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Providing Safe and Practical Environments for Cultural Properties in Historic Buildings… and Beyond

All Nancy Davis really had to do to convince me to present at this conference was read the title: **Beyond the Numbers: Specifying and Achieving an Efficient Preservation Environment.** Although I did not know it at the time, from the day I started as a newly trained conservator at Shelburne Museum in 1982, I stepped onto the path of creating and maintaining efficient preservations environments. If I was to have any success in preserving over 150,000 artifacts exhibited and stored in 29 buildings spread over 40 acres, I would have to do it efficiently, and I would probably have to go "Beyond the Numbers," at least the numbers that conservators were looking to at that time.

Twenty four years ago, when conservators were asked to provide advice on what kind of temperature and humidity numbers were best for the preservation of collections, they would most likely say 68 degrees ± 2 degrees, and 50% relative humidity, ± 2 %. That is generally a correct answer, but as I became more familiar with Shelburne's varied collections and the buildings that housed them, I began to realize that such restrictive standards were not only unreasonable for buildings that included a covered bridge and several barns, but probably unnecessary for the preservation of most of our artifacts. As I toured the various buildings and exhibitions that looked more like open storage than designed exhibits, I found that most of the artifacts were in relatively good condition, even though they were 70-100 years old and had never seen museum environmental control in their lives. The artifacts in poor condition had been damaged by extreme conditions in attics that were too hot, basements that were too wet, or in dry buildings that were heated during the winter and had no humidifiers.

I decided that even though we may not be able to achieve "ideal" museum environments, we could <u>significantly improve</u> conditions by reducing humidity extremes surrounding our artifacts. By keeping relative humidity below 65% in the summer, we could avoid mold growth and prevent significant swelling of organic materials. By keeping humidity above 35% in the winter, we could avoid drying out our collections. Research indicated that our Canadian friends just two hours north of Shelburne had been following these wider RH standards for at least a decade, and in the early 1990's, researchers at the Conservation Analytical Lab would determine that these broader standards were safe for the large majority of historic artifacts. In addition, our artifacts had been "proofed" by high and low humidity extremes for many years. The worst damage had already been done. By narrowing the range of humidity they would experience in the future, we would insure that no new damage would occur even if the new conditions were not ideal.

Adopting broader humidity standards opened up additional possibilities for practical environmental control methods that fell well short of complete control, while still improving environmental conditions and eliminating humidity extremes that cause most artifact damage. Of course, whatever environmental improvements we devised would have to be "efficient" and affordable. Even if we could afford to purchase and install the equipment to create more ideal climates, we probably could not afford to operate and maintain such equipment for 20 years and beyond. Today we call this sustainability.

One big question still remained. What kind of environments could our various buildings support? We certainly did not want to create environments to preserve our artifacts only to destroy the buildings that house them. Only four collections buildings had been built as galleries, and even they had little insulation and no vapor barriers. We knew that humidity introduced into such buildings in winter could result in serious building degradation. Fortunately, Ernie Conrad had just established his firm to specialize in improving museum environments and he was challenged by the question of what type of environmental improvements various building structures could safely support. During a survey of Shelburne's building, he devised a building classification structure that is now cited in the HVAC engineer's "bible," the ASHREA Handbook, Chapter 20, that addresses museum environments.

Class 1 buildings are open structures such as covered bridges or open sheds. These structures have little potential for improvements although they sometimes protect important artifacts from the harsh elements.

Class 2 buildings are sheathed post and beam structures such as barns. The only reasonable climate improvement for such buildings is ventilation to reduce heat and moisture accumulation

Class 3 buildings are wood structures with framed and sided walls with single glazed windows, or uninsulated masonry structures, essentially your basic historic house. In these structures, one can use low level heating to reduce high humidity levels, and employ summer exhaust ventilation.

Class 4 buildings are tightly constructed wooden structures with composite plastered walls and storm windows, or heavy masonry structures, typical of high quality historic houses. These buildings can support low level heating and humidification in the winter and cooling and reheating for dehumidification in the summer.

Class 5 buildings are new structures with insulated walls with vapor barriers and double glazed windows, These buildings can support complete HVAC systems with winter comfort heating and humidification, and cooling and reheating for dehumidification in the summer.

Class 6 structures are rooms-within-a-room, double wall construction with insulated and sealed walls, such as storage vaults specially built to support precision controlled heating, cooling, and humidity control systems.

Armed with the knowledge of what our collections could withstand, and what our buildings could safely support, we were ready to design practical systems to improve collection environments. In 1992, Shelburne Museum received a grant from the National Endowment for the Humanities, Division of Preservation and Access, to support a $1.4 million project to design and install practical climate control systems in 27 of our collections buildings.

It would be foolish to design and install mechanical systems to reduce moisture in a building or filter out dust without first taking steps to reduce moisture and dust at the source. So our first actions included installing rain gutters on buildings and storm drain systems to move water away from buildings, applying calcium chloride to dirt roads to reduce dust, and tightening up buildings by insulating walls, weather-stripping doors, and installing interior storm windows.

Conservation Ventilation

We installed conservation ventilation in nine of our Class 2 barn-like structures. I had noted that during the summer, heat and humidity built up inside many of our historic structures, especially on the second floors. Our consulting engineer calculated that to effectively remove this hot, humid air would require about 7 air changes an hour. However, simply installing and operating an attic fan would solve one problem but create another, introducing seven times as much dust into the collections areas. We solved this problem by not only exhausting air through the attic, but by also using fans to push air into the first floor or basement of the building through filters that trap the dust. In addition, the fans forcing air into the building are sized slightly larger than the exhaust fans so that the entire building is under a slight overpressure, thereby discouraging dust from entering when visitors enter the buildings. The fans are controlled by a humidistat rather than a thermostat. When it is more humid inside than outside, the fans are activated and the hot moist air is replaced by cooler drier air. A study conducted by the Getty Conservation Institute concluded that Conservation Ventilation lowers building humidity levels by about 10%. In addition, moving the air prevents mold growth even when the humidity is above 70%.

Conservation Heating

To reduce humidity in our Class 3 historic house structures we use both conservation ventilation and conservation heating. Conservation Heating is the practice of controlling the humidity in a building by adding or withholding heat. It is possible to dry out a cool, damp building simply by increasing the heat. Conversely, withholding heat and allowing a building to cool during cold weather will keep the humidity high enough to be safe even during cold Vermont winters. In Vermont's temperate climate, Conservation Heating keeps the humidity below 55% in collection buildings during the Fall, Winter, and Spring. Conservation heating is very efficient since only small amounts of heat are generally required to reduce humidity to 55% during the rainy seasons, and during the winter, the heat is seldom called on as the humidity drops to about 30% in our coldest and driest buildings. Of course, the buildings are uncomfortably cold, but since Shelburne is closed November through April, this method works well for us. Conservation Heating and Ventilation are methods of working with nature instead of against nature, always a wise practice.

Cold temperatures do not harm artifacts usually found in historic house museums, as long as items such as furniture are not moved or handled when they are very cold. In fact, the low temperatures reduce the rate of deterioration caused by chemical reactions in wood, paper, textiles, photographs, and other organic materials. One exception is paintings on canvas. Since research has shown that cold temperatures can cause the paint and ground to crack, we remove our historic house paintings to a warmer humidified storage building for the cold winter months.

Modified Use of Conventional HVAC Systems
With care, conventional HVAC systems can be used to improve collections environments in Class 3, 4, 5, and 6 buildings. We have modified the operation of the HVAC system in our Hat and Fragrance Unit, a Class 3 structure and our main textile gallery where we exhibit quilts and coverlets from a collection of over 800 that is recognized as the best in the United States. The HVAC system was designed to effectively heat, cool, and dehumidify the building year round. High summer humidities are reduced by the conventional means of using a cooling coil to super-cool the air to wring out the moisture, then reheating the air to reduce humidity before the conditioned air is discharged into the galleries. However, we do not introduce any humidity into this poorly insulated structure during the winter, choosing instead to allow the building to go cold to keep the humidity around 35% in the winter. I have recorded winter temperatures as low as 0ºF inside this gallery. Not only does withholding heat save us money, but the low temperature extends the life of the textiles, while discouraging insect activity.

The Stagecoach Inn is a good example of a Class 4 structure where we are operating a complete HVAC system including low-level humidification in the winter. However, care must be taken to minimize the amount of humidity introduced into a structure with limited vapor retarding ability or moisture will condense inside cold walls and rot the structure. This building has plaster walls filled with vermiculite insulation and tight interior storm windows. During the winter, the building temperature is reduced to 55 degrees and a steam humidifier is used to introduce a minimum amount of moisture and maintain the humidity between 35 and 40%. Less moisture in the building means less moisture available to penetrate and possibly condense in the walls. At these low temperatures, it is very important to keep the air moving continuously, even when the heat is not on to ensure that there are no cold, isolated interior walls where condensation could occur. Our engineers advised that humidity should not be introduced into buildings at a temperature below 55º because at lower temperatures, even small amounts of moisture can result in high relative humidity levels and increased risk of condensation.

Humidified Class 4 structures must be carefully monitored during cold weather. From experience we have found that if the outside temperature is above 20º F, we can safely humidify the building to 40%. As the outside temperature drops from 20º to 0ºF, the humidity set-point is automatically and gradually reduced to 35%. By observing condensation on the inside of double-glazed windows, the coldest surfaces in the building, while monitoring RH levels inside wall cavities, we have devised a good empirical indicator of a safe moisture level for our structures. Some haze on the windows is a warning that moisture is beginning to condense out on the coldest surfaces in the building. If drops of water begin to run down the window pane, the humidity is too high and must be reduced.

Digital Controls and Monitoring
None of the environmental control methods discussed could be practically employed without the use of digital controls. The 1991 NEH grant provided funds to connect all 27 collections buildings through underground wiring and to purchase and install digital controls, in our case the Johnson Control Metasys building management system. Although actual control of the various building systems is decentralized to 12 control panels that operate independently if communications are disrupted, all the systems can be monitored and adjusted from a central computer. Even the simplest Conservation Ventilation action of activating a fan requires that outside temperature and humidity data be shared throughout the network.

Several companies manufacture reliable direct digital controls, Honeywell, Andover, Control Pak, Johnson Controls, ASI, to name a few. Once properly programmed, any of these digital systems can work very well. The trick is in designing simple control sequences and developing a good relationship with a control technician who understands these somewhat unconventional control strategies. I advise selecting a local control company with the best reputation for customer service in your area. Check references carefully.

The second crucial aspect of a successful environmental control system is a good monitoring program and reliable, consistent humidity sensors. We have over 100 temperature and humidity sensors hard-wired to our climate control computer, 5 Preservation Environmental Monitors and Climate Notebook Software, and 8 hygrothermographs (after all, we need something to keep our interns occupied!) I have found that sensors from the Finnish company Vaisala are best for accurately sensing relative humidity at the low and high temperatures sometimes experienced in our less than ideal environments. RH sensors should be calibrated at least yearly, every 6 months in critical buildings. I spend about 20% of my time monitoring, adjusting, and troubleshooting environmental control systems in 22 buildings. Without the computerized building control system and reliable sensors, it could easily be a full-time job.

And Beyond… Practical Environmental Control for New Buildings
In 2000, we began planning for construction of a new 10,000 sq ft two story storage building. We originally designed a simple building just for artifact storage with no human occupants, utilizing the practical environmental control principals and systems we were successful employing in our historic collection buildings. The site would be very well drained and the building would be very well insulated, but essentially unheated in the winter, with humidistatically controlled Conservation Heating and Ventilation.

During the planning process, our new director decided to include a library and collections management space on the second floor, introducing people to the structure. The cost of the building immediately doubled from $600,000 to $1.2 million because of the requirement for an elevator and a conventional HVAC system for the occupied second floor. Since winter humidification was now required, an aluminized polyester film vapor barrier was carefully installed and taped throughout the entire building. Conservation heating and ventilation were still deemed sufficient to maintain a safe environment for the carriages, furniture, wood sculpture, metals, glass and ceramics to be stored in the 5000 sq ft first floor.

Once the new building came on line, we had a few surprises. Fortunately, we had planned to keep the storage area empty during the first winter to evaluate the building systems before loading in artifacts. I was counting on withholding heat and allowing the building to get cold during the winter to maintain a reasonable humidity level of at least 35% without adding humidity, a successful practice in our historic barns. However, this new construction was nothing like our cold, damp historic barn where high humidity was the major problem. This building was so well insulated that we could not successfully reduce the temperature below 50ºF, even by blowing cold air into the building. The heat from the ground combined with heat generated by the two ventilation fan motors prevented the building from cooling below 50ºF, and when the outside temperature fell below 0ºF, the interior humidity dropped below 20%.

However, as the year progressed, we found that with all systems serving this storage area shut down, the temperature and humidity levels are very steady, changing only gradually with outside conditions. The humidity never exceeds 55% during the spring and fall, and summer temperatures remain below 75 degrees with humidity levels topping out at 60%. By installing a steam humidifier to introduce some moisture into the space during the coldest winter months, we are able to maintain a safe environment that ranges from 40% humidity in the winter to 60% in the summer, at temperatures that range from 50ºF in the winter to 75º in the summer. This is because this well-sealed and insulated first floor storage space is sandwiched between the ground (with a year-round temperature of about 50ºF) and a fully conditioned space above and is filled with large wooden artifacts that act as a significant humidity buffer.

In essence, we are providing environmental control for a 10,000 sq ft partially occupied building at the cost normally associated with a 6000 sq ft building, effectively gaining 4000 sq ft of environmentally controlled storage at no initial cost for HVAC equipment. Energy costs for this 5000 sq ft storage area are very low with only a fan and humidifier operating for two months of the year. We hope this building can act as a model for future energy-efficient museum storage buildings.

Decorative Arts Storage

Our most recent innovation is controlling humidity in a storage building using only Conservation Heating and Direct Expansion (DX) cooling, as opposed to expensive super-cooling and reheating that requires running air conditioning and heating at the same time for 3 seasons of the year. As long as a DX unit, such as a window air conditioner, is running, it dehumidifies quite effectively. However, once it turns off, the humidity can increase rapidly. The trick to effectively dehumidifying a space is to keep the air conditioner running. If the unit is undersized for the space it will run for long periods of time without cooling the space below the set-point, dehumidifying quite effectively. Also, the higher the temperature in the room, the lower the RH. Our goal was to keep the summer temperature below 76 degrees and the RH below 60%.

We began by super-insulating a 30 year-old one-and-a-half story frame structure using blown-in densely packed cellulose insulation. This material has a better insulating value than fiberglass battens and stops all air movement, and hence moisture movement, within the wall and roof cavities. All seams were carefully calked to prevent moisture infiltration. The cellulose is also treated with a fireproofing agent, so enveloping the structure with dense-packed cellulose effectively fire-proofs the building. The building was insulated during the winter, and on completion, the interior temperature increased from 10ºF to 40ºF, picking up heat from the ground.

An American Standard home heating and cooling system was installed. This state-of-the-art gas furnace is designed to increase dehumidification by varying the speed of the fan that moved the air over the cooling coils. When the DX unit is just starting up and the cooling coils inside the air handler are not yet cold, the fans slow to decrease the air flow and keep the air in contact with the cooling coils for a longer period of time, thereby condensing more moisture out of the air. Engineers calculated that a 1.5 to 3 ton cooling unit would be required to effectively cool and dehumidify this building. The insulating contractor estimated that a one-ton unit would be more than adequate to cool the space, especially if we wanted it to be undersized to maximize dehumidification. To be safe, a two-staged 1.5 and 3 ton unit was installed. After 2 summers of operation, the second stage has never been called on and the interior temperature remains below 72 degrees even on the hottest summer days.

Conservation heating controls humidity whenever interior temperatures are below 72 degrees, which in Vermont is most of the Spring and Fall and all of the Winter. The heat is seldom activated in the winter because the RH seldom goes above 50%. When the temperature is above 72ºF, DX cooling dehumidifies the space. Temperature and humidity levels remain very steady, topping out at 72 degrees and 58% in the summer and decreasing to 40ºF and 40% RH in the winter. This colored psychometric chart graphically indicates how we have improved the climate in this building. The orange and yellow areas indicate temperature and humidity conditions ranging from 0 to 95ºF and 40 to 100% RH before improvements were made. The small green area indicates the much more steady conditions presently maintained. It cost $8,000 to insulate the building, and the entire climate control system cost only $16,000 and uses very little energy. This work was funded by a grant from the Institute for Museum and Library Services.

We have recently received NEH funding to insulate the 500 ft long Circus Building and install similar environmental controls in 2007. We anticipate we will need more cooling capacity per square foot for the Circus Building than the Decorative Arts Storage Area because the public will be entering and exiting this exhibit building much more frequently than the staff enters the storage building.

Compromises
In closing, it is important to emphasize that all of these practical environmental improvement methods have disadvantages as well as advantages and the decision to use them involves careful compromise. The fans used for Conservation Ventilation can be quite noisy, and filter boxes need to be added to historic structures. Conservation Heating results in cold buildings that are inhospitable to off-season tour groups or school classes. Access is definitely limited during cold weather. Hot air furnaces are a risk in collection areas. If not properly maintained, fire boxes can rust and crack resulting in puff-backs of soot that could contaminate collections.

Unconventional systems are not well understood by HVAC contractors and training and close supervision is necessary to ensure the systems are properly maintained. A conservator or well trained collection care specialist who thoroughly understands the system needs to be available to regularly monitor conditions and trouble-shoot problems. However, traditional HVAC systems require similar monitoring and maintenance.

Conservators must know their collections intimately to insure that artifacts requiring more stringent temperature or humidity conditions are stored or exhibited in more tightly controlled area.

The compromises can definitely pay off in lower equipment costs, lower long-term fuel costs, and lower maintenance costs for less and simpler equipment. By knowing the environmental conditions that will and will not harm our collections, by embracing broader safe temperature and humidity standards, and by working with nature instead of against it to eliminate temperature and humidity extremes, we can preserve our collections and historic buildings for future generations and maybe even manage to afford to keep our doors open long enough for them to visit.