New York State Energy Research and Development Authority

High Performance Insulation in Existing Multifamily Buildings: A Demonstration Project Using Aerogel Materials

Final Report

November 2013

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High Performance Insulation in Existing Multifamily Buildings: A Demonstration Project Using Aerogel Materials

Final Report

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Abstract

The project sought to demonstrate the viability of using an aerogel insulation system to retrofit the exterior walls of an occupied solid masonry multifamily building with minimal disruption to occupants. In situ heat transfer measurements, energy modeling, and utility use comparison were to be used to determine the installation's effectiveness. Despite the financial incentives, it proved considerably more difficult than anticipated to secure a host site, owing to tenant concerns and, presumably, the general slowing down of investments caused by the recession meant that there were fewer possible options. A host site was secured after nearly three years of attempts, although it did not meet all the initial parameters of the project. Specifically, the building was undergoing a major renovation which meant that a utility billing analysis would not have been able to isolate the effect of the insulation system. Also, because apartments were being vacated for a long period to accomplish the full work plan, we could not prove how quickly an aerogel-only scope of work could be completed. The installation went smoothly and the site owner reported being very satisfied with the material and its ease of use, but concerned with cost. Measured thermal performance of the aerogel insulation matched the manufacturer's claims.

Key Words

aerogel insulation

structural masonry wall insulation

multifamily retrofit

nanotechnology

Table of Contents

Summary

Conservation Services Group (CSG) and Aspen Aerogels (Aspen) set out to demonstrate the use of an innovative insulation product to address high energy consumption in traditionally hard-to-treat multifamily buildings in New York State. The project goals were to provide energy savings to building owners and residents, improve comfort in the buildings, and address marketing barriers to new building products/technologies. The CSG Team intended to investigate insulation challenges in multifamily buildings using Aspen Aerogels' Spaceloft®, which is insulation that delivers high R-values in a thin profile and is applied to the interior surface of the building's exterior walls. This product would allow contractors to more easily treat traditionally un-insulated (or under-insulated) masonry buildings, saving energy without losing as much apartment floor space as would be required with other approaches, eliminating the need to relocate existing services on exterior walls (e.g., electrical and heat distribution), and with limited disruption to occupants. By demonstrating the product's efficacy through this project, we would show the potential for wider application throughout the State and anywhere else such buildings are in need of thermal improvement.

In addition to the environmental and energy goals, the project aimed to address some typical market barriers that a new technology faces. Participating in a demonstration project gave aerogel insulation a chance to show its energy and economic effectiveness, which would have been difficult without the help of the grant from the New York State Research and Development Authority (NYSERDA). This unique nanoporous insulation has a relatively high material cost, but the project intended to demonstrate the distinction between the cost of the material versus the installed cost of a system in which reduced labor costs offset the higher material cost. The project also introduced the technology to the wider marketplace of building owners and construction contractors, who are unfamiliar with or uncertain of its advantages and hesitant about its higher price point. The demonstration project validated this approach to the insulation of existing masonry structures.

The plan was to identify a suitable building with willing ownership and occupants, and to install the aerogel insulation system as a standalone measure (i.e., without other efficiency improvements made at the same time). The isolation of this improvement would have provided multiple benefits. First, it would have allowed us to determine the extent to which household disruption could be minimized, with the premise that a well-coordinated effort might require occupant relocation for a very brief period when compared to what a traditional insulation upgrade would involve. (If properly staged, the work takes only two days and creates a minimum of mess and disruption.) Second, installing just the insulation measure would have made it more straightforward to perform a savings analysis using actual metered energy consumption versus relying on modeling to estimate pre- and post-consumption for the building.

After three years of searching, we found a willing and able participant, Bronx Pro Real Estate Management (dba TPT Davidson Avenue LLC), which was acquiring buildings at 1770 and 1780 Davidson Avenue in the Bronx. However, one important aspect of the project diverged from our original plan: TPT would be conducting extensive renovations throughout the buildings, essentially redoing each apartment with new windows, heating systems, appliances, and finishes. This renovation meant that two key features of the original project would not be achieved. We could not be able to assess the speed and ease with which an insulation-only improvement could be performed, or perform the direct energy consumption comparison based on utility bills. Despite these shortcomings, NYSERDA agreed to proceed with the project so that the other aspects of the demonstration could be explored.

The actual installation of the aerogel insulation went very smoothly, although there were delays due to other aspects of the renovation. Contractor training on proper storage, handling, and installation of the material went well, and the building management company identified no obstacles. Aspen representatives made multiple site visits to observe installation practices, and CSG performed an on-site heat flux analysis to measure the installed performance of the system. During one of the CSG site visits, while using IR thermography to identify suitable locations for the measuring equipment, we noted evidence that some of the corners had not been fully insulated. Once we communicated the issue to TPT and Aspen, Aspen addressed it with installer training on its subsequent site visit.

1 Material Description

Aerogels are open cell, nanoporous materials that have a very high proportion of free void volume (typically more than 90 percent) compared to conventional solids and to traditional insulation materials. Their high pore volume, low solid content, and twisted amorphous inner structure result in low values of thermal conductivity. First invented in the 1930s, aerogels have long been studied for their remarkable properties, including lowest thermal conductivity value of any material.

Silica aerogels prepared via sol-gel processing have some of the best thermal properties of any solid insulation material known. Among its many values, this material provides significant thermal protection in a narrow profile, making it an excellent choice as insulation when there is limited space. The pores, on the order of 10 nanometers (nm) in diameter, are formed by the open silica lattice structures, which have dimensions on the order of 1-2 nm. Essentially, an aerogel is “puffed-up sand” with up to 99 percent open porosity.

Aerogels also have hygrothermal advantages in buildings because they are hydrophobic (sheds liquid water) while being vapor permeable. This combination is resilient and forgiving and helps protect building assemblies against moisture-related degradation. Also, the manufacturing process is flexible so that aerogel insulation can be bonded to any number of traditional construction materials that are selected for interior or exterior placement, and designed with the appropriate vapor permeability for a particular application. Although the original proposal described laminating the aerogel insulation to gypsum wallboard at the factory, aerogel sheeting was ultimately put up in layers and then covered with gypsum wallboard.

The CSG Team intended to investigate insulation challenges in multifamily buildings using Aspen Aerogels’ Spaceloft®, which is insulation that delivers high R-values in a thin profile and is applied to the interior surface of the building's exterior walls. This high R-value/thin profile feature means a less thick insulation layer is need on exterior walls to deliver energy savings than would have been required with competing products. This reduced thickness means slightly less floor area is lost in the apartment for a tenant when insulating with aerogel as compared to other materials.

2 Proposed Evaluation Methodology

Two categories of data were proposed to evaluate the energy savings performance achieved through reduced heat transfer through walls: utility bill analysis and direct measurement of temperatures.

Utility billing analysis comparing pre- and post-aerogel heating/cooling energy consumption would be normalized for weather and occupancy changes. This analysis would require both historical records of energy consumption and a complete heating and cooling season to pass after installation. Also, as noted, a direct consumption comparison would be possible only if the aerogel measure was the only significant change to the building between the two periods.

Direct measurement of temperatures through the existing and the new wall assembly would allow for calculation of effective R-values and the efficiency improvement of the new wall system over the existing one. This measurement requires placing heat flux sensors in the various layers of the assembly during construction, and logging the data over a period of time.

Due to the confounding factors driven by a full building rehab, we could not do long term evaluation based on analysis of the utility bills. Although the heating plant replacement called for in the overall improvement plan was not implemented during the course of our demonstration project, there was extensive work to the building envelope including new windows and as such a utility bill comparison was not possible. As an alternative, we performed an engineering analysis using TREAT software, which is described in detail in Appendix A. The same engineering approach was used to determine cooling savings.

3 Site Identification

Several candidate buildings were investigated over more than three years, with numerous efforts being thwarted due to various reasons including resident objection, economic driver differences between owner and tenants, poor physical candidate buildings, and preference by the owner for other upgrades. Finally, Bronx Pro's Davidson Avenue cluster in the Bronx was identified.

3.1 Initial Candidate Buildings

The following buildings are examples of specific buildings locations that were pursued with significant effort:

- 2008-2009: A co-op housing building in Queens—This 258-unit co-op housing building mainly occupied by elderly residents. Permission to go forward with the project was granted by the Co-op Board, including a cost-share contribution. The project required a vote by residents, and the CSG/Aspen team gave a presentation to them. The response was nervousness about using a new material in the building, concern over disruption to the occupants during construction, and insistence among at least some residents that wall finishes would need to be returned to their original condition. (e.g., custom paint colors and patterns would need to be delivered.) This detail led to a vote not approving the project.
- 2009-2011: A mixed-income housing complex in the Hudson Valley— This building was inspected by CSG and Aspen, and determined to be a good candidate for a Spaceloft retrofit. Winn had also been considering an upgrade to the building, and then approached the New York Department of Housing and Community Renewal for assistance in upgrading. DHCR required the standard energy audit for the complex and recommended funding several technologies, including new boilers. A number of recommendations were presented to DHCR, and although the full package (including aerogel) passed their SIR requirements, the decision was made to fund only measures that screened individually. In addition, aerogel was not a proven material (inherent in the NYSERDA demonstration project) and DHCR did not feel it was appropriate to fund a pilot of an unvalidated new technology. Hence the building was shelved for this NYSERDA project after substantial effort was expended.
- 2011. Nine multifamily buildings across New York — These buildings were visited and evaluated, but none turned out to be good candidate buildings, because of the existing construction, economics of owner-tenant driving forces, or other factors.

3.2 Final Site Selection

In 2012, Davidson Avenue Cluster in the Bronx shown in Figure 1 was selected. The rehab of these buildings, owned by TPT Davidson Avenue LLC, and operated by Bronx Pro, ultimately became the confirmed site for the aerogel installation project. Design and construction costs totaled $19.8 million. Construction began in July 2012. Estimated completion was July 2014, and actual completion is projected for December 2014.

Figure 1. 1770 (left) and 1780 (right) Davidson Avenue

In mid-2011, Bronx Pro began managing six city-owned properties along Davidson and Monroe Avenues in the West Bronx through New York City's Department of Housing Preservation and Development (HPD) Third Party Transfer Program. Bronx Pro also participated in HPD's Participating Loan Program with these buildings. The properties were occupied and include 185 rent stabilized units.

In an effort to ensure long term stability, the Bronx Pro plan was to rehabilitate all six buildings. Although work varied according to current conditions in each building, all units received new kitchens and baths, plumbing, roofs, upgraded electrical, energy efficient windows, intercom and electronic key card access systems, and new elevators where applicable. In an effort to save energy, the interior of all exterior walls will be insulated and highly efficient boilers and hot water heating distribution systems will be installed in all six buildings. All exterior facades were repaired, painted, and cleaned; and existing lobbies, public hallways, and courtyards were upgraded.

HPD provided the financing through its PLP program with JP Morgan Chase acting as the private lender. NYSERDA's contributed toward the aerogel insulation material and installation costs in 1770 and 1780 Davidson Avenue. A Host Site Agreement was executed between CSG and TPT Davidson Avenue LLC in July 2012.

Figure 2. 1770 (top) and 1780 (bottom) Davidson Avenue Site Plans

4 Demonstration Plan

4.1 Modification of Original Plan

The original project plan called for several elements that were not able to be satisfied given some of the constraints of the Davidson Avenue buildings. Specifically, no direct long term billing comparison was possible. The comprehensive set of energy efficiency improvements that were part of the renovations prevented the effect of the aerogel portion of the project from being isolated. The window replacement was the principal confounding factor. (Although the new boilers and baseboard radiation were installed, they have not been activated as of the writing of this report.)

We were also unable to assess the presumed limited impact of the aerogel installation on tenant relocation. Our assumption going into the project was that the aerogel insulation system, being installed as the only energy efficiency measure, would allow for fast construction times and a correspondingly short displacement of tenants from their apartments. However the scope of renovations at Davidson Avenue was quite large, requiring relocation of tenants for weeks and months. There was no way to separately assess the impact of installing the aerogel insulation. The CSG team petitioned NYSERDA to remove these requirements from the project, and the request was granted.

4.2 Project Design Approach

A comprehensive site assessment provided details to allow the design team to determine the best configuration of insulation/finish materials to be used for the project. CSG and Aspen Aerogels completed a preliminary thermal and cost analysis, which led to two design approaches being proposed to the building owner.

The first option was a single layer of Spaceloft 10 blanket (10 mm thickness) aerogel insulation attached directly to the existing interior surfaces of the exterior walls with a new gypsum board and traditional joint skim finish. The second solution added a second layer of Spaceloft 10, using the same finish. The building owner selected the second (two-layer) option. Based on this approach, Aspen developed a statement of work (SOW) and installation methodology. The SOW was refined with TPT and is shown in Appendix B. Preliminary installation instructions were provided to the contractor. Combining the document in Appendix B along with the developed best practices resulted in a deliverable installation manual.

4.3 Identifying and Training Contractor

A key element of this demonstration was verifying that aerogel insulation systems can be readily, easily, and reliably installed by traditional contractors. TPT selected Home Builders 1 as the contractor for the project. Aspen conducted on-site training for contractor personnel working on this project. The initial training included material handling, cutting and installing as well as waste minimization and management. The contractor refined some of the operations and developed some best practices for the cutting, handling and installation of the aerogel materials. Aspen conducted a follow-up site visit to capture refined operations and best practices, which are included in Appendix C.

4.1 Installing Aerogel Insulation System

Aspen supported TPT and Home Builders 1 during the installation phase, making multiple site visits to consult with both groups on installation detailing. Aspen also coordinated the ordering and delivery of the Spaceloft 10 material with TPT. The material was stored in the building basements (shown in Figure 3), cut to size in a nearby work area, and brought in pre-cut lengths to the apartments for installation. The compact storage afforded by the relatively small thickness of the material and the fact that it is shipped in rolls meant that bulk shipments could be accommodated without disruption.

Figure 3. Aerogel Insulation Storage in Basement of 1770 Davidson Avenue

TPT planned an aggressive work schedule that was delayed by the need to vacate apartments in stacks in order to accommodate vertical piping runs with the least overall disruption to tenants. We initially anticipated completion in the summer of 2013, but work was actually not completed until December of 2013.

TPT consistently reported no problems with the installation of the aerogel system and no shortcomings with the product other than price. Nothing unexpected arose for management or contractors during the project, and the contractor quickly and easily picked up techniques for handling and installation, and reported no difficulties. According to the installers, the aerogel installation became "just another thing they have to do."

While the installers initially worked without personal protective equipment, they quickly moved to using gloves and masks once they began handling the material and felt its slippery and desiccating silica residue. One unforeseen benefit they noted was the resilience of the stored material during a small fire in the storage area; the aerogel material was undamaged by the fire or the water that was used to extinguish it. TPT reported being so impressed with the aerogel that they have begun specifying it as standard practice in other renovation projects whenever the budget can accommodate, and are considering using it as they return to buildings that were rehabilitated in the past few years but are now due for cosmetic uplifts and painting.

5 Evaluation

As previously noted, the original evaluation plan called for a year-over-year comparison of the energy consumption of the selected building(s) based on measured fuel consumption, but due to the confounding influence of multiple measures being performed on the Davidson Avenue properties the plan was modified to instead allow for a calculated analysis of savings using energy modeling software. That analysis is provided Appendix A, along with the test procedure and results of the in situ heat flux tests that were conducted to measure the material's performance.

The heat flux testing was conducted in three 2-week periods from January 3 through February 14, 2013 on pairs of apartments: one apartment had been retrofitted with the aerogel insulation system and other had not. During each test period, the apartments were fitted with temperature sensors and onsite recorders to measure and document the interior and exterior air and surface temperatures. The pairs of apartments were selected to match exposure to sun and wind as closely as possible, and to fit into the construction schedule of the project. One sensor was disrupted by the construction crew, but enough data was gathered to confidently assess the performance of the system at R-7.75 (including gypsum board and material compression), which closely matches the manufacturer's claim of R-8.

The effective R-values of the untreated and treated walls were used to model the pre- and post-insulation energy use in TREAT software, matching them as closely as possible to available wall profiles in the software libraries. Other assumptions about set points, ventilation, cooling, and other parameters are detailed in Appendix A. Annual energy savings for heating and cooling were modeled at 384 MMBtu, with resulting savings of $8,215 based on fuel costs of $3.10/gallon for fuel oil, $1.50/therm for natural gas, and $0.21/kilowatt-hour (kWh) for electricity. Using a discount rate of 3 percent and an assumed measure life of 40 years, a maximum installed cost of $7.37 is needed to achieve an Savings to Investment Ratio (SIR) ≥1.0.

6 Conclusion

The technical performance of the aerogel insulation system met expectations. The material was available per schedule, the installers demonstrated a fast learning curve, the installation proceeded generally without problems, and its thermal performance fulfilled promises. The site owner reports intentions to make installation of aerogel a standard practice, assuming that their project budgets can accommodate the up-front cost.

We were not, however, able to demonstrate some other of the project's initial contentions, such as that the aerogel system can be installed in a very tight timeframe and with minimal disruption to occupants. This limitation was due to the larger scope of work in the eventual host site building, and stemmed from being unable to find a building owner who could embark on an insulation-only project. Although we can infer that the system could be installed as anticipated in an occupied dwelling, we still do not know about managing a tight schedule with tenants involved. There were no unforeseen technical problems that arose during the Davidson Avenue work, however, the work took place in unoccupied apartments and tenants' expectations were in the context of a comprehensive overhaul. And since the Davidson Avenue renovations included replacing the heating distribution system and electrical service, we did not learn how aerogel would be installed if existing systems were to remain in place.

Our experience does sugges that aerogel is not a “silver bullet” in terms of motivating building owners to proceed with work. In addition, it did not seem to overcome other common obstacles such as tenant concerns or the array of issues that a building owner faces when considering any major renovation, regardless of the insulation system being considered. It should be noted, however, that this demonstration project launched simultaneously with the recession which dampened investments across the board, making it less likely that any major work would proceed.

Appendix A: Evaluation Report

Evaluation Report

NYSERDA Aerogel Demonstration Project

Morgan Pileggi

July 24, 2013

Contents

Summary

This report details the monitoring and analysis methods used for evaluating the thermal performance the flexible aerogel blanket insulation system. Two layers of 10-mm Spaceloft® blankets were installed in a six-story multifamily building located at 170 Davidson Avenue, Bronx NY. The subject building consists of approximately 74,500 square feet of conditioned space, including 65 apartment units, and is constructed of brick and concrete masonry units. The building is currently heated by a #4 Oil single pipe steam boiler with cast iron radiators. The heating system is in the process of being converted to natural gas with fin-tube-type hot water baseboard. The thermal performance of the walls treated with the aerogel system was compared to that of the untreated walls of the same base construction in the same building during the same period of time. This work was completed as part of the NYSERDA aerogel demonstration project. Testing of the installed product was started on January 3, and was completed on February 14, 2013.

The performance of the aerogel system was quantified by measuring the conductive heat loss coefficient (U-factor) of exterior walls that had been treated with aerogel in comparison to exterior walls that had not been treated. The reduction in heating and cooling cost due to the aerogel treatment was estimated using a computer simulation model and the measured U-factors of the untreated and treated exterior walls. TREAT was the computer program used to simulate energy usage in this evaluation.

Trial	Base Wall	Average dT	Treated	Average dT	Aerogel
1	**4.84**	18.4	**11.01**	32	**6.17**
2	**4.53**	21.6	**14.4**	37.3	**9.87**
3	**4.25**	39.3	**11.46**[1]	35.2	**7.21**
Average	**4.5**	**26.4**	**12.3**	**34.8**	**7.75**

Table 1 - Measured R values of wall assemblies excluding air films

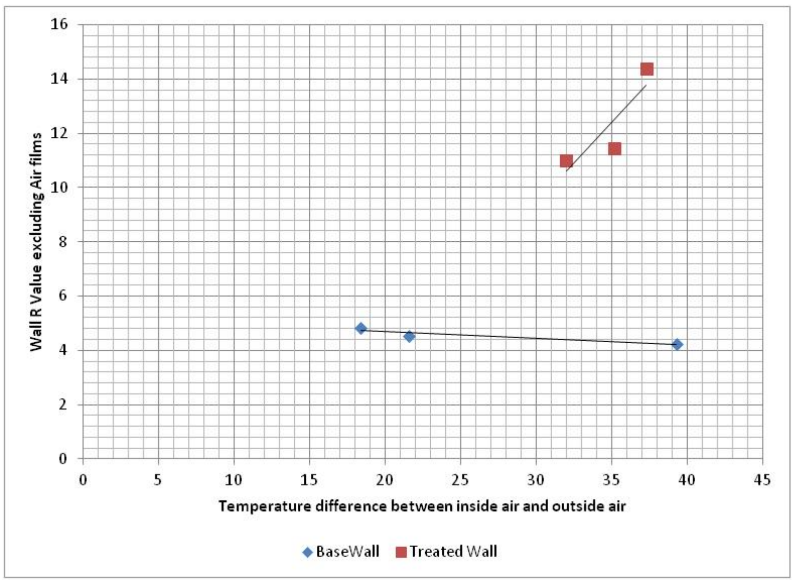


Figure 1 –Wall R values and Delta T across walls

TREAT model results:

Aerogel Treatment Annual Savings

Energy 384 MMBtu

Cost US$8215

Maximum installed cost for a Savings to Investment Ratio (SIR) equal to or greater than 1 is $7.37/ sq ft ($192,563 total cost).

[1] The exterior sensor data for the Treated Trial 3 test was corrupted. Concurrent exterior conditions were used to estimate the exterior surface temperature and therefore calculate the U-factor for this test. The resulting R-value is in line with the values for the other two Treated walls. For more details see Annex A: U-Factor Calculations.

Number and Location of Units Sampled

The U-factor of wall sections that had been treated with the aerogel system and wall sections that had not been treated were both measured. Three trials were performed, with each trial consisting of measurements for both treated and untreated walls during the same time period. All test locations were in heated apartment units. All testing was performed on exterior walls with similar base wall construction. Visual inspection and Infrared thermography were used to select sensor locations and ensure that the measurements were of typical sections of the exterior wall. The wall pairs of simultaneously monitored apartments were selected to minimize dissimilarity in terms of exposure, and exterior sensor locations were selected to reduce potential anomalies created by solar insolation.

All units in the building located at 1770 Davidson Avenue, Bronx NY were assessed for suitability as shown in the following table:

Unit rank for test site			
Ideal	OK	Poor	Unusable

	Unit										
Floor	A	B	C	D	E	F	G	H	I	J	K
1	no Unit A on this floor	Accessible to Vandals	Accessible to Vandals	No Walls Large enough	LV/DA east or semi shaded south	BR1 facing north in shade	BR1 east or semi shaded south	BR1 facing north in shade	BR1 facing east	v	v
2	No Walls Large enough	BR2 semi Shaded south wall	BR2 facing south	No Walls Large enough	LV/DA east or semi shaded south	BR1 facing north in shade	BR1 east or semi shaded south	BR1 facing north in shade	BR2 facing east	BR1 south or west	BR2 facing north in shade
3	No Walls Large enough	BR2 semi Shaded south wall	BR2 facing south	No Walls Large enough	LV/DA east or semi shaded south	BR1 facing north in shade	BR1 east or semi shaded south	BR1 facing north in shade	BR1 facing east	BR1 south or west	BR2 facing north in shade
4	No Walls Large enough	BR2 semi Shaded south wall	BR2 facing south	No Walls Large enough	LV/DA east or semi shaded south	BR1 facing north in shade	BR1 east or semi shaded south	BR1 facing north in shade	BR1 facing east	BR1 south or west	BR2 facing north in shade
5	No Walls Large enough	decorative Brick	No Walls Large enough	No Walls Large enough	LV/DA east or semi shaded south	BR1 facing north in shade	BR1 east or semi shaded south	BR1 facing north in shade	BR2 facing east	BR1 south or west	decorative Brick
6	No Walls Large enough	decorative Brick	No Walls Large enough	No Walls Large enough	LV/DA east or semi shaded south	BR1 facing north in shade	BR1 east or semi shaded south	BR1 facing north in shade	BR2 facing east	BR1 south or west	decorative Brick

Table 2 –Apartment suitability for test cases

After meeting with building management and visiting the site, evaluators selected the following units based on suitability, availability, and whether or not the unit had been treated with the aerogel system:

Trial 1 time period: 1/3/13 to 1/18/13

Treated 4H	Untreated 4B
North	Shaded (alcove) South

Trial 2 time period: 1/18/13 to 1/31/13

Treated 5g	Untreated 3B
Shaded (alcove) South	Shaded (Alcove) South

Trial 3 time period: 1/31/13 to 2/14/13

Treated 6G	Untreated 4E
Shaded (alcove) South	Shaded (alcove) South

Though most of the test locations were on south-facing walls, these wall sections are located in alcoves that provided shading from direct solar exposure to minimize the sun's effect on measured temperatures.

Number, Type, and Location of Sensors and Dataloggers Used

Each of the three trials consisted of two simultaneous tests: one test on a wall section treated with aerogel and one on an untreated section. Two identical test apparatuses were installed. Each test apparatus used four temperature sensors (inside air, inside surface, outside surface, and outside air) connected to a HOBO U12-006 data logger. In addition one Hukseflux HFP01 heat flux sensor was attached to the inside surface of the test wall and connected to a MadgeTech datalogger as shown in the following diagram.

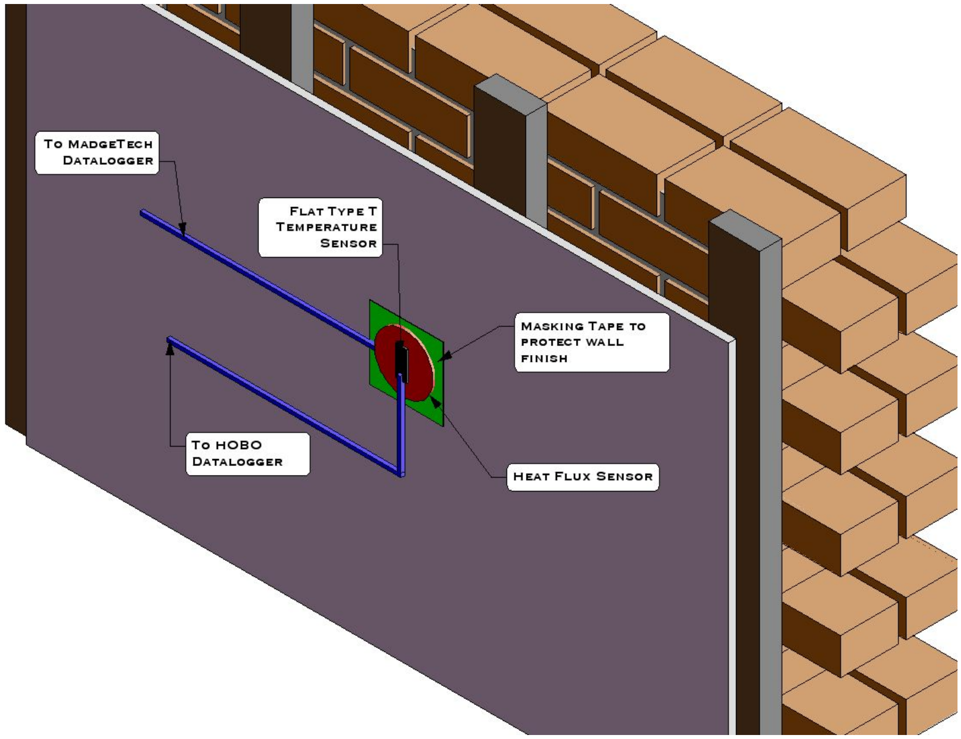


Figure 2 – Interior Equipment Setup Schematic

Figure 3 – Interior Equipment Setup Photo

A 5 inch square of painters tape was applied to the inside surface of the test wall as shown in the photograph above. The heat flux sensor was adhered to the painters tape using double-sided tape.

The indoor air temperature sensors was an Onset TMC20-HD Water/Soil Temperature sensor with an Onset RS3 radiation shield and was mounted to the apartment unit wall with a bracket at the same approximate height as the heat flux sensor.

The Inside surface temperature sensor was an Onset TMC20-HD Water/Soil Temperature sensor adhered to the face of the heat flux meter using tape.

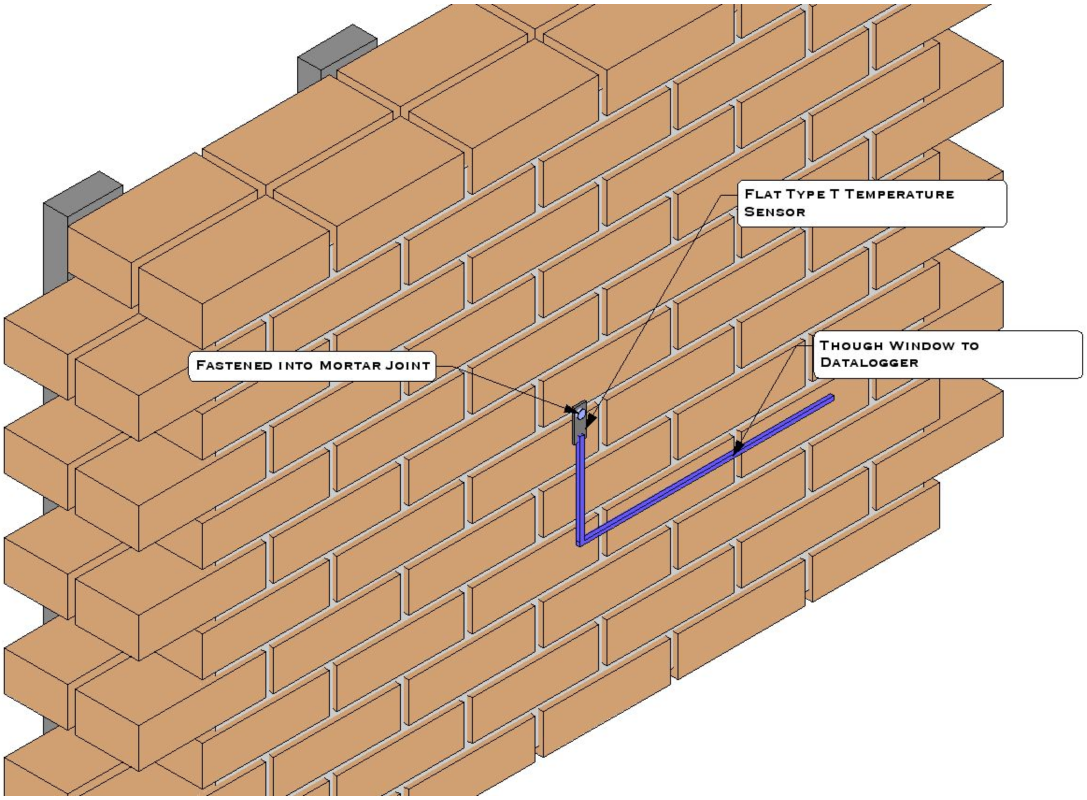


Figure 4 – Exterior Equipment Setup Schematic

Figure 5 – Exterior Air Temperature Sensor Photo

Outside surface temperature sensors were Onset TMC20-HD Water/Soil Temperature sensors attached to the exterior cladding using mechanical fasteners and shielded from solar radiation with light grey plastic tubing as shown in the previous diagram and photograph.

Figure 6 – Exterior Surface Temperature Sensor Photo

Outside air temperature sensors (shown with green bracket in above photograph) were Onset TMC20-HD Water/Soil Temperature sensors mounted on brackets that were attached to the building cladding and shielded from solar radiation using an Onset RS3 radiation shield. Wiring for exterior sensors was routed though the nearest window opening to the datalogger inside the unit.

In two test locations (Treated 6G and Untreated 5G), it was not possible to connect the exterior sensors (exterior air and exterior surface temperature) to the main heat flux apparatus due to incompatible window locations. In these two cases, the external sensors were connected to an additional HOBO U12—006 datalogger located in the corridor. The data streams were combined for analysis.

Infrared thermography was used to ensure that the sensors were not located at sites of thermal bridging.

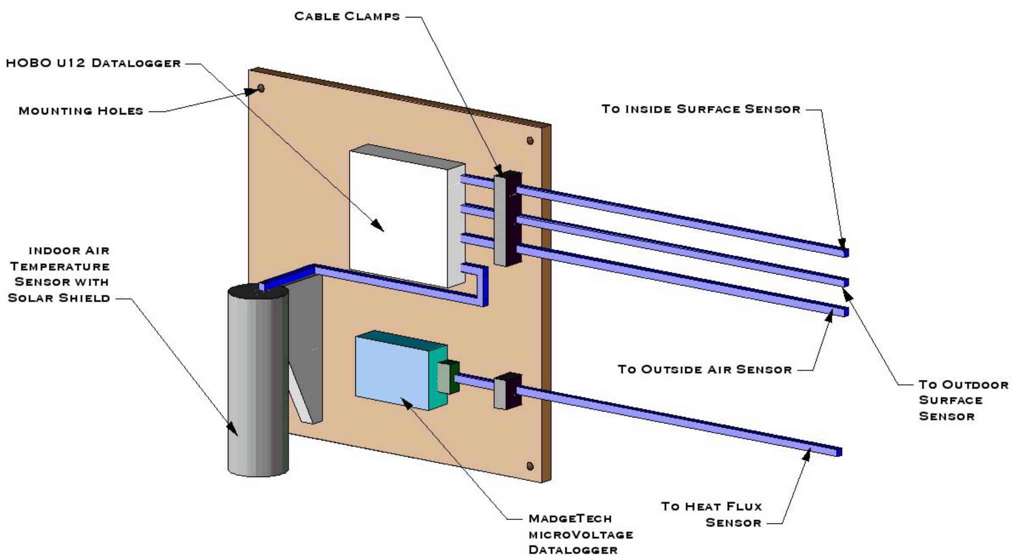


Figure 7 – Interior Instrumentation Board Schematic

Sensors and instrumentation boards (shown in the diagram above) were installed for a minimum of 14 days[2] at each test location.

[2] While all apparatus were left in place for a minimum of 14 days, only the first 5 days of data from the Untreated Trial 1 test was valid because the interior sensor was removed by construction workers. See Annex A U-Factor Calculations for more details.

Calculation of In Situ Thermal Performance of Aerogel System from Monitoring Data

The heat flux (Q) and surface temperatures were measured in six locations for 14 days; three locations were representative of the existing, untreated wall and three representative of the treated wall. The heat flux and temperature data were used to calculate the U-factor of the existing and treated exterior walls.

To reduce the effect of the wall's thermal storage, the average assembly U-factor was calculated as follows:

U = sum[i=1,n]{Qi} / (sum[j = 1,n]{insideTj} - sum[k=1,n]{outsideTk})

Where:

- *sum[i=1,n]{Qi}* is the sum of all heat flux values in the test period.
- *sum[j = 1,n]{insideTj}* is the sum of all inside surface temperature measurement in the test period.
- *sum[j = 1,n]{outsideTj}* is the sum of all outside surface temperature measurement in the test period.

This equation was taken from a similar study: Baker, Paul. Historic Conservation Group. 2011. "'**Historic Scotland Technical Paper 10** U Values and Traditional Buildings: In Situ Measurements and their comparison to calculated values."

The U-factor of the aerogel system was taken as the difference between the treated and untreated walls values. See Annex A for more details about U-factor calculations.

Modeled Performance of the Aerogel System Using Measured In Situ Thermal Characteristics

A simplified TREAT model was created to represent the building located at 1770 Davidson Ave, Bronx NY. The measured U-factors were used to select appropriate wall construction types for both the treated and untreated walls. Additional building data was obtained from Construction Plans and Audit data provided by Association for Energy Affordability (AEA).

Spaces		Floor Area Square Feet	Wall area Square feet
Basement		18,629	5,550
Commons		62,343	1,660
Apartments		12,174	32,660[3]

Table 3 – Space Areas

The building has two basements that were combined into one low ACH unheated space. Within the TREAT model, reference surface 774 (30 feet of stone with R=3) was used to represent both below grade and above grade walls.

All common areas were combined into one heated space. Common walls were represented using TREAT surface 113 (Plaster, Block, and Brick R=4). Above grade floors were observed to be wood frame construction with a variety of finishes. The ceiling surfaces were assumed to be framed construction with built up roofing.

All apartment units were combined into one heated space. TREAT surface 401 (Gyp board, 2x4, 12 inch block R=4.9) was used. The existing apartment walls are similar to the common area walls, but also include an additional layer of 2x4 framing and plaster. The R value of the TREAT surface 401 is 4.9, which is very close to the average measured value of 4.7. This decision is reasonable because using a value that is

[3] This number includes the total exterior wall area of the apartment spaces. The treatable wall area is less due to intersecting floors, ceilings and wall partitions. See Annex B for more information about TREAT modeling details.

slightly higher results in more conservative savings estimates. In addition, surfaces were added to represent the sections of exterior wall that was not treated with aerogel, because of intersecting partitions, floors and ceilings. Additional building components were based on audit information from AEA. See Annex B for more information.

All heating is provided by a #4 oil boiler, and baseline use is assumed to be domestic hot water (DHW) production. No electrical billing data was provided, so calibrating (or “truing up”) the model was impossible. Standard electrical baseloads were used. Infiltration and apartment setpoints were based on data from the AEA audit.

However, billing data for #4 oil was provided. Although the TREAT model cannot be calibrated without billing data for all fuels, the total heating oil (and baseline) consumption were used in the TREAT model to provide a rough estimate. The modeled use is the gallons of #4 oil consumption predicted by the TREAT model broken out by heating and DHW end uses. The normalized billing is the weather normalized gallons of #4 oil used, as determined by AEA from the actual billing data.

Oil #4 use	Modeled use (gallons)	Normalized billing (gallons)	Error
Heating	34,942.2	35,748	-2.3%
DHW	6,018.8	6,084	-1.1%

Table 4 – Fuel Oil Usage

The following adjustments were made to calibrate the model:

Apartment Heating thermostat was fixed at 74°F (no set back)

Commons Heating thermostat was fixed at 72 °F

Added ASHRAE 62.1 2010 compliant local exhaust ventilation (25 cubic feet per minute [cfm] per bathroom; 50 cfm per kitchen) was added for a total of 4875 cfm of continuous mechanical ventilation.

TREAT Model inspector (a model checking feature within TREAT that warns of possible input errors. Responses to each warning are provided.

- Building envelope: low R warning, single glazing warning, low percent glazing warning.
  - Envelope parameters are based on dimensioned construction documents and site visits.
- Lighting/appliances: no appliances use water warning
  - Appliances were not modeled for this project. Appliance data was not available and appliance consumption is not affected by the aerogel treatment.
- HVAC : combustion efficiency was not measured warning
  - Combustion efficiency was not measured. Combustion efficiency was taken from AEA audit data.
- Calculation results: Heating system more than 50% oversized warning; low Cooling Degree Days can result in poor results warning
  - Heat plant size is based on 65 apartment units and 112,000 Btu or input rating per unit. Part load factors are not used, so oversizing the heating plant does not affect the model results.
  - Cooling results may be poor due to low load/ poor modeling parameters. Electrical billing data, which is critical for accurately modeling cooling, was not available.

A surface insulation improvement was used to model the existing walls. TREAT surface 40 (12-inch block with 2” extruded polystyrene R = 13.3) was used for the aerogel treated wall. This surface type was the best match for both thermal capacity and R value. The average measured R value of the aerogel treated wall was 13.4. There were 26,128 sq ft of wall that could be treated with aerogel insulation.

	Base Building	Aerogel Treatment	**Savings**
Heating	$108,321	$100,167	$8,154
Cooling	$6,222	$6,161	$61
Lighting	$19,159	$19,159	$0
Appliances	$1,095	$1,095	$0
Hot Water	$18,658	$18,658	$0
Total	$153,455	$145,240	**$8,215**

Table 5 – Modeled Energy Costs

While cooling was included in the TREAT model, the results ($61 annual savings, see table above) should be taken with a grain of salt because of the challenges in modeling air conditioning usage in such a building. Unlike heating, there is no central cooling equipment. Common areas are not cooled while apartment units may have through-the-wall AC units that are individually controlled and of various efficiencies. The latent cooling load cannot even be estimated without additional instrumentation. It was assumed that 50% of the bedrooms had window-mounted AC units of 12,000 Btu/hr and a SEER of 12. Setpoints were based on AEA audit data.

The actual installed cost of the aerogel treatment will not be available until the project is completed later this year. As such, the modeled savings were used to calculate the maximum allowable installed cost for which the improvement will have an SIR of 1 or greater. The modeled annual savings for the aerogel treatment is 384 MMBtus ($8,215). The maximum installed cost for the treatment to be cost effective (SIR ≥1) is $7.37 per sq ft of treated wall or $192,563 for the total project. See Annex B for more details.

Long-term Evaluation from Utility Billing Analysis

Due to the confounding factors driven by a full building rehab, a long-term evaluation based on analysis of the utility bills was not possible.

The building rehab did not include replacing the heat plant during this season, but extensive work to the building envelope included new windows. Therefore, the utility bills were atypical and not useful for comparative analysis.

Annex A: U-factor Calculations

Sensor data was downloaded onto a laptop using logger software and exported as CSV files.

A propriety CSG Python script was used to aggregate and transform[4] the disparate data streams. The data was compressed to 5-minute intervals and converted to common units. This compressed data was then pasted into an Excel spreadsheet for analysis and plotting of the graphs that follow.

The temperature differences and the heat flux were used to calculate the heat loss coefficient for the inner air film (Uia), the wall (Uwall), and the outer air film (Uio)

Uia = Q / (Tia – Tis)

Uwall = Q / (Tis-Tes)

Uio = Q / (Tes-Tea)

where:

Q = heat flux

Tia = indoor air temperature

Tis = indoor wall surface temperature

Tes = exterior wall surface temperature

Tea = exterior air temperature

The U-value is taken as the average of all the calculated U-values.

[4] The Heat Flux data are logged as voltage measurements. These must be converted into Btu/sq ft using the manufacturer supplied calibration constant (K) and standard units conversion.
Q [Wm^{-2}] = Volts / {K [uV/Wm^{-2}] * 1,000,000}. The data is then converted from wattmeterSq to btu/sqft

The R-value is the inverse of the U-value.

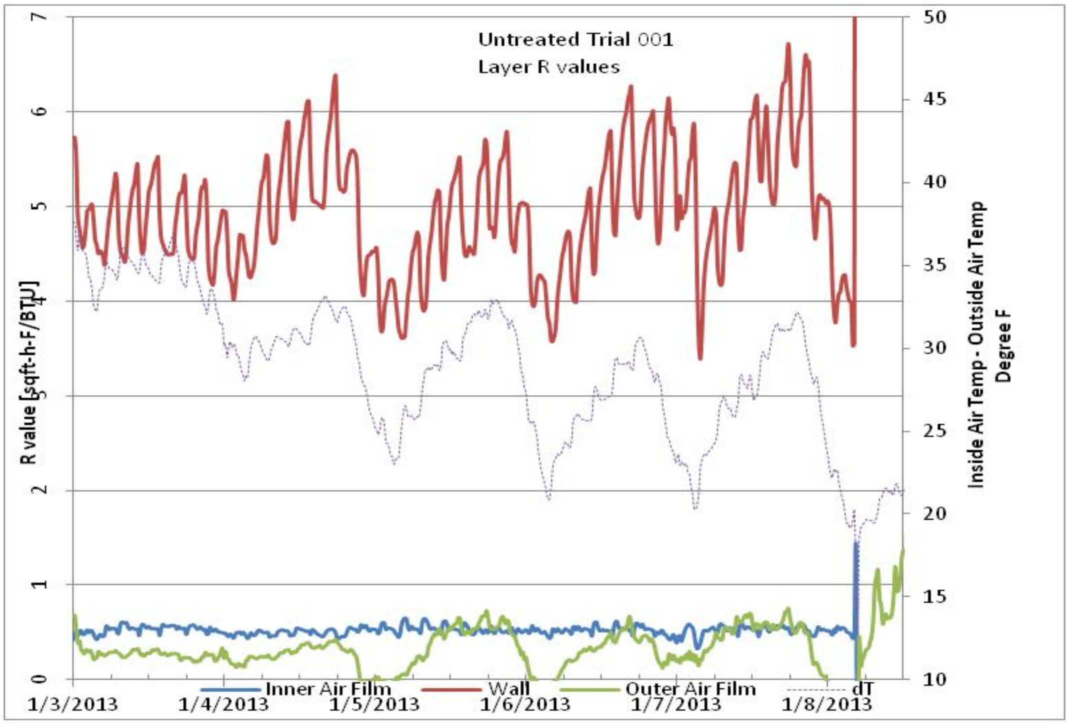


Figure 8 – Trial 1: Untreated wall layer R values over trial time

For the data in the above graph (Untreated Trial 001), the interior sensor was dislodged by work crew on 1/8/13. Remaining trial data was meaningless. From this graph, R value averaged 4.84 with a corresponding average dT of 18.4 °F (Tis – Tes).

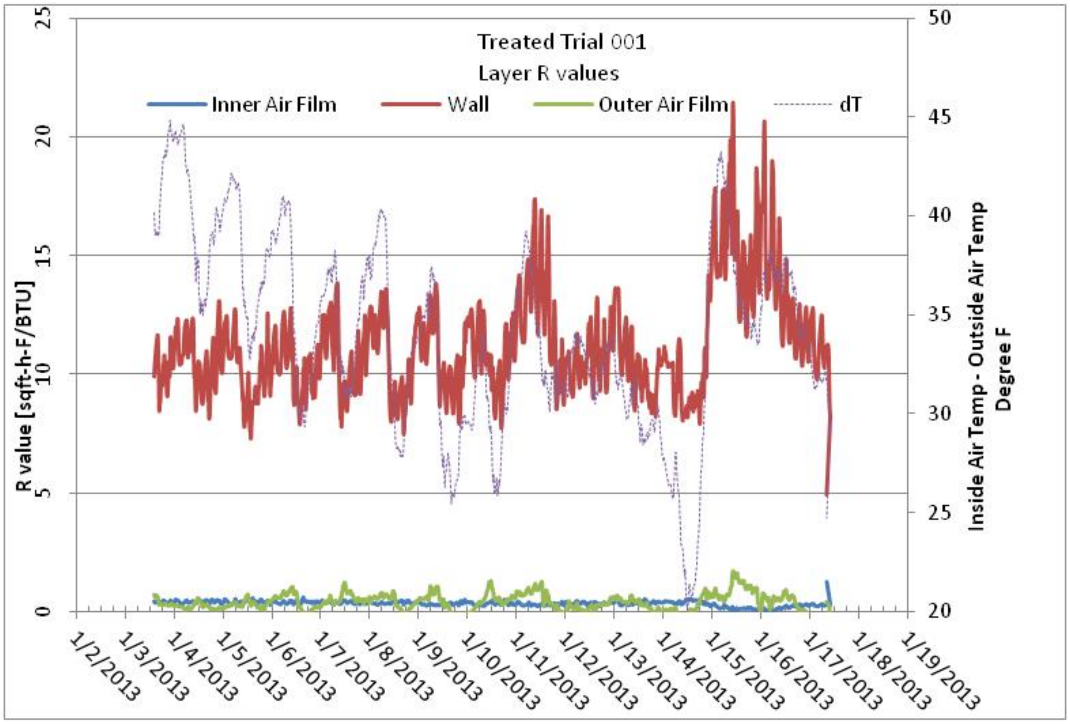


Figure 9 – Trial 1: Treated wall layer R values over trial time

For the Treated Trial 001 (graph above), R value averaged 11.01 with a corresponding average dT of 32.0 °F.

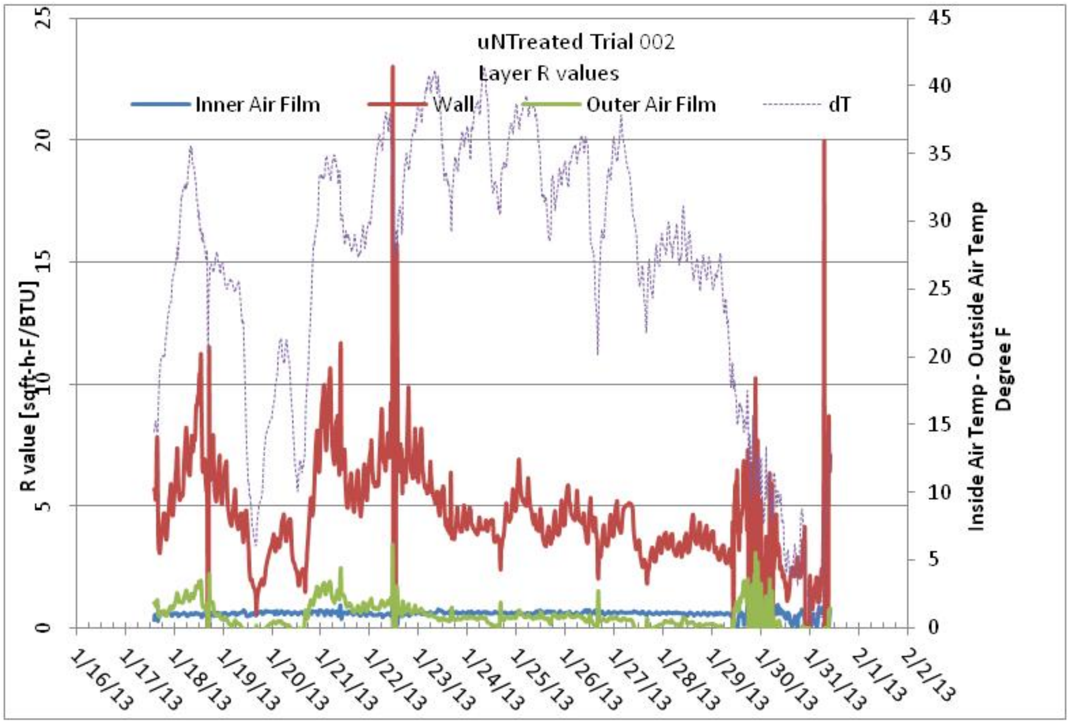


Figure 10 – Trial 2: Untreated wall layer R values over trial time

For the Untreated Trial 002 (graph above), R value averaged 4.53 with a corresponding average dT of 21.6 °F.

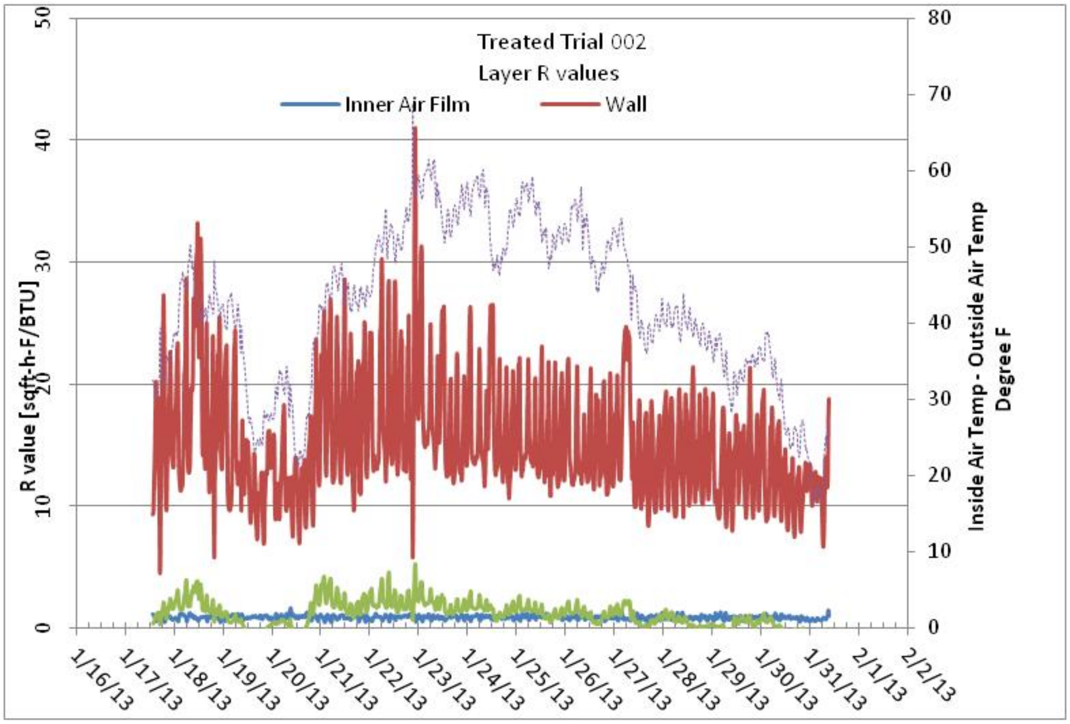


Figure 11 – Trial 2: Treated wall layer R values over trial time

For the Treated Trial 002 (graph above), R value averaged 14.4 with a corresponding average dT of 37.3°F.

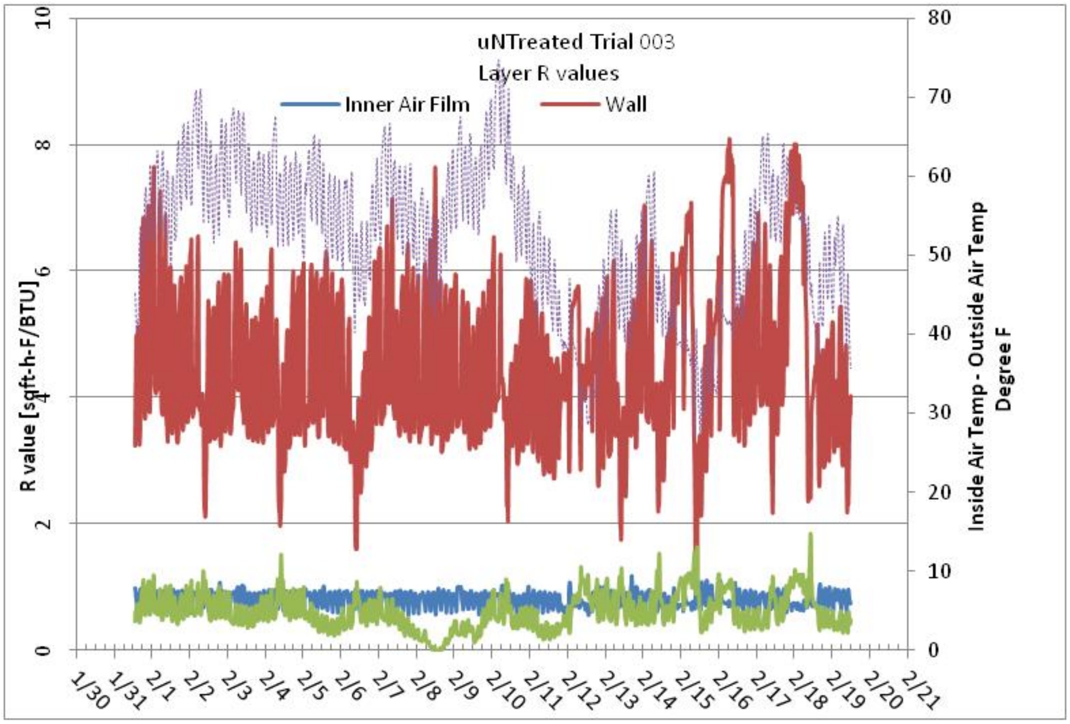


Figure 12 – Trial 3: Untreated wall layer R values over trial time

For the Untreated Trial 003 (graph above), R value averaged 4.25 with a corresponding average dT of 39.3°F.

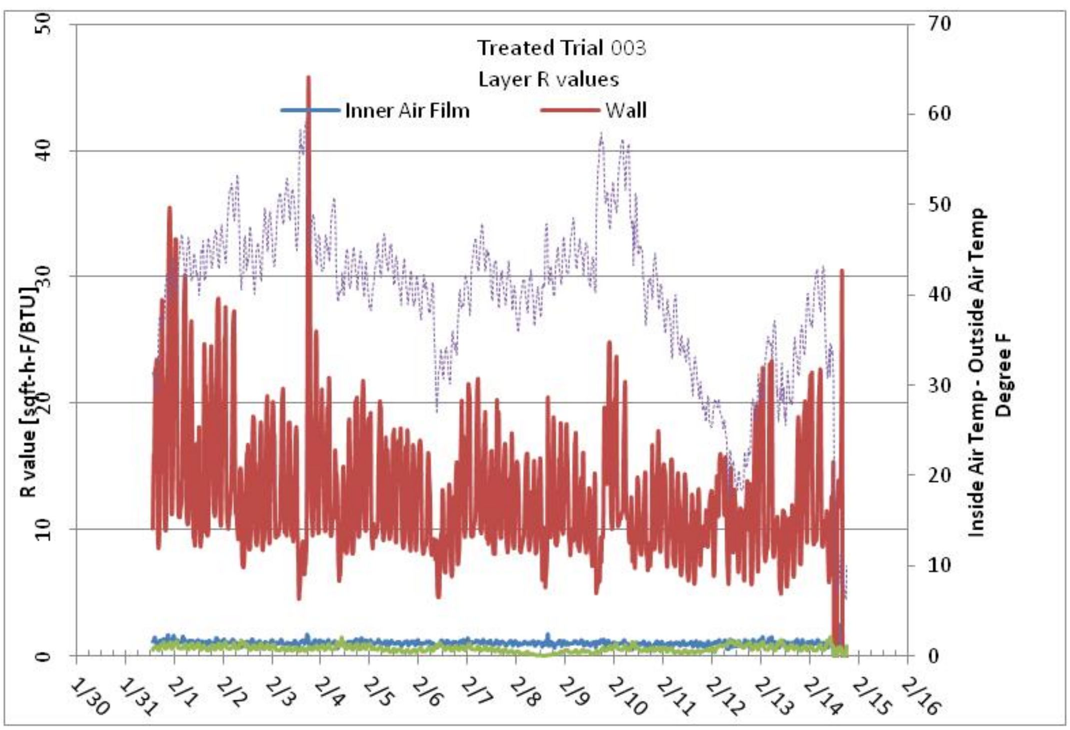


Figure 13 – Trial 3: Treated wall layer R values over trial time

For the Treated Trial 003 (graph above), R value averaged 11.46 with a corresponding average dT of 35.2°F.

The exterior temperature data (exterior surface temperature and exterior air temperature) for the Treated 003 trial was corrupted. These values are needed to determine the R value of the exterior air film. Cross plots from the previous trial show that while the R value of the exterior air film varies widely with changing weather conditions, the value from one sensor location to another is somewhat constant (see plots below). Although the correlation is not perfect (all the data would fall on an x=y line), it does allow an estimation of the R value of the Treated wall.

The exterior air film from Trial 3 untreated data (coincident time period) was used in place of the missing treated Trial 3 exterior temperature data resulting in a reasonable estimation of the wall assembly U-factor for this trial.

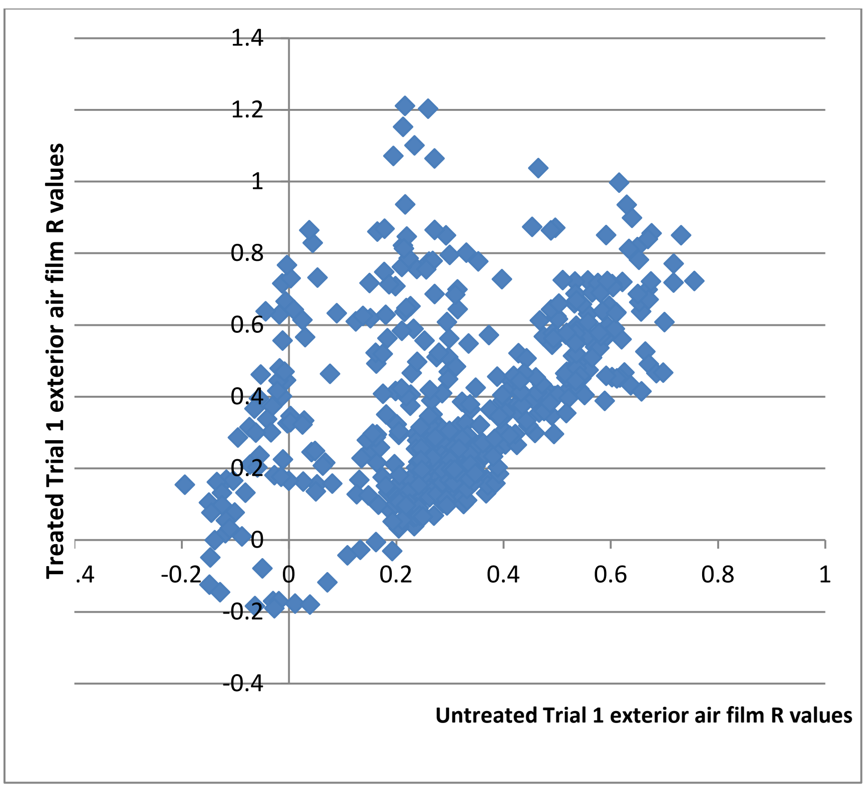


Figure 14 – Cross Plot of Exterior Air Film R-values for Treated and Untreated Trial 1 Walls

Cross plot of Exterior Air film R values for the Treated and untreated Trial 1 wall.

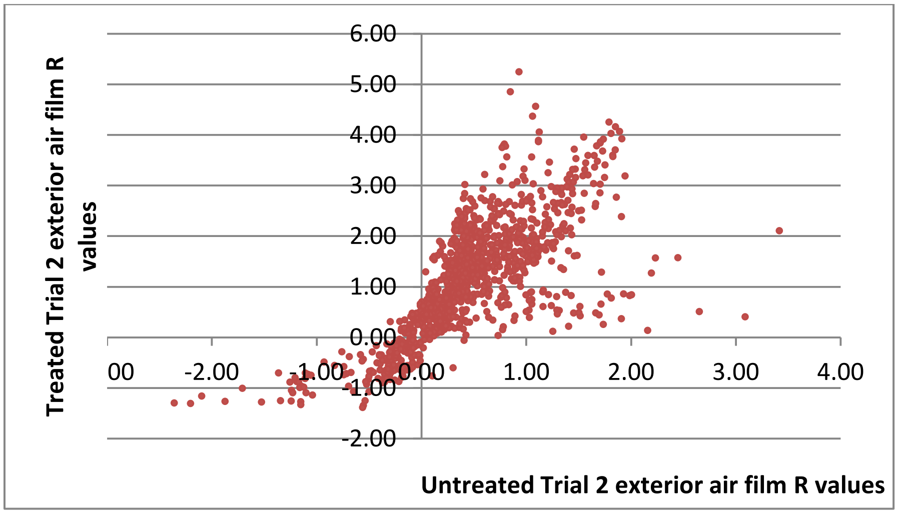


Figure 15 – Cross Plot of Exterior Air Film R-values for Treated and Untreated Trial 2Walls

Cross plot of exterior air film R values for the Treated and untreated walls in Trial 2.

Annex B: TREAT Modeling Details

New York City was used for the daily weather file.

The TMY3 for JFK airport was used for the long term weather.

The following Audit Data was provided by AEA.

area per apt	959.12	sqft
real discount rate	3%	
HHD	4027	
#4 oil	$3.10	gal
NG	$1.50	Therm
Electric	0.21	$/kWh
rated heat input/apt	112000	btu/hr-apt
heat plant efficiency	78%	
Hot water Temperature	108	F
infiltration rate	0.82	ACH

# windows/apt	7.23	
primary window area	2008	sqin
Original BTU/Sqft/HDD	15.49	
Thermostats	Day	Night
Heating	74	72
Cooling	78	80

Table 6 – Audit Data

#4 oil	Gal	Bill
3/14/2011	0	0
4/14/2011	2843	8819
5/13/2011	1260	3910
6/14/2011	484	1501
7/14/2011	441	1369
8/12/2011	487	1511
9/13/2011	586	1816
10/13/2011	1939	6015
11/10/2011	3116	9665
12/14/2011	4947	15347
1/13/2012	6226	19313
2/14/2012	5070	15726
3/15/2012	3413	10586

Table 7 – Fuel Oil Billing History

	Heating	baseline
Actual use use	30812	6084
normalized	35748	6084

Table 8 – Annual Fuel Oil Use

Additional notes identified the Hot water system as a tankless coil. Site visits confirmed the heating system as a Steam Boiler.

The capacity of the heating plant was set at 7,280,000 btu/hr (112 kbtu/hr-unit * 65 units). This is more than 50% oversized based on the TREAT Model Inspector, but does not affect the modeled results

The domestic hot water system was modeled as a Heating boiler with a Tankless coil using the supply temperature (108F) and thermal efficiency of the existing heating boiler (78%) provided by AEA along with default Energy Factors for a tankless coil from the TREAT water heater library (0.5 and 0.2 for heating and non heating seasons respectively). The Usage Adjustment multiplier was set to 0.80 resulting in a baseload of 6019 gallons per year to match the AEA billing analysis results of 6084 gal. Occupancy was calculated from the number of bedrooms in the building

	Number of Bedrooms			Totals	
Floor	1bd	2bd	3bd	beds	units
1	4	4	2	18	10
2	6	3	2	18	11
3	5	5	1	18	11
4	5	5	1	18	11
5	6	3	2	18	11
6	6	3	2	18	11
	1 bd units	2 bd units	3 bd units	beds	Units
Building	32	23	10	108	65
Occupants	64	69	40		173

Table 9 – Unit and Bedroom Inventory

No information about the cooling equipment was provided. It was assumed that 50% of the bedrooms had a Window mounted AC unit of 12,000 btu/hr with an average SEER of 12. The individual cooling units were aggregated into a single cooling system with a capacity of 648 kBtu/hr.

Assumed cooling Eqp	SEER	12
capacity	12000	btu/unit

number	54	0.5/bd
total	648000	btu/hr

Table 10 – Cooling Equipment Assumptions

The floor areas were calculated using the total building footprint (from the construction documents) and the total apartment area provided by AEA (65 units * 959.12 sqft/unit). The commons floor area was calculated as the difference between the total area of non basement floors and the total apartment floor area

Calculated from plans					
	13832		alcoves		1412.5
front	162		13	20	260
back	142		13	35	455
left	91		6	34	204
right	94		21	23.5	493.5
Total area per floor	12419.5	building	74517	sqft total	
apt/floor	10390.47	apts	62342.8	sqft total	
comm/flr	2029.033	commons	12174.2	sqft total	
		bsmt	18629.25	sqft total	

Table 11 – Floor Areas

Exterior wall dimensions were taken from construction documents.

Space	Surface	Adjacent	Facing	area	target R	model R	TREAT ID	construction	height	width
basement	Walls	ground	NA	1650		3	774	heavy masonry	10	165
basement	walls	outside	West	700		3	774	heavy masonry	4	175
basement	Walls	outside	south	930		3	774	heavy masonry	10	93
basement	Walls	outside	East	1420		3	774	heavy masonry	10	142
basement	Walls	outside	North	850		3	774	heavy masonry	10	85
basement	Floor	ground	NA	12376		0.6	43	slab below grade	136	91
commons	Walls	outside	West	340		4	113	double wythe brick&plaster	10	34
commons	Walls	outside	south	0		4	113	double wythe brick&plaster		0
commons	Walls	outside	East	420		4	113	double wythe brick&plaster	10	42
commons	Walls	outside	North	900		4	113	double wythe brick&plaster	10	90
commons	Floor	basement	NA	2040		2.5	49	Framed	102	20
commons	Ceiling	outside	NA	2040		5	260	Framed	102	20
Apartments	Walls	outside	West	6496	4.7	4.9	401	double wythe brick&plaster	8	812
Apartments	Walls	outside	south	8640	4.7	4.9	401	double wythe brick&plaster	8	1080
Apartments	Walls	outside	East	6192	4.7	4.9	401	double wythe brick&plaster	8	774
Apartments	Walls	outside	North	4800	4.7	4.9	401	double wythe brick&plaster	8	600
Apartments	Walls	outside	West	1624		4	113	double wythe brick&plaster	2	812
Apartments	Walls	outside	south	2160		4	113	double wythe brick&plaster	2	1080
Apartments	Walls	outside	East	1548		4	113	double wythe brick&plaster	2	774
Apartments	Walls	outside	North	1200		4	113	double wythe brick&plaster	2	600
Apartments	Ceiling	outside	NA	10440		5	260	Framed	116	90
Apartments	Floor	basement	NA	10440		2.5	49	Framed	116	90

Table 12 – Exterior Wall Dimensions

The exterior walls of the apartment units were divided into Treatable and untreatable sections. The Treatable sections are exposed in the apartment units and have an extra layer of framing and plaster. The untreatable sections use the same wall construction as the common area walls.

Windows counts were taken from Construction documents and exterior photographs

Apartments	Window Type			
Totals	A	B	C	D
North	18	30	18	6
East	0	72	18	12
South	14	78	24	6
West	20	102	18	10
Height	5	5	5	5
Width	3	2	1.25	5

Apartments	Window Type			
1st floor	A	B	C	D
North	3	5	3	1
East	0	12	3	2
South	3	13	2	1
West	4	17	1	0
Apartments	Window Type			
Floor 2-4	A	B	C	D
North	3	5	3	1
East	0	12	3	2
South	3	13	2	1
West	4	17	1	2
Apartments	Window Type			
Floor 5 & 6	A	B	C	D
North	3	5	3	1
East	0	12	3	2
South	1	13	8	1
West	2	17	7	2

Table 13 – Apartment Window Schedule

All apartment windows were double pane metal framed double hung units. All windows were aggregated based on orientation. These aggregate areas were modeled as multiple 4x4 (16 sqft) windows[5].

[5] Treat has restrictions on window size; therefore the aggregate area must be broken into smaller units. A single size window was used to reduce data input time.

	Total	# of
	Area	units
North	832.5	53
East	1132.5	71
South	1290	81
West	1682.5	106
std size	16	
4x4		

Table 14 – Aggregate Apartment Window Areas (sf)

The same methodology was applied to windows in the Common areas

Commons	Window Type			
Whole Building	Double half glazed door	Metal Frame Single pane double hung	Total Area	# standard units
North		6	180	12
East		6	180	12
South		0	0	
West	1	2	78	5
Height	3	6		4
Width	6	5		4

Table 15 – Aggregate Common Space Window Area

Appendix B: Scope of Work for Aerogel Installation

APPENDIX B: Scope of Work for Aerogel Installation

(back to text)

Installation of aerogel blanket insulation as energy conservation measure (ECM) on the interior of the exterior walls of 1770 and 1780 Davidson Ave, New York, NY.

Objective: To improve the energy performance and occupant comfort of 1770 and 1780 Davidson building units by installing two layers of aerogel blanket insulation on the interior side of the exterior walls throughout these two buildings. This improvement is expected to provide significant energy savings. All exterior walls within the living units are in scope for treatment.

Overview of Project Steps:

This summarizes the required actions, which are further detailed below.

1. Initial Preparation of Exterior Walls, including removal of all wood trim and base
2. Staging and Installation of Aerogel Blanket Insulation Material
3. Hanging gypsum wallboard **(completed as part of separate project working on-site)**
4. Joint treatment and trim **(completed as part of separate project working on-site)**
5. Finish work **(completed as part of separate project working on-site)**
6. Coordination with other trades as necessary as related to apartment renovations

Detailed Project Steps:

1. Schedule of Vacant apartments
   - A timeline will be established to determine approximate dates when each unit will be renovated.
   - Timeline TBD based on the requirements of Home Builders 1 LP

2. Initial Preparation of Exterior Walls
   - Exterior walls will need to be prepared for treatment by removing all wood trim including wood base and window surrounds

- A clear path of access will be established that is approximately 3 ft wide in front of each wall to be renovated.
- Removal of all wall mounted devices (light switches, chases and door bells)
- Cover any finished areas with plastic/cloth drop cloths to protect from construction dust/debris.

3. Staging and Installation of Aerogel Blanket Insulation Material
    - Two layers of Spaceloft aerogel blanket will be applied to the wall area
    - Spaceloft aerogel blanket roll material will be pre-cut to the ceiling to floor height outside the unit
    - Cut material will be rolled and placed into plastic bags and staged within the established access path
    - Insulation will be installed vertically from ceiling and draping down to floor or finish height

<u>Aerogel Fastening Technique</u>

1. Pneumatic staple over existing plaster

<u>Aerogel Fastening pattern</u>

1. Field: Minimum 1 staple every 16” o.c. horizontally along the top and vertically at the edges to hold Aerogel in place
2. Openings: Min 1 staple every 6” o.c. along border of opening, or cont. spray adhesive
    - Excess insulation material over areas such as windows, wall sockets and other openings will be carefully removed by cutting material using a razor knife, hot knife or similar. Additional fastening can be applied to secure insulation in the areas that are intended for coverage. A small reveal may be added near window openings to accommodate a clean window trim.
3. Hanging gypsum wallboard **<u>(completed as part of separate project working on-site)</u>**
    - Identification of existing wood strapping locations (16” o.c.) with pencil marks at

ceiling and floor

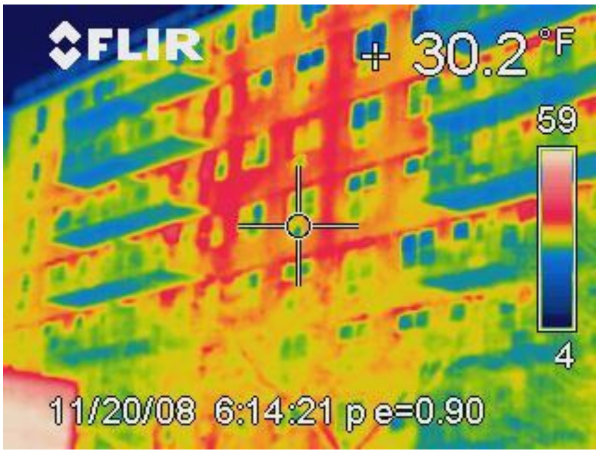
- Ensure that drywall screws are of sufficient length to reach wood strapping (minimum 2" to accommodate existing wall and aerogel insulation)
- Installation by standard technique of gypsum wall board over all areas of exterior wall covered by aerogel

4. Joint treatment and trim **(completed as part of separate project working on-site)**
   - L-trim and caulk installation at all window and door openings
   - Dry wall tape and joint compound applied at joints between gypsum board and along L-trim
   - Sanding of joint compound to provide a quality interior finish
   - Install extension boxes for flush mounted wall sockets
5. Finish work **(completed as part of separate project working on-site)**
   - Replacement of all wall mounted items (light switches, chases and door bells)
   - General cleaning from renovation work
   - Removal of all tools, materials and supplies from unit
6. Coordination of additional construction of units to regular operation
   - Project acceptance will be based on the return of units to a "paint-ready" condition with aerogel insulation installed per the scope above.

Appendix C: Interior Building Renovation Guidelines

SPACELOFT INSULATION INTERIOR BUILDING RENOVATION GUIDLINES

Preferred Installation Manual



Aspen Aerogels® recognizes that performance of our state-of-the-art aerogel insulation materials depends on the total thermal integrity of our system. Therefore, we have

Contents

developed preferred guidelines for installing aerogel blankets.

All of the procedures described in this manual have been field-proven in conjunction with installation partners.

We are constantly striving to develop new application procedures and insulation systems to make our products stand above our competition with quicker delivery times, simpler logistics, and more reliable installation.

We stand behind our products and are willing to work with you to develop application procedures to suit your project-specific execution plan.

Please feel free to contact us for specialized training or recommendations regarding our application procedures.

Safety First

Aerogel materials are engineered with safety and performance as our priorities. Aspen has performed extensive HSE testing and found our materials are safe. For worker comfort when working with aerogel, we recommend dust masks and work gloves to reduce irritation. Standard work gloves and jump suits reduce the "dry feeling" caused by the hydrophobic characteristic of aerogel. An MSDS for Spaceloft is included in Appendix B.

Frequently Asked Questions
But I heard "nanotechnology" is bad?
Aerogel is 95% air, so the nanotechnology refers to the pores in the material.
Is aerogel dust safe?
Our material dust is greater than 15 microns and rated as a "nuisance dust" by
Does aerogel silica cause health problems?
NO. Crystalline silica can be harmful; Aerogel uses amorphous silica, which is not a health hazard beacuse it does not have the shape factor

Material Handling

Aerogel insulations when shipped in full rolls are typically 57" wide weighing approximately 200 lbs per roll. Individual rolls are shrink-wrapped and stacked into delivery truck as shown in picture to right. Individual rolls can be moved manually with two people from the delivery truck to storage area but the use of a pallet jack or forklift will be helpful to speed the process and minimize individual handling and increase safety. If moving rolls manually, the rolls can be moved with the use of an aluminium tube placed through the center of the roll and picked up from either end. The following series of pictures shows the best practices sequencing for moving rolls with a forklift. The specific process will be customized to the location and requirements of the off-loading site.

ONE ROLL

Preparation and Storage

Aerogel insulation materials should be stored in a clean, dry and protected environment. If material has to be stored outdoors, it should be placed on pallets and thoroughly covered with a waterproof tarp or plastic sheeting. Although the aerogel material is hydrophobic, all necessary measures should be taken to protect it from the weather. This guideline details the installation and finishing of Spaceloft in the interior surface of an existing building. Other uses of the material can be developed and documents separately.

Before any Spaceloft insulation material is applied, the surfaces to be insulated shall be clean and free of frost, moisture, or other imperfections.

Optimal Work Setup

To achieve the most productive work environment for use with Aerogel insulations we suggest the following setup.

Bulk Cutting Area

Work Area

Once material is placed in this area from the bulk cutting area it should be checked that it is covered and protected form weather. Ideally the material should be placed as close to the work area as possible. Remove the materials from the packaging and distribute to the work location. Spaceloft can be cut in the field with good scissors or a box cutter. In a shop, a heated knife, pizza wheel/battery or sltiter are effective.

Designing with Spaceloft

There are many considerations when designing a renovation with Spaceloft insulation. The current condition of the building, construction style, moisture movement, air movement, available space, and desired performance outcomes should all be taken into consideration. To achieve the desired outcome, a thermal and/or hygrothermal analysis should be completed on the building design prior to a renovation being undertaken. A sample thermal analysis is included here to demonstrate the approach. This example compares the existing structure to a renovated structure with one layer of Spaceloft, two layers of Spaceloft and a two inch EPS insulation added.

EXAMPLE BUILDING ANALYSIS

The example is a structural brick multifamily building.

Existing Exterior Walls: Double Wythe soft brick U-factor 0.52 from CEC ACM Tables. Wood Framed airspace ¾" to 3.4" R 1.4 from CEC ACM Tables Estimated Assembly U-factor 0.3 (R 3.33) includes all air films.	Improved Exterior Walls 2 layer of Spaceloft Existing wall (R3.33) 0.8" SpaceLoft material (R8) ½" Sheetrock (R0.5) Estimated Assembly U-factor 0.08 (R11.8)
Improved Exterior Walls: 1 layer of Spaceloft added Existing wall (R3.33) 0.4" SpaceLoft material (R4) ½" Sheetrock (R0.5) Estimated Assembly U-factor 0.13 (R7.8)	Improved Exterior Walls EPS w/z channel Existing wall (R3.33) Metal framed 2" wall with r8 cavity insulation R 2.9 (from CEC ACM tables) Estimated Assembly U-factor 0.16 (R6.23)

Seasonal Heating Load from TMY3 data for Example NYC.
A reasonable Reference Temperature is between 60 and 65 F.
Savings for the Spaceloft Treatment (1 and 2 layers) and the Control treatment using EPS were calculated.

Results are shown in the following tables.

Annual Conductive Losses Per Square Foot of Opaque Wall Area (BTU/sqft-year)

T_{ref}	HDD	Existing	Spaceloft	EPS	2 layers Spaceloft
60	3810	27432	11887	14630	7821
61	4028	29002	12567	15468	8268
62	4252	30614	13266	16328	8728
63	4482	32270	13984	17211	9200
64	4716	33955	14714	18109	9680
65	4956	35683	15463	19031	10173

Annual BTU Savings Per Square Foot of Opaque Wall Area

T_{ref}	Spaceloft	EPS	2x Spaceloft
60	15545	12802	19611
61	16434	13534	20734
62	17348	14287	21887
63	18287	15060	23071
64	19241	15846	24275
65	20220	16652	25510

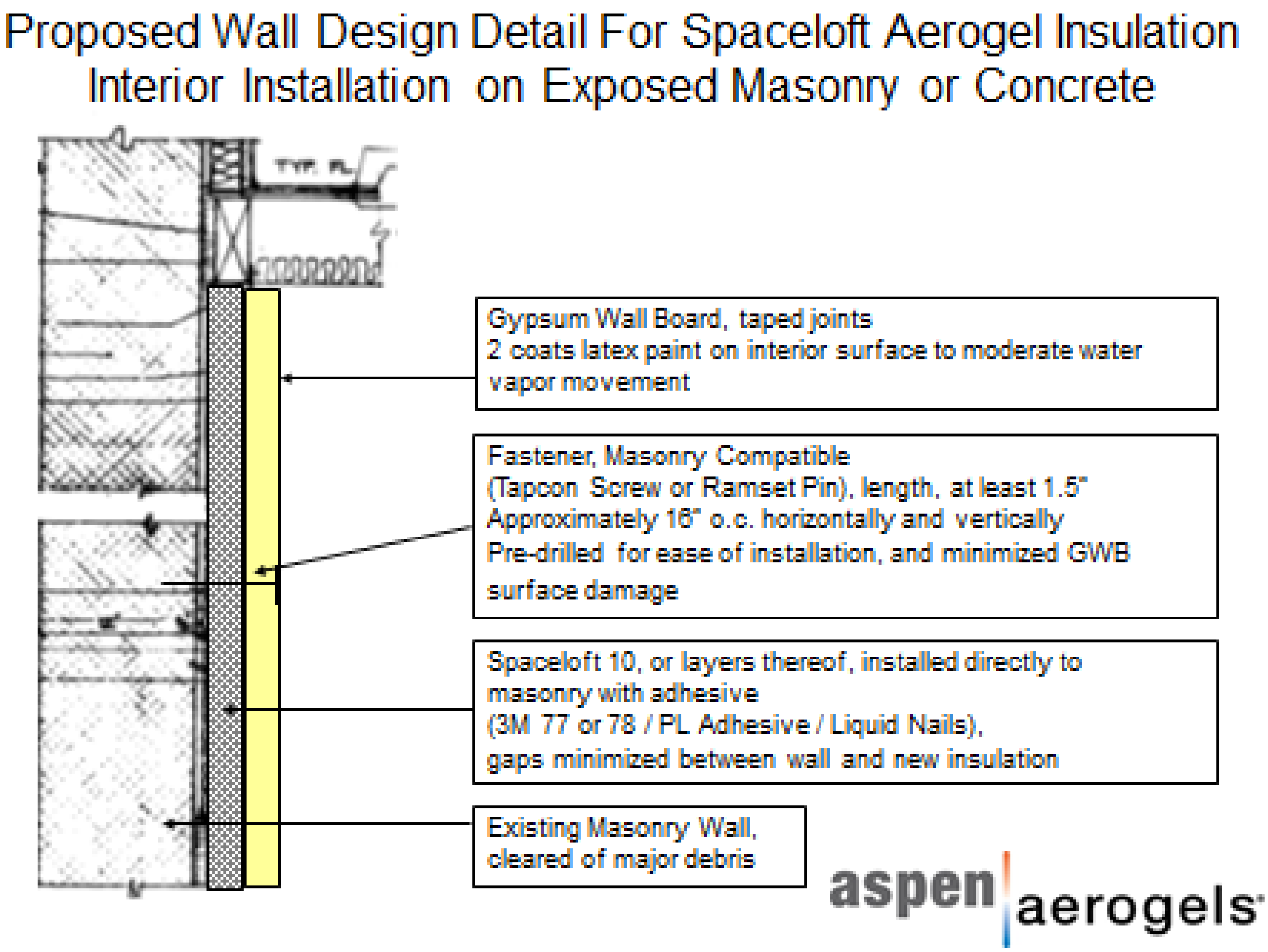
Annual Savings Per Square Foot of Opaque Wall Area at $1.00 per Therm

T_{ref}	Spaceloft	EPS	2x Spaceloft
60	$ 0.16	$ 0.13	$ 0.20
61	$ 0.16	$ 0.14	$ 0.21
62	$ 0.17	$ 0.14	$ 0.22
63	$ 0.18	$ 0.15	$ 0.23
64	$ 0.19	$ 0.16	$ 0.24
65	$ 0.20	$ 0.17	$ 0.26

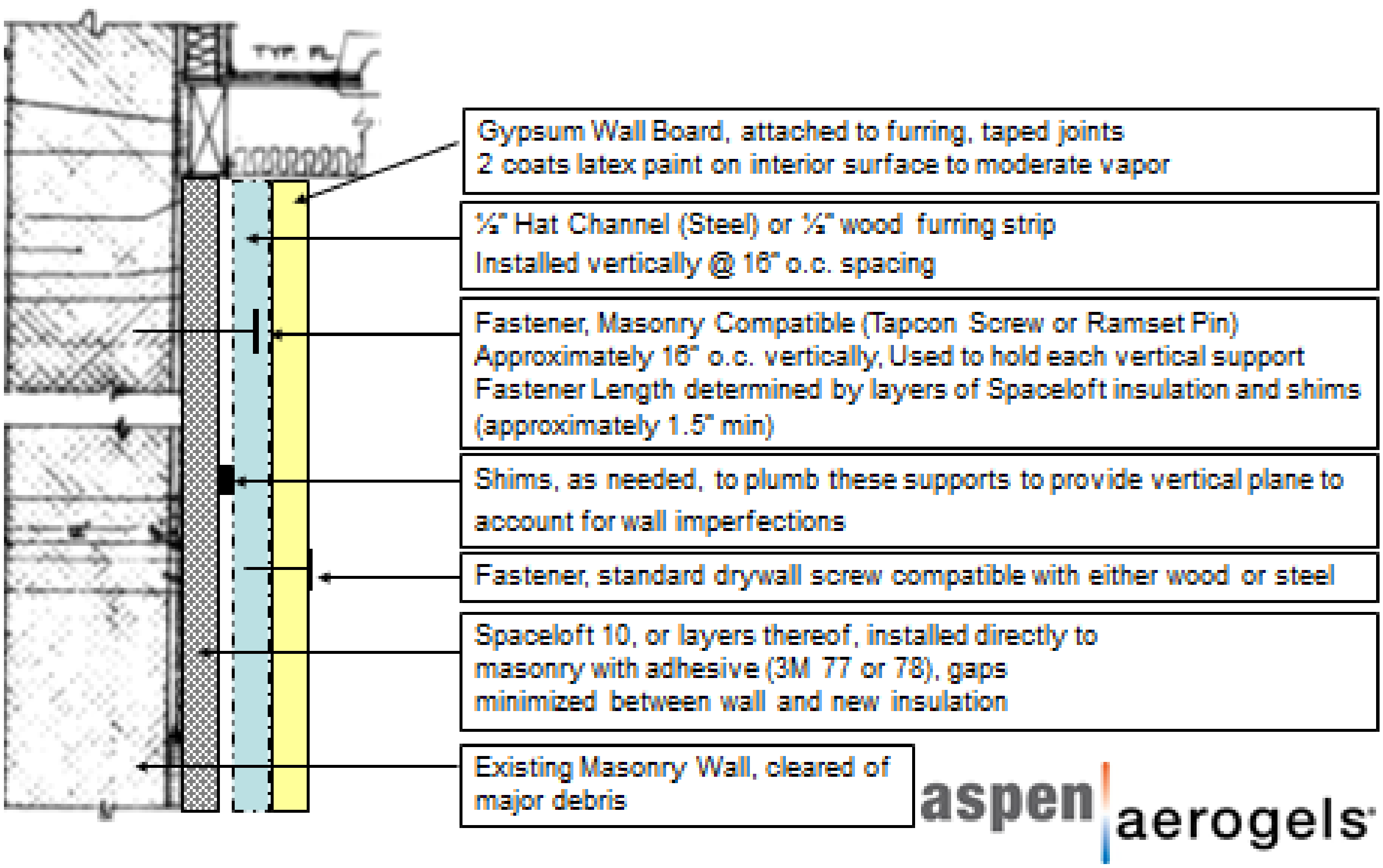
Undiscounted Lifetime savings Per Square Foot of Opaque Wall Area for a 40 year measure lifetime

T_{ref}	Spaceloft	EPS	2x Spaceloft
60	$ 6.22	$ 5.12	$ 7.84
61	$ 6.57	$ 5.41	$ 8.29
62	$ 6.94	$ 5.71	$ 8.75
63	$ 7.31	$ 6.02	$ 9.23
64	$ 7.70	$ 6.34	$ 9.71
65	$ 8.09	$ 6.66	$ 10.20

Spaceloft Interior Wall Assembly Drawings



Proposed Wall Section Design For Spaceloft Aerogel Insulation Interior Installation with Channel for Conduit



Interior Wall Installation Procedure

<u>Objective</u>: To improve the energy performance and occupant comfort by installing layers of aerogel blanket insulation on the interior side of the exterior walls throughout the building. This improvement is expected to provide significant energy savings. All exterior walls within the living units are in scope for treatment.

<u>Overview of Project Steps:</u>

This summarizes the required actions, which are further detailed below

1. Schedule of Vacant apartments
2. Initial Preparation of Exterior Walls, including removal of all wood trim and base
3. Staging and Installation of Aerogel Blanket Insulation Material
4. Hanging gypsum wallboard
5. Joint treatment and trim
6. Finish work
7. Coordination with other trades as necessary as related to apartment renovations

<u>Detailed Project Steps:</u>

1. Schedule of Vacant apartments
    - Establish timeline to determine approximate dates when each unit will be renovated.
    - Develop project plan to coordinate with apartment vacancies

2. Initial Preparation of Exterior Walls
    - Prepare exterior walls by removing wood trim including wood base and window surrounds
    - Establish clear path of access approximately 3 ft wide in front of each wall to be renovated.
    - Remove all wall mounted devices (light switches, chases and door bells). Cover any finished areas with plastic/cloth drop cloths to protect from construction dust/debris.

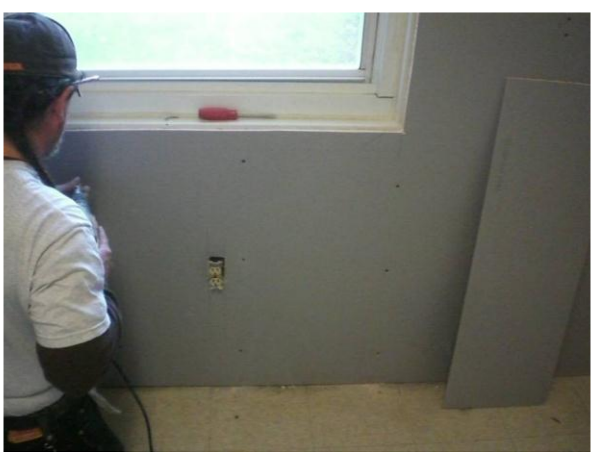
Staging and Installation of Aerogel Blanket Insulation Material

- Two layers of Spaceloft aerogel blanket will be applied to the wall area
- Spaceloft blanket roll material will be pre-cut to the ceiling to floor height outside the unit
- Roll and place cut material into plastic bags and staged within established access path
- Insulation will be installed vertically from ceiling and draping down to floor or finish height

3. Aerogel Fastening Technique
   - Pneumatic staple over existing plaster
   - Aerogel Fastening pattern
     - Field: Minimum 1 staple every 16” o.c. horizontally along the top and vertically at the edges to hold Spaceloft/Aerogel in place
     - Openings: Min 1 staple every 6” o.c. along border of opening, or cont. spray adhesive

Excess insulation material over areas such as windows, wall sockets and other openings will be carefully removed by cutting material using a razor knife, hot knife or similar. Additional fastening can be applied to secure insulation in the areas that are intended for coverage. A small reveal may be added near window openings to accommodate a clean window trim.

4. Hanging gypsum wallboard
    - Identify wood strapping locations (16” o.c.) with pencil marks at ceiling and floor
    - Ensure that drywall screws are of sufficient length to reach wood strapping
      -(minimum 2” to accommodate existing wall and aerogel insulation)
    - Install by standard wall board technique, over all aerogel on exterior walls


5. Joint treatment and trim
   - L-trim and caulk installation at all window and door openings
   - Apply dry wall tape and joint compound at gypsum board joints and along L-trim
   - Sanding of joint compound to provide a quality interior finish
   - Install extension boxes for flush mounted wall sockets

6. Finish work
   - Replacement of all wall mounted items (light switches, chases and door bells)
   - General cleaning from renovation work
   - Removal of all tools, materials and supplies from unit

7. Coordination of additional construction of units to regular operation
    - Project acceptance will be based on the return of units to a "paint-ready" condition with aerogel insulation installed per the scope above.

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High Performance Insulation in Existing Multifamily Buildings: A Demonstration Project Using Aerogel Materials

Energy. Innovation. Solutions.

Final Report
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