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CHAPTER 6:
Analyze Collected Data

In Chapter 3 we discussed the collection of temperature and humidity data and pointed out that gathering data is just a means to an end. The goal is to get meaning from the data through analysis. Accurate data and reliable analysis can provide the basis for many collection management and all environmental management activities. The ability to achieve an optimal and sustainable environment for preservation depends heavily on your ability to draw meaning from collected data.

6A Use Environmental Data to Manage the Environment for Preservation

What do you want the collected temperature and humidity data to tell you? How much information can a hygrothermograph give you about the preservation quality of the location being monitored? Short-term graphs may be useful if you work with temperature and relative humidity targets—either you are in or you are out—but can you determine the significance over time of the short term deviations you see on the charts? Can you determine how the environment will affect the collections stored in the space? We now know, based on decades of research by preservation scientists, that the previously accepted norm—that temperatures should be steady at a human comfort level and short-term fluctuations in relative humidity matter more than long-term trends—is outmoded and counterproductive. Setting targets for an ideal environment and reacting to daily or weekly excursions is the wrong approach.

A better approach is to analyze collected data and use the analysis to:

- Identify decay risks – chemical, mechanical, biological
- Compare the preservation quality of one space to another
- Determine which space is best suited to the long term preservation of various materials
- Review the preservation quality of a particular location from one year to the next
- Document the capabilities of your HVAC system and identify any malfunctions
- Identify and document the need for HVAC system improvements
- Evaluate the effect of changes in HVAC operation and their effect on collection preservation and/or energy-saving approaches

A raw data table, which lists the frequent readings of temperature and RH taken by a datalogger or by the Building Management System, can be useful. However, the amount of data can be staggering and analysis of the data table cannot provide quick and reliable answers to the questions we have about the environment.

If you are relying on data from your Building Management System, remember that the control system requires set targets and tolerances for T & RH that are programmed in. These targets then form the basis for analysis of collected data and limit analysis to determining whether or not and how often the environment stayed within prescribed limits.

Data graphs add some dimension to the data and provide better visualization of change over time. If your software program allows, graphs can be used to compare spaces and view change over time. If you overlay outdoor data and dew point graphs you can learn a lot about the capabilities and functions of your mechanical system. Most electronic datalogger software will provide graphs and statistics.

For effective environmental management, you need to analyze the effects of environmental conditions on collections, which is more complex than understanding time in and out of an "ideal" environment. To meet this need, the best approach is computational analysis. In this approach, calculations are performed on the raw T & RH data in order to estimate the preservation risks or benefits to collections. One advantage of computer analysis is standardization, which removes the subjective aspect of data interpretation. Another is the ability to produce quantitative measurements of the effect of actual environmental conditions on the rate of material decay and the preservation of collections.

6B Use IPI's Preservation Metrics™ to Analyze the Risk of Material Decay

In study after study, IPI observed that heat and humidity were the primary drivers of most forms of decay. Although the importance of temperature and relative humidity had been well documented in the research community, there were few resources available to help preservation staff understand the impact of real-life environments on collections. Recognizing the need for a way to transform data into tools that are applicable to the management the environment for preservation, IPI developed Preservation Metrics™.

Preservation Metrics™ transform temperature and relative humidity data into quantitative numerical measures of collection decay risk. IPI developed metrics for chemical change in organic objects, dimensional change or mechanical damage, the potential for biological decay or mold risk, and moisture-induced corrosion. Each metric evaluates the quality of environments over a period of time into a single value representing the degree of risk for a particular form of material decay, taking into account all the ups and downs of T and RH during the monitoring period. To use the metrics effectively, you simply need to understand what forms of decay they address and what the numeric values tell you about the preservation quality of the space.

IPI's Preservation Metrics™ were developed to provide quick, automated analysis of environmentally-induced decay. They allow you to accurately and objectively determine how well each storage area is performing for collection preservation, how well one environment is performing compared to another, and how various collection materials are faring in a particular location. Metrics can flag potential problems and document the impact of changes or adjustments made to improve conditions. Analysis based on metrics can be used to argue for funding or other resources needed to make improvements in storage conditions.

Natural Aging – Assess the Risk of Chemical Decay

PRESERVATION INDEX (PI) AND TIME-WEIGHTED PRESERVATION INDEX (TWPI)

- Vulnerable collections include all organic materials such as paper, wood, textiles, plastics, leather, dyes, etc. Fast decaying organic materials include acidic paper, color photographs, and cellulosic plastics

Environments influence the rate of natural aging (spontaneous chemical reactions within organic materials and with air and moisture) by providing heat energy and moisture, which is a reactant in many decay reactions. Therefore temperature (T) and relative humidity (RH) are key determinants of the rate of this kind of deterioration. Every combination of T & RH is associated with an overall rate of chemical decay. IPI developed a table which assigned values (Preservation Index or PI) to every such combination of T & RH. The higher the PI value, the longer it will take for a given amount of decay to occur.

If environments stayed at the same T & RH all the time, PI would be all you need to know to describe the environment's effect on chemical decay. But environments vary, so you need a way to integrate ups and downs over time. During warmer and moister periods, collections deteriorate faster. During cooler and drier periods, they deteriorate slower. To account for this, when you consider how PI values 'average' out over time, you have to properly 'weight' each unit of time in the overall calculation of decay rate. That is why the most useful metric for chemical decay is the Time-Weighted Preservation Index (TWPI). It's best used when looking at a full calendar year of data because it properly weights a cool winter with a warm summer. This is why review and analysis of a full year of data, covering all seasons of the year, is most reliable.

TWPI applies to all organic materials and is the most significant preservation metric for book and document collections. TWPI values are very useful in determining which spaces are best for storing vulnerable organic materials. TWPI is best interpreted not as a prediction of lifetime but in a relative fashion. For example, if room A has a TWPI of 50 and room B has a TWPI of 100, it means that the reactions of decay are happening twice as fast in room A than room B. Interpreting the TWPI metric is simple – higher numbers are always better.

TWPI > 75	**GOOD – slow rate of chemical decay in organic materials**
TWPI 45 – 75	**OK – generally OK but fast decaying organic materials will be at elevated risk**
TWPI < 45	**RISK – accelerated rate of chemical decay in organic materials especially for fast decaying organic materials**

Mechanical Damage – Assess the Risk of Dimensional Change

EQUILIBRIUM MOISTURE CONTENT (%EMC) AND DIMENSIONAL CHANGE (%DC)

- Vulnerable collections include composite objects such as rare books, paintings, furniture, musical instruments, tools, etc. Sensitive or fast responding hygroscopic material can include paintings, rare books, vellum manuscripts, inlaid wood, or musical instruments

Wood, paper, textiles and many other hygroscopic (water-absorbing) materials change size and shape depending on how much water they contain. These are physical or mechanical behaviors (in the sense of not involving any chemical change to the material) that can harm collection objects. These reactions are dependent mainly on the profile of RH over time. The preservation risks to hygroscopic materials are most acute during periods of extreme dryness or dampness, and when large excursions between these extremes occur.

IPI modeled the metrics for the physical/mechanical risks to collections posed by environmental conditions on the behavior of an imaginary block of wood. The critical things to know are: How dry did it get, how damp did it get, and how large was the difference between those extremes? To answer the first two questions, IPI uses an estimate of the moisture content of wood derived from the actual observed T & RH data in the environment. This estimate of the moisture content of wood is expressed as Percent Equilibrium Moisture Content (%EMC). It is the percent by weight of water contained in the wood. If the wood were weighed, then dried by heating and weighed again, the difference in weight would be the water content.

To answer the question regarding magnitude of excursions from dry to damp, IPI estimates how much change in size (expressed as a percentage of original size) that the difference in moisture content represents. There are actually three separate metrics that matter in estimating physical risks to collections: How dry did it get is represented by the minimum %EMC observed in the data, how damp did it get is represented by the maximum %EMC, and the difference in size (based on how the water content of wood affects its expansion and contraction) is called Percent Dimensional Change (%DC). Interpreting the mechanical damage metrics may seem complicated at first, but remember what each metric represents and it becomes easier – you want an environment that is not too dry or too damp, with limited fluctuation between the two.

Min EMC ≥ 5% AND Max EMC ≤ 12.5% AND %DC ≤ 0.5%	**GOOD – minimal risk of physical damage; not too dry or too damp, and almost no fluctuation between the two**
Min EMC ≥ 5% AND Max EMC ≤ 12.5% AND 0.5% < %DC ≤ 1.5%	**OK – not too dry or too damp and minimal fluctuation between the two, however sensitive material may be at higher risk**
Min EMC < 5% OR Max EMC > 12.5% OR %DC > 1.5%	**RISK – heightened risk of physical damage; either too dry, too damp, or too much fluctuation between the two**

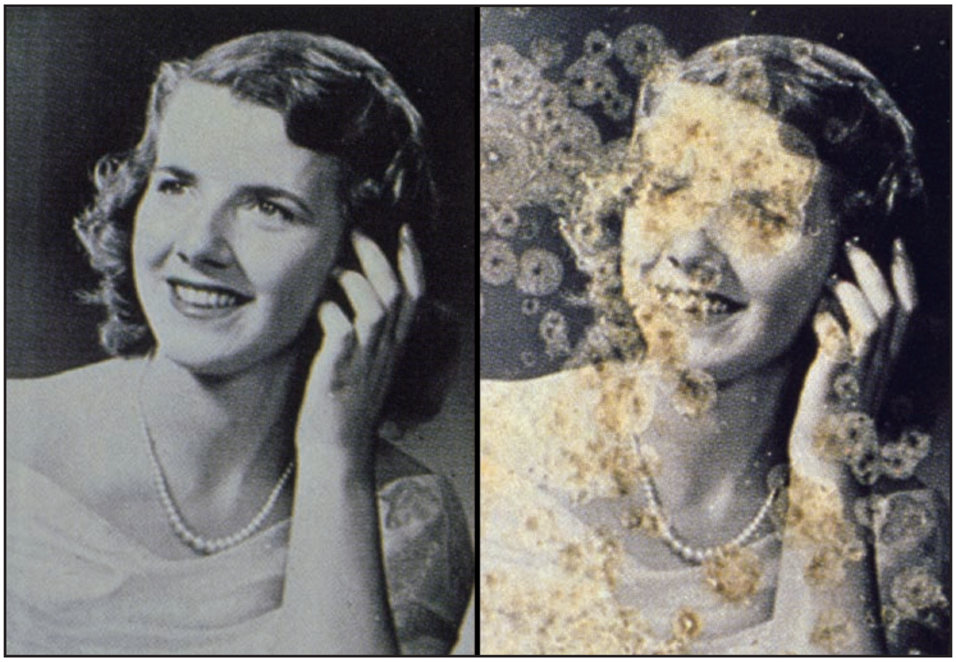
Mold Risk – Assess the Risk of Biological Decay

MOLD RISK FACTOR (MRF)

- Vulnerable collections – all organic materials including paper, wood, textiles, leather, etc., and inorganic materials with organic films.

To develop the metric for biological decay, data was analyzed to determine if environmental conditions promote biological decay, including the growth of xerophilic mold and mildew and the risk of insect infestation. IPI's analysis was based on empirical studies with food grains. The algorithm that creates the MRF value integrates over time, creating a running sum of progress toward mold germination. The MRF number represents the risk of mold germination and subsequent growth. 0.5 indicates that mold spores are half way to germination. Look for an MRF of 0.5 or less for an environment with little or no risk of biological decay. There is no OK rating for mold growth – either there is the potential for mold germination (RISK) or there isn't (GOOD). Alerting users of the potential for RISK allows time to react and take preventative action before any visible or vegetative mold appears.

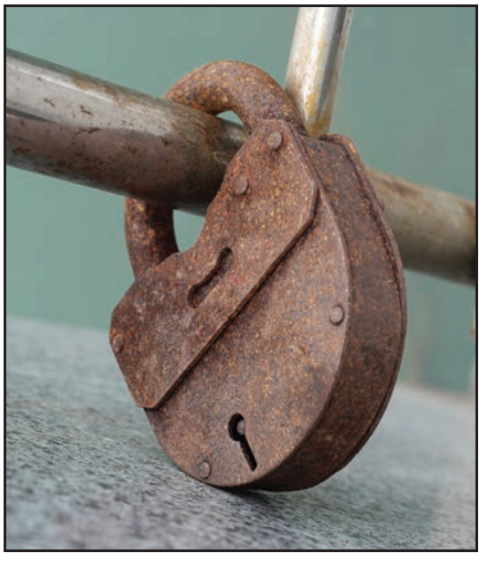
MRF ≤ 0.5	**GOOD – little or no risk of mold growth**
MRF > 0.5	**RISK – environment with mold spores have germinated, entering a vegetative mold state and visible mold could be actively growing**



Metal Corrosion – Assess the Risk of Metal Corrosion

MAXIMUM EQUILIBRIUM MOISTURE CONTENT (MAX %EMC)

- Vulnerable collections include metal objects and objects with metal components (including some images, textiles, inks for example). Highly sensitive materials include archaeological or salt-encrusted metals.



The metal corrosion metric represents the degree environmental conditions promote moisture-induced corrosion in vulnerable metal objects. As with mechanical damage, analysis of T & RH data is based on a moving average of relative humidity levels. The algorithm incorporates two levels of severity based on adjusted RH. The metric used to indicate the risk of metal corrosion is Max EMC (excessive dampness). The metric numbers indicate the maximum level of moisture content in the environment.

Max EMC ≤ 7.0	**GOOD – minimal risk of corrosion due to excessive dampness**
7.1 ≤ Max EMC ≤ 10.5	**OK – limited risk of excessive dampness; however sensitive material may be at higher risk**
Max EMC > 10.5	**RISK – risk of corrosion due to extended periods of dampness**

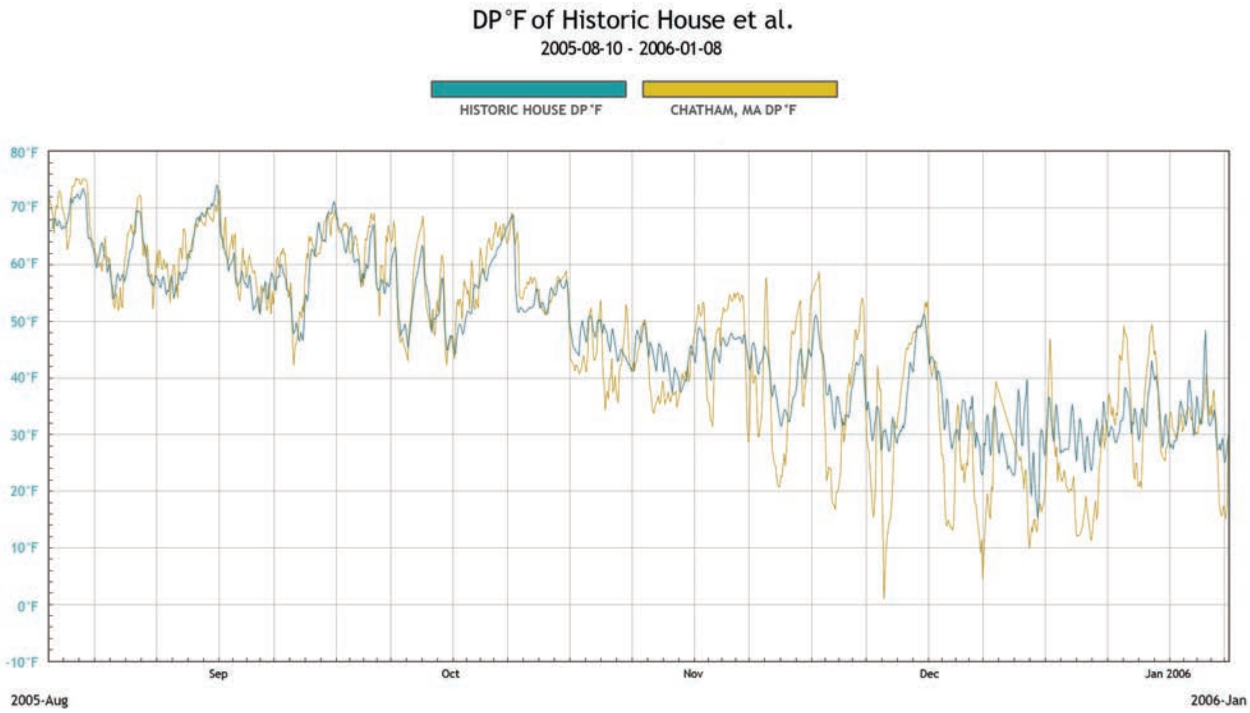
IPI's Preservation Metrics™ are based on decades of research. IPI has written about them in various publications and proven their usefulness and accuracy during field trials in many different institutions. Preservation Metrics™ are only available in the software and websites created by IPI.

6C Data Analysis and Mechanical System Performance

There are useful techniques in data analysis that can help you better understand the performance of your mechanical systems. A few of them are illustrated and explained below.

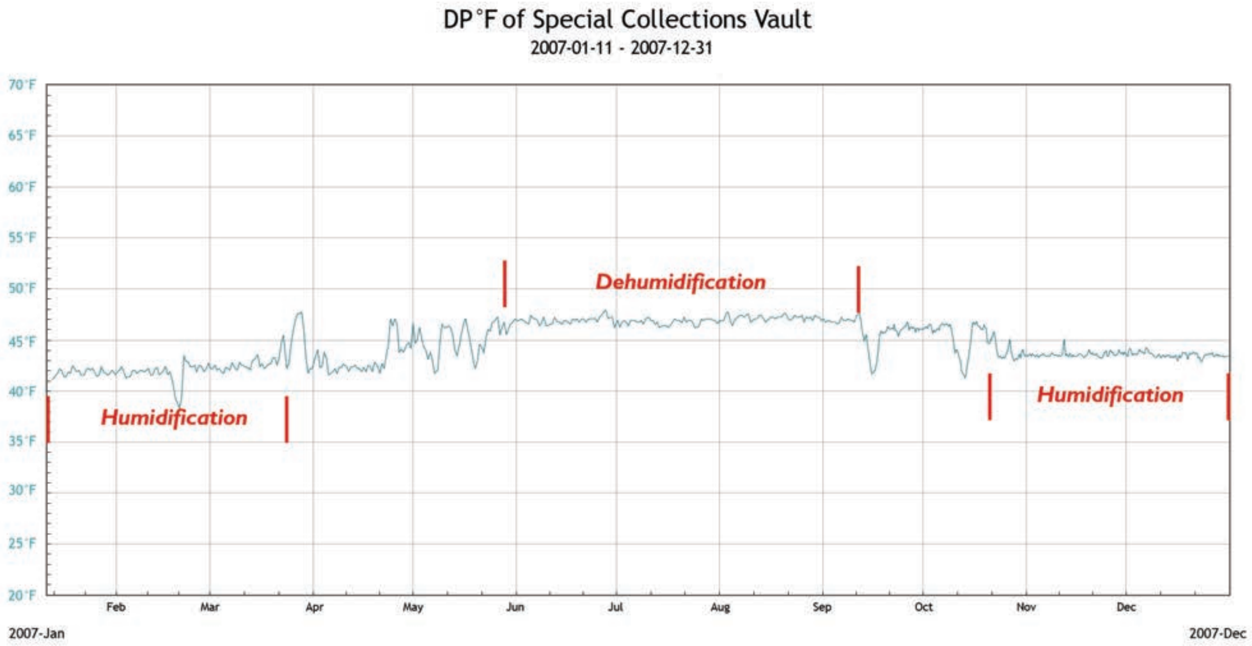
Identify Periods of Humidification and Dehumidification

You can determine whether humidifiers are in use by overlaying a full year of indoor and outdoor dew point data on one graph. The graph below shows a location with no humidification or dehumidification. When no humidification is taking place, the indoor and outdoor curves will lie on top of each other, as they do in the first few months show in the graph below (the fall season). During the winter season, the indoor dew point (in teal) follows the same pattern as the outdoor (in yellow) but doesn't quite reach the same extremes. It's normal for indoor dew points to remain a little higher than outdoor, even on cold days, because some moisture is released by water-absorbing elements of buildings and collections.



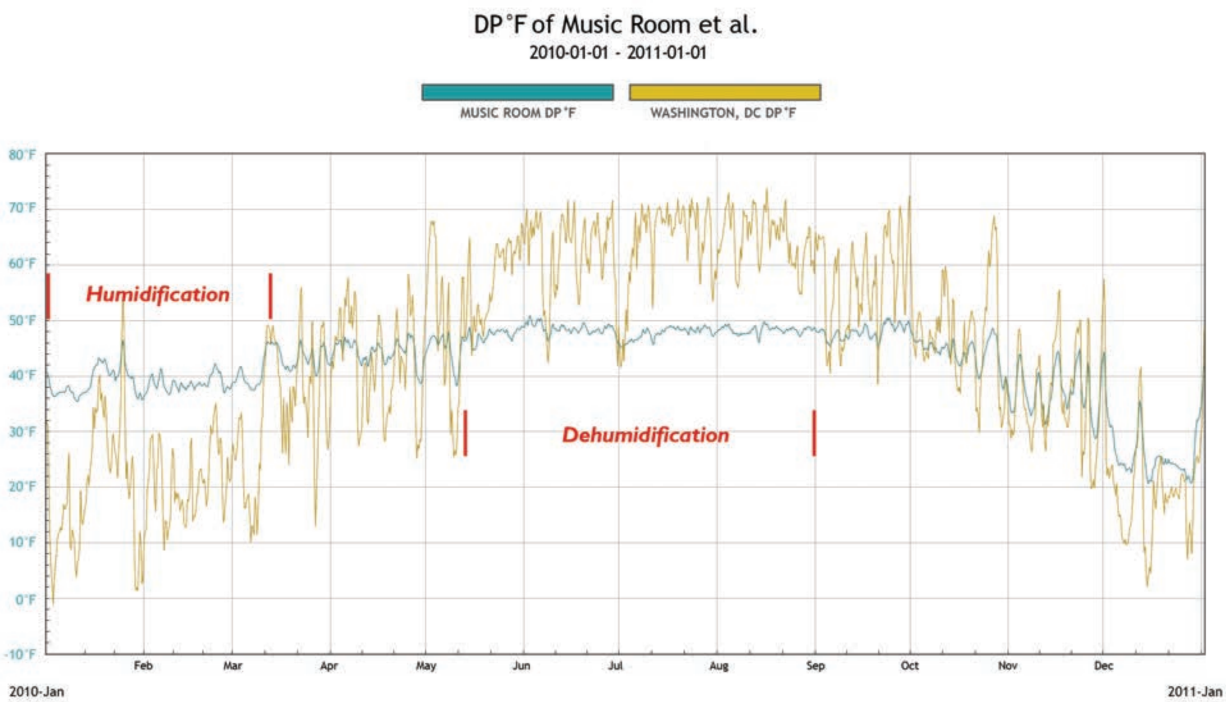
Indoor and Outdoor Dew Point – No Humidification or Dehumidification

If a humidifier is in use, the indoor dew point graph will have a "floor" (a level below which the dew point temperature will not go). The next graph of storage location data illustrates that humidification ran from January 2007 to April 2007, and again from late October through December, keeping the dew point temperature above 40°F. You can also see periods of dehumidification when the dew point is kept under 45°F from early June to early September.



Indoor Dew Point – Location with Humidification and Dehumidification

The graph below shows a full year of indoor and outdoor dew point data for a space in Washington, DC. Note that although the indoor (teal) and outdoor (yellow) lines differ, the major outdoor ups and downs in dew point temperature do have some influence on indoor conditions.



Full Year of Indoor and Outdoor Dew Point

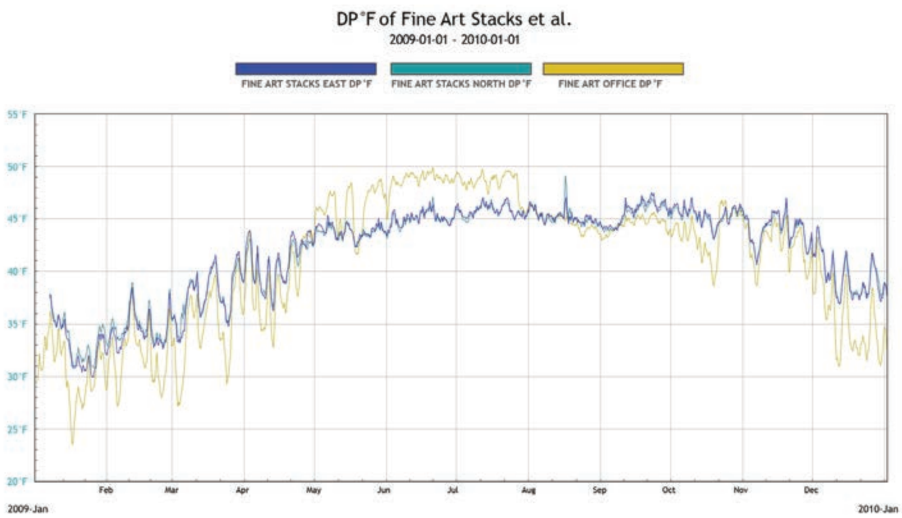
During the winter months of January through late March, the outdoor dew points are fairly low, much too low to provide an appropriate RH when the air is heated to room temperature. The indoor dew points are higher, moving around a bit but mainly staying in the range of 30-40°F. This indicates that the mechanical system serving this space is humidifying the air.

In the summer months (May through September in this location) outdoor dew points are consistently higher than indoors, indicating that dehumidification is taking place. The blue line shows that indoor dew points average near the high 40°s and are relatively well controlled within a narrow range. When the indoor summer dew point line is fairly flat, that is evidence that the mechanical system is asserting control and regulating the indoor dew point. From the preservation point of view, this is good news, because in many cases properly managing the indoor summer dew point is the key to reducing the rate of natural aging. For preservation, cooler and drier is better, and a low summer dew point allows you to have both cool temperatures and moderately low RH's, which will improve the TWPI—and thereby reduce the rate of chemical decay. Finally, the DP graph from late October through December shows a lack of humidification, as the indoor dew point drifts downward.

There are periods during the 'transition' months (March through May, and October and November) when the indoor and outdoor dew point lines lie on top of each other, and near the desired range of 35-45°F. During these times, no humidification or dehumidification is apparently going on, nor is any necessary—but just in case it might be, this would be a good time to check that energy is not being wasted by the systems acting like they do during the summer, sub-cooling and re-heating air to remove moisture that isn't really there in the first place. Such unnecessary work done on outside air can add up to very significant energy costs.

Determine Which System Serves the Space

Analysis of dew point graphs from different locations during the same time period can help to clarify which mechanical systems affect a particular location. Although they may share the same source of outside air, two AHU's usually do not do exactly the same amount of humidification or dehumidification. This means that their plots of dew point temperature over the course of time will not be exactly the same. Often this fact can help separate which space is served by which AHU. Consider the following graph of three locations in the same building served by two different systems:

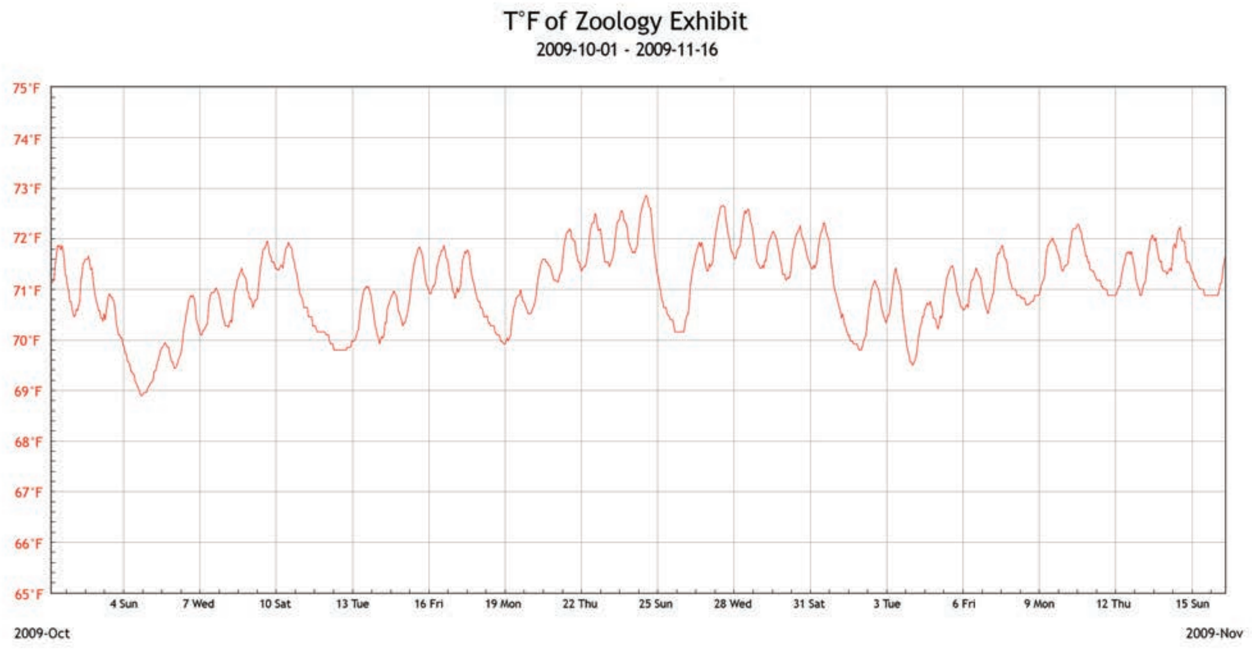


You'll notice that the yellow line has an entirely different shape than the blue and teal lines, which are almost identical. This indicates that the space represented by the yellow curve has either a different AHU serving it, or else shares the same AHU but has additional equipment that modifies the air before reaching the space.

Identify Night Time Setbacks and Lighting Schedules

The next graph shows temperature from one storage location over several weeks. Notice that the days of the week are indicated at the bottom of the graph – each vertical mark indicates one 24-hour period. The saw tooth pattern seen in this graph is typical in spaces where temperature settings are lowered or AHUs are shut down during evening or unoccupied hours, then raised again, or where lights go off at night and on again in the morning.

Remember to keep the temperature range on the Y axis of the graph in mind when you see this—the swings illustrated in this graph actually fall within a 4 degree range. Magnifying the graph makes the changes seem disproportionate but helps illustrate the daily fluctuations.



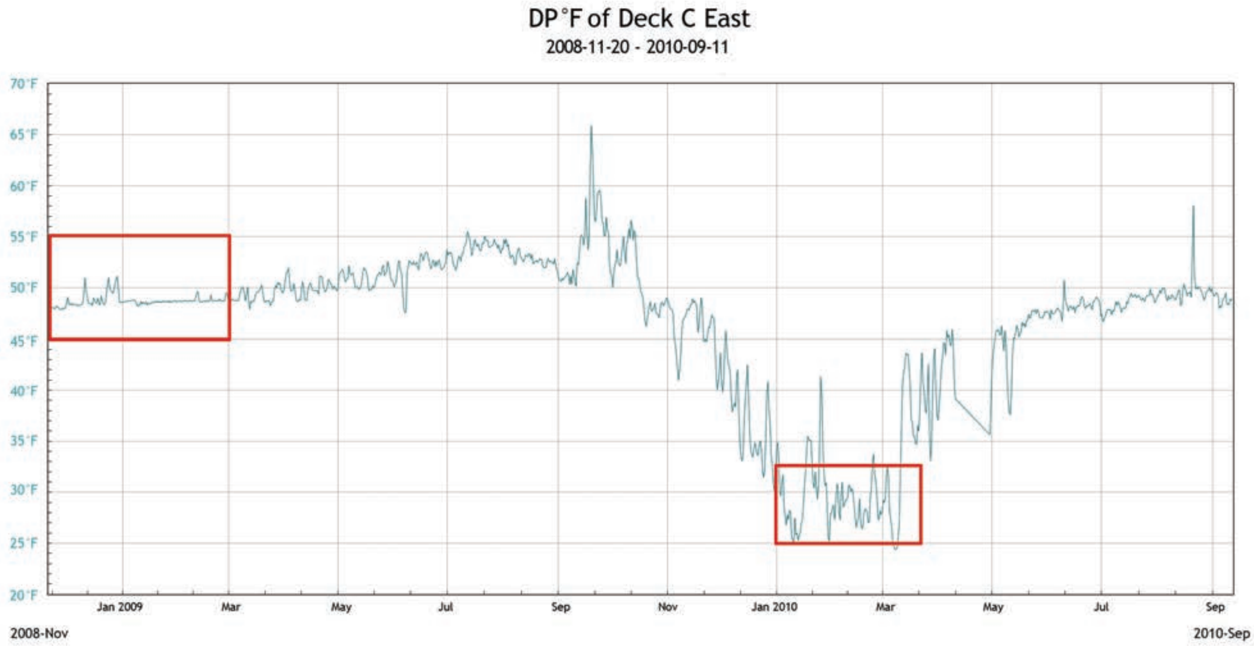
Temperature Readings over Several Weeks in One Location

Track Changes in Humidification and Dehumidification

Analysis of dew point graphs from storage locations can determine whether or not your mechanical system is providing adequate humidification during the winter heating season, or dehumidification during the summer. You can identify which spaces are humidified or dehumidified, when the system kicks in, and if system settings have changed over time.

The following graph shows the dew point temperature in one space over several months—including two winter heating seasons. During the first winter (December 2008 through March 2009) the dew point temperature is maintained around 48°- 49°F. Compare this data to that gathered during the same period in the following year. Clearly no humidification is in place in 2010 since the dew point temperature dropped to 35°F or less in December and even lower over the next few months.

This graph illustrates why it is best to gather and analyze environmental data over a long period of time. Mechanical systems break down, settings are changed, other incidents occur and without accurate data you can't identify or address issues that affect preservation. It also illustrates the need to create an Environmental Management Team to analyze data, identify sub-optimal conditions, and institute operational changes.



Changes in Dew Point in One Location through Two Winter Seasons