White Paper Report

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Frelinghuysen Morris House & Studio
Sustaining Cultural Humanities Collections:
Planning for Sustainable Environmental Conditions to Preserve Collections
Grant Number PF-50094-10
Period: 3/01/2010 to 12/31/2011

White Paper

Note from the Director Kinney Frelinghuysen

From the moment of their inception, house museums often share the predicament of the change of their use to suit a new mission. The resultant upgrades of HVAC equipment take the building and collections into uncharted environmental management territory that varies with each building and collection. This remarkable project illuminates the complexity of factors that play in the function of a historic house museum and collections stewardship. It was well designed and executed with equal consideration to the data and the practical details such as the equipment, the role of museum staff, the nature of its collection, and purpose of the institution. While the overall environmental performance of the Frelinghuysen Morris House and Studio (FMH&S) has been determined to be favorable, the analysis demonstrates that raw data taken in isolation can mask other phenomena and give a false sense of security or a discouraging prognosis of inadequacy. Proper categorization of the building is a must for steering the analysis and avoiding the confusion of trying to meet with standards designed for purpose built museums. Vigilance, discipline and periodic and consistent professional evaluation constitute the right approach to preservation and point the way forward for systematic improvements in reducing risks to the building and collections while reducing energy consumption. Summaries of collected data, with the engineer's comments, can be viewed in Appendix A of the report. FMH&S is grateful for the NEH in making this evaluation possible.

The project outlined in this report can serve as a guide and inspiration to other similar institutions. FMH&S especially recommends the project approach to its fellow members of the Historic Artists Homes and Studios (HAHS), an Associate Sites program of the National Trust for Historic Preservation. During the course of this NEH grant description of the goals of the project and explanations of the visible equipment were incorporated into the seasonal public house tour. FMH&S issued press releases. It was also the focus of the 2010 membership drive, which featured a photo of the exterior weather monitoring station on the invitation to a members' event. The project and grant were announced on the www.frelinghuysen.org website in 2011. The full white paper and W&HA/WJ&A technical report will be made available once it has been submitted and approved by NEH. Lastly, the Director has actively encouraged members of the Historic Artists Homes and Studios and others to examine the report and communicate their experiences with climate issues at their sites to him for further discussion.

INTRODUCTION:

The Frelinghuysen Morris Foundation was founded in 1988 to celebrate the artistic and cultural contributions of Suzy Frelinghuysen and George L. K. Morris, and to ensure the preservation of their home, studio and works.

The Frelinghuysen Morris House and Studio was the home and creative workspace of American Abstract Artists George L. K. Morris (1905–1975) and Suzy Frelinghuysen (1911-1988). The white-stucco-clad studio building with saw-tooth roof was constructed by Morris in 1930. Morris attributed his inspiration to Le Corbusier's design for Amédée Ozenfant's Paris studio where he had studied. Morris' studio near Lenox, Massachusetts was the first International style building in New England, predating the Wadsworth Athenaeum's Avery Memorial Building and the Gropius House in Lexington, Massachusetts. In 1941, Morris and Frelinghuysen added the two-story, white-stucco-clad house, with characteristic industrial steel window sash and a glass block lantern set above the entry hall and spiral stair.

Opened to the public in 1998 as a historic house museum, the house and studio reflect the aesthetics and creativity of Frelinghuysen and Morris, who were avant-garde collectors, intellectuals and artists. Morris executed a large mural on the exterior wall overlooking the automobile forecourt and created frescoes in the living room, incorporating reverse-painted glass mosaics. Frelinghuysen painted murals in the dining room and in her bedroom. The artistic works of Morris and Frelinghuysen and those of their more famous colleagues and contemporaries, including Picasso, Braque, Leger and Gris, are hung throughout the house. Original furniture by Modern masters Frankl, Deskey, Rohde, Pfisterer, Lascaze, Mathsson, Eames and Aalto complete the harmonious ensemble of art, architecture and design.

The house and studio provide a context for interpretation of the owners' lives, their artistic works and influences, and the influence that they exerted upon the New York art scene and its collecting institutions, such as the Museum of Modern Art. This report documents a successful and highly collaborative project which, with funding through the Sustaining Cultural Humanities Program of the National Endowment for the Humanities, Grant Number PF-50094-10, will sustain the stewardship of this important site for future generations.

PROJECT BACKGROUND

In 2007, with funding from the Preservation Assistance Grant Program of the National Endowment for the Humanities, the FMF retained Wendy Jessup of Wendy Jessup and Associates, Inc. (WJ&A) to develop a Long-Range Preservation Plan for the site, which pulled together recommendations from numerous previous studies to provide a "road-map" to guide the preservation of the collections and the International-Style house and studio over the next five to ten years.

The Long-Range Preservation Plan identified a need to plan for future sustainable interior environmental improvements for preservation of the historic furnishings, building fabric and murals in the House and Studio. Funding from the Cynthia Woods Mitchell Fund for Historic Interiors of the National Trust for Historic Preservation enabled the FMF to engage Wendy Jessup and Associates, Inc. and Michael C. Henry PE, AIA, of Watson & Henry Associates (W&HA) to design the Interior Environmental Improvements Plan.

The Interior Environmental Improvements Plan was comprised of two phases:

- Phase I: a year-long monitoring program using automatic dataloggers to collect the data critical for understanding the building performance and potential risks to the collections with particular concern for the murals.

- Phase II: analysis of the collected data to evaluate the comportment of the building and its systems in moderating the challenging New England climate, and development of recommendations for facilities improvements and operating strategies to provide long-term preservation of the house and studio, the furnishings and the artwork.

The Frelinghuysen Morris Foundation provided full funding for purchase of the monitoring equipment and engaged Michael Henry and Wendy Jessup to deploy the equipment; train FMF staff in its operation and maintenance, and in the downloading and transmittal of collected environmental data to the consulting team for archiving until funding could be found for future analysis.

In 2010, FMF received a grant from the National Endowment for the Humanities Sustaining Cultural Heritage Collections program to undertake Phase 2 of the Environmental Improvements Plan: evaluation of the data and development of strategies for on-going sustainable preservation of the site.

To assure continued integrity of this nationally important historic resource the entire project has been undertaken in adherence with The Secretary of Interior's *Standards for the Treatment of Historic Properties,* 1995, the New Orleans Charter for the Joint Preservation of Historic Structures and Artifacts, the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) *Applications Handbook, Chapter 21: Museums, Galleries, Archives and Libraries* and other prevailing professional conservation, museological and historic preservation guidelines and standards.

METHODOLOGY

Phase 1 environmental monitoring program began in February 2010.

After preparation of the equipment and a monitoring instruction manual, Mr. Henry and Ms. Jessup assisted by FMF staff, installed equipment and sensors to collect:

- Exterior conditions:

    - Atmospheric temperature, relative humidity, and calculated dew point;
    - Precipitation (i.e. rain, snow, etc.); and,
    - Solar radiation.

- Interior conditions:

    - Temperature, relative humidity and calculated dew point in representative and/or critical spaces in the three HVAC zones in the House and Studio;
    - Approximation of natural light levels to determine the effect of solar heat gain through windows in rooms with large areas of fenestration;
    - Concentration of corrosive gaseous pollutants;
    - Temperature, relative humidity, calculated dew point and soil moisture in crawl spaces beneath the House and Studio; and,
    - Opening and closing of three perimeter doors routinely accessed for building entry.

- Building envelope performance indicators (temperature, relative humidity and calculated dew point) in selected locations:

    - One wall cavity in the Living Room;
    - Under roof cavity of the Living Room; and
    - Skylight/laylight cavity of the Studio; and
    - Interior wall surface temperature near the Living Room frescoes.

Each month of the monitoring year, FMF staff downloaded the dataloggers and transmitted the data files via email to WJ&A's offices, where the data was assembled into time-trend graphs and tables of seasonal statistics, and archived to await analysis.

Once funding from NEH-SCHC was received, Phase II commenced. W&HA analyzed the statistical data and classified the interior environmental performance of each space according to the ASHRAE Class of Control; WJ&A evaluated the data using Climate Notebook® to determine mold risk and the potential for mechanical and chemical damage; and data collected by the corrosion monitoring datalogger was sent to Purafil for analysis.

The information generated through these multiple analyses was presented to FMF staff, stakeholders and advisors during a participatory and highly collaborative workshop, facilitated by Mr. Henry and Ms. Jessup, to develop objectives and strategies for environmental improvements that will provide long-term preservation of the building, its furnishings and the collections.

INTERPRETATION OF PHASE 1 MONITORING DATA

Corrosion Risk from Gaseous Pollutants

Data from the *Purafil® OnGuard® 3000* corrosion monitor and analysis using the proprietary software indicates that the rates of metal corrosion in the Living Room from 05 March 2010 to 05 May 2011 indicates that the reactivity rates for metal corrosion is at the low end of what is allowable for Class C1/S1 environments, which are more stringent than those considered acceptable for historic house museums. Therefore, intervention against gaseous pollutants is unnecessary.

Class of Control of Interior Spaces

The extent to which temperature and relative humidity are controlled within a space can be classified using Table 3 in Chapter 21, *Museums, Galleries, Archives and Libraries* of the 2007 *Applications Handbook* of the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE). For ease of reference, the table has been reformatted below:

	ASHRAE Control Class Criteria	AA	A Float RH	A Fixed RH	B	C	D
Dry Bulb Temp °F	Average (note 1)	70	70	70	70	70	70
	Max (annual)	83	83	83	86	86	No Limit
	Min (annual)	57	48	48	48	No Limit	No Limit
	Max Seasonal Setpoint Shift	↑9 ↓9	↑9 ↓18	↑9 ↓18	↑18 ↓18	No Limit	No Limit
	"Short Fluctuations" Max 24 hr range	±4 (≤8)	±4 (≤8)	±4 (≤8)	±9 (≤18)	No Limit	No Limit
Relative Humidity %	Average (note 1)	50	50	50	50	50	50
	Max (annual)	55	65	60	70	75	75
	Min (annual)	45	35	40	30	25	No Limit
	Max Seasonal Setpoint Shift	None	↑10 ↓10	None	↑10 ↓10	No Limit	No Limit
	"Short Fluctuations" Max 24 hr range	±5 ≤10	±5 ≤10	±10 ≤20	±10 ≤20	No Limit	No Limit

The Class of Control that can be achieved in a building used for collections is a function of two primary and equally important, considerations:

- The vulnerability or fragility of the collections with respect to environmental factors;
- The ability of the building envelope and mechanical systems to maintain the desired interior temperature and relative humidity in the context of the exterior climate.

These two considerations must be balanced. For example, tight environmental control for highly vulnerable collections cannot be achieved in a building with an unsubstantial building envelope.

For the first consideration, the ranking of environmental risks to collections associated with each class of control is as follows:

- Class AA: lowest risk
- Class A (Float RH): very low risk
- Class A (Fixed RH): very low risk
- Class B: moderate risk
- Class C: high risk
- Class D: highest risk

For the second consideration, the highest class of control that can reasonably be achieved in a given building type in the Zone 5A (Cool-Humid) climate of Massachusetts is as follows:

Class AA:	Requires metal wall construction, interior rooms with sealed walls and controlled occupancy;
Class A (Float RH):	Requires insulated structures, double glazing, vapor retardant, double doors;
Class A (Fixed RH):	Requires insulated structures, double glazing, vapor retardant, double doors;
Class B:	Requires heavy masonry or composite walls with plaster. Tight construction, storm windows;
Class C:	Requires uninsulated masonry or framed and sided walls, single glazed windows;
Class D	Requires sheathed post and beam structure.

Based on observations of the construction of the *Frelinghuysen Morris House and Studio*, the building envelope consists of framed and sided walls with the primary limitation on envelope performance being the single-glazed windows and doors and the thermal bridging in the metal window sash and frames. Thus, the environmental performance in the building could be expected to be Control Class C.

However, the staff at FMH&S has implemented a number of building envelope and environmental management strategies that offset the performance limitations of the building envelope at the windows and doors. These include:

- Closing the building to visitors and tours during the low temperature, low humidity months of winter;

- Installing insulated panels on many of the large openings with fixed and/or operable glazing in both the House and the studio;

- Installing plastic film over smaller windows to approximate double glazing and isolate the metal frames and sash from condensation;

- Lowering the winter interior temperature in order to elevate the winter relative

humidity while keeping dew point temperature low, thereby minimizing the risk of condensation within the building envelope.

These strategies, if continued can effectively improve the envelope classification, so that a Class B environment can be expected in winter at a minimum.

Analysis of the Phase 1 environmental monitoring data generally substantiates this expectation and demonstrates the efficacy of the strategies currently used.

The seasonal environmental performance at the *Frelinghuysen House and Studio* may be summarized as follows:

- **Temperature control** in all spaces is within Class AA limits for maximum and minimum temperatures, seasonal fluctuations and short term fluctuations. This is not surprising, since temperature is easier to control than relative humidity; however, from the standpoint of collections conservation, temperature control is less important than relative humidity control;

- **Relative humidity control** in all spaces is generally within Class B limits for maximum and minimum relative humidity, seasonal fluctuations and short term fluctuations. In summer and fall, the environmental performance for relative humidity control approximates Class A Float or A Fixed;

- **Exceptions to Class B relative humidity control** occur primarily in winter, and occasionally during spring, and consist of minimum relative humidity below the Class B threshold of 35%RH as well as seasonal fluctuations wider than the Class B limit of 20%RH;

- **Overall environmental control** is very good, bordering on Class A Float, taking into account the building envelope and the climate.

Table 3 of ASHRAE Chapter 21 identifies the conservation consequences of Class B and Class A Float environmental control as follows:

- **Class B:** Moderate risk of mechanical damage to high vulnerability artifacts; tiny risk to most paintings, most photographs, some artifacts, some books; no risk to many artifacts and most books. Chemically unstable objects unusable within decades, less if routinely at 86°F, but cold winter periods double life;

- **Class A Float:** Small risk of mechanical damage to high vulnerability artifacts; no mechanical risk to most artifacts, paintings, photographs, and books. Chemically unstable objects unusable within decades.

Based on the above, these environments would be acceptable for most collections materials exhibited in the House and Studio.

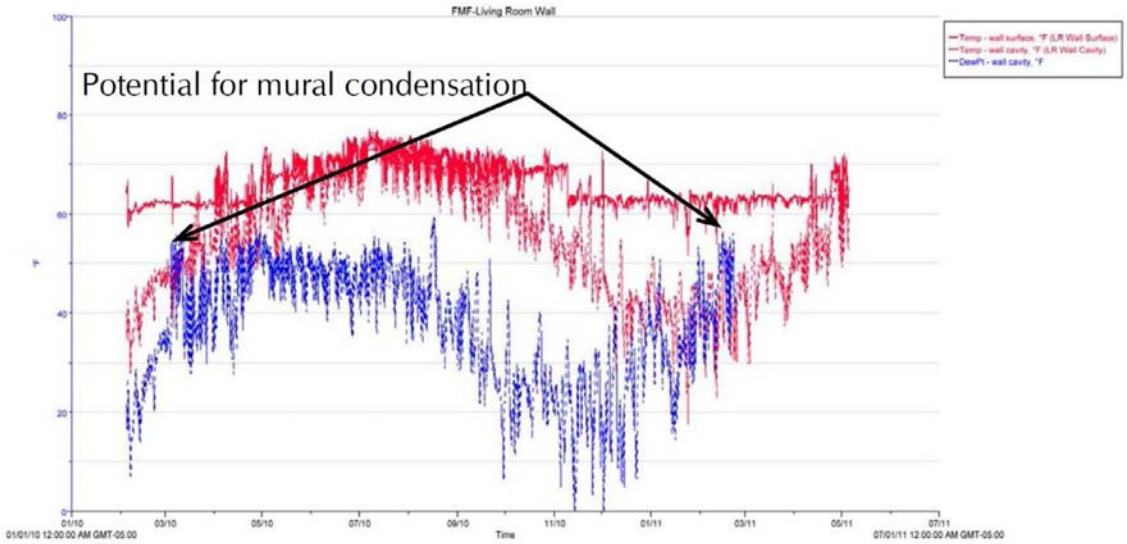
Intrawall Moisture and Condensation Risk on the Painted Glass in the Murals

As part of Phase 1, wall and ceiling temperatures were monitored, as well as wall and ceiling cavity conditions, in an effort to determine if moisture vapor in the intrawall cavity could condense on the interior (wall) side of the painted glass fragments in the Living Room mural.

The data trend plot below shows:

- Interior (room-side) surface temperature of the wall;
- Cavity air temperature;
- Cavity air dew point temperature.

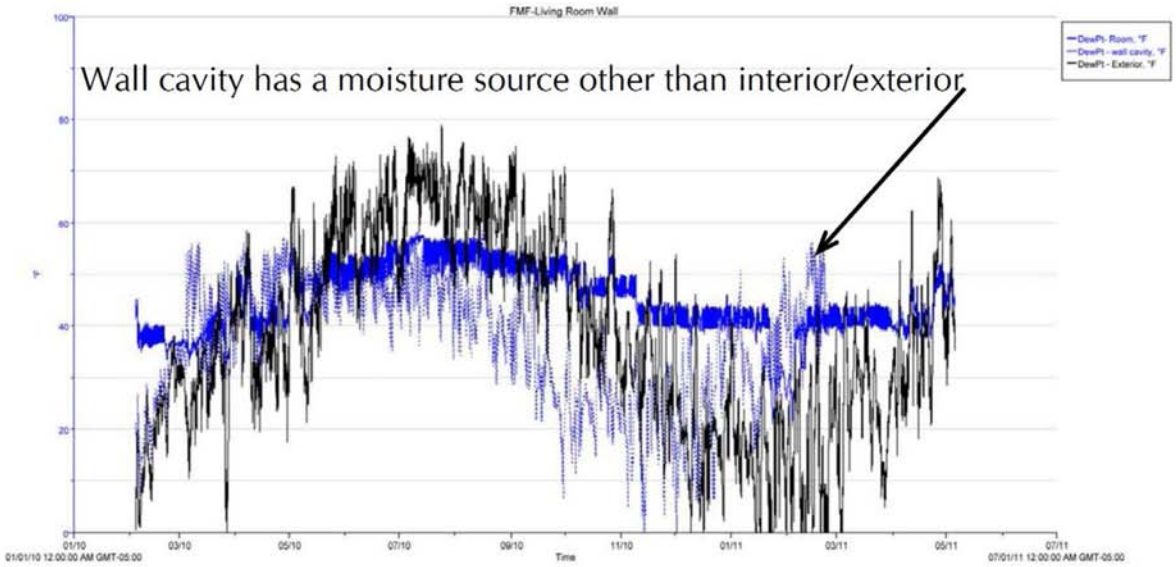
If the temperature of the glass fragment in the wall falls below the dew point temperature of the cavity, there is risk of condensation on the painted surface. However, the surface temperature of the glass fragment cannot not be measured directly because attachment of a sensor to the glass will damage the glass; therefore, the temperature of the glass fragment must be estimated from the wall surface temperature. A conservative estimate would be that the glass temperature is affected slightly by cavity temperature and therefore glass temperature is biased toward cavity temperature by several degrees warmer or cooler than the wall surface temperature.



The trend plot shows that there was a potential for condensation in March of both 2010 and 2011: this would occur during rising exterior dew point temperature from spring rains and depressed temperature of the north-facing wall after winter; it is aggravated somewhat by the intentional set-back of room temperature that is an effective part of winter relative humidity management for the collections.

A simulation of the hygrothermal response of the living room mural wall was run using WUFI® (Wärme und Feuchte Instationär) software (http://www.wufi-pro.com/). The interior air conditions were set as sinusoidal over 12 months with temperature at 67°F ±2.5°F and the relative humidity at 42%RH ±5.5%RH, which approximated the seasonal set back. Exterior conditions were run using climate data from Albany, NY, the closest data source. The WUFI® simulation did not indicate the risk of condensation on the cavity face of the interior plaster/glass.

Comparison of the collected monitoring data and the WUFI® simulation suggest that there might be a source of moisture in the wall cavity; this would explain the higher dew point temperature in the monitoring data. The trend plot below indicates that cavity dew point temperature generally trends lower than exterior dewpoint in summer and higher than the exterior dew point in winter. In March, the cavity dew point temperature increase is independent of both interior and exterior dew point temperatures. This suggests that the building materials may be releasing stored moisture as the building warms in spring.



The possible condensation of cavity moisture on the backside of the painted glass fragments in the wall mural is a complex phenomenon, but the measurements suggest that the occurrence is credible, even if the *WUFI*® simulation does not. Two key conditions, wall surface temperature, and cavity moisture, might be managed to reduce the possibility of condensation on the glass.

This is the first time that building envelope performance has been positively linked to deterioration of the murals and further study of the wall murals will be required. The information from the Environmental Improvements Plan is critical to the FMF's ongoing efforts in the development of a program for mural conservation, including funding.

Detachment of Mural Paints

There is evidence of damage in the murals on the exterior walls of the Living Room and this damage may be due to moisture and soluble salt migration. Some mid-twentieth

century house paints are susceptible to moisture vapor migration and moisture vapor content of the substrate. A recent technical paper relates this phenomenon to use of zinc-oxide containing underlayers by some abstract expressionist artists. [1]

The technical paper is compelling, and wall murals at the Frelinghuysen Morris House and Studio should be investigated to determine if a zinc-oxide paint layer is on the architectural plaster under the mural.

RECOMMENDED STRATEGIES FOR ENVIRONMENTAL IMPROVEMENTS

A workshop was convened at the *Frelinghuysen Morris House and Studio* on 26 May 2011 for the purposes of reviewing the analysis and conclusions of the monitoring program and for determining possible strategies for improving the conservation environment of the House and Studio. Michael C. Henry and Wendy C. Jessup presented the information and facilitated the discussion.

The workshop participants included:

- T. Kinney Frelinghuysen;
- Linda Frelinghuysen;
- Sean McCusker;
- Megan Krentsa;
- Sandy Bergen;
- Marilyn E. Kaplan, RA, Preservation Architecture;
- William Foulks, Building Conservation Associates;
- Chris Sgroi, Energy Consultant to Preservation Architecture.

The results are summarized here in terms of:

- Objectives;
- Strategies.

Objectives:

The objectives answer the dual questions:

- What must be achieved for overall protection of the resource?
- Where does environmental management fit within these goals?

The stated objectives are:

[1] Rogala, Dawn, Susan Lake, Christopher Maines and Marion Mecklenberg. *Condition Problems Related to the Use of Zinc-Oxide Underlayers: Examination of Selected Abstract Expressionist Paintings from the Collection of the Hirshhorn Museum and Sculpture Garden, Smithsonian Institution. Journal of the American Institute for Conservation*, V49, N2, pp. 96-113. 2010.

- Collections:
  1. Preserve the murals;
  2. Keep the art collections in the house;
  3. Continue to exhibit the collections in context (most valuable resource): powerful educational tool;

- Philosophy:
  1. Establish a period of significance and a period of interpretation for the House and Studio;
  2. Practice "slow conservation," measured conservation actions without rushing into technological fixes;
  3. Take a holistic approach to preservation of the collections and building resource in context of the site;
  4. Take time to make balanced decisions and document steps/measures taken;
  5. Capture documentation related to the house, such as letters, drawings, and photographs, to inform present and future stewardship of the building and collections. This will require organization of the primary material as well as scanning into digital format;

- Building and Site:
  1. Preserve the building and its interior and exterior architecture;
  2. Preserve the pristine look of the exterior, which is well documented;
  3. Reduce energy consumption and costs of operations;
  4. Preserve views while minimizing light entry to cut solar gain and UV using a targeted approach based upon the areas of greatest collections vulnerability.

Strategies

In order to achieve the above objectives, the following recommended strategies were developed:

- Reduce moisture load and dehumidification by the systems; this will reduce energy consumption and improve relative humidity stability. It will reduce the risk of moisture migration from the basement walls and spaces to the first floor wall cavities:
  1. Mitigate the liquid moisture problem in crawlspace by constructing a sump pit to drain the soil. Install a tight-fitting cover and a sump pump; Note that soon after the workshop, while contracting for the sump pit an existing functioning drain was uncovered from beneath silt which had built up over the years.
  2. Cover exposed soil in the crawl space with a vapor retarder to reduce evaporation of soil moisture. Griffolyn® Type-90 FR (fire-retardant) vapor retarder would be the best choice and is manufactured by Reef Industries, Inc., (www.reefindustries.com).
  3. Install a dehumidifier in the basement for moisture vapor control in the crawlspace and basement. The Ultra-Aire™ 100V ventilating dehumidifier by Therma-Stor, LLC, www.ultra-aire.com is suitable for this application. Note that this unit does not need to be controlled by the existing Einstein control system in the house.
  4. Ultimately, develop a plan to intercept groundwater outside the building;

- Reduce heat loss through windows in wintertime and reduce air and moisture vapor infiltration/exfiltration. This will reduce energy consumption and will stabilize interior relative humidity and reduce interior particulates.:
  1. In the near term, continue to apply insulation panels in winter, but refine/improve design and installation to tighten fit and reduce moisture migration and condensation on window/door glass and metal sash/frames;
  2. Consider caulking panel edges;
  3. Restore the windows and doors. The metal windows need very good surface preparation and coating application for durability;

- Reduce light damage to the collections and reduce solar gain during cooling seasons; this will reduce air conditioning load and energy consumption:
  1. Preserve views while minimizing light entry to cut solar gain and ultraviolet light using a targeted approach based upon the areas of greatest collections vulnerability;
  2. Add light-reducing shades and operate to cut light levels;
  3. Use Saflex interlayer in laminated glass for replacement glazing during long-term restoration of the windows (exercise care with edge treatments because sealants can attack the laminated glass);
  4. Reaffirm and improve operating protocols for closing shades when the house is not open to the public. During the summertime, this can eliminate up to 10 hours of daylight exposure to light-sensitive materials;
  5. For light control in the stairway tower of the foyer, consider using a shade in the radius track at ceiling and position panels according to seasonal patterns of direct sunlight entry;

- Improve operation of the existing HVAC system. This will reduce energy consumption and will maintain interior environmental stability within the targeted ASHRAE performance:
  1. Improve humidifier reliability to eliminate occasional low RH excursions in winter.
  2. Install separate dehumidification equipment for reduced energy costs. Install a dehumidifier in the basement for moisture vapor control in the first floor; moisture vapor diffusion should be sufficient for moisture management in the other zones. The *Ultra-Aire™ 100V* ventilating dehumidifier by Therma-Stor, LLC, www.ultra-aire.com is suitable for this application. The unit should be ordered with the *optional MERV-14 filter*. The control of the unit should be integrated into the present HVAC control system and the activation setpoint for the dehumidifier should be set at the upper limit of the desired relative humidity range, with a deadband so that shut-off occurs when RH is equal to the average RH value for the season. Consider replacing the existing RH sensors in the house with sensors manufactured by Vaisala (http://www.vaisala.com/en/products/humidity/Pages/default.aspx); these must be compatible with the Einstein control system.
  3. Continue winter temperature setback to 62°F (heating on) with a small deadband, but begin to raise thermostat setting during third week in February with step-wise increase of 5°F increments every two weeks. Cooling on setting should be 75°F. This measure should help reduce the prospect of condensation on the glass fragments in the murals;

4. Use RH set point for winter humidification to 40%RH (on) to 45%RH (off) range during winter. Winter dehumidification set point should be 55%RH (on) to 50% RH (off) and summer dehumidification set point should be 60%RH (on) to 55% RH (off);

- Develop a long term plan to reduce heating and cooling costs. This involves longer term capital improvements:
  1. Explore use of the pond and the brook for cooling. If pond and/or the brook remain cool during the summer one might work as a heat sink for a water-cooled condenser. The savings would be off-set by the additional energy costs to pump the cooling water up to the house;
  2. Explore options (long-term) for use of alternative energy on barn (PV/solar/future technologies);

- Reduce heat loss through the building walls and roof:
  1. Investigate and document existing insulation material, hazard/toxicity and thickness/placement and depth of existing wall/ceiling assembly framing;
  2. Evaluate whether insulation upgrades/replacement will be cost effective. Do not apply spray-on foam insulation on underside of roof because it will reduce drying surface area for roof deck and because of smoke/off-gassing concerns. Do not use packed cellulose insulation in walls because of potential for leaks in the parapet. Apply insulation above ceiling, not on underside of roof;
  3. If insulation is replaced, consider application of vapor retarder on the warm side (interior side) of the insulated cavity. Vapor retarder placement is critical for moisture vapor control;
  4. Evaluate whether a reflective "cool" roof will reduce cooling loads. Investigate what level of cleaning/maintenance is required to avoid performance degradation;
  5. Evaluate effectiveness of roof cavity ventilation;
  6. Find places where walls open into cavity and fire-stop and draft-stop these openings to reduce/eliminate open communication between roof and wall cavities and to reduce thermal siphoning of moisture vapor from the basement;
  7. Confirm that floor joists at top of basement walls are fire-stopped and draft-stopped. Check chimney cleanouts also;

- Replace the roof. This is a priority project for obvious reasons, and can now move forward, informed by the Environmental Improvements Plan:
  1. Resolve the insulation and performance questions outlined above;
  2. Replace the roof using a temporary intersection at the parapet cap. The permanent intersection detail will be applied with the stucco restoration;
  3. Provide overflow scuppers in the parapet (far corner; reopened mid-roof scupper): install overflow scupper in every drainage zone.

- Develop and implement a plan for conservation of the murals on the interior of the house, noting that mural conservation will require access through the exterior stucco):
  1. Secure a proposal for investigation and conservation treatment of the murals from a conservator who specializes in /architectural finishes/reverse-painted glass and who can work collaboratively with the building conservation team;

2. Develop funding for the mural conservation;
3. Perform material analysis and look for iron-oxide-based plaster undercoat;
4. Open the exterior wall and investigate the cavity behind the mural;
5. Develop a design to protect cavity side of mural areas from moisture and condensation;

- Restore the stucco:
  1. Perform testing to determine original stucco materials and stucco mix design, original and subsequent paint types, vapor permeability and crack susceptibility of both the original and the replacement stucco and the paints;
  2. Confirm that the conservation treatment of the interior murals is complete and successful;
  3. Determine necessity and placement of expansion/crack control joints;
  4. Investigate stucco and coating materials maintenance and cleaning needs. Investigate new vapor permeable, anti-microbial, water-resistant masonry coatings but also consider indoor air quality and health.

- Sequencing:
  1. Complete all major improvements in five to ten years;
  2. Implement mitigative measures now, including source moisture control;
  3. Replace roof. This work is necessary now;
  4. Restore windows and doors while continuing winter panel insert program. This must be done before stucco restoration because frame restoration will affect stucco. Do one or two sample windows now so that problems can be resolved and costs can be identified. Investigate permanent secondary glazing. Restoring the windows is essential to reducing energy costs and further stabilizing the interior environment;
  5. Conserve the murals after the roof replacement;
  6. Restore exterior stucco. Restore a sample section first so that problems can be resolved and costs can be identified before contracting for the full treatment.

SUMMARY

The *Frelinghuysen Morris House and Studio* has benefited from a careful, thoughtful and reflective, rather than reactive, approach to stewardship and resolution of conservation issues. The environmental management is very good, especially considering the envelope and climate; however, the energy consumption is high. This report outlines a plan that should result in energy cost reduction in the future. Many of the recommended strategies involve the building envelope and are necessarily interventive and therefore must be planned and executed in conjunction with, and in correct sequencing of, necessary repairs to the architectural fabric. Implementation of these strategies must also take into account the special considerations of embedded artistic features such as the wall murals.

Watson & Henry Associates and Wendy Jessup and Associates, Inc., are pleased to have been a part of this important project, and look forward to advancing the conservation and stewardship of the *Frelinghuysen Morris House and Studio* in the future.