

### **Analysis of 1990s Environmental Control at Historic New England**

Historic New England, the oldest, largest, and most comprehensive regional preservation organization in the country, was formed in 1910 by William Summer Appleton under the name the Society for the Preservation of New England Antiquities (SPNEA). Historic New England today offers a wide variety of ways to experience the lives and stories of New Englanders including 36 historic properties, traveling exhibitions of New England treasures, comprehensive archives, exceptional educational programs and events and a tradition of stewardship and partnership with private owners of historic properties.

The historic house collection, spanning in age from 1664 to 1938, includes 14 National Historic Landmarks and 19 properties listed either on the National Register of Historic Places or as a contributing structure to a National Register historic district. The 36 sites include over 140 buildings, 1200 acres, and 40,000 objects. The integration of landscapes, buildings and collections allows visitors to experience in a real and personal way the lives and stories of the individuals and families who made New England what it is today.

In 1993, responding to increased concerns about the care of its collections and buildings, Historic New England, embarked on a multi-year project funded by the National Endowment for the Humanities (NEH) to improve environmental conditions at eight of its most important properties. Recognizing that controlling relative humidity was the greatest need, Historic New England implemented a plan in four-phases to: monitor and identify sources of moisture; eliminate those sources of moisture infiltration; update existing heating systems to humidity-sensitive systems; and install modern controls for these systems. In addition to stabilizing the environment at the sites and demonstrating that low-cost environmental control could work, the project was intended to spearhead the movement towards state-of-the-art humidity and temperature controls for historic house museums. More than fifteen years after undertaking the project and ten years from its completion, Historic New England is reviewing the performance of the systems and assessing current conditions at the sites to determine whether the goals were achieved or whether a different approach needs to be considered for controlling the environments in historic houses.

As part of the original planning for the project recording hygrothermographs were used to monitor spaces in each house. Unfortunately the organization only had a handful of the machines so they were rotated through different rooms for periods of two to four weeks. The drawback of this methodology was that data for a full year for each space in each property was never collected leading to an incomplete picture of the site conditions. Sources of moisture infiltration were also identified at each house. An environmental engineer was commissioned to analyze the data and provide recommendations for each site.

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In 1993 work was initiated to eliminate the sources of moisture at the sites. It was found that all eight properties had significant moisture infiltration with clear failures in the water dispersion system – from the roof to the foundation. These failures, plus in many cases the buildings are located in areas with a high water table, resulted in extraordinarily wet basements. Projects were implemented to repair roofs, flashing, and gutters. In many locations terraces were re-graded, and underground drainage systems and dry wells were installed to move water away from the foundations and basements.

To address the interior environments of the eight buildings, humidistatic techniques were introduced. Humidistatic control of the environment uses sensors to measure the relative humidity in the air and then activates a system based on those readings. Seven different systems were implemented in the eight properties which relied on different ways of affecting RH when a sensor was triggered. The seven systems provided:

- Humidistatic hot air in the museum space
- Humidistatic ventilation in the museum space, basement ventilation
- Humidistatic hot air, radiators, dehumidification and cooling in the museum space
- Heat at constant temp throughout the museum space and basement
- Humidistatic heating using radiators in the museum space
- Humidistatic heat and ventilation in the museum space
- Humidistatic ventilation in the basement only

A goal of the project was to use existing equipment wherever possible, but it became necessary to install a number of new pieces of equipment at the sites. This new equipment was generally related to providing extra ventilation in the spaces. The systems and their set points were all designed to help achieve a stable RH level of 45%  $\pm$ 5% and an overall goal of minimizing fluctuations in RH in the houses.

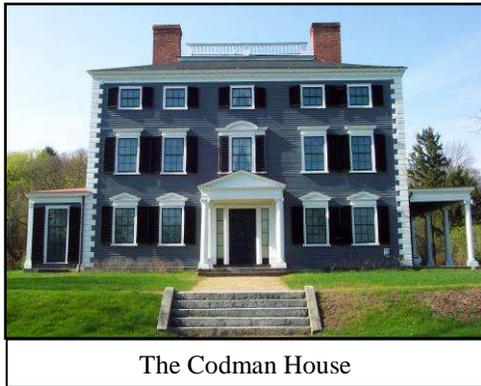
A Direct Digital Control (DDC) was installed at each site to control all aspects of the system according to a psychometric algorithm based on temperature and RH readings. A master control box was installed in the basement with a telephone line and a modem to allow internet access. A central computer work station was set up at the Historic New England headquarters to allow staff to monitor all eight sites through the internet.

The most problematic portion of the systems from their inception was the DDC-Historic New England interface. Telecommunication issues plagued the operators from the beginning and the result was that Historic New England staff members were rarely able to access the systems through the internet from their central work station. Since there was no user interface on the master control box at each site, in order to manipulate the system the manufacturer had to meet staff on site in order to plug in to the system.

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### Case Study One: Codman House

The Codman House, an eighteenth-century country house located in Lincoln, Massachusetts, was the recipient of a system designed to regulate relative humidity through hot air heating in the museum spaces and ventilation in the basement. The Codman House, built circa 1740, underwent additions and alterations in the 1780s and then again in the 1860s. The wooden frame structure has three full stories plus an attic and a full, brick-lined basement. Historic New England acquired the property in 1969 with its incredible accumulation of Codman belongings, furnishings and paintings, spanning generations of family collecting.



Prior to the systems modifications, the environmental conditions were monitored at Codman for a total of 34 days, split between January of 1990 and June 1990, with readings for the basement and a second floor space. The average basement reading was 57% RH in the winter and 60% RH in the summer, with a standard deviation of about 10% for each. Readings on the second floor averaged 50% RH with a standard deviation of about 3%. Neither space was achieving the desired 45% RH,

however the fluctuations were not extreme for the house.

Moisture mitigation was the first funded portion of the 1990s project and the scope of work at Codman included repairs to the gutters, replacement of the roof, rebuilding and capping of the chimneys, and repairs to the existing drywell system. The work was successfully completed, but no records have been found of post-work monitoring so the initial success of the mitigation efforts on the overall conditions cannot now be assessed.

The second phase of work was to update the heating system to be humidistatically controlled. The main component of the system was an existing air-handler for the museum with ductwork delivering air to the first and second floor, a return air duct in the first floor hall and a filtered fresh air supply ducted from a basement window. Heat would now temper the air in response to relative humidity readings within the museum. In addition, a new basement ventilation system was installed consisting of two exhaust fans in basement windows with a separate open window to provide supply. In addition to ventilation the basement fans were meant to create an area of low pressure in the basement, thereby drawing air from the museum into the basement since air travels from high pressure to low pressure. If the area of low pressure were in the museum then the moist basement air might be drawn up into the museum. The third part of the system was a 24 inch fan positioned at the top of an existing elevator shaft to ventilate the museum to the exterior.



Workers replacing the roof.

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The elevator shaft was connected to the first, second, and third floors but separated from the basement. The entire system was controlled by a DDC installed in the basement.

Environmental data collection was sparse in the years immediately after the installation of the system. Currently, Historic New England has about 34 days' worth of data, split between January and April of 1997 for the basement and second floor space. The RH in these spaces continued to average numbers similar to the 1992 readings – about 60% for the basement and 50% for the second floor. These numbers represent no significant change to the environmental conditions from before the system upgrades, but unfortunately they also do not represent a comprehensive assessment of the environment.

As with the other systems, Codman was plagued by communication issues. Within a few years staff had lost the ability to communicate with the system except through expensive service calls, and the DDC started sending out instructions without apparent input. The museum air handler and heat, the basement exhaust fans and the elevator fan began to operate at unexpected times. Off-site control via modem and the internet no longer worked, and the service calls resulted in high bills and no improvement in control.

After meeting with an environmental engineer in 2007 it was decided to shut down the fan at the top of the elevator shaft. The concern was that the fan was creating an area of low pressure in the museum, thereby drawing in air from other locations such as the moister basement. Monitoring of the RH before and after shutting down the fan revealed this action had very little effect on the RH but did affect the temperature swings. In order to further test the ability of ventilation to affect the RH in the house, the basement ventilation fans were also shut down and the basement windows were sealed as well as possible. Monitoring did not reveal any noticeable change to the basement RH.

It was necessary in 2007 to replace the boiler for the system due to old age. It was also necessary as part of the new installation to decide whether to control the new system with a DDC or use a more local and simplified control system. Historic New England was not ready to re-invest in a DDC system based on its experiences with the 1990s system as well as an additional experiment at a different site in 2005 with a newer DDC system. The decision was made to keep the system local and understandable with a simple humidistat to operate the museum air handler within the desired RH range with additional checks on temperature. When the system is not required to regulate humidity it acts purely as a ventilation system and moves air through the museum. An additional zone of simple radiator heat and dehumidification was installed in the basement to help mitigate moisture in the basement before it might migrate into the museum. The system has been installed for less than a year but the data to date has reflected positive change.

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### Case Study Two: Cogswell's Grant

In 1937, Bertram K. and Nina Little purchased this 1728 farmhouse overlooking the Essex River as a family retreat and place to entertain. Nina Little, through her research and innumerable publications, charted new areas of American folk art such as decorative painting, floor coverings, boxes, and New England pottery. When they restored the farmhouse, the Littles preserved original 18th-century finishes and carefully documented their work, but they also decorated the house for visual delight rather than historic accuracy. The result is rich in atmosphere and crowded with collections of things -- primitive paintings, redware, painted furniture, stacked Shaker boxes, weather vanes and decoys -- that have since come to define the country look. Historic New England was given the property in 1984 and began formally operating the property in 1996.

The two-story farmhouse is of timber frame construction with an unfinished cellar. The two-story rear ell was once the kitchen wing but today houses the caretaker apartment and staff offices. The house was used as a country retreat in the twentieth-century and, although it had limited heat, the main house was mostly shut down in the wintertime. As with Codman, prior to work commencing environmental conditions at the house were monitored. The relative humidity in 1992 tended to remain high, averaging between 55% and 85% RH throughout the house, with a particularly damp basement.



Cogswell's Grant



Exterior trenching.

As part of the moisture mitigation the house was fitted with new gutters, downspouts and a collection system that carried the water away from the house. Foundation drains were installed along several facades and a swale was created to help divert water away from the rear of the house. Again, like Codman and the other six sites, if any monitoring of the environment was done after these mitigation efforts the records have not been found so their immediate impact is unknown.

Heat had not been operable in the museum for a number of years and it was decided to install a ventilation system instead. This system differed from most of the other 1990s systems because no heat was used to temper the air moving through the museum. Only filtered outdoor air was used. The museum air handler, which was supplied by an outdoor air intake ducted through the basement,

delivered air to the first floor through ductwork. An exhaust fan in the attic drew the air

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through the house and out. Two additional fans ventilated the basement by drawing air in one basement window and exhausting it through a separate window. Like all the 1990s systems a DDC was installed to operate the separate components of the system.

Once again, environmental data collection was initially spotty after the new system was installed. From April through December of 2001, temperature and RH data were collected in the dining room and the bed chamber above the dining room. The data indicate that in the dining room humidity fluctuated quite a bit, with the majority of readings above 60% RH. The second floor room was more stable but also fluctuated around the 55% RH line. The numbers represent an improvement to the environmental conditions in the house, but only a marginal one. Data collected for the same period in 2007 show very high humidity readings and fluctuations throughout the house.

In addition to the problem of high humidity, the past several years have been plagued by elevated instances of mold growth on the collections and walls in certain spaces. The mold was coupled with peeling architectural finishes and a general agreement that the house smelled musty. Staff turned their attention to the ventilation system in 2007 and identified a number of flaws in the design and a breakdown in the system. The first issue uncovered was that the attic exhaust fan was twice as powerful as the intake fan, turning the museum into an area of low pressure which was potentially drawing air from the moist basement into the museum. A passive duct system was found connecting the dining room with the bed chamber above and it was in these two rooms that the mold blooms were the worst. After exploring a crawlspace in the basement staff discovered that open ductwork also connected the basement to the dining room. A highway for moisture to travel from the high pressure basement to the low pressure museum existed. Further investigation in the crawlspace found that in areas that were very hard to access large joints had opened in the ductwork allowing moist basement air to enter the ductwork and be fed straight into the museum.

To mitigate these different issues, an effort was made to balance the exhaust and intake fans of the basement. The fans were eventually shut down when conditions failed to improve, but this also resulted in little change to the environment in the house. As at Codman, the DDC at Cogswell's Grant was not operating in expected ways. It was decided that more harm was occurring than good and the entire system was shut down.

For the next step at Cogswell's Grant, Historic New England is planning to add a small amount of heat and dehumidification to the basement, in yet another attempt to reduce the moisture in the basement. The ventilation system has been shut down, parts have been dismantled, and the open ductwork will be sealed. The entire system at Cogswell's Grant will have to be redesigned at some point in the near future.

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### Conclusions:

The 1990s climate control project was exciting for Historic New England and focused attention on environmental conditions in all its historic house museums. Today, the project has clarified a new approach to environmental control systems for Historic New England. Unfortunately, this new approach is not necessarily embodied in the 1990s systems themselves, but rather in what was learned from designing, implementing and operating those systems. With the perspective of ten years (1998-2008) Historic New England can now look back at this project and identify ways in which the program did not meet the goals originally outlined. Those goals were to: monitor the environment and identify sources of moisture; eliminate those sources of moisture infiltration; use non-intrusive humidistatic systems to control humidity; and install modern digital controls for these systems. The larger goal was to spearhead a movement towards state-of-the-art humidity and temperature sensors and controls for historic house museums.

### Monitor the Environment to Identify Sources of Moisture:

Monitoring before and after the project was problematic because the recording hygrothermographs were expensive, sensitive, and the data was hard to analyze. The DDCs were also intended to store environmental data, but the difficulties in modem communication prevented this data from being saved. Despite improvements to monitoring technology, monitoring in the ten years following the project continued to be an issue and incomplete record sets have made analysis difficult. Historic New England has learned that monitoring needs to be systematic and organized so that the methods by which staff collect data, sort data, and analyze data are standardized and maintained.

### Eliminate the Sources of Moisture:

It is hard to argue with the concept of keeping moisture out of an historic house. Although this paper has not focused on this aspect of the project, a great deal of resources were expended on accomplishing this. The original NEH funding proposal concluded that money spent proactively to keep moisture out of a building would be money well spent, and we would reach the same conclusion today. Unfortunately not enough monitoring data exists to verify whether the work to eliminate sources of moisture alone were sufficient to stabilize the RH at the sites. Based on the examples of Codman and Cogswell's Grant, it appears that the mitigation efforts generally prevented historic fabric from being damaged from water infiltration. However, the efforts did not substantially mitigate RH conditions on the inside of the houses.

Moisture traveling through the soil and into basements was a specific area where the project efforts to eliminate sources of moisture were not successful. Common practice dictates that vapor barriers around basements and on the floors will prevent the basement RH from reaching extreme levels and make it easier to mitigate. As part of the project staff made a clear decision not to replace the basements with concrete foundations and floors in order to protect historic fabric. Historic New England staff would continue to support this position today. In several basement spaces, vapor barriers were installed, but these barriers were most often laid on the surface of the floor in the basement and not flashed through the connection points, causing moisture problems at connection points. In most cases these barriers have been removed and study continues as to the viability of these applications.

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### Humidistatic Measures:

Seven different systems were installed into eight of the houses, partially in an effort to determine whether any single system was better than the others. In the two case studies illustrated, the systems installed did not affect a great change to the environment. In addition, the six other houses in which different types were used did not show substantial change to the RH within the museums. Conclusions from the project written in 1999 indicate that staff believed that the systems were fairly successful in decreasing fluctuations in conditions. Humidistatic heating in winter was seen as successful, but ventilation did not seem to be able to affect a reduction in RH in the museums. This is because there were only a few times that the outside air was dryer than indoor air and it is only then that a positive change could be possible.

In general these conclusions have now been echoed ten years later in the latest analysis. Ventilation systems have been shut off one by one to determine if they affect the museum environments. As shown in the two case studies the lack of these systems have not affected the overall performance. Looking at the RH readings from before the project, directly after and in 2007-2008 one draws the conclusion that none of the eight systems made a significant change to the environment. The 1999 report carefully dances around the issue that only winter readings and not readings from spring, summer or fall, show the system attaining the 45% RH standard.

Additional issues focus mostly on the equipment. In many cases it is clear that corners were cut, either knowingly or unknowingly, and the result was inefficient and poorly sized equipment. When systems are installed under these conditions, they result in high costs and frequent maintenance issues. Since the reassessment of the NEH project began, when replacing equipment Historic New England has been especially focused on sizing the equipment properly for the task, and spending more money up front on better equipment so that costs are kept lower throughout the operating life of the system.

### Controls

The larger goal of the 1990s project was to usher in a new era of state-of-the-art controls for historic house museums. Unfortunately the controls failed on a number of levels – some technical, some due to the contractor and some due to Historic New England. Communication with the controls from off-site was never consistently possible and by 2002 it was nonexistent. The original control company was never able to re-establish a successful connection to the system once it was lost, which meant that any modifications to the system had to be implemented with a control company technician on site plugged directly into the DDC. In addition, the original DDCs were installed on the DOS platform and were never upgraded to more modern operating systems. When calculating for low-cost systems the cost of constant upgrades to the communication systems were never factored. In 2005, the modern equivalent of the 1990s DDC was installed at one of the sites in an effort to re-establish the ability to communicate with the system from off-site. Although the control is currently operating, the system has also been plagued by three years of difficulties, primarily with establishing and maintaining internet access, in addition to problems with other functions that are still not performing as expected.

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Due to all of these factors, some internal and some external, Historic New England has refined its approach to controlling the environment in the historic houses to the four following principles:

- A perfectly stable environment of 45% RH is not achievable in a historic house museum and it is likely that such an environment would be detrimental to the building fabric through four seasons. Historic New England has embraced a more elastic approach to stabilizing the environment but not at the cost and expense of the collections, buildings or finances. A range of 30% RH to 60% RH is now the goal.
- It is important to not only monitor the conditions in the environment but also to save the data for future analysis. Historic New England has undertaken an exhaustive process to assess its current protocols for monitoring, placement of monitors, collection of data and analysis of data. With 36 properties the data can be overwhelming if organization is not a priority.
- The more equipment installed in a house the more complex it becomes to operate, control and maintain. Complexity is the bane of the historic house museum if site staff can not operate the system, your local contractor can not understand its operational guidelines and, in the case of Historic New England, your technical staff are already stretched thin managing a number of properties in a number of states.
- In addition to keeping the system simple it is important to take small steps towards your goal. Monitor the conditions and make a small change. If the conditions improve assess whether more changes are necessary and if the conditions do not improve look at your original assumptions. One of the failings of the 1990s project was that moisture mitigation efforts were taken and then systems were installed that relied on multiple components such as basement ventilation and museum ventilation without monitoring the individual pieces. Historic New England is now backtracking the effort by shutting down one component at a time and monitoring if these individual pieces help the conditions or hinder.

Historic New England's analysis of these 1990s systems is not complete. The project is continuing with upgrading, or in the case of many of the systems, downgrading of the 1990s systems to maximize efficiencies. Historic New England is also experimenting with new systems in properties not included in the original 1990s project. Many of these systems are starting as simple as radiators and dehumidifiers in the basement with monitoring to determine the effects on the environment in the upper floors. Historic New England is hopeful that its findings, in keeping with the goals of the 1990s project, will help usher in a new approach to climate control in historic house museums.

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