Town of Warner

Building Energy Performance Reports

BUILDING STRATEGIES FOR AN AFFORDABLE FUTURE

S.E.E.D.S.

SUSTAINABLE ENERGY EDUCATION DEMONSTRATION SERVICES

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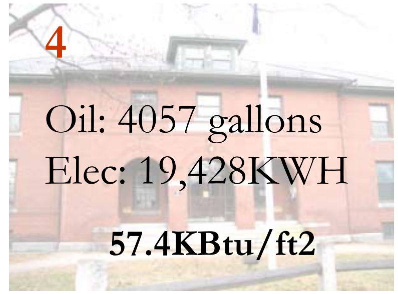
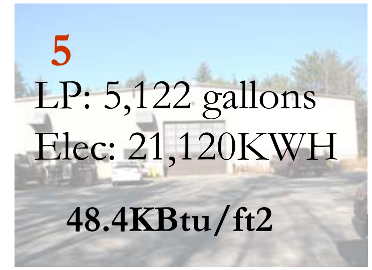
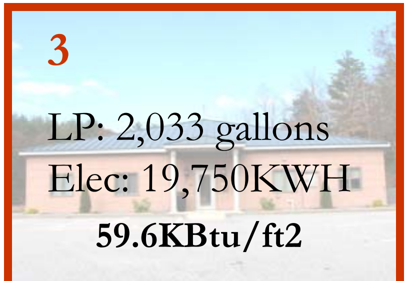
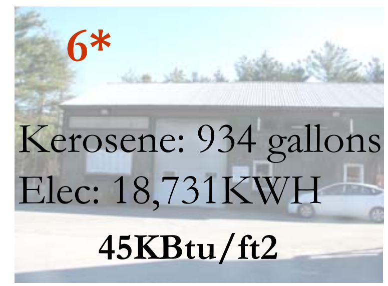
2008 Town Building Energy Use









	Gallons	Btu's	Dollars
Oil	10,706	1,483MM	$32,118
LP	9,455	861MM	$11,555
Elec	237,906	812MM	$37,332
TOTALS		**2,946MM**	**$81,000**

Town Building 2008 Utility Costs

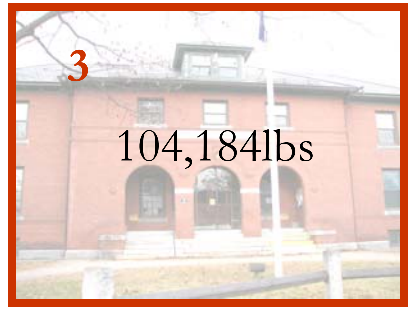
4

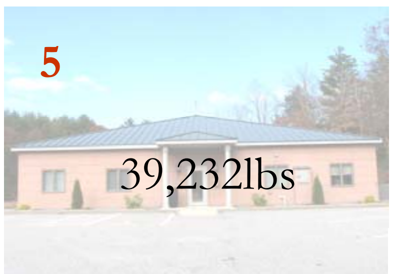
5

6

8

Town Building 2008 Greenhouse Emissions





Town Building Air Leakage Rates

ACH50 – Air changes per hour at -50Pa; relative to building **volume**

Cfm/ft2 shell – cubic feet of air per minute relative to **surface area** of shell

Summary of Prominent De-ficiencies

Prioritize by **Highest Costs** -
Dollar$ and Greenhouse Gas Emissions

Contents

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 Conditioned 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

The Building Envelope

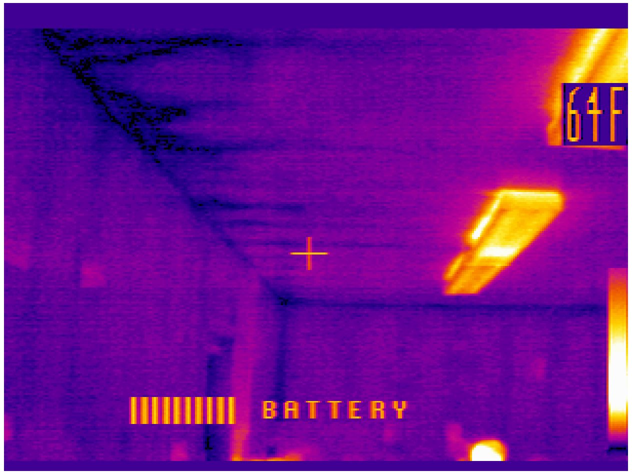
The "envelope" can be described as the control layers of a building's shell which separate the inside conditioned space from the outside climatic conditions. These control layers are responsible for managing the movement of air, moisture, and heat. The more extreme the climate conditions, the more important 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.

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.

Heating and Cooling A Building

Conventional thinking has historically been about supply side: the heating or cooling equipment to put in a building – what kind of system and fuel choice. Codes for energy conservation have been influenced by the least expensive or compromised approach to insulation and not making the details cumbersome for the many trades who actually work in those 'control layers'.

But in a changing climate and peak oil world, Effective Conservation is the most important first step. Reducing demand. To design, build, or retrofit our homes and buildings to require FAR less energy input to achieve comfort, durability, and indoor health. The more effective the envelope, ie the less heat loss or gain, the smaller the heating and cooling equipment and the less energy needed to generate or remove Btu's.

That brings us to thinking about Thermodynamics – or Heat Transfer.

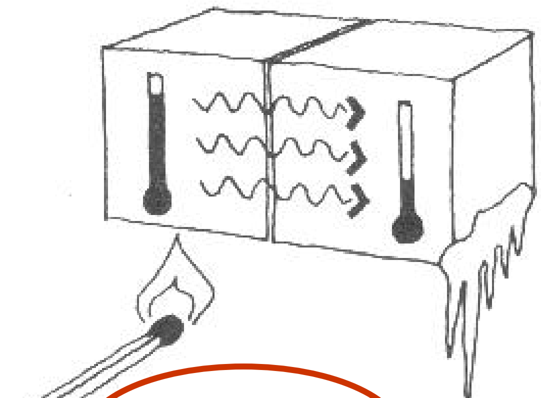
And because we haven't been thinking about thermodynamics very much throughout the 100 or so years of cheap sources of energy – we have been operating out of a bunch of myths which now need to be busted. To name a few:

1. "Heat rises"
2. "You don't want to make buildings too tight"
3. "Walls need to breathe"
4. "R-Values listed on fiberglass batts or bags are real"
5. "It doesn't matter"
   (In response to just about every performance detail in construction)

HEAT MOVES TO → COLD

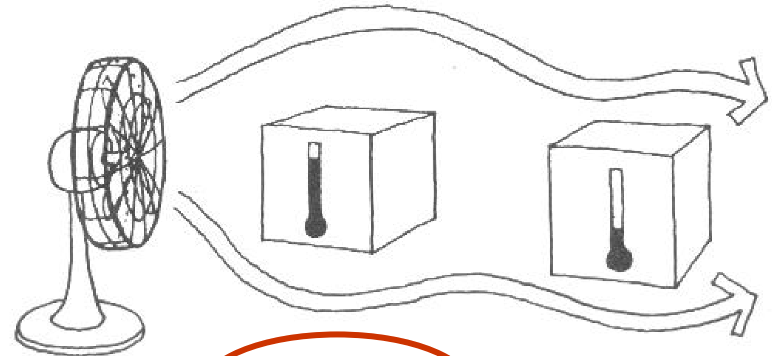
Via Three Basic Methods of Heat Transfer

All happen at once- with one dominating!



Conduction

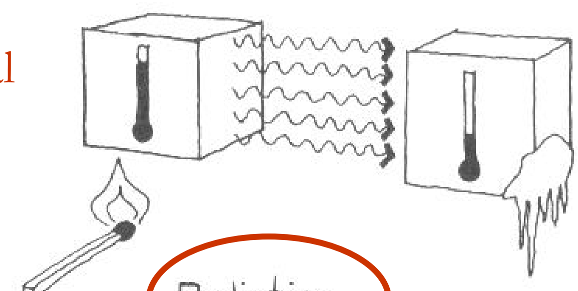
Direct contact thorough a solid material



Convection

8.3

Thorough air or fluid



Radiation

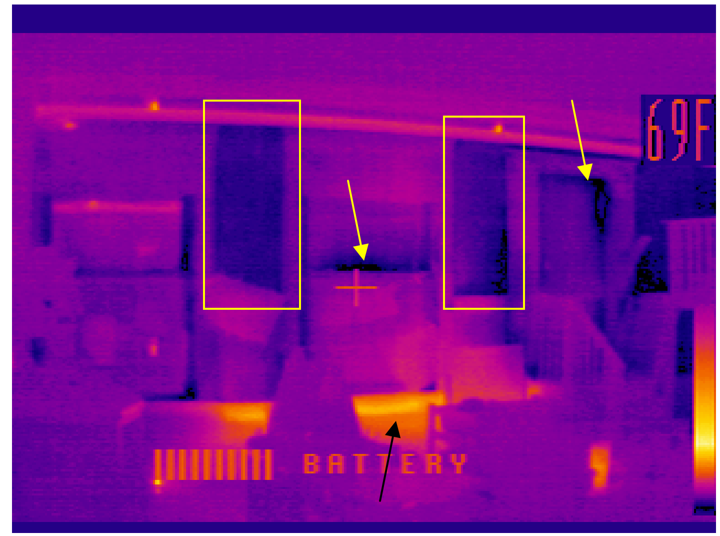
From a heat source in visible contact

contact with solid

HEAT → COLD

CONDUCTION

Molecule to molecule transfer of kinetic energy.



Rate of Transfer 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. 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". Dark areas in a cavity usually indicate missing or compromised insulation. In the above image, the dark areas between the windows depict the even coolth of an uninsulated masonry wall.

Also note the heat radiating from baseboards and coolth convecting between window sashes.

via a fluid

HEAT → COLD

CONVECTION

Physically moving the molecules from one place to another.

Convection moves heat via a fluid such as air or water. 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 cool areas at the edge of this old flue hole is an example of "wind-washing" and heat loss by convection.

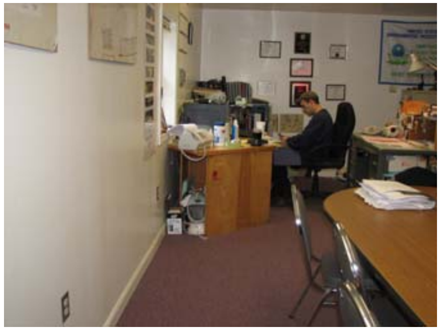
Convection can also play a role even without gaps in the interior air barrier. Air easily flows thorough fiberglass, cooling (or heating) to the back of interior surfaces.

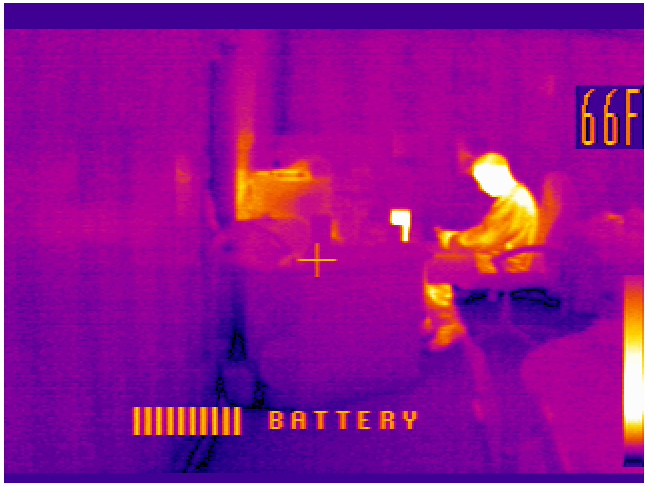
"Wind washing"

visual contact

HEAT → **COLD**

Thermography helps illustrate heat transfer.





RADIATION

Transfer of heat thorough space via electromagnetic waves

Radiation can play a key role in heat transfer both into a building thorough solar heat gain thorough windows, people and equipment and as heat loss thorough those same windows at night or on the north side all the time. Infra red cameras do not always accurately record glass temperatures or other reflective surfaces, due to properties of emmisvity, but can give a general sense of heat loss or gain.

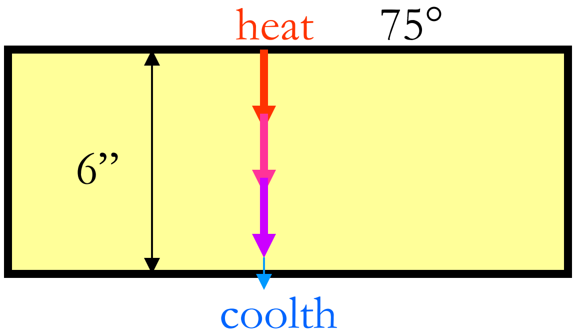
Radiation is also a dominate way of distributing heat into a building such as thorough the above 'radiators' ie the human body, computers, and other appliances – including heating equipment!

Standing next a single pane window on a cold, clear night makes us feel colder because our body's heat is literally radiating towards the coolth of the glass. That's why thermal pane windows can improve the comfort of a room – sometimes even more than the actual energy or dollar savings accounts for!

Of course, conversely, standing in front of a single pane south facing window on a cold but very sunny day can warm us from the sun's radiation! Always a balancing act.

Mythbuster: Fiberglass Insulation and R-Value

R-Values refer to the resistance to heat transfer by conduction only and are tested in laboratories under very specific circumstances. For example, to test fiberglass batts, a section of batt is placed in a completely sealed box – the fiberglass painstakingly installed at full loft so that the edges are in full contact with all sides of the box and therefore in direct contact with an air barrier on all six sides of the batt.   Resistance to heat transfer is then measured in a zero moisture and zero air movement environment and from a standard 75°F. Owens Corning helped establish this 75°F testing standard – coincidentally, it is the temperature in which fiberglass performs the best.

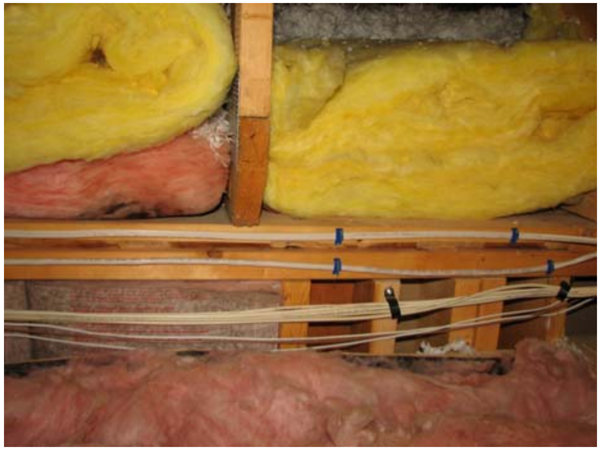


Rate of transfer…
calculations…=R19

The insulation is in direct contact with a continuous and effective air barrier on all six sides – experiencing no wind or air flow or fluctuations in temperature. And this is how the R19 stamp gets on all 6” fiberglass rolls.

The fact is that in extreme temperatures on either side, “R-Value” performance is dramatically reduced.

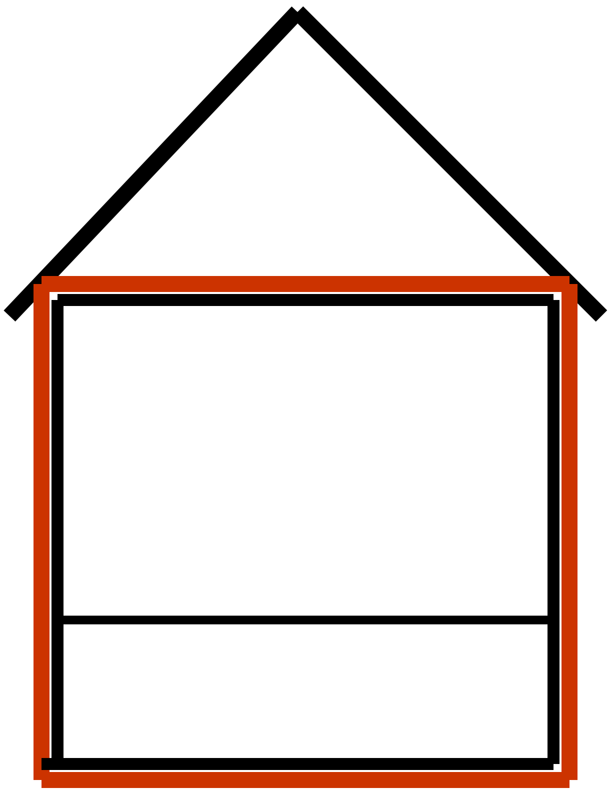
The other facts are that fiberglass is rarely perfectly installed in direct contact with a continuous air barrier on all six sides and that we don't live in zero moisture, mild climate conditions. In other words, the ***effective R-Value*** of insulations such as fiberglass is often between 30-100% less than the stated R-Value. In addition the temp difference between inside and outside in heating climates is far more extreme than in cooling. Fiberglass batts, therefore, may be far more appropriate in the south than in cold climates - zones 5 and above. I recommend replacing all exposed fiberglass.



Happy Basements are Warm and Dry

- Want your heating (conditioning) equipment inside conditioned space.
- Insulating between a conditioned floor and crawl space or basement can also lead to mold and other moisture issues as warm, moisture laden, air will condense when it hits cooler surfaces such as the edges of wood floor joists.
- Closed cell foams – while not very environmentally or wallet friendly in themselves, are the best products for below grade surfaces. They seal air gaps; resist moisture; spray applied adhere to uneven surfaces; and provide high R values. Once the foundation walls are air, moisture, and thermally sealed, you can air seal and insulate the duct work or pipes and deprive the crawlspace and basement of all that inadvertent heating! Those areas will be drier and warmer with less conditioning.
- Seal off dirt floors to reduce moisture throughout the building. If you aren't comfortable hanging out in your basement because of its air quality…make it better – Cause you're breathing it upstairs, too.
- Insulate slabs whenever possible. Sure the earth is 45-50 degrees. But if you're thermostat is set above 50 degrees…you're losing heat to the earth.

Summary: Conservation First – and that's all about the envelope!



Heating equipment is supposed to be sized to be able to replace all the heat lost thorough the envelope in one hour during one of the coldest winter temps. The more effective the envelope performs, the less heat is lost – the less heat input is needed and the smaller the equipment!!!! (Or summer A/C units!)

Heat transfers via Conduction, Convection and Radiation. Reducing heat transfer thorough the envelope reduces the need to rely on energy and equipment to generate – or remove – Btu's from a space. Need to manage: Air; Moisture; Heat Transfer

Btu = one thermal unit = amount of heat needed to raise one lb of water one degree F = the heat from one match .

Blower Door Test & Results Glossary

Measuring Air Infiltration and the Air or Pressure Barrier

Convective and Conductive Heat Losses and Moisture Transfer

CFM50: Amount of **cubic feet** of air per **minute** when the building is at **-50** pascals pressure difference with respect to outside**.**

ACH50: Air Changes per **Hour** Rate at **-50pa:** CFM50 * 60 / Volume

This relates CFM50 to the volume of the building and is generally about ventilation rates as opposed to heat loss. Standard Residential Construction practices is generally between 7 and 9ACH50 and 2009 IECC sets 7ACH50 limit. Energy Star's limit is 5ACH50. High Performance Homes under 1ACH50. Currently no standard for non residential buildings.

ACHnat: Estimated rate of **Air Changes** per **Hour** under **natural** conditions ACH50/N

Conditions vary ACH day to day, but throughout the year the outdoor climate impacts indoors considerably. Estimates are based on a "Correlation Factor" which is a single number derived from considering exposure to wind, elevation, and climate. "N" typically ranges from 15-17.

Estimated cost of envelope air leakage: Another mathematical formula, which in this report, is calculated thorough a software program called Tectite.

Leakage Area (Canadian EqLA @10pa)

Total size of hole if add all cracks and gaps together

Minneapolis Leakage Ratio:

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.

Can't Reach 50 Factor: Some buildings have such high infiltration rates, that one fan can not achieve -50 pascals – its just too leaky. This is a multiplying factor based on depressurization achieved.

Heating Systems

Most of the heating equipment in Warner's Town buildings are hot water boilers which distribute heat by pumping hot water thorough (hydronic) baseboards or radiators in each room. There are a few hot air furnaces which heat air and then use fans to blow hot air into the building – usually, but not always, thorough ducts. Any steam systems have been converted to hot water. All the fuels listed below can be used to heat air or water. The efficiency of a system depends on several factors, including how much heat potential is in a unit of fuel burned and how efficiently the equipment is at utilizing the btu's for heating the building.

Annual **F**uel **U**tilization **E**fficiency

AFUE: The overall efficiency of the heating unit you use

(AFUE) is expressed as a percentage. It is a measure of how effectively a heating system turns heat released from burning fuel into heat you can use to warm your building. No heating system converts 100% of the fuels energy into heat. All heating systems will lose some heat due to start-up, cool-down, and heat escaping up the chimney with combustion gasses. Most oil burners have AFUE ratings between 82 and 87% though the older the get, their performance can drop into the high 70's or below.

High efficiency gas or propane boilers can be "condensing" which means they can operate at much higher efficiencies – between 95 - 98%.

Beyond the AFUE, there are other ways one system can be more efficient than another. Modulating boilers can fluctuate how much fuel is used or how hot the water gets based on the outdoor conditions. In other words, heating equipment should be sized to be able to heat the building on the most extreme condition – yet 99% of the time, outside temps are far less than extreme – about half the time in NH, temps are above 30 degrees! So a modulating boiler can use an 'outdoor' resent sensor to gauge how cold it is, and how many Btu's are needed at that time – instead of ramping up its entire capacity. A boiler or furnace operating at full tilt often satisfies the thermostat setting fairly quickly, and then shuts off without achieving a steady state operates far less efficiently or happily. Boiler sizing is a key issue with heating equipment. Most equipment is found to be 1.5 to 2 to 2.5 times oversized. Proper sizing to the calculated heat load of the building is important, especially as buildings get tighter thorough air sealing and other energy upgrades.

A word about setting back thermostats at night. It always conserves energy, but how far down to set it depends on the building's envelope, the type of distribution system and how long it takes to get the building back to comfort. Radiant floor systems, for example, are not a good match for nighttime set backs. More, there is no magic, one number fits all situations.

Fuel Energy Sources

On Site Combustion

- **Oil.** Heating oil is processed from crude oil into a variety of grades. For the most part, Warner uses #2 grade Heating Oil which has, depending on quality, anywhere from 130,000 to 142,000Btu's per gallon giving it a considerable 'bang for the buck'. The Northeastern States are the primary users of heating oil in the country. 75% of all heating oil used in the US is used in the Northeast, whereas the rest of the country uses natural gas from the US or Canada. Nearly 100% of NE's heating oil comes from foreign sources and primarily the middle east. Oil contributes almost 23lbs of greenhouse gasses for every gallon burned. Oil boilers are generally 82-87% efficient and need to be cleaned and tuned up annually.
- **Natural Gas** has 100,000 Btu's per therm and produces just over 12lbs of greenhouse gasses as well as fewer other pollutants. It is also a fossil fuel, but in greater supply on this continent, especially in Canada. It is available in only a few communities in NH.
- **Propane** is a by product of the petroleum industry and is primarily made from heating oil here in NE, however it can easily be made from natural gas as well. It has fewer Btu's than Gas – about 91,000Btu's per gallon but emits only a little more greenhouse gas – 12.24 lbs/gallon. Gas and propane heating equipment often uses condensing technology with efficiencies between 95-98%.
- **Kerosene** is referred to as #1 heating oil burns and emits like oil with approx 134,000 Btu's per gallon.
- **Waste Oil** is very similar to burning #2 oil.
- **Biofuel**. B20 (20% biofuel and 80% petroleum oil) is chemically similar to diesel and used as heating oil. It is an effective solvent, however so it has been known to clean out sludge in and old tank which means filters need to be checked often during the first year of use. Some burners need to be modified and at cold temps, higher blends biofuel can gel, making winter delivery a challenge. Feedstock and supplies vary. However, it is a much cleaner burning fuel. The City of Keene burns only B20 in its fleet and is thrilled with the results, including cleaner, healthier garages.
- **Cordwood** varies in heat capacity depending on species and water content. For fairly seasoned hardwoods, I generally use 25MMbtu's per cord, though dry oak can offer over 32MMbtu's whereas pine with 20% moisture has less than 18MMBtu's per cord. Wood stoves or boilers rarely exceed 80% efficiency, though can be considered somewhat 'carbon neutral. Wood gasification boilers have higher efficiencies and can be located indoors. Outdoor wood boilers have higher distribution losses – as does any equipment which is located outside the thermal envelope of the building it is heating.
- **Wood Pellets** Pellets have about 36,000,000 Btu's per ton though stove efficiencies vary considerably. They burn more cleanly than wood, though it is important to note that the feedstock are often transported great distances to be processed into pellets. The pellet processing factory may or may not use petroleum to make pellets.

ENERGY SOURCES
Off Site Combustion

Electricity

The nation's electric grid is still 50% generated from coal, though NE has a "cleaner mix". While it is projected that we will be relying on electricity more and more in the future, the primary sources have not yet been determined (clean coal still a pipe dream ect…) There are two basic ways electricity can be used for heating a building, though with a number of variations.

•**Resistance.** Baseboard or space heaters. 100% efficient, yet only 3412 Btu's per KW so has been very expensive. Warner has a number of small units in various buildings.

•**Heat Pumps.**

- **Air to air heat pumps** have been around for decades, both for cooling (refrigeration) and heating during mild seasons. Essentially, heat is compressed from cold air and delivered or removed depending on whether you are cooling or heating. Most heating heat pumps rely on a back up heat source (usually expensive resistance baseboards) in colder temperatures because they could only extract heat from temps above 25 or 30 degrees. While the heat pumps were fairly efficient, the back up resistance heat for our region makes this an expensive option.
- A few years ago, Hallowell, a new company in Maine, emerged with a transformative Acadia air to air heat pump technology which they claim is capable of extracting heat from temps down to -20 and at efficiencies between 250-280%. Like most heat pumps, this is still an forced hot air system which requires duct work in the building for distribution. They are also a little more expensive to install and yet it is likely far less to operate in the foreseeable future. Additionally, all risks associated with on site combustion are eliminated. Hallowell expects to be producing an air to water system in the next few years (for forced hot water systems)
- **Ground Source Heat Pumps** This is usually referred to as "Geothermal" in New England. True geothermal exists where one can access very hot water deep in the earth. Geothermal springs in the west will likely play an increasingly large role in producing electricity. Here in NE, we tap into the relatively stable temps in the earth (year round 40-50°F below 6 feet) and use a ground source heat pump to extract heat, pumping it into cooler air or water. This is a very efficient heating and cooling system though very expensive and with a high embodied energy involved with drilling or digging. It is still a fairly complex feat of engineering and if not done well, fraught with problems. Properly designed, and in the right application (commercial buildings with high cooling loads in the summer) it can be an elegant and appropriate technology, though not the "squeaky Green" technology contrary to popular belief. Adequate protection over aquifers and groundwater have yet to be put in place.

A Few Words on Sun and Wind

There are many resources available to learn about using the sun and wind as energy sources. This is intended as a ***very*** brief primer or reality check as relevant to Warner's Town buildings.

"Passive Technologies"

A building's orientation, shape, and other design features can have a significant influence on how the effects of sun, wind, and water impact a building's energy use. Southern glazing can help warm a building during the day in winter, to be offset by the heat loss at night. Southern windows can also help make a building overheat in the summer, unless overhangs are designed to shade those windows during the summer. Overhangs are also very important in reducing the impact of rain and snow on a building. Roof temperature is most effected by orientation and color again based on the impact of the sun. Wind can be a great cooling strategy in the summer, but unshielded northwesterly winds can increase a winter's heat bill. Some of theses features can be added to a building and will be suggested where relevant.

"Active Technologies"

Solar energy can be used to make electricity (thorough Photo voltaics or PV arrays or systems) or to heat water (Solar thermal) which can in turn be used for domestic hot water needs or supplement space heating. Winter cloud cover and the sun's low angle in the cold months make solar thermal space heating, not impossible in NH, but not a great match except for the most unique buildings. PV systems are beginning to become more cost effective and should be considered in any long term town energy master plan. Wind is a wonderful resource in NH but is **very** site specific and even sites which people think of as windy, may not have the kind of consistent, non turbulent, wind best for wind turbines. Unfortunately, just as with "geothermal" positive marketing has resulted in many system installations where they do not belong. Properly located and designed and installed correctly, these are very important resources.

The most important first and second steps always involves Conserving Energy or Nega Watts. The most cost effective way to save energy is to use less. In short: Reduce heating and electrical loads first, then consider the most appropriate systems and the cleanest, most renewable energy sources to provide the energy needed.

This report focuses on Energy Conservation and primarily on energy used for heating.

Old Graded School

ANNUAL ENERGY USE SUMMARY

Heating Fuel
4,746 Gallons

Electricity
20,160 Kwh

Propane
? gallons

Note that there are two aspects to reducing energy use: Conservation and Efficiency. Upgrading the envelope and thermostat settings conserve energy by reducing the amount needed for comfort. Upgrading equipment and distribution systems improve the efficiency of how energy is delivered.

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)

Oil: 4746 gallons x 138,500 Btu's/gallon = 657,321,000 Btu's or **657.3 MMBtus**

Electricity : 21,160 KWH x 3412 Btu/kwh = 72,197,920 **Btus or 72.2 MM Btu's**

Total Energy in Btu's = 730MBtu's /10,168 FT2 = 72KBtu/ft2 **(propane not included)**

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

Whole Building: 9332CFM50
Means that **9332 cubic feet of air per minute** was pulled thorough leaks and gaps in the air barrier when the building was under pressure at -50 pascals with respect to outside.

Air Change per Hour Rate at -50pa: 5.88ACH50
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 6 times every hour**. The math: CFM50 x 60 / building volume

Standard Residential Construction practices is generally between 7 and 9ACH50 and 2009 IECC sets 7ACH50 limit.

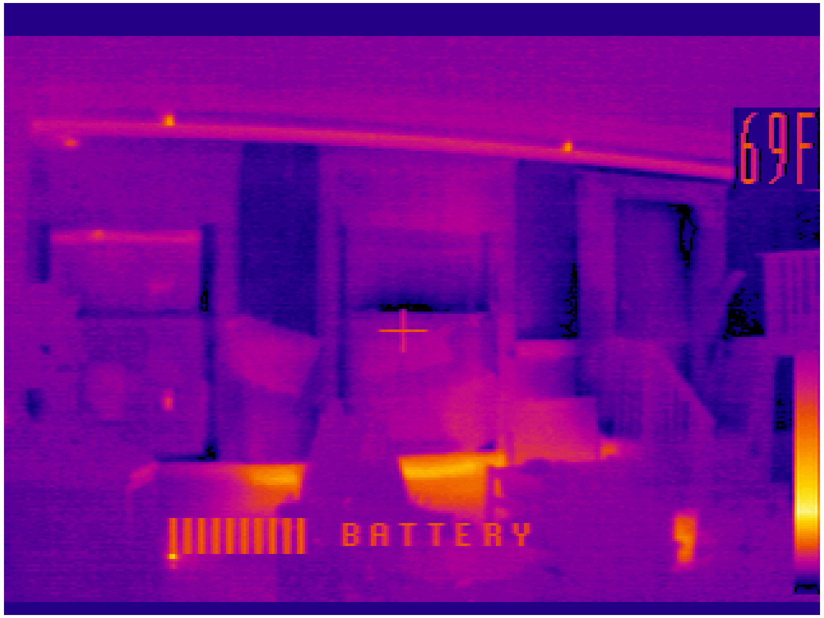
Energy Star's limit is 5ACH50. High Performance Homes under 1ACH50. Currently no standard for non residential buildings.

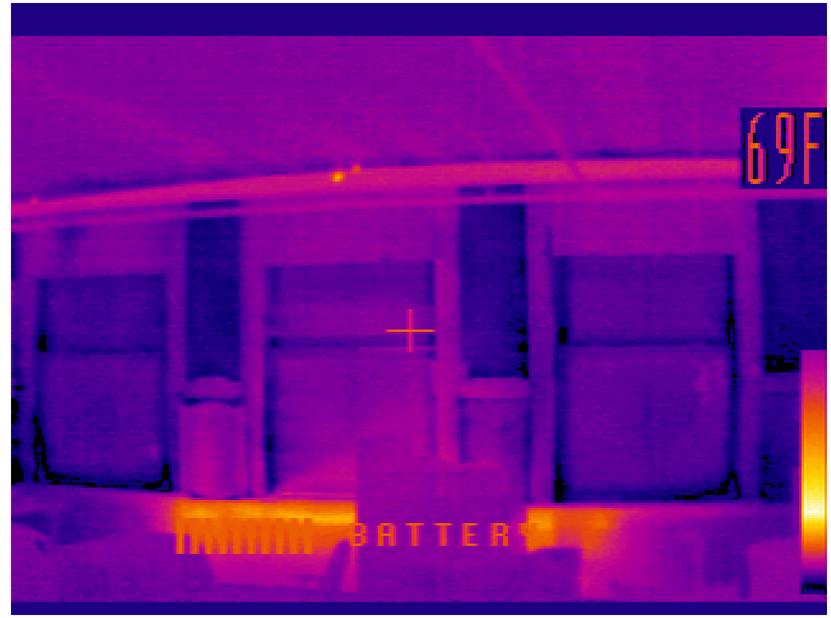
Estimated Annual Air Change Rate: .37 ACH Winter: .63ACH Summer: .32 ACH
Conditions vary ACH day to day, but throughout the year the outdoor climate impacts indoors considerably. On average in winter, you are heating the air which is replaced by outdoor air approximately every 38 minutes or so.

Estimated cost of envelope air leakage: $2640 at $3.50 gallon or approx 16% of heating bill

Leakage Area (Canadian EqLA @10pa)963 in2 or 6.7sq feet
Total size of hole if add all cracks and gaps together

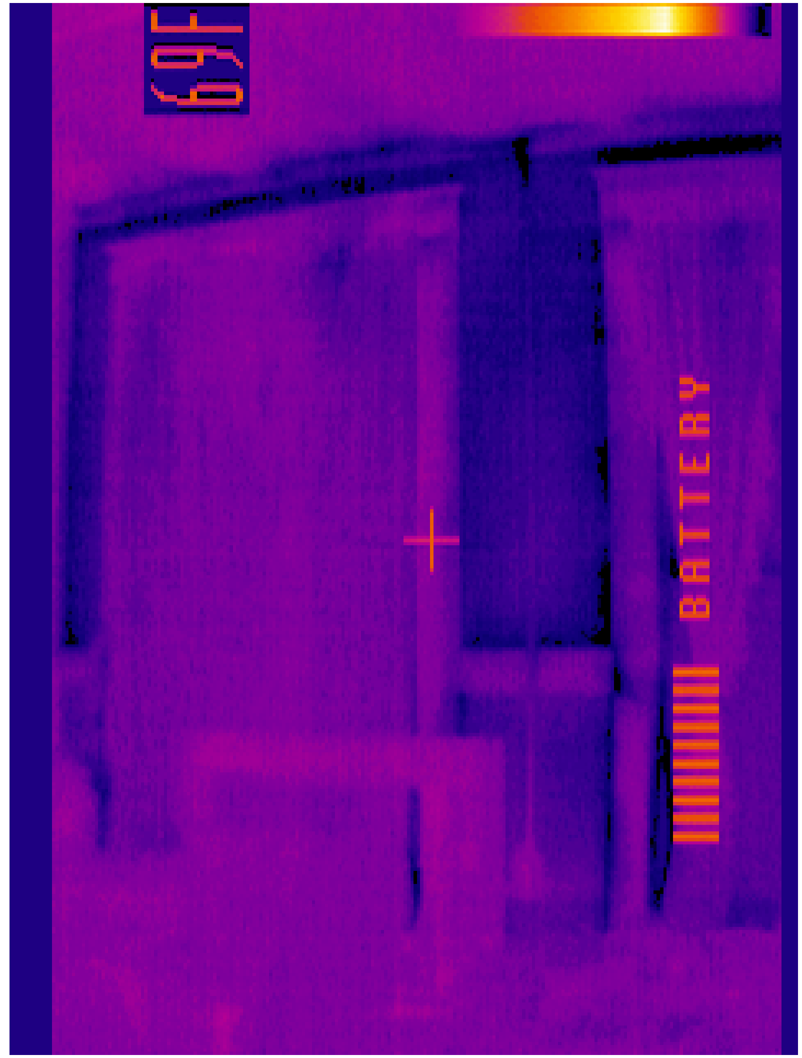
Minneapolis Leakage Ratio: .79 CFM50 per ft2 of envelope surface area
This is using the CFM50 relative to the surface area of the shell or envelope, since heat loss is based on surface area not volume.



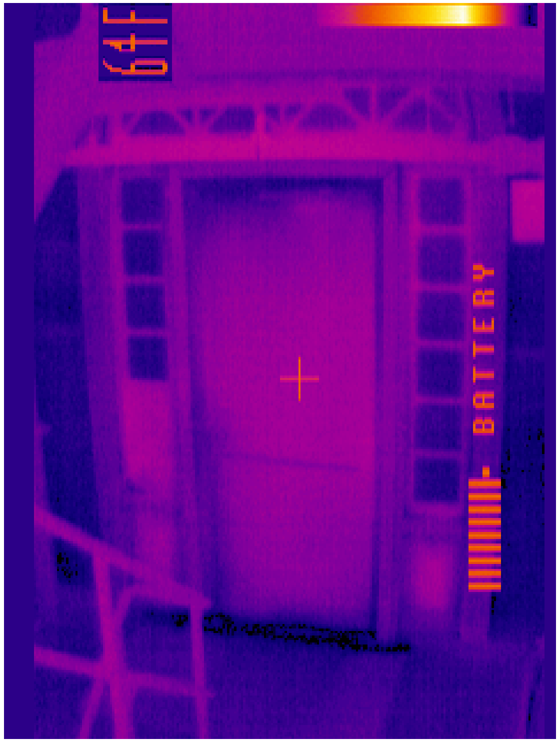


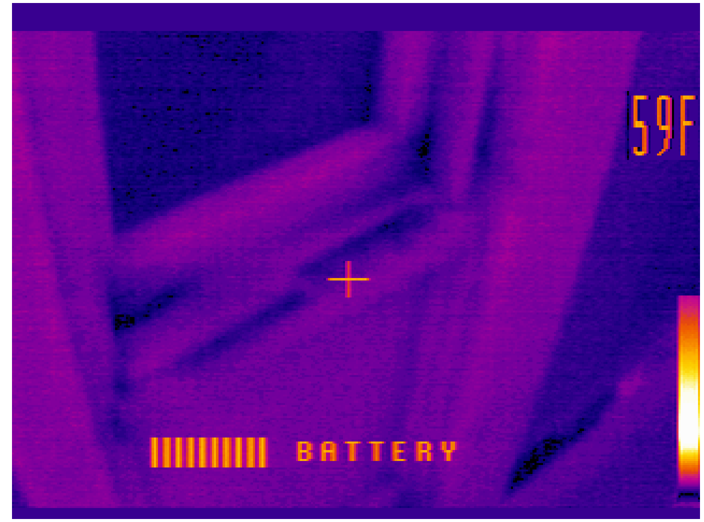
Masonry walls appear uninsulated. Windows are all double pane but of several varieties and fairly 'air leaky'. Each room has an outside exit, which also leak air. Radiating baseboards generally surround each room in order to make up for these high heat loss conditions.

While masonry in itself makes a good air barrier, unless openings in the wall (windows and doors, ect) were foam or caulked seal, they can be particularly leaky. These are the primary reasons why this building uses so much energy: **the air tight walls are not insulated, and the holes in the walls are not air sealed.**



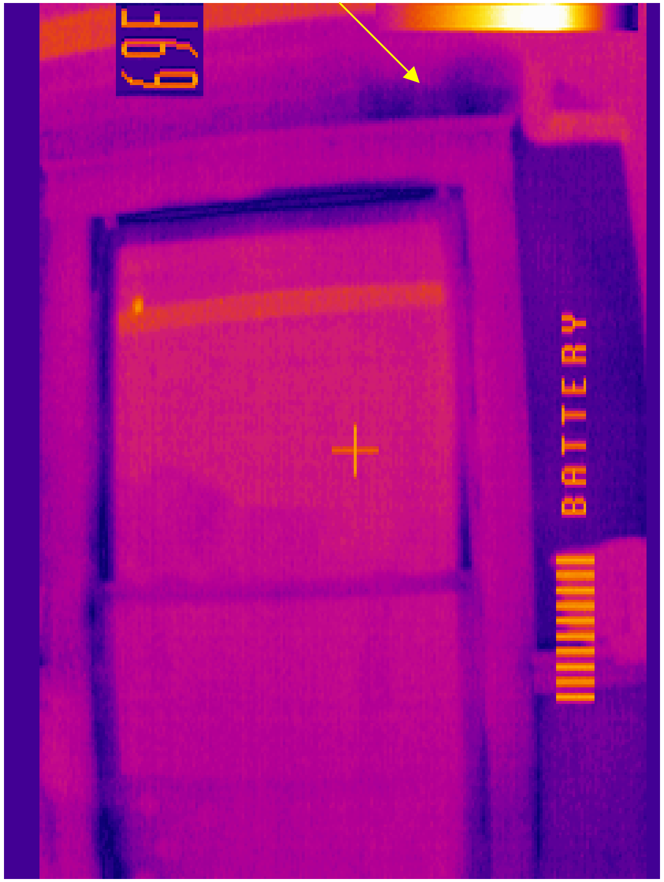
(and there are a couple of large single pane windows left in the two stairwells!)

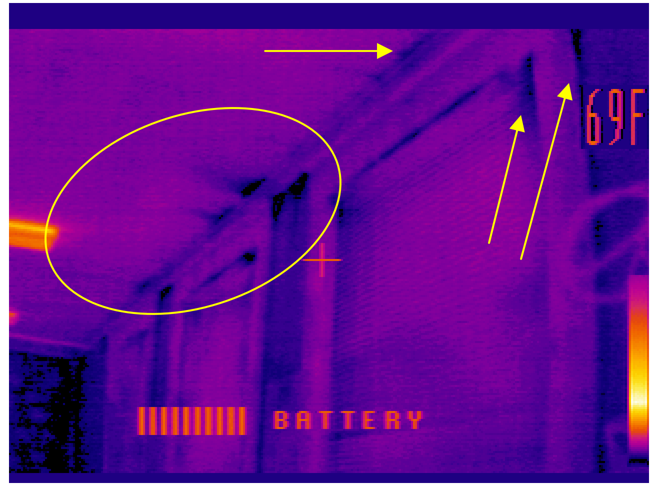




Permanent interior, fixed double paned storms, sealed in place, are recommended for these single pane windows.

Effective air sealing requires removing all trim and sealing the rough opening around the window unit, as well as the sashes themselves.

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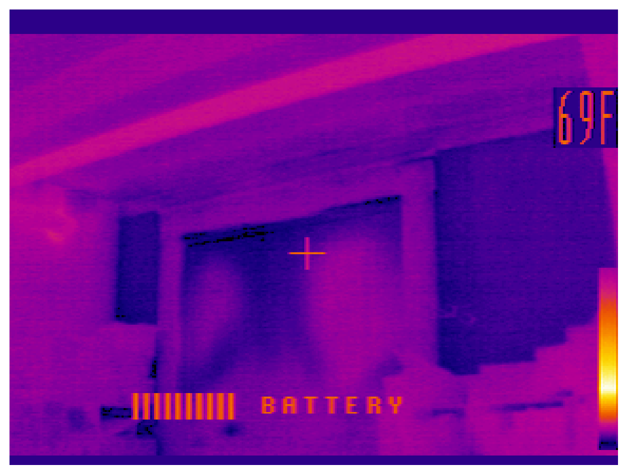
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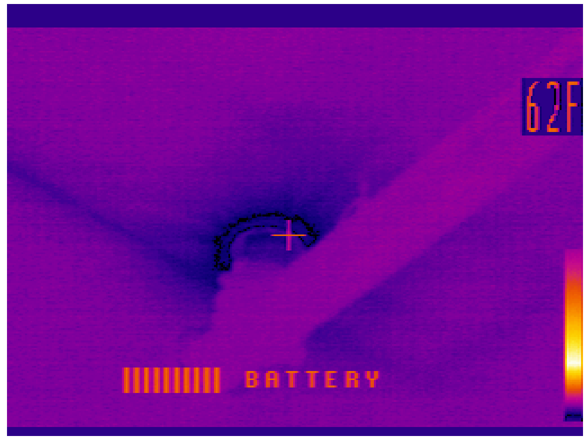
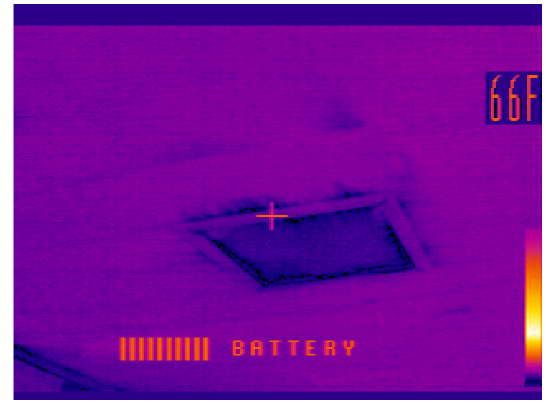
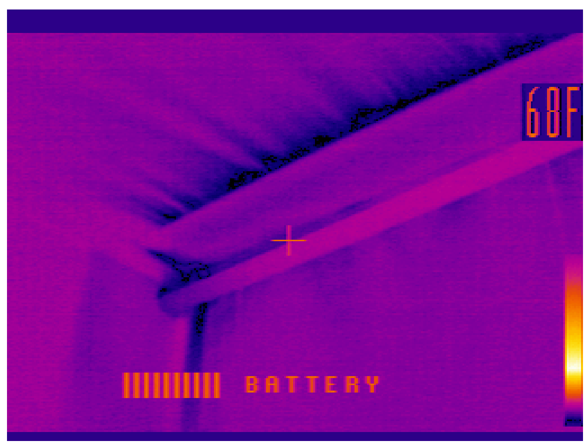
And then there's the connection to the attic. The ceiling has significant gaps in the air barrier – and there is an opportunity to increase effective insulation levels as well.







Attic's cellulose insulation ranges from 2-5" in depth in between joists for effective levels ranging from R6 to R15 with all framing approx R6. Residential codes call for R49 in New Hampshire. While non residential have lower requirements, low energy buildings often shoot for R50-R60!

Attics are a great place to see construction materials used the building but which may be covered. The ceramic tiles above can also be seen in a wall cavity in the basement and behind the stairs in the large stairwell.

Original 8" Masonry walls

Newer 6" concrete block with 2" brick facade

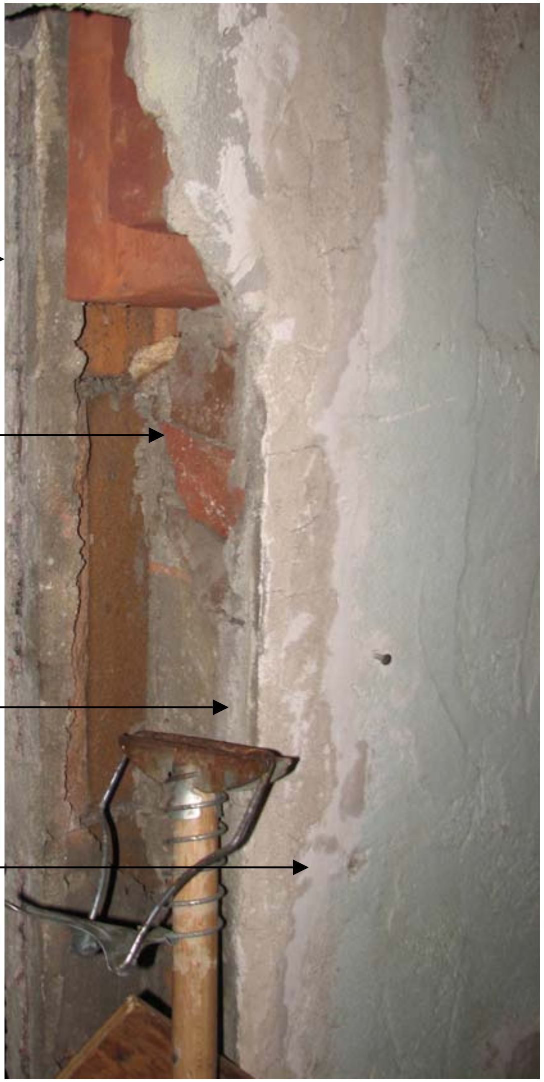
Estimated R3

Exterior Cement stucco

Brick and mortar

Ceramic tile

Interior plaster finish



Estimated R5

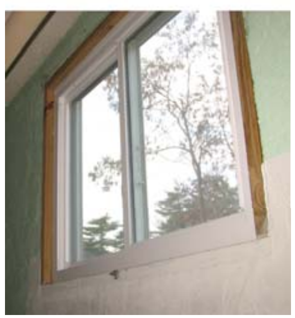
Glazing

R1

2 entry ways are on remaining single pane

Mix of window types –

R2 for unit average



Ceilings and Roofs

For estimating purposes, ceiling has been conservatively assessed at R14.

With no access to the ceiling under this roof and no drawings, the insulation is an unknown. However, Ed believes he saw an 1" rigid foam, so for estimating purposes, the roof is assessed at R5. The next step would be to make a hole in the ceiling and do a physical inspection of this assembly.

North Wall

Total wall area: 1985 ft2

Glazing: 78ft2 @R2.2
Doors: 17ft2 @R1
Net AG: 1890 ft2 @ R6
Below grade : 360ft @R6

Ceiling

2745ft2 @ R14

East and West walls

Original: (2) 1357 =2714
Glazing: (2) 118 =236
Single Pane: (2) 36 = 72
Doors: (2) 17 = 34
Above Grade Fnd: (2) 80 = 160
Net Wall: (2) 1106 = 2212
Below Gr Fnd: (2) 172 = 344

New: (2) 320 = 640
Newer glazing: (2) 84 = 168
Net newer walls: (2) 460 = 920
Slab edge: (2) 17 = 34

South walls

Original: 1357 ft2 @R6
New: 695 ft2@ R3
Glazing: 165 ft2@ R2.2
Newer glazing: 210 ft2 @R2.2
Doors: 77 ft2 @R1.5
Net original walls: 1137 ft2@R6
Net newer walls: 460ft2 @R3
Foundation: 12ft2 @R6
Slab edge: 30ft @R1

Roof: 1933 ft2 @ R7

Existing Heat Loss Peak Operating Loads:
Walls, windows, doors: 52,600Btu/hr
Roof at R5 (?): 22,809Btu/hr

Total: 75,400Btu/hr

Plan A Heat Loss Peak Operating Loads:
Walls, windows, doors: 13,190Btu/hr
Roof at R5 (?): 3,258Btu/hr

Total: 16,448Btu/hr

Heating Equipment

1) This building is heated only (no cooling) via a standard efficiency, sectional, cast-iron boiler providing hot water to baseboard fin tube radiation and convectors throughout the building. The zoning controlling the pumps is minimal (two zones), however, additional zoning has been achieved through the use of self-contained thermostatic valves (SCV's) installed in the piping serving the radiation. The SCV's provide some means of comfort control via a dial that allows the occupant to make the room warmer or cooler. Unlike a thermostat, the dials do not provide a reading of the actual room temperature or the ability to set the temperature to a specific setting. It is not clear how these SCV's affect the pumps as a means of bypass was not found (i.e., if all the SCV's close, the pumps may be "dead-headed" – that is, pumping, but not moving any water). It appears that an outdoor reset controller is used to modulate the temperature of the hot water supplied to the building based on outdoor air temperature via a mixing valve in the boiler room. – Comments from Scott Hening

Distribution

Variable pumps may provide some efficiencies

Ventilation: Exhaust only

2.) There are no mechanical ventilation systems providing outdoor air to the building. There are some exhaust fans that serve bathrooms, though it appears they are not all functioning at this time. Due to the large windows, it is possible that many spaces in this building may meet ventilation code via “natural” ventilation. The requirement is that the windows are maintained in an accessible and operable condition, and that the operable area is equal to at least 4% of the floor area being ventilated. This can be applied to interior spaces too if the opening between the interior and exterior spaces meet the dimensional guidelines described by the code. For spaces without natural ventilation, mechanical ventilation must be provided. Typically 15 CFM per person in classrooms, 20 CFM per person in office spaces and 0.10 CFM/Sq Ft of outside air in corridors is required. For spaces that are mechanically ventilated, ventilation must be provided whenever the space is occupied, and must be capable of providing enough OA to satisfy the fully occupied condition, though reduction of the OA CFM via CO_2 control is allowed. - Hening

Make up combustion air

3.) The combustion air assembly serving the boiler does not appear to meet code.

Comments from Scott on Condensing Boilers

- Though not essential, a boiler replacement with a high-efficiency, gas-fired condensing boiler (or pair of boilers) could be beneficial after the envelope improvements are made. To evaluate this we'll need to calculate the maximum heat demand of the building after the envelope upgrades are made, and consider whether mechanical ventilation will be added, as these two components will comprise the total heating load of the building. Once we know the maximum heat load of the building, we can compare with the existing boiler capacity and estimate savings. We can, however, say the following without any calculations:

- A condensing boiler will operate at higher efficiency under most operating conditions – sometimes at much higher efficiency (during warmer weather) - though the cost per BTU will be greater (propane vs. oil). The envelope improvements will allow the building to be heated with cooler water, and the cooler the water, the greater the efficiency gains provided by a condensing boiler.

- A condensing boiler will lose much less heat to the boiler room. Note that when we were there, the Senior Room appeared to be getting substantial heat from the boiler room below. This works fine sometimes (when it is cold), but it is uncontrolled and can result in overheating during warmer weather (and wasting energy when the windows are opened to cool the space down).

- With a condensing boiler, the combustion air assembly could be removed (typically a 4" PVC pipe is all that is needed for combustion air).

Summary of Recommendations

I. Air Sealing - $4,000

- Weather-strip all doors which are not being replaced.
- Air Seal all windows which are not being addressed otherwise.
- Air seal ceiling plane, including chimney flashing and spray foam at perimeter

II. Ceiling - $7,500

1. Install folding stair system to attic (onto stage for height) with sealed thermo dome.
2. Add 14" cellulose for total R50 assembly.

III. Basement - $9,400

1. Install 2" closed cell foam on all accessible basement walls – rigid or spray – and finish surface appropriate to location.

IV. Addition - $105,000

1. Install R20 EIFS (Sto or other) to three exterior walls with cement board and finish coat.
2. Integrate and flash new R3 thermopane fixed windows to exterior of existing fixed windows and insulate frames.
3. After checking for structural concerns and dryness of assembly, build up roof with R30 rigid foam in layers and a) new membrane or b) control layer and ballast (5#/ft2. Adding insulating will increase snow loads and an inverted roof has extra weight of ballast (approx 5#/ft2). New roof allows for extending overhang over thicker walls below – at least 2".
4. Install R20 EIFS on original south facing wall. This allows for proper flashing of wall and roof connection.
5. Replace all doors on south wall with insulated and well gasketed doors and install insulated frames around windows.

V. Ventilation - $3,500 for engineering - $24,000 for minimal system

1. Replace existing open shaft passive ventilation with ducted HRV for continuous operation (estimat5ing 400CFM) during operating hours with minimum 65% heat recovery and to be turned off on all closed hours.
2. Upgrade combustion air assembly to meet code (for safety as opposed to energy efficiency)

VI. Heating Distribution System - $5,000?

1. Install basic Direct Digital Control (DDC). Review piping layout. Remove Self Contained Thermostatic Controls (SCV's) and install Automatic Control Valves (ACV's) and thermostats.
2. Consider replacing the existing pipes with variable speed pumps.

VII. Other -$1,600

1. Supply Watts Up meters and or replace refrigerators. Consider sharing refrigeration.

VIII. ALTERNATE ADD: $90,000

1. Install EIFS on remaining Original Walls with similar tie ins to windows and doors, for a complete building wrap.

Reasonable Results

Based on current oil use of 4746 gallons (or approximately 657MMBtu's) it would be reasonable to expect that energy conservation measures thorough envelope upgrade items I-IV should reduce the heat load between 35 and 40%. Using the existing heating system and controls, that would indicate a reduction of fuel use to 2850 to 3100 gallons a year.

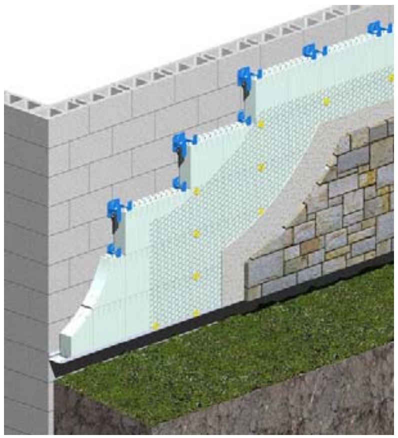
The Alternate Upgrade, involving the entire exterior of the building could be expected to result in an annual fuel use of 2400-2500 gallons per heating season. This is a conservative estimate. It is also possible that it could use considerably less.

Installing a digital control system and variable pumps will have less of an impact on an upgraded envelope, but could still save an additional 100 gallons while also improving comfort. The reality is that dramatic improvements to the envelope can dramatically alter the way a building functions and the increased level of controls will help assure better comfort throughout the building.

All combined, a 50% reduction of heating fuel can be expected. Please note that this is *after* adding a ventilation system to provide code required ventilation while people are in the building.

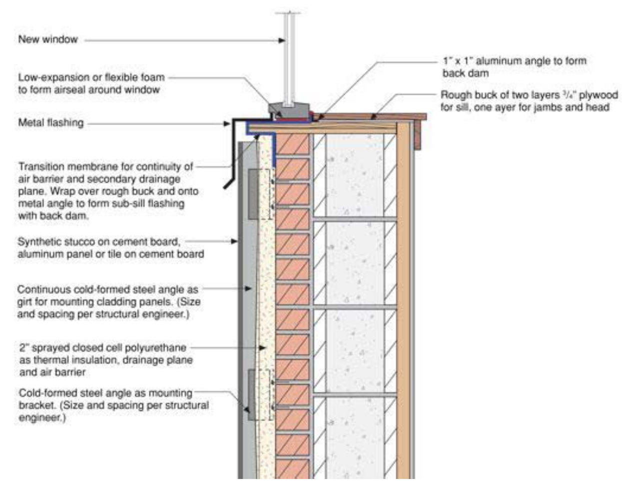
At least one year after the renovations, it is recommended that you explore replacing the existing boiler to a high efficiency, condensing propane boiler. A condensing boiler can operate at far lower water temperatures which increases efficiency beyond the far higher combustion efficiency. Such a boiler is direct vented which eliminates the need to supply combustion air. More importantly, the boiler could be sized to meet the new heat load and also be fully modulating to respond to the actual temperature outdoors. All of these aspects could increase the efficiency of the equipment from an estimated 78-80% to 92-94%. The trade off is that propane has fewer btu's per gallon so there may not be the kind of dollar cost savings. But since propane also generates about 60% less carbon than oil, actual carbon emissions are dramatically reduced by switching to propane.

It is interesting to note that while DOE usually suggests using a 2-3% annual increase for the cost of energy, a historic analysis of the last 30 years indicates an actual annual increase of 6.8% in that time period. Energy costs generally go up 1.75-3% each year, then spike 15-25%, then go along for a few years at the smaller increases. While spikes are impossible to predict, history suggests it would be foolish to ignore them in long range planning. This is more true for the future now than in any time in the past. As discussed with Clyde, financial projections are left to the town, based on the financial and energy futures picture with which you are most comfortable.



There are many ways to insulate the exterior of walls. My recommendation is to target a continuous R20 (4" EPS) upgrade while integrating thermal upgrades to the windows and doors, and a new insulated roof assembly with extended overhang. Insulating the south facing wall at the same time allows for better integration with the roof – flashing and thermal continuity. I discussed this with Michael Bruss of Bruss Inc, and he recommended. Sto EIFS as the least expensive approach with strong track record in NE.

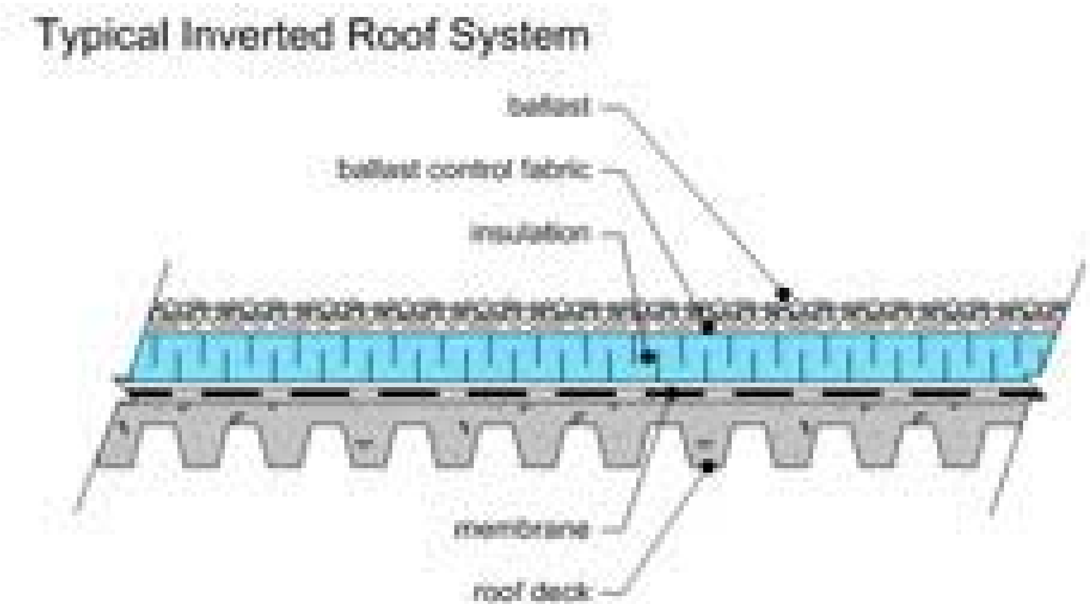
My estimates are based on MEANS data, but guestimates on window and other details. Strongly advise you to contact Michael for more detailed estimates for wall and roof.



Roof Upgrade - considerations

- Easy to upgrade by adding insulation
- Often can leave membrane in place
- Confirm MC before over clad
- Issues with curbs / parapets (not as much in this case)
- Need to explore existing structure
- And need to examine existing insulation to make sure it, and the entire assembly, is dry.
- Limit new penetrations.
- Doors may have to be raised or made shorter; another good reason to replace.

Inverted Roofs



- Pros:
  - Preferred approach
  - Exterior insulation eliminates thermal bridges
  - Protects membrane
- Cons:
  - Added weight of ballast
  - Can only use XPS

Exposed Membranes

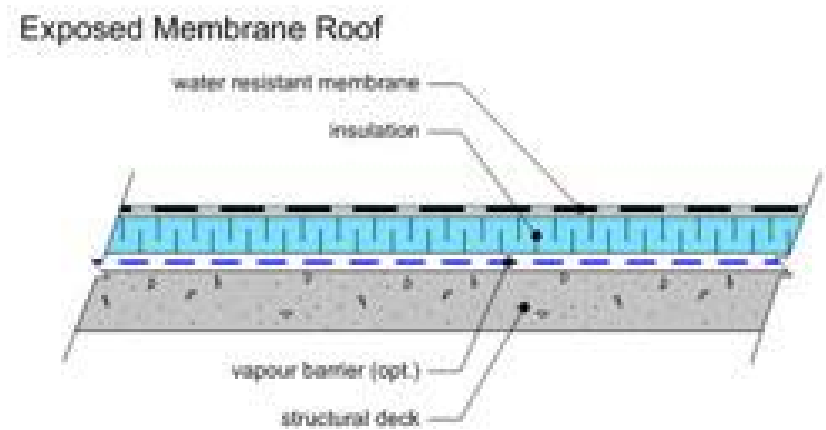
- Pros:

-Lightest weight

-Wide variety of insulation and membranes

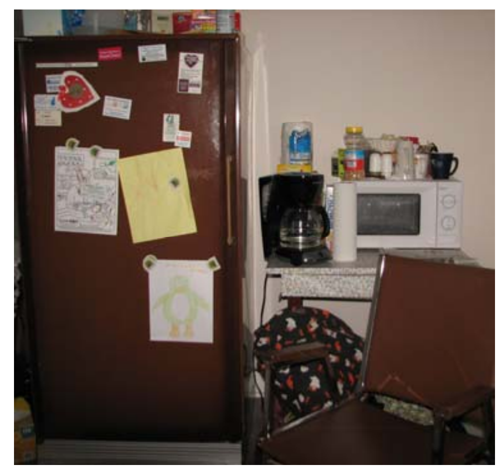
- Cons:

– Exposed membrane!



Other

Start to Monitor Appliances Elec Consumption or Replace any over five years old. Small apt sized or single door (bottom right) can use a lot of energy!!



Waste Treatment Plant









ANNUAL ENERGY USE SUMMARY

1200 gallons

1000 gallons

Heating Fuel -2200 LP Gallons

Electricity
130,968 Kwh

Note that there are two aspects to reducing energy use: Conservation and Efficiency. Upgrading the envelope and thermostat settings conserve energy by reducing the amount needed for comfort. Upgrading equipment and distribution systems improve the efficiency of how energy is delivered.

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)

Oil: 2200 gallons x 91,500 Btu's/gallon = 201,300,00 Btu's or **201 MMBtus**

Electricity : 130,968 KWH x 3412 Btu/kwh = 446,862,816 **Btus or 447 MM Btu's**

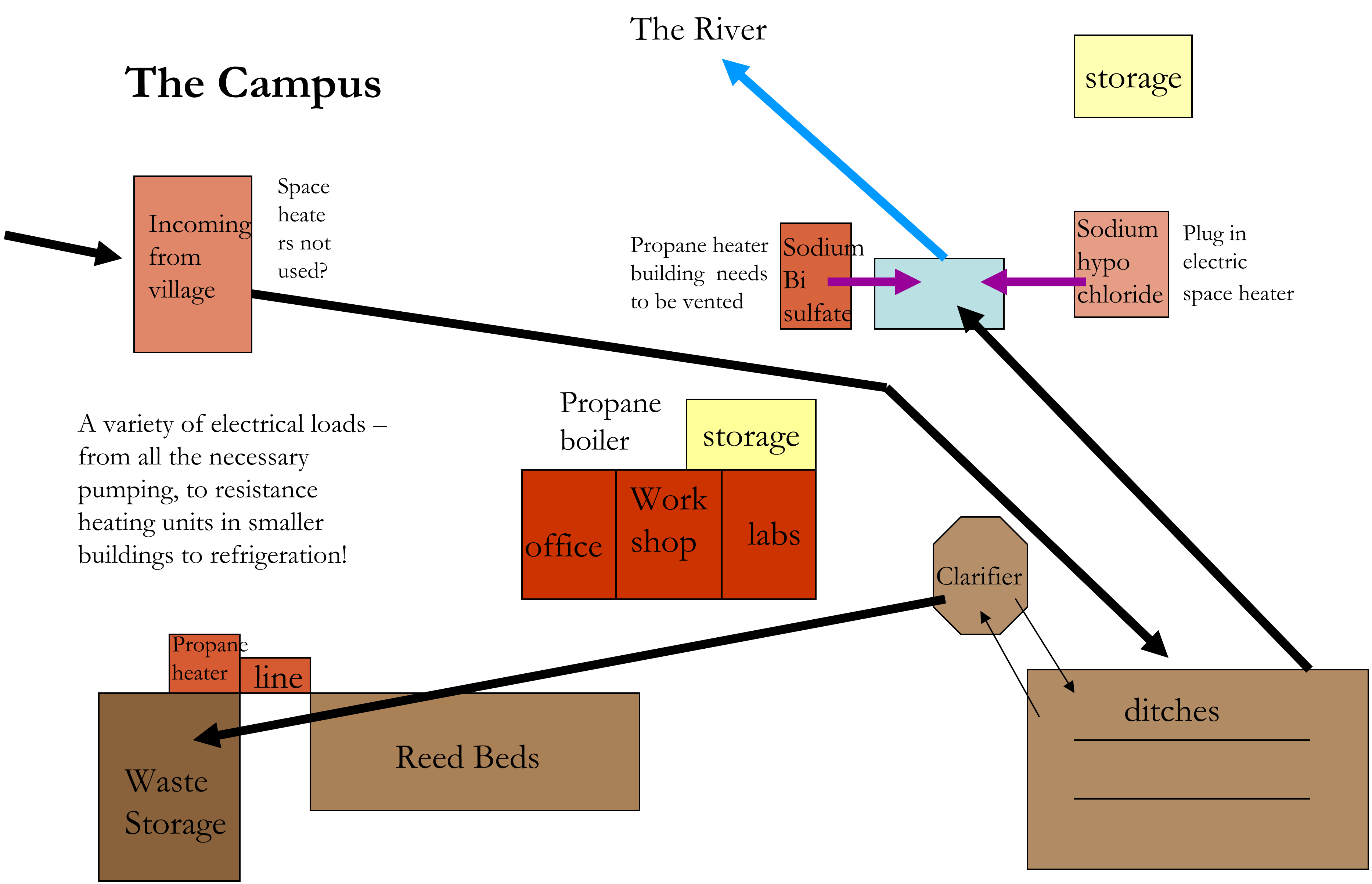
Total Energy in Btu's =648MBtu's 2243FT2 = *289KBtu/ft2

Pump house - Incoming from Village, then pumped onto Circulating Tanks.

As I understand it…..

Pumps in the main building (right) circulate everything in these holding tanks then moves it onto the Clarifier building for solids to settle. Liquid is returned to these tanks or to chemical treatment and, when necessary, solids are pumped to wastes storage. Treated water is destined to gravity flow back to the river and solid wastes are transported by truck to Concord.

The Campus



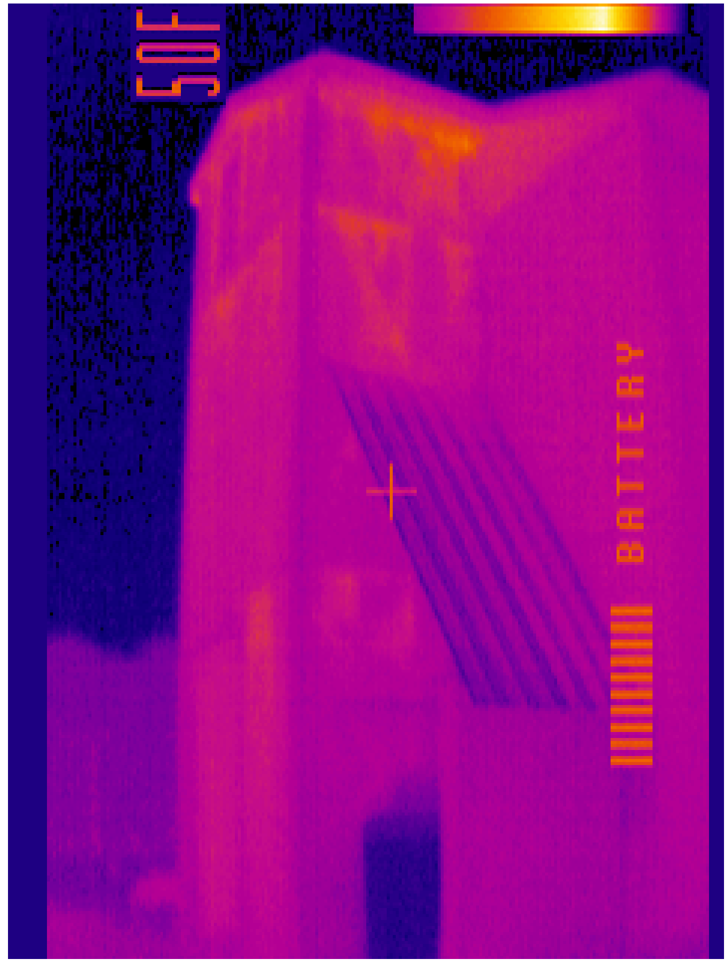
A variety of electrical loads – from all the necessary pumping, to resistance heating units in smaller buildings to refrigeration!

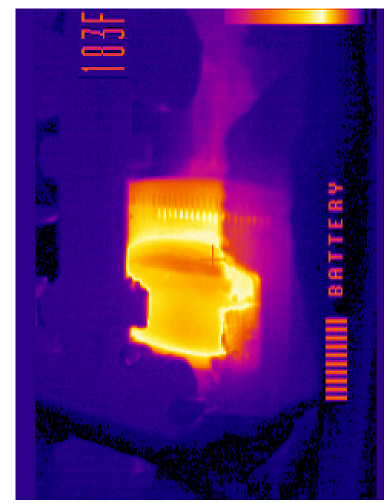
Buildings in Red and Orange are heated. Orange buildings just have to be warmed enough to keep whatever is in them from freezing.

According to the records provided, this “Sludge Building” uses 1000 gallons a year to keep a pipe to the reed beds from freezing.

Based on the assessed heat loss, it should be able to be kept at 50 degrees for less than 200 gallons of propane.

I suspect this heater is on all of the time, no matter what the inside or outside temperature.





I also suspect the hatch cover to the storage area is rarely in place.

As usual, the place to start is establishing effective air and insulation barriers.

This line has been insulated but also uses a heat tape to prevent freezing – especially where it enters the reed beds where it is most unprotected.

Recommended Strategy

1. Remove all existing insulation in tower.
2. Dense pack cellulose into all 6" cavities.
3. Fill above ceiling with 15" cellulose.
4. Install 2" rigid, foil faced polyisocynurate on all four walls.
5. Frame floor with 2x4's and spray closed cell foam, then cover with 1" foil faced poly iso and cover with plywood.
6. Create 4" hatch door on hinges which can easily be opened, closed, and sealed shut.
7. Install fixed thermopane storm on the inside of the light window and gasket seal.
8. Replace door and insulate if necessary with 2" foam board (R10).
9. Remove foam lined box and berm and re plumb the line to enter the reed bed 2-3 feet inside from the edge. Encase entire pipe in a 2x2 box made from 10" SIPS ripped SIPS panels with all seams foamed in place. This will create a solid, continuous R40 assembly which should prevent freezing.

The building will have a UA value of 25 and could be expected to be kept at 50degrees for well under 5,000,000 Btu's as opposed to the 91,000,000Btu't it apparently uses now. Whatever heating device is used, it should be thermostatically controlled to maintain a minimum 45 degrees. It is possible it will only be needed in most extreme temps…and possible a 100watt light bulb may be adequate to prevent freezing.

Total costs should range between $5-6000. Depending on the heater unit, simple pay back within 2 ½ to 3 years.

Main office building, workshop and labs

Main Building: Office, Workshop and Lab

Blower Door Test & Results

Measuring Air Infiltration and the Air or Pressure Barrier

Convective and Conductive Heat Losses and Moisture Transfer

Whole Building: 1402 CFM50

Means that **1402 cubic feet of air per minute** would be pulled thorough leaks and gaps in the air barrier when the building was under pressure at -50 pascals with respect to outside.

Air Change per Hour Rate at -50pa: 6.02ACH50
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 **over 6 times every hour**. The math: CFM50 x 60 / building volume

Standard Residential Construction practices is generally between 7 and 9ACH50 and 2009 IECC sets 7ACH50 limit.

Energy Star's limit is 5ACH50. High Performance Homes under 1ACH50. Currently no standard for non residential buildings.

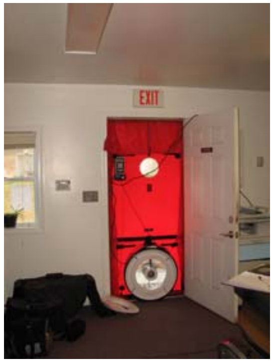
Estimated Annual Air Change Rate: .13 ACH Winter: .46ACH Summer: .25 ACH
Conditions vary ACH day to day, but throughout the year the outdoor climate impacts indoors considerably. On average in winter, you are heating the air which is replaced by outdoor air almost once every hour.

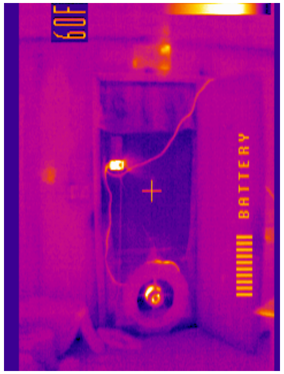
Estimated cost of envelope air leakage: $400 at $3.50 gallon

Leakage Area (Canadian EqLA @10pa)151 in2 or .97sq feet
Total size of hole if add all cracks and gaps together

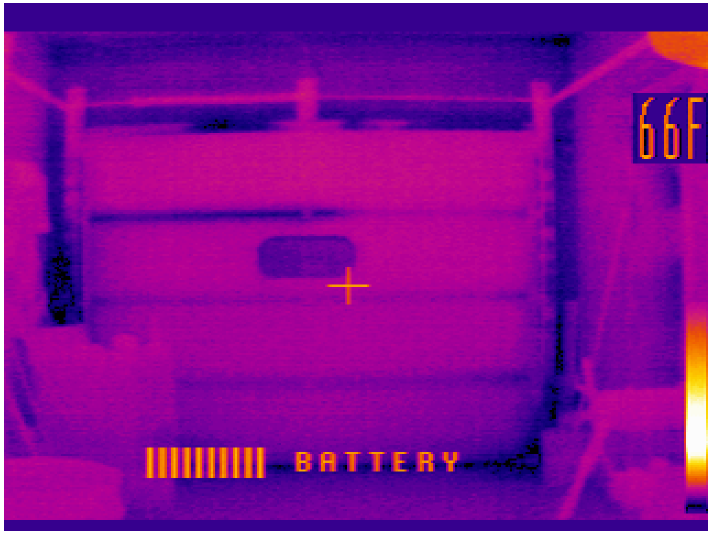
Minneapolis Leakage Ratio: .45 CFM50 per ft2 of envelope surface area

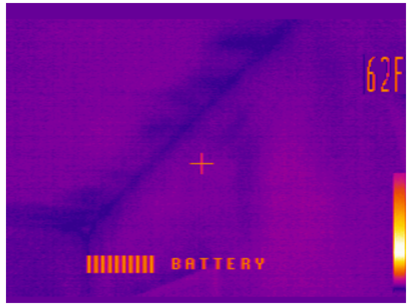
This is using the CFM50 relative to the surface area of the shell or envelope, since heat loss is based on surface area not volume.





Garage door most significant contributor to air leakage. As they do not use this for vehicle storage, removing the door and framing in a 2x6 wall with one large oversized insulated door is recommended.

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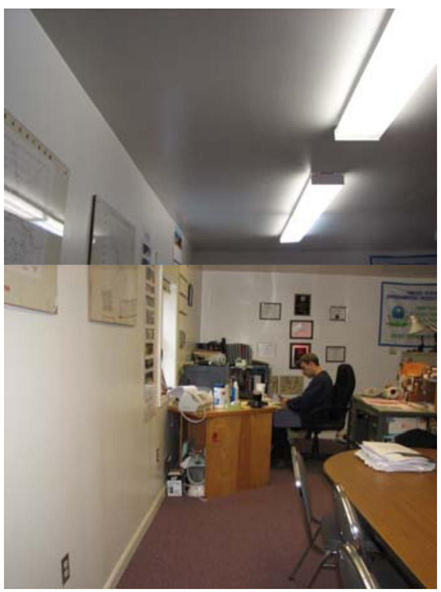

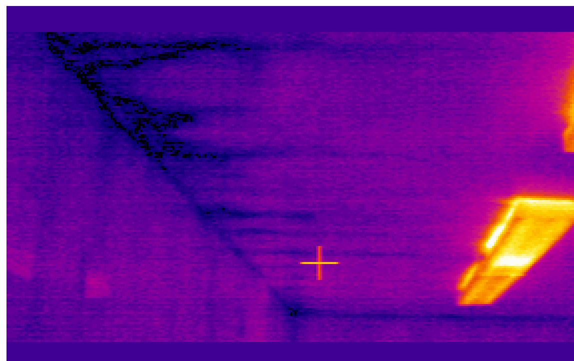


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BATTERY

Ceiling has 6"batts on strapping with poly layer underneath – so fiberglass is not in direct contact with any air barrier. Effective R10-15 at best. Very small, vented attic space. Low pitch roof with 2x4 truss won't allow for snow loads, so roof has to be shoveled.

Ideally, a new, steeper roof could be constructed with more room to properly air seal and insulated to min R40.

Distribution – modine space heater (above) and FHW baseboards in office and labs.

Boiler Valiant Propane - Atmospheric
134K Input
Net IBR 116,500
Approx 86% combustion efficiency

Recommended Strategies

1.Remove garage door and frame 2x6 wall, installing an extra wide insulated hinged door, with minimum 6 ft2 thermopane glazing, to allow for necessary functions. Dense pack cellulose in wall cavities against 2" exterior XPS for R30 assembly and no thermal bridging; firing strips and new siding to match office. Estimated cost: $1750

2. Add 2" XPS to exterior of office walls with insect protection at bottom edge; firing strips; and new siding. Pull soffit and foam seal over top plate if accessible connect with rigid on walls. Either pull (3) windows, extend jambs, re-flash and air seal, or frame from exterior with special attention to flashing and air sealing. Estimated cost: $3375

3.Remove all fiberglass batts in ceiling and blow in 16" cellulose. Foam seal along ceiling connection to brick of original building. Increase gable vent size. Estimated cost: $1800

(Roof already has to have snow shoveled off and this will only make that more important. Better plan would be to remove roof and rebuild at steeper pitch – I'd be happy to consult on assembly if that is the plan.)

4. Air sealing remaining four windows and double entry doors. (remove A/C unit each winter.) Estimated cost: $250

5. Install programmable thermostats and set back to 50degrees or more each night. Estimated cost: $200. Improvements should bring back to temp easily. If not, reported insulation in roof was overestimated and there is opportunity there as well. Original masonry walls is suspected to have R10 rigid foam, but if not, that too is an opportunity.

6. Install door to basement which can be sealed closed and install rigid foam on back of wall between lab and stairwell. Estimated: $1000

7. Install foil faced rigid polyiso on basement walls four feet down from ceiling. Estimated $860.

Total estimated costs for above improvements: $9235

Estimated heating fuel reduction: 25% or 550 gallons /yr. Estimated payback 5+ years at 6% annual increased energy cost.

OTHER

1. Consider re-thinking refrigeration. Currently 3 small units – one commercial unit for chemicals and the other two primarily for food – both underused. But sometimes overflow for chemical bottles. Either replace two small units with one very efficient model with separate freezer compartment, or one larger unit to serve all three.

Plus in Watts Up Meter to dehumidifier in basement. It may be possible to further reduce humidity levels and energy loss passively by insulating entire walls but tracking humidity for a year first is advised.

It is not known how much fuel is used to heat this 120 ft2 building, but the heat loss on this mild day is clearly evident in the IR. The challenge here is that the building needs to be well ventilated because of the toxicity of the Sodium BiSulfate fumes. The envelope can be upgraded considerably for passive freeze prevention, but without heat recovery ventilation, it is hard to know how much savings can happen from envelope upgrades alone.

One reasonable step would be to meter the propane usage to know how much fuel is being used in a season.

Metering gas used is recommended to assess cost effectiveness of retrofit or building a SIPS or otherwise super insulated new box.

Rigid board has been stuffed under the floor with minimal impact. As heat will conduct to cold thorough thermal bridging and gaps. The good intentions behind "Every little bit helps" is lost on thermodynamics.

The same is true for this building which now houses sodium hypo chloride. The building was not heated on the day of the site visit. Evidently a portable electric heater is used during coldest weather. I do not believe it is vented now – the fan was installed when it was also storage for the sodium bi-sulfate. Both of these sheds could be super insulated with 5-6" of foam on all sides and be kept from freezing with a thermostatically controlled hundred watt light bulb. Without knowing how much it takes to heat the existing set up, impossible to calculate cost savings. Gasketing the door for air sealing is warranted under any situation.

I recommend metering electrical demand for heating, as well as installing HOBO data collectors in all buildings to track temp and RH year round.

With such a large array of electrical uses, it is recommended that a comprehensive metering system be installed to monitor systems efficiency and assess individual appliance loads. It would be easy to assume that the annual KWH usage is justified because of all the loads, and therefore overlook a problem or these 'smaller' appliance loads such as dehumidification, heating, and refrigeration. Electrical systems analysis is beyond my expertise and the scope of this audit. Check with your utility company about services offered.

HOBO offers comprehensive energy monitoring equipment systems. Contact info on next slide to set up an appointment with a sales rep or TA.. $5,000 has been budgeted for whole campus energy monitoring – electrical loads as well as temp and RH,, by virtue of a dart throw.

Contact Info for HOBO Data Loggers at www.onsetcomp.com

Phone:

1-800-LOGGERS

(1-800-564-4377)

508-759-9500 (Southern MA, USA)

Fax:

508-759-9100

Email:

- **Tech Support**
- **Sales**
- **Webmaster**
- Customer Service
- **Website Feedback**

Hours:

8am to 5pm ET, Monday through Friday

Mailing Address:

PO Box 3450
Pocasset, MA 02559-3450

Physical Address:

470 MacArthur Blvd
Bourne, MA 02532
Meet Onset staff at **upcoming events!**

Town Hall

ANNUAL ENERGY USE SUMMARY

Heating Fuel
4057 Gallons

Electricity 19,428 Kwh

Note that there are two aspects to reducing energy use: Conservation and Efficiency. Upgrading the envelope and thermostat settings conserve energy by reducing the amount needed for comfort. Upgrading equipment and distribution systems improve the efficiency of how energy is delivered.

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)

Oil: 4057 gallons x 138,500 Btu's/gallon = 561,894,500 Btu's or **562MMBtus**

Electricity :19425KWH x 3412 Btu/kwh = 63,370 **Btus or 63MM Btu's**

Total Energy in Btu's =562 + 63 MMBtu's / 10,898FT2 = 57.4KBtu/ft2

Blower Door Test & Results

Measuring Air Infiltration and the Air or Pressure Barrier

Convective and Conductive Heat Losses and Moisture Transfer

Whole Building: 17,838FM50

Air Change per Hour Rate at -50pa: 8.02ACH50

This means that at -50pa (as if a 20mph wind was blowing on all sides of the building at once) the air would completely change **over 8 times every hour**. The math: CFM50 x 60 / building volume. Standard Residential Construction practices is generally between 7 and 9ACH50 and 2009 IECC sets 7ACH50 limit. Energy Star's limit is 5ACH50. High Performance Homes under 1ACH50. Currently no standard for non residential buildings.

Estimated Annual Air Change Rate: .66 ACH Winter: .91ACH Summer: .45 ACH

Conditions vary ACH day to day, but throughout the year the outdoor climate impacts indoors considerably. On average in winter, you are heating the air which is replaced by outdoor air every hour or so.

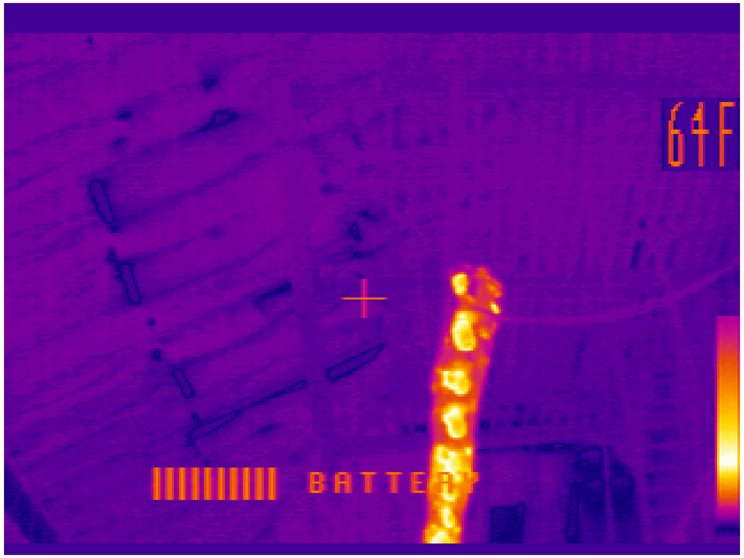
Estimated cost of envelope air leakage: $4535 at $3.00 gallon or approx 35% of heating bill

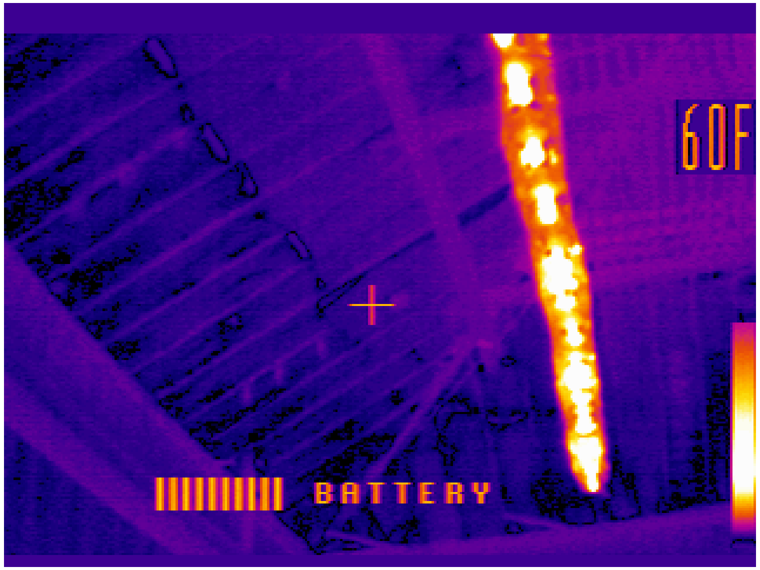
Leakage Area (Canadian EqLA @10pa)1841 in2 or 12.8sq feet

Total size of hole if add all cracks and gaps together

Minneapolis Leakage Ratio: 1.2 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.

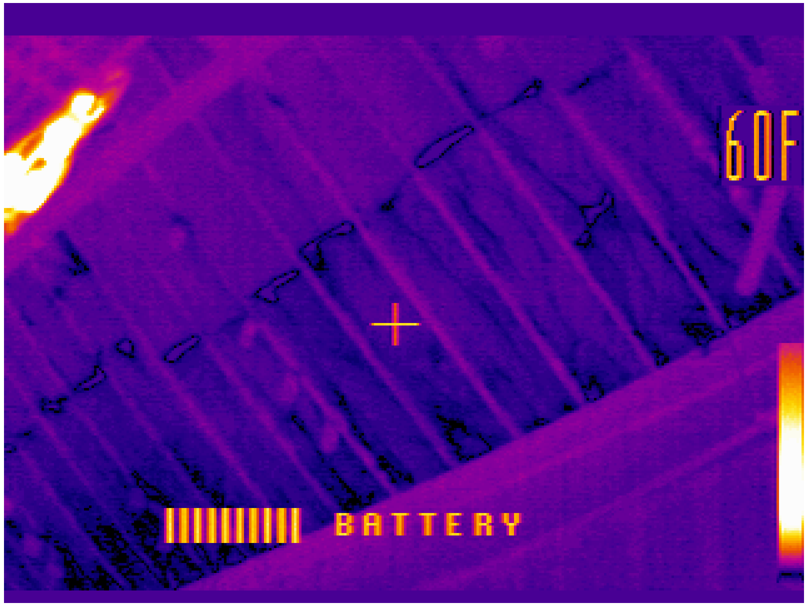


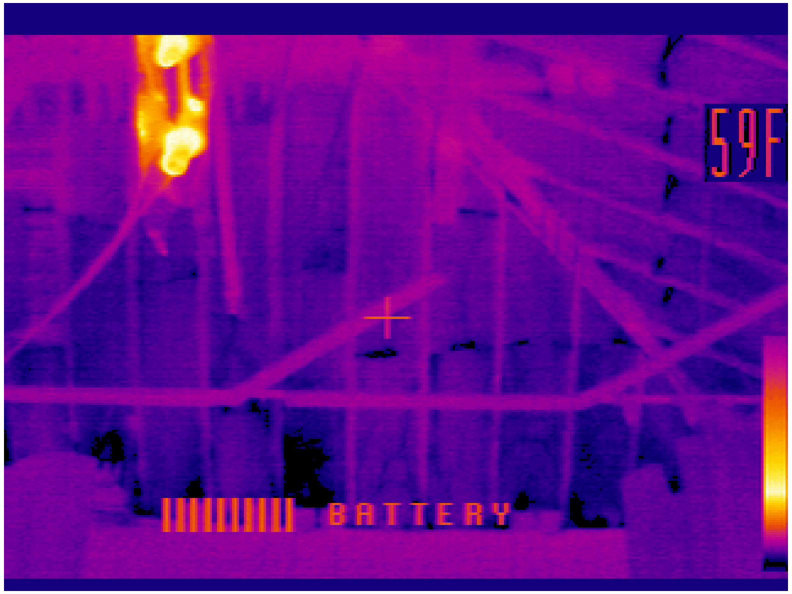


At -20pa

The most obvious opportunities for envelope upgrade lies in air sealing all windows and improving the performance of insulated ceilings. Insulating the exterior basement wall, especially in the meeting room is also recommended.

Remove all fiberglass batts is recommended. For optimal performance, strapping the 2x6 rafters for an 11" cavity – filling with dense pack foam and then covering with 2" foil faced polyiso for an R52 sloped ceiling assembly. This will also greatly reduce air infiltration.

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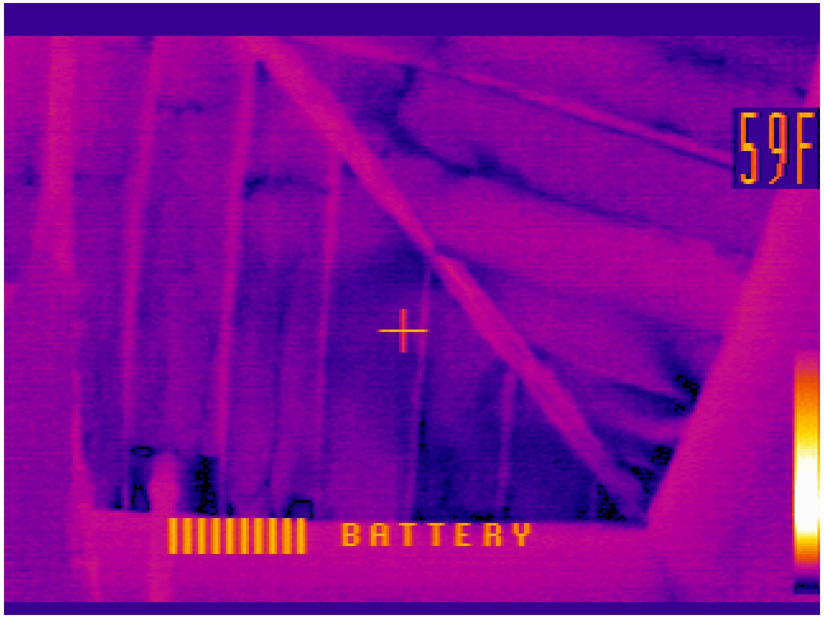
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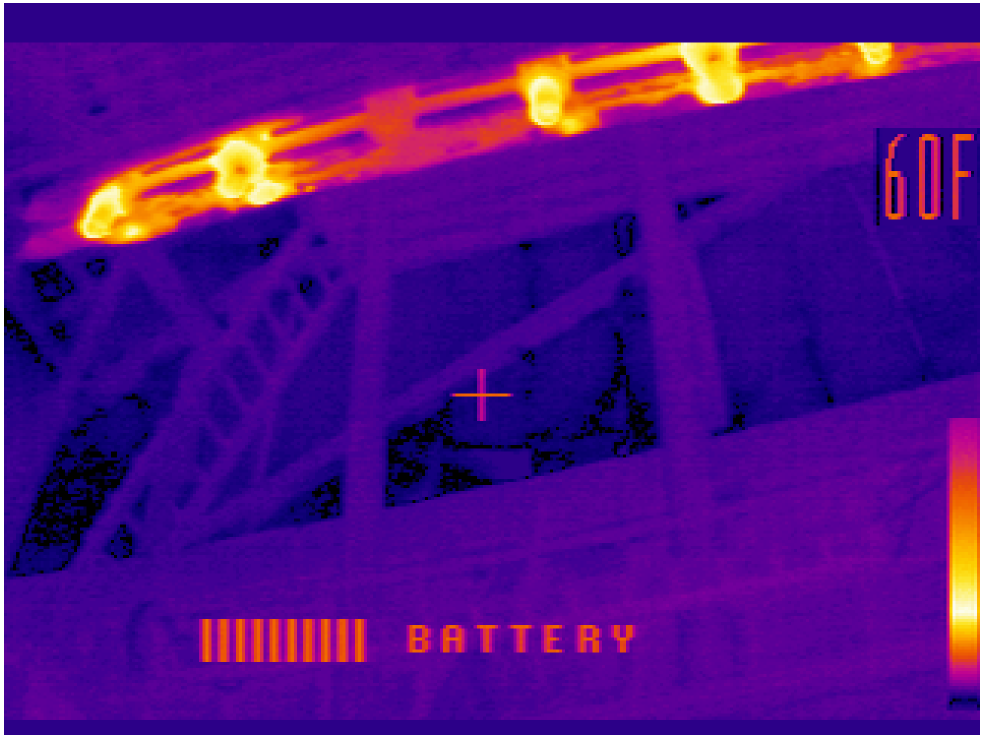
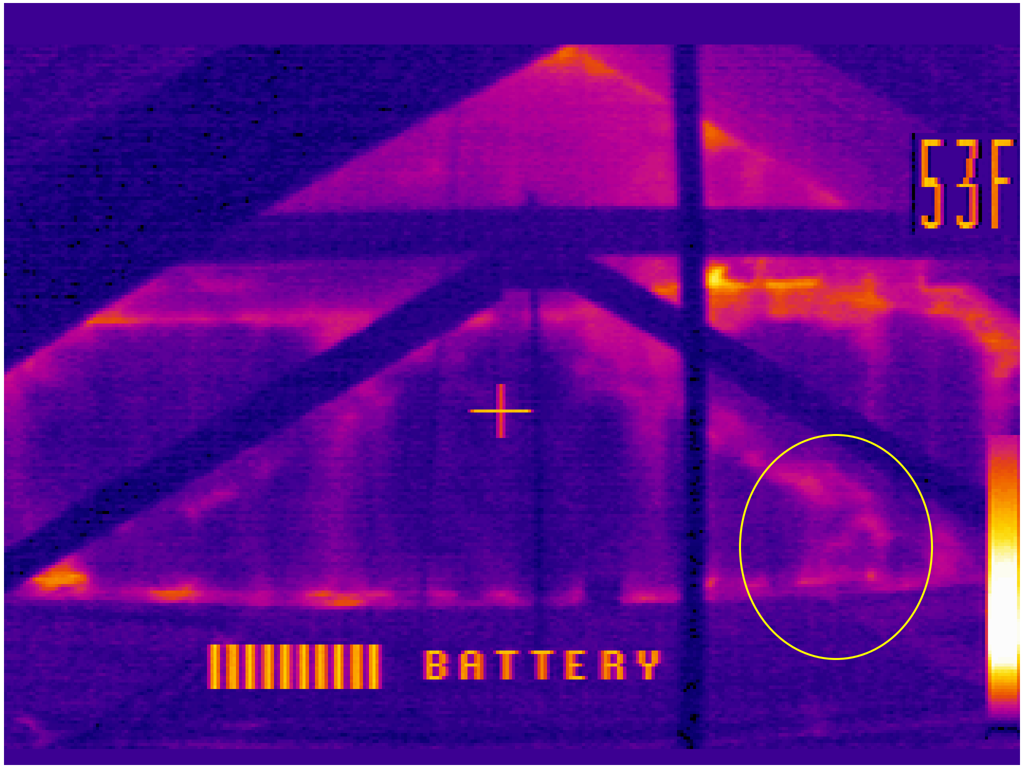
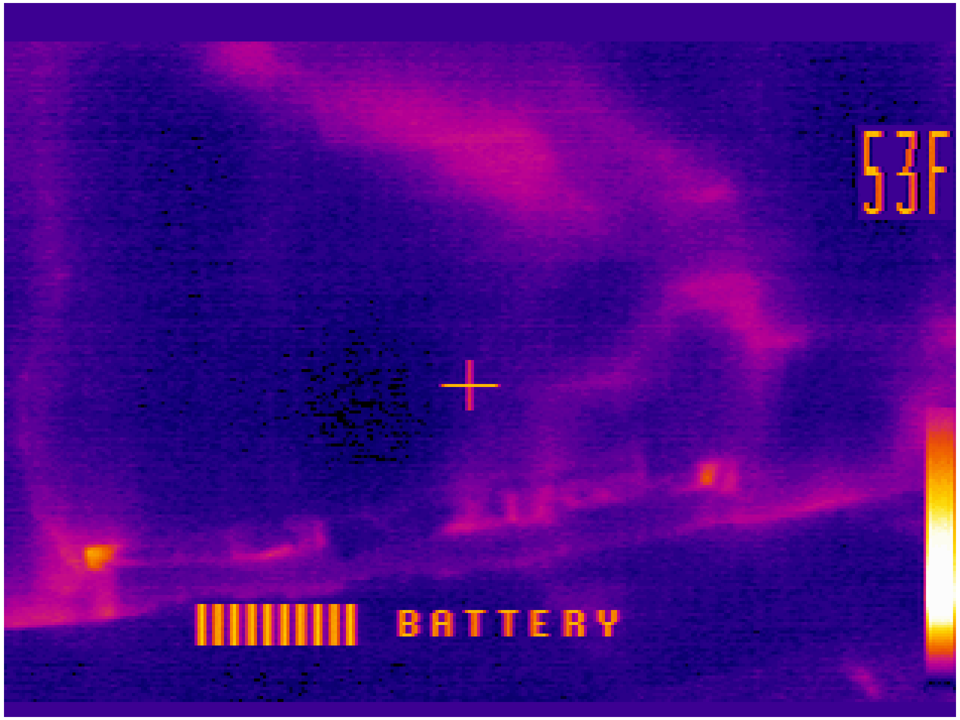
Same for all vertical walls, though targeting an R24.



Gut plaster, remove fiberglass, dense pack, and install rigid for a continuous and effective barrier to reduce heat loss and make all those pretty colors go away!

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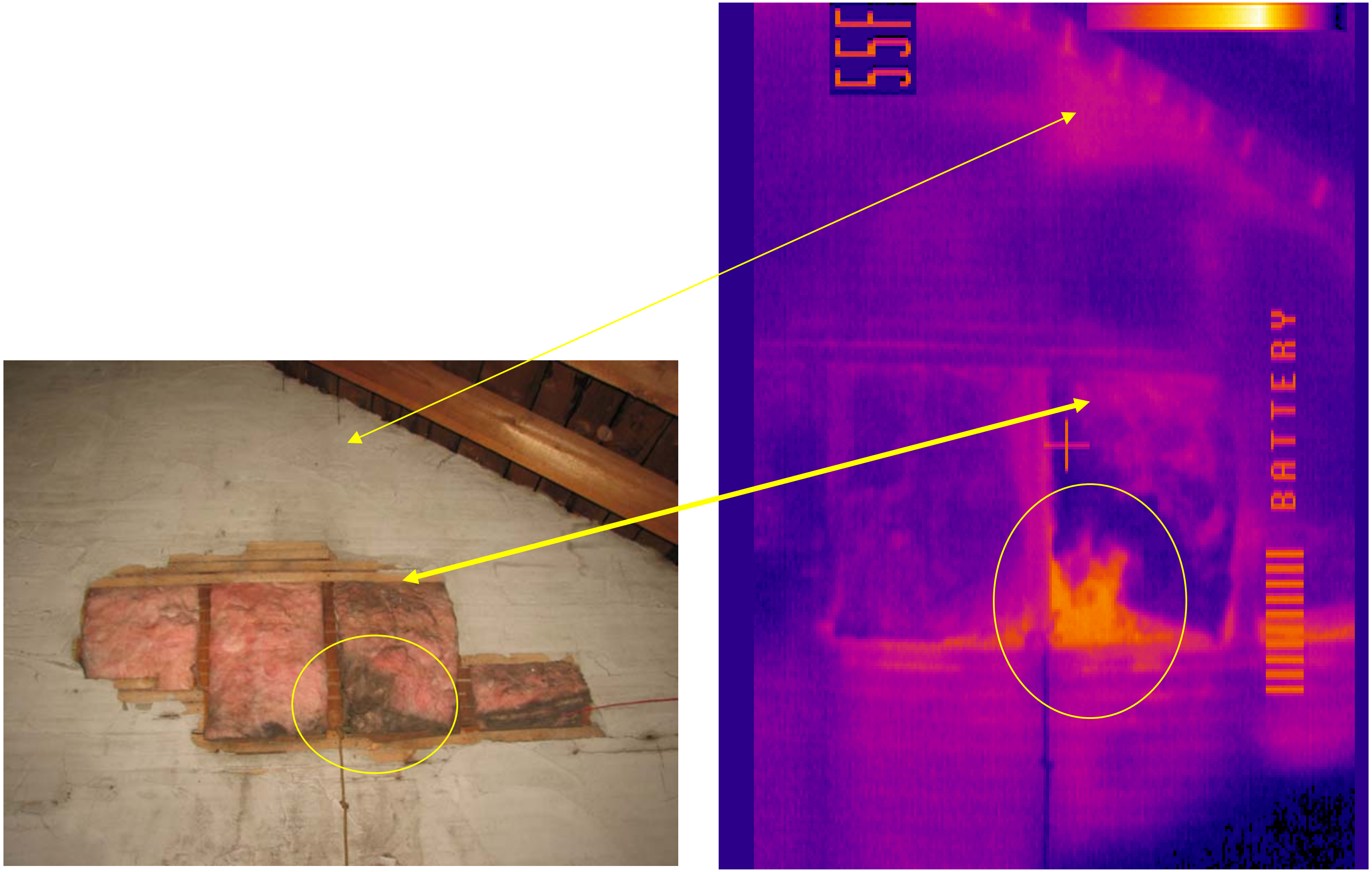
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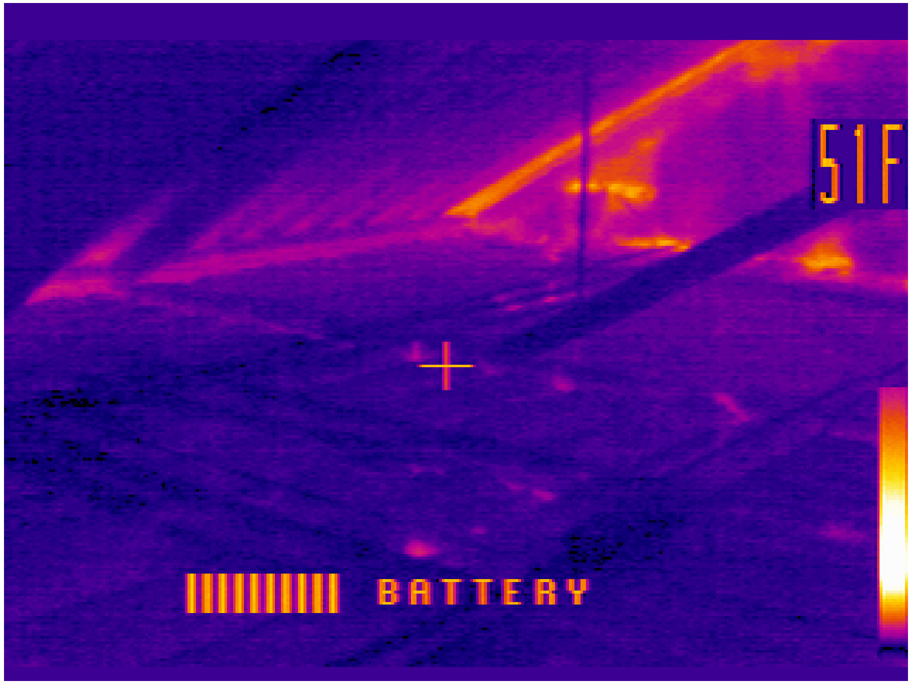
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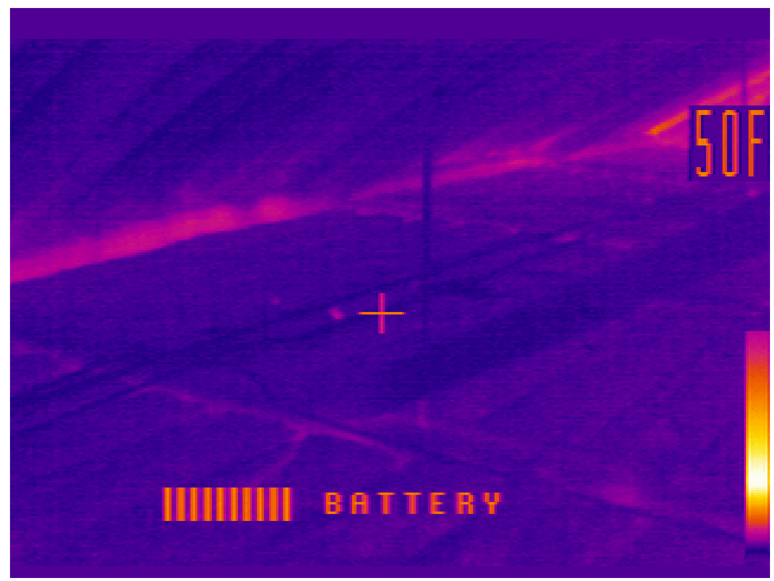
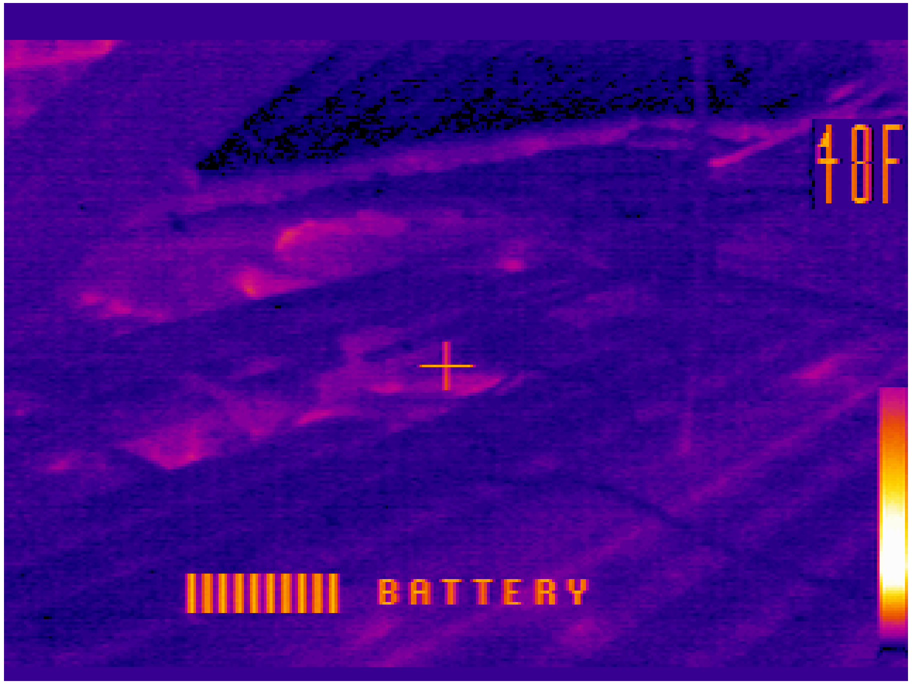
Ice dams form when roof sheathing is warmed from below. Heat loss above the top plate and warm air rising between framing members or other penetrations are often likely suspects.

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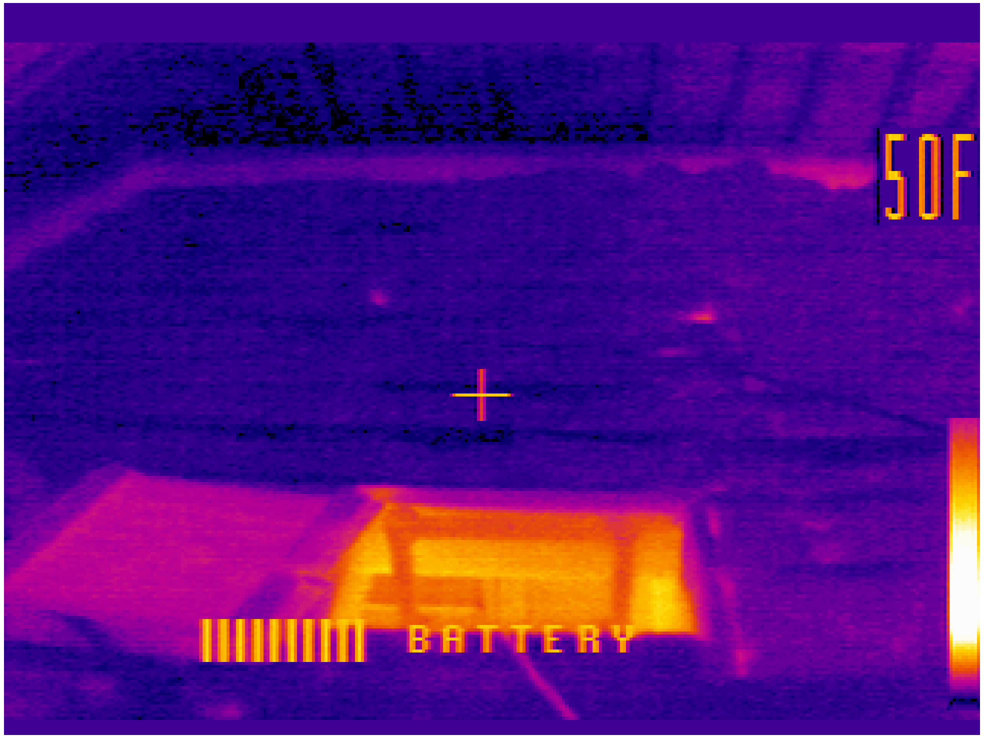
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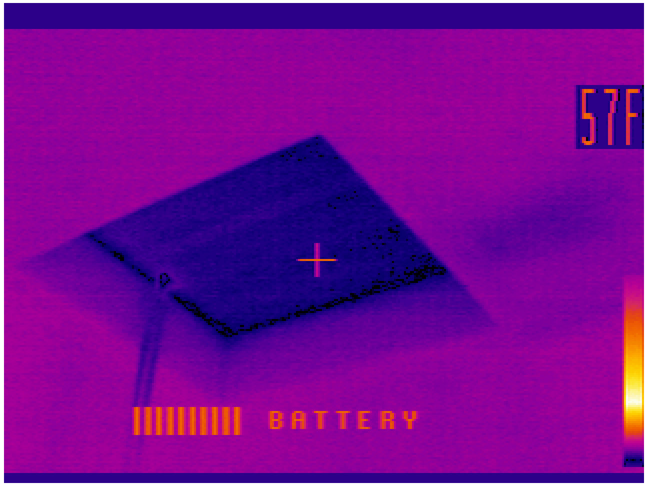
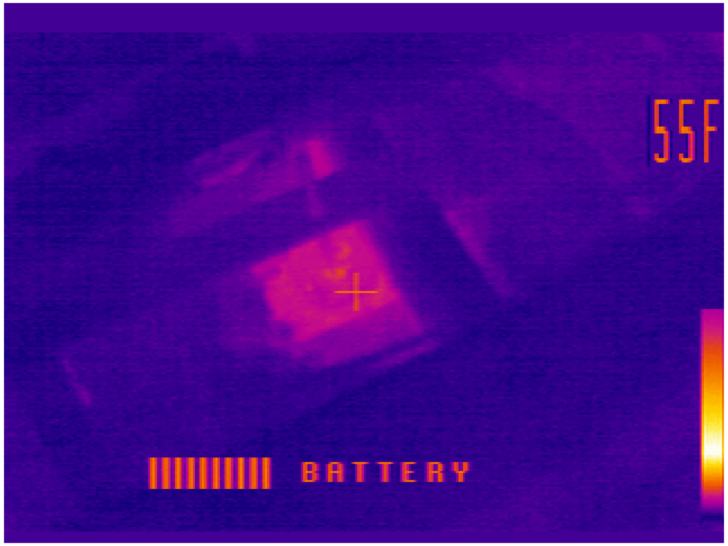


For attic work, this hatch will need to be converted to a folding attic stairwell, covered by a gasketed thermadome. I think installing near the back of the balcony section might be best and then sealing this access of completely.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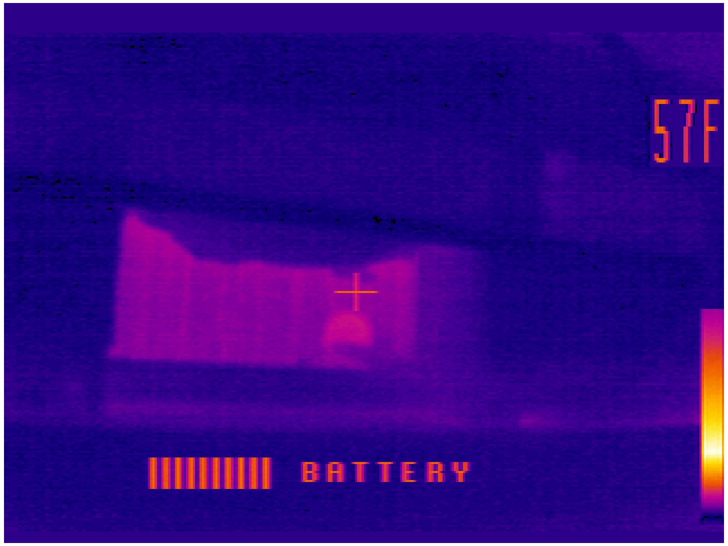
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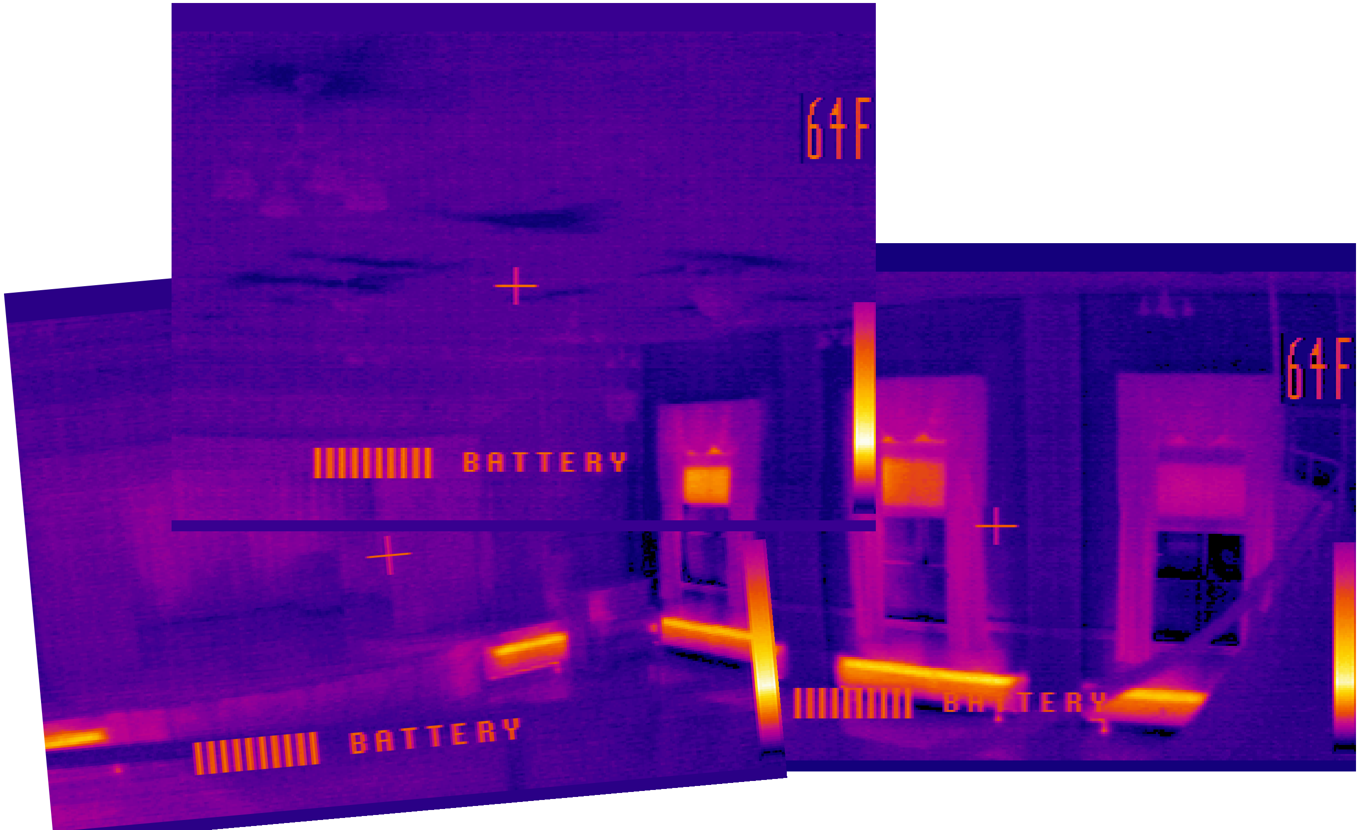
BATTERY

Since air sealing is so important, the only way to make meaningful improvements is to remove existing decking and all fiberglass batts and other insulating materials.
It appears that there is a tin ceiling below the lathe and plaster, and from the balcony, I was able to actually push up on the ceiling and make it move!
Therefore I think the best solution is to use spray foam against the lathe and plaster at least 4" of foam in the 8" cavities, and spraying over the joists to eliminate thermal bridging. All fixtures will have to be checked to make sure they can be encased in foam. If not, change fixtures or create a proper sealed box.
Wherever a walkway is desired, build a new 2x6 frame.
Then blow 8" cellulose over the entire foamed floor for an R52 and replace decking over the new framing.
The foam should protect the ceiling from the weight as well as an effective air and moisture barrier, and an R24. The moisture barrier is also important as it is unlikely that the basement will be effectively sealed and vapor will migrate up into the attic.

Adding cellulose is a more cost effective way to beef up the Rvalue to R52.

Please note that this is worth getting the contractor on site to devise the best approach and I will be available to discuss or review strategy if desired. I strongly recommend Building Energy Technologies for this and all air sealing and insulation work. The estimate for this work is based on 4" spray foam and cellulose for the floor area.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BATTERY
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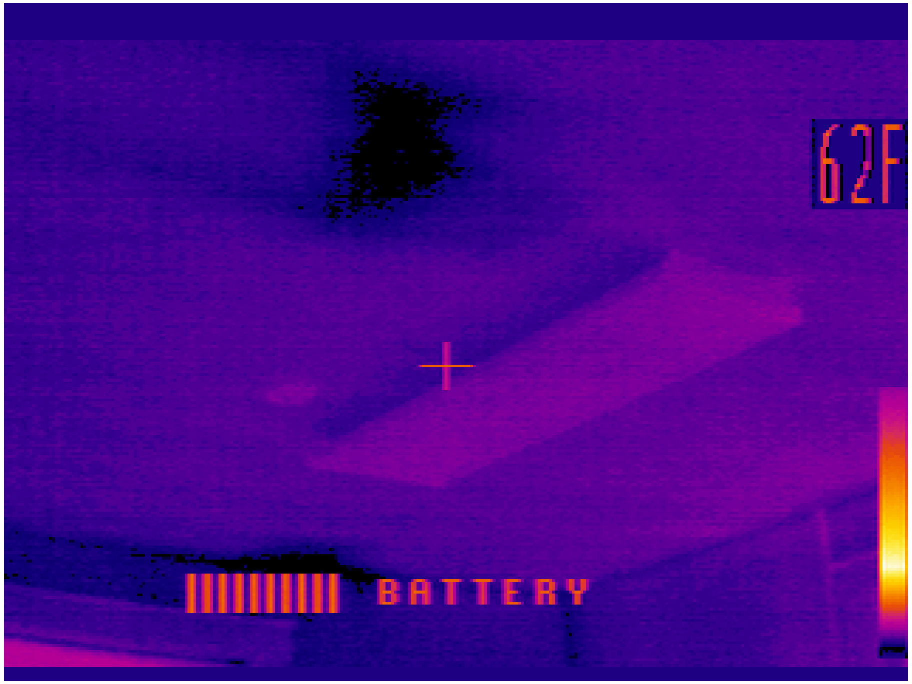
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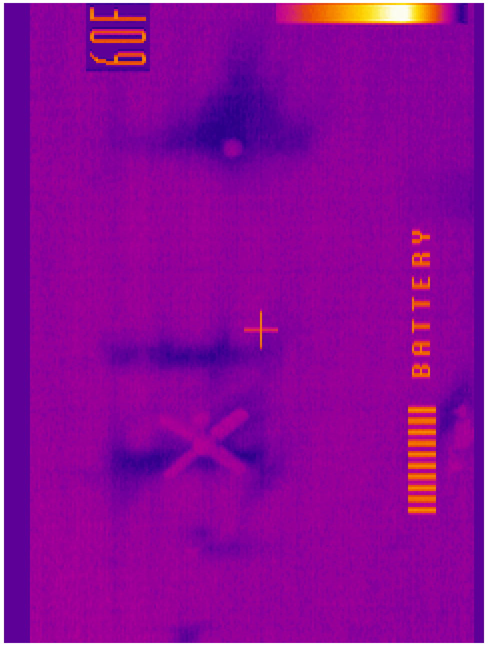
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BATTERY


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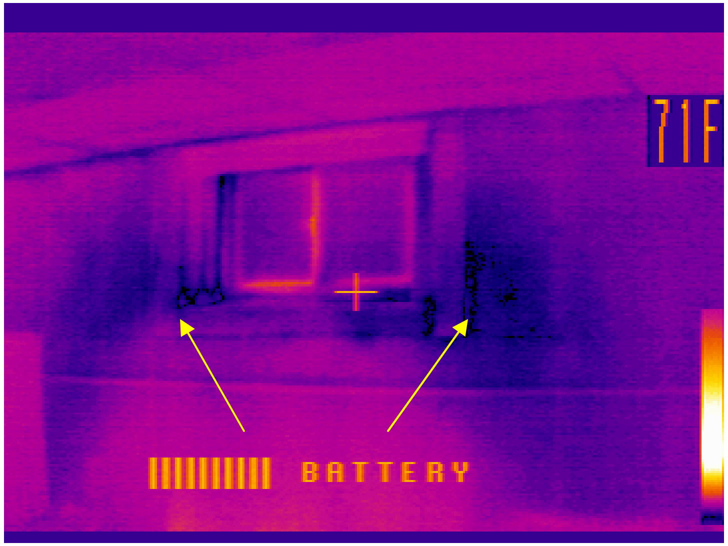
BATTERY

These exterior walls are a good candidate for a retrofit: gutting down to foundation surface, (including temporary relocation of baseboard) framing a 2x4 wall offset from foundation 2", and spraying 2-5" closed cell foam, tapered from top to bottom and then installing drywall. Windows can be air sealed at that time with extension jambs and finished trim. This will improve comfort as well as save some energy. Thermostat could be set further back with quicker heating time. Same treatment recommended for adjoining wall under entry way office exterior walls.

The very best approach would include insulating the slab floor and re-flooring but it is presumed this would be cost prohibitive. Shouldn't presume anything, so at least mentioning the idea here.

Stripping down to window openings and air sealing will have a significant impact in itself!

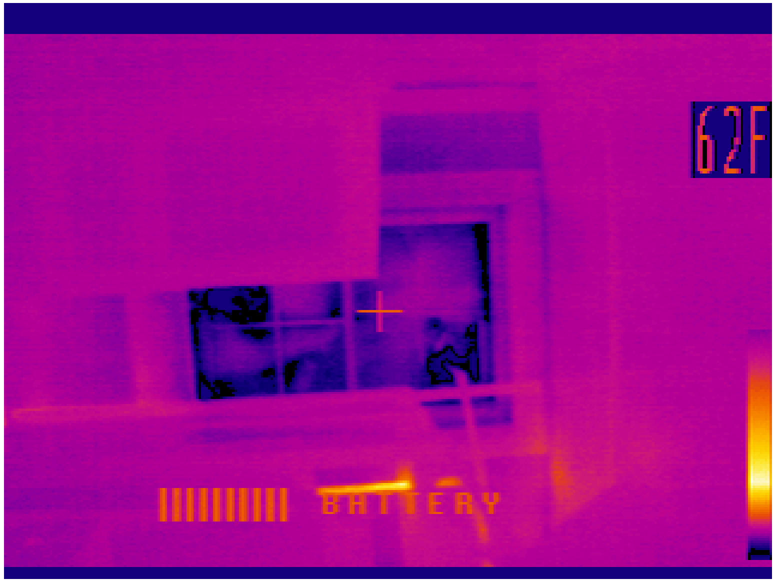
These walls appear framed already, though it is not known whether the wood is in contact with the foundation – which is not desirable as condensation is likely to occur. A small invasive test spot (cut a hole in the wall) will confirm whether re-framing would be necessary.



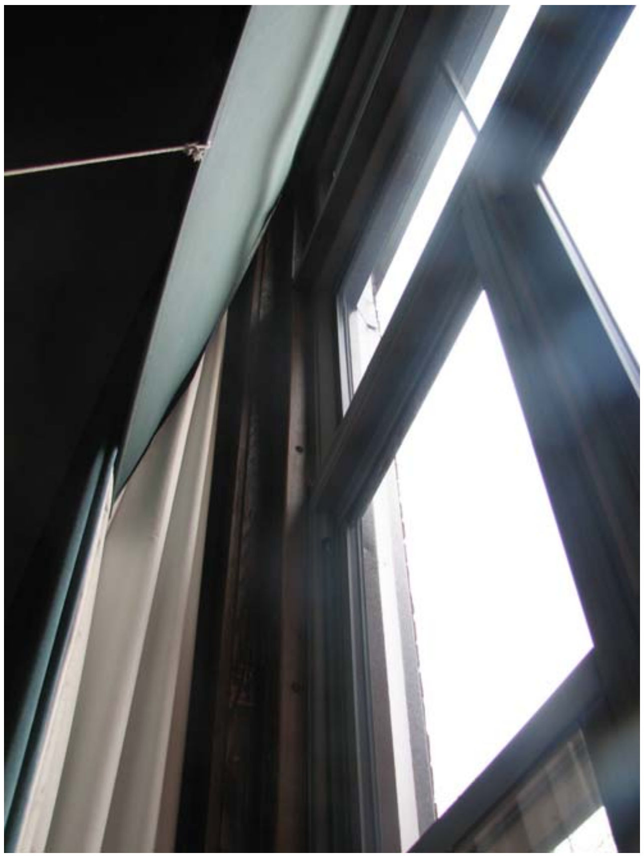


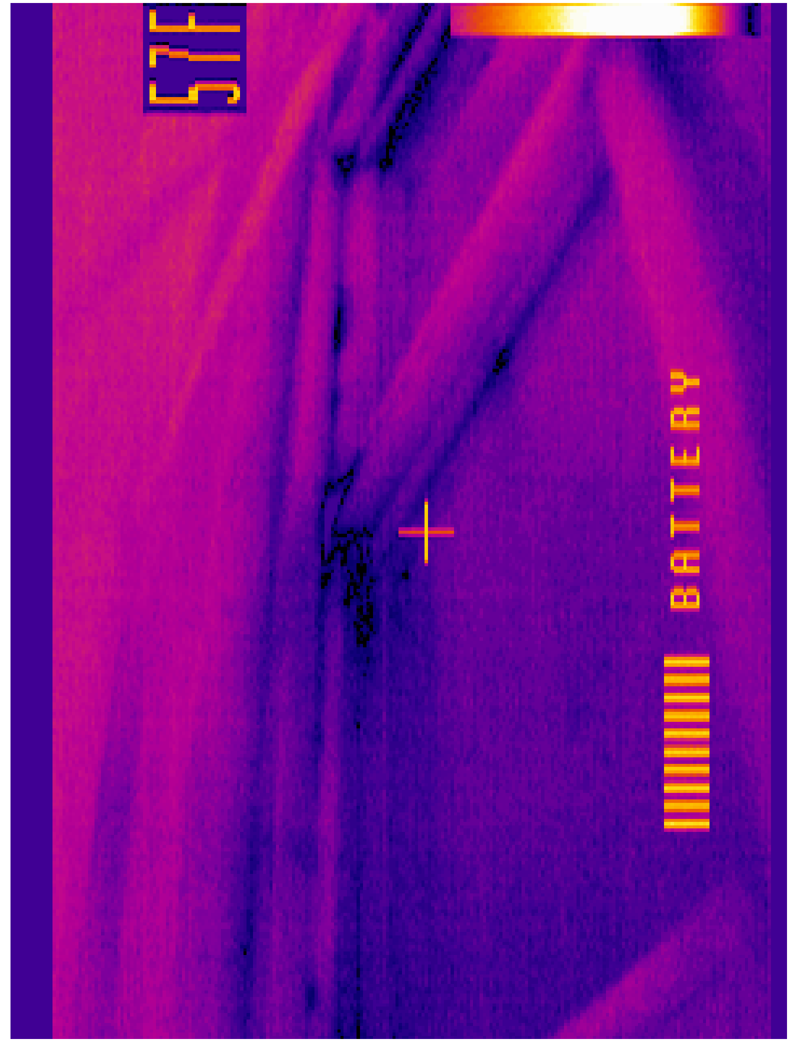
The above pattern suggests water leakage – probably in the past – and perhaps before exterior patching below the window. Gutting this area of wall to make sure all has effectively dried is advised for building durability and health benefits.

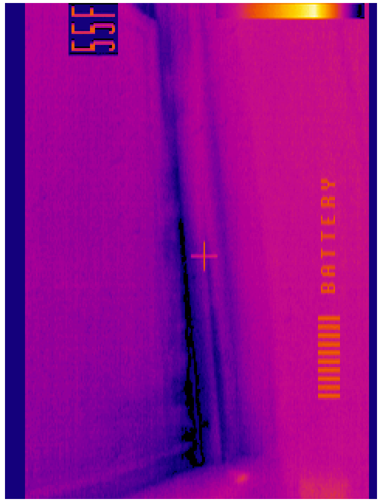
Woodwork may make retrofitting this stairwell area cost prohibitive, however air sealing the window opening and adding an interior, air tight, storm, is recommended.

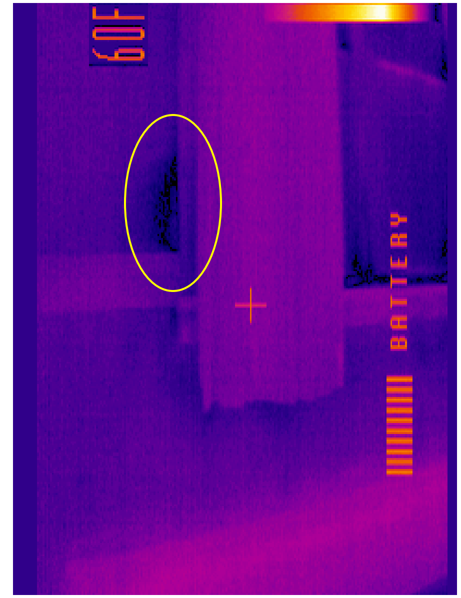


Windows can leak air wherever the sash or unit ends and the rough opening or trim begins. All of it can be sealed.

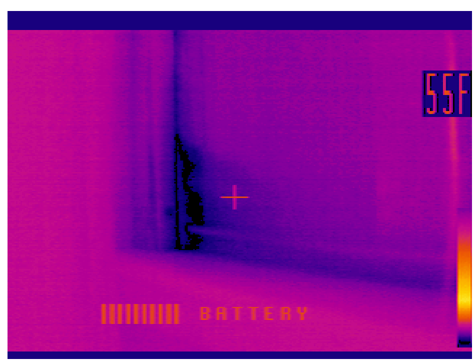




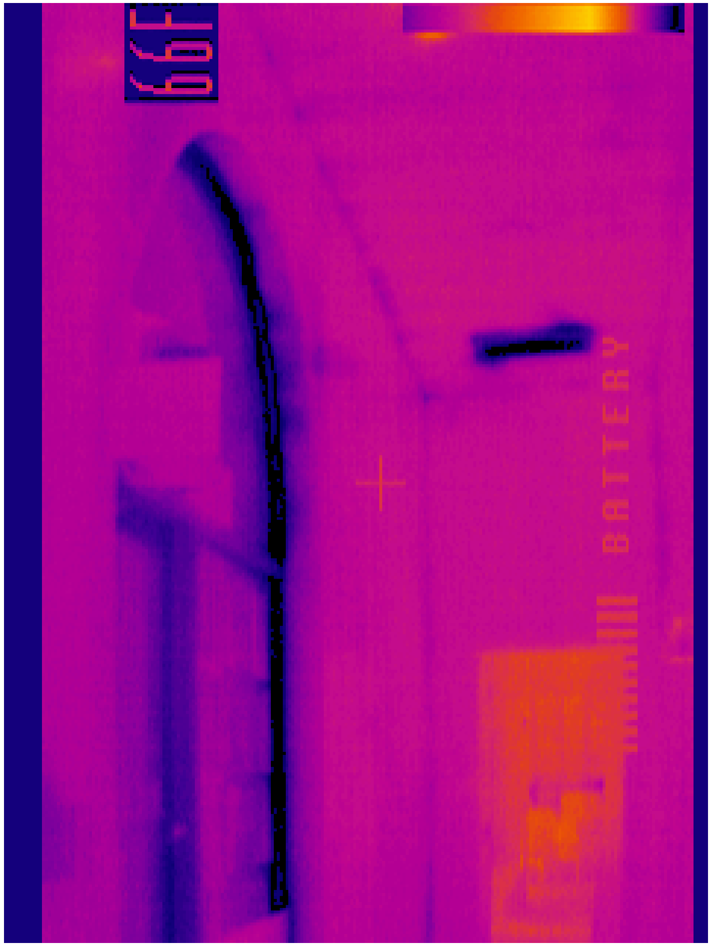




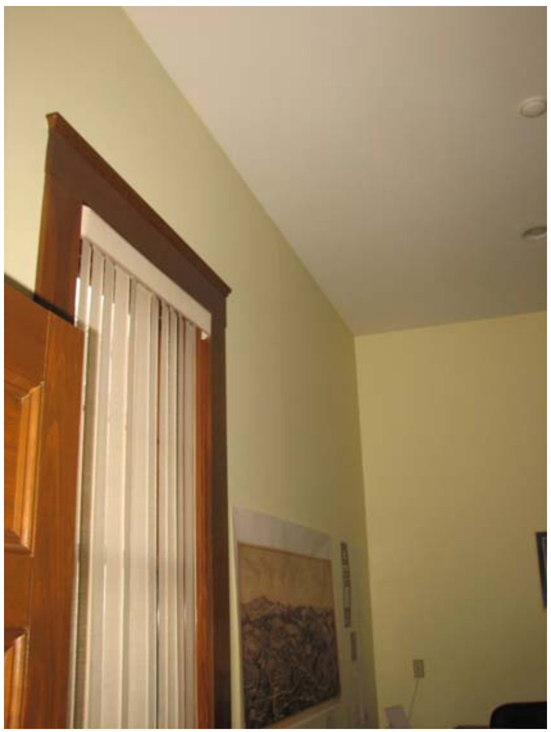
Removing trim and sealing from the rough opening inwards is recommended.

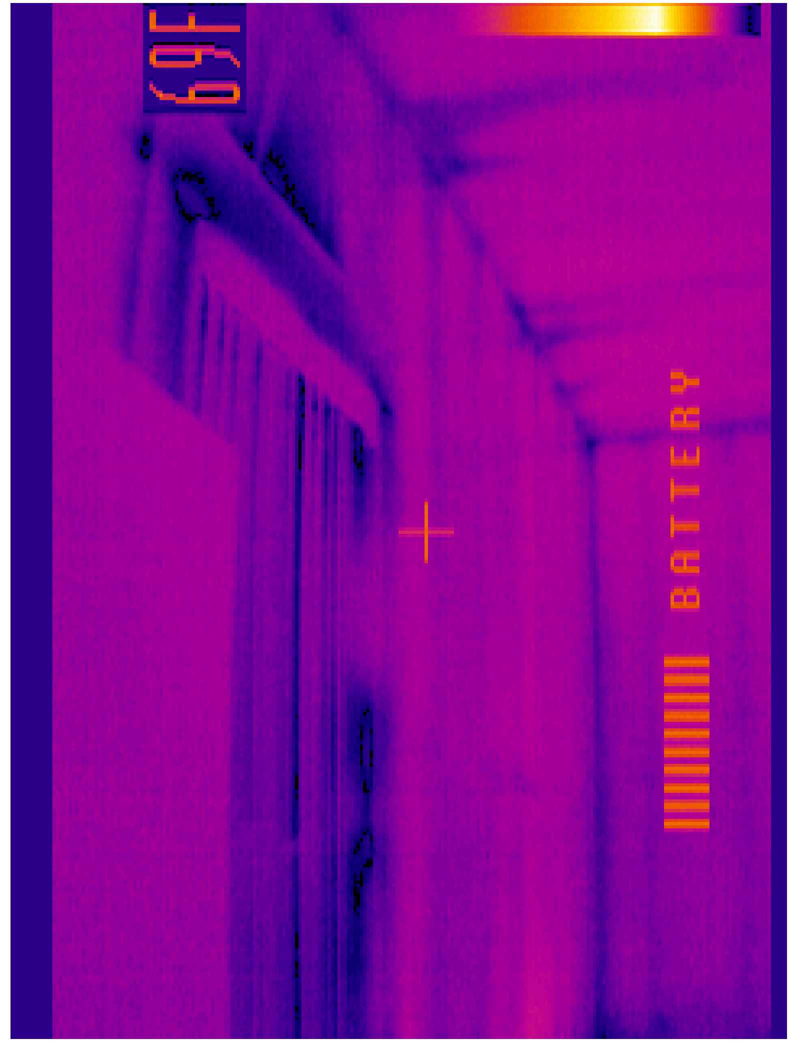


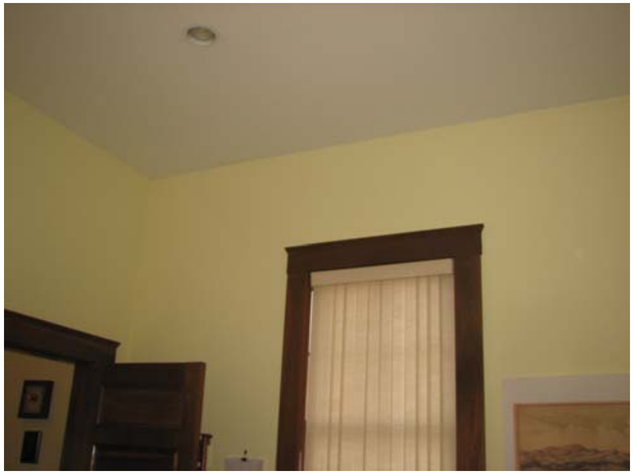
Not just the old openings – not at all!

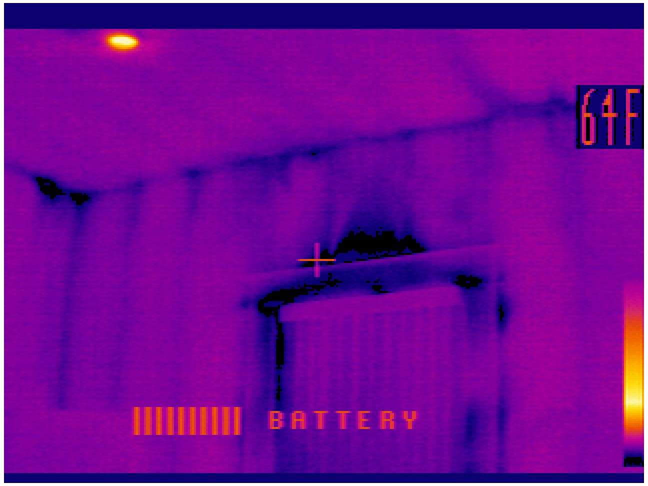


Window rough opening sealing is called for. Access to above top plates from attic above.





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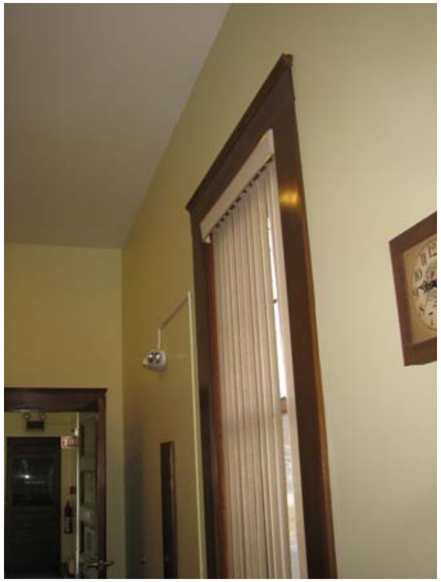

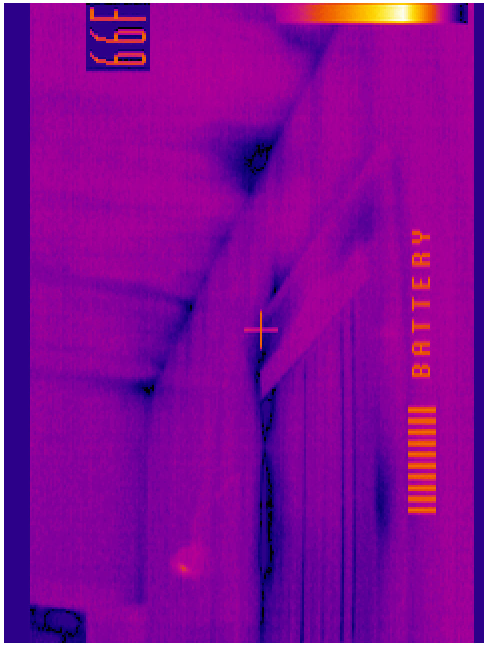
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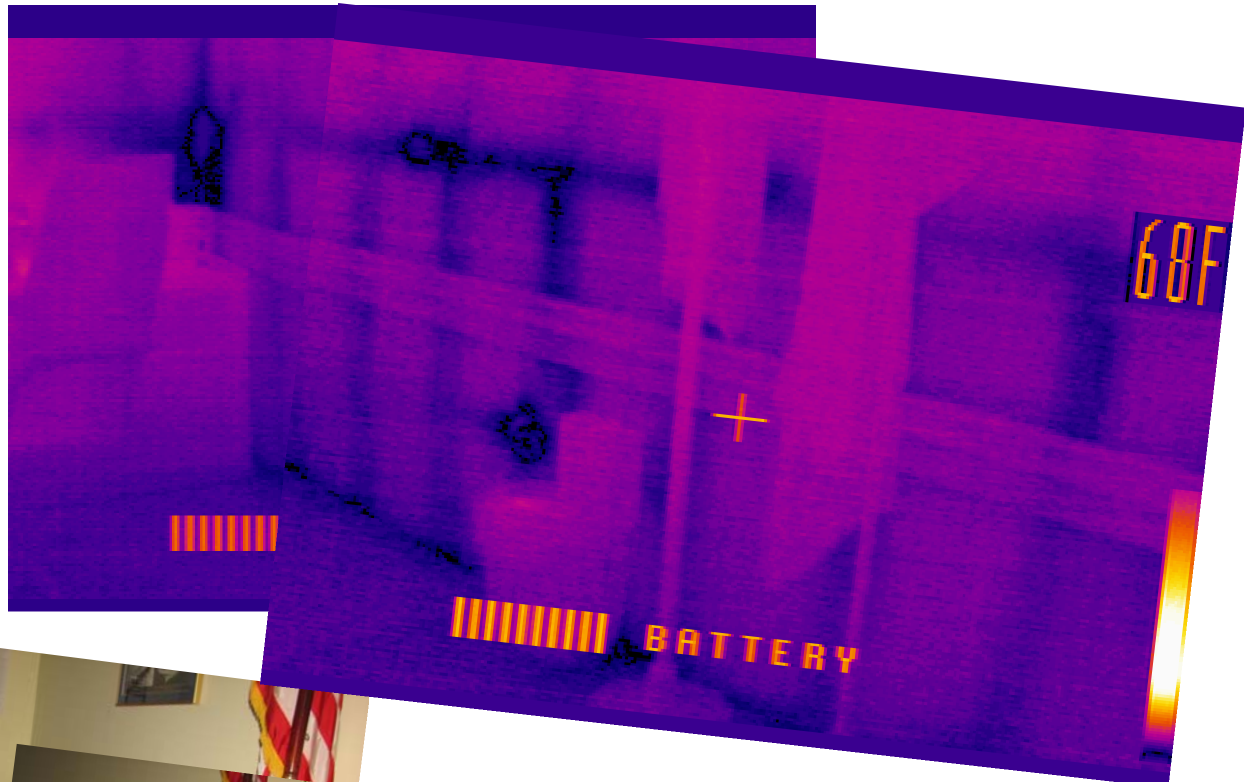
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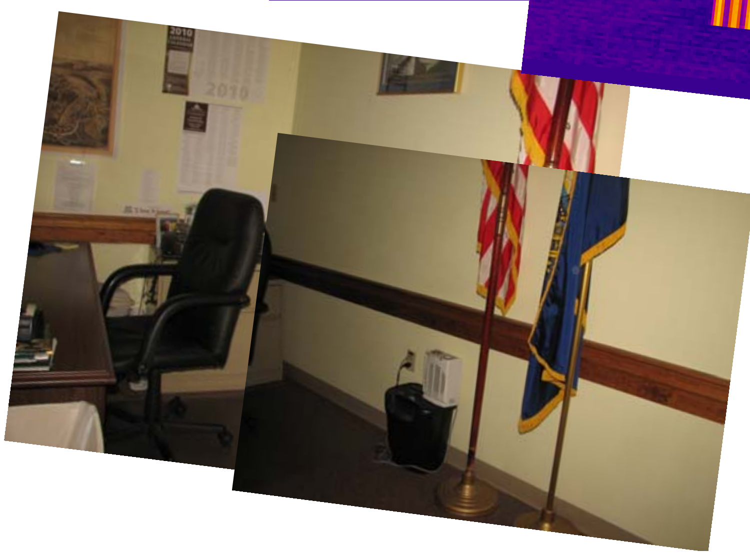
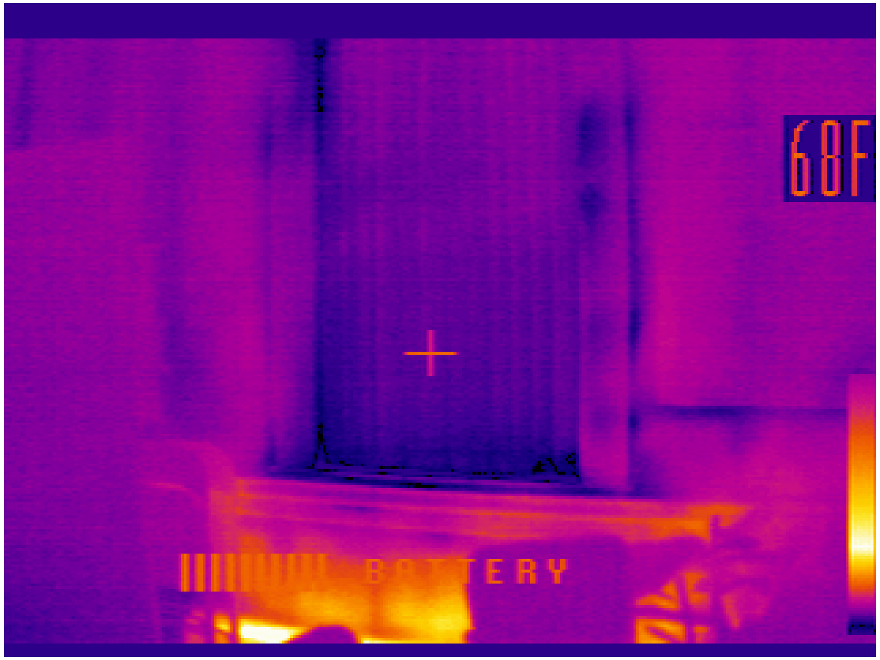


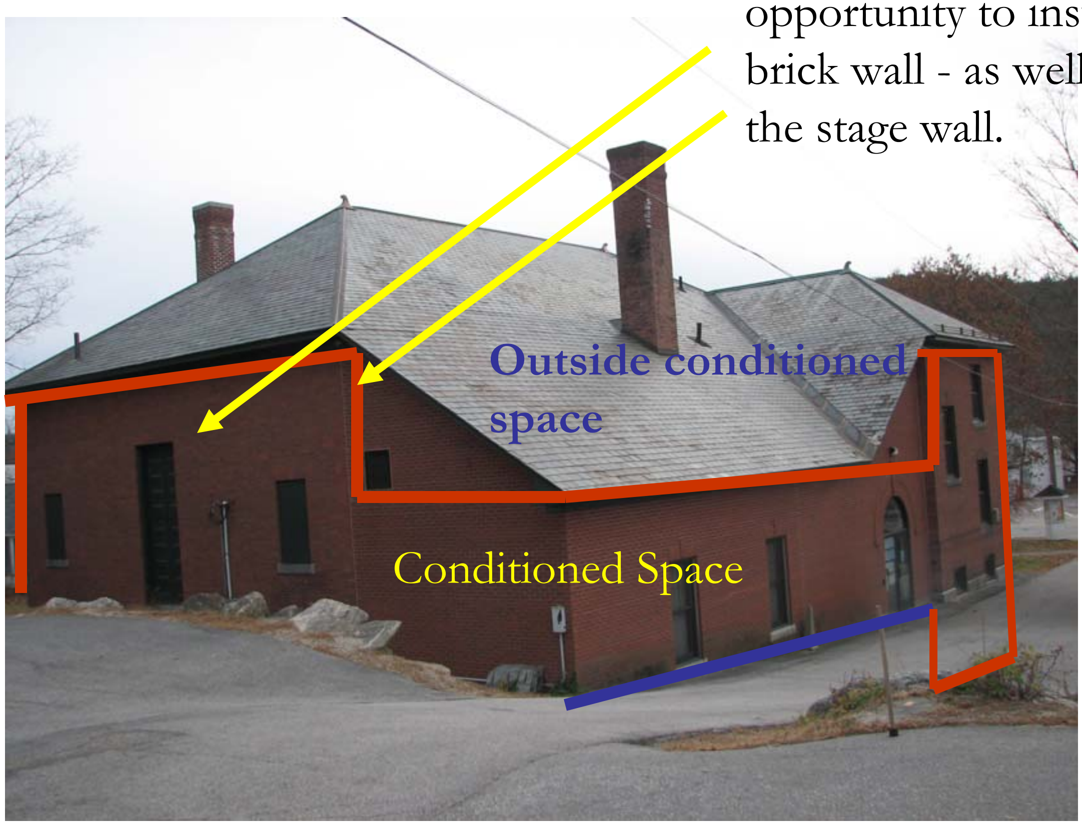

68F


Air seal/foam
this top of wall


Good
opportunity to
insulate this
wall!

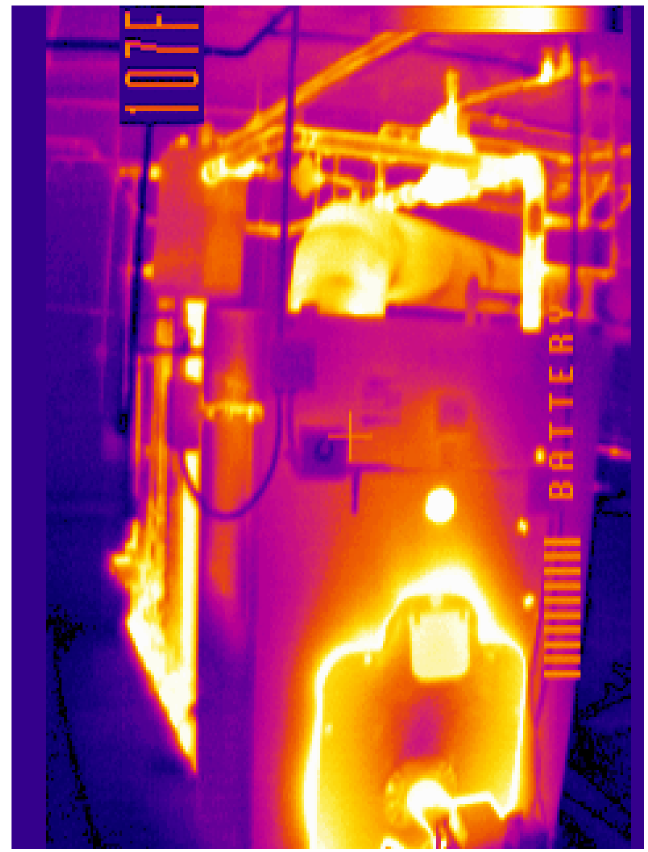

Air seal all ceiling
penetrations

As this attic is "outside conditioned space" there is an opportunity to insulate its back brick wall - as well as the back of the stage wall.

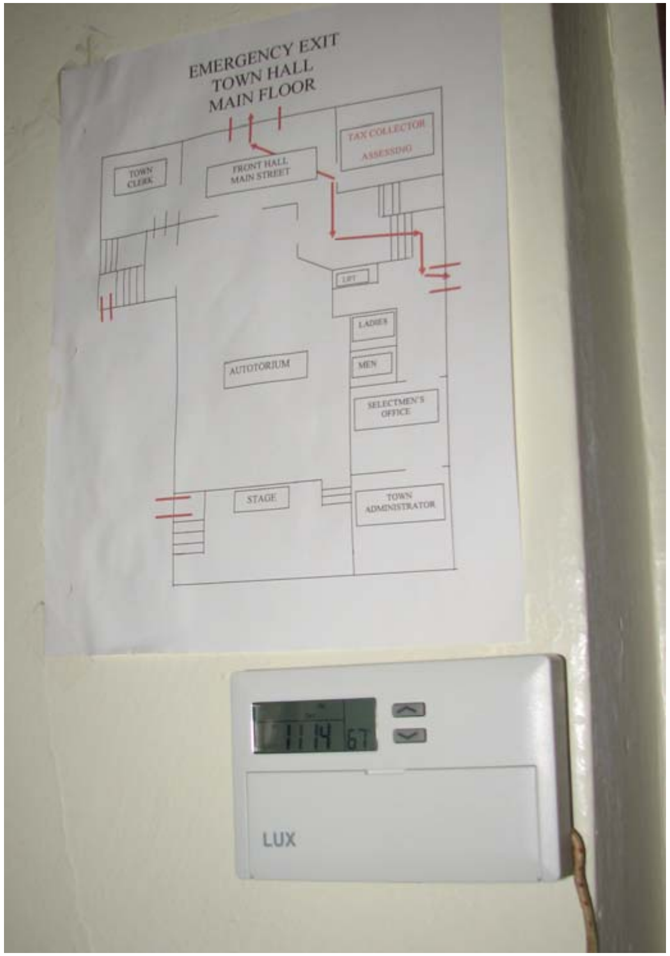


Equipment

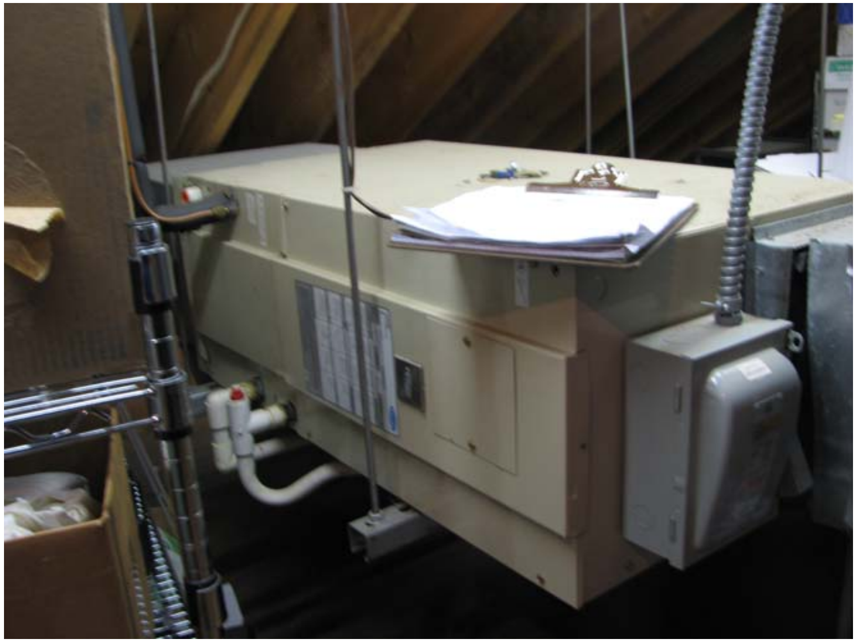
Boiler



Distribution



Office Cooling



Making Tap Water Hot

Presumed that hot water use is minimal….switching to a tank less water heater will definitely reduce energy use, especially in the summer. But hard to project savings since this tank isn't metered. In general – heating water to be stored hot – especially when not called upon very often - is not an efficient use of energy.

Heating System Upgrade

The discussions for this building are very similar to the Graded School building. In this case, however, the existing boiler is very old and inefficient, making it an obvious candidate for replacement. Here again, we would want to have a handle on the building maximum total heating load after envelope improvements are made (including both shell and ventilation). But, I would --consider all the same things as the Graded School:

•high-efficiency condensing boiler
•basic DDC controls
•variable-speed pumping and
•addition of mechanical ventilation via energy or heat recovery units.

In this case, the number of circulators in the boiler room indicate that the building is already broken up into a fair number of zones, so the addition of ACV's and variable speed pumping will not likely result in much energy savings.

– Scott Hening opinion on Town Hall Heating System