Energy Conservation, Inc.
1150 Main Street
P.O. Box 726
Hanson, MA 02341

March 18, 2020

Mr. Michael Farrell
Town Administrator
Town of Georgetown
1 Library Street
Georgetown, MA 01833

Georgetown Green Communities weatherization projects 2020

Dear Mr. Farrell,

Energy Conservation is pleased to provide you with this proposal for the installation of the energy efficiency weatherization improvement measures indicated below.

(See the attached Report for full details)

The following Energy Efficiency Measures are based on information provided from utility usage analysis, energy usage comparisons, and on-site equipment evaluations performed by Energy Conservation:

Building	Projected annual cost savings	Total installed cost	National Grid Gas incentive	Net cost to the Town of Georgetown	Simple payback period (in years)
Town Hall	$ 3,557.07	$ 72,283.56	$ 1,466.00	$ 70,817.56	19.91
Public Safety	$ 2,754.61	$ 66,080.00	$ 1,486.00	$ 64,594.00	23.45
Totals	**$ 6,311.68**	**$ 138,363.56**	**$ 2,952.00**	**$ 135,411.56**	**21.45**

The Town of Georgetown shall pay a total of $135,411.56 to Energy Conservation upon project completion.

Christopher J. Collins
President, Energy Conservation

November 2, 2020
Date

Accepted: Town of Georgetown

Title

Date

Clarifications

All the removed equipment will be disposed of properly. Labor warranty is one-year on workmanship of installation. Energy Conservation shall assign to the Town of Georgetown its rights to any and all warranties from the manufacturers or otherwise with respect to the equipment purchased by the Town of Georgetown from Energy Conservation.

Energy Conservation agrees to procure and maintain, at the sole cost and expense of Energy Conservation, with a reputable and financially responsible insurance carrier or carriers, property damage and public liability insurance in the amount of not less than $1,000,000 worker's compensation in the amount set forth by each state and a crime rider in the amount of not less than $250,000.

Energy Conservation further agrees to name the Town of Georgetown and its parents, affiliates and subsidiaries as additional insurers and to provide the Town of Georgetown with an insurance certificate as evidence of such coverage. In the event of cancellation or material modification of any policy, written notice of such cancellation or modification shall be given to the Town of Georgetown at least thirty days prior to such cancellation or modification as to each policy.

Energy Conservation represents and warrants that the installation of all the equipment by Energy Conservation or its subcontractors shall be performed in a professional and workmanlike manner by qualified personnel and in accordance with all federal, state and municipal laws, rules and regulations and the policies and procedures of the Town of Georgetown.

Energy Conservation, Inc.
P.O. Box 726
Hanson, MA 02341
ECI-NE.com

Georgetown MA

Building Envelope Inspection Report

October 31, 2019

Georgetown, MA

Facilities Information			
Project:	**Georgetown MA** **Georgetown, MA**		
Facilities:	**NRSD Middle-High School** **Perley Preschool, COA, and Admin** **Penn Brook Elementary School** **Public Safety Building** **School Garage** **Town Hall** **DPW/Highway Department - Building-1** **DPW/Highway Department - Building-2** **Municipal Light Department - Office Building** **Municipal Light Department - High Bay** **Peabody Public Library**		
Utility Information			
Heating Fuel(s):	**Natural Gas**	**Cost:**	**$1.10 - $1.1568/therm**
Other Energy:	**Electricity**	**Cost:**	**$0.1564 - $0.2117/kWh**
Inspection Information			
Inspector Name(s):	**Charley Casey**		
Inspection Date:	**September 9-11, 2019**		
Energy Conservation , Inc. Contact Information			
Inquiries:	**Christopher Collins** **Energy Conservation , Inc.** **P.O. Box 726** **1150 Main Street** **Hanson, MA 02341** **chris@eci-ne.com**		

Inspection Performed

Building envelope inspections were performed on twelve buildings located in Georgetown. MA. However, only eleven buildings are included in this report, as we were notified by the Water Department manager that the Water Department structure is slated for demolition in the near future and, thus, no retrofit measures are specified. The facilities inspected are listed on the Project Information page. The inspector(s) used visual observations and smoke tracer tests in accordance with ASTM E-1186 to identify the location and severity of air leakage paths. Other inspection tools that may have been used include blower, duct blasters and/or micro leakage meters per ASTM E-779, infrared scans, hot-wire anemometer, and/or ultrasound detection per ASTM E-1186.

These air leakage paths are detailed in the scope of work. Areas inspected include roof-wall joints, elevation changes, soffit areas, roofs, walls, windows, doors, and attic connections.

While it is never economically feasible to address all the penetrations in a building envelope, our assessment is that we can address the equivalent of a **64.74 square foot** hole in total across the buildings studied at a reasonable cost and having a significant impact on future energy consumption.

Building Characteristics

These buildings represent a cross-section of construction styles, which include:

- Steel-frame and CMU walls with flat and sloped concrete and/or metal roofing
- Masonry and brick walls with steel-framed pitched and/or flat metal roofing
- Masonry and brick walls with wood-framed pitched and/or flat wood roofing
- Wood-frame walls with wood and/or brick siding, flat and sloped wood roof systems
- Steel-frame, with corrugated metal walls and corrugated sloped roof decks, batt insulation and poly affixed to the interior surfaces of the walls and roof deck
- One, two, and three-story structures
- Stand-alone structures, structures with several wings, and/or bump-out sections directly attached and/or connected via enclosed corridors.

The buildings are used for various purposes, which include:

- Public Schools
- Solely office/administrative
- Traditional municipal police and fire stations
- Utility services facilities, e.g. municipal light department office and high bay

- Vehicle maintenance & storage with/without support staff offices, e.g. highway and public-school departments
- Public Library services

Overall, the buildings are in fair-to-good condition and well-maintained by staff. During our inspection, we found that the building envelopes range from fairly to moderately to quite leaky, partly due to age-deterioration, failing weatherstrip, failing/missing sealants, construction framing details along attic floors and knee walls, and failing or missing air barriers.

Significant Issues

Repairing the air barriers and/or insulation (e.g. thermal barriers) will help solve several significant problems that the client experiences. Below are some examples at specific sites, as well as some general issue that our inspector(s) encountered.

Public Safety Building, Ref #4

The Chief noted significant issues with temperature control and occupant comfort within the upper floor. Our inspection found that the building envelope is quite leaky, partly due to failing weatherstrip and sealants, but more so to construction framing details, i.e. no effective air barrier in place along the majority of the second floor. Installing an effective air barrier between the conditioned spaces and the attic/outdoors will greatly improve occupant comfort, IAQ, and the thermal performance of the existing insulation. Additionally, this will significantly improve the energy performance of the building and the structural integrity of the roof, attic, ceiling and wall framing components, finished surfaces, and suspended ceilings.

Town Hall, Ref #5

Staff noted considerable comfort and indoor air quality (IAQ) issues along the third floor due to drafty windows, stating “this office area is colder in winter and has hotter/more humid conditions during the spring/summer than the rest of the building,” and one town administrative staffer noted “it’s cold and drafty in our area all winter, especially near the windows.” Our inspection noted the building envelope is fairly leaky, partly attributed to failing weatherstrip and sealants and the upper level’s considerable air-leakage and poor thermal performance. The third level is constructed within the conditioned attic space, which connects directly to the outdoors - allowing ongoing heat losses all winter and infiltration of hot, humid outdoor air and pollutants, partly causing the comfort and indoor air quality issues. Installing an effective air barrier along the underside of the sloped roof framing will tighten the building envelope and improve the performance of the existing insulation. This will significantly improve occupant comfort, IAQ, and the overall energy performance. The windows tested leaky and need new weatherstrip (including additional sash locks and pulley seals). Air-sealing the windows will improve occupant comfort, IAQ, and the structural integrity of the adjoining building systems (e.g. wall, ceiling and floor framing, and finished surfaces) due to reduced moisture infiltration.

Municipal Light Department Office Building, Ref #7

During our inspection of the Light Department's office structure, the building manager noted temperature and humidity control (i.e. "hot & cold spots") issues and corresponding "occupant comfort issues" throughout. There are ice dams where electrical tape is used to control them. Because there is no air barrier above the suspended ceiling, the space above batts is wide open to the attic and outdoors via the attic/roof venting. There are voids and fallen sections of the batts throughout the ceiling, as well as several framing chases and pipe and electric conduit penetrations throughout the attic truss framing. All of this leads to the ice dam and comfort issues. Our work will solve these problems.

General Issues

Beyond these specific problem areas, we identified several significant air leakage paths in many of the buildings we inspected. The key leakage areas are:

- Roof-wall joints
- Exterior, basement, attic/knee wall access, and overhead door systems
- Window systems
- Skylight and roof-top fans that connect the unconditioned mechanical rooms and outdoors directly to the conditioned spaces within the building envelopes
- Construction framing details causing misalignment of air and thermal barriers, and/or no effective air barriers being in place

These air leakage defects are leading to significant occupant comfort and IAQ issues, ongoing moisture intrusion (causing deterioration of building framing components and finished surfaces), ongoing repairs and/or replacement of key building systems, and poor energy performance overall.

Most of the air leakage paths identified during our building assessments are a direct result of misalignment of the building's thermal and air barriers, stemming from design issues, implementation issues during construction and/or maintenance activities, or deterioration of materials over time.

Sealing these air leakage pathways can reduce the energy usage of these buildings considerably, improve structural integrity (by stopping the intrusion of moisture, which can cause a significant amount of deterioration to the various construction materials/systems), and greatly improve the comfort and IAQ of the building occupants.

"By Others"

We also identified building issues that are not directly related to the tightness or performance of the building air barrier systems, or they cannot be addressed as an energy measure due to structural details. We are referencing them here to bring them to staff's attention so that any relevant follow-up tasks can be done. These include:

Perley School, Ref #2

During our inspection, we noted that there are a few sections within the original building that are void of effective air barriers, specifically along the southeast corner. Within this section, there is merely a suspended ceiling in place, with no rigid air (or thermal) barrier in place to separate the conditioned spaces from the unconditioned attic. The suspended ceiling's method of installation (merely suspended on wires from underside of roof framing, 20+ feet above) does not provide the framing needed to affix an effective rigid air barrier. Furthermore, the 20+ foot drop from the attic floor platform will not allow access to perform the retrofit measure. We highly recommend installing the necessary framing to create a solid surface ceiling and, ultimately, a thermal (insulation) material in this section (**by others**). The installation of an effective air and thermal barrier will considerably improve energy performance, occupant comfort, and the structural integrity of the adjoining building systems (due to reduced condensation and ongoing moisture intrusion within the ceiling framing and finished surfaces).

Town Hall, Ref #5

During our inspection, we noted evidence of ongoing bulk water, moisture, and vapor intrusion within the basement at the brick/masonry and fieldstone foundation sections. This deterioration can impact the structural integrity of not only the foundation, but of the adjoining wall and floor framing systems and adjoining finished surfaces. We highly recommend that an inspection/evaluation of the foundation drainage system be performed **(by others)**. The end goal would be to develop and implement possible repairs and/or upgrades to the drainage system, or waterproofing, to address the ongoing moisture conditions within the building and improve the structural integrity of the foundation and adjoining wall and floor framing systems.

Highway Department, Ref #6

During our inspection, the department manager and staff noted issues with the upper exterior walls' exhaust fans. They noted that three of the four exhaust fans have been blocked-off, due to performance failures (ongoing repairs to keep running) and considerable drafts and moisture intrusion attributed to the dampers not shutting completely. The fourth fan is currently the only one operable. We highly recommend replacing the exhaust fans **(by others)**. New fans with actuated damper controls (to keep the dampers closed when the fans are not in use) will improve energy performance and occupant comfort (minimizing the drafts and heat losses through the open dampers).

All Sites

Reducing the heating and cooling loads should help the central HVAC system's performance, but we highly recommend that a full evaluation of the HVAC systems be performed (**by others**). Part of that evaluation should be to balance the systems after air-sealing retrofits are performed.

Pricing

The total price of building envelope work scoped in this document is **$329,632.45** with estimated annual **savings of $20,524.56** resulting in a combined **payback of 16.06** years **and a reduction of 3.82%** from the baseline energy consumption. Tables by building, and a summary tab, are provided in the savings calculation spreadsheets.

Reference #	Building Name	Estimated Costs	Estimated Annual Savings	Simple Payback
	Heating			
1	NRSD Middle-Senior HS	[redacted]	$ 4,257.90	[redacted]
2	Perley Pre-School_COA_Admin		$ 2,260.38	
3	Penn Brook ES		$ 1,147.91	
4	Public Safety_School Garage		$ 2,523.13	
5	Town Hall		$ 3,061.15	
6	DPW_Highway Department		$ 528.55	
7	Municipal Light Department		$ 2,432.09	
8	Peabody Public Library		$ 1,553.76	
	Cooling			
1	NRSD Middle-Senior HS	[redacted]	$ 688.48	[redacted]
2	Perley Pre-School_COA_Admin		$ 389.91	
3	Penn Brook ES		$ 203.45	
4	Public Safety_School Garage		$ 231.48	
5	Town Hall		$ 495.92	
6	DPW_Highway Department		$ 63.36	
7	Municipal Light Department		$ 278.55	
8	Peabody Public Library		$ 408.56	
	Combined			
1	NRSD Middle-Senior HS	$ 47,614.19	$ 4,946.37	9.63
2	Perley Pre-School_COA_Admin	$ 31,091.89	$ 2,650.29	11.73
3	Penn Brook ES	$ 12,564.98	$ 1,351.35	9.30
4	Public Safety_School Garage	$ 66,080.00	$ 2,754.61	23.99
5	Town Hall	$ 72,283.56	$ 3,557.07	20.32
6	DPW_Highway Department	$ 9,176.57	$ 591.91	15.50
7	Municipal Light Department	$ 60,155.74	$ 2,710.64	22.19
8	Peabody Public Library	$ 30,665.52	$ 1,962.32	15.63
	Total	$ 329,632.45	$ 20,524.56	16.06
Summary Hole Size =		64.74	Square Feet	
Facilities' Total Square Footage =		347,987	Square Feet	

NRSD Middle-High School (Ref #1)

The original Middle School-High School was built in 1964. An addition was constructed, and a complete gut-rehab project was performed in 1995-98. The structure has steel framing, CMU/brick masonry wall systems, and flat metal and concrete roof systems. It is in good condition and is well-maintained by staff. The building envelope is somewhat leaky, partly due to failing weatherstrip and construction framing details along the one-story front office section.

Doors

The exterior doors in the building are leaky and need to be weatherstripped. The doors in the building are blue and white. Black, white, and/or mill-finish door kits will be fine. Weatherstrip the doors, per the Quality Assurance System (QAS) manual and floor plan.

- Weatherstrip standard-size exterior doors, **total 32 doors**
- Weatherstrip non-standard, 3’6” W x 7’ H, exterior doors, **total 2 doors**

Overhead Doors

There are two sectional-type overhead doors, each measuring 10’ W X 8’ H. The doors tested leaky and should be weatherstripped, per the QAS manual and floor plan.

- Weatherstrip the 10’ W X 8’ H overhead doors, **total 2 doors**

Roof-Wall

The roof-wall joint is leaky along the one-story front office section. The junctures need to be air-sealed with 2-component, closed-cell, polyurethane spray foam. All flutes on steel decking must be punched and sealed. Air-seal the roof-wall junctures, per the QAS manual and floor plan.

- Air-seal the roof-wall junctures and any framing penetrations, 2-lines (1-line at top, 1-line at bottom of beam), at 13’ working height above suspended ceiling, **total 250 LF**

Roof Top Fans

There are seventy fans on the roof that need to be air-sealed along the chases and framing details. Fans should be serviced annually. Inspect fan for proper operation. Inspect and clean dampers. Air-seal the roof fans, per the QAS manual and floor plan.

- Inspect and air-seal the roof top fans, **total 70 roof fans**

Perley Preschool, COA, and Admin (Ref #2)

Along with the preschool, this structure houses the School Administration Department and the COA-Senior Center. It was built in 1950. Two additions were later built along the southeast and north elevations, with renovations performed concurrently. The original structure has wood and steel framing, with brick/masonry wall systems and sloped steel, wood-framed roof systems. The additions have steel and wood framing, metal-framed wall systems with brick exteriors, and wood and metal roof systems consisting of sloped and flat sections. The original structure is in fair-good condition, and the additions are in good condition. The building is well-maintained by staff. The building envelope is somewhat leaky, partly attributed to failing weatherstrip and sealants, as well as to construction framing details within original sections.

Doors

The exterior and boiler room doors in the building are leaky and need to be weatherstripped. The boiler room door needs fire-rated materials. The doors in the building are purple, blue, red, white, and brushed-metal. Black, white, and mill-finished door kits will be fine. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip standard-size exterior doors, **total 19 doors**
- Weatherstrip non-standard, 3’6” W x 7’ H, exterior doors, **total 2 doors**
- Weatherstrip non-standard, 3’6” W x 7’6’ H, exterior doors, **total 4 doors**
- Weatherstrip standard-size mechanical room door using fire-rated materials, **total 1 door**

Windows

There are nine window assembly types. The newer metal-framed, double-pane windows (WAT-1 through WAT-3) tested tight. The wood-framed, single-pane windows tested leaky along the sashes (WAT-4 to WAT-8). New spring-bronze weatherstrip needs to be installed along each sash for WAT-4, WAT-6, WAT-8, and WAT-9. The WAT-6 and WAT-8 units also need side-mount sash locks installed. The WAT-5 and WAT-7 units show some signs of age-deterioration and are unused. They should be sealed shut along the sashes and, where relevant, meeting rails, 1-line, with non-foam sealants. Weatherstrip and air-seal the window units, per the QAS manual and floor plan.

- Weatherstrip the WAT-4, WAT-6, WAT-8, and WAT-9 units with spring-bronze along the sashes, **total 564 LF**

- Seal shut WAT-5 and WAT-7 units along the sashes and meeting rails, where existing, 1-line, using non-foam sealants, **total 150 LF**

- Install side-mount sash locks on the stops adjacent to the meeting rails of WAT-6 and WAT-8 windows, making sure the sashes will remain open when sash locks are engaged, **total 50 windows/100 side-mount sash locks**

Skylights

There are fifteen skylights that need to be sealed, 1-line, along the frame-curb junctures (some backer materials may be needed to fill gaps along the frame-curb junctures). Air-seal the skylights along the framing from the exterior, per the QAS manual and floor plan.

- Air-seal the 11 - 3'6" W x 3'6" L skylights from the exterior, 1-line, at the framing (backer may be needed), **total 11 skylights/154 LF**

- Air-seal the 4 - 4'6" W x 10' L skylights from the exterior, 1-line, at the framing (backer may be needed), **total 4 skylights/116 LF**

Roof Top Fans

There are twenty fans on the roof that need to be air-sealed along the chases and framing details. Fans should be serviced annually. Inspect fan for proper operation. Inspect and clean dampers. Air-seal the roof fans, per the QAS manual.

- Inspect and air-seal the roof top fans, **total 20 roof fans**

Penn Brook Elementary School (Ref #3)

The original school was demolished, and the new Penn Brook Elementary School was built in 2015. It has steel framing, CMU/brick masonry wall systems, and flat and sloped metal roof systems. The structure is in good condition and very well-maintained by staff. The building envelope is moderately leaky, due to failing weatherstrip and sealants.

Doors

The exterior and boiler room doors in the building are leaky and need to be weatherstripped. The doors in the building are blue, beige, white, and brushed-aluminum. Black, white, and mill-finished door kits will be fine. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip standard-size exterior doors, **total 17 doors**
- Weatherstrip non-standard exterior door, 3’6” W x 7’ H, **total 1 door**
- Weatherstrip non-standard exterior door, 4’ W x 7’ H, **total 1 door**
- Weatherstrip non-standard exterior doors, 3’ W x 8’ H, **total 8 doors**
- Weatherstrip standard-size mechanical room door using fire-rated materials, **total 1 door**

Windows

There are 10 window assembly types. The WAT-2 and WAT-3 units are metal-framed and double-pane. These units tested tight. The WAT-1 and WAT-4 through WAT-10 windows are a series of adjoined sub-units (eight different configurations). These units tested leaky at the corners where the horizontal and vertical mullions join. The boxed-out framing is either 3”, 8”, or 10” deep. These corner seams need to be air-sealed, 1-line, along each of the seams/joints of each sub-unit using non-foam sealants, per the QAS manual and floor plan.

- Air-seal the WAT-1 and WAT-4 to WAT-10 units along corners where the mullions join, 1-line, using non-foam sealants, **total 708 LF**

Public Safety Building (Ref #4a)

The Public Safety Building was built in 1987. It houses the police and fire departments, with a 4-bay high bay (fire) and 2-bay sally port (police). It has wood-framed, insulated wall systems with clapboard exterior, and sloped wood roof systems. The structure is in good condition and well-maintained by staff. The building envelope is quite leaky, due partly to failing weatherstrip and sealants, as well as construction framing details, i.e. no effective air barrier in place between majority of the second floor and unconditioned attic.

Doors

The exterior doors are leaky and need to be weatherstripped. The doors are brushed-metal, blue, and grey. Mill-finished door kits will be fine. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip standard-size exterior doors, **total 4 doors**

Pull-down Stairs

Access to attic space is via pull-down stairs in the sally port.
These stairs need to be weatherstripped, dammed around, and have a removeable insulated stair cover installed. Weatherstrip and insulate the pull-down stairs, per the QAS and floor plans.

- Install a Therma-Dome or custom-fabricated removeable cover of 4” rigid foam board insulation over the 2’6” W x 5’ L pull-down stairs at the Public Safety Building. Weatherstrip the access and build a dam around it that will hold a person’s weight and is higher than the surrounding insulation, **total 1 pull-down stair cover and dam**

Overhead Doors

There are six sectional-type overhead doors: two measure 9’ W X 14’ H and the remaining four measure 12’ W x 12’ H. The doors tested leaky and should be weatherstripped, per the QAS manual and floor plan.

- Weatherstrip the 9’ W X 8’ H overhead doors, **total 2 doors**

- Weatherstrip the 12’ W X 12’ H overhead doors, **total 4 doors**

Windows

There are 3 window assembly types. All are metal-frame, double-pane units. The WAT-2 windows tested leaky along sashes. New weatherstrip needs to be installed (double-channel left/right sides, single-channel top/bottom edges). All windows tested leaky along frame-wall junctures. They need to be air-sealed, 1-line, with non-foam sealants. A few of the units are elevated, with a max working height of 12 feet. Weatherstrip and air-seal the windows, per the QAS manual and floor plan.

- Weatherstrip the WAT-2 units (double-channel on the left/right, single-channel on the top/bottom), **total 414 LF**

- Air-seal the WAT-1, WAT-2, and WAT-3 units along the frame-wall junctures, 1-line, using non-foam sealants, **total 482 LF**

Air Barriers

The sloped wood roof sections have no insulation. In a large section of the second level, there is no effective air barrier in place, merely batt insulation fitted within the truss framing (with second layer atop) and a thin poly liner stapled to the bottom of the framing. There are torn, missing, and deteriorated sections of the poly throughout. A rigid air barrier needs to be installed on the bottom of the truss framing, above the suspended ceiling, using 1” fire-rated board insulation, sealing all seams. The working height to the bottom of the truss framing is 12’. Install and air barrier, per the QAS manual and floor plan.

- Install an effective air barrier affixing 1” fire-rated board insulation to the bottom of the truss framing, sealing seams with 2-component, closed-cell, polyurethane spray foam, **total 3,895 SF**

School Garage (Ref #4b)

The School Maintenance Garage was built recently with wood-framed, insulated walls (wood panel siding) and a wood-framed sloped roof system. The R-19 fiberglass batts are still exposed within the exterior walls and sloped roof framing. The school representative noted construction was still underway concerning the interior surfaces. The structure is in good condition, aside from the unfinished interior wall and roof surfaces. It appears well-maintained by staff, considering repairs/construction were ongoing. The building envelope is moderately leaky, due to failing weatherstrip and sealants, as well as incomplete framing details along the exterior walls and interior roof surface.

Doors

The exterior doors are leaky and need to be weatherstripped. The door in the School Maintenance Garage is white. A white or mill-finish door kit will be fine. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip standard-size door, **total 1 door**

Overhead Doors

There are two sectional-type overhead doors that measure 9’ W X 10’ H. The doors tested leaky and should be weatherstripped, per the QAS manual and floor plan.

- Weatherstrip the 9’ W X 10’ H overhead doors, **total 2 doors**

Windows

There is only one window assembly type. They are single-pane, metal-frame and tested leaky along sashes and frame-wall junctures. New weatherstrip needs to be installed on each sash, and these windows need to be air-sealed,1-line, at their frame-wall junctures. Weatherstrip and air-seal the windows, per the QAS manual and floor plan.

- Weatherstrip the WAT-1 units at each sash, **total 56 LF**

- Air-seal the WAT-1 units along frame-wall junctures, 1-line, using non-foam sealants, **total 70 LF**

Town Hall (Ref #5)

The Town Hall was initially built in 1865. Renovations were performed in 1983 and 2001. It has wood-framed wall systems (insulated in 2001) with clapboard exterior. The roof is a wood, sloped, rafter-type system. The structure is in fair/good condition (especially considering its age) and is well-maintained by staff. The building envelope is moderately leaky, partly due to failing weatherstrip and sealants, older, leaky windows, and construction framing details along the structure's top sections.

Doors

The exterior and boiler room doors in the building are leaky and need to be weatherstripped. The doors in the building are brown and wood. Brown or mill-finish and spring-bronze door kits will be fine. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip non-standard exterior door, 3'6" W x 7' H, **total 1 door**
- Weatherstrip non-standard boiler room door, 3'6" W x 7' H, using fire-rated materials, **total 1 door**
- Weatherstrip the front-entry, non-standard exterior wood doors, 2'6" W x 7'6" H, using spring-bronze type materials, **total 2 doors**

Windows

There are six window assembly types. The WAT-1, WAT-2, and WAT-3 units are wood-framed, single-pane, and double-hung. They tested leaky along the sashes. New, spring-bronze weatherstrip needs to be installed. These windows also need side-mount sash locks and pulley seals installed. The WAT-1 through WAT-5 units tested leaky along frame-wall junctures. Each of these windows needs to be air-sealed, 1-line, with non-foam sealants. WAT-6 is metal-frame, double-pane hoppers and tested tight. Weatherstrip and air-seal the windows, per the QAS manual and floor plan.

- Weatherstrip the WAT-1, WAT-2, and WAT-3 units with spring-bronze kits, **total 1,175 LF**
- Air-seal the WAT-1 through WAT-5 units along frame-wall junctures, 1-line, using non-foam sealants, **total 1,273 LF**
- Install side-mount sash locks on the WAT-1, WAT-2, and WAT-3 units, **total 62 windows/124 sash locks**

- Install pulley seals on the WAT-1, WAT-2, and WAT-3 units (if there is no rope or chains in place, block the holes with non-foam sealant), **total 62 windows/124 pulley seals**

Roof Deck: Air-Seal and Insulate

The attic is set up as conditioned space, with R-19 batt insulation (Kraft-faced) within the open framing of the roof deck. The wood-framed exterior walls extend 2' H above the floored attic framing. These walls have un-faced R-13 batts. The dormer walls are also insulated. None of the insulation has an air barrier.

Approximately half of the third floor is conditioned office space. Some of the walls partitioning these offices off from the unfinished attic are insulated. It is not needed, and the other office walls do not insulation added. The space outside of the offices is used for storage, so items may need to be moved when working there.

Because the attic area is directly open to the outdoors, there are currently considerable temperature and humidity swings. This has generated major occupant comfort and indoor air quality (IAQ) issues (noted by staff within the third-floor office area) and deterioration of the stored files/office equipment.

To establish and align air and thermal barriers, effectively bringing the attic area into the building envelope, and to improve the performance of the existing insulation, rigid 1" fire-rated insulation needs to be installed on the underside of the sloped roof sections, the dormer wall surfaces, and the 2' high exposed exterior walls, sealing all seams.

The maximum working height is approximately 16'-18' at the peak, with a working headroom height of approximately 3' along the eaves. Access to the attic areas is via staircase.

- Install 1" rigid, fire-rated foam insulation to the underside of the sloped wood roof decks, sealing all seams, **total 6,133 SF**

- Install 1" rigid, fire-rated foam insulation to the interior surfaces of the two wood-framed dormer walls, sealing all seams, **total 164 SF**

- Install 1" rigid, fire-rated foam insulation to the interior surfaces of the exposed exterior walls (2' above the attic floor), sealing all seams, **total 564 SF**

DPW/Highway Department – Building-1 (Ref #6a)

The Highway Department Building-1's (newer) high bay was built in 2002. The vehicle storage high bay has corrugated metal interior and exterior wall surfaces, as well as a corrugated metal-sloped roof system. The walls and attic space are insulated. There are no windows. The high bay is in good condition and well-maintained by staff. The building envelope is somewhat leaky, with considerable air-leakage identified along exterior and overhead door systems.

Doors

The exterior doors are leaky and need to be weatherstripped. The doors are white. White or mill-finished door kits will be fine. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip standard-size exterior doors, **total 3 doors**

Overhead Doors

There are two sectional-type overhead doors that measure 14' W X 14' H. These doors tested leaky and should be weatherstripped, per the QAS manual and floor plan.

- Weatherstrip the 14' W X 14' H overhead doors, **total 2 doors**

DPW/Highway Department – Building-2 (Ref #6b)

The Highway Department Building-2's (original) high bay was built in 1970. The vehicle maintenance high bay has corrugated metal interior and exterior wall surfaces, as well as a corrugated metal-sloped roof system. Batt insulation and poly barriers are affixed to the interior surfaces of the walls and roof surface. The high bay is in fair-to-good condition (considering age and type-of-use) and fairly well-maintained by staff. The building envelope is somewhat leaky, with substantial air-leakage identified along exterior and sectional-type overhead door systems.

Doors

The exterior doors are leaky and need to be weatherstripped. The doors are white. White or mill-finished door kits will be fine. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip standard-size exterior door, **total 1 door**

Overhead Doors

There are two sectional-type overhead doors that measure 14'6" W X 14' H. These doors tested leaky and should be weatherstripped, per the QAS manual and floor plan.

- Weatherstrip the 14'6" W X 14' H overhead doors, **total 2 doors**

Windows

There is only one window at Building-2's high bay That unit that tested leaky along frame-wall junctures. The metal, double-pane, fixed unit needs to be air-sealed, 1-line, with non-foam sealants. Air-seal the window, per the QAS manual and floor plan.

- Air-seal the WAT-1 unit along frame-wall junctures, 1-line, using non-foam sealants, **total 16 LF**

Municipal Light Department – Office Building (Ref #7a)

The Municipal Light Department's office building was built in 1984. Renovations were performed in 1998, when the high bay structure was built directly behind it. The office has wood-framed walls with masonry exterior and a wood-framed slope roof system. The structure is in fair-to-good condition and well-maintained by staff. The building envelope is quite leaky, due partly to failing weatherstrip and sealants along with construction framing details (i.e. there is no effective air barrier in place along the top of the building). Staff noted that defroster cable has been installed along the roof eaves to address ongoing ice dams.

Doors

The exterior doors are leaky and need to be weatherstripped. The doors are brown. Brown of mill-finish door kits will be fine. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip standard-size exterior doors, **total 4 doors**

Attic Hatches

Because there is currently no air barrier above the drop ceiling, there is no dedicated access to the office building's attic space. People can just lift a ceiling tile and move insulation aside to enter the attic space. After the air barrier is installed (see below) an attic access hatch needs to be framed-out within the truss framing, and a new access hatch needs to be installed. This hatch needs to be weatherstripped and insulated with 4" of rigid board insulation.

- Install framing and 2' W x 3' L attic access hatch within the attic truss framing, weatherstripping and insulating with 4" rigid foam board insulation, **total 1 new hatch**

Overhead Doors

There is one sectional-type overhead door that measures 8'6" W X 8' H. It tested leaky and should be weatherstripped, per the QAS manual and floor plan.

- Weatherstrip the 8'6" W X 8' H overhead door, **total 1 door**

Windows

There are two window assembly types at the office building. They are metal-framed, double-pane sliders. They tested leaky along the frame-wall junctures. These windows need to be air-sealed, 1-line, with non-foam sealants. Air-seal the windows, per the

QAS manual and floor plan.

- Air-seal the windows along the frame-wall junctures, 1-line, using non-foam sealants, **total 163 LF**

Air Barrier

The sloped wood roof, with truss framing, has no insulation. The roof assembly has soffit and ridge venting. There is R-30 batt insulation fitted within the bottom of the truss framing. There is essentially no air barrier in place, allowing ongoing heat losses (during heating season) and air, moisture, and pollutant infiltration during the spring, summer, and early fall. A rigid air barrier needs to be installed on the bottom of the truss framing, above the suspended ceiling, using 1” fire-rated board insulation, sealing all seams and penetrations. The working height to the bottom of the truss framing is 10’. The bottom of the truss is approximately 10” above the suspended ceiling.

- Install an effective air barrier, affixing 1” fire-rated board insulation to the bottom of the truss framing, sealing seams and penetrations with 2-component, closed-cell, polyurethane spray foam, **total 4,000 SF**

Municipal Light Department – High Bay (Ref #7)

The high bay was built in 1998. It has corrugated metal interior and exterior wall surfaces along with a corrugated metal sloped roof system. The walls and roof are insulated. There are no windows at the high bay. The structure is in good condition and is well-maintained by staff. The building envelope is somewhat leaky, with significant air-leakage identified along the exterior and overhead door systems.

Doors

The exterior doors are leaky and need to be weatherstripped. The doors are beige. Brown or mill-finished door kits will be fine. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip standard-size exterior doors, **total 2 doors**

Overhead Doors

There are four sectional-type overhead doors that measure 12' W X 14' H. The doors tested leaky and should be weatherstripped, per the QAS manual and floor plan.

- Weatherstrip the 12' W X 14' H overhead doors, **total 4 door**

Peabody Public Library (Ref #8)

The original library structure was built in 1904. A substantial renovation was performed in 1980. In 2006, the large addition was built as a renovation was performed on the original section. This original structure has wood framing, brick/masonry wall systems, and sloped wood roof systems. The addition has steel framing, brick/masonry walls, and a flat, metal roof system. Overall, the structure is in fair/good condition and well-maintained by staff. The building envelope is quite leaky, partly due to failing weatherstrip and sealants, as well as construction framing details along several sections.

Doors

The exterior, mechanical room, and knee wall/attic access doors in the building are leaky and need to be weatherstripped. One of the knee wall doors will need to have 3" rigid board insulation installed. The doors in the building are white, beige, and wood. White, mill-finish and spring-bronze door kits/materials will be fine. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip standard-size exterior, mechanical room, and attic access doors, **total 12 doors**
- Weatherstrip non-standard, 3'6" W x 7' H, exterior door using spring-bronze materials, **total 1 door**
- Weatherstrip standard-size mechanical room doors with fire-rated materials, **total 2 doors**

Windows

There are six window assembly types. The WAT-4 units tested tight, as did the addition's newer, metal-framed, double-pane windows (WAT-6). The WAT-3 and WAT-5 units are wood-framed, double-hung, and casement-type. These windows tested leaky along the sashes. As they are unused, these windows should be sealed shut along the sashes, 1-line, using non-foam sealants. Additionally, the WAT-3 units are a source of staff and customer complaints who state, "it's excessively cold when working/sitting near these units." After the windows are sealed shut, interior storms should be installed to improve comfort. The WAT-1 and WAT-2 units tested leaky along frame-wall junctures. These wood-framed, single-pane windows need to be air-sealed, 1-line, with non-foam sealants. Weatherstrip and air-seal the windows, per the QAS manual and floor plan.

- Air-seal the WAT-1 and WAT-2 units along frame-wall junctures, 1-line, using non-foam sealants, **total 84 LF**

- Seal shut the WAT-3 and WAT-5 units along the sashes, 1-line, using non-foam sealants, **total 214 LF**

- Install interior storms to the WAT-3 units, **total 113 SF**

Roof-Wall

The roof-wall junctures are leaky at the addition and sections along the building joints (original-to-addition junctures). The junctures need to be air-sealed with 2-component, closed-cell, polyurethane spray foam. All flutes on steel decking must be punched and sealed. A small (38 LF) section (curved bump-out at end of addition) has a solid sheetrock ceiling that extends 12' into the room. The extension wands will be needed in this small section. There are 56 lineal feet of roof-wall junctures (skylight-ceiling) to be air-sealed, 2-lines (1-line at the top, 1-line at the bottom of the framing details), along the large curved skylight overlooking the open floor to below. This is at 26' working height with direct access to the junctures. A small lift could be used from the lower level, up through the opening, to access the junctures (extension ladders are an option as well). Air-seal the roof-wall junctures, per the QAS manual and floor plan.

- Air-seal the building joint and any framing penetrations, 1-line, at 14' working height above suspended ceiling, **total 54 LF**

- Air-seal the roof-wall junctures and any framing penetrations, 2-lines (1-line top, 1-line bottom of beam), at 14' working height above suspended ceiling, **total 306 LF**

- Air-seal the roof-wall framing junctures (skylight-ceiling), 2-lines (1-line at the top and 1-line at the bottom of the framing details), along the large curved skylight overlooking the open floor to below. It is at 26' working height with direct access to the junctures (extension ladders), **total 56 LF**

Knee Wall: Air-Sealing

The attic has rafter-style framing, with approximately 9" of blown cellulose in the floor framing (much of it is floored, and the section along the eaves is open beam: all insulated). The knee wall separating the conditioned space and attic area has R-11 batt insulation fitted in the framing, but it is void of an effective air barrier. Within the conditioned space and beyond the knee wall, there is a solid surface ceiling in place with batt insulation atop the ceiling. There is no access to the upper attic area. To establish an effective air barrier and align with the existing thermal barrier, 1” rigid board insulation needs to be affixed to the rear of the 9’ high knee walls, sealing seams with 2-component, closed-cell, polyurethane spray foam. There is no open-floor framing detail to be air-sealed. However, directly above the knee wall, the knee wall-to-roof slope framing junctures need to be blocked with rigid board insulation, sealing seams with 2-component, closed-cell, polyurethane spray foam. There are 34 lineal feet of 9’ H knee walls and 12 lineal feet of a 4’ H knee wall section above the access door with (16” o/c) framing. Access to the attic area is via standard-size door, which needs to be weatherstripped and have 4” rigid board insulation affixed. The working height along the knee wall is 13 feet. Air-seal the knee wall and the bottom of the slopes. There are no slopes to block in the section above the door.

- Air-seal the rear of the 9’ H knee wall and the 12 LF x 4’ H section above the access door with 1” rigid insulation board affixed to the framing, sealing seams with 2-component, closed-cell, polyurethane spray foam, **total 354 SF**

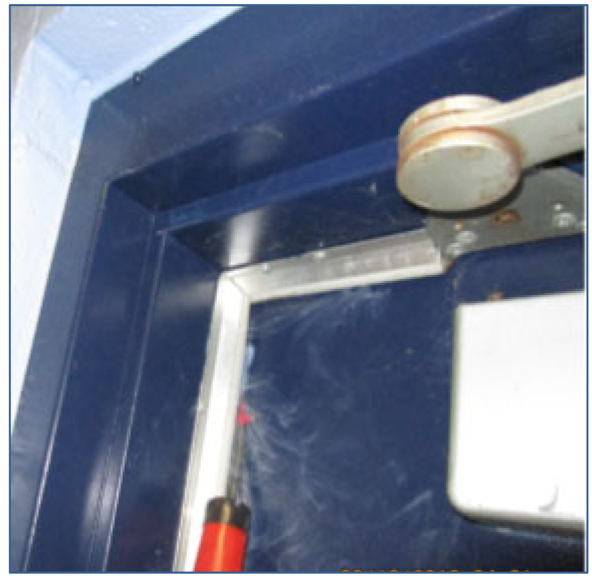
- Air-seal the bottom of the slopes with rigid board insulation, sealing seams with 2-component, closed-cell, polyurethane spray foam, **total 34 LF**

Roof Deck: Air-Seal and Insulate

Within the conditioned attic/storage space, the attic floor has approximately 9” of blown cellulose insulation (loose-filled, 12” floor cavity). Partially insulated knee walls separate the moderately conditioned storage space (i.e. a large register within the supply duct). There is no access to the insulated upper attic. The sloped wood roof deck framing has R-19 batt insulation within the open framing, but it is void of an effective air barrier. The attic space is used to store furniture, files, and equipment. This attic space is essentially within the building envelope and directly conditioned. To establish and align air and thermal barriers, effectively bringing attic storage into the building envelope, and improve the performance of the existing insulation, 1” rigid, fire-rated insulation needs to be affixed to the underside of the sloped roof framing, sealing all seams. There are 1,120 square feet of wood roof deck surfaces to be air-sealed with 1” rigid, fire-rated insulation. The max working height is 14’, with approximately 2’ headroom along the eaves. Access to the space is via a standard-size door.

- Affix 1” rigid, fire-rated board insulation to the underside of the sloped wood roof decks, sealing all seams, **total 1,120 SF**

Doors

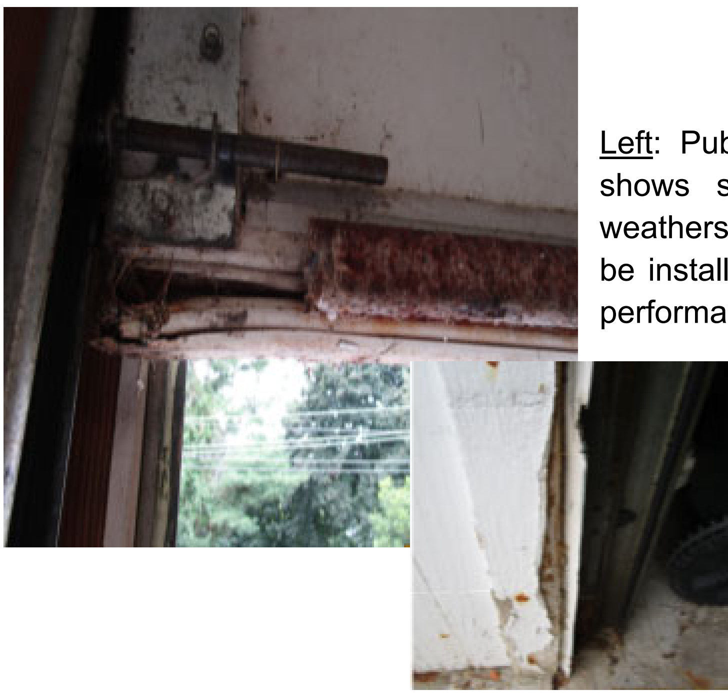


Right: MS-HS – tracer smoke testing along the exterior doors identified significant air-leakage, due to failing weatherstrip. Note the smoke being blown back into the conditioned building space, indicating considerable air infiltration. New weatherstrip needs to be installed on the exterior door systems.

Left: Town Hall – photo shows tracer smoke test being performed along exterior double-door system. Note the large (1/4”) gap, with daylight peering through along the center, and the smoke being blown back into the building. This signifies sizable air and moisture infiltration through the building envelope. New weatherstrip needs to be installed on the exterior door systems.

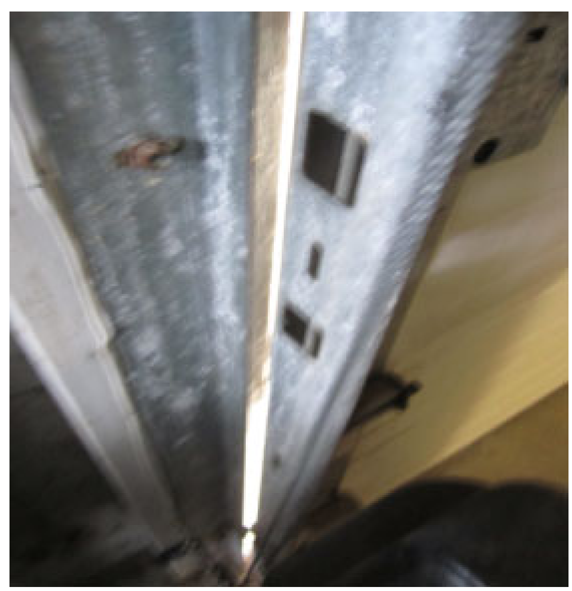
Right: Peabody Library – the doors (third floor) leading to the attic spaces behind the knee walls are effectively exterior doors. These doors lack weatherstrip and, as such, need weatherstrip installed.

Right: Highway Dept. Bldg. #2 – tracer smoke testing along the overhead doors indicates substantial air-leakage. Note the smoke being pulled out of the building's conditioned space, representing ongoing heat loss during the heating season and heat, moisture, and outdoor pollutant infiltration during the spring, summer, and early fall seasons. New, durable weatherstrip needs to be installed on the overhead door systems in both buildings.



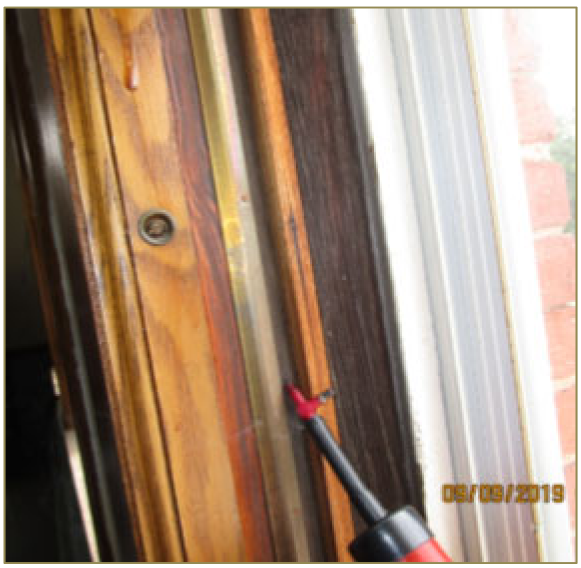
Left: Public Safety – the overhead door system shows significant signs of deterioration of its weatherstrip. New, durable weatherstrip needs to be installed on each of the doors to improve their performance and that of the building overall.

Right: Municipal Light Dept. – note the daylight showing through the edges of the overhead door. These large gaps are due to failing and/or missing sections of weatherstrip. New, more durable and effective materials need to be installed on the overhead doors at the two Light Dept. buildings.



Windows

Right: Penn Brook E.S. – photo shows one of the many large, fixed windows throughout the school. Testing indicates that most of these are leaky along the mullion details at the corner seams (insert). Each of the large window systems (library, stairwell landings, etc.) need to have these details air-sealed using non-foam sealants.



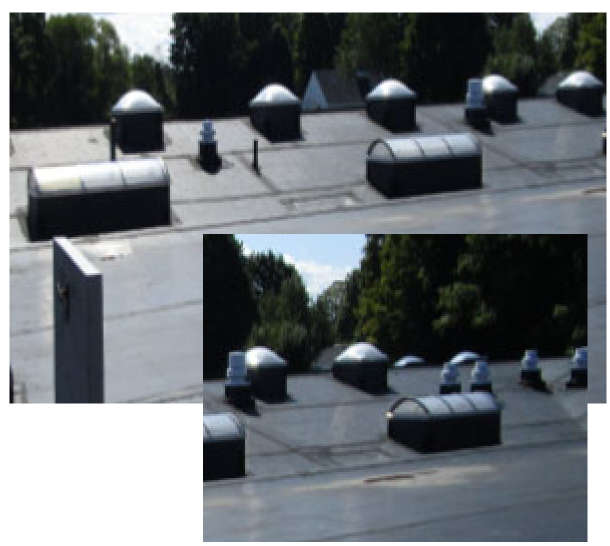
Left: Perley School – testing along the window systems identified significant air-leakage, due to failures with the existing weatherstrip. New weatherstrip needs to be installed along the sashes and meeting rails to tighten these units, alleviating drafts and improving occupant comfort and the energy performance of the windows.

Right: Town Hall – smoke testing along the wood, double-hung windows indicates air-leakage, partly due to some shrinkage in the wood framing, but mostly due to failing or missing weatherstrip. New weatherstrip (including sash locks and pulley seals) needs to be installed on the wood-framed and metal-framed windows basement sections.

Windows & Skylights

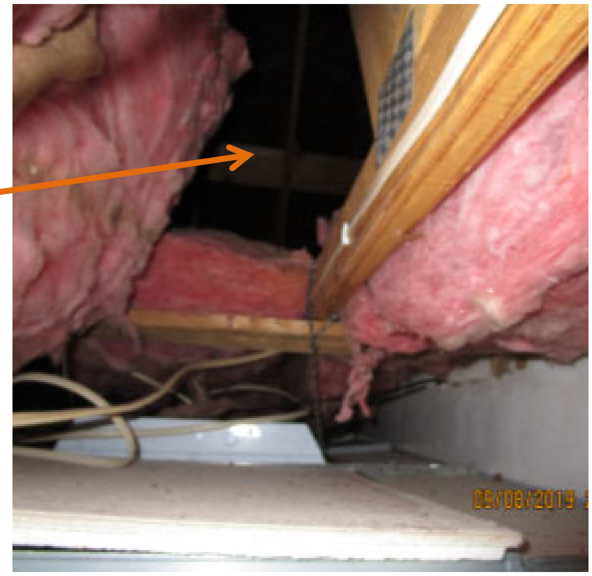
Right: Public Safety – tracer smoke testing along the frame-wall junctures. Note the smoke being blown away from the seam and back into the conditioned space, indicating significant air-leakage that bypasses the window. These leakage paths allow for drafts and enable outdoor humidity and pollutants (e.g. pollen) to enter the building. These frame-wall junctures need to be air-sealed using non-foam sealants.

Left: Public Safety – photo shows example of the deteriorated weatherstrip on the windows. The (insert) photo show the dirt, insect remains, and other outdoor pollutants that enter through these air-leakage paths into the building, lending to poor occupant comfort and IAQ. New weatherstrip needs to be installed to alleviate these drafts and improve occupant comfort and IAQ.

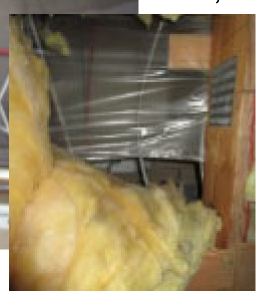


Right: Perley School – the photos show the square and rectangular skylights and roof-top fans along the flat roof. The skylights and fans connect the outdoors directly to the conditioned spaces below, due to sealant failures and framing details along the curbs and fan chases. The skylights and fans need to have these air-leakage paths sealed.

Air Barriers



Right: Light Dept. Office – the photo shows the truss framing, with batt insulation fitted within the framing directly over the suspended ceiling. Looking through the void, you can see the **underside of the sloped wood roof deck**. There is no effective air barrier between the building's conditioned spaces and the attic/outdoors. An effective air barrier needs to be affixed to the underside of the truss framing, creating aligned air and thermal barriers and improving occupant comfort, IAQ, and the overall energy performance of the building.



Left: Public Safety – throughout most of the upper floor, there is no effective air barrier above the suspended ceiling. Note the batt insulation falling out from between the truss framing, and the thin plastic torn, fallen, and missing in sections. The insert photo shows the same detail from the attic side. As with the Light Department, an effective air barrier needs to be installed above the suspended ceilings to establish and align effective air and thermal barriers.

Knee Walls & Attics

Right: Library – photo shows a section of the knee wall, which is essentially an exterior wall, as it separates the third floor's conditioned space from the unconditioned attic area. The insulated wall is very leaky (note the large duct penetrations) and has no effective air barrier. A rigid air barrier needs to be installed, affixed to the knee wall framing and sealed to improve the energy performance of the walls and occupant comfort within the conditioned space.

Right: Library – Along the other side of the original building, the attic/storage area is conditioned space (below, heating vent). Here, the insulated roof deck needs to have an effective air barrier affixed to the underside of the deck framing, covering and improving the performance of the existing insulation. This will effectively align the air and thermal barriers, bringing the conditioned space into the building envelope and improving the condition of the space and overall energy performance of the building.

Left: Library – the heating duct/register conditions the space used for storage of files, equipment, and other office materials. Without an effective air barrier in place, the performance of the existing insulation is dramatically reduced, and communication with the outdoors is ongoing. Installing an effective air barrier will greatly improve the performance of this space and that of the building overall.

Right: Town Hall – the center of the third floor is used for office space and is surrounded by knee walls. Because the thermal barrier is the roof deck, the knee walls do not need insulation. But the insulation does need an air barrier. To establish and align effective air and thermal barriers, the underside of the insulated roof deck needs to have an effective air barrier installed along the exterior walls, which extend 2’ above the floor, to assure a continuous air barrier.

APPENDIX 1 –
BUILDING ENVELOPE OVERVIEW

Building envelope retrofits are designed to improve deficient areas of a building's thermal and/or air (pressure) boundaries. For thermal deficiencies, this is done through increasing the R-value of building components, by either replacing components (e.g. windows) and/or by installing insulation. For pressure-related deficiencies, the retrofit focuses on sealing up areas where unwanted air migration occurs.

Air movement across the building's pressure boundaries may be intentional – designed to introduce fresh air or to exhaust stale air – or unintentional. Intentional air movement is known as ventilation. Unintentional air movement is known as air leakage. Air leakage can result in conditioned air moving from inside the building to outside and/or unconditioned outside air moving into the conditioned building. Many times, intentional efforts at ventilation result in additional unintentional leakage via building junctures.

The Effects of Pressure and Hole-Size on Air Flow in Buildings

A simple orifice calculation for air flow is:

$$\sqrt{P} \times A\ in^2 \times 1.07 = \text{flow in cfm} \text{ (if the pressure is in Pascals)}$$

The two main factors air leakage are pressure and hole-size. Air flow increases by the square root of the pressure and linearly via the hole-size. When evaluating a building envelope for retrofit, we are constantly on the lookout for gaps, cracks and holes that provide pathways to the exterior – the linear component.

There are 3 driving forces that move air across the pressure boundaries of a building:

- Stack Effect – pressure caused by the density difference between outside and interior air, due to temperature differentials;
- Wind Effect – wind driven pressures; and
- Mechanical Effect –either deliberate or inadvertent pressure imbalances created by the HVAC systems.

The potential for unintentional airflow exists in all buildings due to the presence of these three physical effects. This air flow can either be into the building – infiltration; or out of the building – exfiltration. The airflow itself is made possible by the flaws in the building envelope – gaps, cracks and holes.

So, the two fundamental concerns are the continuity of the building's air barrier and the pressures at which the building operates.

Savvy design engineers will attempt to balance a building's HVAC systems to reduce the effects of all three driving forces. Buildings so balanced perform much better from an airflow standpoint but are still regularly subjected to forces outside the range of intentional design parameters, and are susceptible to changes by occupants and staff.

A recent study on building commissioning recommended that buildings be reviewed every 5 years or so to determine if they are still in balance and make adjustments if needed to keep them in balance. In the majority of the buildings we investigate for building envelope retrofits, we request that the building be "re-balanced' following the building envelope repairs.

In addition, the leakier the building, the more difficult it is to maintain that balance as the various pressure effects work on the building and the energy penalty of maintaining the desired pressure increases. Tightening the building envelope decreases the energy use and increases the likelihood that the building will perform within design pressure parameters. Some physicists and engineers are beginning to speculate whether building pressurization is necessary with a tight building envelope.

How Leaky Are Buildings?

Many believe that institutional and commercial buildings are tight structures. Several pieces of research, as well as our direct observations in the field over many years, belie this assumption.

"It is often assumed that commercial and institutional buildings are fairly airtight and that envelope air leakage does not have a significant impact on energy consumption and indoor air quality in these buildings. Furthermore, it is also assumed that more recently constructed buildings are tighter than older buildings. The fact of the matter is that very few data are available on the airtightness of building envelopes in commercial and institutional buildings. The data that do exist show significant levels of air leakage in these buildings and do not support correlations of airtightness with building age, size, or construction." ***Airtightness of Commercial and Institutional Buildings: Blowing Holes in the Myth of Tight Buildings****, Andrew K. Persily, Ph.D.****,*** *Thermal Envelopes VII Conference.*

APPENDIX 1 –
BUILDING ENVELOPE OVERVIEW

“Many discussions in the popular press and the technical literature still refer to commercial and institutional buildings, and newer buildings in particular, as being airtight. ’Tight buildings’ often are blamed for a host of indoor air quality problems including high rates of health complaints and more serious illnesses among building occupants. Furthermore, discussions and analyses of energy consumption in commercial and institutional buildings frequently are based on the assumption that envelope air leakage is not a significant portion of the energy used for space conditioning. These statements are almost never supported by any test data or airflow analysis for the buildings in question.” ***Airtightness of Commercial Buildings in the U.S.*** *Steven J. Emmerich and Andrew K. Persily, Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, MD, USA.*

Retrofitting a building’s envelope generally involves sealing various gaps, cracks and holes that currently allow uncontrolled migration of air between the inside and the outside of the building. Building envelope retrofits have wonderful opportunities for energy savings. There are many other non-energy benefits associated with the work. Thermal comfort of occupants is often improved. Indoor air quality is often helped as outside pollutants are stopped from entering the building. Pressure differences from mechanical system imbalances can be mitigated. Pest, odor, and water infiltration headaches are often taken care of by building envelope retrofit work. In many instances, repairing building envelope issues can increase the time before structural issues manifest themselves.

Common Air Sealing Needs

Lack of continuity in a building’s air barrier is frequently found in a number of areas. Common measures include roof-wall joint sealing, repair of soffit openings, replacement and/or weatherstripping and sealing windows and doors.

Doors: Doors are very cost effective to weatherstrip. The proper weatherstrip should be ample, durable, and capable of transitioning between seasonal variations. It should be completely air tight at all times when the door is closed. A number of products have thin bulbs, which cannot accommodate seasonal variances. Others are made of brushes, which close the hole down but do not completely seal it. Oftentimes the “fuzz” product in a frame is worn or lacks a silicone or Teflon tab in the middle to completely block the flow. Carefully selected replacement weatherstrip products for windows and doors have been proven over time to be durable and effective.

APPENDIX 1 –
BUILDING ENVELOPE OVERVIEW

Windows: Windows are also a common measure. Replacement windows generally have extremely long paybacks. Whenever possible, it is much more cost effective to air seal and weatherstrip windows rather than replace them. Many times, replacement windows leak around the frames due to the installation procedures. These can be made air tight with appropriate sealants.

Roof-wall: Often the juncture where the roof and the wall meet is not airtight. The usual approach is to seal this joint with 2-component, closed-cell polyurethane foam. This provides a durable, monolithic seal and stops leakage around the perimeter of the roof. Elevation changes – where second or third stories attach to lower structures – are sometimes areas of great leakage. In addition to 2-component foam, backer rods and caulks are sometimes appropriate for these junctures or rock-wool and fire-rated mastic

Soffits: Soffits are often areas of significant leakage. Some are several feet high, going around the entire perimeter of the building. The severity of the problem varies – we find them ranging from wide open to totally sealed. We frequently find fiberglass insulation installed over the gap. Usually some has fallen, leaving a gaping hole. Even if the fiberglass is still in place, it is not a good seal in and of itself. The rule of thumb is that if it will not hold water, then it will not stop air flow. Similarly, we see failures of polyethylene and other non-rigid materials that cannot be effectively fastened used in attempts to air seal these junctures. These materials are not able to stand up to the building pressures they are exposed to and are easily pierced and torn.

Penetrations: There are other miscellaneous penetrations throughout buildings, including utility chases, plumbing and electrical penetrations, HVAC duct penetrations and boots that are not sealed, rooftop fan curbs not sealed, and more. A well-trained inspector is needed to identify all the penetrations that should be sealed.

Insulation and By-passes: Finally, we often see a misalignment of the thermal and air barriers of the building. When the air barrier is not in direct contact with the thermal boundary, the insulation is bypassed and does not function at its rated values. Similarly, cold air can intrude behind the insulation and make direct contact with the air barrier. This provides an opportunity for condensation on internal building surfaces. The condensation can lead to building degradation and/or mold problems. On occasion, buildings lack insulation in the walls or attic/roof deck and insulation needs to be added.

APPENDIX 2 – TESTING METHODOLOGIES

There are three applicable standards for determining airflow in buildings. They are ASTM E1186, ASTM E779, and ASTM E783.

ASTM E1186

ASTM E1186 ***Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*** cites a number of different methodologies for determining leakage locations. The pertinent ones for testing at this site are: ASTM E1186 section 4.1.1 Combined building depressurization (or pressurization) and infrared scanning; section 4.1.2 Building depressurization (or pressurization) and smoke tracers; section 4.1.3 Building depressurization (or pressurization) and air-flow measuring devices; and section 4.1.4 Generated sound and sound detection.

We use a variety of tests depending on the local conditions. A very popular methodology is section 4.1.1, the infrared approach. However, air leakage is very difficult to detect using IR. If the building is cooled or heated and the outside weather is sufficiently different, then this method may yield good results depending on cladding, cloud cover, etc. – and most importantly, operator skill. Section 4.1.2, smoke tracer testing is the gold standard within the retrofit industry as it is not subject to as many of the limitations as are the other methodologies. Section 4.1.3 air flow measuring devices can be used when there are sufficient pressure differentials across the building envelope. Section 4.1.4 generated sound can really help when conditions are benign with limited pressure differentials. In this instance a noisemaker is deployed and the sound signals tracked through fissures within the building envelope. Fan pressurization/depressurization can also be performed to spur smoke movement, allow the use of IR or enable anemometers to record flows. The other applicable standards are tracer gas testing and chamber tests in conjunction with pressure differentials.

ASTM E1186 is a strictly qualitative test. It is used to locate the sources or pathways of air leakage. It does not quantify the extent of the leakage. The inspectors determine the crack size of the leakage area in order to estimate the effects of the leakage and the potential savings. The principal Energy Conservation Field inspectors have decades of combined experience in the energy efficiency building envelope retrofit field. Their decisions are based upon thousands of similar calls in the past and the results of many retrofits.

APPENDIX 2 – TESTING METHODOLOGIES

There is a quantitative approach to determining the amount of air leakage. Buildings can be pressure tested in conformance with the ASTM E779 to quantify the air flow across the building envelope at various pressure differentials.

ASTM E779

ASTM E779 ***Standard Test Method Determining Air Leakage Rate by Fan Pressurization*** is the standard driving the U.S. Army Corp of Engineers' (USACE) test protocol for new construction projects. The same whole building tests can be performed on existing structures. This is a significant standard because the practices described under ASTM E1186 are qualitative, determining the air leakage sites rather than determining quantitative leakage rates. So, for Measurement and Verification (M&V), the E779 can document and verify the actual reductions forecast in the initial site inspection.

The buildings may be tested under pressurization or depressurization in increments between 25 and 75 Pascals. A minimum of 6 measurements must be made. Preferably, 10 measurements are taken. Baseline pressure measurements must be recorded prior to conducting the test and immediately following the test.

This type of testing can supplement the ASTM E1186 tests and quantify leakage rates. They may be included for measurement and verification (M&V), to document actual reductions. Generally, we rely on pre- and post-tests using the E1186 tests only, due to the significant costs and inconvenience associated with multi-fan blower door testing.

ASTM E783

ASTM E783 ***Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors*** uses microleakage detection devices. Microleakage testing requires setting up to measure leakage at a specific opening, taking the measurement, tearing down the testing setup, installing the measure, then repeating the testing process. Each test takes approximately one hour for the pre-test and one hour for the post-test. During the testing, the window or door is not available for egress. Again, these tests are usually not necessary, but can be done if needed or desired.