Jaffrey Town Offices
Energy Assessment
March 2009

BUILDING STRATEGIES FOR AN AFFORDABLE FUTURE
S.E.E.D.S.
SUSTAINABLE ENERGY EDUCATION DEMONSTRATION SERVICES
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Energy Performance Assessment Preface

This energy assessment was conducted on behalf of The Jaffrey Energy Committee and planned prior to the completion of the Turner Group's Facility Assessment.. The selection of The Town Office building for a pro bono energy assessment was due to the facts that it is a highly visible and frequented town building and it is most similar to residential construction of all town buildings, therefore a potential energy retrofit demonstration site for town residents.

Drawbacks to its selection are the facts that its total energy consumption is among the lowest in the town and the recommendation from the Turner Group that the Town should "seriously consider setting aside funds for a new Town Office Building."

So in consideration of the many limitations of the building's used for Town Offices for the long term, (space; accessibility; and maintenance costs, and the relatively lower energy use, this assessment is offered in keeping with HL Turner Group's recommendation for "Further study should be undertaken to determine the most effective ways and locations to improve the insulation (and ventilation) of the building. Recommendations are general but offered for two different levels of energy reduction. Option A is offered to reduce energy use and improve comfort and durability in the most cost effective manner possible.

The latter to provide an example of a deep energy retrofit to effect a high performance building: ie a building which is durable, comfortable and provides healthy indoor air, all for minimal energy input. Deep Energy Retrofits are gaining in awareness and program interest and yet require high upfront costs so generally happen on buildings where there is long term commitment or other reason for investment.

The Assessment addressed Envelope or Enclosure upgrades in greater detail than mechanical systems and yet it is important to note that all buildings work as a whole and integrated system of these component system parts.

Finally, conventional modeling has not been included at this time. Though this building is actually a good candidate for modeling (and not all are) the report is submitted as is for your deliberations for this upcoming meeting on November 16th. Please note that the work here constitutes most of what is covered in a formal energy audit, and may well suffice for pursuing federal or state grants towards improvements. Work estimates and projected energy reductions are what are lacking. The assessment itself is comprehensive.

Respectfully submitted,

Margaret Dillon

Summary of Recommendations – Tier 1

Envelope or Enclosure Upgrades

1. Remove all fiberglass on exterior wall in chase between 1st and 2nd floor. Spray 2 part 2" urethane foam in cavities and over wall studs to create a continuous air, moisture and thermal barrier and cover with intumescent paint for 1 hour flame rating. Effective R12 cont Est Cost $2800
2. Gut existing fiberglass insulation above second floor. Several options exist but all of them labor intensive as there is a jungle of wires, pipes and ducts in a narrow area. Several options were suggested by HL Turner Group. It is recommended that a rigid air barrier be established in direct contact with an effective thermal barrier and that the enclosure control layers be moved to the roof slopes – ie air, moisture and insulation layers be located at the roof slopes with insulation on the interior and exterior. Strap the 2x6's with 2x's for a cavity depth of 7" , cover with 1" XPS and dense pack cellulose for an interior R-30. End walls will also need to be strapped and filled and gable vents sealed. The goal is a cold, unvented roof assembly. Est cost: for new installations: $7,500 ROUGH guess at gutting and wire management: $3500. (Note: engineering concerns around snow loads still need to be explored – or consider Tier 2 upgrade)

   Further, any duct work or heating delivery systems should be air sealed with mastic and insulated to R6 and included within the thermal envelope. Est. cost: 750.00.
3. Remove fiberglass behind all knee wall areas and accessible slopes. Install 2" thermax on slopes and dense pack cellulose behind. R28 cont Est Cost: $3200
4. Spot fill wall voids over 1 ft2. Est Cost: $350
5. Replace window units with quality wood/alum clad max U.33 and max SHGC .4.. Est cost: $14,250

Total estimate (rough) for above upgrades: $32,350

Impact: Dramatic reduction or elimination of all ice dams; significant increase in comfort and reduced temperature differentiation between floors; reduced propane use of approximately 400-500 gallons.

HVAC

Introducing outside air into the two heating units with accessible return plenums will improve air quality however exploring an entire new heating system is advised at the time of these energy retrofits. Each of the three units are oversized, each has operational issues, and none are operating efficiently.

One option is to convert to hydronic heating by replacing the first floor closet split system with a sealed combustion, high efficiency, condensing, modulating boiler with outdoor rest controls to serve the entire building. Running plastic tubing up above both ceilings will not be much more cumbersome than air sealing, insulating and removing kinks in existing ducts, which also need to be cleaned. Tubing could serve individually controlled radiating panels in each office for greater comfort and efficiency. Outdoor thermostat resets and programmable thermostats can also improve annual system efficiency 5-10% while condensing boilers offer 96-98% burner efficiency. Office environments with forced hot air systems are notorious for employee comfort complaints. Hydronic systems offer greater comfort, more efficiently, and with fewer pressure imbalances in the building.

Two HRV's could be installed within the existing duct work system (if cleaned), one for each floor, with outdoor air and exhaust vents installed.

The cost should be considerably less than the $70,000 slated for mid term replacements of all three existing units in the Turner Group Report. Integrating the conversion with envelope upgrades will be more cost effective and possibly eligible for stimulus funds as well as reaping energy savings immediately.

Summary of Recommendations – Tier 2

1. Roof shingle replacement is also recommended within the next 8-12 years. With the envelope defined at the roof, installing 2-3" of XPS foam on roof sheathing for an additional and continuous R10-15. Metal roofing would prevent snow load build up – though a new diverting roof over the entrance would need to constructed. This assembly would assure the performance of a cold roof, unvented assembly: air tight with virtually no thermal bridging.
2. Along the lines of a deep energy retrofit and conversion to a high performance building; removing the vinyl siding and installing 2" rigid foam to the exterior converts the minimally insulated 2x4 walls to a far more effective cont R10 plus random R7-9 existing.

   Slab edge insulation could also be added at that time. Extending roof as necessary at gable ends makes it advantageous to warp walls and roof at the same time. Best case scenario would also include replacing even higher performing (R5) windows at this time with new extension jambs or other 'wall thickening' options. Opportunities for additional air sealing will also present themselves.

   Running vertical furring strips aligned with 2x4's before new siding provide a drainage plane and drying space behind siding.

Estimated costs are not offered, as there are many variables due to timing of different options. Needless to say the roof insulation could be expected to add $10-15,000 to a new roof, as would converting to metal roofing.

The impact of these Tier 2 recommendations would reduce the size of the single boiler to a modulation range of 15,000-40,000 Btu as well as a new Building UA Value of 390. In combination of the improved HVAC system, this suggests a combined 80% reduction of propane use while creating a vastly more comfortable, durable and healthier building environment. While not addressing space needs, security concerns or accessibility for a Town Office Building, the building would be a viable asset well into the 21st century as well as a demonstration project for the town and state.

ANNUAL ENERGY USE SUMMARY



Propane
1957 Gallons
space and water heating

Electricity
KWH
Buildings Lights, Appliances,
heating/cooling fans,& pumps, ect

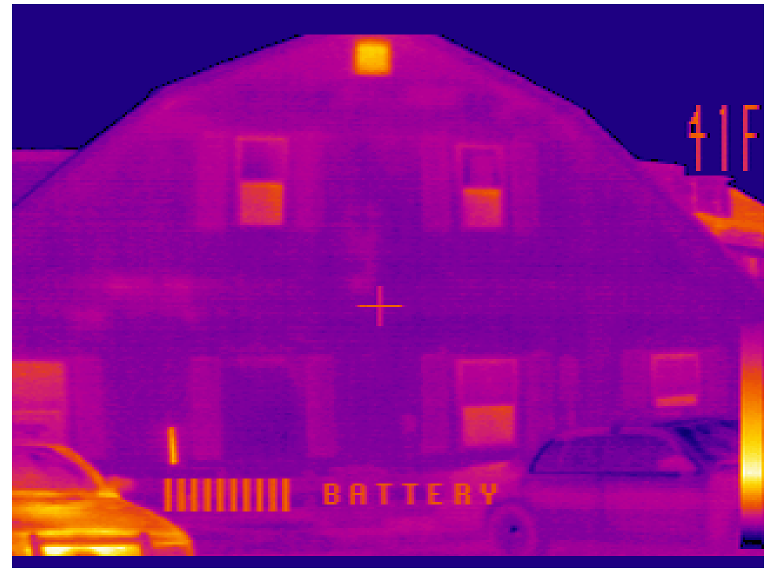
Building Energy Metric: British Thermal Units (Btu) can be used as a measurement for all energy - in terms of each sources' heat output. Btu's per square foot is often the way building energy use is discussed. For example the 2030 Challenge calls for carbon neutral buildings by 2030 and uses this metric to establish reduction goals by building type. (http://www.architecture2030.org)

Propane : 1957 gallons x 91,500 Btu's/gallon =179,065,500Btu's or **179 MMBtus**
Electricity for Lights, Heating A/C, ect: 30,320KWH x 3412 Btu/kwh =103,451,840 or **103 MMBtus**

Total heating & cooling & elec: **282 MMBtu's** / 5,360 ft2 = **52.6 KBtu's per square** foot.

The Building Envelope

The “envelope” or “enclosure can be described as the control layers of a building’s shell which separate the inside conditioned space from the outside climatic conditions. These control layers are responsible for managing the movement of air, moisture, and heat. The more extreme the climate conditions, the more important the envelope’s role. **Continuity is key.** Reducing energy demand in a cold climate requires us to improve the envelope performance to better minimize heat transfer. A high performing envelope will have a **continuous air barrier in direct contact with a continuous and effective thermal barrier.**



Infra red scanning is helpful in locating air gaps and insulation deficiencies in the envelope and to help develop an overall strategy to air seal and insulate them.

A **high performing envelope**, with mechanical ventilation for adequate fresh air exchange, provides comfort, durability, and healthy indoor air quality with minimal energy input. A high performance envelope allows for **passive surviveability** or even comfort during periods when energy supply is limited or interrupted. They will be the foundation for a sustainable future.

Planning Guide for a Strategic Energy Upgrade

I. Health and Safety (and Durability)

1. Indoor Air Quality: Eliminate - Isolate - Ventilate
    a. Basement Moisture
    b. Soil Gasses
    c. Combustion Gasses
    d. Moisture in Living Space
    e. Toxic Materials
2. Fire Safety

II. Reducing Heat Load

1. Convective Losses – Seal air leaks
2. Conductive Losses – Insulate
3. Radiation Losses/Gains – Window assessment / upgrade

III. Improving Efficiency

1. Reduce Distribution Losses
2. Systems Assessment and Upgrade

IV. Mechanical Balanced Ventilation and Heat Recovery

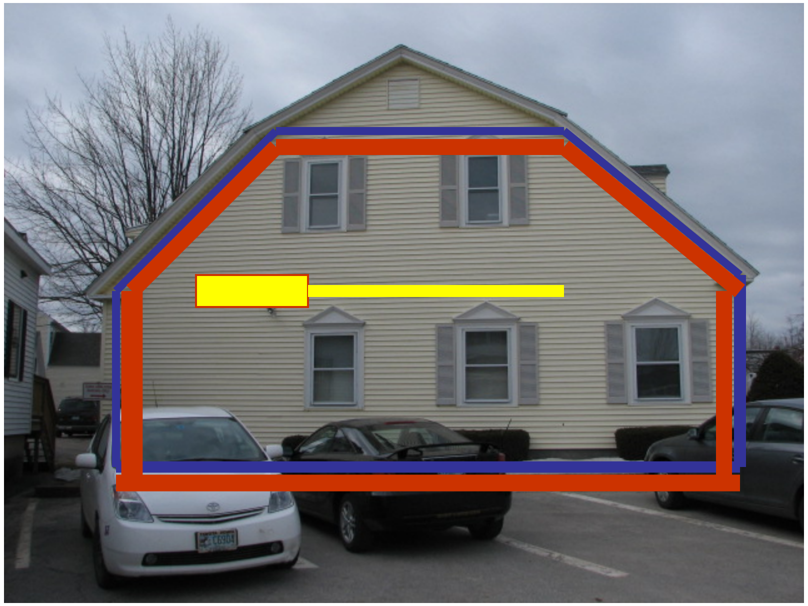
V. Reducing Electrical Load

1. Lighting
2. Appliances
3. Management Tools (Power Strips; Programmable Timers; Motion Sensors, ect)

VI. Fuel and or Renewable Energy Options

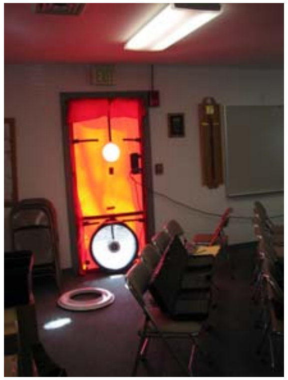
Goals of a Whole Building Performance Assessment

Strategic Elements I-IV



- Define and assess the envelope thorough blower door testing, thermography, and physical inspection.
- Identify opportunities to improve the performance of the envelope.
- Evaluate existing heating and ventilation equipment and recommend upgrades where appropriate.
- Address other specific concerns or questions of the building owners.

Blower Door Test & Results
Measuring Air Infiltration and the Air or Pressure Barrier
Convective and Conductive Heat Losses and Moisture Transfer



Whole Building: 9002 CFM50

Means that 9002 cubic feet of air per minute was pulled thorough leaks and gaps in the air barrier with the building under pressure at -50 pascals with respect to outside.

Air Change per Hour Rate at -50pa: 12.85**ACH50**

This means that at -50 pas (as if a 20mph wind was blowing on all sides of the building at once) the air would completely change almost 13 times every hour. The math: CFM50 x 60 / building volume

Standard Construction practices is generally between 7 and 9ACH50.

Energy Star's home limit is 5ACH50. High Performance Homes under 1ACH50

Estimated Annual Air Change Rate: .6 ACH Winter: 1.22 Summer:.63

This is an estimate for natural conditions – without the blower door. Annual average is about what one looks for adequate ventilation – when in fact in winter, there is far more uncontrolled air infiltration than needed. In winter, you use oil to heat the air which is replaced by outdoor air every 90 minutes or so.

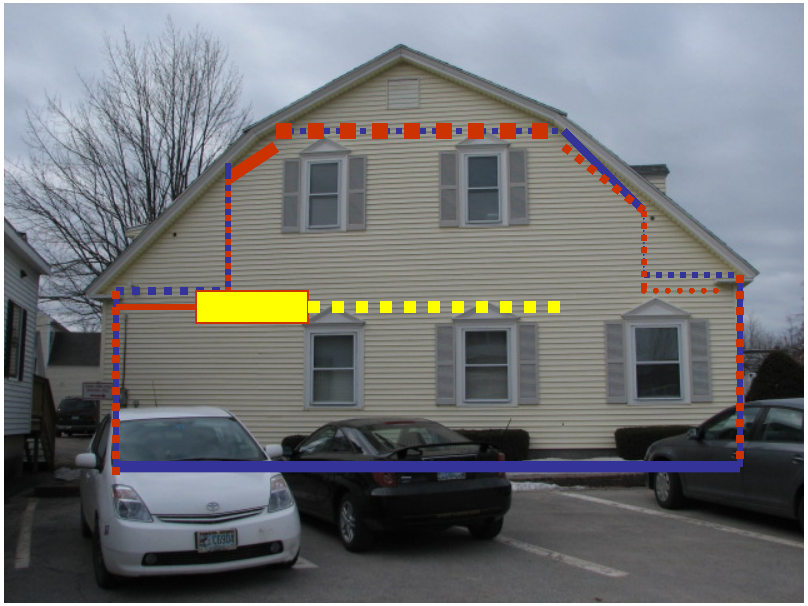
Estimated cost of air leakage: $2200 or approximately 20% of heating fuel
at $3.50 gallon oil.

Estimated Leakage Area (LBL @ 4 pa) 494 in2 or about 3 ½ sq feet
Total size of hole if add all cracks and gaps together

Minneapolis Leakage Ratio: 1.81 CFM50 per ft2 of envelope surface area

This is using the CFM50 relative to the surface area of the shell or envelope, since heat loss is based on surface area not volume. Army Corps of Engineer's new Standard for all Federal Buildings is .25CFM75 per ft2 shell or about 1200CFM50 for the Town Offices; 7.5 x tighter.

Envelope Performance Assessment



In addition to envelope air leaks, unsealed ducts influence pressure differentials throughout the building and especially in the chase between floors. Buildings are sometimes slightly pressurized intentionally, yet this leads to considerable heat loss and can lead to moisture issues in cavities.

Air Flow at 50 pascals: 9002 CFM50

Air exchange in relationship to volume: **12.85 ACH50** or
estimated 1.22 ACHnat in winter

Air Barrier tightness relating to heat loss and based on shell surface area:
1.81CFM50 ft2 shell SA

Leakage Area: 494 in2 ELA @4pa or a cumulative 3 ½ square foot hole in the wall contact with solid

HEAT → COLD

CONDUCTION

Molecule to molecule transfer of kinetic energy.

<u>Rate of Transfer</u> Depends on

- Material Properties - Conductivity
- Thickness
- Surface Area
- Temperature Difference

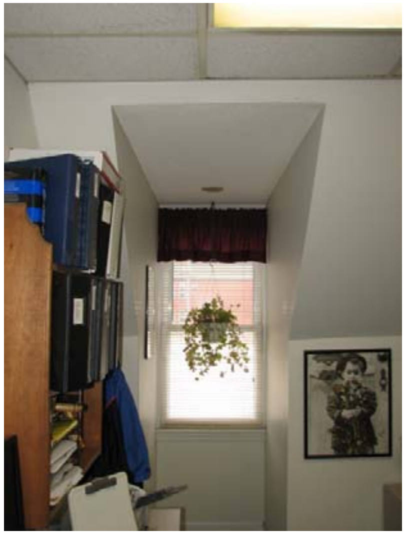
Darker colors – even if faint - depict cooler surface temperatures. Dark straight lines often show location of framing lumber in an insulated wall because wood conducts heat more rapidly than the insulation in the wall cavities – between the studs. In an un-insulated wall, the studs are lighter because the wood resists heat transfer more than the empty – darker - cavities. When a highly conductivity material, such as wood, glass, or steel, is in contact with both the interior and exterior finish surfaces, it is called "thermal bridging". Corners and top plates can create colder surfaces because of multiple studs and/or air infiltration.

via a fluid

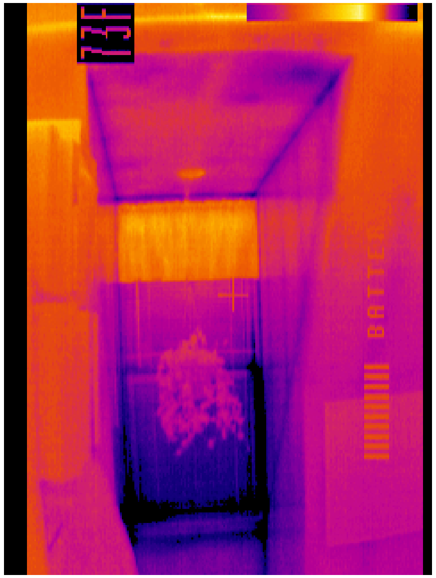
HEAT ⟶ COLD

CONVECTION

Convection moves heat via a fluid such as air or water: Physically moving the molecules from one place to another.



With the blower door fan running, cool (and dry or damp) air is drawn out thorough holes, gaps, or cracks in the envelope and can be seen as wind-washing. The cold air coming in thorough this window is a form of "wind-washing" and heat loss by convection. Effective air sealing can make a significant difference reducing heat loss and improving comfort, however in this case, this window simply no longer fits the window opening.



Convection can also play a role even without gaps in the interior air barrier. Air easily flows thorough fiberglass, cooling (or heating) to the back of interior surfaces and can be seen her at the ceiling in this dormer.

visual contact

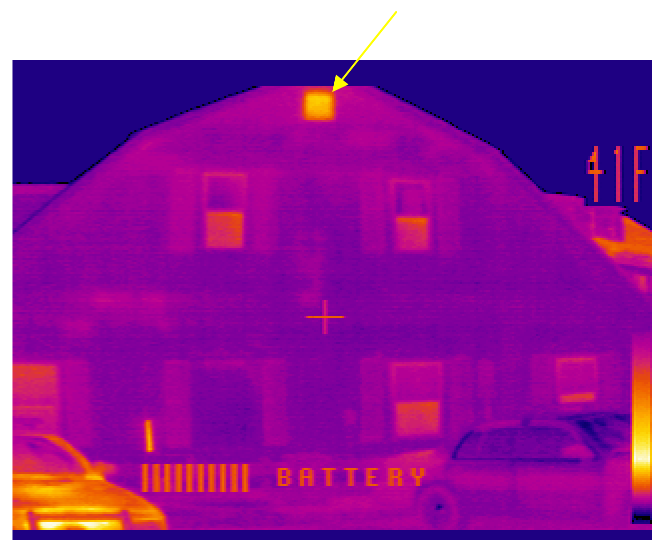
HEAT → COLD

Thermography helps illustrate heat transfer.

RADIATION

Transfer of heat thorough space via electromagnetic waves

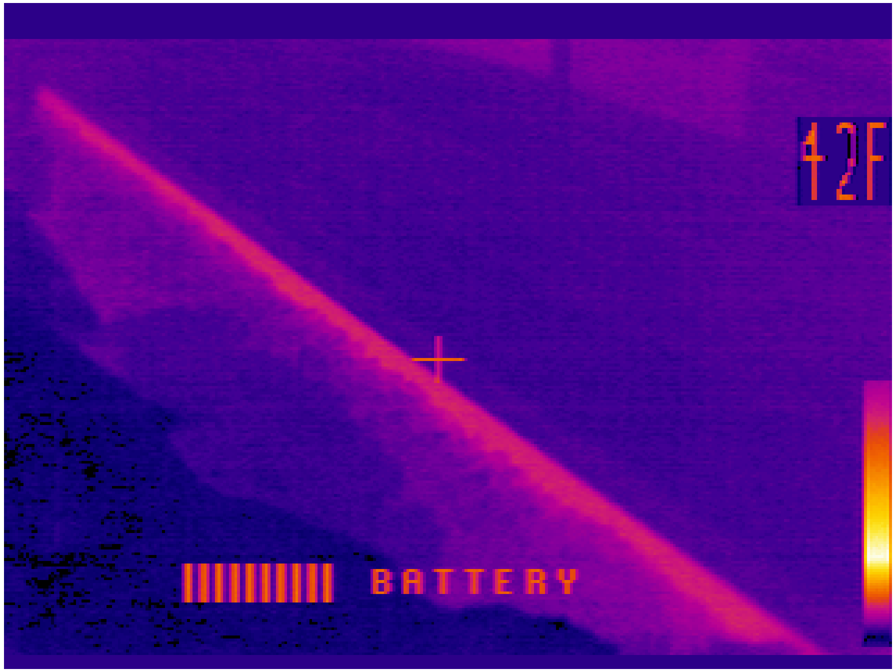
Radiation plays a key role in heat transfer both into and out of a building thorough windows especially. Solar heat gain thorough windows increases cooling costs as heat radiating out windows in the winter (right). Infra red cameras do not always accurately record glass temperatures or other reflective surfaces, due to properties of emmisvity, but can give a good sense of warmer – or colder surface temps.



Of special note is the heat loss from the attic vent. This photo was taken early morning on a cloudy day, before solar radiation had impacted the attic temperature. The heat depicted in the vent is almost entirely from conditioned space or heating ducts below.

Slab Foundation – Uninsulated

Now required by code, heat losses thorough uninsulated slabs and foundation can be substantial. A deep energy retrofit scope would include accessing this slab edge and installing rigid insulation appropriate for exterior, below grade applications.

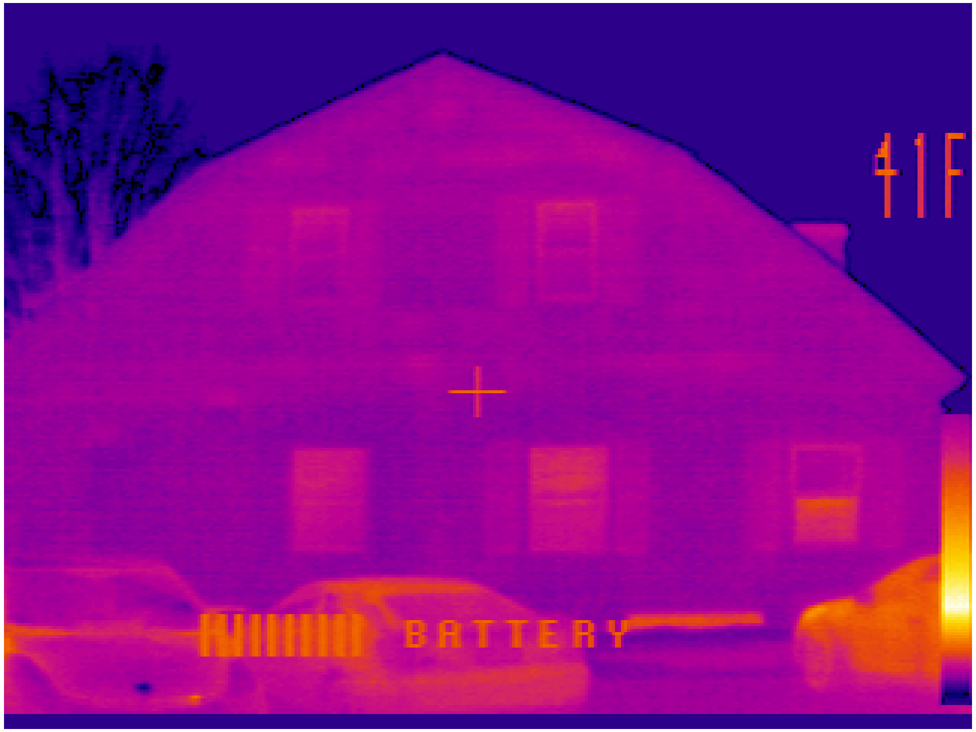


Walls

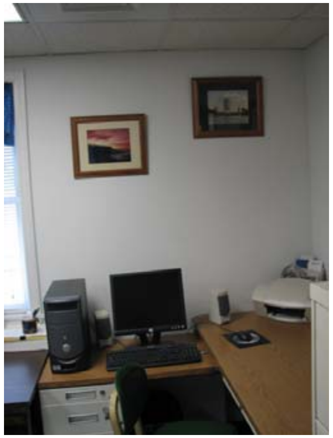
Structure includes some post and beam with 2x4 walls. Approx 70-80% cavities have 3 ½" fiberglass batts – remaining cavities are either uninsulated or fiberglass is so compromised as to be less effective than intended.

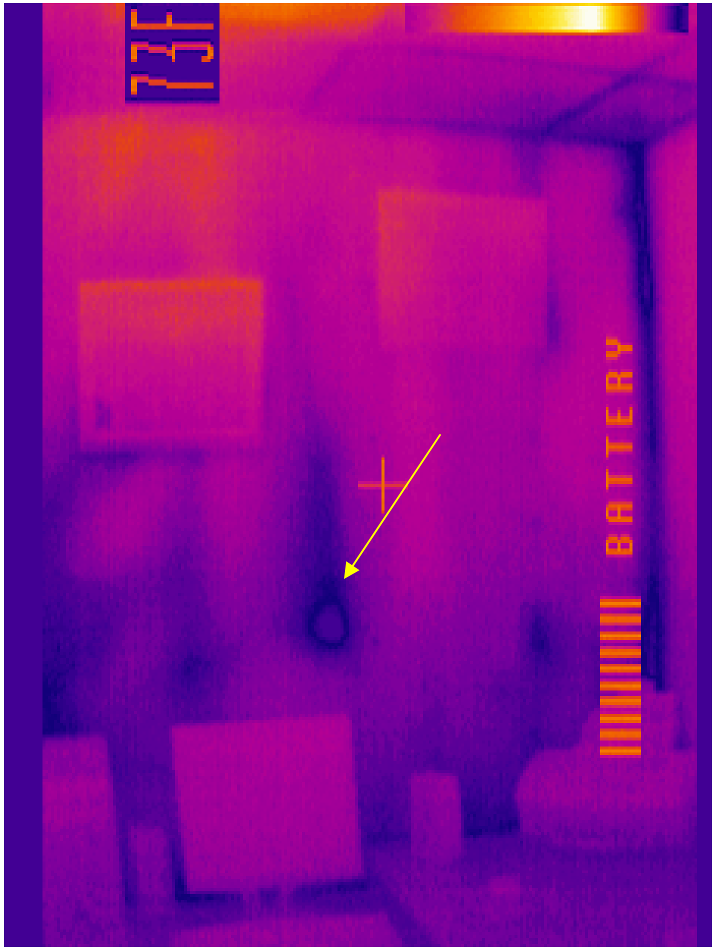
Area between floors with heating ducts and one of the air handlers is especially lacking, as is above the ceiling on the 2nd floor, though very difficult to access. Equally or more important to gaps in insulation is the lack of an effective and continuous air barrier. Ice dams are more often caused by warm air rising which is the case in this building as indicated by the image above.

Similar patterns on opposite end.

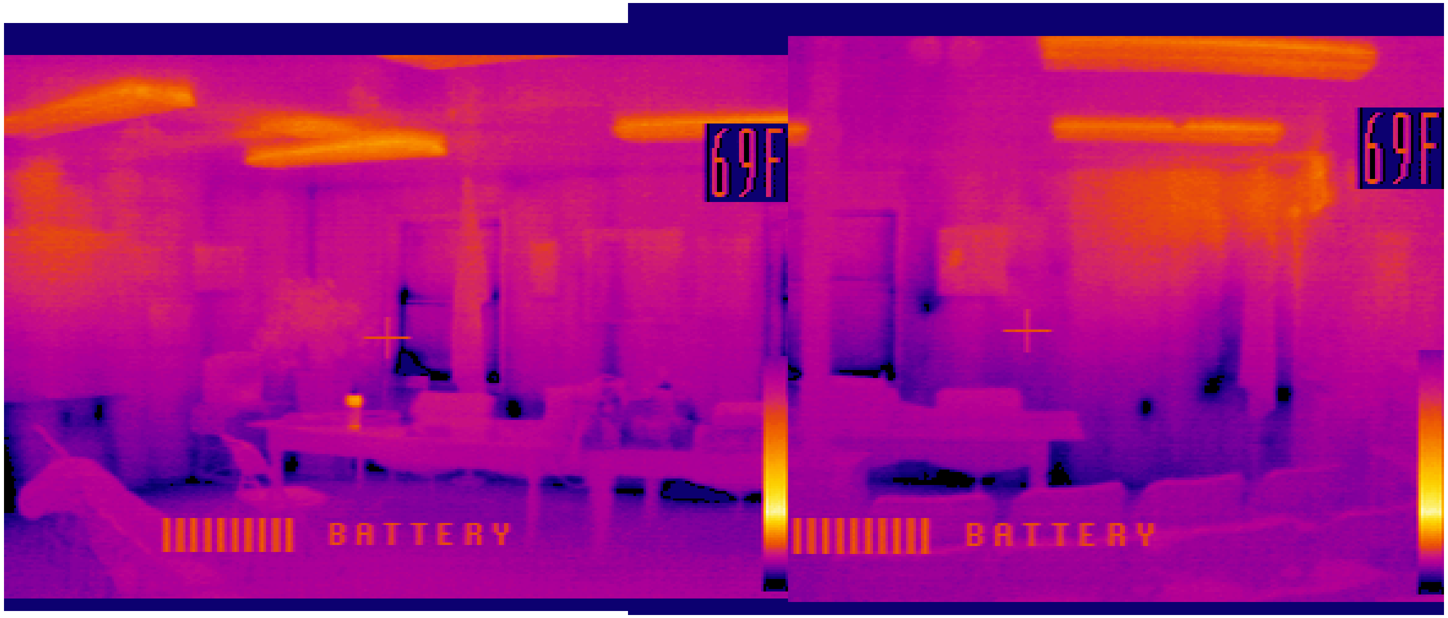


A lack of continuous air barrier compounds the envelope's thermal deficiencies. Circular patterns like this may indicate moisture problems, though invasive measures are needed to be sure. Thermal performance is compromised.

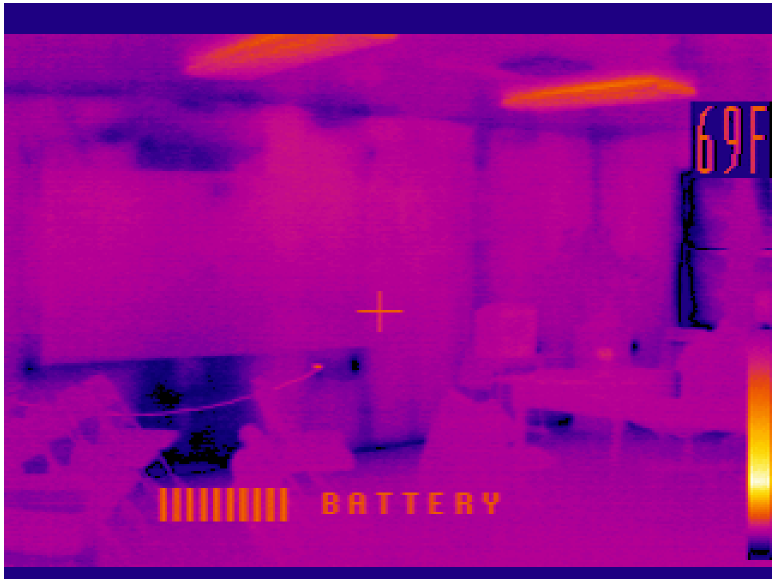


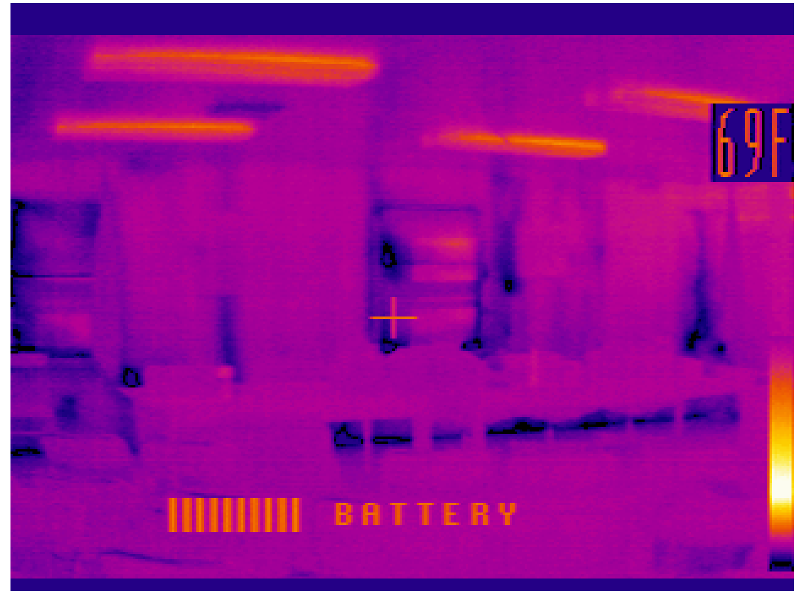


Cavities without insulation.



Rivco windows do not fit tightly and are a substantial portion of overall air infiltration.





At -30 pa

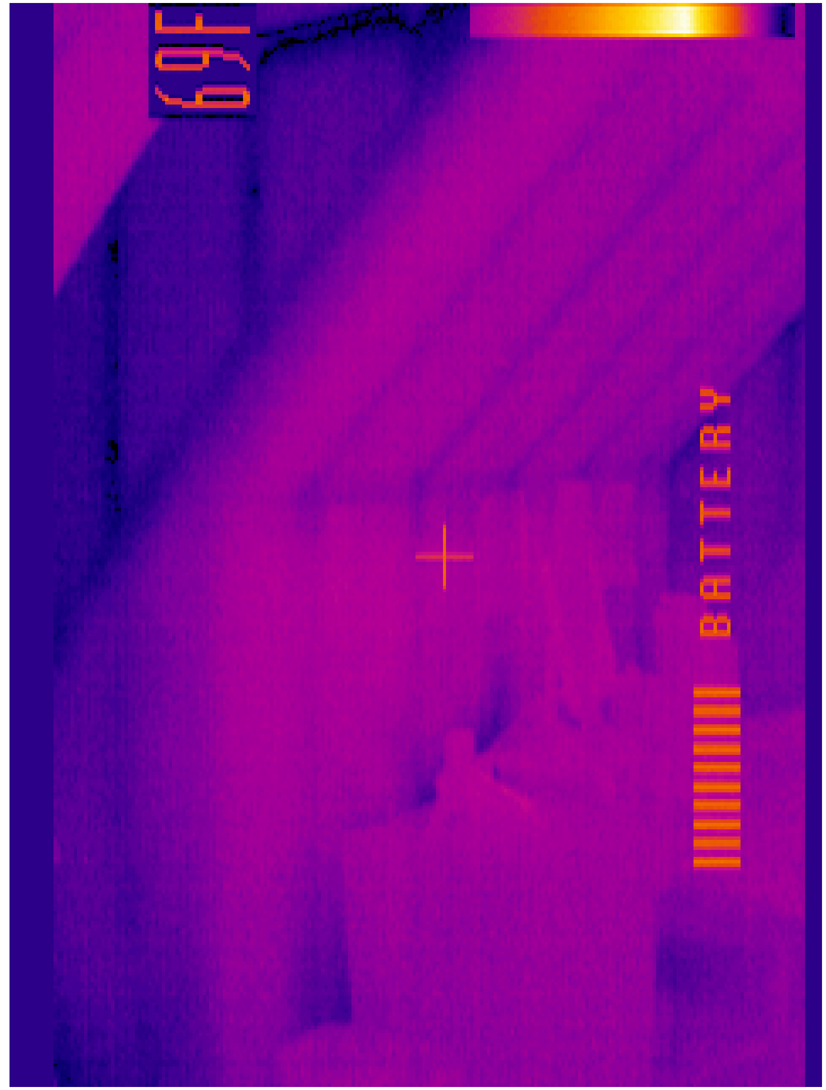
Missing insulation, large gaps in the air barrier, especially where bottom plate/sill sits on slab, other framing connections and leaky windows.

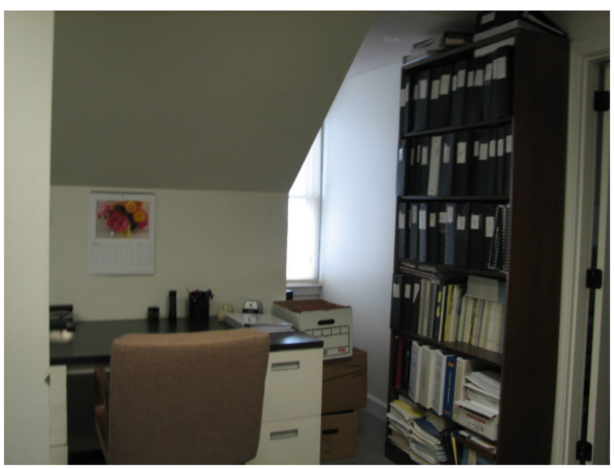

62F
BATTERY

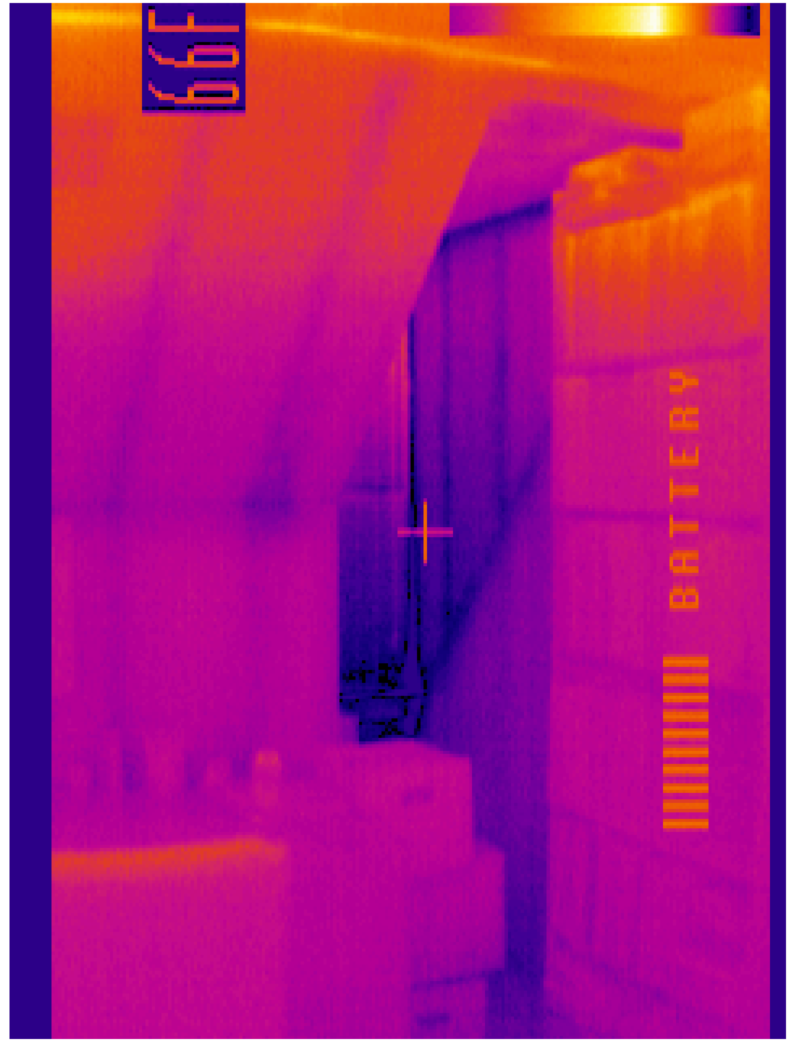
The ceiling chase between 1st and 2nd floors. Missing insulation, air barrier and leaky heating ducts.

Chase above 2nd floor lacks air barrier and insulation levels vary. Significant amount of air blown fiberglass particles in air even without HVAC system on. Ducts located above and outside the thermal envelope are a source of considerable heat loss.

Ceiling slopes and knee walls



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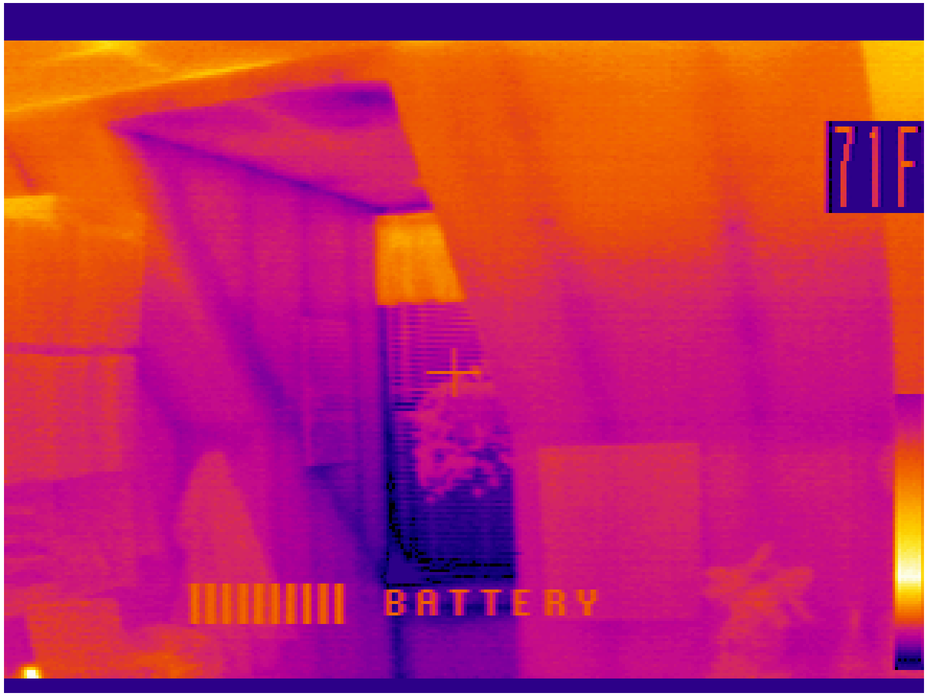
BATTERY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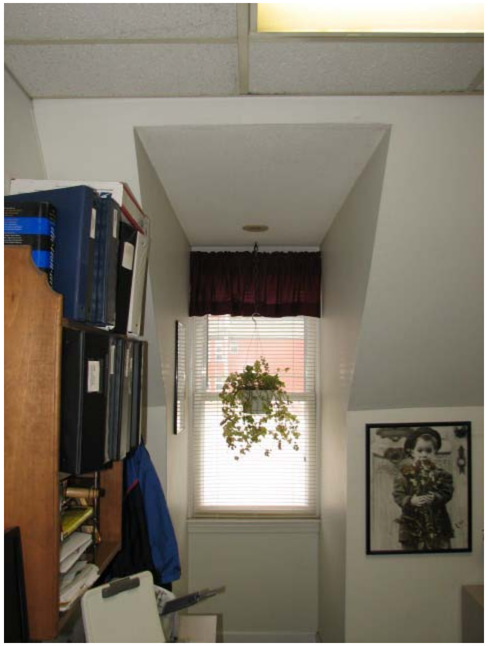
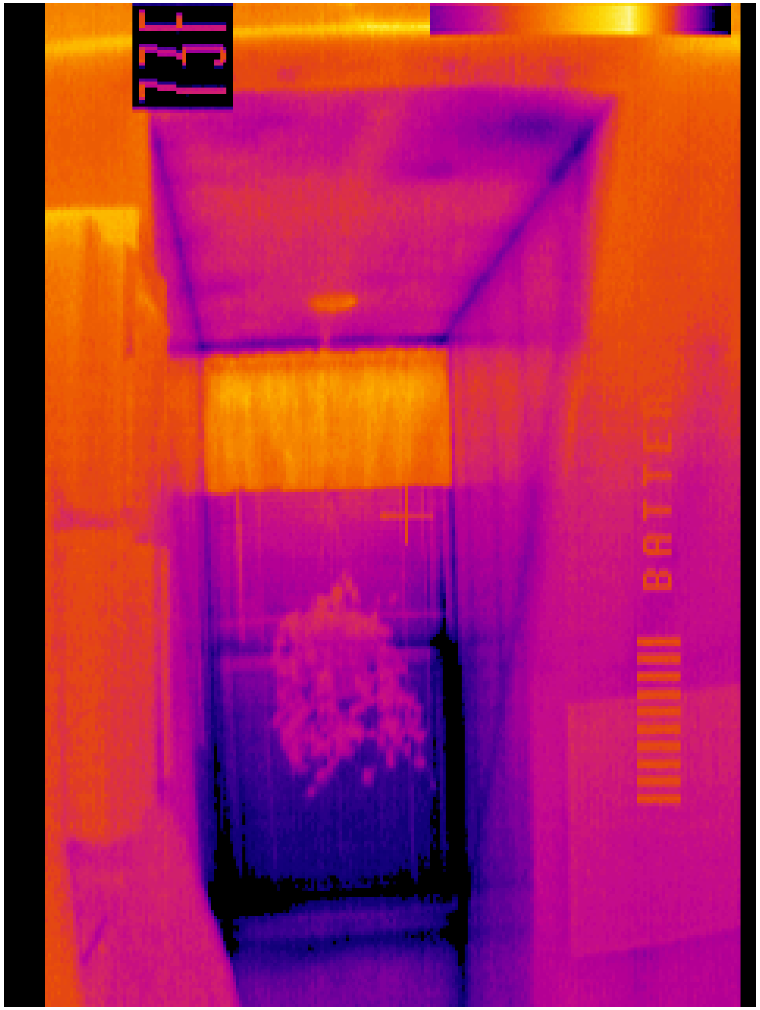
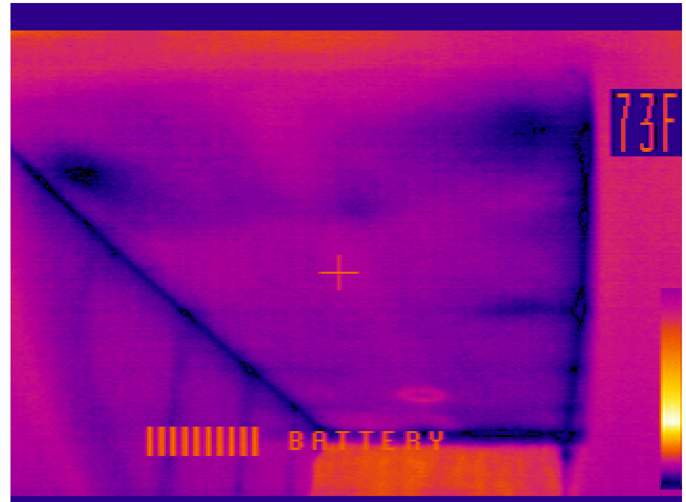
BATTERY



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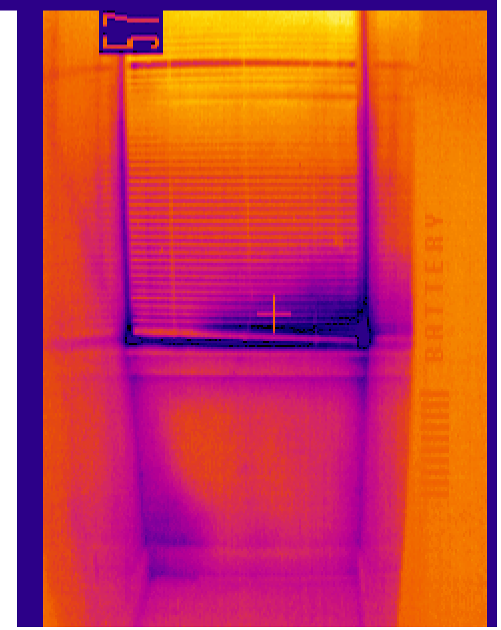
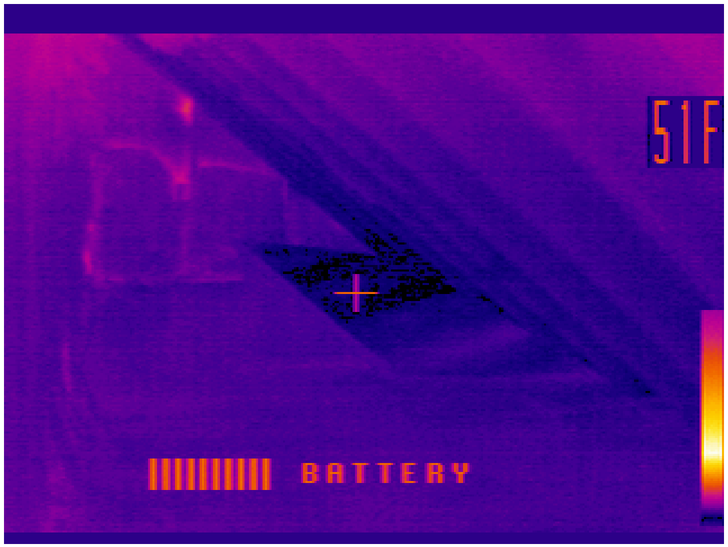
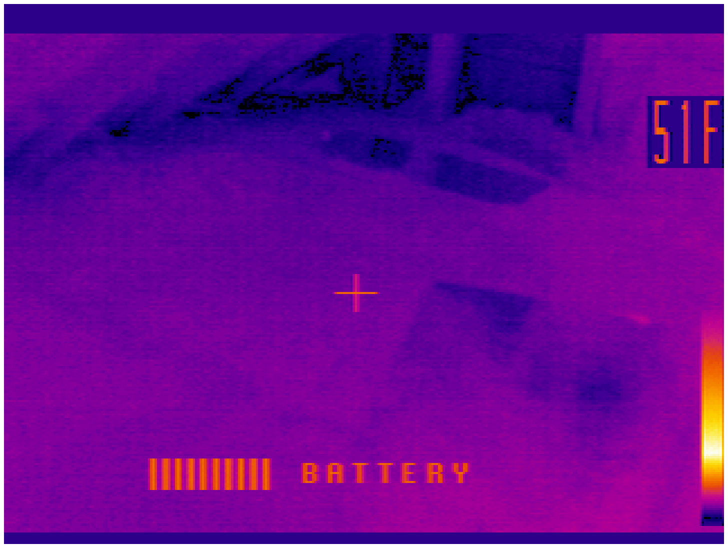

BATTERY

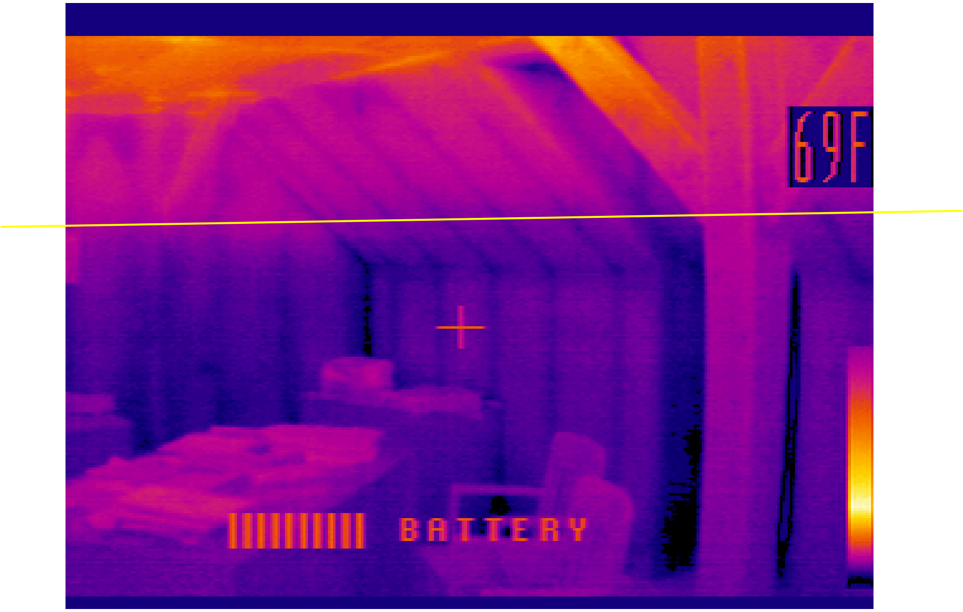
Significant gaps in both air and thermal barriers – which also results in deficiencies in moisture management.





For either option, I recommend yanking out slope and end wall fiberglass and using either spray foam or dense pack cellulose in the slopes and covering with 2” thermax but only for Option A. Creates an effective air and moisture barrier and far superior thermal barrier.

Warm air rising and pressure dynamics



Evidence of “warm air rising”. However, air sealing at both top and bottom of a building reduces this kind of distribution pattern – as will proper balancing of supply and return air. High performance buildings with effective and continuous thermal and pressure barriers do not experience significant temperature differences between floors on low rise buildings. For even greater comfort, zonal distribution, and energy efficiency, installing hydronic system with wall panel radiators is recommended.

Windows

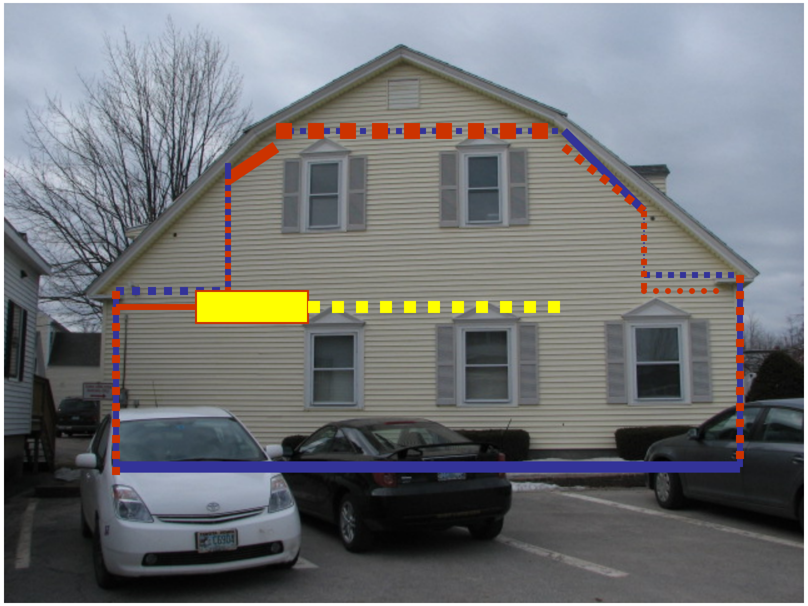
More often than not, window replacement comes far down on a list of recommended upgrades for several reasons: Air sealing existing can often make the more significant impact at a far lesser expense; installation details matter a great deal and are often neglected; typical replacement windows improve R-Values from 1.5 or 2 to R3 and considering that most buildings have glazing to wall ratios between 10 and 20%, this increase is almost insignificant.

However these windows may be the exception to the rule. They are especially low performers; and many do not close completely nor not fit the rough openings well which would require such heroic air sealing efforts that full unit replacement with high quality windows is advised.

This would also allow for advanced flashing techniques as well as proper and effective air sealing of the entire rough opening.

Envelope Performance Assessment

Thermal Layer

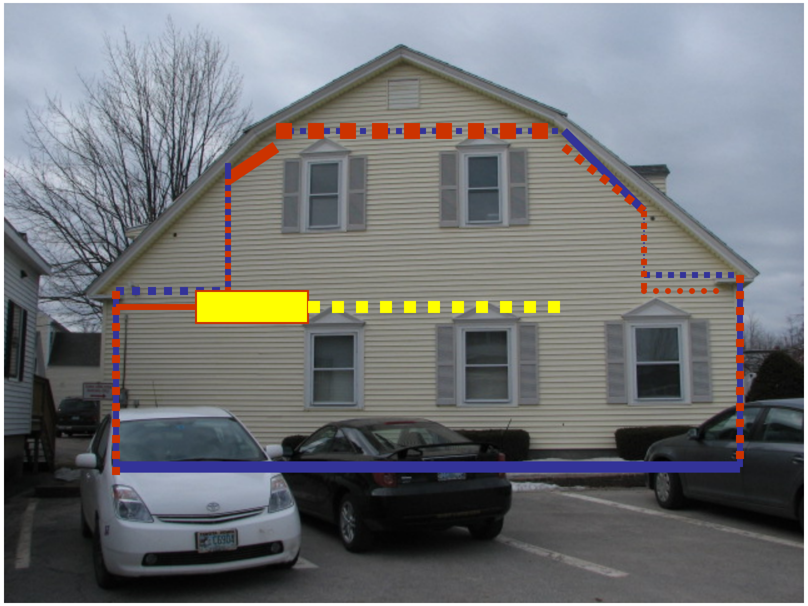


Estimated Peak Heat Load Btu/hr

Air infiltration	30,549	42%
2x4 Walls with 3 ½" fiberglass batts – some missing -	20,600	31%
Rivco Windows	7,019	10%
Slab	6,700	9%
Ceiling	5,900	8%
Total	**72,221**	**100%**

Envelope Performance Assessment

Thermal Layer



Existing Peak Heat Load	Btu/hr		Tier 1 Upgrade	Tier 2 Deep
Air infiltration	30,549	42%	15,275	10,183
2x4 Walls with 3 ½" fiberglass batts – some missing -	20,600	31%	17,900	7,500
Windows - poor	7,019	10%	4,913	2,948
Slab - uninsulated	6,700	9%	6,700	670
Ceiling -varying amounts of fg; no air barrier	5,900	8%	4,141	3,000
Total Design Peak Heat Load	**72,221**	**100%**	**50,274**	**25,151**
Building UA Value	**1,078**		**750**	**456**

Mechanical Equipment

Three separate propane, direct vent, hydro air units supply three zones of heating:

1st floor ceiling above vault.. Location not known to employees.

Emergency disconnect above ceiling tile, also unknown.

Employees complained of often being cold.

3rd unit in closet on 2nd floor near center of building, but too small an area to photograph.

Estimated overall system efficiency 80-82%
Excludes distribution losses thorough duct leakage.
Insulated flex ducts are crimped in some places; duct tape
Used for air sealing – has dried and peeled back in places. Mastic
recommended for all sealing all joints in ducts.

1st floor closet off meeting room.
Thermostat in meeting room.

For all air sealing and insulation work, I strongly recommend contractors who have been trained in building science. The only contractors I personally recommend are those at Building Energy Technologies in Concord: 724-7849.

For questions or more information, contact me at 532-8979 or mdillon@wildblue.net

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