

From the preservation manager's perspective, basic analysis is less helpful because he or she is concerned not so much with whether the observed conditions stay within pre-defined targets, but with the impact of those conditions on the preservation or deterioration of collections. Operating targets are simple and static. Deterioration mechanisms of particular collection materials and their interactions with heat and moisture are complex and dynamic.

Too often, monitoring has focused on identifying "incorrect" temperature and RH conditions, looking for unusual events and being a watchdog on the building operators. This process assumes that all the work of defining the best possible environment has already been done, which is almost never the case, and that facilities can't be trusted to do its job, which is usually not the case either. Collections are diverse, incorporating a wide range of material types and vulnerabilities. Too often, target set points are based on incomplete, incorrect, or outdated information. The building's mechanical system may not have the ability to achieve or maintain what staff members ask for.

What IPI has learned is that defining the optimal environment is a cross-disciplinary process of information sharing and compromise, and not the exclusive province of preservation, collections staff, or facilities staff. Institutional environmental management (including, but not limited to the monitoring task) is in fact a *new discipline* that includes what the conservator and collection staff know, what the engineer and building operators know, and how a museum or library really works. Whoever undertakes this process has little chance of success unless his or her immediate supervisor—and, crucially, the upper management of the institution—understands and supports the effort.

- **The Preservation Management Process**

To Achieve an Optimum Preservation Environment in your Institution, we recommend the following activities:

Start-Up Activities

1) Acquire the ability to monitor the actual environment.

- Acquire tools: loggers, software
- Acquire skills: software training

Gather information about:

- Your local climate
- Your building design
- Your mechanical system
- The collections and materials in each storage area.
- The activities that take place where collections are located.

2) Document the capabilities of the HVAC systems.

- Systems are designed to moderate the outdoor climate
- Define the geography served by each HVAC system
- Define the capability of each HVAC system (heat-cool-dehumidify-filter)
- Define the seasonal capabilities (summer vs. winter dewpoint)

Identify any malfunctions that compromise the system's ability to deliver the best possible climate at all times.

3) Set up a Preservation Management team to:

- Define what the critical vulnerabilities (most important kinds of environmentally-induced decay for example) are for collections stored in the space(s) served by each mechanical system.
- Determine the lowest temperature that collections area staff and occupants will accept.
- In consideration of above, negotiate the "optimal" environment for each collection area expressed in measurable metrics.
- Implement any system repairs indicated.
- Adjust system settings and control to achieve optimum performance.

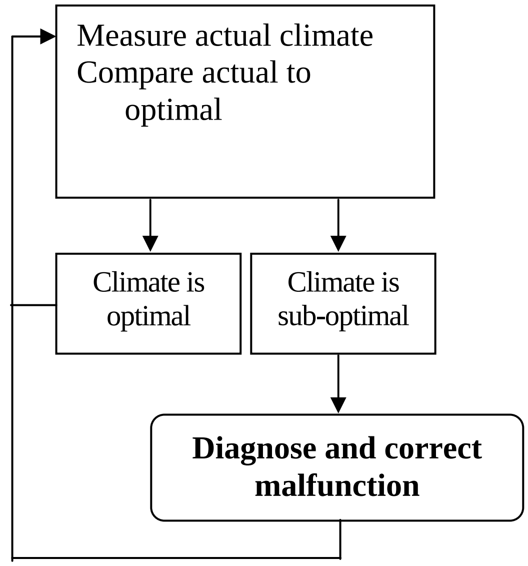
Ongoing Activities

4) Monitor the actual environment.

5) Compare actual to optimal.

6) Promptly correct any deviations.

More detail on these activities can be found in Chapter Eight.



This process requires the detailed knowledge provided by a team of staff representing preservation, collections and facilities, who come together to consider all relevant factors and negotiate the optimal climate possible.
More detail on the structure and tasks of a Preservation Management Team is included in Chapter Eight.

Chapter Two ~ Questions to Answer on Your Own
Environmental Monitoring

What is the history of environmental monitoring in your institution?
How has data been collected? Where? How is the data used?

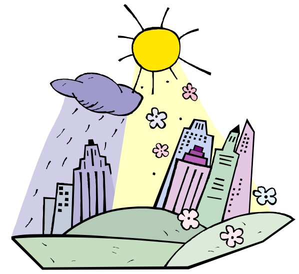
What staff is involved in environmental monitoring?
How are problems with the environment resolved?

Do you have set points? Do they vary by collection?

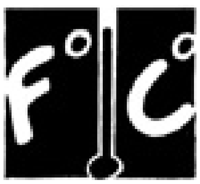
Design the ideal monitoring situation for your institution.
How many monitors, where would they be located?
What would the process of data review entail?

Identify key plays to be part of a Preservation Management Team for your institution.
What areas of expertise would be represented?

Chapter Three The Effect of the Environment on Natural Aging and the Rate of Decay



As noted in the previous chapter, management of the environment is a critically important component of collection care. Your ability to control the levels of heat energy and moisture content in the air directly affects your ability to preserve the collections in your care. Obviously many other environmental factors, such as light, dirt, dust and atmospheric pollutants, influence material decay – but temperature, relative humidity (RH) and dewpoint directly affect the rate of deterioration in almost all materials.



Temperature is the measure of the motion of molecules in a material. As temperature increases the molecules move faster and collide with greater force, increasing the chances for a chemical reaction to occur. At higher temperatures, biological activity also increases as insects eat more and breed faster, and mold growth increases. Certain materials soften at high temperatures resulting in sagging, adhesive failure, dust collection on soft surfaces, increased stickiness in some plastics, etc. At low temperatures some materials contract and may become brittle. Temperature is expressed in degrees Fahrenheit (F) or degrees Celsius (C).

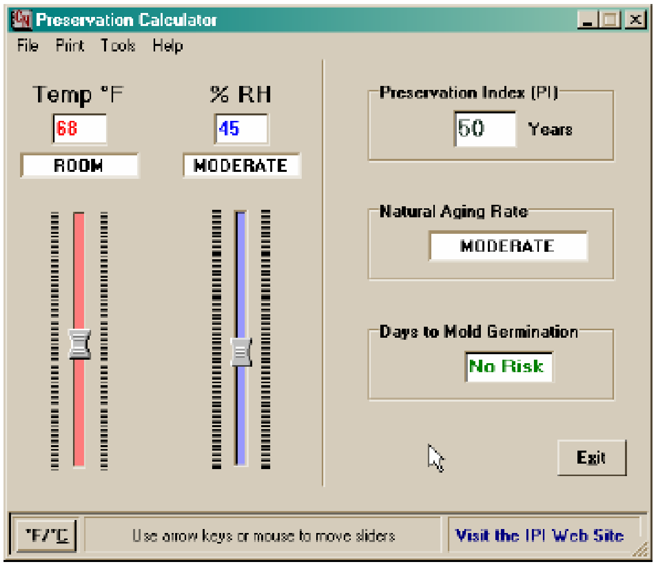
Relative Humidity (RH) represents how saturated the air is with water vapor. RH is a significant environmental parameter because it determines how much water will be present in collection objects once they have come to equilibrium with the surrounding air. All organic and some inorganic materials are hygroscopic – they absorb and release water depending on the relative humidity of the surrounding air. As RH increases, objects absorb more water; as it decreases they release moisture. At high humidity levels chemical reactions may increase and speed up the rate of decay. RH is expressed as a percentage from 0 to 100.

Simply stated, the higher the temperature is the faster the rate of deterioration due to chemical change or biological activity will be. The effects of relative humidity are not quite as straightforward. In general, higher humidity leads to faster chemical and biological deterioration. Humidity is also the major factor in physical or mechanical forms of decay such as warping, tearing, splitting and cracking. There will be more about dewpoint later in the chapter.

High RH causes metal corrosion, fading of dyes, swelling and warping of wood and ivory, buckling of paper, softening of adhesives and an increase in biological activity. Mold growth can become a problem at 65% RH and above. At low humidity levels wood and ivory will shrink, warp and crack; leather and photo emulsions will shrink, stiffen, crack and flake; paper, fibers and adhesives will desiccate.

Sources of water in collection storage can include outdoor humidity, rain, local bodies of water, wet ground, leaking pipes and broken gutters, moisture in walls, human respiration and perspiration, wet mopping, flooding, and cycles of condensation and evaporation.

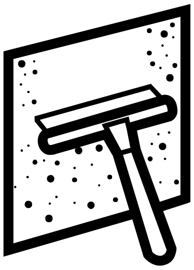
The Preservation Calculator was created by IPI as a planning and analysis tool for collection storage environments. It very simply illustrates how temperature and relative humidity affect the rate of natural aging in organic materials such as plastics, paper, textiles, plant and animal products, and dyes. Two forms of decay are illustrated: natural aging from spontaneous chemical change; and mold germination in a particular environment.



The Preservation Calculator allows you to compare conditions from one storage area to another, and to review temperature and relative humidity settings as you plan new storage environments. It is meant to supplement, not replace, the consideration of a wide range of environmental factors and forms of deterioration. Preservation Calculator is available under "Tools" on the Main Page of Climate Notebook. It is a stand-alone program that can be downloaded from the IPI website at www.imagepermanenceinstitute.org.

- **Temperature, RH, and Dewpoint: Three Interrelated Quantities**

Temperature (T), Relative Humidity (RH), and Dewpoint (DP) are three different, but related, aspects of moist air. Every environment has exactly one combination of temperature, relative humidity and dewpoint. Change any of these three things, and you have a different environment.



- **Dewpoint** is a measure of the *absolute amount* of water in the air. As air is circulated into and around a building, its absolute moisture content—and therefore its dewpoint—does not change unless it is humidified or dehumidified. In other words, unless the mechanical systems add or remove water from the air, the outdoor dewpoint and the indoor dewpoint are the same. Dewpoint is the temperature at which water will begin to condense out of the air expressed in degrees F or C. When the dewpoint is higher, the actual weight of water per unit volume of air is higher.

To manage the storage environment effectively, you need to develop an understanding of what temperature, relative humidity and dewpoint are, and how they relate to each other.

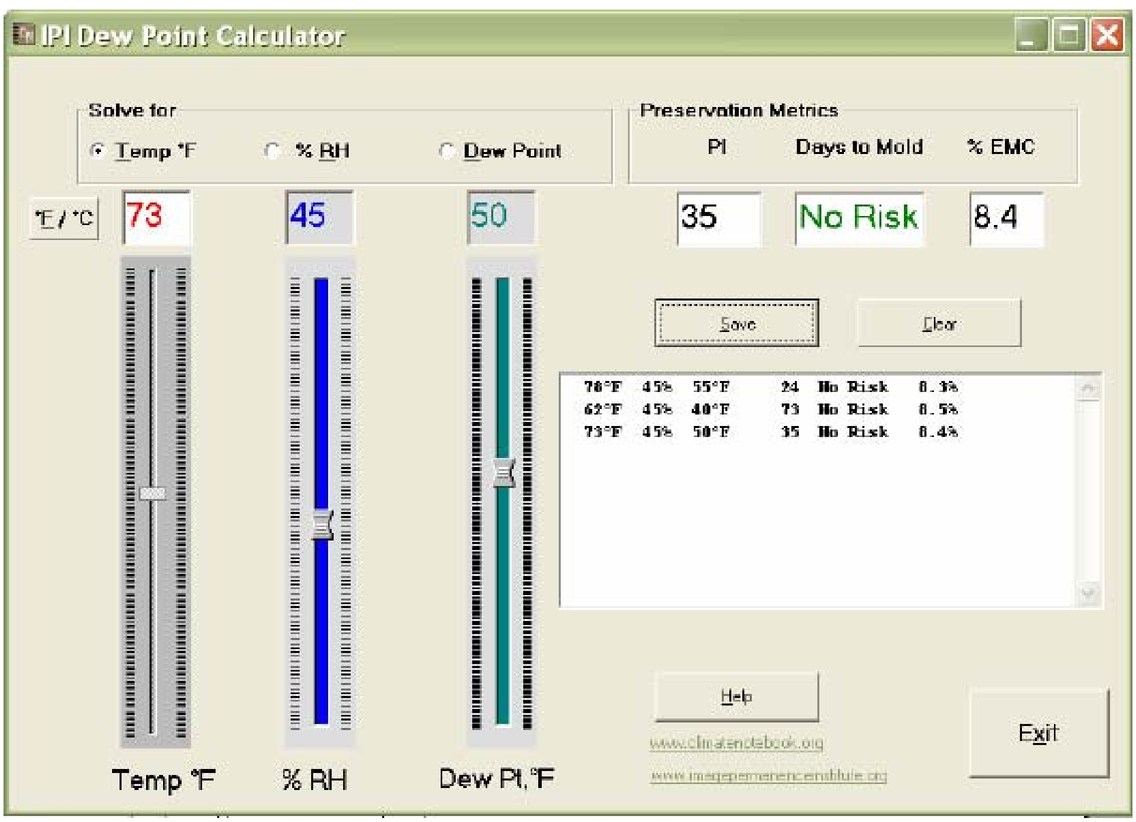
It takes some effort, but when you "get it," you will have the key to good analysis and decision-making about your storage environments. Here are some key facts:

- At constant temperature - RH and dewpoint increase and decrease together.
- At constant RH - temperature and dewpoint increase and decrease together.
- At constant dewpoint - temperature and RH go in opposite directions.
    - Higher temperature → Lower RH
    - Lower temperature → Higher RH

  As the air cools the RH increases until it reaches 100%, whereupon condensation occurs. Cooling air below the dewpoint is the normal means by which mechanical systems achieve dehumidification in the summertime. As long as condensation doesn't occur and no water is added to the air, temperature and RH will vary, but dewpoint will stay the same.

IPI's DewPoint Calculator

A newly designed "DewPoint Calculator" can be found under "Tools" on the Main Page, or in the "Compare Notebooks" view under the "Tools" in the main menu bar.



The DewPoint Calculator illustrates the interrelation of temperature, RH, and dewpoint and is used to explore aspects of this relationship in a storage or display environment. If you know any two of these elements, the calculator will allow you to determine the other. Click the radio button in the “Solve for” box to determine which quantity is the “unknown,” then move the other two “variable” sliders. The memo box on the right allows you to temporarily save the characteristics of environments so that you can compare several different conditions.

Try exploring these relationships:

- Find the dewpoint temperatures of some common room conditions (for example, 70°F, 50 % RH and 70°F, 20 % RH. Dewpoint is the “solve for” element in this case.
- Explore why it’s so dry indoors when outdoor air with a 15°F dewpoint is heated to room temperature. Make RH the “solve for” element since you know the dewpoint temperature and you can set the room temperature – what RH can you achieve?
- Explore why it’s so humid indoors when outdoor air with a 65°F dewpoint is cooled to 70°F. Again, RH is the “solve for” element.

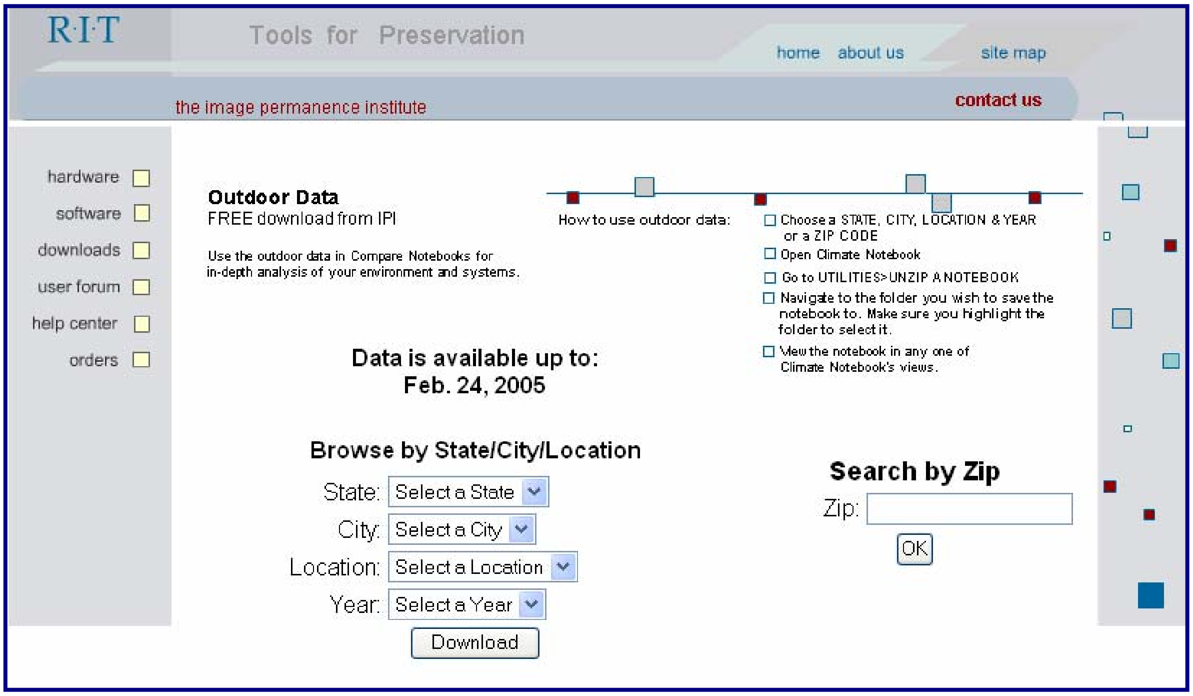
One reason that we are interested in graphs and statistics about dewpoint is that looking at a comparison between indoor and outdoor dewpoint graphs easily shows when mechanical systems are humidifying or dehumidifying. More importantly, **we have come to realize that in many cases the preservation quality of the storage environment depends more on achieving low summertime dewpoints than any other single factor.**

The Outdoor Climate

The outdoor climate is very important because it has a profound influence on what happens ***indoors.*** The place to begin with analysis of the conditions experienced by collections indoors is to examine the nature of the outdoor climate, particularly the dewpoint temperature. While everyone has some experience and understanding of the local weather, a closer look using the same types of analysis we will apply to collection storage spaces can be rewarding. Examining the outdoor climate also serves as a good introduction to the analysis techniques themselves.

Getting Outdoor Data from the Climate Notebook Web Site

IPI maintains a continuously updated source of outdoor data on the web at www.climatenotebook.org/stationdata/. This site contains data from more than 1,000 US locations. The source of the data is the National Oceanic and Atmospheric Administration (NOAA). IPI downloads the data from NOAA, makes Climate Notebook “notebook” files from it and makes them available to anyone. The web page looks like this:



To access the data, locations can be chosen by zip code or by specifying state, city, and location (larger cities have more than one monitoring site). When the location has been chosen, select the year of data you are interested in, from 2002 to the present. Click "download" and save the data to a local folder where you keep your notebook data. The data will be saved as a "zip" file using the familiar zip compression format. Zipped files are faster to download, but they must be "unzipped" before you can view them in Climate Notebook. Choose "Unzip a Notebook" from the Utilities menu on the main screen of Climate Notebook or else from the "Outdoor Data" menu item in the Compare Notebooks screen.

Try downloading and opening outdoor data from the last several years in the location where you live. After you have done that, you can join together the notebooks from several years into one continuous file by using the "Combine Notebooks" feature in the "Import Data" screen.

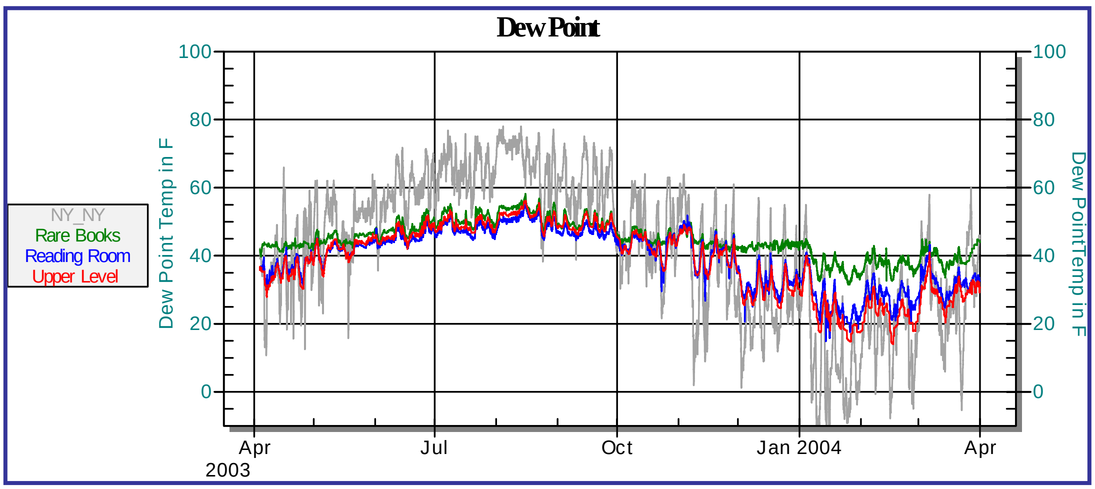
What to Look For in Your Outdoor Data

Assuming you have successfully opened a notebook file in Compare Notebooks containing a full year of outdoor data for your city, look first at graphs of temperature, RH, and dewpoint for the whole year.

- Consider temperature first. Outdoor data typically shows moderate daily fluctuations in temperature and quite significant daily fluctuations in RH. More important than daily fluctuations are the long-term seasonal trends. Most places have a winter season with cold temperatures and a warm summer. How extreme are the seasonal temperature differences in your area?

- The RH trends during the year will be a function of temperature and dewpoint. Consider the shape of the dewpoint graph. In many temperate places the shape of the temperature and dewpoint graphs are roughly similar—like a mountain, with the peak occurring in summer. This means summer times are hot and the air has lots of moisture in it. The opposite is true for winter—the air is both cool and dry. If this is the case, it follows that the RH graph will (allowing for the bouncing around of daily fluctuations) mostly be a flat line, usually at a moderate to fairly high RH level. In tropical locations the dewpoints are high all year long, the temperatures are uniformly quite warm, and therefore the RH line is also flat in shape and uniformly high.

The outdoor dewpoints throughout the year are especially significant in determining how much "work" mechanical systems must do to create a benign environment indoors for the collections. When outdoor dewpoints are high and the air is warm, the systems must both cool the air and wring the moisture out of it. Simply cooling the air isn't enough; if you just cool without dehumidifying, the RH indoors will be much too high. Many systems use "sub-cooling" (cooling well below the dewpoint so that moisture condenses on the



coils and drains away) to wring the moisture out of the air. You can see this dehumidifying effect quite clearly in the graph below.

This sub-cooling leaves the air at 100% RH and quite cold, too cold and humid to send into the collection spaces. The answer is to heat the air back up again (a process known as re-heating) to raise its temperature and lower the RH to acceptable levels. Just how much sub-cooling and reheating is necessary depends on the outdoor dewpoints and the desired indoor conditions. Unfortunately, the most desirable preservation conditions (simultaneously cool *and* dry) require the most energy to accomplish. When the cooling coils can't do all the sub-cooling they need to because the chilled water supply is not cold enough or there isn't enough chilled water available, the preservation quality (as measured by TWPI) of the spaces will suffer.

Chapter Three ~ Questions to Answer on Your Own
The Effect of the Environment on Natural Aging and the Rate of Decay

Go to the TMY2 (Typical Meteorological Year) File located on the Climate Notebook installation disk. Choose files from a variety of regions for comparison.

Review various regions to see how the range of heat, humidity and dewpoints influence the TWPI, MRF and DCI.

Choose a TMY2 file for your region:

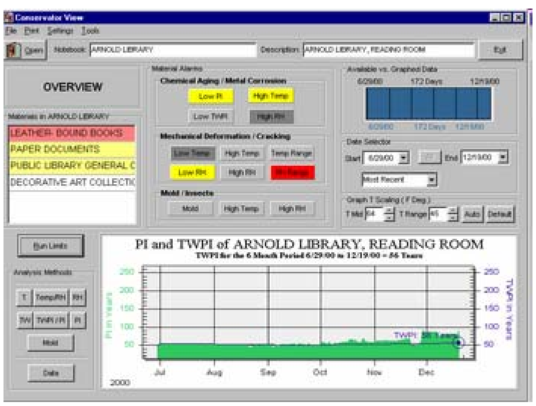
- Note seasonal trends and variations in temperature and humidity.
- Note daily relative humidity fluctuations.
- Look at the dewpoint, a major factor influencing the preservation quality of the environment. What are the seasonal variations?
- Review the data summary noting average temperature and relative humidity, rather than the extremes of each.
- Note the annual TWPI of the outdoor data, which represents the preservation quality of the environment in your location. You'll note a strong inverse correlation between high dewpoints and low TWPIs.

Where does your environment stand by comparison to other regions? Good quality is represented by low summer dewpoints, low summer temperatures, and low relative humidity (but not so low as to be dry).

Chapter 4 Development of Preservation Quality Metrics

We all agree that temperature and relative humidity are the important factors in chemical decay, mechanical damage and biodeterioration. We understand that in general cooler and drier (but not too dry) conditions are better for collections. But how do you know if you are providing the best preservation environment that you can? How do you really know how fast the collection is aging? What factors have the most impact on the long-term preservation of the collection? Which materials are most vulnerable? Where should you monitor to get the best information, and for how long? What is the best way to improve a storage area that is “underperforming”? The metrics, tools and procedures outlined in this workbook were designed to answer these and other questions.

The speed controls on natural aging are the temperature and relative humidity in the storage environment.



Successful management of the storage environment requires that the effects of temperature and relative humidity conditions on the decay of collections be understood and controlled. The preservation manager needs analytical tools that can evaluate the quality of storage and display conditions that are *quantitative and directly related to the preservation or deterioration of collections*. IPI has been working for more than a decade to develop and refine such methods.[1 2] Scientists at IPI have developed algorithms that provide quantitative measures of the risk of three important kinds of decay: natural aging (spontaneous chemical change in organic objects), mold, and dimensional change. These algorithms operate on temperature and RH readings made over a period of time and provide single-value metrics of the “preservation quality” of a particular storage environment. These metrics have been incorporated into Climate Notebook and can be used to analyze collection storage environments.

In recent years, a number of authors have discussed approaches to environmental assessment and preservation management from the point of view of a general treatment

[1] Reilly, J.M., Nishimura, D.W., and Zinn, E., New Tools for Preservation: Assessing Long-Term Environmental Effects on Library and Archives Collections, (Washington, DC: The Commission on Preservation and Access, 1995).
[2] James M. Reilly, Environmental Monitoring and Preservation Management Research at the Image Permanence Institute, Abbey Newsletter, vol 27, #2, 2004, pp 9-12.

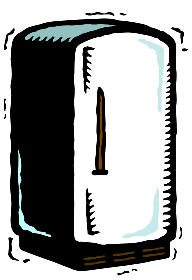
of decay reaction kinetics.[3] Sebera was the first to describe how collection life, temperature, and RH could be inter-related using a kinetics model based solely on theory and assumptions about the likely activation energies of decay reactions.[4] Others have combined models of chemical kinetics and physical behavior to define storage conditions.[5]

To manage anything you have to have a way to measure it.

Preservation Index (PI) - A New Measure of the Storage Environment

The Preservation Index is a means of expressing how ambient temperature and RH affect the chemical decay rate of collections. PI illustrates, in years, how long it will take for vulnerable organic materials such as poor-quality paper to become noticeably deteriorated under current (and unchanging) environmental conditions. PI is not a predictor of the useful life of any object or collection, but is a convenient comparative measure, using short-lived materials as a yardstick.

PI values have been calculated for every combination of temperature and RH. A moderate temperature of 68°F (20°C) and an RH of 45% yield a PI of 50 years. This means a typical short-lived material such as a color photograph would undergo noticeable deterioration (but not disintegrate) in about 50 years in this environment.



For the sake of comparison, the environment inside your refrigerator (at 41°F or 5°C and 45%RH) has a PI of 360 years. This means it would take 360 years for organic material in your refrigerator to become as deteriorated as they would in 50 years at 68°F (20°C). Lowering the RH in the refrigerator to 20% raises the PI to 775 – double what it was at 45%, and fifteen times what it was at room temperature. In the freezer (0°F or -18°C), the PI is 9999 years, as the rate of chemical reaction slows down considerably.

Remember that the PI is not a literal "year", and the numbers apply to short-lived organic materials. However, they do illustrate how the storage environment can speed up or slow down the life of collections. One of the most important lessons in environmental analysis is to realize that a small decrease in temperature from room conditions, or a reduction in RH, can make a significant difference in the natural aging rate.

Time-Weighted Preservation Index (TWPI) - A Cumulative Measurement

The Preservation Index is calculated based on unchanging temperature and relative humidity levels. In reality, the storage environment is dynamic, shifting with the weather,

[3] Stefan Michalski, Double the life for each five-degree drop, more than double the life for each halving of the relative humidity, Preprints of the 13th Triennial Meeting of ICOM, 2002, pp.66-72.
[4] Sebera, Donald k. Isoperms: An Environmental management Tool, (Washington, DC: The Commission on Preservation and Access, 1994).
[5] Marion F. Mecklenburg and Charles Tumosa, Temperature and Relative Humidity Effects on the Mechanical and Chemical Stability of Collections. ASHRAE Journal, 1999, pp 77-82.

the seasons, or the dial settings on the thermostat. TWPI adds the element of time and the cumulative effect of deterioration to the PI to give a more realistic estimate of the long term effect of an environment on preservation. It was designed to illustrate the effects of fluctuating conditions, over a whole period of time, as a single value.

PI and TWPI were the first two metrics designed to allow cultural institutions to ***quantify the preservation quality*** of an environment. This development allows the piles of weekly hygrothermograph charts and other temperature and humidity data that institutions collect to be visualized, organized, tracked and analyzed. To get the best analysis, data should be collected in each location for one full year. This allows you to see seasonal changes, and their effect on the environment. Typically, winter months are cool and dry, resulting in high PI numbers, and summer months are warm and humid, with low PI numbers. The TWPI was designed to reflect the cumulative effect of both good days and bad.

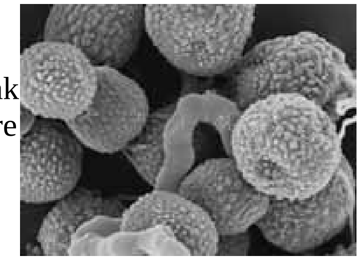
TWPI is not calculated as a simple average of PI values. Instead, it takes into account all the ups and downs of temperature and RH. In calculating the natural aging rate over time, you have to look at each interval of time (for example, each hour) and correctly "weight" the impact of that interval on the overall rate of decay. To get a high TWPI (a slow rate of natural aging) over a full year, there must not be a large proportion of hours that have a low PI, because they quickly drag down the overall average. The "bad times" have a disproportionate effect on TWPI.

Consider a bottle of milk. It might last two weeks in the refrigerator before spoiling. If left out on the counter, it would spoil in about a day. Suppose you kept the bottle of milk in the refrigerator for 12 hours each day and on the counter for the other 12 hours. How long would it take to spoil? An average of the lifetimes in and out of the refrigerator is not the correct average – the in the fridge life of 14 days X the counter top life of 1 day gives an average of 7.5 days. We know the milk spoils in one day, so after two days of half-in/half-out the milk will have spent one day on the counter and it will be spoiled. The time spent in the "bad" environment has more impact on the life of the material than the time spent in the "good" environment. Deterioration is cumulative and progressive, and it doesn't reverse itself when conditions improve.

The higher the PI or TWPI value, the better the environment is for the preservation of collections. TWPI values below 50 signal inappropriate conditions for vulnerable materials such as paper, photographs, and weakened textiles. Well-designed and carefully controlled storage environments will often have a TWPI value of 200 or more.

Mold Risk Factor (MRF) - Identifying Favorable Conditions
A third preservation quality measure for storage and display environments is the Mold Risk Factor (MRF). It is a number derived from temperature and relative humidity data over a period of time which expresses the likelihood and severity of mold growth on susceptible collection materials. The MRF is intended to give warning when conditions are such that mold might begin to grow on collection objects, and to quantify the potential severity of a mold problem. The higher the MRF, the worse a mold problem is likely to be.

Because conditions that favor progress toward spore germination are roughly the same ones that facilitate active growth of mold, the likelihood of a destructive mold outbreak is high when the MRF is high. While temperature and RH are decisive factors for mold risk, the actual occurrence of mold is also very dependent on the materials present in the collection, the history of previous active mold outbreaks, lighting conditions, and ventilation.



Mold Damage to Collections
Mold damage can be very destructive to a collection. While inorganic materials like metals, stone, and ceramics offer no nutrients to mold, organic materials such as paper, leather, textiles, natural history specimens, and plastics are quite susceptible.

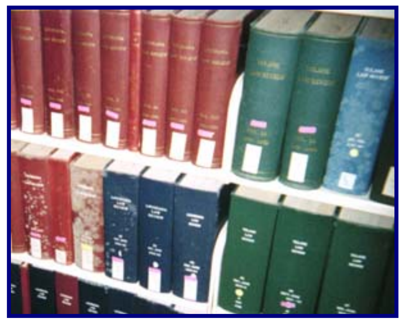
Mold (also called mildew) survives by excreting enzymes that digest organic matter. Mold requires moisture to actively grow and thrive. When they are actively growing, molds reproduce sexually, but they can also reproduce via an asexual reproduction cycle involving spores. Spores are almost omnipresent and can survive prolonged periods of dryness, germinating into actively growing mold when conditions are favorable.

Spores will not germinate if the RH is below 65 %, or if the temperature is below 36°F (2°C) or above 113°F (45°C). The optimum temperature for mold growth is about 86°F (30°C). Germination times range from two days under very favorable growth conditions to three years or more in marginal conditions.

Calculating the Mold Risk Factor
The estimates of time to mold germination used by Climate Notebook were derived from empirical data taken from published mold studies performed with food grains. A mathematical model relating temperature, relative humidity, and time for spore germination was created from the published data by Douglas W. Nishimura of IPI, adapting and extending modeling methods used by authors of the original mold studies as well as models used by Stefan Michalski of the Canadian Conservation Institute.

The “Days to Mold Germination” values in the Preservation Calculator express the number of days required for spores of several common mold species to germinate at a particular environmental condition. The estimates of days to mold germination apply to xerophilic mold species (those that can tolerate periods of dryness) such as aspergillus and penicillium. These types of mold are common in cultural property collections and can be quite destructive. The help file in Preservation Calculator has more information on the origins of these predictions and gives references for the published data on mold growth.

While the estimates of time to germination in the Preservation Calculator are useful, they are based on steady conditions. What happens when conditions vary over time? The algorithm for calculation of MRF considers each interval of time (one hour, for example) separately. The program calculates how much progress mold spores have made toward germination during each interval, starting at the beginning of the data and working to the end. If during the first hour the temperature and relative humidity were such that it would ten days to reach germination, then during that hour the spores progressed 1/240th of the way to germination (1/10th times 1/24th). If the next hour were similar in temperature and RH, after two hours the spores would be 1/240th + 1/240th, or 1/120th of the way along. This running sum is ***Mold Risk Factor***.



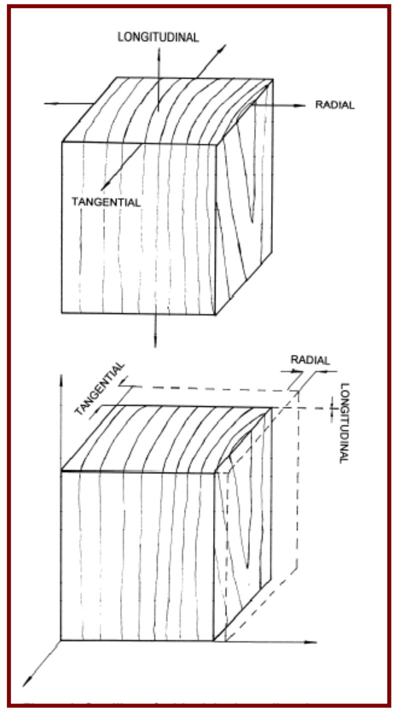
When the running sum reaches the full amount of time in favorable conditions for the spores to achieve germination, the running sum has a value of “1” and presumably the spores would now be germinated into actively growing mold, referred to as the "vegetative" state (the state where fuzzy growth might start to appear on objects). From this point, assuming conditions remain favorable, the mold growth continues. If the running sum reaches a value of “2”, it means that conditions were favorable for twice the minimum time needed for germination, and so on.

There is no upper limit on MRF. However, another assumption in the model that Climate Notebook uses to calculate MRF is that after germination, if conditions become unfavorable (i.e., dry out) for twenty-four hours straight, then the vegetatively growing mold will die. In doing so, more spores will be produced, ready to start the cycle over again if conditions improve. In that case, the running sum will start again. In the analysis of environmental data, Climate Notebook reports the highest value that the running sum achieved in the entire data set as the Maximum Mold Risk Factor.

MRF 0	**Mold should not be a problem at all.**
MRF 0 to1	**Progress toward mold spore germination has been made.**
MRF above 1	**Mold has most likely germinated.** **When the MRF is greater than 1, the number represents how bad the problem is likely to be.**
MRF 5	**Conditions were such that mold spores were in favorable conditions for 5 times the minimum time needed for germination.**

Dimensional Change Metrics – Reaching Equilibrium with the Environment
The most recent algorithms incorporated into Climate Notebook software are the ***Dimensional Change Metrics***, measures of the potential for physical change in organic material caused by gain or loss of moisture. Such forms of deterioration may be described as "physical" or "mechanical" because they do not involve chemical reactions or require the presence of living organisms. Although it can be very difficult to predict when any individual object could be damaged by improper RH, the new metrics do tell us something useful about the risk of environmentally induced physical damage.

The dimensional change metrics in CNB are modeled on the behavior of a virtual block of wood of average species. Using equations from USDA Forest Service Forest Products Laboratory, two important characteristics of this imaginary piece of wood can be calculated from the raw temperature and humidity data: the moisture content (expressed as a percentage of its weight) and the dimensional change (expressed as a percent expansion or contraction from its original width. Wood is the prototypical moisture-absorbing material, and its behavior can be used as a rough guide to how other water-absorbing materials such as paper, vellum, leather, and cellulosic plastics would behave in the same environment.



Shrinkage is proportional to the amount of water exchanged between a piece of wood and its environment. Wood is anisotropic, meaning its dimensions change differently in three directions: tangentially, radially, and longitudinally. Tangential dimensional change has the highest rate of change due to parallel orientation of microfibrils along the axis of the cell wall. Variations in humidity levels result in dimensional changes -- wood absorbs moisture and swells in high humidity; it releases moisture and shrinks in low humidity.

All organic materials are hygroscopic, absorbing and releasing moisture in an effort to reach equilibrium with the surrounding environment. The amount of moisture in a material at a certain relative humidity is called the ***Equilibrium Moisture Content (EMC)*** – a balance between the wood's moisture content and that of the surrounding environment. Mechanical or physical damage results as objects react to the level of moisture in the environment – evidenced by shrinkage, brittleness, cracking, loosening of joints, swelling, warping, distortion, etc. Damage may occur suddenly or in small increments. Laminate and composite materials such as photographs, magnetic media, veneered or inlayed furniture, and paintings are particularly vulnerable.

It turns out to be surprisingly useful to know how much dimensional change is likely to occur in a particular set of conditions – something that even experts cannot estimate by "eyeballing" the raw data. In one case in IPI's experience, a rare book vault with its own dedicated mechanical systems was found to engender more dimensional change than the general library stacks, which were thought to have a far inferior environment.

Because there are a number of aspects to consider in assessing the risk of environmentally-induced dimensional changes, Climate Notebook uses five different numerical metrics to illustrate moisture content: Minimum, Maximum, and Average Equilibration Moisture Content (EMC); percent Dimensional Change Maximum and Dimensional Change Index.

Max %DC numbers identify areas with significant fluctuations in the environment.
1% indicates a controlled environment.
2.5% or more indicates a risk of mechanical damage to sensitive materials.
EMC max and min numbers illustrate whether the risk of damage is from excessive dryness, excessive dampness or both.

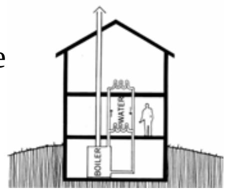
The table below gives an overview of the three main analytical approaches incorporated into Climate Notebook. The numerical metrics based on these approaches have a valuable role in both evaluating existing spaces and planning new ones. Each refers to a specific type of deterioration and measures the combined effects of temperature and RH over time.

Analysis Method	Deterioration Problem Addressed	Basis for Analysis	Algorithm	Examples of Deterioration	Numbers to Achieve
Time-Weighted Preservation Index (TWPI)	Spontaneous chemical change at the molecular level	Generalized treatment of decay reaction kinetics	Integrates over time, weighting each time interval according to reaction rate	Fading of dyes & pigments, embrittlement of papers & textiles, yellowing, or darkening	Higher is better
Mold Risk Factor (MRF)	Mold growth	Based on empirical studies of mold germination on food grains	Integrates over time, creates running sum of progress toward mold germination	Staining or weakening of textiles and papers	0 to1 indicates some progress toward germination, 1 or above indicates mold growth
Dimensional Change Metrics	Physical damage due to moisture absorption or desorption	Based on physical behavior of wood of "average species"	Estimates moisture content and dimensional changes over time	Warping, cracking or buckling, delamination, splitting, loosening joints	1% indicates controlled conditions, 2.5% or higher indicate dangerous dimensional change.

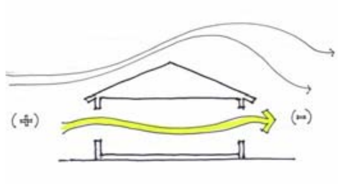
Chapter Five Understand Your Building and its Climate Control System

- **The Evolution of Climate Control**[6]

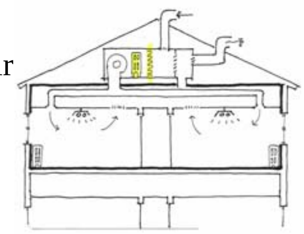
One of the reasons that humans created buildings was to help keep out the elements -- rain, snow, wind and cold. Fire provided heat, but needed to be managed – evolving from a fire pit to a stove, and eventually a boiler in the basement of the building. At this point, heat is transported through the building using water or steam.



Windows, designed to let in light, also provided ventilation. Building design allowed for this ventilation by including double hung windows and transoms above doors. This design only works if the building is no more than two rooms wide. Large buildings included courtyards or were designed in T or H-shapes to accommodate the need for air flow through the space.



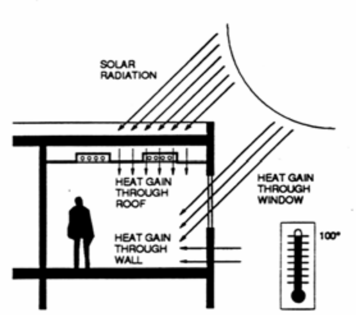
Electricity eventually allowed for a constant source of ventilation with the incorporation of fans, designed to let outside air in and take inside air out. Electricity facilitated control of heating, ventilation and air conditioning, and allowed the configuration of buildings to change. As climate control systems developed, dependence on perimeter spaces in building design was reduced. Today's buildings are sealed from the exterior and "breathe" through their climate control or HVAC (heating, ventilating and air conditioning) systems.

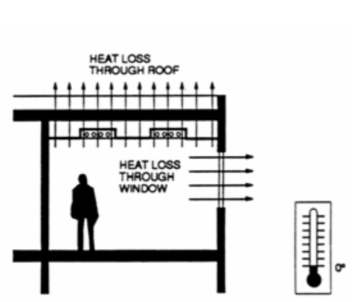


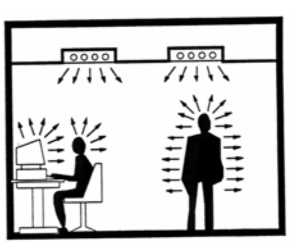
- **What HVAC Systems are Designed to Do**

HVAC systems are designed first and foremost to provide human comfort. Engineers are all familiar with psychometric charts which identify target specifications for climate control settings designed to provide physical comfort for the majority of building occupants.

HVAC systems are designed to remove perimeter heat gain from solar radiation, and to supplement perimeter heat loss moving from the inside out. Systems also remove heat gain which builds up in the buildings interior zones from lights, machinery and people.

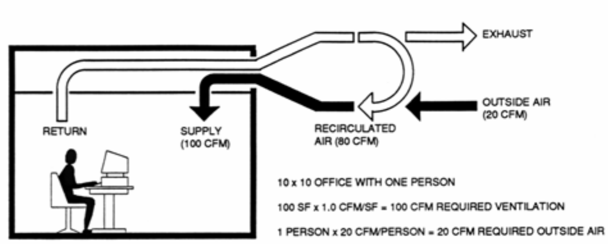






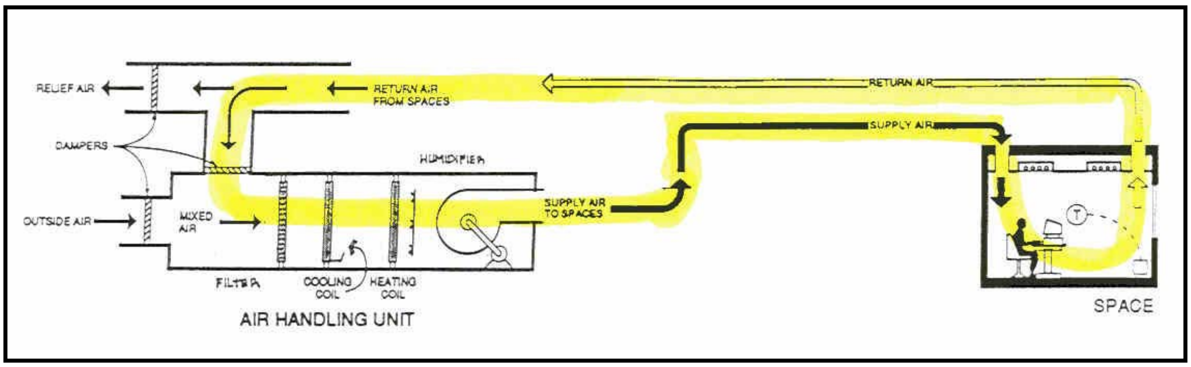
[6] Peter Herzog, Herzog/Wheeler & Associates, St. Paul, Minnesota.

HVAC systems are designed to provide ventilation by moving air in and out of the building in a loop, with a percentage of the air in the space always coming from the outside. ***This loop is the key component in understanding the system in your building.*** Moving and conditioning this air stream is often the largest expense in the institution's energy budget. All the components and configurations that you will learn about your mechanical system are part of this circular stream of moving air. It is along this loop that temperature can be raised or lowered, humidity levels can be raised or lowered, filtration can occur and outside air can be added or removed.



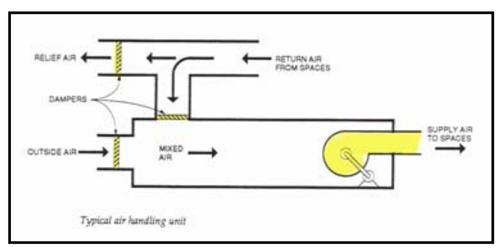
- **Understand Your Mechanical System**

The air inside your building came from the outside, and was then moderated by your building's mechanical system. Knowing something about the design and location of mechanical systems in your buildings is essential to achieving a preservation environment for collections. You will need to determine the level to which the climate control systems in your buildings can modify the temperature and humidity of the outside air.



HVAC System Components and Configuration

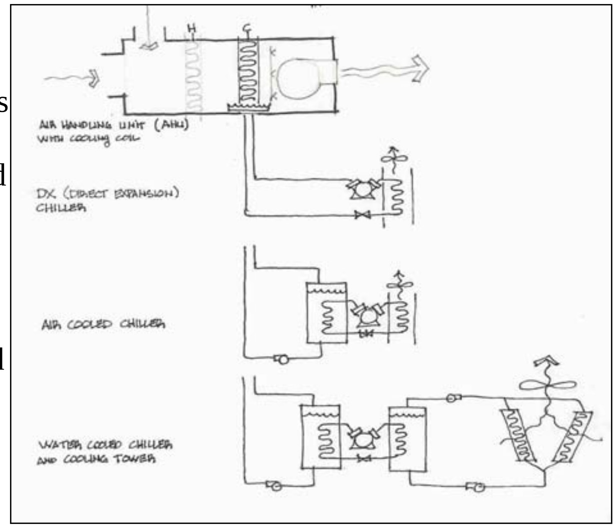
Most, if not all, of this modification of the air in the building takes place inside the ***Air Handling Unit (AHU).*** The main components of the AHU are the fan, ducts and dampers. The fan moves the air through the ducts, and dampers open and shut to modulate the amount of air.



Typical air handling unit

The AHU often includes several other components. Filters are in place to keep "gunk" out of the system, to control particulates or remove contaminants. Heating coils in the AHU are controlled by a thermostat. Hot water or steam produced by the boiler (which is peripheral to the AHU system) allows the selected temperature to be achieved in air passing through the heating coil. A humidifier in the AHU (connected to a peripheral steam generator) blows in steam to add moisture to the air. A cooling coil/dehumidifier cools the air and takes moisture out as the air passes through.

The chilling is provided peripherally to the cooling coil in the AHU by a refrigeration system. The basics components of the refrigeration system include the compressor, evaporator and condenser. Think of this system as a sponge – the evaporator sucks moisture up and the condenser squeezes moisture out. Common refrigeration systems include the AHU with a cooling coil, the DX or direct expansion chiller, an air cooled chiller, and a water cooled chiller and cooling tower. The equipment arrangement and system design varies, but the basic functions are the same. Heat is removed by blowing in cool air to absorb the hot air, and help us get the temperature in the space that we want. In a preservation environment, temperature is critical – we want the space to be as cool as possible.



Mechanical systems are designed have some or all of the following capabilities:

Ventilation (outside air) is provided by adding some outside air to the stream of air entering the room. It is important to determine how much outside air enters the space. The interests of preservation and energy-efficiency are best served by ensuring that no unnecessary outside air be introduced.

Air filtration is provided by passing all air delivered to spaces through one or more filters to remove particulates. Often additional filters are added to remove gaseous components in the air.

Heating is provided to spaces by passing a stream of air over a warm heating coil and conveying that air to the space. On occasion heat may be introduced to a space directly using convectors or radiators.

Humidification is accomplished by introducing water vapor (usually steam) into the stream of air before it enters the space. Humidity can be added by the cooling coil or the humidifier in the AHU.

Cooling/Dehumidifying is accomplished by passing a stream of air over a cold coil before delivering that air to the space. If the temperature of the cooling coil is below the dewpoint temperature of the air, moisture will condense on the coil thereby dehumidifying the air. One key determinant of the preservation environment is how cold and dry the cooling coil can make the air.

Some buildings have humidistatically controlled systems which are designed to maintain a stable RH by manipulating and varying the temperature. A humidistat sensor adjusts the temperature up if the RH rises above a set point, and maintains it until the RH drops back. If interior RH is lower than exterior RH, dampers are opened by sensors and the air is circulated through the building. If exterior RH is too high, the dampers remain closed.

Smaller institutions may have residential-type systems consisting of furnaces and window or through-the-wall air conditioners. Buildings with very basic systems often rely on portable humidifiers and dehumidifiers to manage the level of moisture in the air.

- **Portable Humidifiers** add moisture to the air, raising the RH. They can counteract the drying effect of low-moisture outside air in the winter months. Fans may be needed for circulation.
- **Portable Dehumidifiers** remove moisture from the air and lower the RH. Their use should not be considered a long-term solution to the presence of moisture. To achieve a preservation environment, you need to determine why the space is damp and remove the source of the moisture.

Buildings commonly have multiple climate control systems, and these systems commonly serve multiple spaces. The “Schedules” section of mechanical system design plans will show how heating, ventilating and air conditioning are distributed in buildings, and identify the location of the equipment that provides it. Copies of these plans should be acquired to become a part of the Preservation Environment Management file.

Building Management Systems (BMS)
Often large buildings or complexes have computerized building management systems (BMS) that allow building engineers to monitor and control the performance of air conditioning equipment. A BMS can be quite complex, incorporating sophisticated energy conservation functions, graphical displays, and reporting options for hundreds of variables.

In cultural institutions, storage and display areas that require special environmental conditions are often connected to a BMS. It is very possible that the BMS sensors for temperature and RH could be used to gather data for analysis using Climate Notebook software. However, a few general cautions apply, and you should consider the following:

How can BMS data be imported into Climate Notebook?

Often, a text file can be created that Climate Notebook can recognize. If the file can be in Climate Notebook’s CSV (comma-separated) format, it can be directly imported. Otherwise, some custom programming may be required to create a CSV format data file.

A variety of software tools, including Microsoft® Excel, Microsoft® Word, Microsoft® Notepad, and Word® Perfect, can be used to create CSV files.

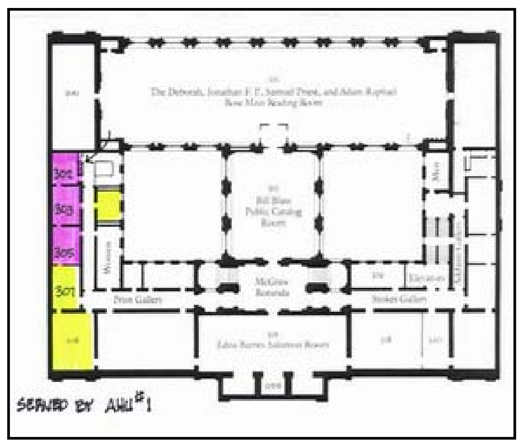
- Are the BMS sensors sufficiently accurate or do they need to be re-calibrated?
- Does their placement reflect the actual environment that the collection is experiencing?
- Are sensors placed in return air ducts to monitor a mixture of air returning from the controlled space?
- Are the sensor locations correctly marked on the BMS computer?

It is very important to gather data about your mechanical system through monitoring. Even a new mechanical system needs to be monitored to check on its performance. Analysis of this data will help you identify the needs and problems of your current system, define areas that need further investigation, and determine a course of action for performance improvement.

- **Activities to Help you Better Understand Your Mechanical System**

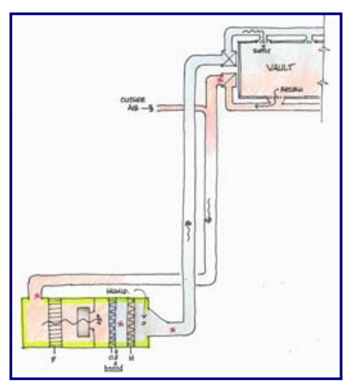
It is useful to be able to visualize the equipment that creates the climate for collections areas, and also to visualize how equipment is configured to create the HVAC system. Meet with your facilities manager to gather information about the system. Locate the air handlers that serve collection storage and exhibition areas. Become familiar with where the outside air enters and how the air from the space is returned to the unit. Note the location of filters, cooling coil, heating coil and supply fan. Trace the air path or "loop" of the air that eventually arrives at the collections space.

Create Schematic Diagrams or "Cartoons"



It can be very useful to create schematic diagrams to record the information you gather as you develop an understanding of the HVAC system in the building. These simple drawings easily illustrate the basics of air flow and energy use in the rooms being monitored. Diagrams can provide an easy way to recall the relationship of interconnected energy-consuming devices.

It's helpful to create a drawing indicating the areas served by each air-handling unit or heat pump. Understanding the "zones" for heating or cooling will be very useful during analysis of the storage environment. The mechanical design plan should include a list of the air-handling units. Sketch the boundaries served by each air handler on the schematic floor plan. Do a schematic sketch of the air flow path from the rooftop units to the spaces they serve.



If possible, do a little research to help you understand how the units are intended to operate. Review the "sequence of operation" found in the building construction specifications. This will indicate operating characteristics such as daily schedules programmed into the air handler control timer, programmed "off" periods and associated override thermostat settings, etc.

Understand the Limitations of Your Building

Every level of environmental influence has to be considered when thinking strategically about a preservation environment for collections. Understanding the environmental impact at each level -- from the outdoors, to the building, the room, the storage system, and enclosures -- can help you target limited institutional resources for the greatest overall benefit to collections.

The building envelope is the collection's primary "enclosure," providing the first level of protection against the outdoor environment. The design and construction of the building greatly influences the impact that thermal conditions and moisture will have on collections.

Ernest A. Conrad, President of the Landmark Facilities Group, Inc. has devised a classification system for buildings or rooms, with three **Climate Control Categories**[7]. Each category has two classifications. They are:

1. Uncontrolled Building – a structure with no installed system for heating or cooling.

- **1.a. No mechanical devices**. Basically, an open structure with an environment that equals the outdoors.
- **1.b. Ventilation only**. No systems for heating or cooling, but sides and roof are enclosed.

2. Partially Controlled Building – construction includes some kind of mechanical system to provide temperature control only.

- **2.a. Heating and ventilation**. Limited climate control consisting of low level tempered heating and exhaust ventilation. Single glazed windows, no insulation or vapor barriers present. No humidity control.
- **2.b. Basic HVAC**. A ducted system of heating and cooling which may be capable of limited humidification and dehumidification re-heat. Low air filtration usually, modest insulation, storm windows, attics insulated and vented to the outdoors. Capable of year round temperature control and limited humidity control.

3. Climate Controlled Building – usually designed to be humidified, with systems that can accurately control both temperature and humidity levels year round.

- **3.a. Climate control with drift.** Ducted HVAC systems with devices to mechanically humidify and perform process logic to dehumidify. Scheduled seasonal drift is intentionally selected, usually to prevent winter time condensation and/or to reduce the cost of maintaining low summer temperature and humidity levels. Usually well insulated with good vapor

[7] "The Realistic Preservation Environment", Ernest Conrad, P.E., President, Landmark Facilities Group, Inc., presented at the National Archive and Records Administration's 14th Annual Preservation Conference, March 1999.

retardant characteristics.

3.b. Special constant environments. Specifically constructed to meet specialized environmental needs, with precision climate control components. Can hold constant temperature and humidity levels within defined limits.

Heat Loads

Once the climate control category of the building envelope has been determined, it is important to identify the source and impact of heat loads in the collection storage space. Mr. Conrad lists six heat loads sources:

Solar – heat energy from the sun, which enters the building through windows, doors and skylights.
Transmission – heat energy that moves through a wall or roof caused by a temperature difference on either side. Most significant in winter when the difference between the inside and outside temperature is greatest.
Lights – and other electric devices contribute heat energy to a space.
People – produce a heat load which is about half water vapor and half warmth. This can vary with the temperature of the room (hotter room – more water output). Unless the room is crowded with people, the influence is small.
Infiltration – the movement of moisture laden air from one space to another. This air can move through an opening, or through porous materials.
Minimum Outdoor Air – the mandated amount of outdoor air which must be introduced into all occupied spaces for indoor air quality purposes.

Moisture

Building-related problems that can cause high levels of relative humidity within the structure include roof, ceiling, or window leaks; gaps in walls, floors, or foundation vapor barriers; leaking plumbing; damaged gutters and downspouts; wet walls and foundations from poor drainage; deteriorated brick or masonry; open water sources such as sinks or toilets.

The room environment responds to the building envelope, and relies on mechanical systems for climate control. An understanding of the floor plan and how the climate control elements are laid out within the building will help you understand the mechanical systems that affect collection storage areas. Architectural floor plans and full building sections provide an overview of the general configuration of the building. We recommend that you review floor plans of your facility and identify the location of energy management activities. The floor plans can then be used to record the location of data loggers and other information-gathering devices.

Chapter Five ~ Questions to Answer on Your Own
Understand Your Building and its Climate Control System

Describe each Building that houses collections:

Date of original construction

Date and description of major additions or renovations

Type of construction, predominant materials

General condition of the building

Are renovations planned for the building(s)?

Have preservation concerns been addressed?

Are engineers/architects/designers aware of the role of environment in preservation?

Checklist of Items to Collect

Architectural drawings

- Floor plans
- Building sections and elevations

Mechanical drawings and specifications

- Plans showing equipment and corresponding areas served
- Plans of mechanical equipment rooms showing major equipment
- Schedule listing equipment and their capacities.

Floor plans:

Identify all areas where collections are stored

Identify the location of water pipes, bathrooms, and any other sources of water

Identify the location of HVAC equipment – sources of heat, ventilation, air conditioning within the storage area.

What areas of your building have had problems with temperature levels?

What areas of your building have had problems with high or low humidity levels?

Has your building had problems with excess moisture? What has the source of the problem been?

Climate Control Systems:

Identify the basic type of environmental control in your building(s).

Uncontrolled
Partially Controlled
Climate Controlled

How is the temperature level determined? Who has access to controls for changing the settings?

Does the building have air conditioning? Is it building-wide or localized? Who has access to controls for changing the settings?

Is the climate control operated 24 hours a day, 365 days a year?
Are storage areas controlled separately from other areas of the building?

What temperature and RH is the system designed to maintain? Does it do it? Who monitors it? Who maintains it? How are malfunctions dealt with?

Are there sources of natural light in collection storage and exhibition spaces? What type of artificial light is used? Are lights turned off when storage areas are unoccupied?

HVAC System Documentation

Herzog/Wheeler & Associates, 3-22-05

One key activity in achieving and sustaining optimal collections environments is to define the best environment that the existing HVAC systems are capable of delivering. This activity begins with gathering the documents from which the systems were constructed in order to answer the following questions:

1. What systems serve the collections areas?
2. Where are they located?
3. What are their heating/cooling, humidifying and dehumidifying capabilities?
4. What are their air filtering capabilities?
5. How much outside air (ventilation) do they bring in?
6. How are these systems controlled?

The answers to these questions can be found in the HVAC drawings, and in that portion of the “Mechanical Specifications” titled “Sequence of Operation” of HVAC equipment. Copies of these documents should be acquired and become a permanent part of a “Preservation Environment Management” file.

Ultimately, this file should contain the following information:

Identification of relevant HVAC systems and zones
On copies of architectural or HVAC floor plans, locate the HVAC system that serves collections areas and, using a highlighter, trace the boundaries of the zone served by each system.

Identification of climate control capabilities
Make a copy of the HVAC System Documentation forms on the following pages for each relevant system in your institution, and fill in as much information as possible.

HVAC System Documentation Forms
Herzog/Wheeler & Associates, 3-22-05

Name of Institution: ____

Name of Building: ____

Contact Name/Phone: ____

System Name: ____
(Examples: RTU #1 is Rooftop Unit #1; AHU #1 is Air Handling Unit #1)

Description of Area Served: ____

Location of Unit: ____
(Examples: on roof; in mechanical penthouse; in basement mechanical room)

Cooling/Dehumidifying Capability (from design drawings):

Type of cooling coil:
- None
- Direct Expansion (DX)
- Chilled Water

Design conditions of air leaving the cooling coil:
Dry bulb temperature ________________
Wet bulb temperature ________________
Dewpoint temperature _______________

If the system has desiccant cooling, provide design leaving air conditions:
Dry bulb temperature ________________
Wet bulb temperature ________________
Dewpoint temperature _______________

Heating Capability (from design drawings):

Type of heating:
- None
- Gas-fired heater
- Electric heater
- Steam or hot water heating coil

Location of heating capability (check all that apply):
- In outside air stream (preheat)
- In mixed air stream before cooling coil
- After cooling coil (reheat)

Humidifying Capability:

Type of Humidifier:

- None
- Steam injection from heating boiler
- Steam injection from dedicated steam generator
- Ultrasonic

Control Sensor Locations:

Where is the sensor located that controls the space temperature?

- In the space
- In the supply duct
- In the return duct
- Other (explain) ___________________________

Where is the sensor located that controls the space RH?

- In the space
- In the supply duct
- In the return duct
- Other (explain) ___________________________

Ventilation Capability (from design drawings):

System maximum air handling capacity: _______________ CFM
System minimum outside air capacity: _______________ CFM

Filtration Capability (check all that apply):

- Particulate pre-filter ________% effective
- Particulate final filter _______% effective
- Gas phase filtration – type: __________________

System Control:

The system is equipped with:

- Pneumatic control
- Direct digital control (DDC)
- Combination of pneumatic and DDC
- Other (explain) ____________________________

Describe the operating schedule:

- Continuous
- Scheduled operation:

On from _____________ to _______________weekdays
On from _____________ to _______________ Saturday
On from _____________ to _______________ Sunday

What are the maintained space conditions?

	Maximum	Average	Minimum	Notes
Summer temperature				
Summer RH				
Winter temperature				
Winter RH				

The above maintained space conditions were determined by:

- Occupant observation
- Hygrothermograph data
- Datalogger information
- Other (explain) ______________________________

Chapter Six Collection Materials and their Response to the Environment

In any discussion of the role of the environment in preservation, distinguishing between chemical, physical, and biological decay processes is very important. Some collection materials are more susceptible to chemical decay, while for others mold growth or humidity-induced warping and shrinkage are more dangerous. Each material has its own characteristics, and most have multiple susceptibilities. To assess the "preservation quality" of any given storage environment, the temperature, humidity, and patterns of temperature and humidity change must all be considered; each must be examined in terms of the potential for causing chemical, physical, or biological deterioration in the collection.

A poor storage environment greatly increases the rate of decay of all organic and some inorganic materials. This deterioration increases significantly when materials are under the influence of inappropriate storage temperature and relative humidity. Of course, other factors influence the rate of decay – light, air pollution, dust, inappropriate handling and so on. Some materials are inherently unstable and require special attention. It is important to develop a basic understanding of the physical nature of the materials in your collection and how they are affected by the environment.

Basic Material Types

Organic – derived from once living things, plants or animals.

- Animal – leather, ivory, horn, bone, skin, vellum, feathers, silk, wool, some pigments, insect and animal specimens.
- Vegetable – paper, parchment, cotton, wood, linen, flax, bark, grass, plastics, some pigments, and botanical specimens.
- Common characteristics – organic materials contain carbon, are combustible, and are susceptible to deterioration from extremes and changes in relative humidity and temperature. They absorb water and emit water to the surrounding air in order to reach equilibrium (hygroscopic), are sensitive to light, and are a source of food for mold, insects and vermin.

Inorganic – have a geological origin.

- man-made – metal, enamel, ceramic, glass
- natural – stone, minerals, some pigments
- common characteristics – have undergone extreme pressure or heat, usually not combustible at normal temperature, can react with the environment to change their chemical structure (corrosion or dissolution), not usually sensitive to light.

Composite – made up of two or more materials.

- Organic composite – oil on canvas, painted wood, etc.
- Inorganic composite – metal and enamel

- Mixed organic/inorganic composites – fork with bone handle, textile with metal beads, etc.
- Individual materials will react with the environment in different ways, often in opposition to each other, setting up physical stress and causing chemical interactions that cause deterioration.

The Effect of the Environment on Collection Materials

Deterioration is inevitable. It is a natural aging process by which an object reaches a state of physical and chemical equilibrium with its immediate environment. But the rate of deterioration can be controlled by modifying the environment. There are three basic types of deterioration:

Chemical Decay - a chemical reaction that causes changes in an object at the atomic and molecular level. Examples of chemical decay include metal corrosion, deterioration of pigments, staining by acidic materials, and embrittlement of pulp papers and textiles.

Mechanical Decay – a change in the physical structure of an object. Caused by changes in the environment that lead to stresses in an object. These include variation in and improper levels of temperature and relative humidity. Examples include softening of plastics and waxes, cracking and buckling of wood, warping, shattering, and cracking. Mechanical damage is also caused by mechanical force resulting in chipping, cracking, crushing, abrasion, pressure distortion, tearing and so on.

Biological Decay - caused by the attack of biological organisms on objects and materials. Mold spores are always present in the atmosphere and just require a sustained high RH for a certain period of time to propagate. Organics are particularly susceptible. Some examples of biological decay are staining from mold growth and loss due to feeding by insects or their larvae.

Each quantitative value in Climate Notebook represents a particular form of collection deterioration. The TWPI number illustrates chemical decay, the MRF is associated with biological decay, and the DCI metrics represents mechanical decay.

Inherent Vice

Certain types of objects deteriorate as a natural consequence of their physical characteristics. This occurs because of the incompatibility of different materials or the instability of the materials. Examples include cellulose nitrate film, wood pulp paper, many 20th century plastics, improperly applied paint, and salt deposits in archaeological ceramics.

Signs of Natural Aging
Discoloration and embrittlement of paper
Deterioration, warping and embrittlement of plastics
Fading of dyes in color images and textiles
Corrosion of metals
Deterioration of glass and minerals
Cracking of wood from expansion and contraction
Loosening of joints in furniture and other composites
Paint loss on paintings and deformation of canvas
Cockling of paper

General Considerations for Preservation Quality
The "preservation quality" of an environment is best judged in terms of relative risks and benefits. Because decay occurs through different mechanisms – chemical, mechanical, and biological – conditions that bring benefits for one decay mechanism may bring increased risk with another. For example, extreme dryness will slow down chemical change, eliminating corrosion risk in metals and slowing the natural aging in organic materials. However, for some objects, such as vellum-bound books, dryness presents unacceptable physical danger from shrinkage and brittleness, especially when handled.

Every well-designed climate will represent a compromise that attempts to balance the degree of risks and benefits arising from differing mechanisms of deterioration. There is no single condition that minimizes every type of risk. You will need to consider all the major classes of objects that will be stored in a particular environment and estimate the degree of risk or benefit that will be created for the materials by the environment.

If more than one kind of object or material is present, it's necessary to make the best compromise among the competing risks and benefits for *all* the object types, based on their individual vulnerability to decay.

For chemical decay, both moisture and temperature play a role. For organic materials such as paper, vellum, wood, textiles and plastics, chemical decay is ongoing and spontaneous. Benefits accrue as objects become cooler and drier because decreased thermal energy retards the rate of chemical reactions. Dry conditions starve chemical reactions of water needed for the reactions to take place.

Physical decay is driven primarily by extremes of RH, although temperature can affect the degree of risk if prevailing conditions are cold enough to cause brittleness. Estimating the degree of risk from improper RH conditions is difficult to generalize because the construction details of composite objects have a strong influence on their behavior. Risks accrue from excessive dampness because of differential expansion, sagging, warping, and permanent deformation. Risks arising from excessive dryness include brittleness, contraction, cracking and tearing. Risks also accrue from repeated changes in moisture content that cause slow progression of micro-cracks and other forms of "fatigue" in materials. Benefits accrue from steady RH conditions that center on a value where the object is at minimum risk from stresses induced by dryness or dampness.

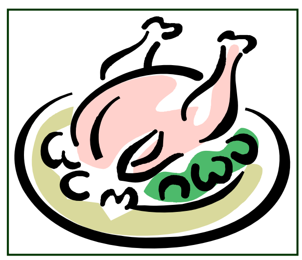
Biological decay is driven by heat and especially by moisture because life processes are biochemical reactions governed by the same rate-controlling factors as any other chemical process. In practice, mold and insects pose the most acute biological preservation risks. Generally, maintaining RH conditions below 60% eliminates any risk from mold growth. Insect infestations are minimized by keeping RH below 50% and temperatures cool.

Understanding Equilibration: When Your Collection "Feels" a Change in Temperature or Relative Humidity

A little understood but quite important aspect of managing preservation environments is knowing when and to what degree collection objects "feel" (adjust to) a change in room conditions. In scientific terms, this is referred to as equilibrium relationships for temperature and moisture. The topic can be quite complex, but a few simple rules will help. First of all, we divide the subject into two parts: temperature equilibrium and moisture equilibrium. Collection objects come to equilibrium with changing room temperature quite rapidly. If there is a one-time change in room temperature, say from 70F to 50 F, how long will it take for all objects in the room to have an internal temperature of 50 F? The answer will depend somewhat on what kind of object we're talking about, and will also depend on how massive the object is and also how much surface area it has. This makes sense from everyday life—a chicken thaws faster than a turkey. But even a turkey doesn't take more than about 24 hours to thaw. Temperature equilibration happens fairly fast and with most objects is complete in a *few hours to a full day or so*.

Example:
A frozen turkey will take longer to thaw than a frozen chicken because of differences in mass.

The plastic wrapping on the frozen turkey does not slow down the thawing, but it does keep it from drying out.



Moisture equilibration is an entirely different story. How long will it take for an object to fully equilibrate to a one-time RH change from 20 % to 50 %? The answer is probably longer than you think. A single book on a shelf at room temperature will take about a month to reach equilibrium with the surrounding air, a shelf full of books a little longer.

Moisture permeates objects by diffusion, a process that is strongly temperature dependent. The rate of moisture absorption slows down at cold conditions, so in cold vault the book might take several months to equilibrate to a new RH level. The outer surfaces of objects equilibrate first, then the insides. Most of the moisture in the text block of a book enters and exits through the exposed top edge, spine, and foredge rather than through the covers. Since the outer edges of the text block equilibrate first, they get a chance to experience more absorption and desorption of moisture than the middle does. The outer edges "see" more damp and dry periods than the middle. The damp periods together with more frequent absorption and desorption (along with air pollutants) help explain the familiar sight of discolored leaf edges in books. The middle of the book responds only to long-term RH trends.

Part of the difficulty in assessing the threat from fluctuating RH levels is determining whether an object has had time to come to equilibrium with the fluctuations in question. Certainly some part of the outer surface is affected by even short fluctuations, but does enough of the object equilibrate to make a difference? When we try to asses the risk of improper RH conditions we need to take account of equilibration behavior. Climate Notebook does this with its mechanical risk metrics (Dimensional change and EMC) by allowing the user to input an equilibration time. This can vary from one day to 90 days. The analyst needs to know something about the behavior of collection objects so the proper equilibration time can be used. Thirty days is the default.

Chapter Six ~ Questions to Answer on Your Own
Collection Materials and their Response to the Environment

What materials are present in each storage area?

How are they organized for storage (subject, type, etc.)?

What collections are the most “valuable” – important, representative of your mission, etc?

What collections/materials are the most vulnerable – most at risk to environmental damage?

Which are most at risk of chemical, mechanical and/or biological deterioration?

What other activities take place in the storage area?

Is there a history of environmentally-induced problems in the storage areas?

Chapter Seven Analyze the Preservation Quality of Your Storage Environment

Environmental monitoring is important, but it is not an end unto itself. The data you've gathered must be analyzed, and then appropriate actions should be taken to improve the preservation quality of the storage. The development of preservation quality metrics and the ability to visualize and manipulate data in Climate Notebook combined with the involvement of all key players in your institution allows for **a radical new approach to managing the storage environment.**

Monitoring generates large quantities of data -- large institutions may have dozens or even hundreds of monitoring locations. Simply to organize and manipulate such large data sets requires considerable effort. Most software sold with building automation systems or standalone data loggers was not designed for managing a continuous monitoring effort for several locations. Climate Notebook was designed to organize and visualize large quantities of data from multiple logger sites during a long period of time. Rather than have separate files containing data from a single location, Climate Notebook keeps all the data together in one file called a notebook file. This file also holds information about the location, including a list of object types stored there, location and logger descriptions, and target T and RH values.

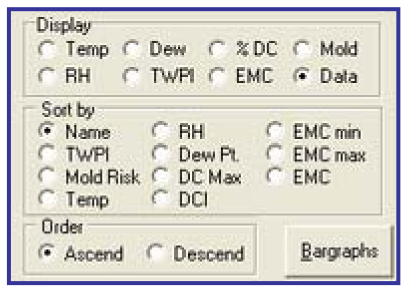
The analysis approaches developed at IPI can be described as ***performance-based environmental assessment***. Traditional approaches are based on setting specific targets for temperature and RH and watching for any divergence from these targets. Performance-based analysis deals with numerical estimates of the risks or benefits associated with a set of environmental conditions. Performance-based metrics quantify the effect of environmental conditions on promoting or retarding general modes of collection decay such as chemical change, mold growth, and physical changes.

Prior to the development of these tools, any attempt to go beyond a target-based analysis immediately moved outside the realm of "fact" and into the murky world of "opinion," where any interpretation of conditions seemed subjective and insubstantial compared to the weight of agreed-upon norms and long-established patterns. No wonder institutions have done comparatively little environmental monitoring, and even less analysis of data that has been gathered. They simply lacked the ability to draw meaningful conclusions from the data. When conditions departed from target values they were unable to determine the degree of risk that resulted. They had no means to evaluate the preservation impact of conditions either in relative or absolute terms.

Using Climate Notebook allows you to look at what the mechanical system is actually doing and, with some work, determine what it is capable of achieving. With an understanding of the materials in your collection, you can make realistic assessments of what effect the current environment has, and what effect changes made in the storage environment will have. Weighing all this information, in context with your climate and your building, allows you to determine the "optimal" preservation environment for your location. The optimal situation ensures that the rate of collection decay is as slow as it can be, and that the building's mechanical system is providing the best storage environment it is capable of.

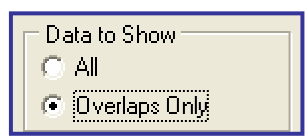
- **Step-by-Step Evaluation**

Analyze Data in Compare Notebooks View



At IPI, we have found that we do most of our work in the Compare Notebooks view (a "Compare Notebooks Tutorial" can be selected from the "How To" menu in Climate Notebook). This view allows you to sort Notebook files by specific properties, choose to view all data or look only at overlapping data. It is possible to compare one year to another, or one area to another.

The best analysis is based on the temperature and RH of a storage area over time. The most accurate TWPI is based on data from a full year since the best averages take a full seasonal range into consideration. In most locations winter is cool and dry, summer is warm and humid. Data with two summers and one winter, or vice versa, will be skewed.



For the best analysis, compare data from various locations during the same period of time. If you have data from several locations but the monitoring period varies, you can use the "Overlaps Only" feature in Compare Notebooks to work with just the overlapping periods of time. Once the data is trimmed, the program re-calculates the average temperature, RH, dewpoint, TWPI, MRF and DCI. You can also choose specific Start and End Dates and the program will re-calculate the averages for easier comparison.

The data table below illustrates environmental data from a range of sample locations. Numbers highlighted in red indicate conditions that are not appropriate for the long term storage of important collection materials. For TWPI this means conditions with too fast a rate of natural aging or chemical decay. In the Mold column, red numbers indicate that storage conditions are such that mold growth is likely to occur. Numbers in red in the DC Max column indicate areas with significant fluctuations in the environment presenting a risk of mechanical damage to sensitive materials. EMC Max and EMC Min show areas with either sustained high or low humidity at levels that can cause deformation of sensitive objects.

NAME	DESC	START	END	T	RH	DP	TWPI	MOLD	DC Max	DCI	EMC max	EMC min	EMC
Darbanville	NORTH STORAGE,	2/5/1998	7/14/1998	71	37	42	48	0	1.36	37	10.4	5.5	7.2
Ivy Hall	IVY HALL 2ND FLO(	8/2/1996	1/7/1997	71	41	45	37	0	1.05	34	9.8	6	7.9
Mould Castle	RARE BOOK ROOM	8/5/1998	1/5/1999	68	51	48	33	2.13	2.62	76	15.4	6	9.9
Omaha Whaling Mu	HARPOON ROOM	8/7/1997	1/11/1998	71	36	43	50	0	0.56	16	7.8	5.8	7.2
Tara	TARA FRONT HALL	11/21/1997	2/9/1999	70	62	57	21	0.94	0.97	15	13.7	10.2	11.3
WestStacks	WEST STACKS MAI	8/5/1997	1/13/1998	70	45	45	40	0.13	1.91	63	12.7	5.8	8.4
AVERAGE	OF ALL 6 NOTEBOO	-----	-----	70	45	47	38	0.54	1.41	40	11.6	6.6	8.6

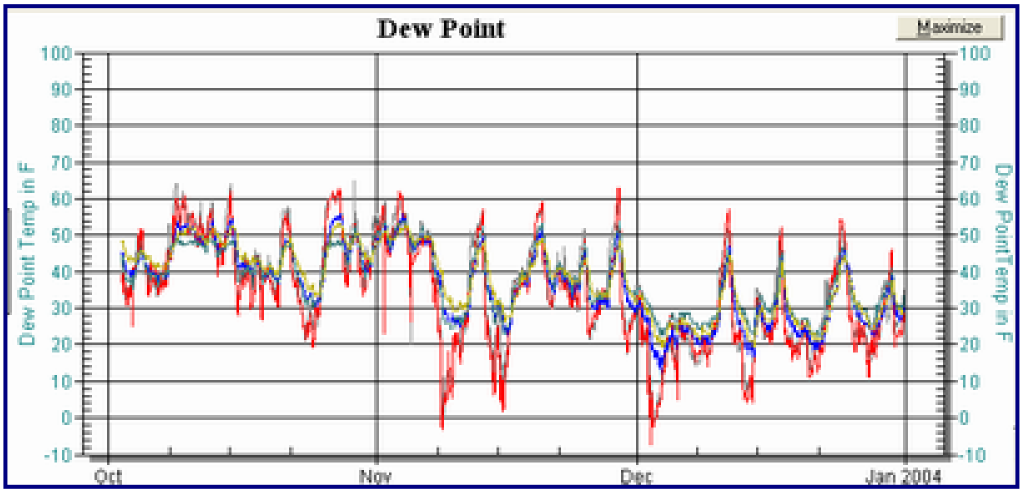
Consider the Influence of Your Local Climate, the Performance of Your Mechanical System and the Vulnerabilities of Your Collection

Overlaying graphs of indoor and outdoor conditions can help you learn a great deal about what your mechanical systems are doing. You can see which areas are heating, cooling and humidifying, and when. You can compare temperature, dewpoint, and relative humidity from several spaces at once. As you look at your data, consider what it tells you about the mechanical system:

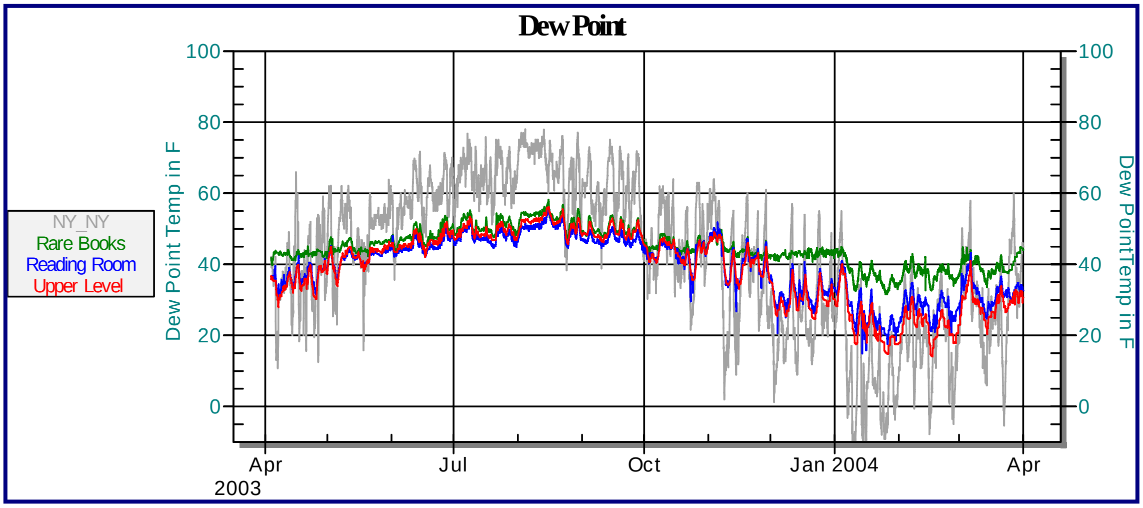
- Are you seeing temperature and RH levels that you expect to?
- If you have set points, are they being maintained?
- Is there evidence of dehumidification in summer and humidification in winter?
- Do the metrics show an acceptable storage environment, or is there room for improvement?
- Would reducing temperature, adding or removing moisture, or lowering the summertime dewpoint improve the environment?

Facilities staff should look at the long term trends. Does the data show a pattern of seasonal, weekly, or daily variations in temperature and RH? Are there anomalies in the data that indicate problems in the system? Is the system controlling the temperature and RH to the degree that it is capable of? Which spaces are performing best, which are not, and how could the performance be improved?

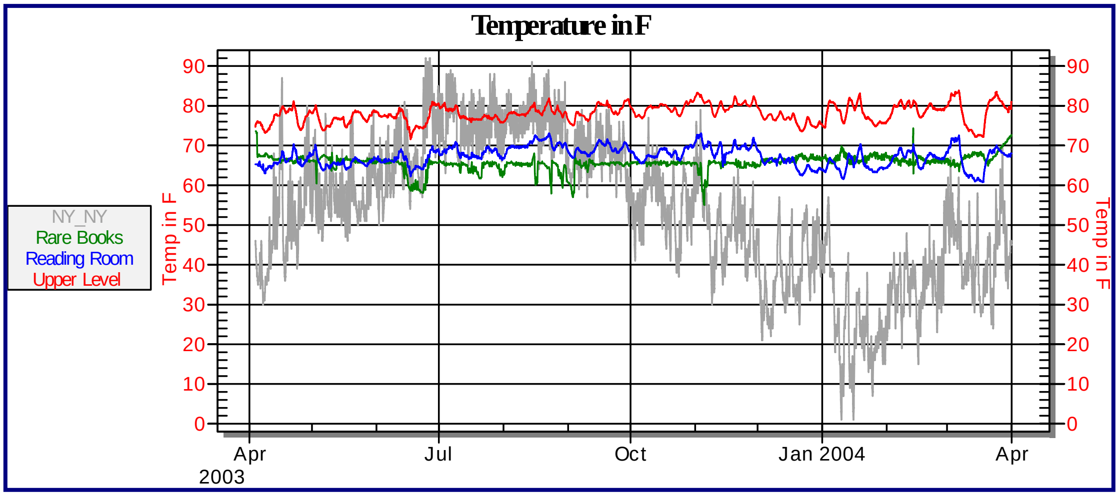
The influence of your local climate was discussed in Chapter 3 of this workbook. Comparing the inside and outside dewpoints will help you see to what degree the outside air has been modified. In the graph below, the dewpoint outside (red) and inside (green, yellow and blue) has been measured. It's quite clear that the mechanical system for the inside spaces is doing nothing to raise or lower the moisture content (i.e., the dew point) of the outside air.



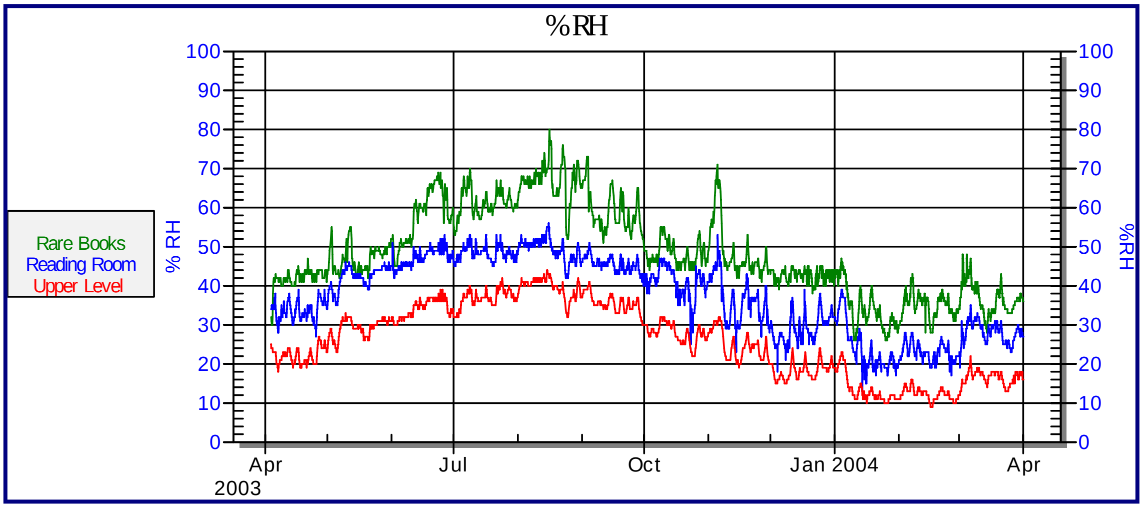
The dewpoint graph below tells a different story. In this graph, the gray trend represents the outdoor air; the red, blue, and green trends are conditions inside. The gray trend shows you that the summertime dewpoint is high in this climate, and can go quite low in January. The red, blue and green trends indicate that all three spaces are dehumidified during the summer – we know this because the dewpoint in all three spaces is lower than the outside dewpoint. In the winter, the green trend, which represents data from a Rare Book room, shows humidification while the red (Upper Level Stacks) and blue (Reading Room) do not. This indicates that the Rare Book room has a different mechanical system with better humidity control. Theoretically, this should benefit the rare book collections, but let's continue analysis by looking at temperature and RH data for these spaces to see how this space compares to the others.



The temperature graph shows us that Rare Books has the lowest temperature, and it is fairly steady. The temperature in the Upper Level Stacks is quite high, around 80°F all year. Based on what we've seen so far, Rare Books seems to be providing the best preservation environment for the collections in the space.



You'll notice that in the %RH graph below the outdoor data has been removed. The outdoor RH varies widely on a daily basis and makes the graph difficult to view. In this view, we see that the RH in the Rare Books storage is much too high -- reaching 80% in August – with fluctuations all year long.



Even though the Rare Book room has humidity control all year long, it has **the same summertime dewpoint temperature** as the Reading Room and the Upper Level Stacks. Look again at the Temperature graph and notice that all summer the Rare Book area is about 5 degrees cooler than the Reading Room and is about 15 degrees cooler than the Upper Level Stacks. **Given the same dewpoint a lower temperature results in a higher %RH.**

Since all three spaces have the same summertime dewpoint any difference in their dry bulb temperature is going to result in a difference in %RH. So it makes sense that the Upper Level Stacks, with the highest temperature, has the lowest %RH and that Rare Books, with the lowest temperature, has the highest %RH. The best preservation environment is one that is **simultaneously cool and dry, which is only possible with a low dewpoint temperature.** Next, we'll look at the data table to see the effect of the differences in Temperature and %RH on the preservation quality for each of these spaces. Which area do you think will have the best TWPI (natural aging rate)? Which has the lowest dimensional change; the lowest Mold Risk Factor?

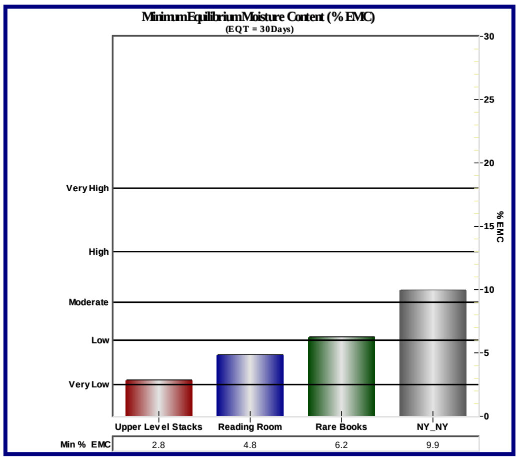
The data is sorted by descending TWPI, which is the measure we look at to judge overall preservation quality. The Upper Level Stacks, the warmest and driest area, has the worst TWPI of all three spaces, and is only slightly better than conditions outside in NYC. We find the highest TWPI in the Reading Room where conditions are moderately cool and dry all year long. Even with year-round humidity control, the Rare Books space (the coolest and most humid) is only achieving a TWPI of 53, which is not even as good as the Reading Room, and certainly not appropriate for long-term storage of important collections. Looking again at the data-table we see that the Rare Books room also has the highest level of dimensional change, an important consideration for valuable rare book library materials. We even see that the very high summertime RH in the Rare Books room is introducing a (very) slight Mold Risk, while no risk for Mold is present in the other two spaces.

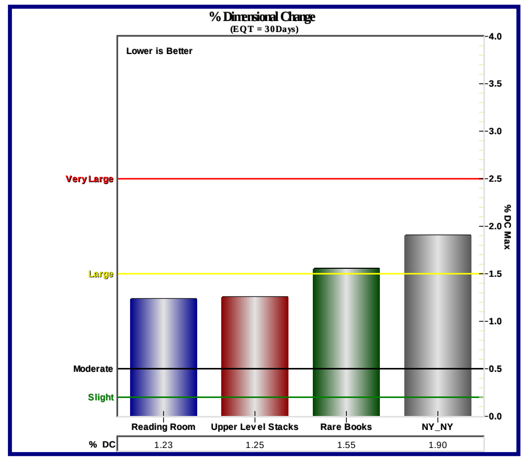
NAME	DESC	START	END	T	RH	DP	TWPI	MOLD	DC Max	DCI	EMC max	EMC min	EMC
Reading Room		4/3/2003	3/31/2004	67	37	39	61	0	1.23	38	9.2	**4.8**	7.4
Rare Books		4/3/2003	3/31/2004	66	40	41	53	0.11	**1.55**	38	11.7	6.2	7.8
Upper Level Stack:		4/3/2003	3/31/2004	78	23	35	**38**	0	1.25	41	7.3	**2.8**	**4.9**
NY_NY	NOAA WEATHER	4/3/2003	3/31/2004	54	69	43	**36**	**6.63**	**1.9**	44	**16.7**	9.9	**13.2**
AVERAGE	OF ALL 4 NOTEBOC	-----	-----	66	42	39	47	**1.69**	1.48	40	11.2	5.9	8.4

Finally we will use the **Bargraphs** option in the Compare Notebooks View which will help to visualize the magnitude of these problems. The bargraph below shows the TWPI numbers in the three spaces and the outdoors. Remember that higher numbers are better. All the storage spaces should, but do not currently achieve a "Slow Aging Rate" of 79. The collections in the Upper Level Stacks are particularly at risk for damage due to chemical decay.

Looking back at the data table, you see that the temperature in this space is much too high for collection materials (78°F). The data also shows that the %RH in this space is very low, causing a concern in terms of Minimum EMC. Using the Preservation Calculator with Dewpoint in Compare Notebooks demonstrates that simply lowering the temperature here would simultaneously improve the natural aging rate and raise the %RH, alleviating both risks.

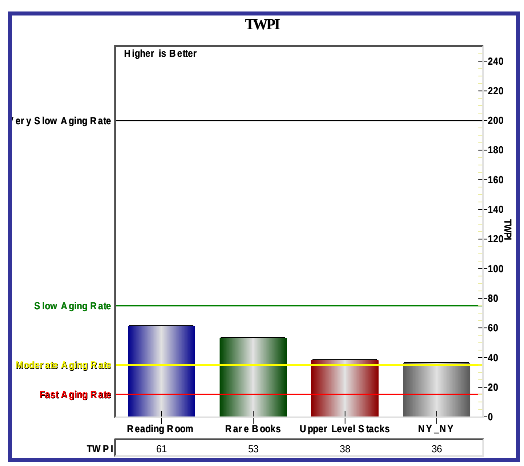
The bargraph on the left side illustrates **% Dimensional Change** with an equilibration period of 30 days, and gives a quick visual glance at where problem areas lie. This graph indicates that the environment in the Rare Books storage area is such that vulnerable materials would experience a 1.55% (or Large) change in dimension, which is undesirable.





The bargraph on the right illustrates the Minimum **Equilibrium Moisture Content (%EMC)** for these same areas. Minimum equilibrium moisture content quantifies the danger of extended periods of low RH. The bargraph makes it easy to see that all three storage locations equilibrate to Low (6% or less) moisture contents. These low moisture contents present a risk to library materials such as leather and vellum bound books, parchment, and paper. These are risks due to shrinkage, warping, embrittlement, etc. Very low %EMC also adds to the risk due to dimensional change (illustrated above).

The value and importance of the collections stored in the Rare Book room require, but do not have, an environment that maximizes **TWPI** by being both cool and dry all year, that minimizes %Dimensional Change by controlling the summer-to-winter variation in %RH, and that eliminates all risk due to biological damage (Mold Risk). Currently, the Reading Room is doing the best it can given the system capabilities. Finally, action should be taken to resolve why the Upper Level Stacks are so warm all year.



Collection Vulnerabilities

Once Climate Notebook software has analyzed the data and calculated the metrics, their interpretation requires additional information about the collection objects stored in the space. What forms of deterioration are significant for the materials present?

Compare the preservation quality metrics for various storage locations. What environmental problems are illustrated in the data from the storage areas? Remember that high TWPI numbers indicate chemical decay problems, high MRF numbers indicate a concern about mold growth, and inappropriate numbers in the Dimensional Change metrics signal a potential problem with mechanical damage.

Review the location of vulnerable and/or valuable collections within your building. Are the most susceptible to environmental damage stored in the best environment for their long term preservation? For a library or archival collection, all three metrics are important, but the most significant is the TWPI because it addresses environmental effects on the spontaneous chemical reactions that underlie the discoloration and weakening of paper. It would also be the most important metric for color photographs because dye fading is a response to temperature and moisture content in the environment.

TWPI would not be as significant as EMC and DC for oak furniture because the threat of dimensional changes from absorption and desorption of water is much more important than spontaneous chemical change.

MRF numbers are particularly important for organic collection materials, especially textiles, plant and animal specimens, ethnographic collections and the like. Although the metric in Climate Notebook is specific to mold growth, other biological decay can occur in these conditions from algae, bacteria, insects and other pests.

In all cases, it is necessary to know the general nature of the collections and their principal vulnerabilities in order to make good environmental assessments using the metrics in Climate Notebook.

It is also important to assess your own collection in terms of its “value” – meaning rarity, significance, importance to your institutional mission, etc., as well as its vulnerability to environmental damage. Obviously, rare book collections require a better storage environment than circulating library materials. Which materials in your collection are most at risk of chemical, mechanical and/or biological deterioration?

Chapter Seven ~ Questions to Answer on Your Own
Evaluate: Analyze the Preservation quality of Your Storage Environment

Select different data sets for analysis:

- Temperature Comparison Graph
    - Look for similar trends in data.
    - What mechanical system serves the spaces?

- Relative Humidity Comparison Graph
    - Note seasonal trends

- Dewpoint Comparison Graph
    - Note how the mechanical alters the dewpoint through humidification/dehumidification.
    - Note seasonal patterns.

- Data Summary
    - Sort by various metrics – TWPI, MRF, DCI
    - Sort by other factors – T, RH, Dewpoint

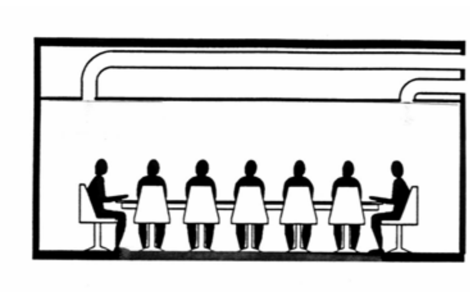
Chapter Eight Take Action to Improve the Preservation Quality of your Environment

- Create a Process for Managing the Environment

Unless your data indicates that the environment is good in every location all the time, action needs to be taken. What's the best response to a given situation? It depends. The most effective action plan has to take into account the outdoor climate, the function of mechanical system, the vulnerabilities of collection materials and the activities that take place in the storage area.

A meaningful collaboration with facilities managers, preservation managers and collections staff is the most effective way to analyze the environment and all the factors influencing it. Ideally, this effort takes place in a forum where possible actions can be explained, discussed and agreed upon. Institutional management has to support the process over the long run.

A Preservation Environment isn't something you fix, it's something you manage.



Preservation Management Team

We strongly recommend the development of a team of "stake holders" in environmental management. The Preservation Management Team structure outlined below can lead to an increased awareness of all the factors involved, and a meaningful collaboration which leads to corrective action. Climate Notebook makes it possible to develop a common foundation on which to visualize the rate of natural aging and predict certain kinds of potential damage. The software can also simulate the benefits of environmental improvements to support recommended actions.

PRESERVATION	COLLECTIONS	FACILITIES
• Understands effects of environment on collections • Can identify significant metrics • Acquires ability to measure • Monitors progress	• Identifies key participants • Informs staff of importance of climate optimization • Understands use of space & collections	• Understands history & function of bldg • Informs staff of importance of climate optimization • Helps define capability of HVAC systems

↓

Negotiate optimal climate

The cooperation of the facilities manager and engineering staff is essential. Facilities staff is often stretched thin, more focused on immediate operations than historical trends. It may take time to find someone who fully understands the mechanical system and how it works, or someone who is willing to try various “fixes” and monitor the results. In the long run, however, when optimal system function has been achieved, the work load for facilities staff should be reduced, as systems operate more efficiently. The constant reaction to complaints about temperature and response to short-term “blips” in the data will be replaced by a much more effective system of environmental management.

Preservation and collection care staff need to be open to new ways of looking at the storage environment. A broader view, taking the capabilities and limits of the building and the mechanical system into account, is necessary. Long term trends need to be understood as well as short-term fluctuations outside the prescribed set points. Staff who work around collections may need to better understand the advantage of cool temperatures to the materials they are responsible for preserving.

Our research and practice has shown that when this collaborative process is in place, lasting changes can be made that improve collection longevity and allow the institution’s leadership to document the professionalism and success of their stewardship.

- **Taking Action**

One of the most important elements of achieving a preservation environment is to maintain clear and consistent communication between all of the key players. When everyone involved is clear about the project goals, the factors to be considered, the metrics used for assessment, and the time-line to be followed, the most efficient and effective change can occur. From the beginning of the project it is vital to have everyone present for these discussions, because, ***defining the optimal environment is a cross-disciplinary process of information sharing and compromise, and not the exclusive province of preservation, collections staff, or facilities staff.***

An essential element of IPI’s approach to environmental monitoring is that monitoring should lead to action. What’s the best response to a given situation? It depends on the collection, the outdoor climate, and the mechanical systems. To take appropriate action, you must understand each of these elements. Achieving a Preservation Environment is then possible, but not at all easy or quick.

The process for managing the preservation environment includes two main components:

- Start-Up Activities, and
- Ongoing Activities

The basic requirements for these are outlined on the next page.

- **Preservation Environment Management Process**

<u>Start-Up Activities – to Achieve a Preservation Environment</u>

1) Acquire the ability to monitor the actual environment in the space.
.
  - Acquire tools: loggers, software
  - Acquire skills: software training

2) Document the capabilities of the building and it's HVAC systems.

a) Determine the best Preservation Index (PI) for all conditions throughout the annual weather cycle.
  - Systems are designed to moderate the outdoor climate
  - Define the geography served by each HVAC system
  - Define the capability of each HVAC system (to heat-cool-humidify-dehumidify-filter the air)
  - Define the seasonal capabilities (summer vs. winter dewpoint)

b) Identify any malfunctions that compromise the system's ability to deliver the best possible PI at all times.

3) Set up a Preservation Management team to accomplish the following:

a) Define what environment is best for collections stored in the space(s) served by each system.

b) Determine what the capabilities of the HVAC system are in terms of delivering the desired temperature and RH.

c) Determine the lowest temperature that collections area occupants will accept.

d) In consideration of above, negotiate the "optimal" environment for each collection area expressed in measurable metrics (annual profile of temperature, RH and PI).

d) Implement any system repairs indicated in 2(b) above.

e) Adjust system settings and control to achieve optimum performance.

Ongoing Activities – to Maintain a Preservation Environment

4) Monitor the actual environment (sustain optimal environment).

- Determine the best location for loggers and acquire data
- Analyze data

5) Compare actual to optimal

- Decide when to do a comparison of data (a full year is recommended)
  - Set a schedule
  - Identify most critical times
  - Compare key measurable metrics: Temperature, RH, Dewpoint, PI

6) Promptly correct any deviations

- Don't underestimate the importance of facilities staff participation on the team
- Consider any possible effects of long-term deviations from optimal environment

Chapter Eight ~ Questions to Answer on Your Own
Taking Action to Improve the Environment - Guidelines for Your Institution

Review the existing Preservation Management Process in your institution:

- Does the institution have a long range strategic plan?
- Is collection preservation addressed in this plan?
- Is there a written preservation plan? Is environment covered in it?
- Are administrators/trustees aware of preservation needs and committed to the protection of collections? Are they aware of the role of environment in it?
- Who supervises preservation activities? Is there a committee?
- What preservation activities are normally carried out?
- Does the institution have plans for expansion or renovation of collection storage in the foreseeable future?
- What are seen as the most serious preservation problems?
- What steps have been taken to prolong the life of collections?

    Upgrading storage materials/space/containers/cabinets
    Improving environmental conditions?
    Ongoing conservation treatment?
    Reformatting?

- Identify key personnel in management, facilities, preservation, and collection management who have a role in determining the storage environment.
- Identify priorities for achieving or improving the preservation environment for collections in your institution.

Chapter Nine Keeping the Data Organized

As the organizations we've worked with have expanded their monitoring, gathering data from over 100 locations in some cases, the need for several levels of data management has emerged. As the number of logger locations increases, and the years of data pile up, it becomes more and more important to remember how you have named and organized your Notebook Files. You can save a great deal of time later on if you plan for the organization and retrieval of your data files early on in the process.

- **File Organization and Management**

The most common importing problems occur when we lose track of where data files are located on our computer. As noted above, you will save yourself a lot of time if you plan the data file locations and names in advance. Remember that you have to open a Notebook File (it has an **.nbk** extension) that you created before you can import the data from the logger into it.

- Establish a file structure that you can remember and will use consistently.
- Use meaningful file names. This will make it easier to find things quickly.
- Do not use any form of punctuation or special characters in your file names except for the _ underscore.

NOTE: Do not rename notebook files using Windows Explore. The only way to change the name of a notebook is within Climate Notebook. Go to Utilities > Rename a Notebook. Renaming notebooks in any other way will make the files inaccessible through CNB.

Organizing Notebook Folders and Files

🗀 **My Documents Folder** ⇨
    🗀 **<u>My Notebooks Folder</u>** ⇨
        🗀 **Individual Folders by Logger Location** ⇩
            🗀**Library**
            🗀**Prints and Posters**
            🗀**Textile Vault**
            To hold <u>Notebook Files</u> of logger data ⇩
                🗎 **Room 15 Stack 12 SW**

🗀 Notebook Folder
When you make a new Notebook, your first step will be to choose the location for your folders and files. Climate Notebook automatically creates a folder called "My Notebooks" inside your "My Documents" folder and suggests that you designate it as your default Notebook Folder.

If you would rather store your Notebook files somewhere else, the "Set Default Notebook Folder" button on the Settings page lets you designate a new default Notebook Folder. Newly created notebook files will be placed in the designated default Notebook Folder.

🗎 Notebook Files
Your next step is to name the Notebook File and describe the monitoring location. Individual Notebook Files hold all your temperature and humidity data from a particular storage or display area. One Notebook File will need to be created for every location you will have readings from. Generally, each Notebook File will be named after the physical location where the data is being gathered. Since you need to create the Notebook File before you put data into it, think through the following in advance.

- ***New Notebook File Name***. This name, in a brief format, will identify the file by the monitoring point location and should be unique and easily identifiable. “Room 15” may not work as well in the long run as “Room 15 Deck 12 SW”.
- ***Location Description.*** This slightly longer identifier will appear as the title on all your graphs and reports.
- ***Logger Name.*** Most loggers will have a unique identifier, such as a serial number, which you can enter here.
- ***Target Temperature and Relative Humidity***. These settings and their tolerances (acceptable points above and below the target) are entered for each new Notebook File, and should reflect the ideal conditions for the room.
- ***Select Collection Materials*** allows you to create a list of collections – both broadly for a range of collections, or more specifically by material – found in the monitored location.

Combining Notebooks
A new feature in CNB version 3 allows you to merge data from two or more Notebook Files into a single Notebook File. This is useful when you have multiple notebooks for the same location and would like to combine them into one. For example, some users create a new notebook for the same location every month; with Combine Notebooks they can merge all of these notebooks together, covering the range of dates. This is also a useful function for combining notebooks of outdoor weather data[8]. If you want to see the weather from October 2003 through April 2004 you will need to combine the 2003 and 2004 data.

> ***Note: The Combine Notebooks function merges ALL of the data from one notebook into the other.*** If the data overlaps at all there will be duplication of data

[8] Outdoor weather data from www.climatenotebook.org/stationdata can be downloaded for each year.

(double the data points). You can avoid this by removing the period of overlap from one of the notebooks with the Remove Data function before merging.

Saving File Lists
When you have a group of Notebooks together that you will want to refer to again later you can click on "Save File List". Take note of what you name this file list.

Loading File Lists
Once you have saved a File List of Notebooks you can access this list by choosing "Load File List" in the Compare Notebooks View. Just double click on the list you want to load.

- **Location Profile**

As we are all aware, a wide range of factors influence the collections in a given environment. We understand that institutions need to track a range of information related to the monitoring location. People tend to keep several lists to remind themselves of the room location, collections involved, history of monitoring and so on. Based on this experience, we are developing a ***Location Profile*** for Climate Notebook that will allow users to organize various fields of information associated with the monitoring location. There are four primary categories of information:

- **Location Information**
  - Building, floor, room, and shelf identifiers associated with the logger location. You could include fields for the function of the space (storage, study, office, etc.), the size of the room, the date of construction, or the type of storage furniture used.
- **Monitor Information**
  - ID # for the monitor and the Notebook name, dates for initial monitor placement, download dates.
- **Collection Information**
  - Name of the department or division responsible for the collection, the collection type, and the primary materials stored in the space.
- **Mechanical System Information**
  - Information about the heating, cooling, ventilating, and humidification available in the space. Air handlers, chilled water temperatures and other details could be tracked.

This module will be very useful during analysis when a large number of buildings and mechanical systems are involved. It will allow you to compare a group of locations that are served by the same air handler, that house a certain type of collection material, that are the responsibility of a particular department, and so on.