SPACER PAGE for numbering

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2009-2010 Town Building Energy Costs

Oil: $9,111 Elec: $6,005

DPW Office and Highway Garage:$15,116

Oil: $8,374
Elec: $8,964

Library: $17,338

Propane $5117
Elec: $5,873

Fire Station: $10,990

Propane: $1,864
Elec: $3,910

Transfer: $5,774

Propane: $3,306
Elec: $5,036

Town Offices: $8,342

Elec: $65,936

Oil: $2,142

Oil: $6,726

Total Wastewater Costs: $74,804

Propane: $3,898
Elec: $2,961

Water Supply: $6,859

Oil: $2,790
Elec: $7,040

Police Station: $9,830

Propane $3,179
Elec: $3,744

$1,070

Recreation: $7,993

Oil: $2,478
Elec: $261

Central Storage:$2,739

Propane $3,129
Elec $44,708

Total Water Costs: $57,435

2009-2010 Town Building Energy Use


Oil: 4,865 gallons Elec: 38,280 kWh

DPW Office and Highway Garage


Oil: 4,520gals
Elec: 53,440kWh

Library


Oil: 2,846 gals
Elec: 35,320 kWh

Fire Station


Propane: 851gals
Elec: 20,720kWh

Recycling/Transfer 00


Pro: 1838 gals
Elec:28,625 kWh

Town Offices


Elec: 482,400 kWh

Oil:979 gals

Oil: 3,486 gals

Wastewater


Prop: 2500 gals
Elec: 16,020 kWh

Water Supply


Oil: 1221 gals
Elec: 46,056 kWh

Police Station


Prop: 996 gals
Elec: 22,160

687 gals

Recreation


Oil:1127 gals
Elec: 261 kWh

Central Storage


700gals
172,919kWh

Prop:272 gals
60,840kWh

Prop:950gals
Elec:29,300

4,482
kWh

6,384
kWh

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 practices 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 approach to insulation and not making the details cumbersome for the many trades who the install the controls layers in a building envelope or enclosure which ultimately determine the amount of heating and cooling energy needed.

But as the costs of fossil fuel energy is expected to continue to rise in in a peak oil, changing climate world, energy efficiency and conservation is taking a new role in the design, construction, and management of buildings. Clean and renewable energy sources and technologies are essential, but reducing demand is a critical first step. A building's energy performance is becoming a more highly valued aspect of the design and construction industry, as indicated by the growing demand for high performance and 'green building.' This trend is also evident in the ongoing development of the International Building Code. The goal of a high performance building is succinct: To design, build, or retrofit our homes and buildings to require far less energy input to achieve comfort, durability, and indoor health. For most buildings in a cold climate, such as New Hampshire's, 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. The one possible exception is in the large commercial or manufacturing industry, where the activity inside the building can generate so much heat, the dominant energy load becomes the active removal of that heat, even in the winter.

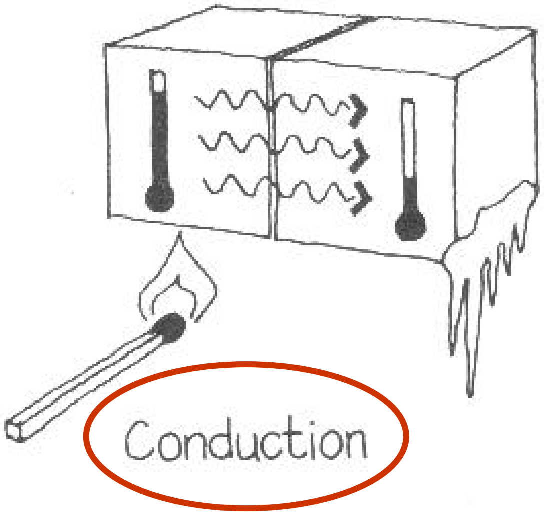
To understand the principles behind this shift towards high performance building envelopes, it is very helpful to review the fundamental of Thermodynamics, or Heat Transfer. Since we haven't been thinking about thermodynamics very much throughout the 100 or so years of cheap sources of energy – we have been operating out of a number 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)

The next few slides are an attempt to dispel some of these myths which ultimately impact the energy use in buildings. Starting with: *Heat* moves to cold; *warm air* rises. More than semantics, it has prevented us from seeing the value, up till now, of insulating foundations and slabs. "If heat rises, why bother insulating under a slab; it doesn't matter." If we considered that *warm air rises*, we would have perhaps been more diligent about creating an air barrier at ceiling and roof planes and prevented most, if not all of the ice dams which grace our New Hampshire landscape each winter. Adding air permeable insulation to reduce heat moving to cold doesn't fully address the problem. It is for these reasons and more, the following slides are offered.

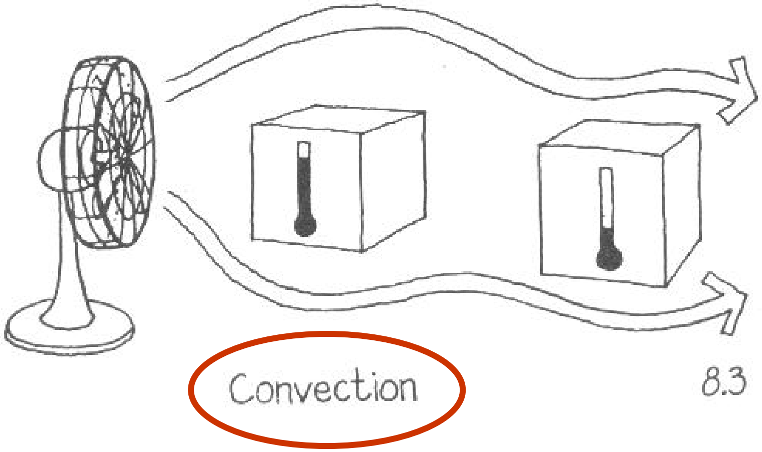
HEAT ALAWYS MOVES TO COLD

Via Three Basic Methods of Heat Transfer

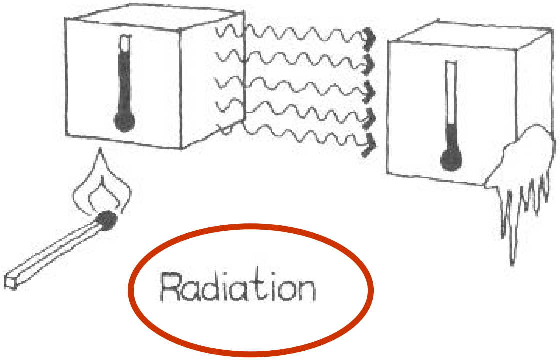


Direct contact thorough a solid material

All happen at once- with one dominating!



Thorough air or fluid



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 and especially metal conduct 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 in the ceilings depict framing thermal bridging and cavities without insulation. Corners are typically colder because of multiple studs which increase conductive losses.

via a fluid

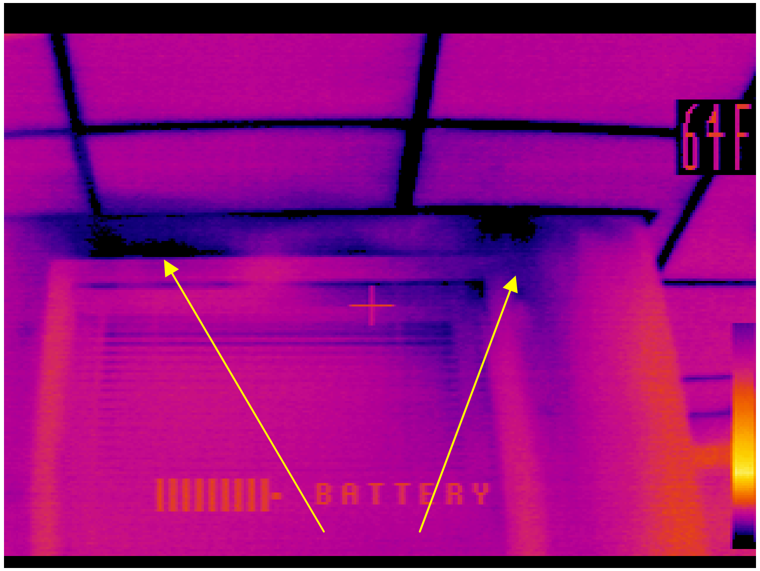
HEAT → **COLD**

CONVECTION

Physically moving the molecules from one place to another.

Convection moves heat via a fluid such as air or water. With, or without, 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 the top of this wall and from the rough window opening 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"

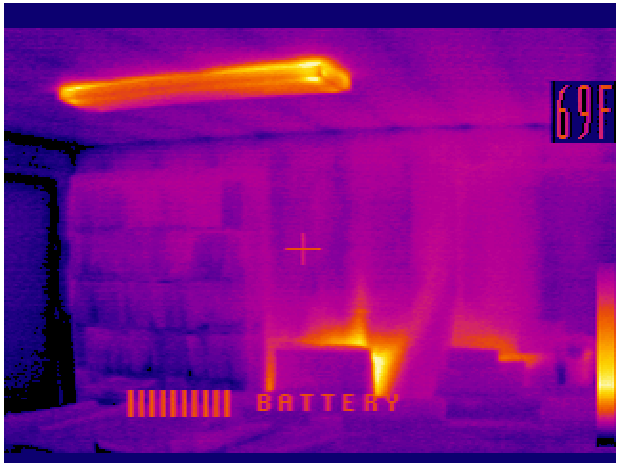
visual contact

HEAT → **COLD**

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.



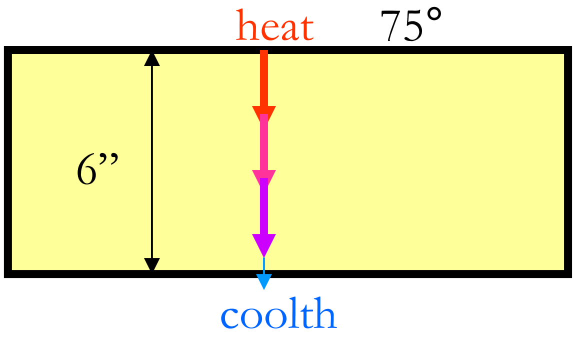
Radiation is also a dominate way of distributing heat into a building such as thorough the above ‘radiators’ ie the hydronic baseboard, lights, as well as computers, and other appliances – and people!

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 cold outside through the clear (and highly conductive 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!

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. 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 why R19 stamp gets on 6” fiberglass rolls.



heat 75°

6”

coolth

Rate of transfer calculation = R19

The reality is that when not installed with those parameters, and in windy or extreme temperatures, “R-Value” performance is dramatically reduced. The EPA estimates that reduction can be up to 50% or more. Combine that fact with the impact of thermal bridging in studs, an “R19 wall” can be found to perform as a “R16” or “R12” or sometimes even lower. This matters a great deal when we are concerned with the rising costs of energy.

The fact is that fiberglass is rarely (never) 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.

Happy Basements (and slabs) are Warm and Dry

Steps to a Happy Basement:

- Put 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. Best to insulate the foundation.
- 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. The earth may be 45-50 degrees. But unless that's the temperature you want to achieve, you're losing heat to the earth.

Air Infiltration Discussion

Efforts to air seal a building during construction are minimal, partly due to the belief that a building 'has to breathe' so it is better not to make it too tight. And also because such attention to detail in the envelope takes time and, as mentioned before, has not been valued throughout the era of cheap oil. With the rising costs of energy, it is likely we will start placing far more value in the details of envelope construction and retrofits. The breathing issue is also important to address.

Buildings don't breathe, however, it is VERY important that they be kept dry. Keep water out, but if it does get in, allow it to get, or dry, out. The reason we have such wonderful old buildings in New England (and elsewhere) is precisely because they are so drafty! Any water that got in would be allowed to dry out in what are often stiff winds that blow thorough them. During our first exposure to the energy crises in the 70's, we responded by adding insulation and closing all those gaps – which resulted in many instances of mold and rot and eventually "sick building syndrome." Building scientists now see that those efforts at energy conservation did not, in part, deal with moisture, uncontrolled air infiltration or mechanical ventilation adequately. In fact, Building Science has emerged as a field to a large degree in order to address managing water in light of our need to conserve energy.

In conclusion: In addition to good drainage at the perimeter of a building, a continuous and effective air barrier is a critical strategy to manage air, moisture and heat transfer - which then requires mechanical ventilation with heat recovery to maintain good air quality because people, plants and animals DO need to breathe and increasingly, with minimal fossil fuel energy input.

Blower door testing helps quantify the tightness of a building's envelope or enclosure. It can also help locate sources of air leakage and other pressure diagnostics.

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)

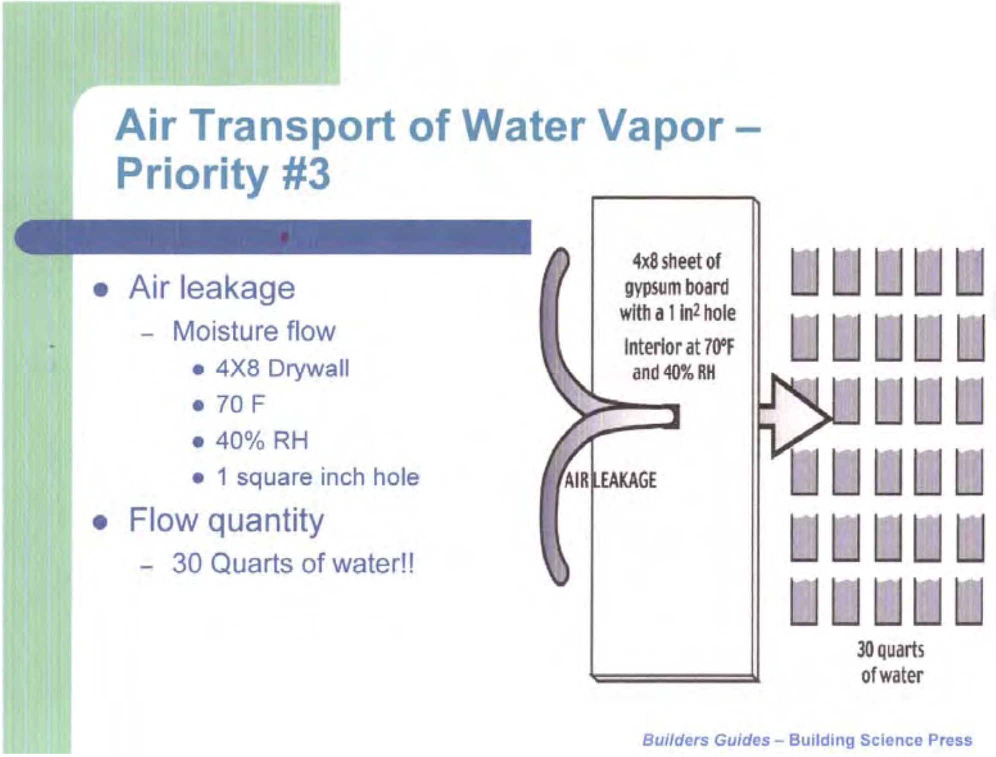
Total size of hole if add all cracks and gaps together

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.

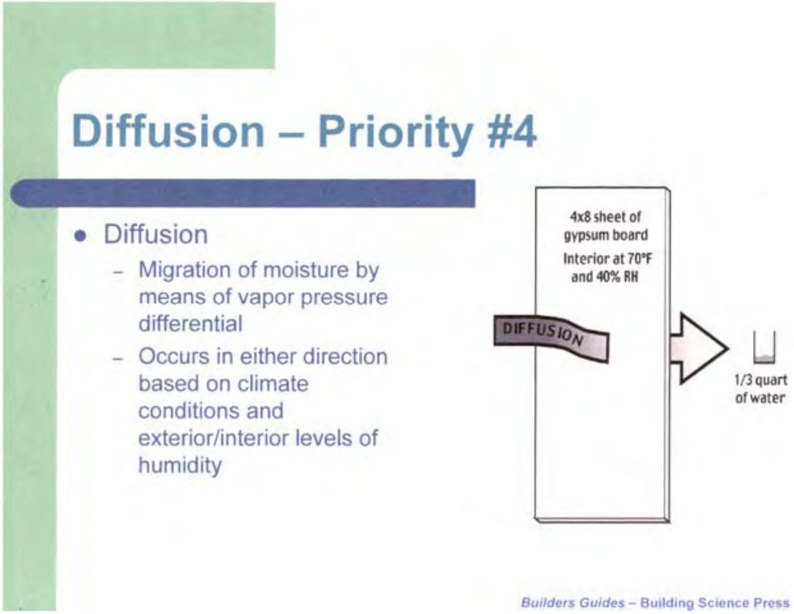
A little perspective…



Air Transport of Water Vapor – Priority #3

- Air leakage
  - Moisture flow
    - 4X8 Drywall
    - 70 F
    - 40% RH
    - 1 square inch hole
- Flow quantity
  - 30 Quarts of water!!

Builders Guides – Building Science Press



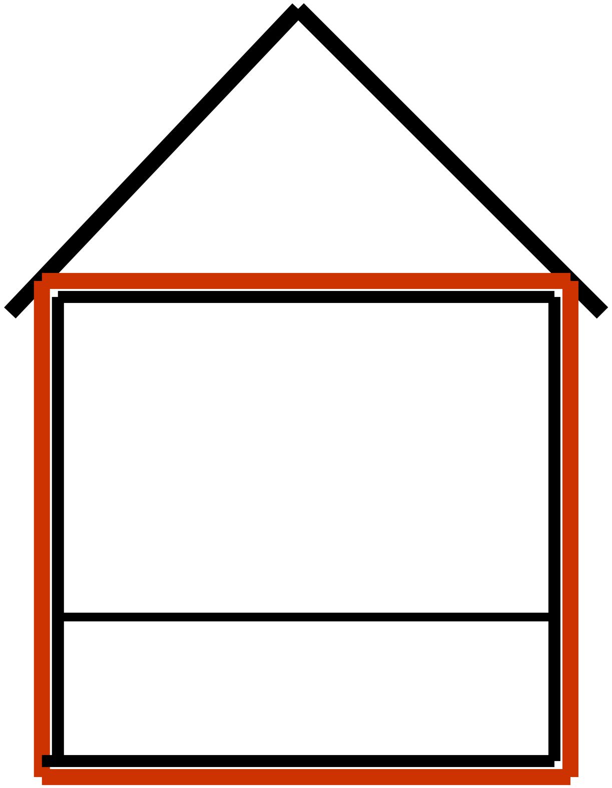
Diffusion – Priority #4

- Diffusion
  - Migration of moisture by means of vapor pressure differential
  - Occurs in either direction based on climate conditions and exterior/interior levels of humidity

Builders Guides – Building Science Press

The above charts from Building Science Press show that FAR more water vapor can enter a wall assembly via air infiltration than diffuse thorough a solid air barrier. This is included to help illustrate the **triple importance of an effective air barrier – for moisture management; comfort; and energy conservation!**

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 is at slowing heat loss, the less heat (energy) 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 .

Heating Systems

Many of the heating systems in Jaffrey's Town buildings are hot water boilers which distribute heat by pumping hot water thorough (hydronic) baseboards or radiators in each room. There are also 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. Hybrid systems heat water with a boiler, then an air handler pushes air past a then a hot water coil to force hot air through 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, Jaffrey 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 80-87% 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 91,333 Btu'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 78% 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.
- **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 Jaffrey'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 specially designed 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.

Center Storage

163 Mountain Road (RT 124)

Rectangular, 2160 ft2 (30 x 72) uninsulated concrete block, brick façade on north side with two overhead doors, and "cold" roof.

Garage bay under a gable roof and 12' back storage under a shed roof in the back.

Built before 1960 as a fire station; currently used for storage of vehicles and other apparatus and equipment.

This is the north facing side of the building.

ANNUAL ENERGY USE SUMMARY

Heating Fuel
1,072 gallons oil
(two year average)

Meter# G43108834

Electricity
760 Kwh

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: 1072 gallons x 140,000 Btu's/gallon = 150,080,000 Btu's or **150 MMBtus**

Electricity : **760kWh** x 3412 Btu/kwh = 2,593,120**Btus or 2.6MM Btu's for site energy**
760kWh x 11,396 Btu/kWh = 8,660,960 includes generation source energy

Total Site Energy in Btu's = 152.6 MMBtu's / 2160FT2 = 70.6KBtu/ft2
Total Site Energy in Btu's = 158.6 MMBtu's /2160 FT2 = 73.4KBtu/ft2

Blower Door Test & Results

Measuring Air Infiltration and the Air or Pressure Barrier

Convective and Conductive Heat Losses and Moisture Transfer

Whole Building: 4230CFM50

Means that **4230 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: 10.22 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 **over 10 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.

Estimated Annual Air Change Rate: .68ACH Winter: . 87ACH Summer: .48ACH
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 80 minutes or so.

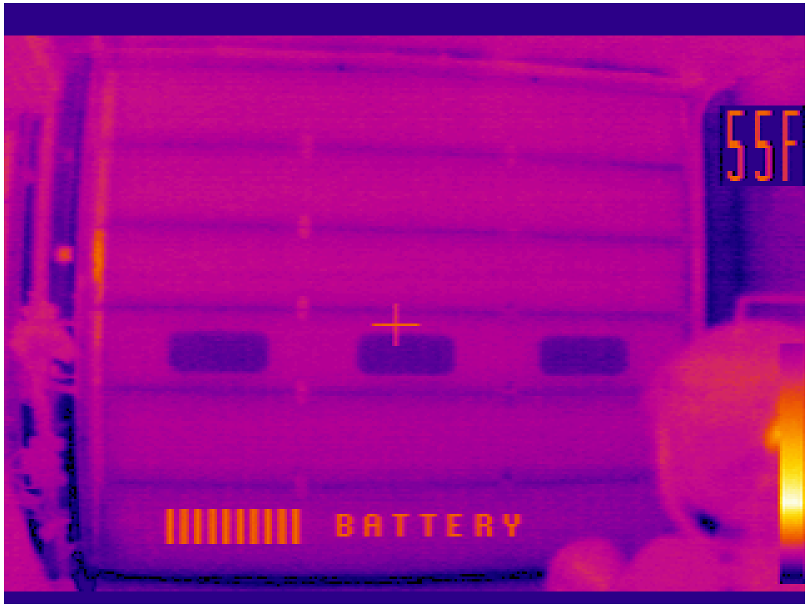
Estimated cost of envelope air leakage: $745 at $3.00 gallon or approx 25% of heating bill

Leakage Area (Canadian EqLA @10pa) 497 in2 or 3.45 sq feet
Total size of hole if add all cracks and gaps together

Minneapolis Leakage Ratio: .95 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.

Champion Overhead Doors from Dummerston, Vt. are in good condition. According to the Turner Report, doors were installed around 2006.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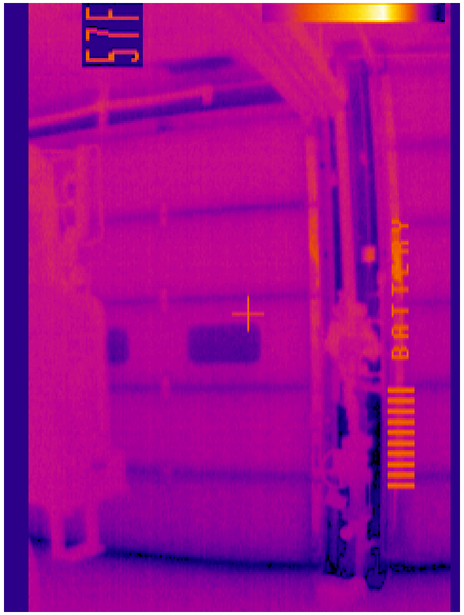
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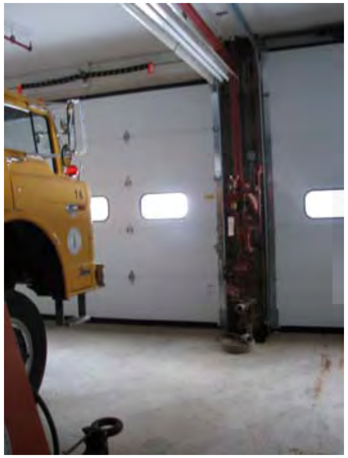

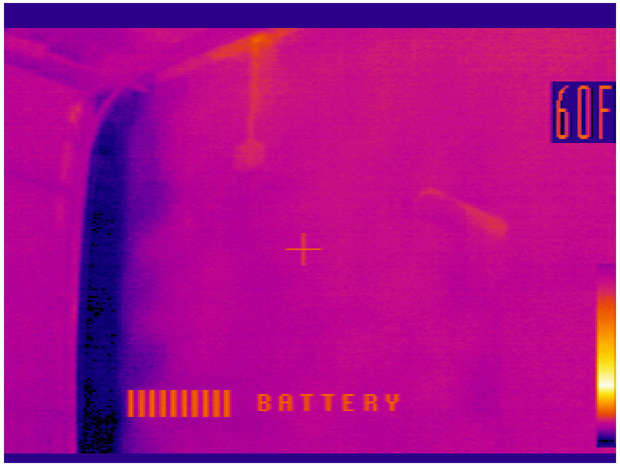

Doors are in good condition but still allow air leakage along the tracks.


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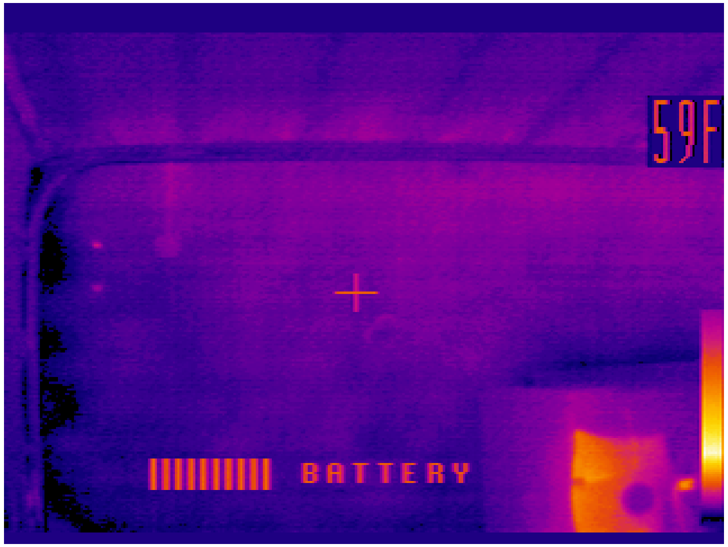
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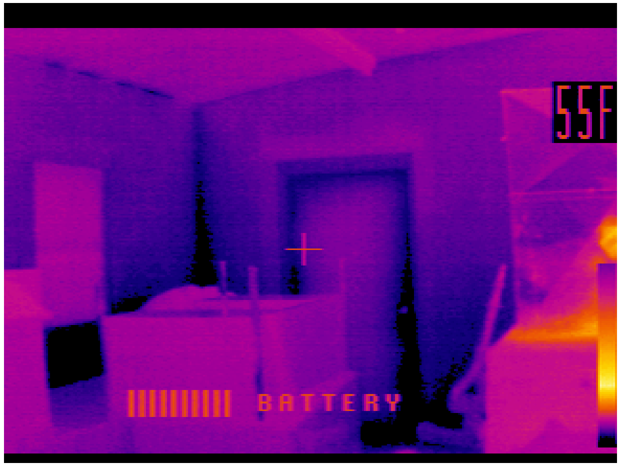
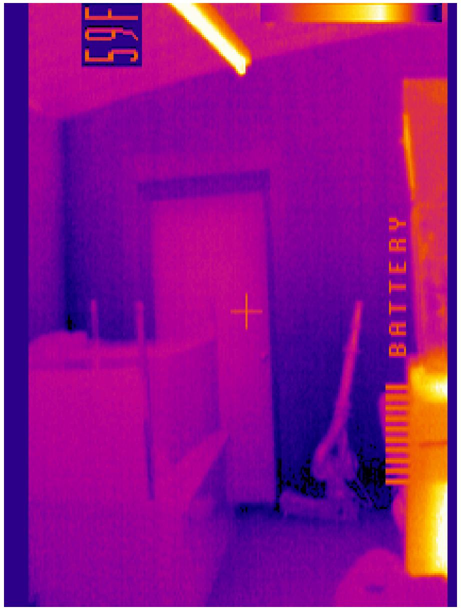
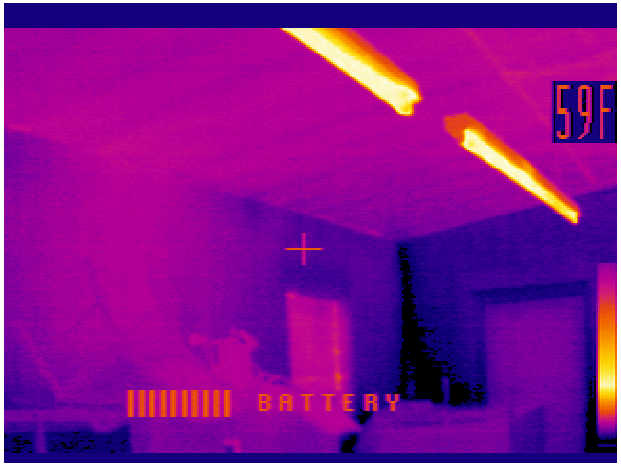
BATTERY

Ceiling insulation levels are unknown due to not being able to access the attic hatch. Clear thermal bridging indicates insulation is in cavities only and the Turner Report states “a limited amount of insulation in the attic space.”





Walls are entirely uninsulated.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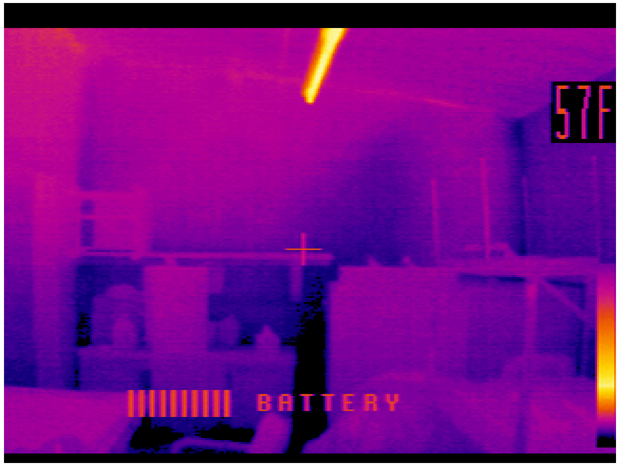
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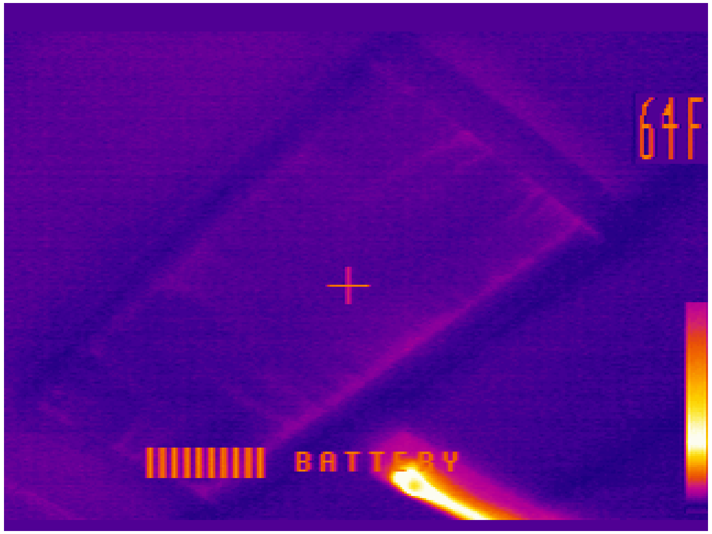
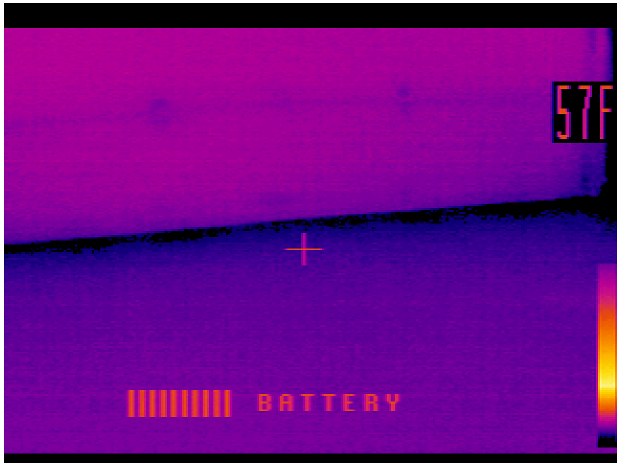


Attic has been heated by the sun and now warmer than the bays. Bright colored hatch edges indicate warm air infiltration around an unsealed hatch.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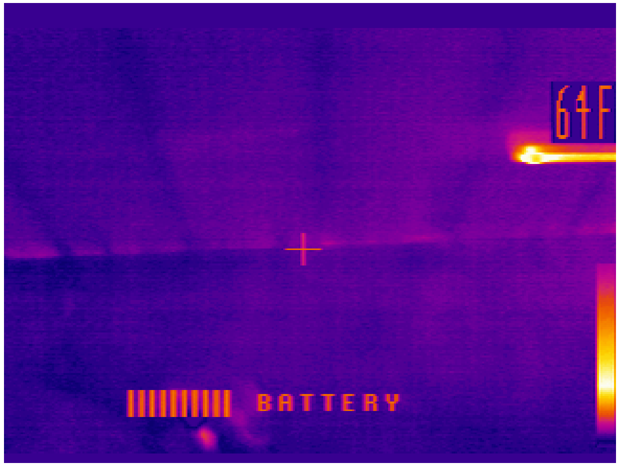
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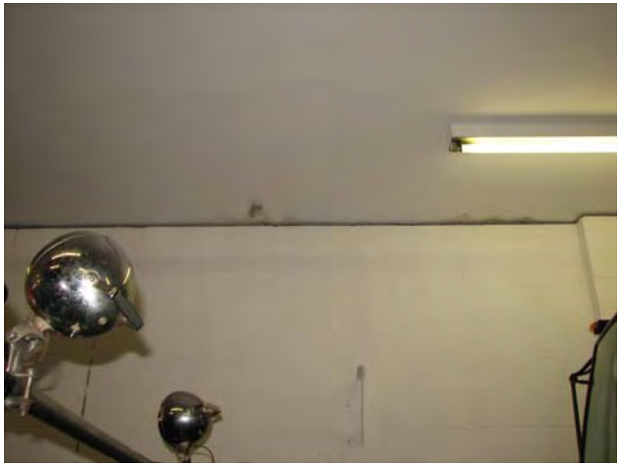


Indications of air transported moisture at transition of roof and wall.

Equipment

Thermopride Model
OL 16 125 RB
Input 156,250Btu/hr
1.25GPH   115V

Set to 60º year round

Department of Public Works

A 40’ x 100’ concrete block building built in 1964, with a 22’x28’ frame addition in the back. The bay doors face southeast, potentially offering an excellent location for a roof mounted PV array.

Energy costs totaled $15,911 and 155.6But/sf

Administration Office and Eight Bay Garage

ANNUAL ENERGY USE SUMMARY

Meter #S40459919

Heating Fuel
4513 Gallons
5329 4 yr average

Electricity
38,280KWH

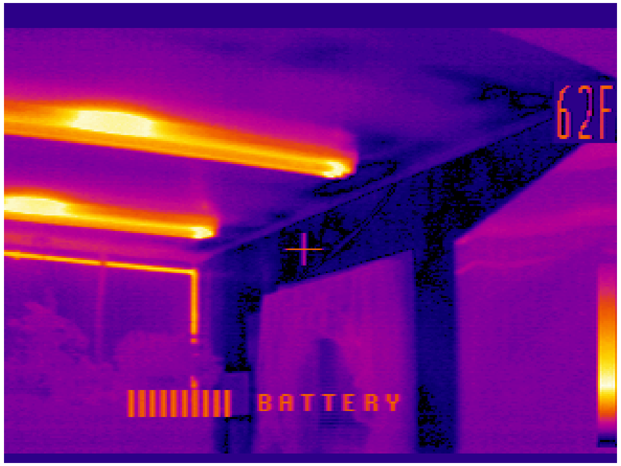
Building Energy Metric: British Thermal Units (Btu) can be used as a measurement for all energy - in terms of each sources' heat output. Btu's per square foot is often the way building energy use is discussed. For example the 2030 Challenge calls for carbon neutral buildings by 2030 and uses this metric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

Oil: 4513 gallons x 140,000 Btu's/gallon = 631,820,000 Btu's or **631.8 MMBtus**

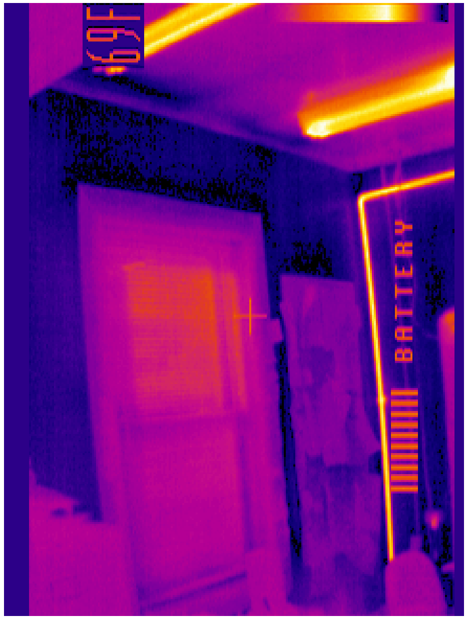
Electricity: 38,280kWh x 3412 Btu/kwh =130,611,360**Btus or 130.6MM Btu's for site energy**
38,280kWh x 11,396 Btu/kWh =436,238,880 includes generation source energy

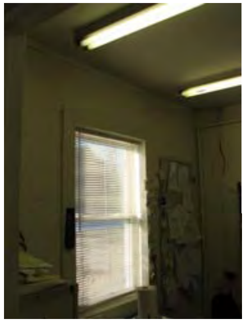
Total Site Energy in Btu's =762.4 MMBtu's / 4900FT2 = 155.6KBtu/ft2
Total Site Energy in Btu's =1,068 MMBtu's /4900FT2 = 218KBtu/ft2

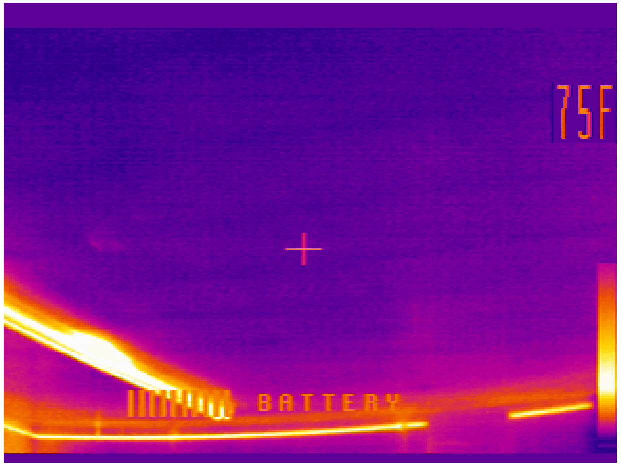
All walls except in the 1986 addition are uninsulated and very cold in the winter. In summer, warm moist air condenses causing moisture related problems and/or high energy use to dehumidify.



Dark colors indicate cold surface temperatures and bright colors indicate relatively warmer temps.



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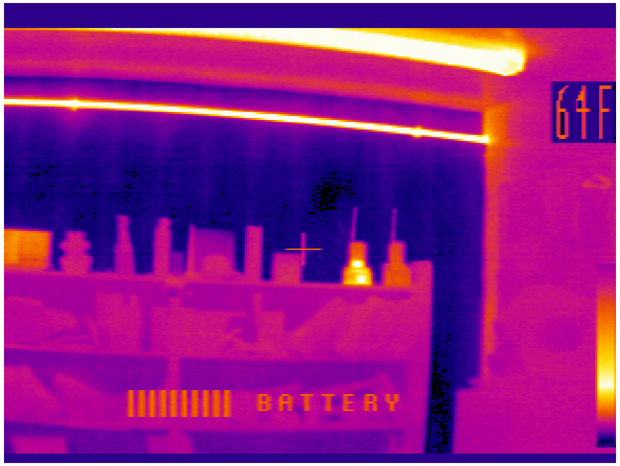
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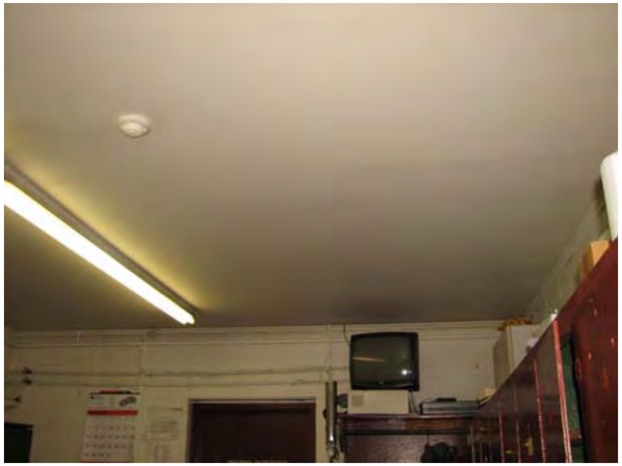
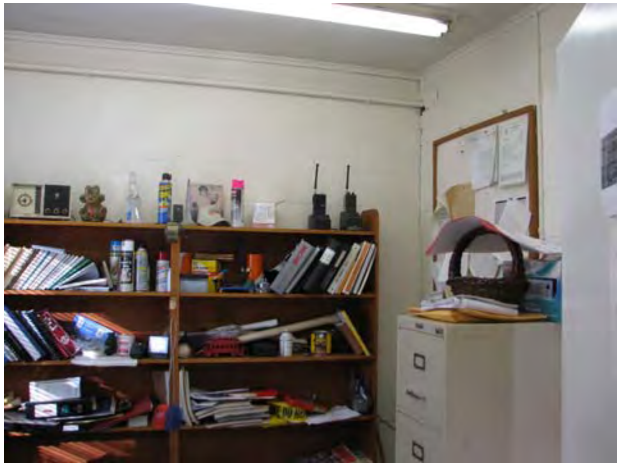
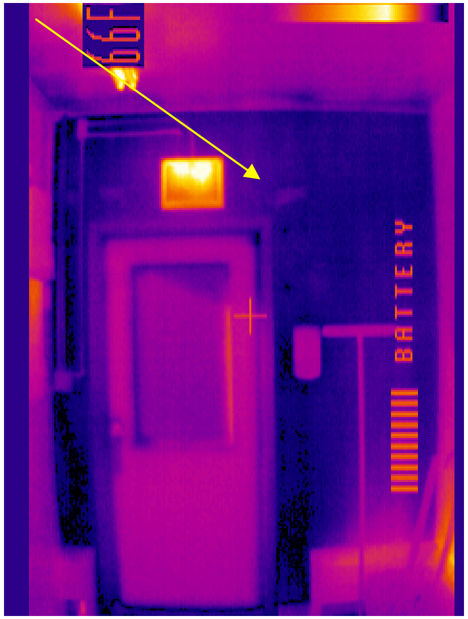
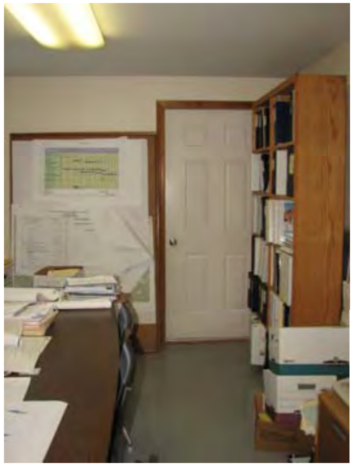
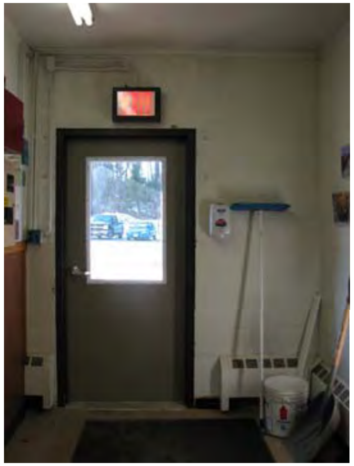




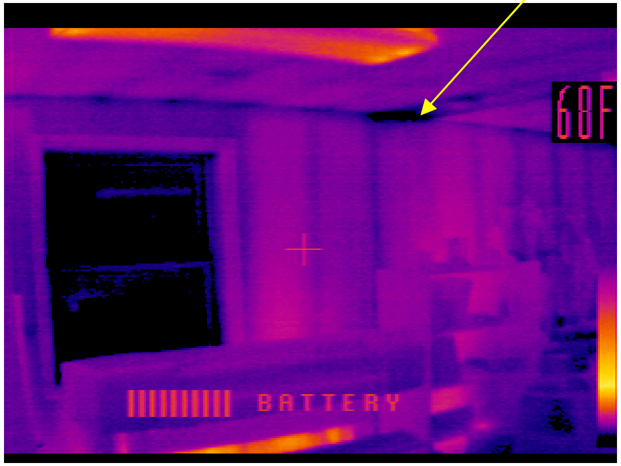


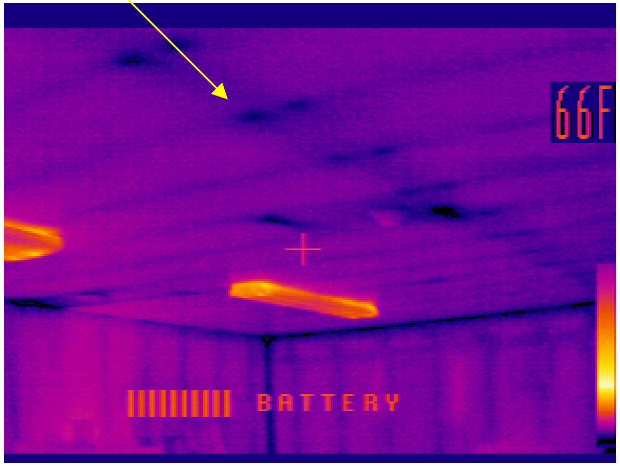


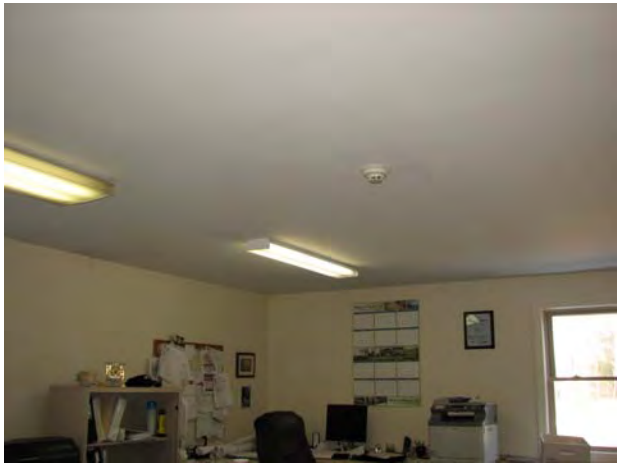
Both doors could be weather-stripped. Note the differences between an insulated and un insulated, R1 block wall.



Thermal bridging and cold areas with voids and/or air movement contribute to make this a cold office.

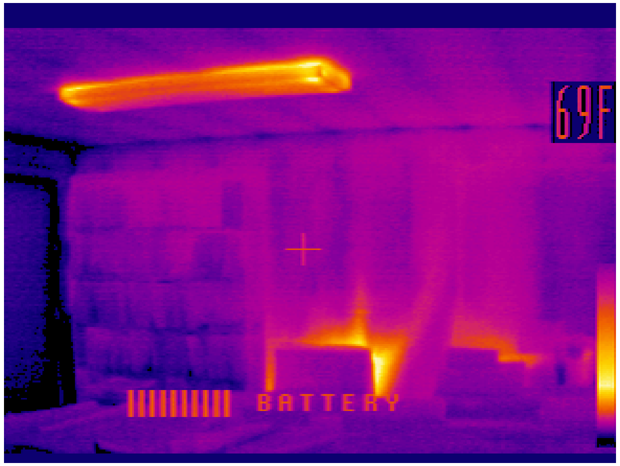


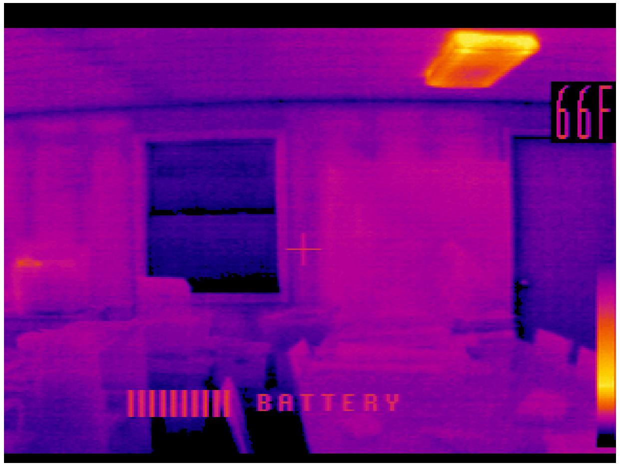


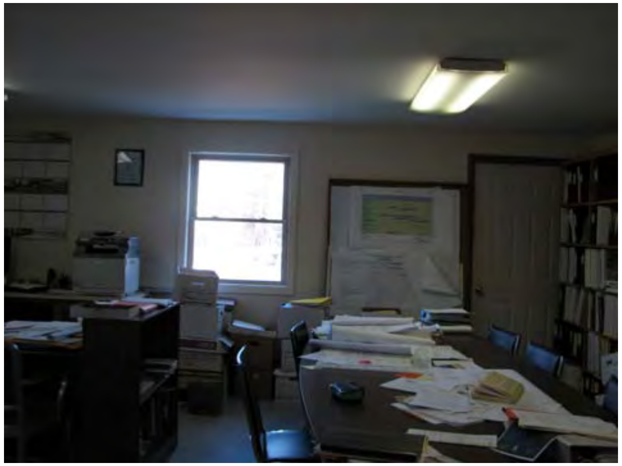


…compounded by a cold slab floor and air infiltration at the bottom plate.

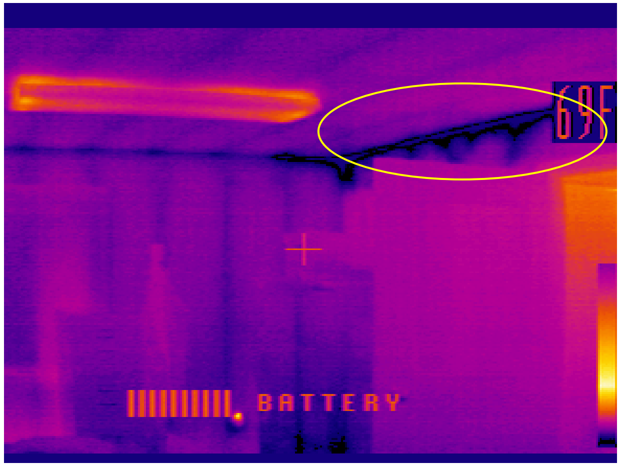
In addition, the room is surrounded with hydronic baseboard, though much of it is blocked, reducing capacity and efficiency of distribution.

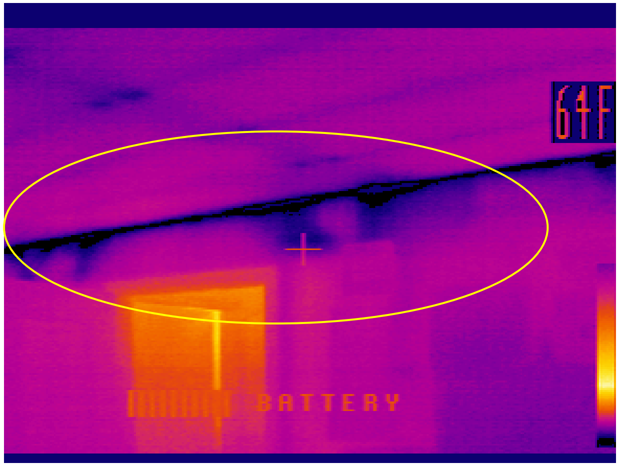


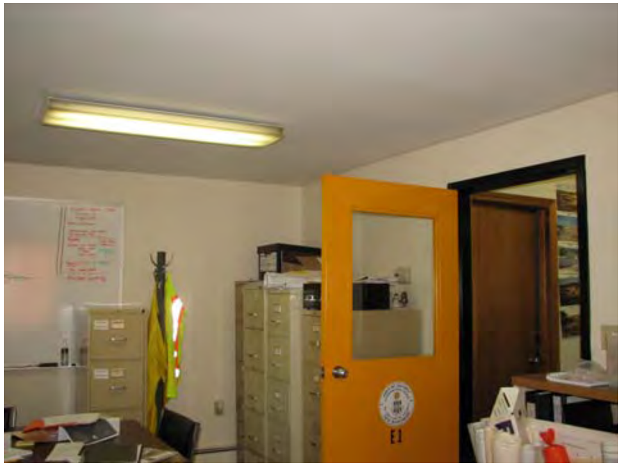


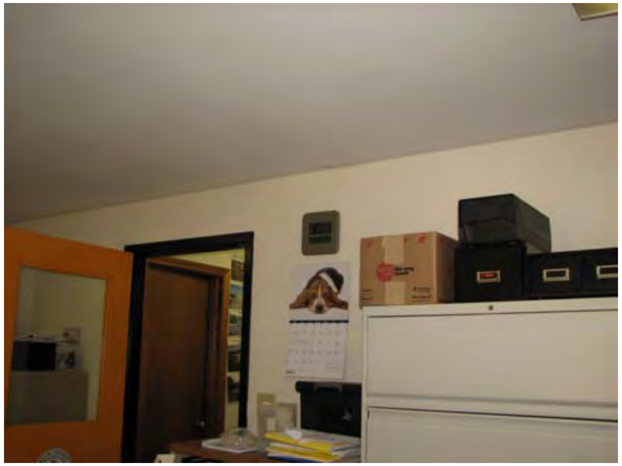


And the lack of an air barrier in the ceiling – especially at the junction of where the where the two additions meet.

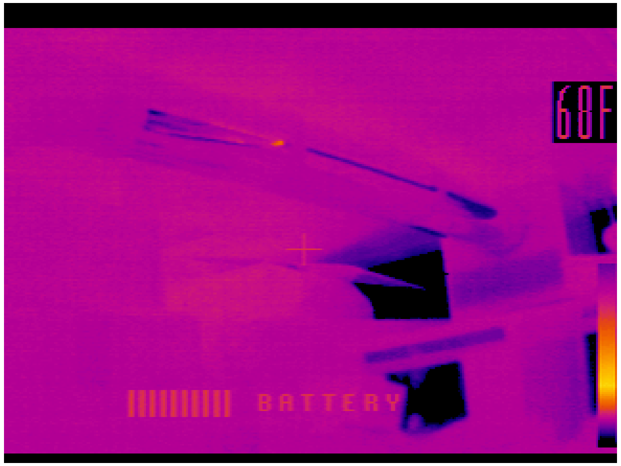


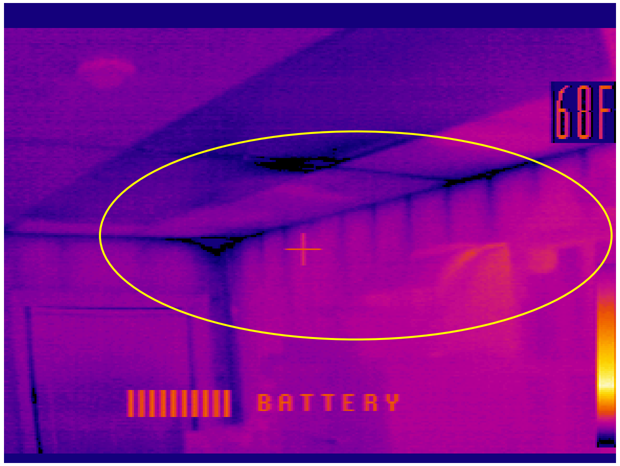




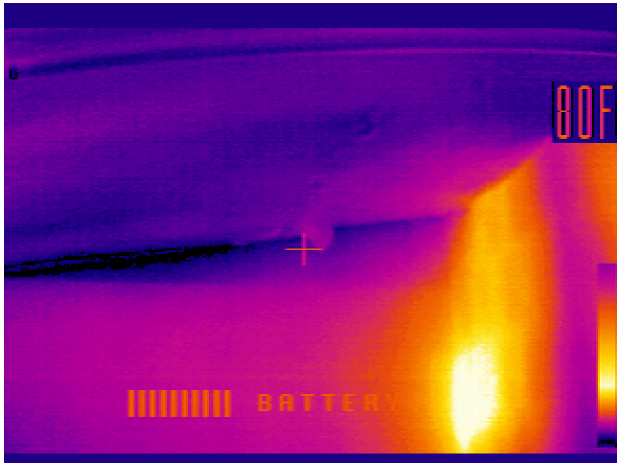


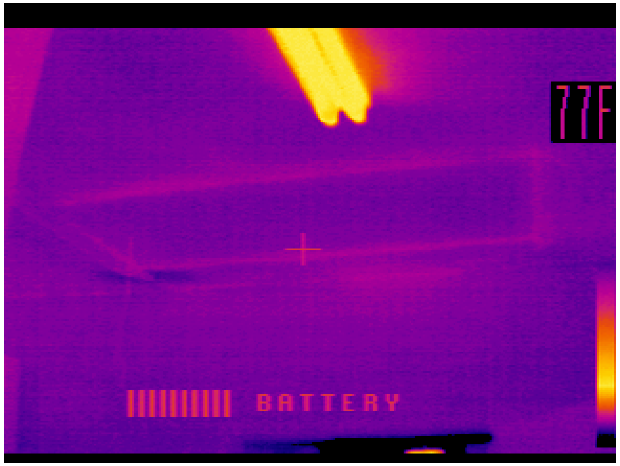
The 1980 addition is especially vulnerable.

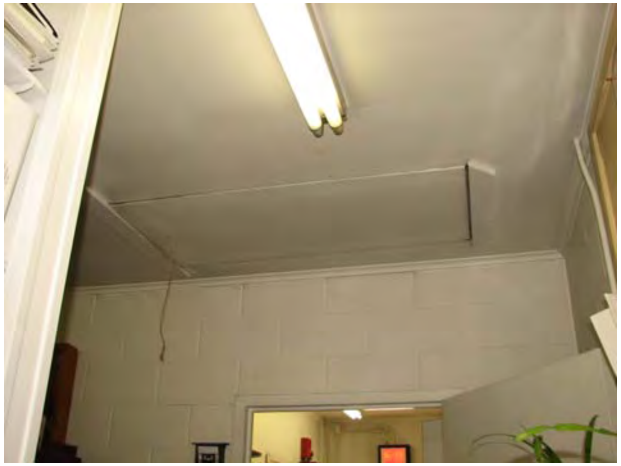




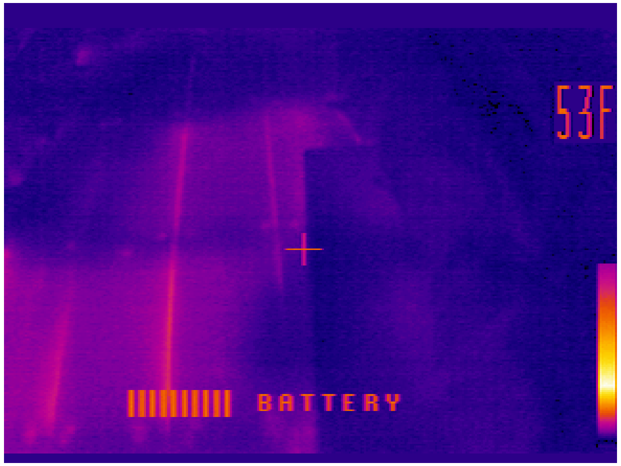
Water damage from past leakage
(and present?)

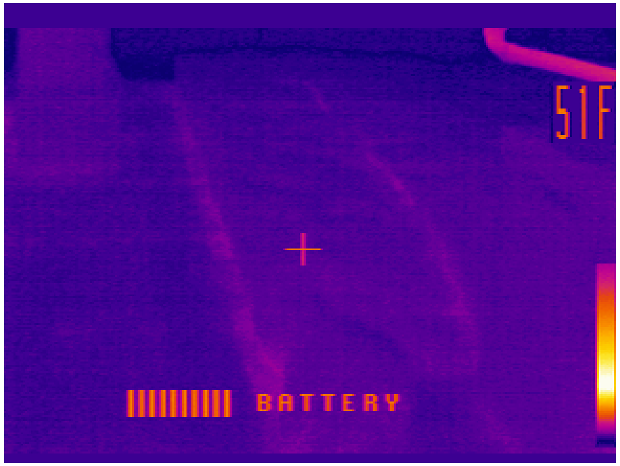




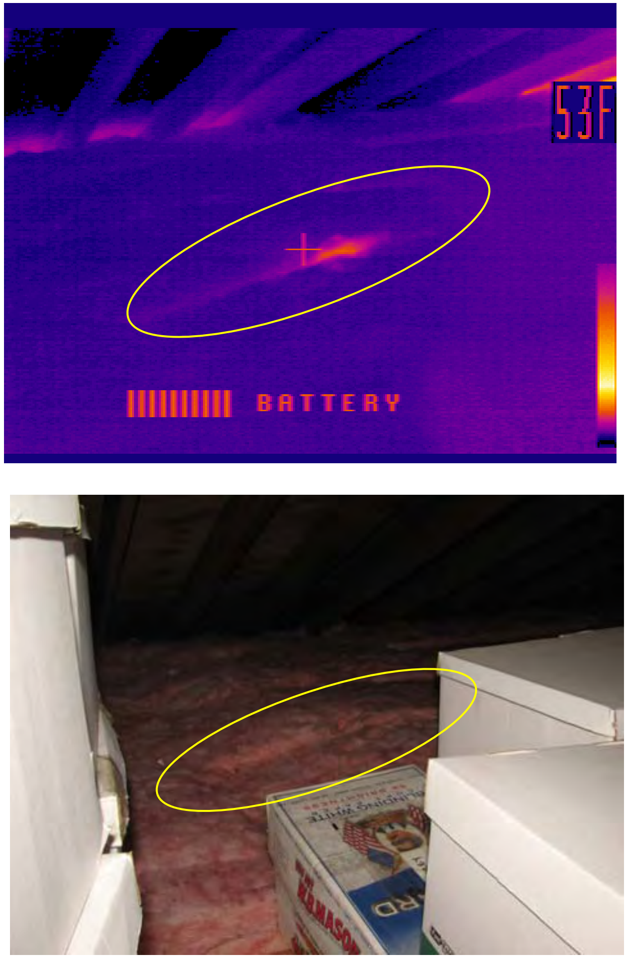


Even after insulation had been added, without an air barrier or continuity, there is still significant heat loss into the attic.





Continuity matters



The end wall, shared with the garage, shows significant heat loss from the garage into this cold attic.

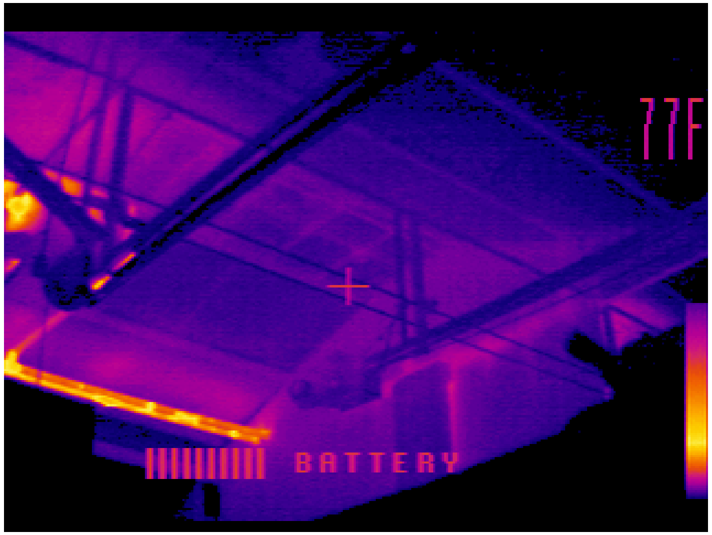
2x4 framed attic floor framed with 3.5” batts. Recently, 6” batts were laid crosswise for additional depth, but little no air sealing occurred, reducing the potential for reduced energy use.

Uninsulated wall shared with heated garage

Attic access

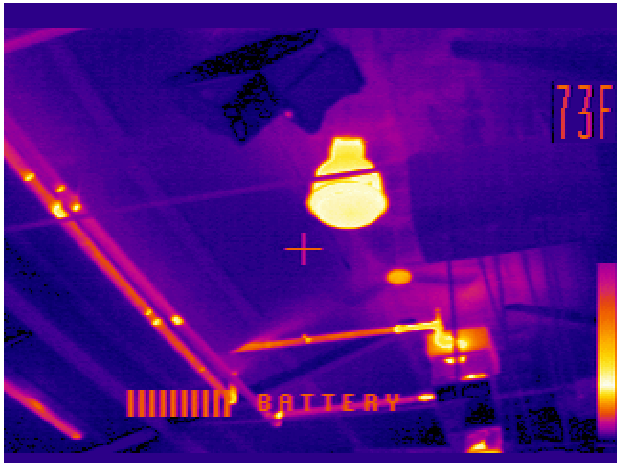
Draft cap helps, but lacking gasket seal.

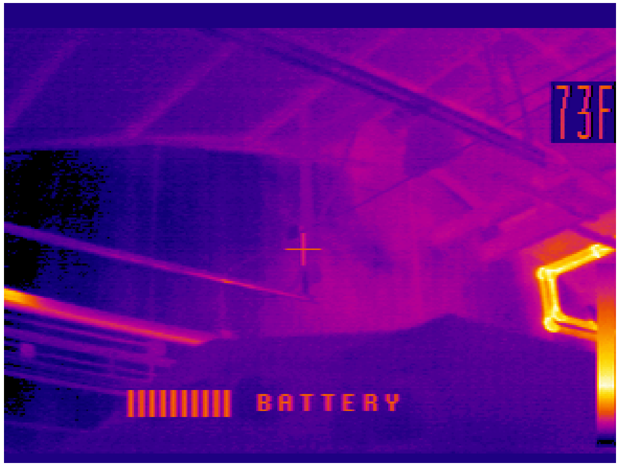
Garage Bays



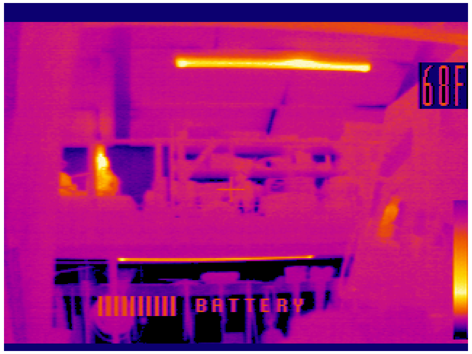
Ceilings have fiberglass batts above 6” EPS (R4 per inch and vapor permeable) panels for a potential R26 assembly, though many gaps and voids, especially at a 4-5’ strip at the roof peak, diminish the effective performance.

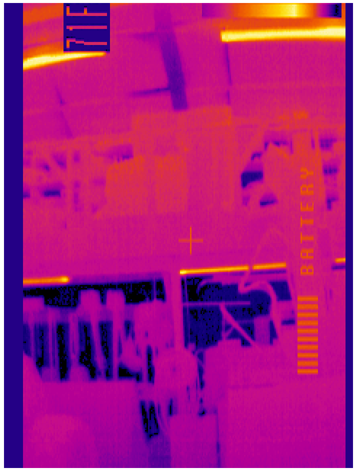
Garage Bays





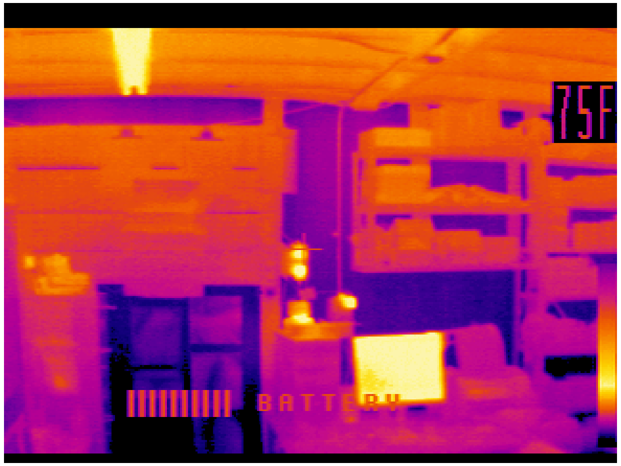
Garage Bays

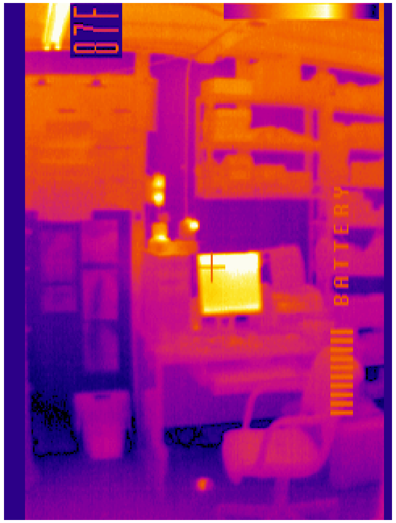


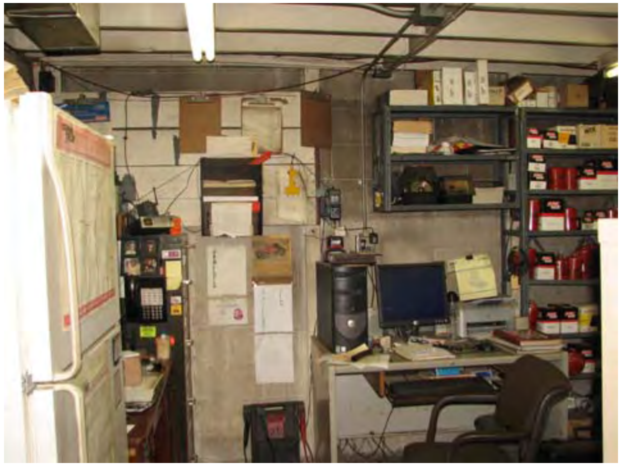


Since heat doesn't rise but moves to cold, R1 block walls conduct a tremendous amount of heat.

Garage Bays



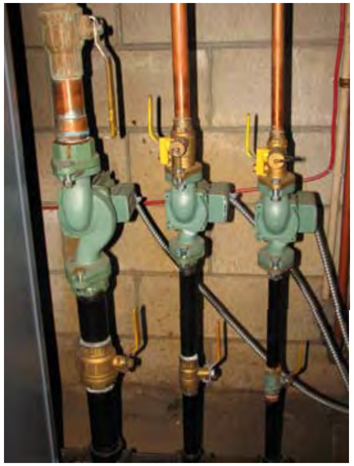




Garage Bays

Doors are in fair to good condition and may have an effective value of R6, though large gaps at top, bottom, and sides have a significant impact.

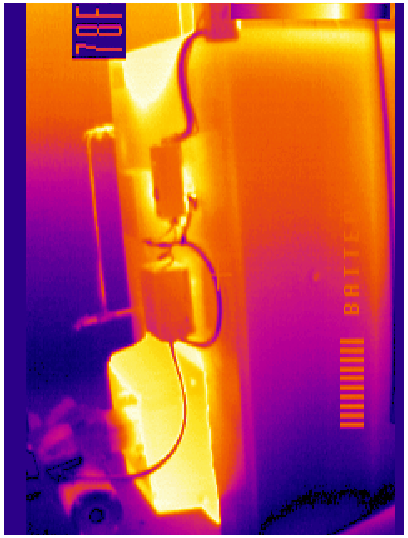
Equipment



Three zones running to baseboards in office and five Modine type heaters in garage bays.

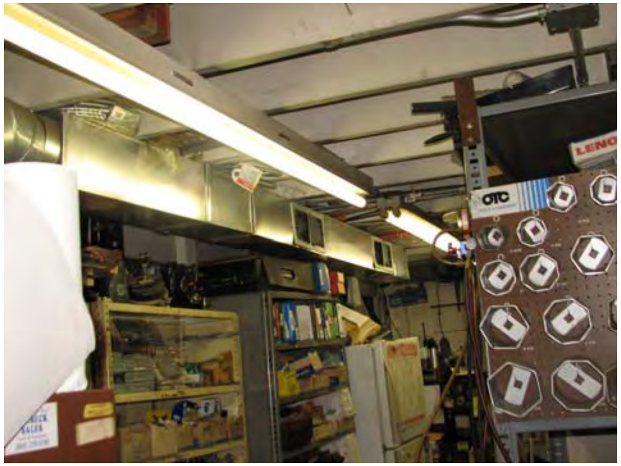
Bradford and White Indirect water heater, installed in 2009

New, Weil McLain Model 80, 680MMBtu AFUE85%



Equipment

Hot water also feeds this fan forced hot air duct into garage office.

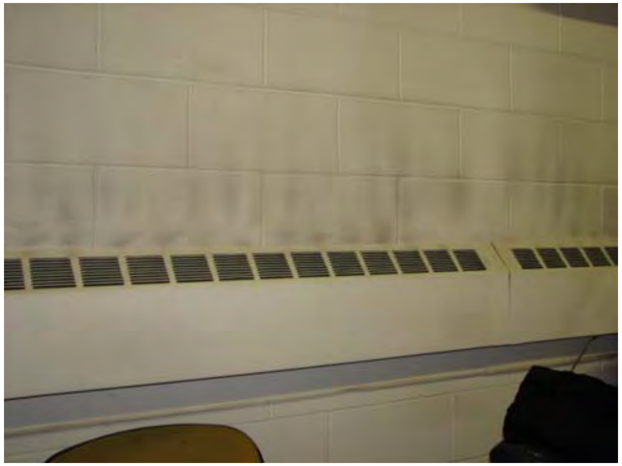


Equipment

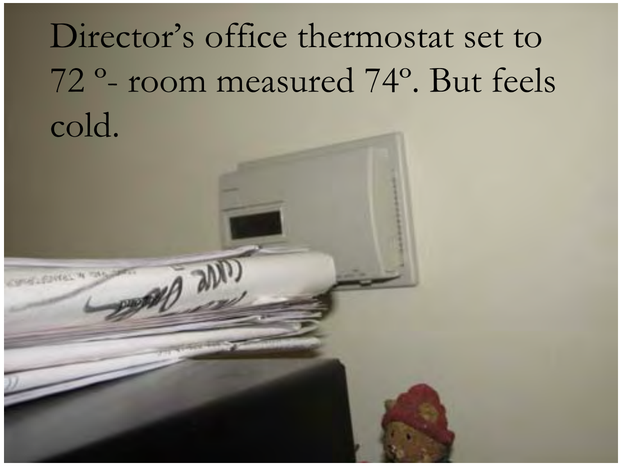
Forced hot air systems in garages can compound air quality concerns.

Equipment

Air connection to garage bays are a potential human health hazard.



Director's office thermostat set to 72 º- room measured 74º. But feels cold.

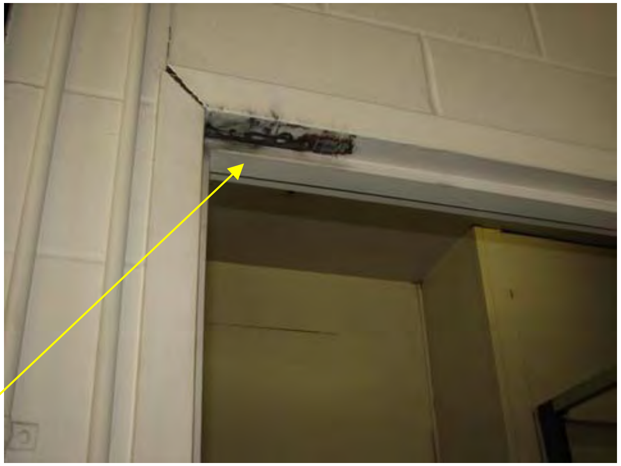


Lighting and Fan Equipment

Ceiling fans used to try to force warm air back down with little effect.

Four large Mercury Halide lights in addition to 8 foot T12 fluorescent lamps.

Ventilation Equipment



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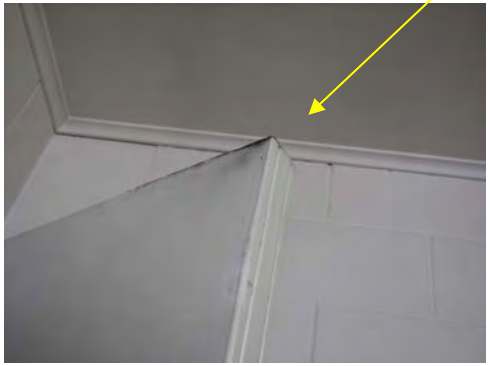
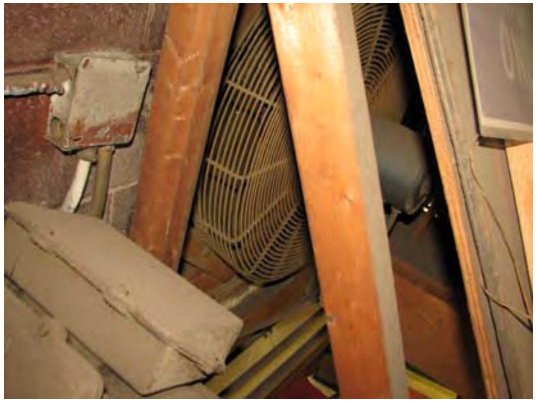


Top corner of bathroom door shows dirt collection as air is pulled from office through bath exhaust.

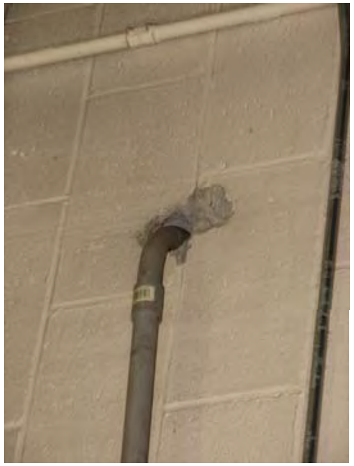
Exhaust fan louvers.

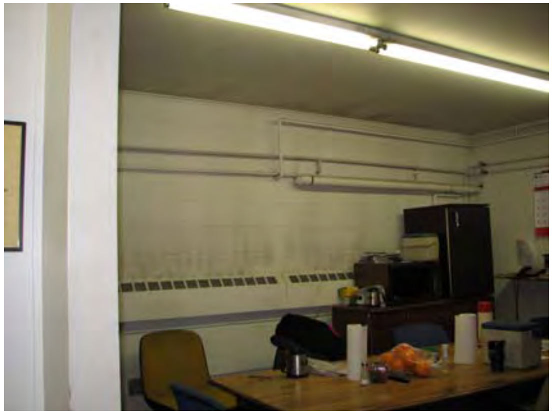
Garage exhaust fan
on mezzanine

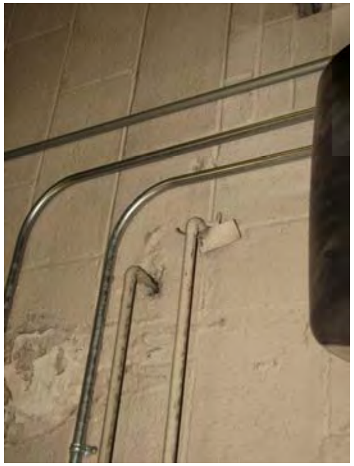


Wall between offices and equipment bays

allows for many air pathways







Diesel generator.

Uninsulated walls show conditioned of paint and wear.

Basically an outdoor boiler room with low shed roof. Significant heat loss, but at least it melts the snow off potential collection point.

Cracking and breaking blocks as reported by H.L.Turner, Inc.

Jaffrey Fire Station

Front of the building faces slightly east of north

Total energy costs for June'09 - July'10: $10,990 and 61.6KBtu/sf

ANNUAL ENERGY USE SUMMARY

Heating Fuel

2,846 Gallons Oil

(4 year average. '09-'10 2,272)

Indirect Hot Water off boiler and 35 gallon heat exchange tank approx 200+ gallons for summer use

Meter #G23600555

Electricity

35,320 Kwh

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: 2846 gallons x 140,000 Btu's/gallon = 398,440,000Btu's or **398 MMBtus**

Electricity : 35320 kWh x 3412 Btu/kwh =120,511,840**Btus or 120.5 MM Btu's for site energy**
35320 kWh x 11,396 Btu/kWh includes generation source energy = **402.5MMBtu's**

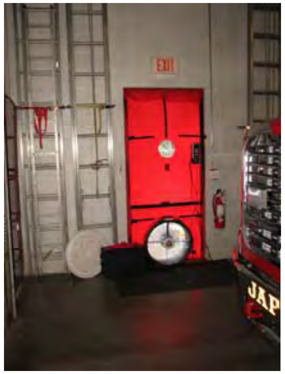
Total Site Energy in Btu's = 518.5MMBtu's / 8421FT2 = 61.6KBtu/ft2

Total Site Energy in Btu's = 1,060.5.MMBtu's / 8421 FT2 = 126KBtu/ft2

Blower Door Test & Results

Measuring Air Infiltration and the Air or Pressure Barrier

Convective and Conductive Heat Losses and Moisture Transfer



Whole Building: 9840CFM50

Means that **9840 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: 4.69 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 5 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: .31ACH Winter: .37ACH Summer: .18ACH

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 2 ½ hours or so.

Estimated cost of envelope air leakage: $1,648 at $3.00 gallon or approx 20% of heating bill

Leakage Area (Canadian EqLA @10pa) 1016 in2 or 7 sq feet

Total size of hole if add all cracks and gaps together

Minneapolis Leakage Ratio: .69 CFM50 per ft2 of envelope surface area

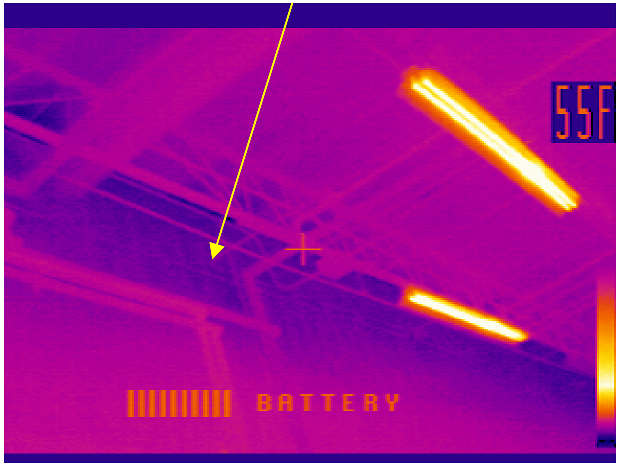
This is using the CFM50 relative to the surface area of the shell or envelope, since heat loss is based on surface area not volume.

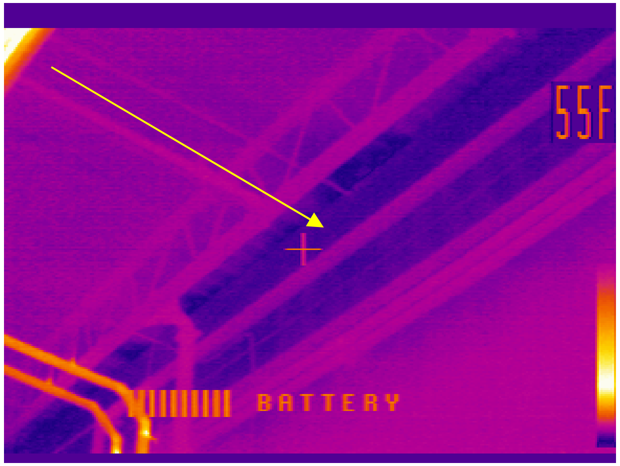
A total of three separate tests were conducted: Garage Bays; Meeting room and offices/kitchen; and Whole Building. The results were fairly similar, as it is primarily a large masonry structure so the 'relative leakiness' of each section was statistically similar. The results above reflect Whole Building Only as it is the most relevant in everyday operations. It is a relatively tight building as compared to frame structures.

The other significant result was that there is a very strong connection between the two primary zones. In other words the wall between the garage and the rest of the building does not constitute an air barrier. Therefore even if the garage bays are kept cooler than the main office area, the offices will continue to lose heat to the garages. Of equal importance, any fumes, moisture, or other air quality issues in one area will freely migrate to the other.

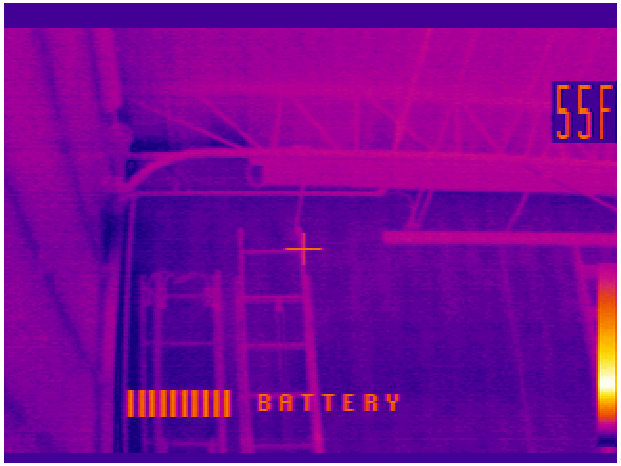
Garage Bays

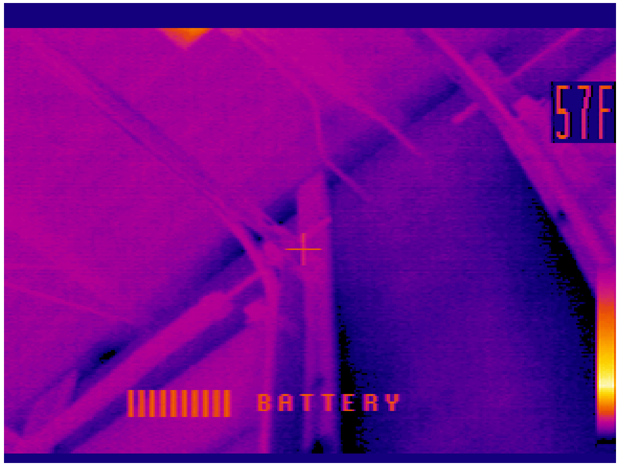
Colder wall section at top shows where lower roof ends – and exposed, uninsulated wall section above.

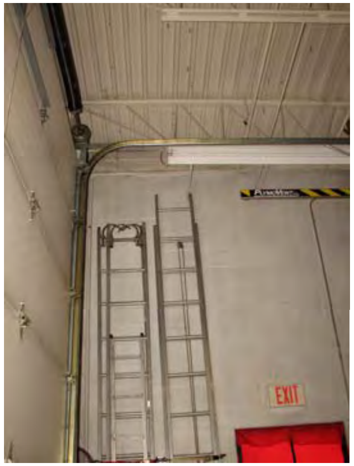




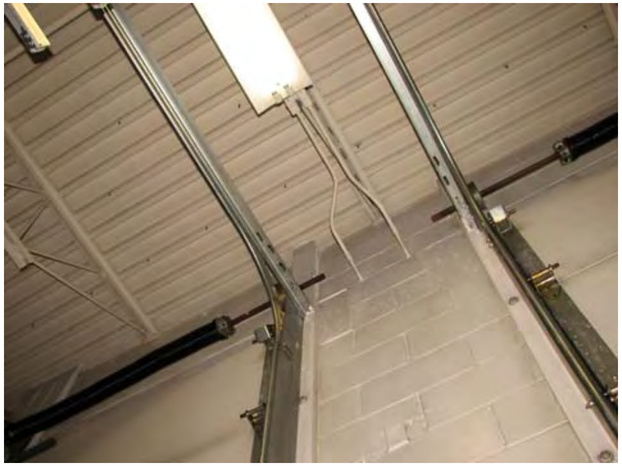
Garage Bays



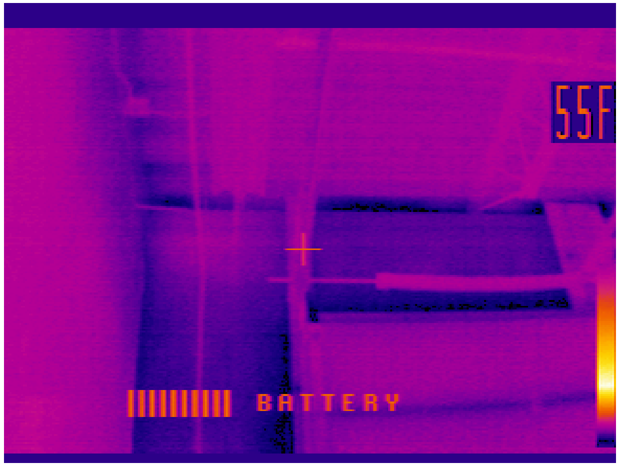




Site visit notes indicate was told that there was 2" rigid applied to outside block wall, but IR suggests otherwise – ie un insulated block walls except where 2x4 insulated cavities exist behind sheetrock.

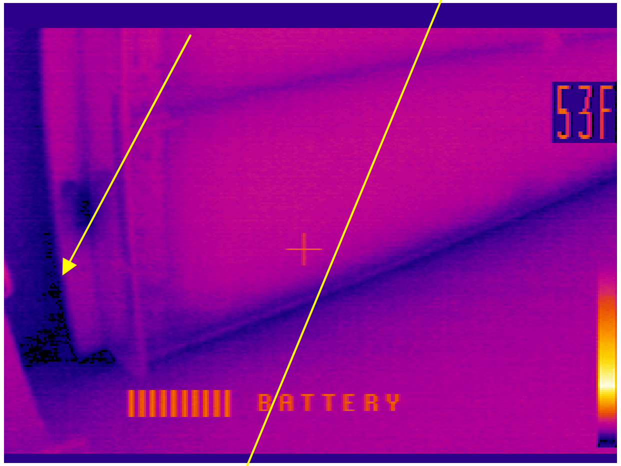


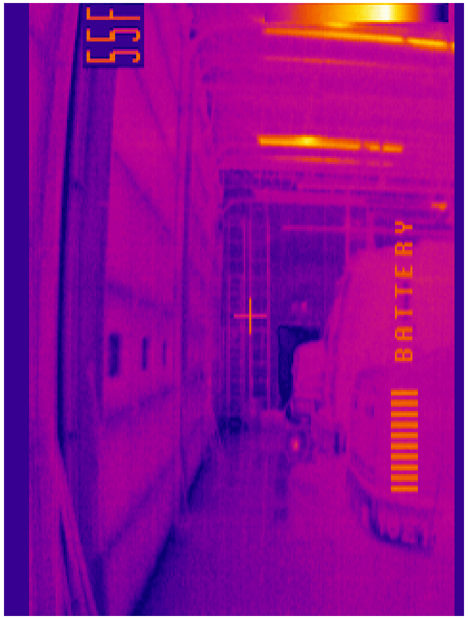
Garage Bays



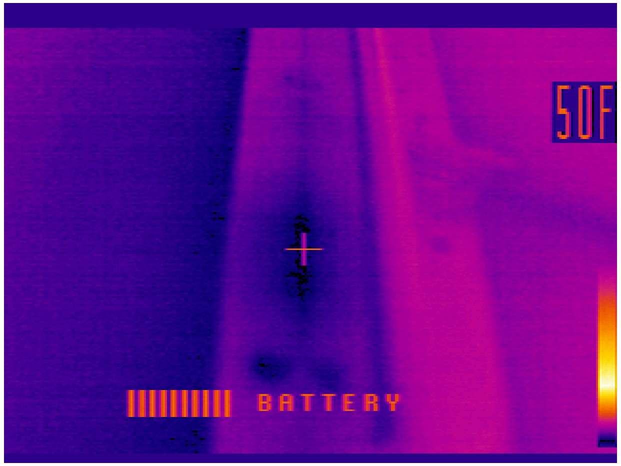
Garage Bays

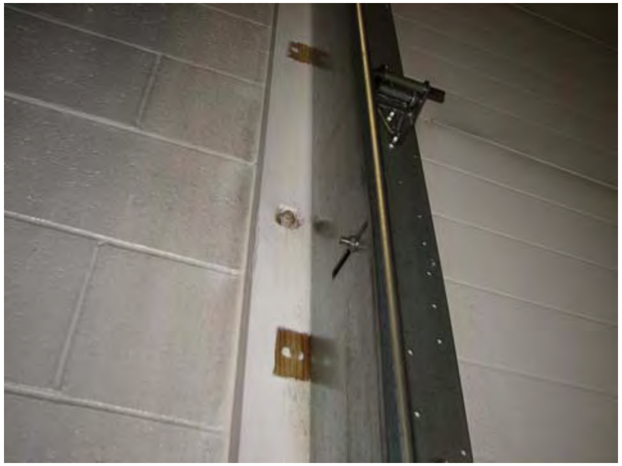
Door leaks lose heat and collect dirt and moisture.

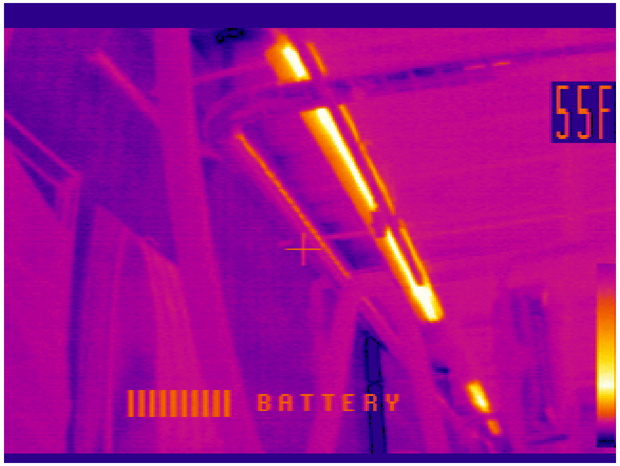


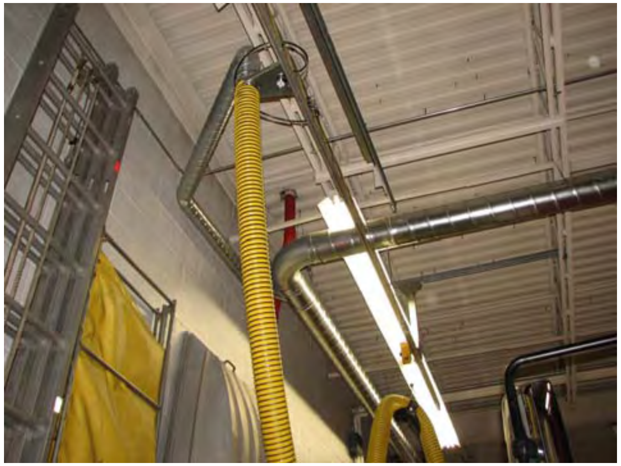


Garage Bays



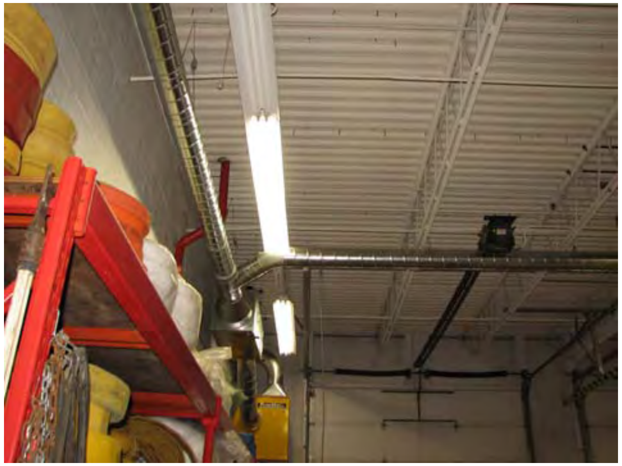




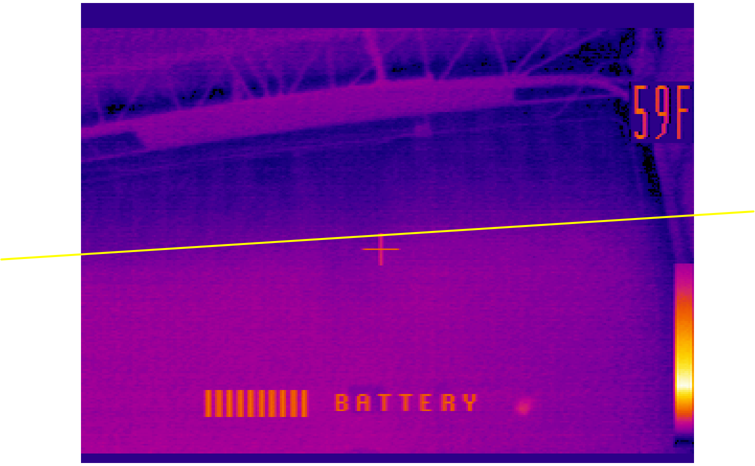


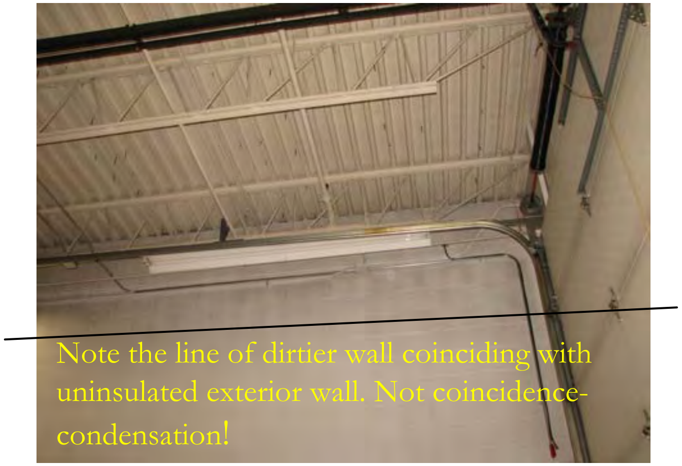
Garage Bays

Hollow concrete blocks show typical pattern – not air infiltration under roof deck.

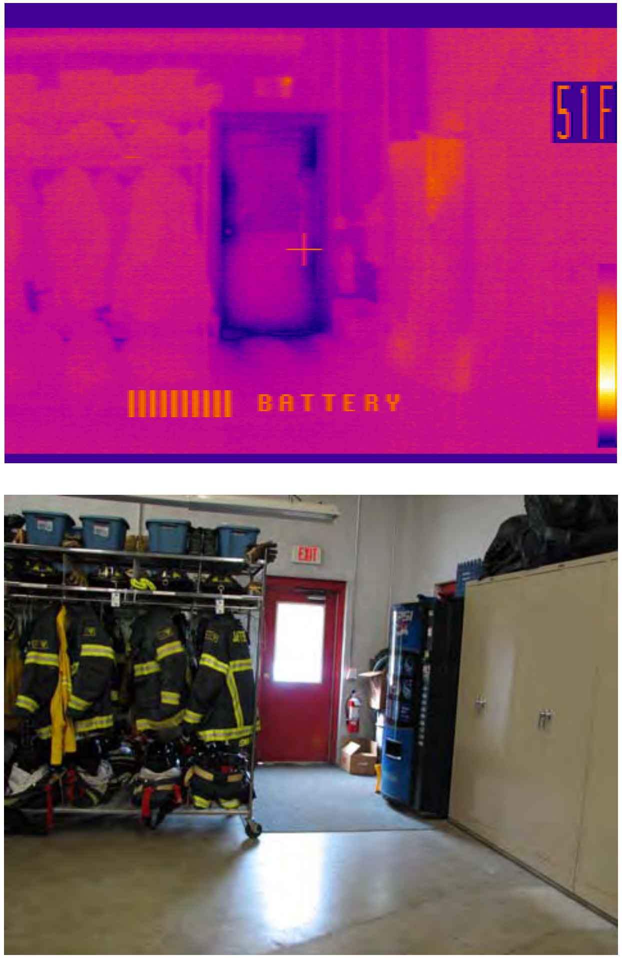


Station Bays



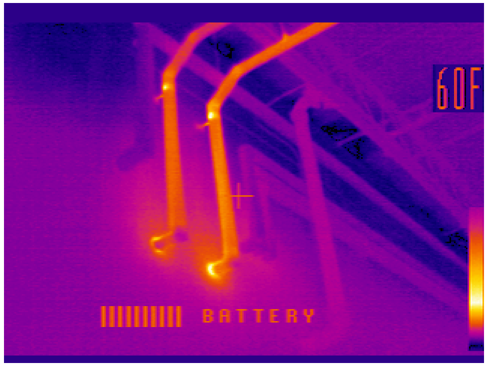

Note the line of dirtier wall coinciding with uninsulated exterior wall. Not coincidence- condensation!

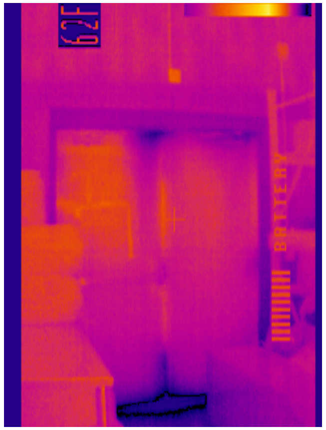
Doors

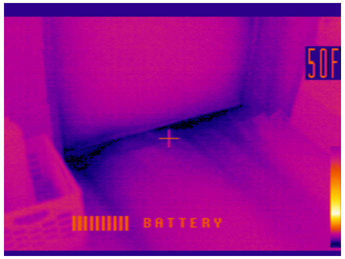


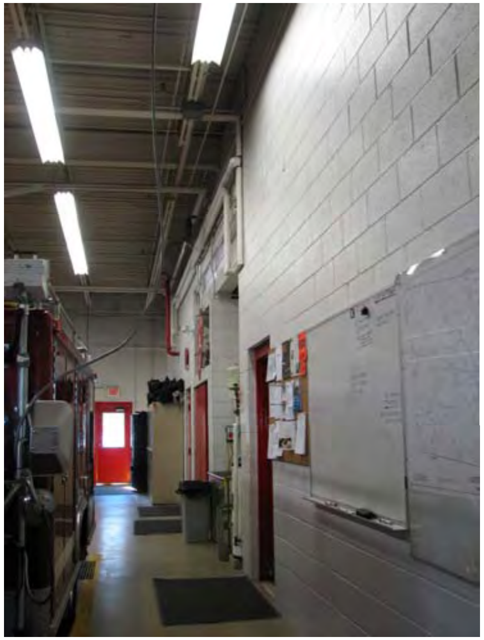
All doors leak air, moisture, and heat.

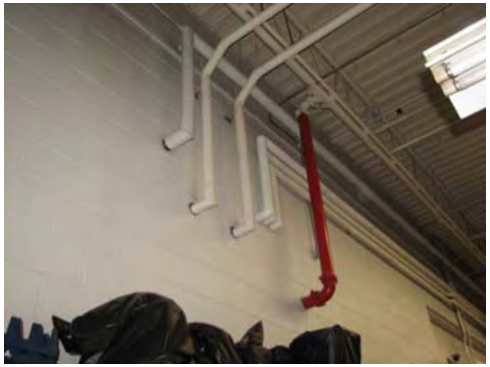
Interior Wall between Office area and Garage Bays

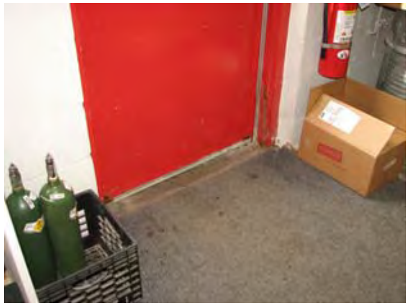






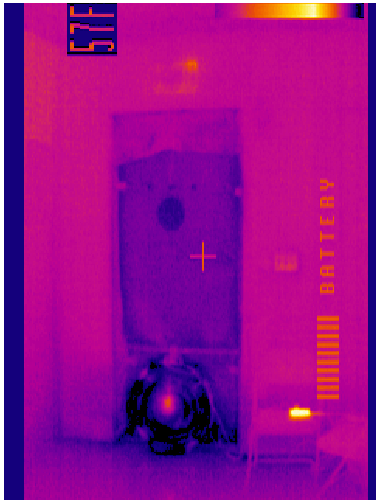


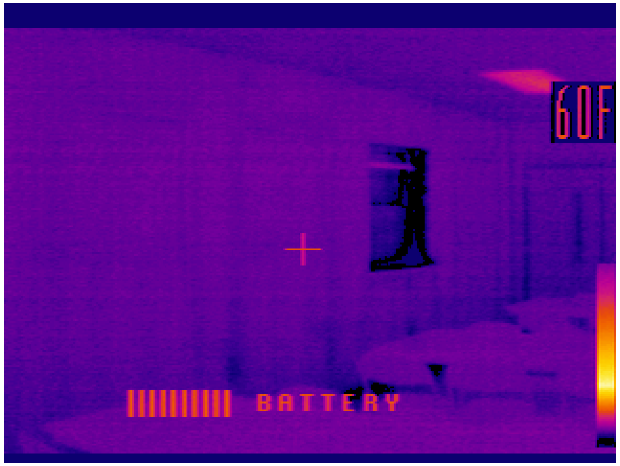




The wall between a garage space and 'living' space is an important air barrier to maintain for moisture and air quality. Since the bays are a separate heating zone and often kept cooler, it is also an important heat loss barrier as well.

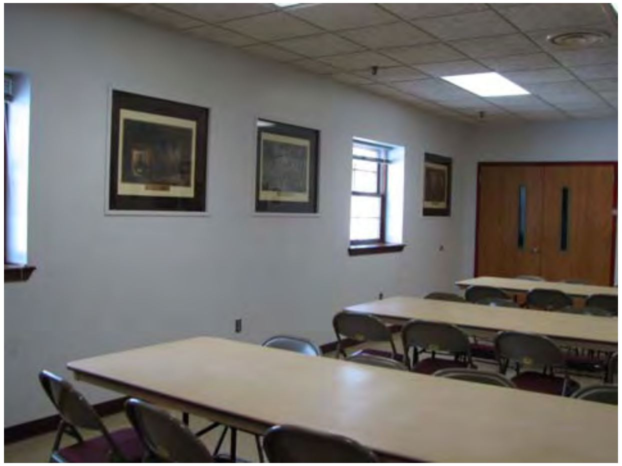
Fire Station Offices and Meeting Room





Within the last 5 years, walls in the meeting room and Chief's office were framed with 2x4's and insulated with 3.5" fiberglass batts for an estimated assembly value of R8.

Double pane windows were not replaced; estimated at R2 and leak a lot of air.

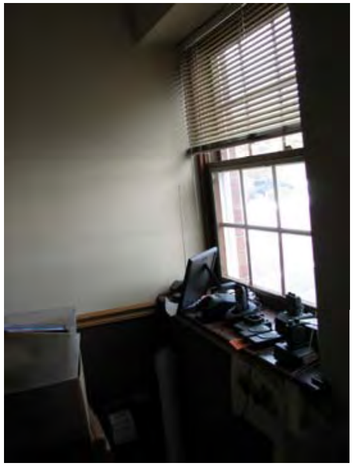


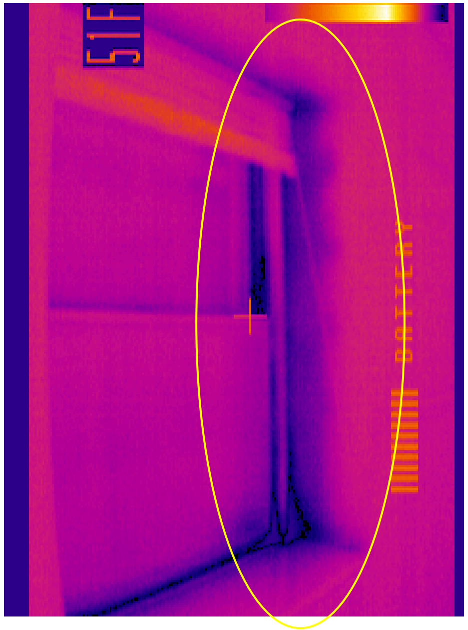
Fire Station Offices and Meeting Room

Sporadic fiberglass above suspended ceilings serves as effective filters and indicate the amount of particulates in the building.

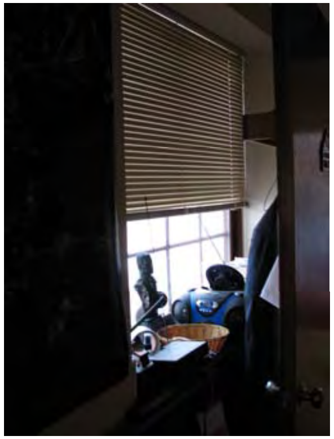
Windows

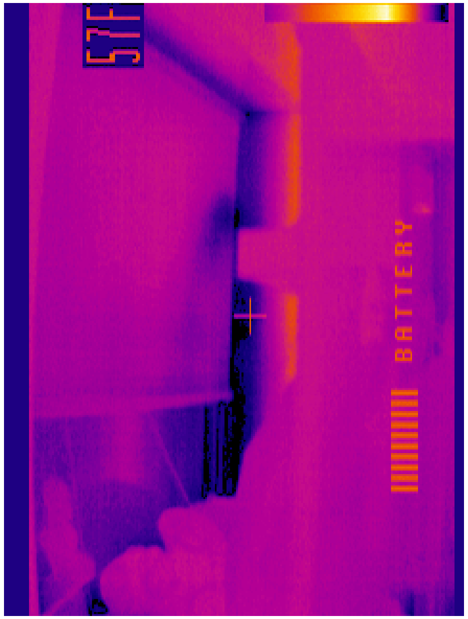
Chief's office windows cannot close completely. Replacement of all windows would benefit from tighter seals and an opportunity for air sealing and insulating, as well as minor improvement in glazing.

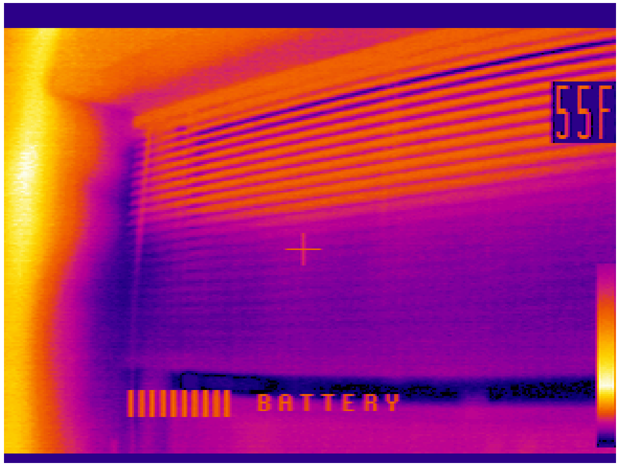




Windows

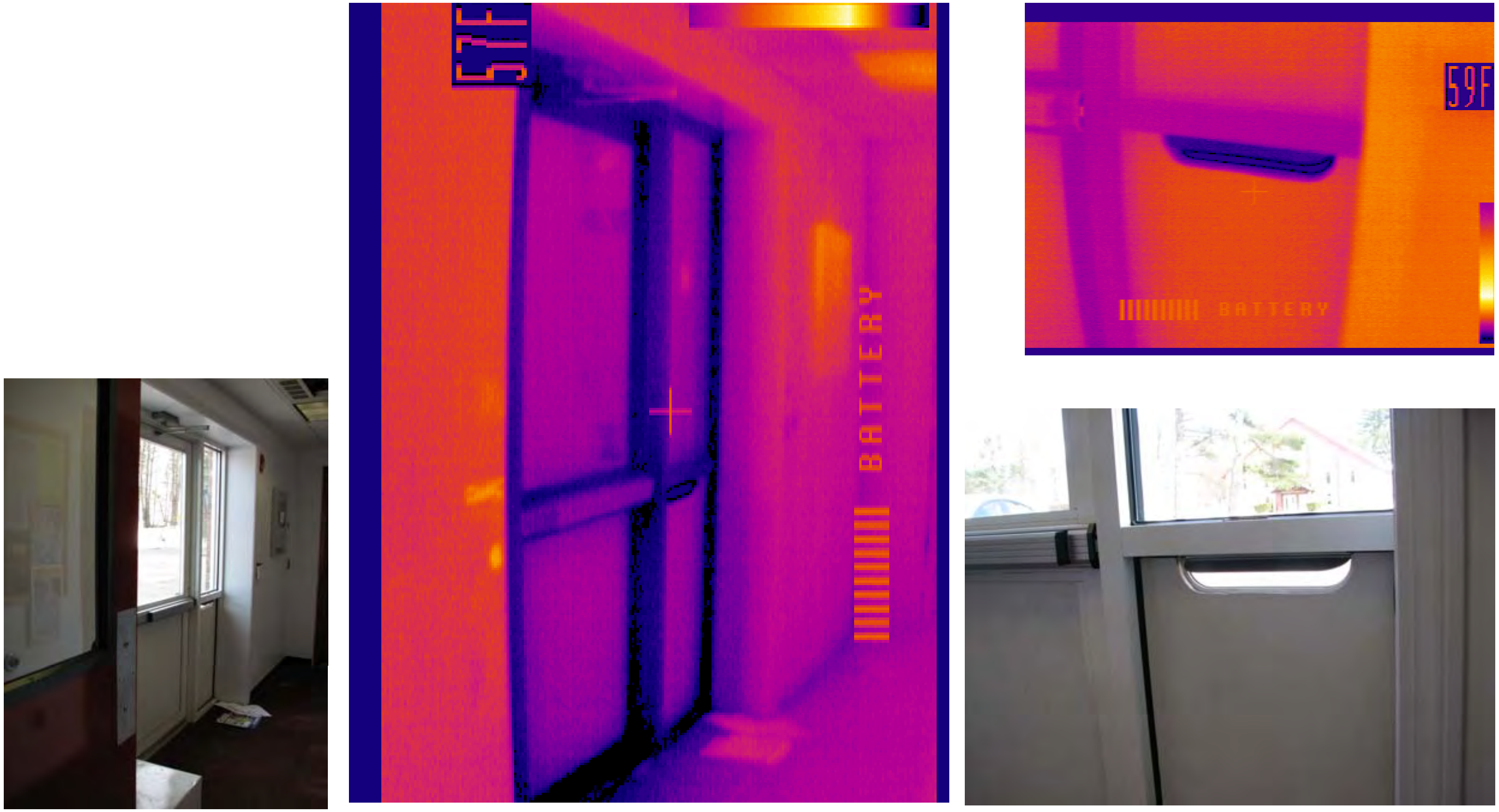






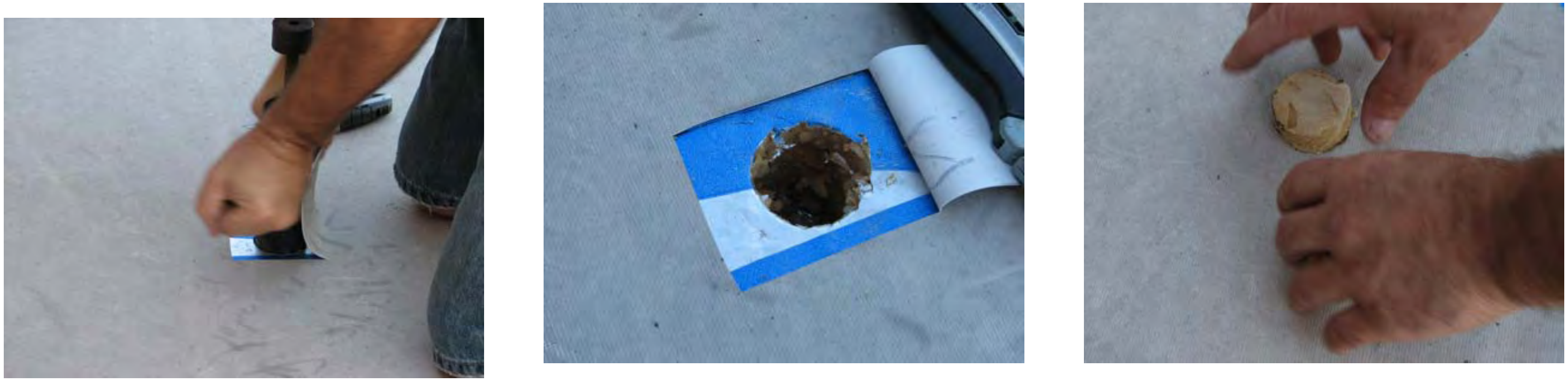
Chief's office has an air conditioner unit for summer use.

Doors



Roof

Both roof sections were re surfaced in 1999 by Johnson & Sons. Its considered a 20 year roof membrane, though 4 years left on the warranty.

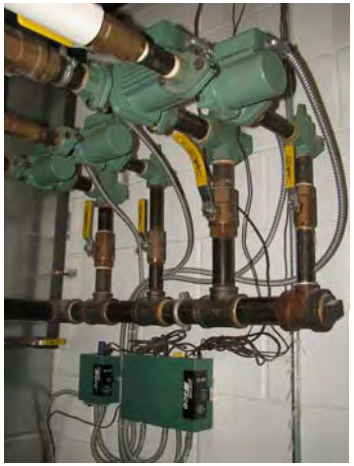


In 2009, a new stove hood exhaust was installed, and Victor Johnson did that as well. Victor kindly performed a core to verify insulation thickness (7/25/10). We found two layers of foil faced polyiso – 1" over 2" for a total of 3". Aged performance slightly under R6 for a total R17+ on both roofs.

We discussed upgrading the walls and or the roof. Victor said he can easily add membrane over an extended overhang (if walls are built out); and roof over existing; peel off and reuse, adding where necessary; or tear it off, build up, and apply new membrane.

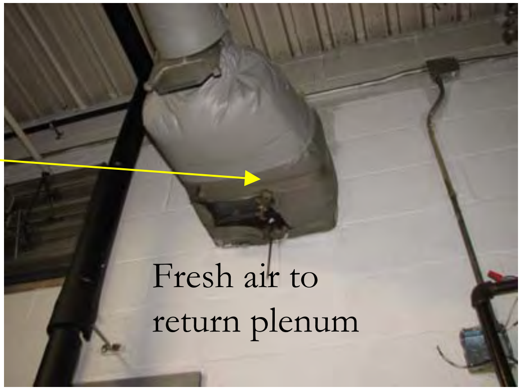
Heating Equipment

3 zones and water heater



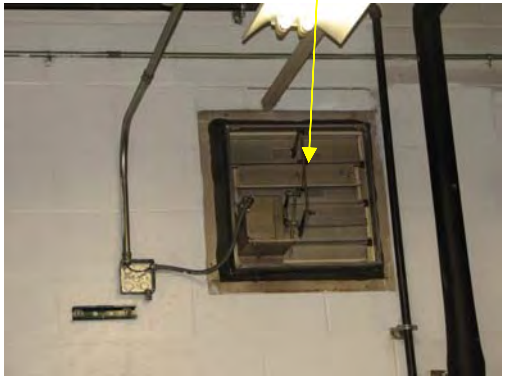
Burnham Oil Boiler installed 8/2000 Gross 483MBH Net 420MBH
4.2 GPH 83%AFUE Carlin Burner 31CD water temps L-170 H-210

Heating Equipment



Fresh air to return plenum

2000 CFM air handler



Combustion make up air mechanical vents – wired together

O – PAC AIR HANDLER
EL : VRHT 95-60
TS : 120 VAC, SINGLE PHASE, 60 HZ
AL AMPS : 11.3 (MAXIMUM)
AXIMUM FUSE : 15 AMPS
AN MOTOR : 3/4 H.P. FLA 10.3 AMPS
AXIMUM WATER TEMP. : 200°F

HEATING CAPACITY @ 6GPM IN BTUS :
130°F → 79,500 160°F → 120,500
140°F → 93,000 180°F → 147,500

AIR FLOW @ 0.30" EXT H_2O (Hi) → 2000 CFM
SERIAL NO : 991000047
VRV PRODUCTS
1875 DEWEY AVENUE, BENTON HARBOR, MI. 49022

VRV PRODUCTS
1875 Dewey Ave., Benton Harbor, MI 49022

In the event spare parts become necessary, state the description, part number and serial number (refer to data label).

MODEL: VRHT 95-60

Relay	PU1P2T
Transformer	PU30va
Motor	MT 3/4 0678
Door switch	2MCO
Capacitor	15 SIL OVAL-AM.RAD
Coil	7800285
Housing	MORR-10-8R

This was blocked in winter -

Insulated flex ducts above suspended ceiling

Entry hall sees a lot of rain and slush and dehumidifier used to help dry. Recommend removing carpet and dehumidifier in this area. A mop and bucket can help control bulk water and dirt when necessary.

Site visit: July 25th 2010, 8am. 76 degrees and humid. Boiler comes on to heat hot water for 15 minutes – boiler room gets to 87°F. Even with 35 gallon heat exchange tank, over 200 gallons oil used to heat water in summer – from cycling 483MMBtu Burnham boiler.

During 5 hour March site visit, boiler came on 7 or 8 times for less than 10 minutes each time. Conclusion: envelope heat loss requires frequent heating cycles but boiler is sized too large creating very short and inefficient cycles.

Equipment

Four ceiling mounted, fan assisted Modines heat bays.

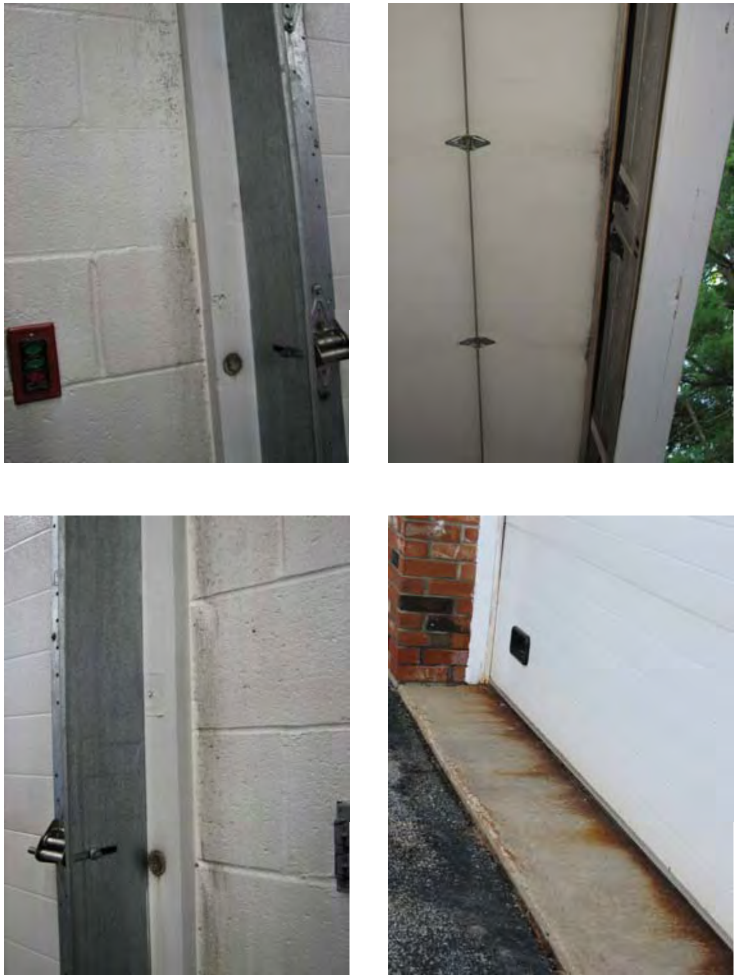
Exhaust Equipment

Code compliant stove hood exhaust installed in 2009 per Turner Report recommendation

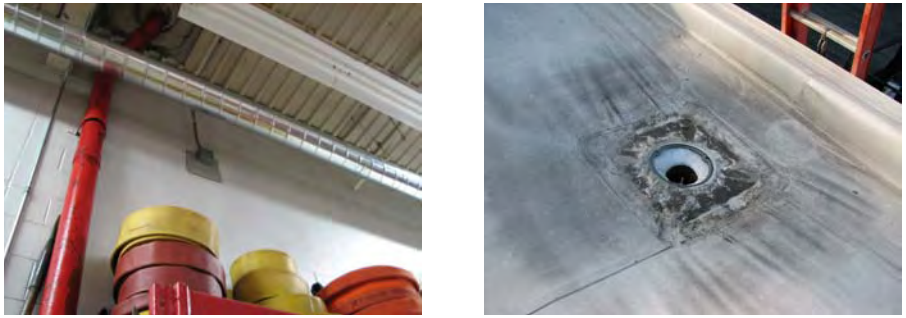
Code compliant Plymovent Vehicle Exhaust

Auto release tail pipe exhaust system great improvement. Still, hot engines also emit a variety of chemically filled fumes and petroleum particles. Building also can have high levels of moisture which is not exhausted through this system.

Moisture

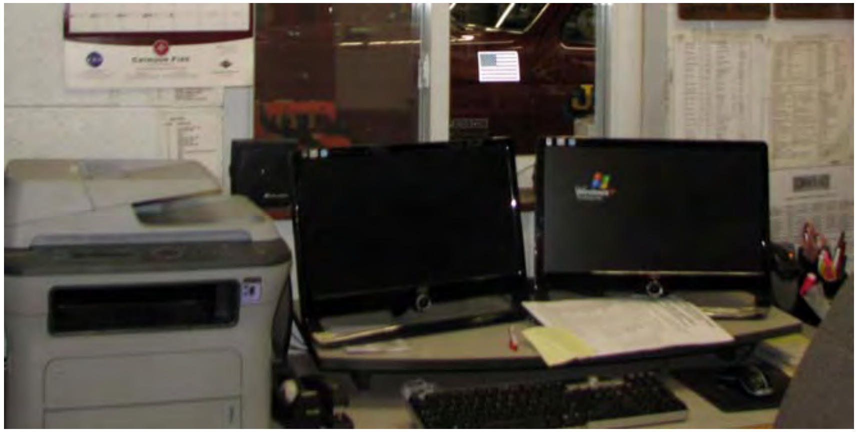


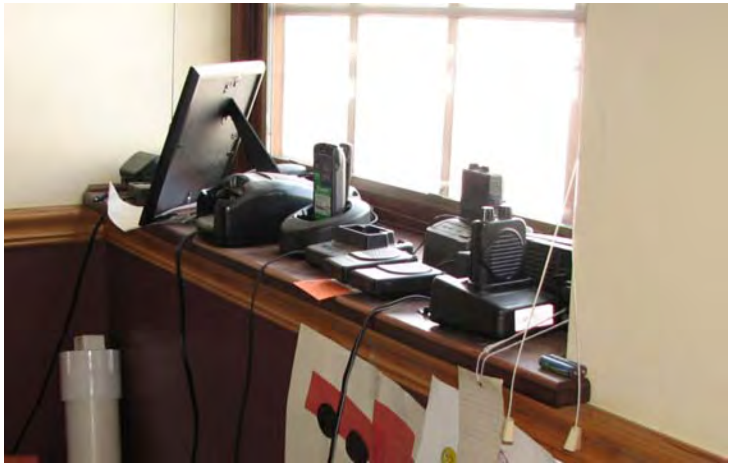
Mold and dirt accumulate near cracks and gaps where exfiltration takes place.



Neither roof drain has screen or leaf trap which increases risk of leaks near the drain

Electronic Equipment





Appliances and Other Plug Loads

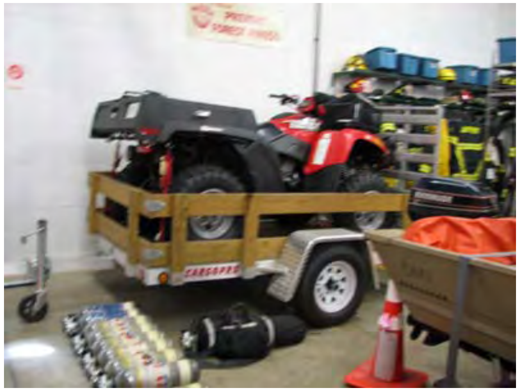
Old Kenmore Freezer, located next to boiler, draws 617 watts

In-focus projector auto screen
Worthington Generator
Air Compressor
Pepsi Machine
Dehumidifier
Emerson Microwave
Kenig one cup coffee
Buns 3 pot coffee machine
Amana TM18V2L
Ice Maker
DW Burner
Crock Pot
Emolian paper towel dispenser

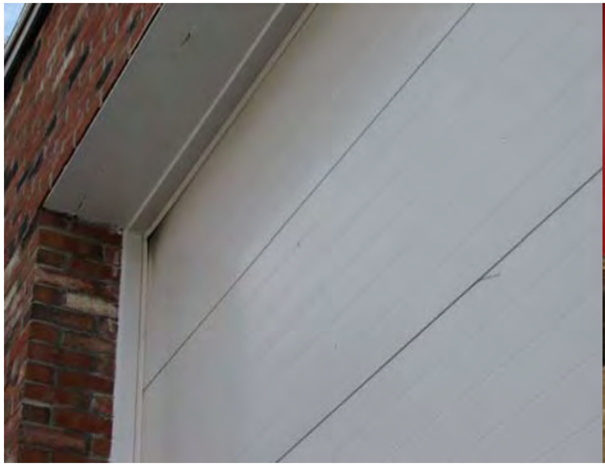
Milnor washing machine

Amana top load washer and dryer

Apparatus

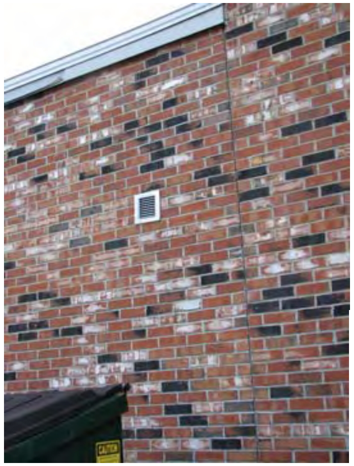


Air leakage



The louvered vent to the left appears to be the former strategy to introduce combustion make up air but is no longer used so is now just a hole in the envelope.

Mysteries



This small mystery wall vent has no apparent opening on the inside.

It appears that there is mortar between the brink veneer and slab foundation, yet no evidence of weep holes from the drainage plane. The moss may be a result of wicked moisture's downward flow? Or surface drainage towards, not away, from the building?

This hole, now sealed, indicates a minimal air space, if any, behind the brick veneer. Is it vented at top or bottom? Exterior insulation strategies would be effected by the answer..

Jaffrey Library

Energy Assessment

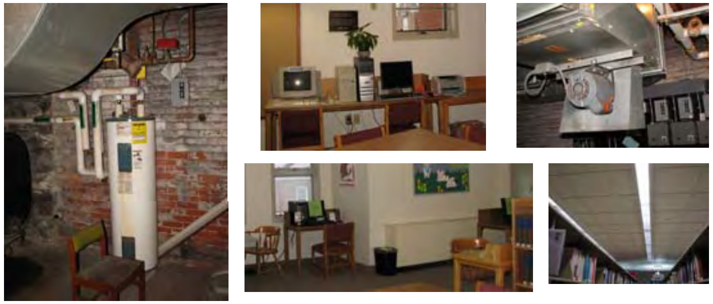
Total energy costs from June '09 to July '10:
$17,698 and 54.7KBtu/sf

ANNUAL ENERGY USE SUMMARY

Heating Oil

3961 Gallons

Meter #G28078274



Electricity

53,440Kwh

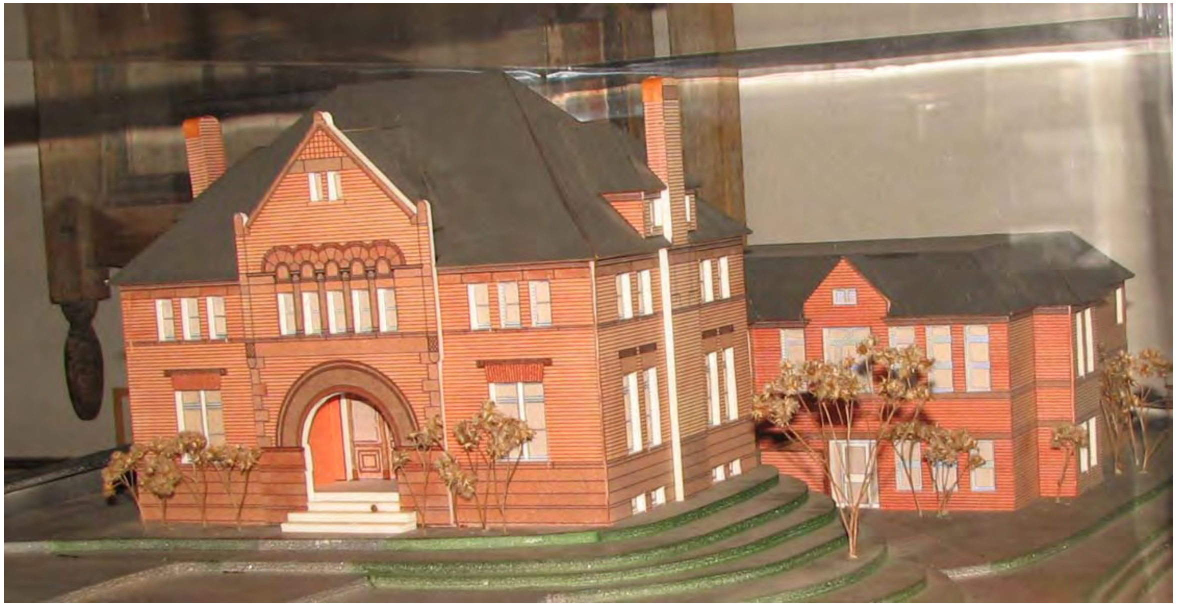
Building Energy Metric: British Thermal Units (Btu) can be used as a measurement for all energy - in terms of each sources' heat output. Btu's per square foot is often the way building energy use is discussed. For example the 2030 Challenge calls for carbon neutral buildings by 2030 and uses this metric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

Oil: 3961 gallons x 140,000 Btu's/gallon =554,540,000Btu's or **554.5 MMBtus**

Electricity : 53,440 kWh x 3412 Btu/kwh = 182,337,280 or **182.3 MM Btu's for site electrical**
53,440 kWh x 11,396 Btu/kWh = **609MMBtu's** includes generation source energy

Total Site Energy in Btu's = 737 MMBtu's / 13,474FT2 = 54.7KBtu/ft2

Total Site Energy in Btu's =1164 MMBtu's / 13,474 FT2 = 83.3 KBtu/ft2



Facing slightly east of south

Facing slightly south of east

Facing northwest

Facing north

Blower Door Test & Results

Measuring Air Infiltration and the Air or Pressure Barrier

Convective and Conductive Heat Losses and Moisture Transfer

Whole Building: 16,825 CFM50

Means that **16,829 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: 8.44 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 **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: .50ACHnat ACH Winter: .96ACH Summer: .48ACH
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 55 minutes or so.

Estimated cost of envelope air leakage: **$2,940 at $2.19 gallon or approx 38% of heating bill**
$3,625 at $2.70 gallon

Leakage Area (Canadian EqLA @10pa) 1737 in2 or 12 sq feet
Total size of hole if add all cracks and gaps together

Minneapolis Leakage Ratio: **1.33 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.

After improving the envelope to reduce heat loads (air sealing; insulation; and moisture management)….then address the HVAC equipment for efficiency and proper sizing.

1. **Reduce Demand**
2. **Improve Efficiency of Equipment and Distribution of Energy**
3. **Convert to Clean, Renewable Energy Sources**

Heating and Distribution Equipment

Two boilers with two fairly new burners. Total 502,000 Btu/hr capacity and 436,000 btu/hr net Boilers currently operating at 85% efficiency which means 15% of the generated heat goes up the chimney. Note that as the brick chimney is heated, it does radiate some heat into the building so not all heat is lost.

Fresh make up air for combustion – fan runs continuously

Becket and Carlin Burners

Water temperature can be adjusted for shoulder seasons, though true modulating boilers with outdoor reset sensors would be more efficient.

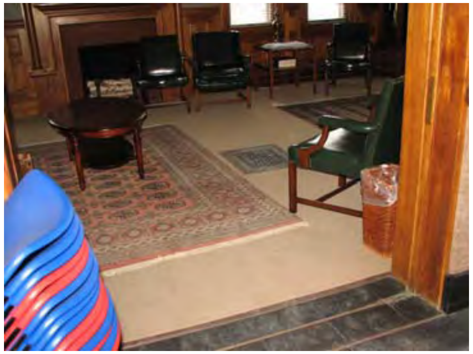
By converting the heat coils, variable speed circulating pumps would also improve efficiency.

Electric hot water tank

Heating and Distribution Equipment

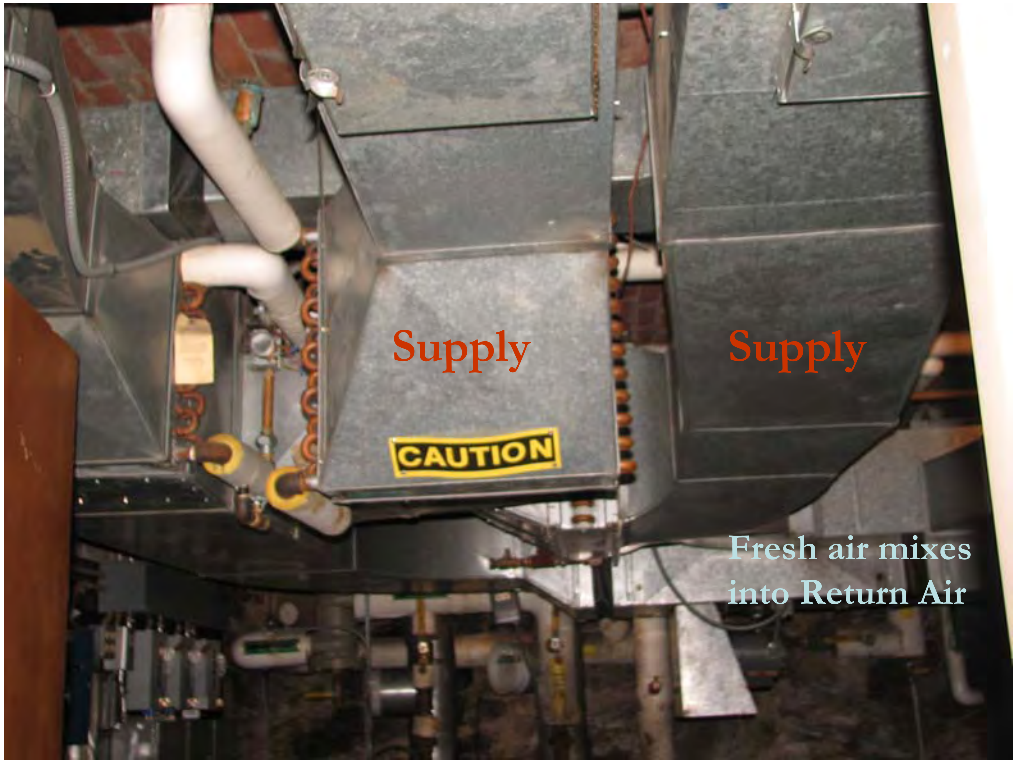
Blower fan

Passes return air by hot water coils and…



Through supply registers in historic portion of building

Heating Equipment



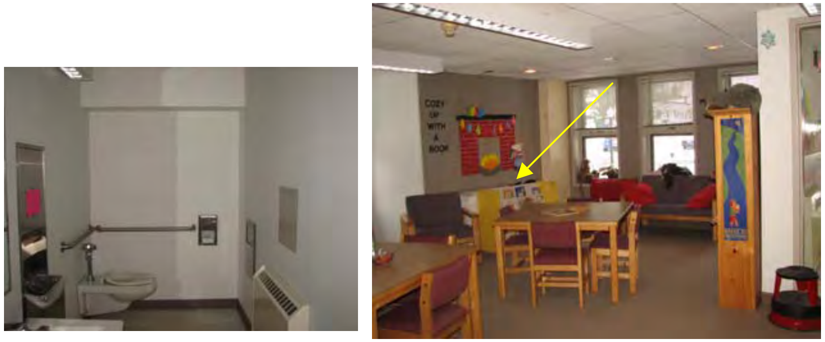
Fresh Air for Ventilation. Also runs continuously and year round

Converting to a sealed combustion boiler will allow sealing of combustion make up air fan and eliminating this mechanical room space heater.

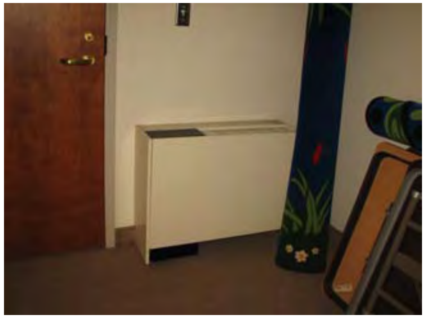
Hot air supplied to reading rooms above and to basement in this duct run.

Heating Equipment

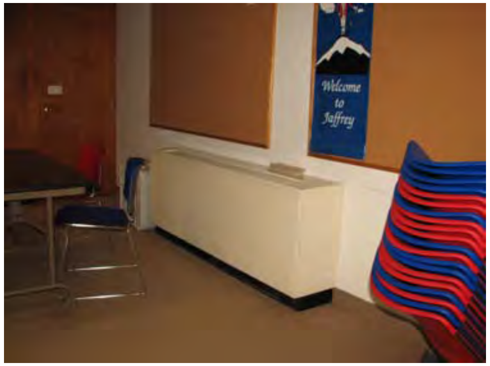
And boiler also sends 160 degree water to these basement space units



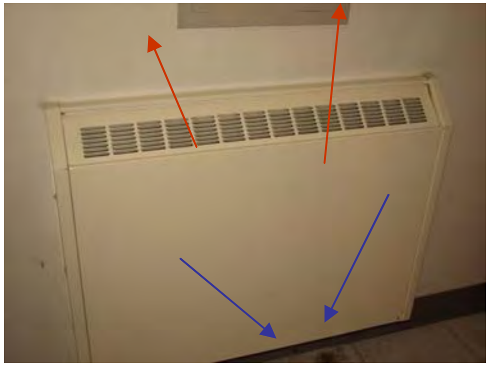
Individual thermostats



Hall fan coil unit.



Suspect this would be connected to outside fresh air supply for ventilation requirements in this meeting room, but no evidence of duct work in 2x4 interior wall. And it is known to get 'very stuffy'.

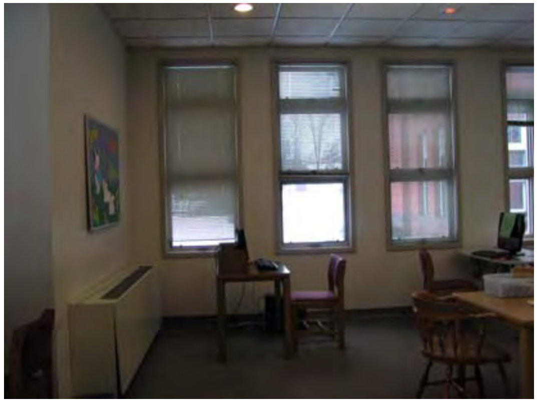


No fan, kitchen room with passive convective looping from radiated heat

Entry fan coil unit - Forced warm air only, not connected outside fresh air

Heating Equipment and Distribution

Main Floor, newer wing



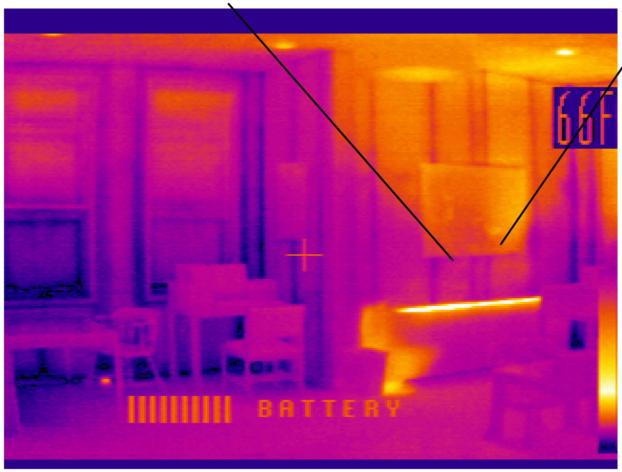
stack and computer area

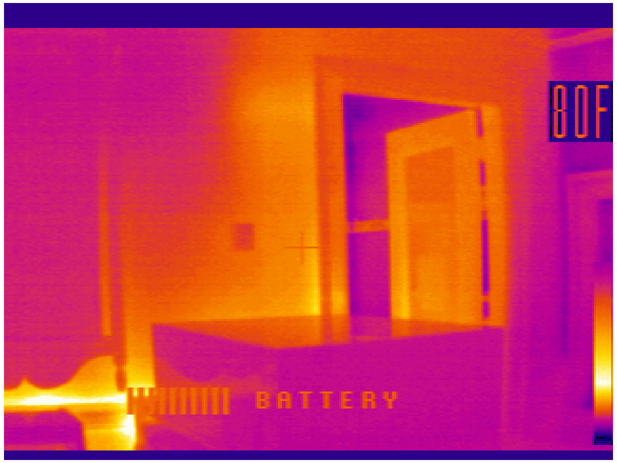
Fan used in winter to help distribute warmth.

Many more fans used in summer also to distribute warmth - away

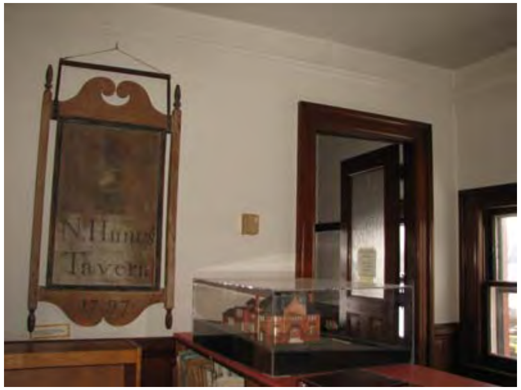
Distribution of Air and Heat

Distributing heat efficiently is also an important consideration.





This unused 2nd floor closet was over 85 degrees on this 30 degree day.

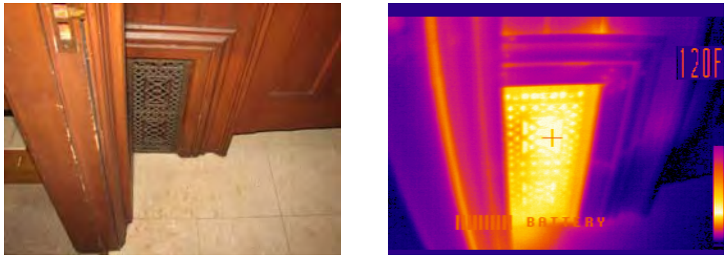


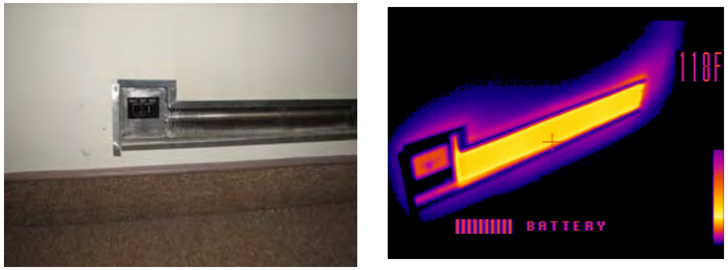
Thermostat is kept set at 65°F night and day throughout the winter; temp at information desk was 70.8° on day of site visit (outdoor temp 36° and rainy).

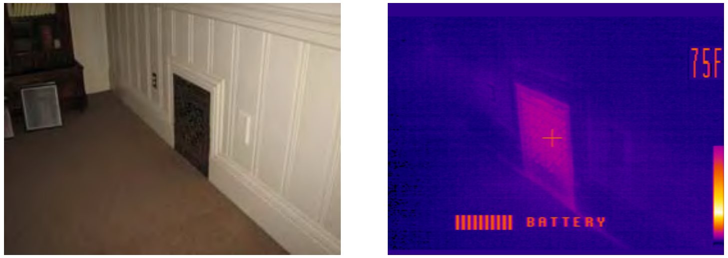
Distribution of Fresh Air and Warmth

Main Floor, historic wing

Distribution of Heat to 2nd floor, h



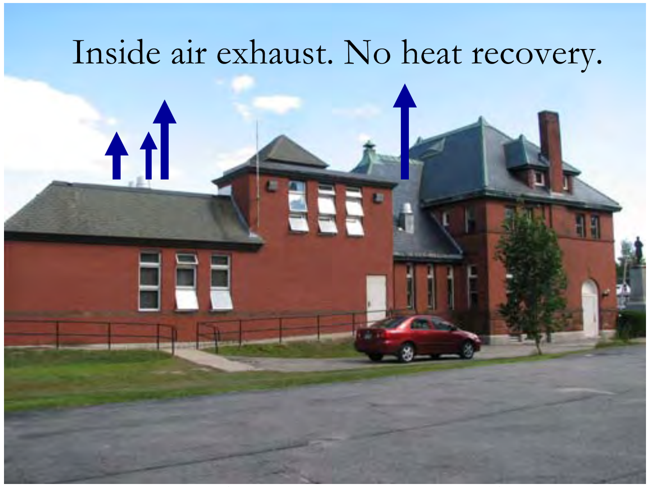




Air exchange and ventilation.

Fresh air ducted into Return air handler unit,

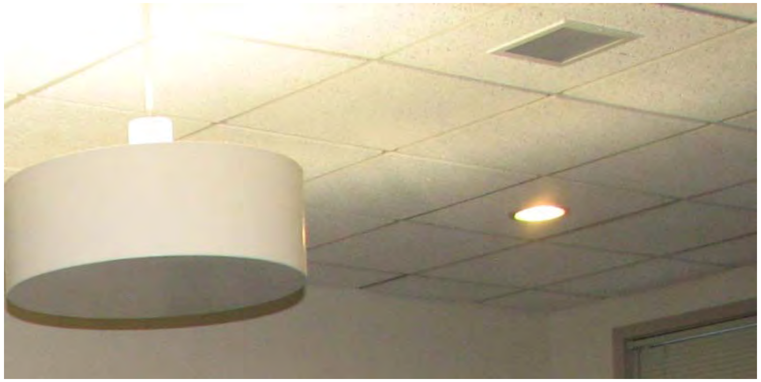
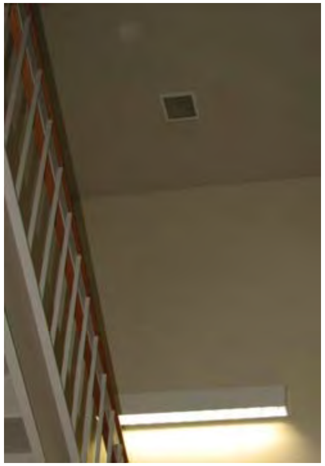
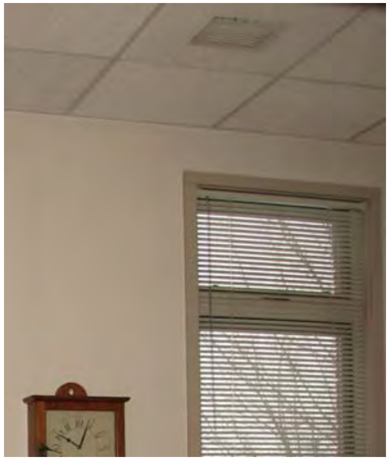
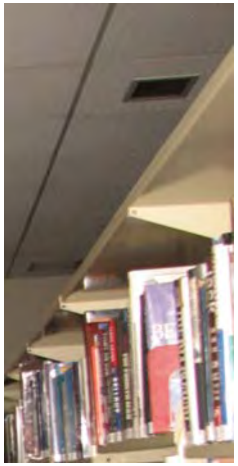
Fresh air drawn into boiler room for make up combustion air.



Plus uncontrolled air infiltration and exfiltration, mostly through window and door openings.

Outside fresh air (all year) drawn into three fan coil wall units. These openings were not sealed for the blower door test so are part of the total 12sf hole in the wall!

Exhaust vents in the new wing

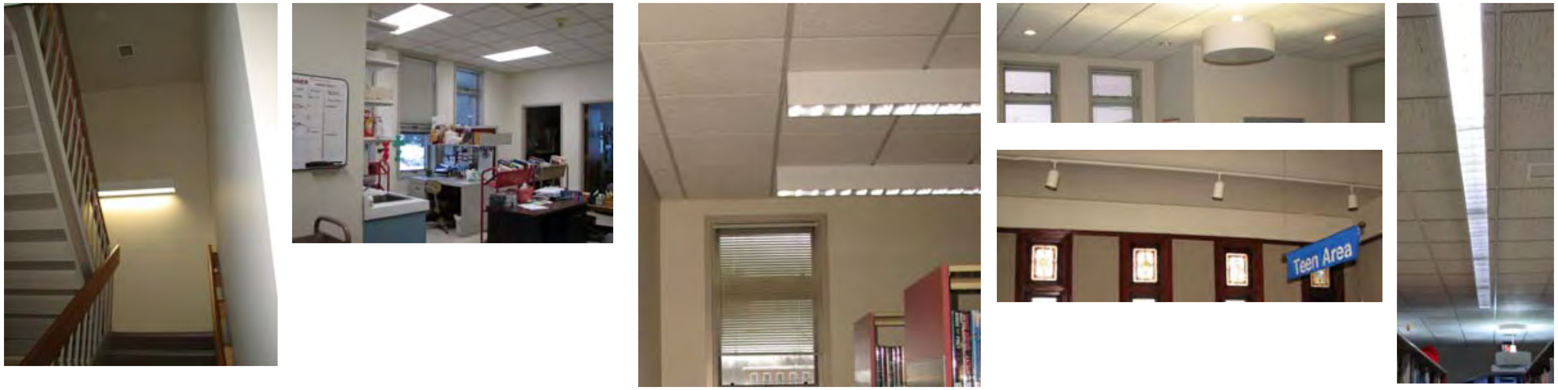

Hot water pipes run through fan coil unit which is also connected to outside fresh air grill. Delivers heated fresh air in winter and outside fresh air in summer. Small exhaust registers vent winter and summer air to outside.

Other Electric Loads

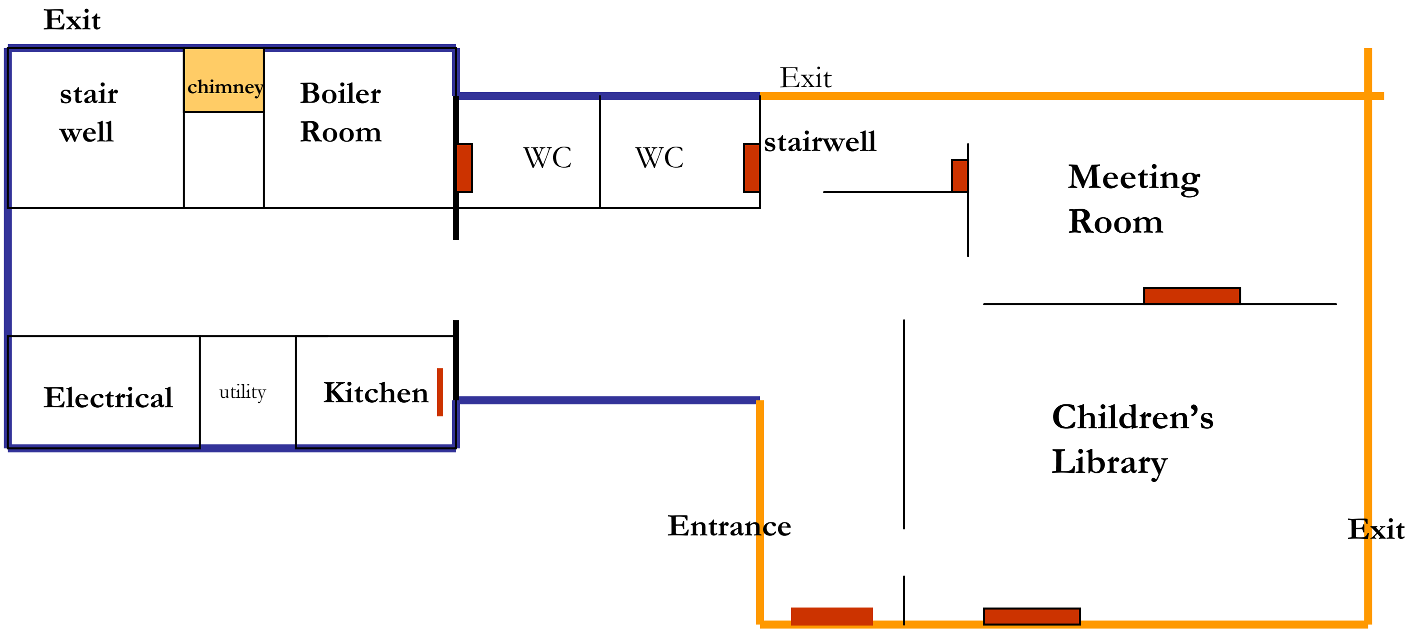
Computers

Kitchen appliances

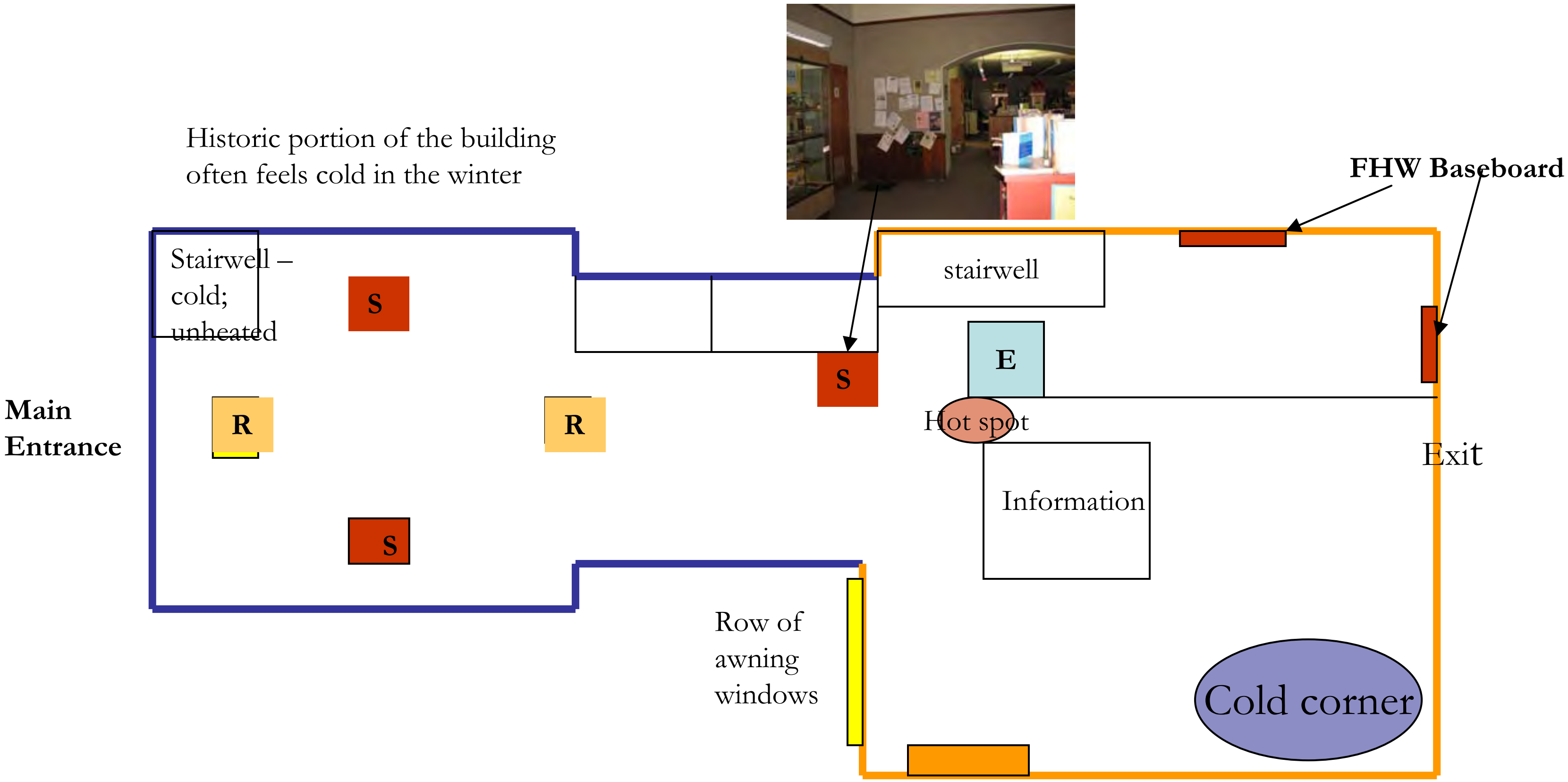
Lights



Conceptual Floor Plan
Basement



Conceptual Floor Plan
Main Floor



Historic portion of the building often feels cold in the winter

FHW Baseboard

Stairwell – cold; unheated

S

Main Entrance

R

R

S

S

stairwell

E

Hot spot

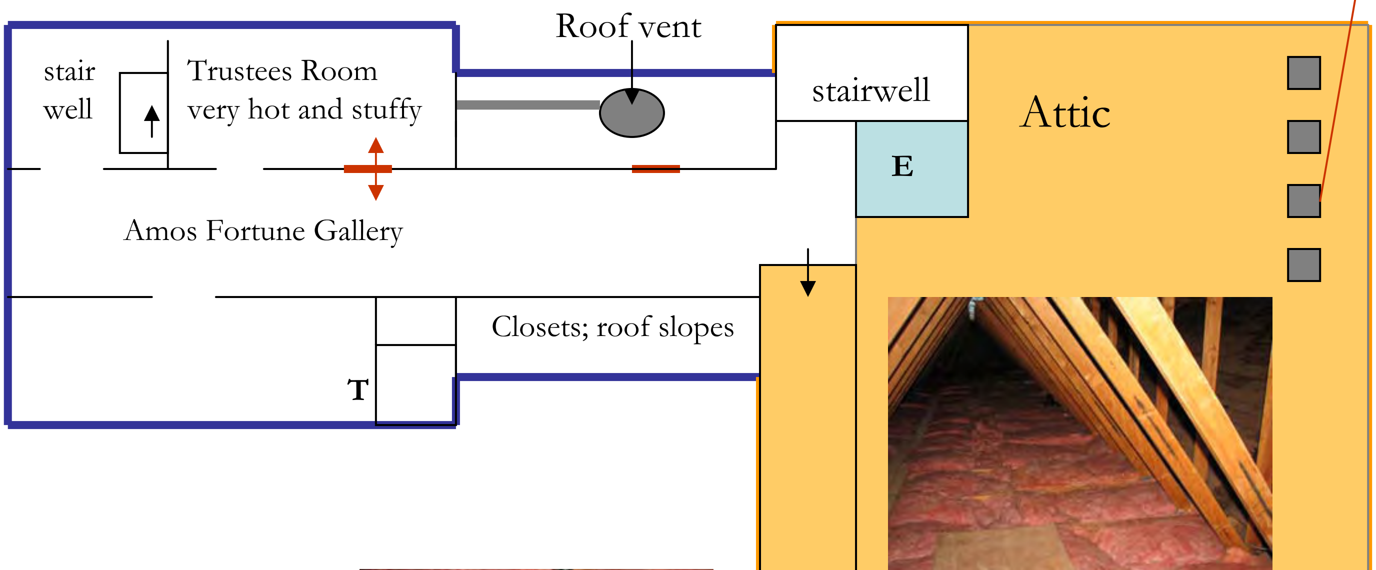
Exit

Information

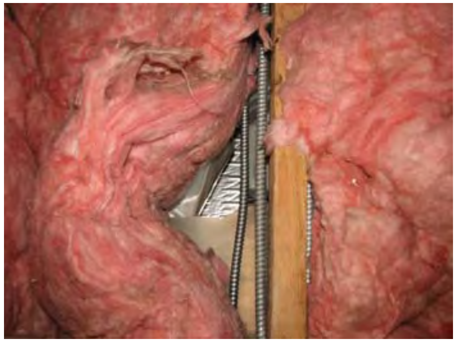
Row of awning windows

Cold corner

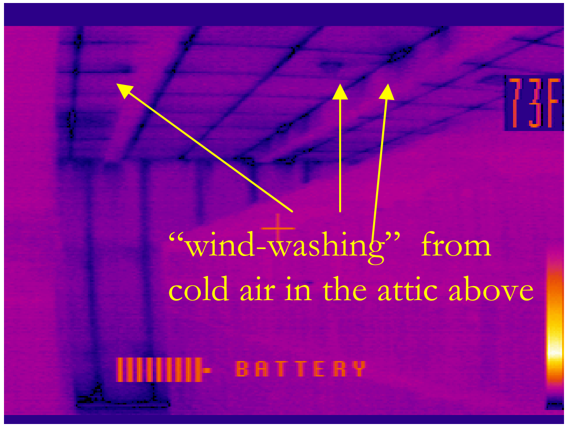
Conceptual Floor Plan
Second Floor



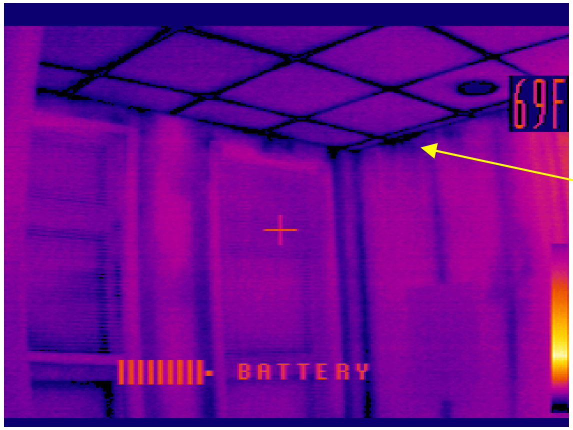
2x6 joists with 6” fg batts over layer of poly with holes and a layer of Reflectix. Then a 9” chase above dropped ceiling tiles. No continuous air barrier.



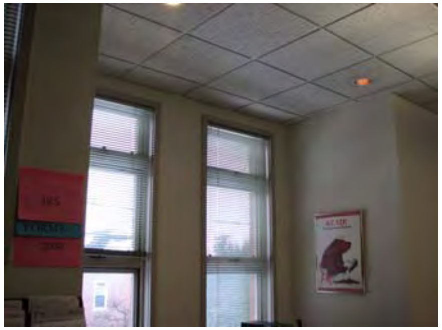
Infra red images of the Main Floor stack room ceiling indicate the lack of an effective air barrier in contact with the insulation.



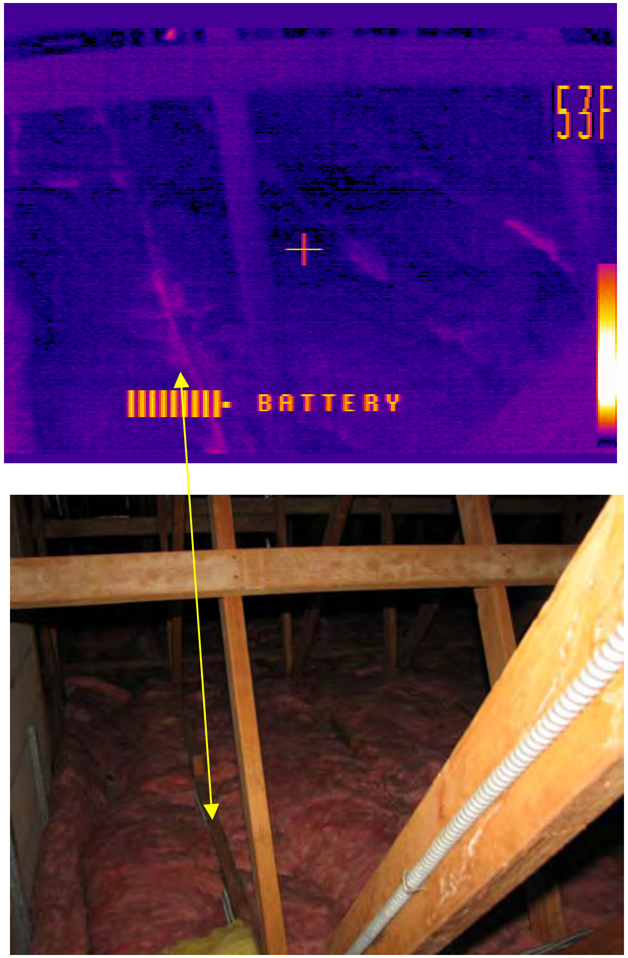
“wind-washing” from cold air in the attic above

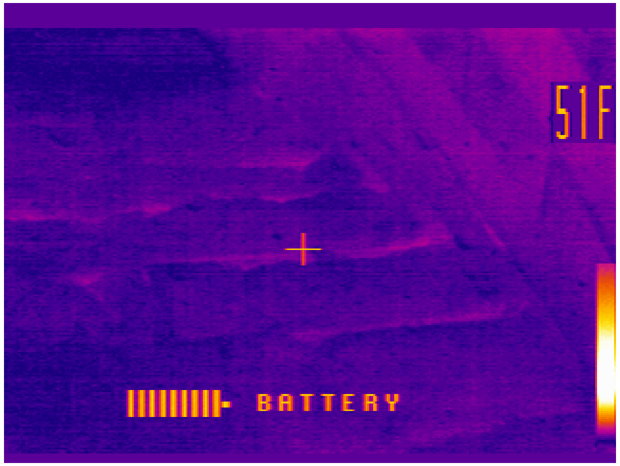


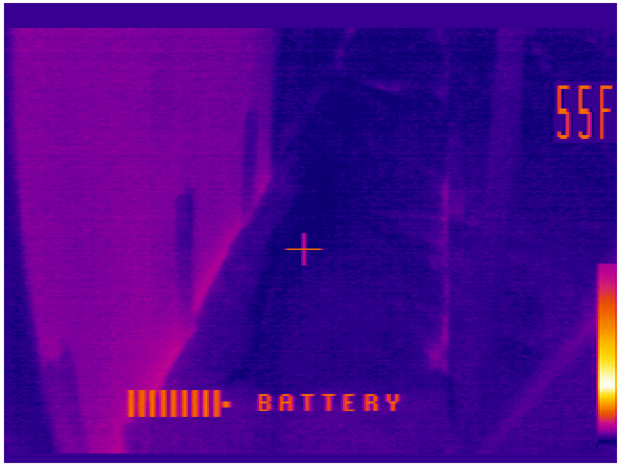
Cold, attic air being drawn down near the top plates and onto perimeter walls.

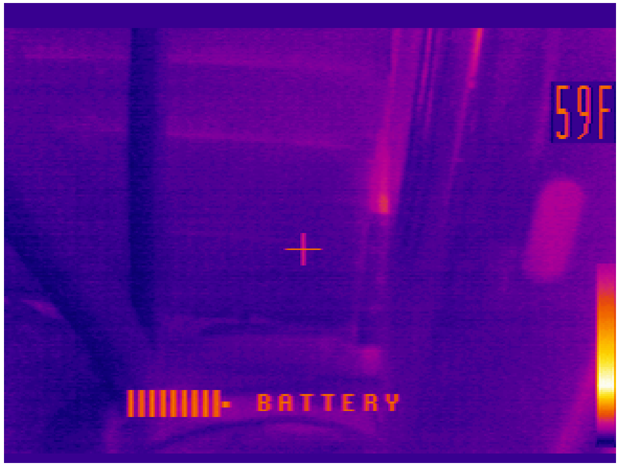


Looking at the insulation from outside conditioned space, note the relative warmth (brighter colors) especially above the wood joists. It was in the mid 30's outside at this time and 72° inside. In the low 50's, this "cold attic" is actually both inside and outside because of warm air rising and heat conducting to cold from the space below. Either way, the library is losing heat and money!

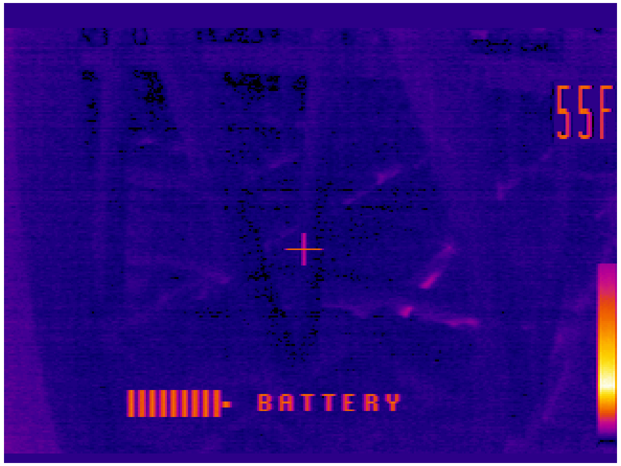


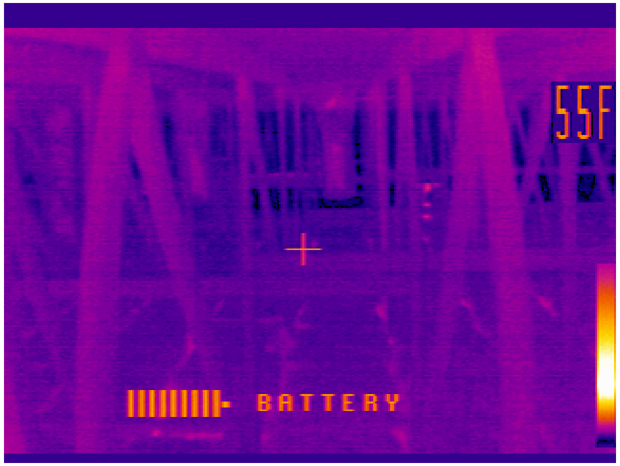






This is over the ‘hot spot’ area near the information desk.


55F
BATTERY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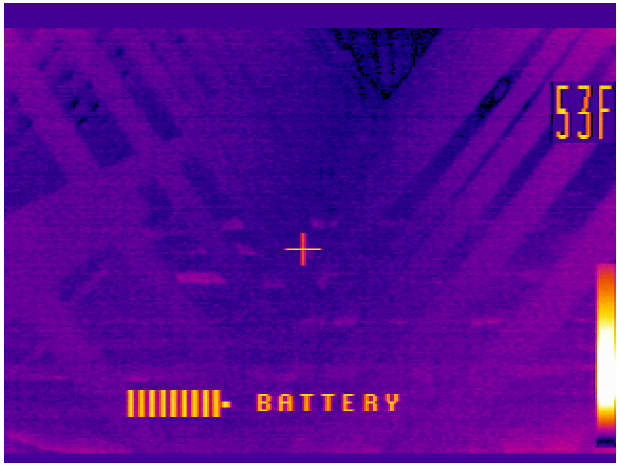
68F
BATTERY


53F
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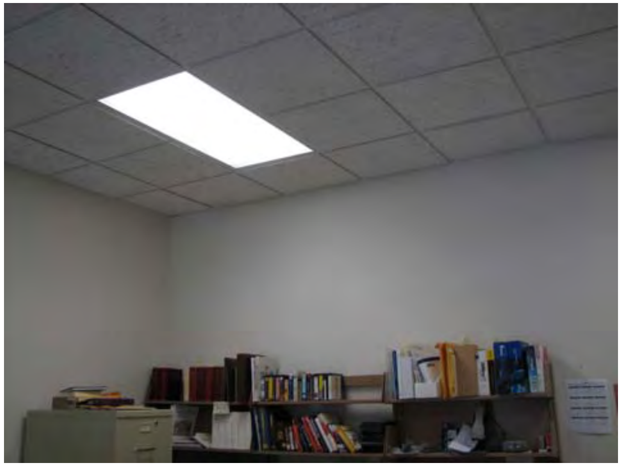
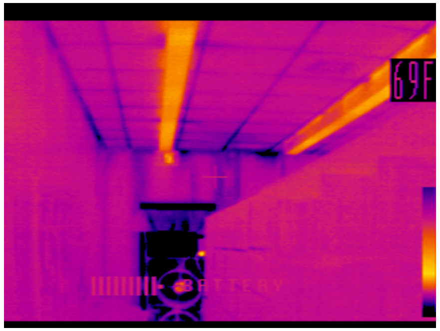
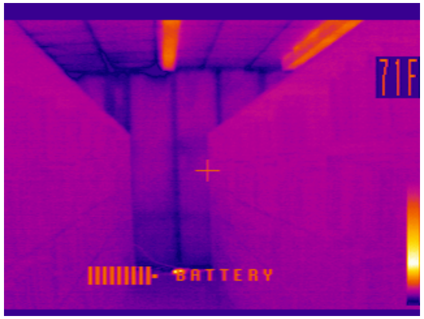
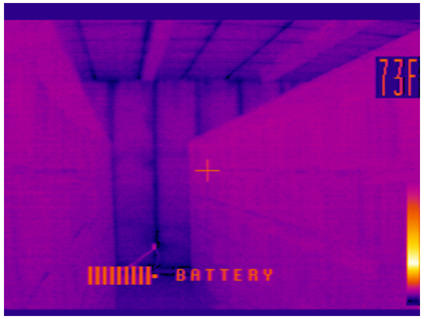
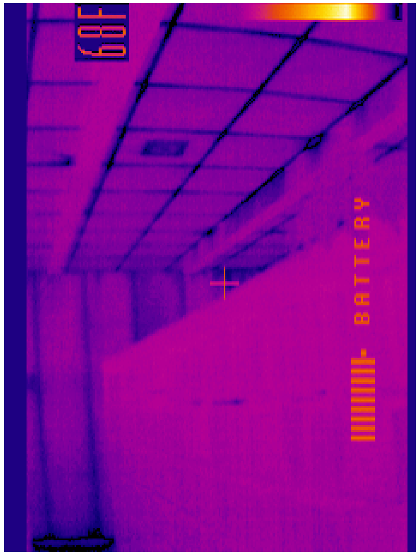


The vertical lines on the back wall depict thermal bridging at the metal studs. The black lines on the ceiling are more indicative of the shiny, reflective surface of the metal framework for the suspended ceiling. They may be cold too, but the camera is not adjusted for the emissivity of reflective surfaces.

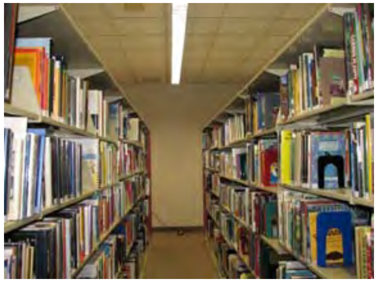


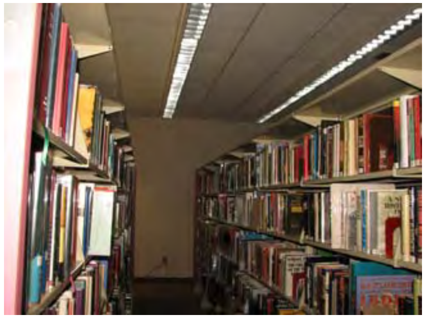


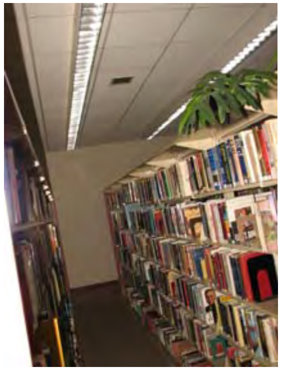




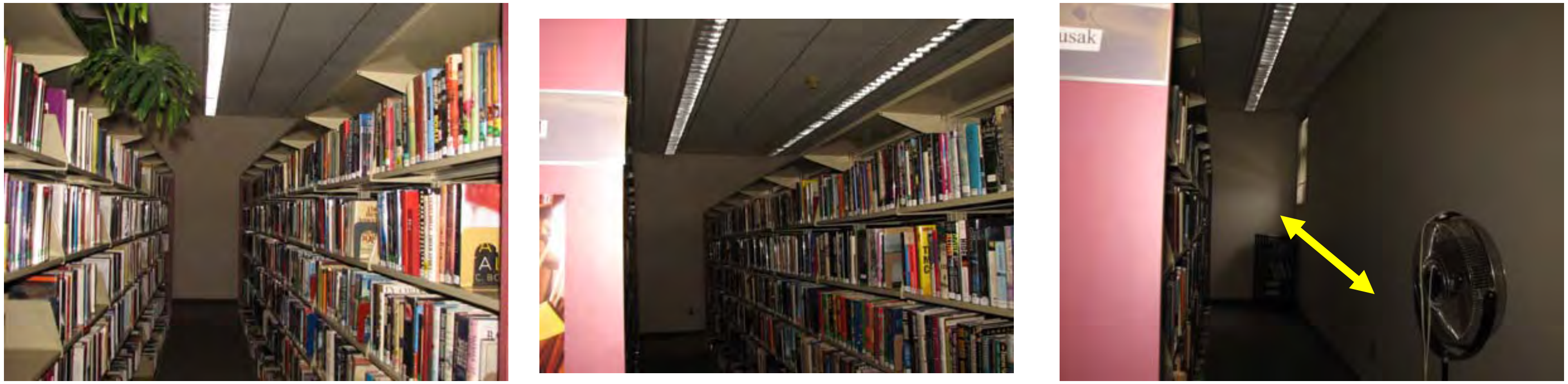
Thermal bridging is a significant factor in how a building loses heat.



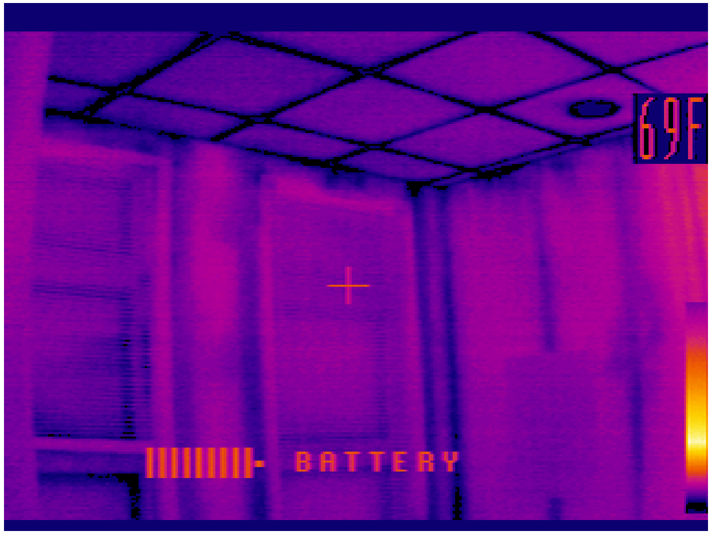


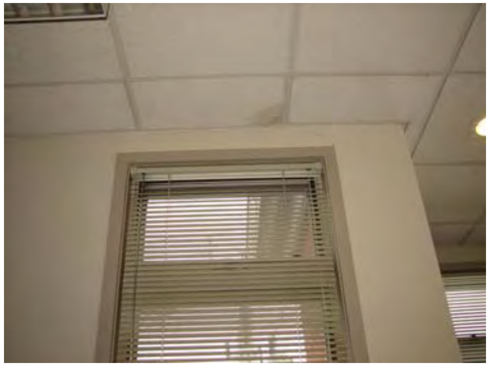


The fan below runs in the winter in an attempt to send heat to that cold corner. It is partly due to distribution issues, but far more to the air infiltration from the attic above and multiple metal studs in the corner.

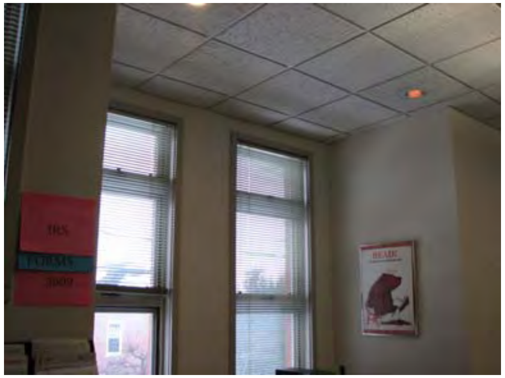


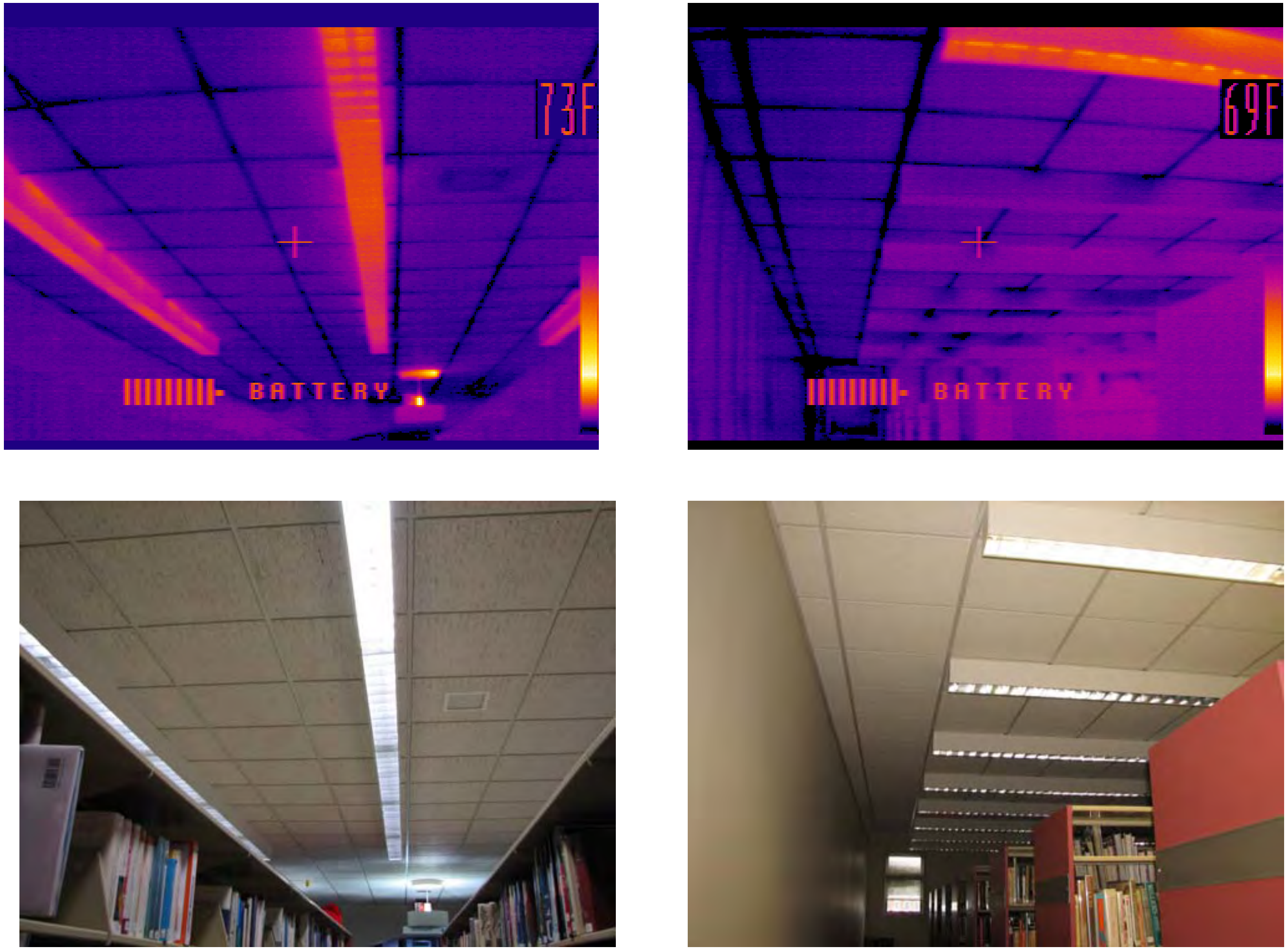
Air seal to reduce heat loss and the corner will be warmer on its own!





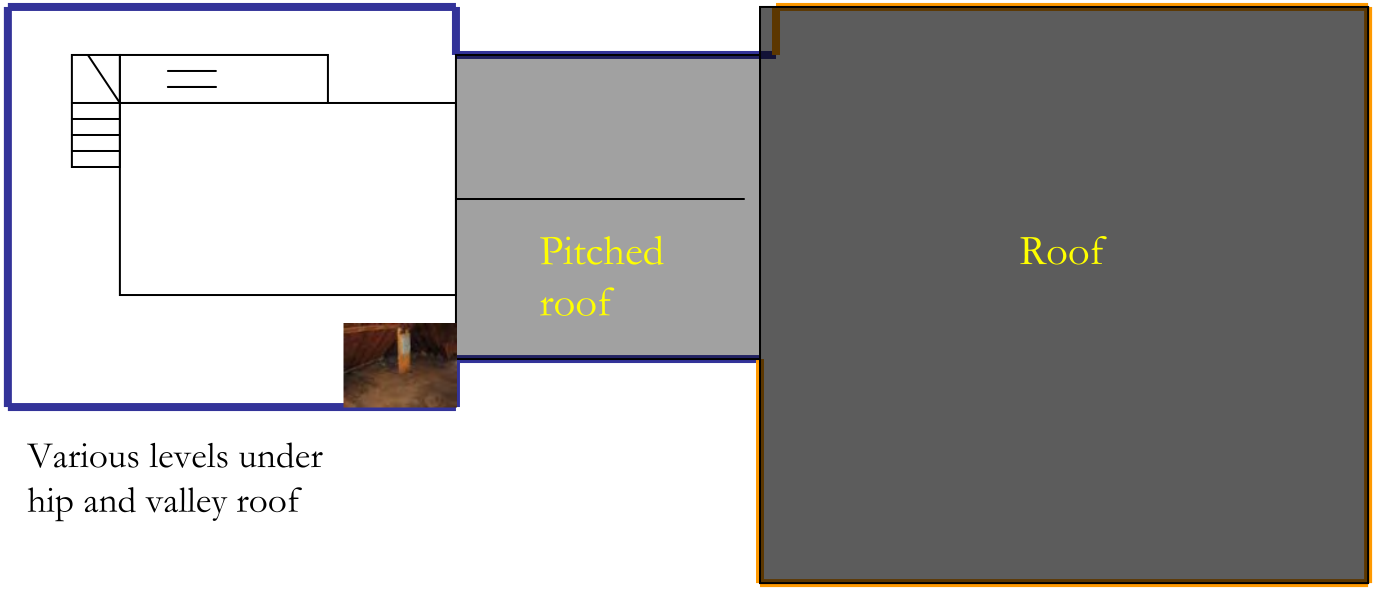
This air leakage is coming from both the attic and the rough window opening. Note the coldest part of the pattern to determine direction.





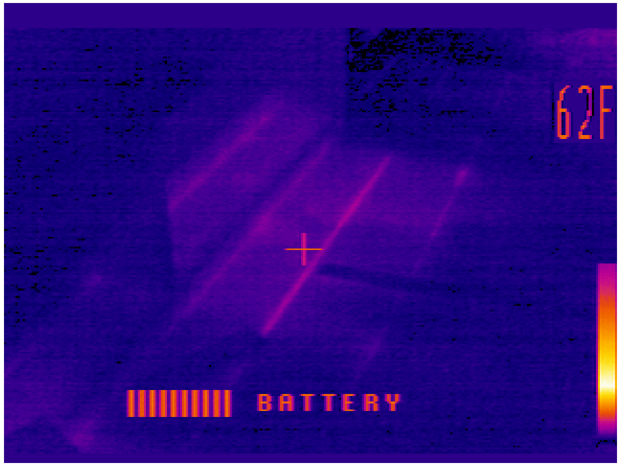
Suspended ceilings ***look*** like they form an air barrier…hence the saying “Eye tight is not Airtight”

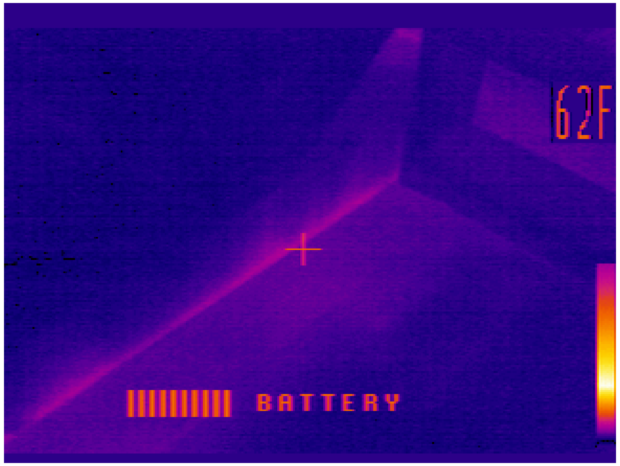
Conceptual Floor Plan
Original Attic

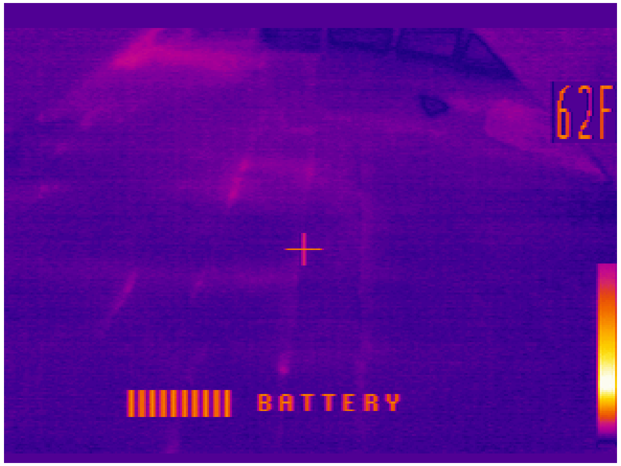


Various levels under hip and valley roof

There is insulation below the floor boards, but an unknown amount and without an air barrier, its potential effectiveness is greatly diminished.






62F
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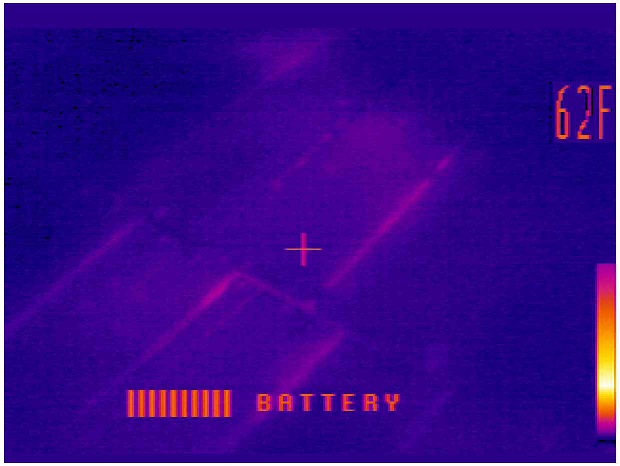
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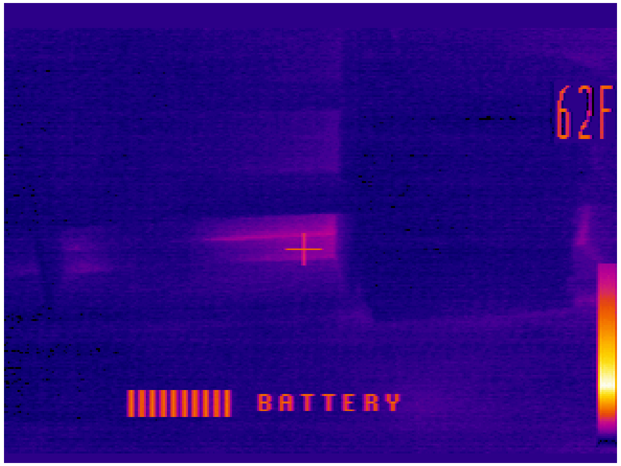
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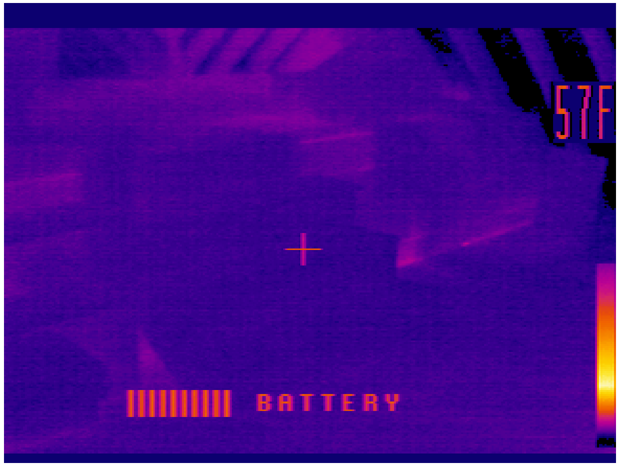
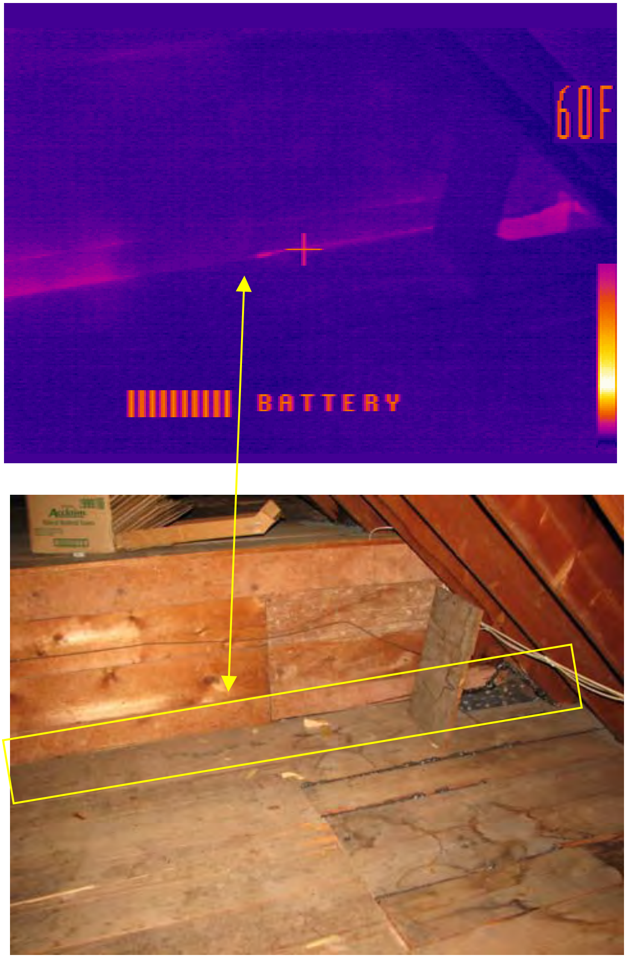
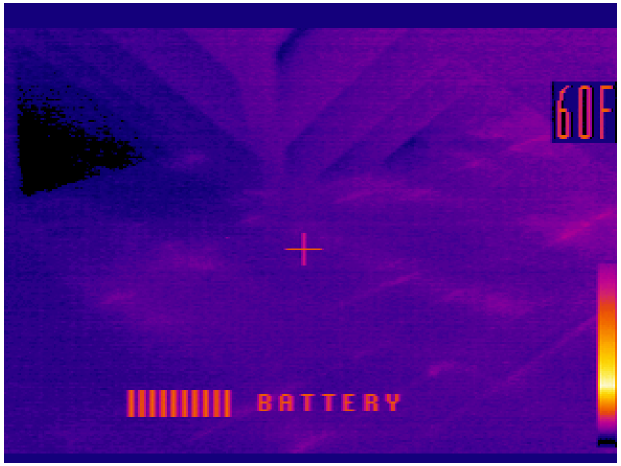

57F
BATTERY

In fact, while adding insulation would also be advised, “simply” establishing a continuous air barrier would make a significant difference to this attic and the library as a whole.

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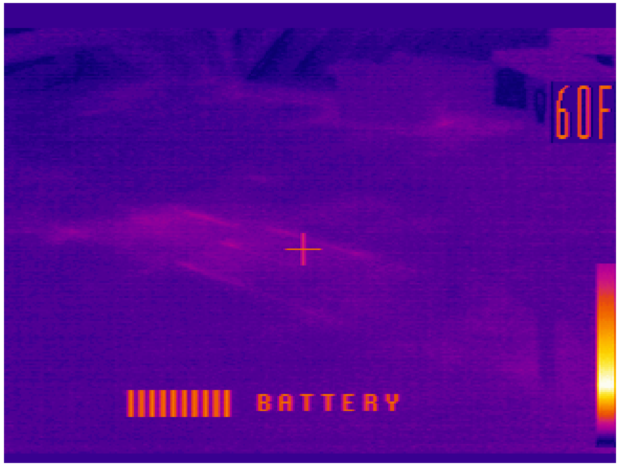
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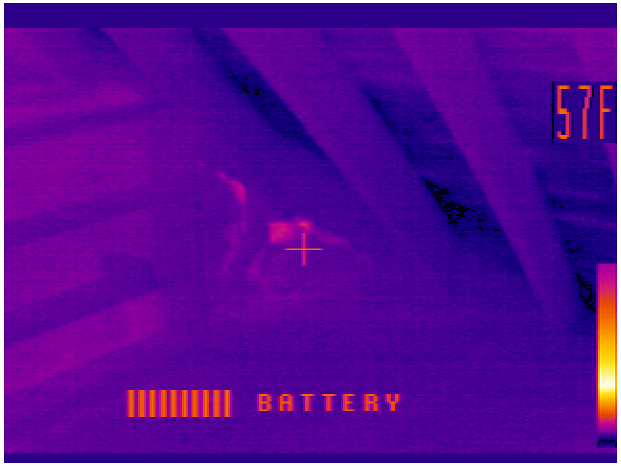
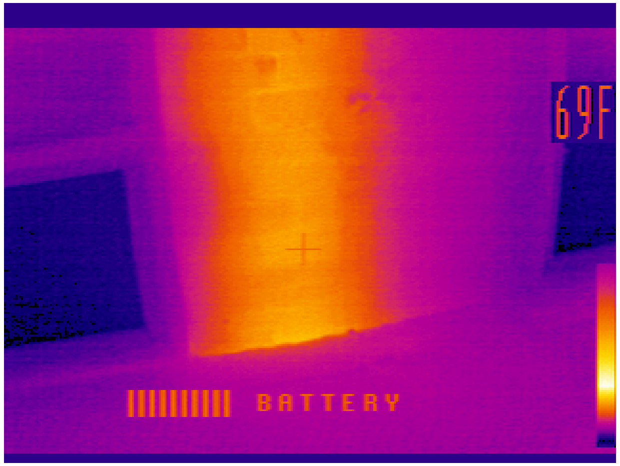
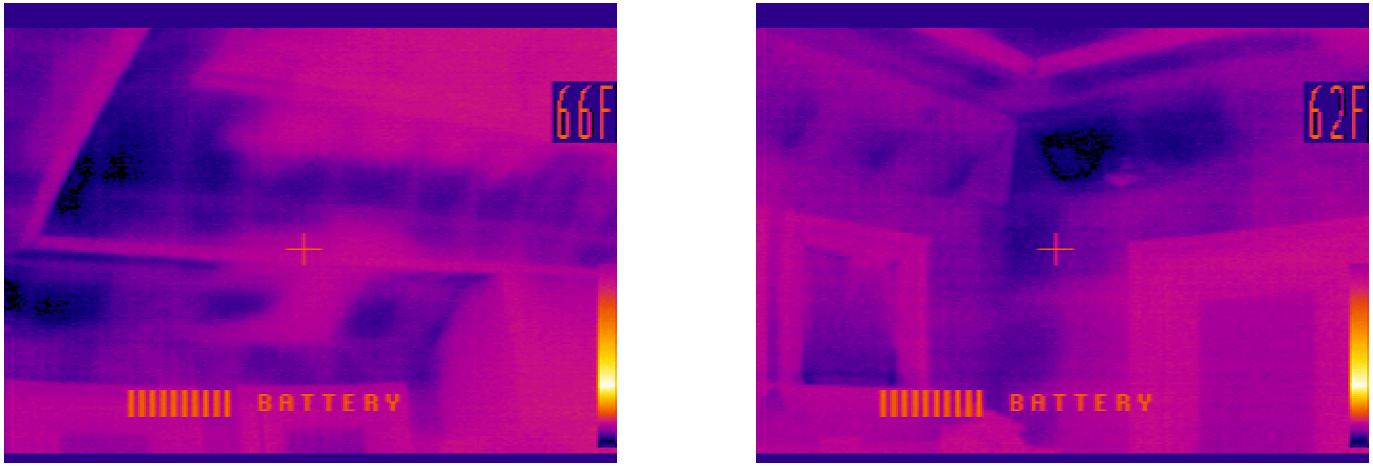


Includes flashing the chimney, though this brick will still be a source of warmth in this “cold attic”

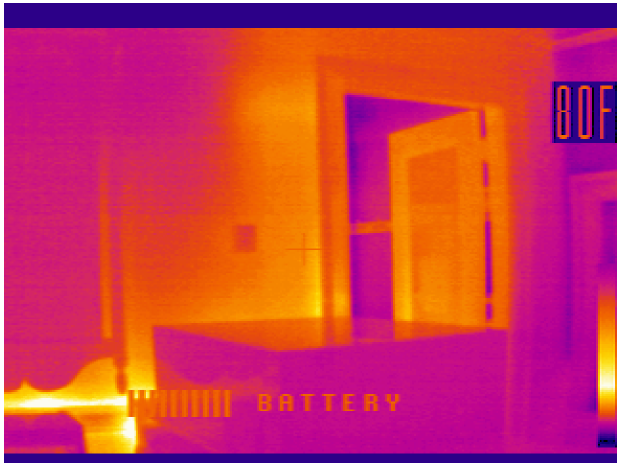


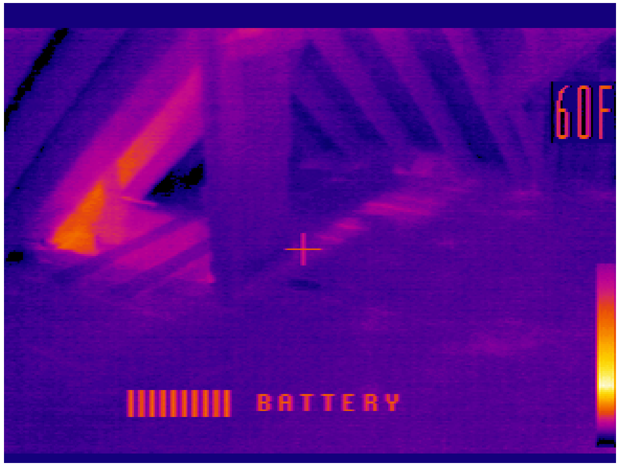
And looking up at the ceiling from underneath….

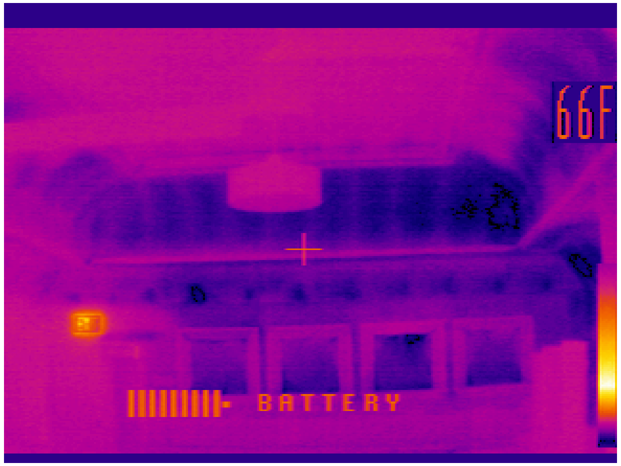


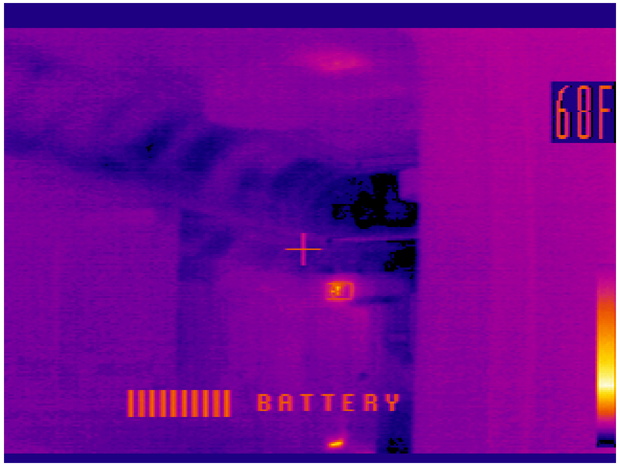
Blown and batt fiberglass insulation can be seen in the attic, however the raised dais over this vaulted ceiling area appears to be minimally insulated, especially at the sloped perimeter. There does not appear to be a continuous air barrier. Insulation levels and effectiveness can only be roughly guestimated.

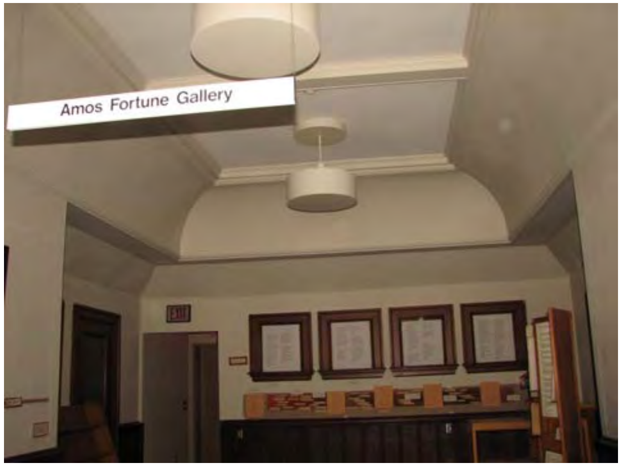
This connection between conditioned and unconditioned space is significant – especially and partly because of the high temperature of this corner on the 2nd floor. The attic should not be 60º - a result of an inadequate air and thermal barrier; but this room corner should not be heated to 80º. That's an issue of the heating and distribution system.



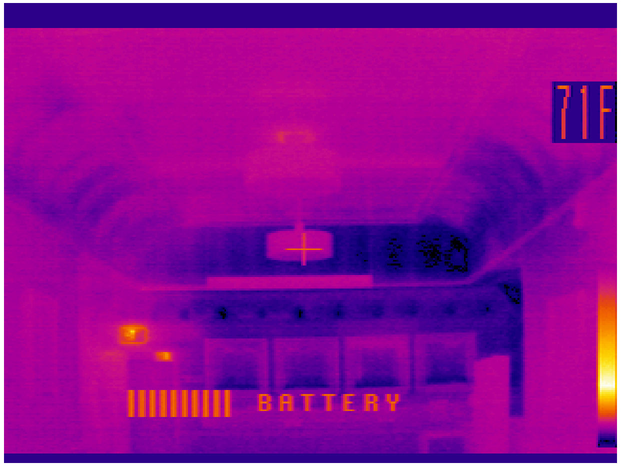


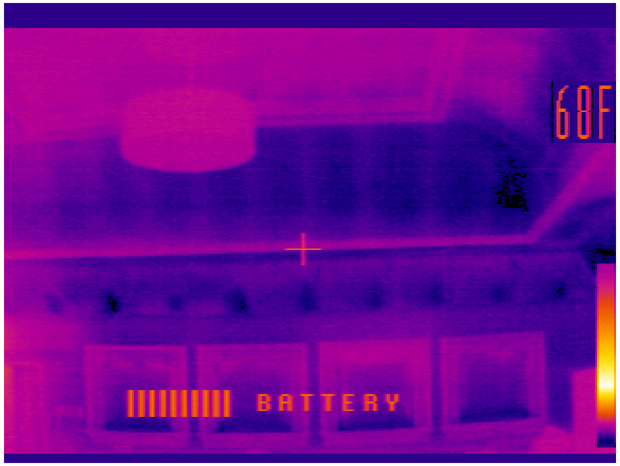

66F
BATTERY


68F
BATTERY

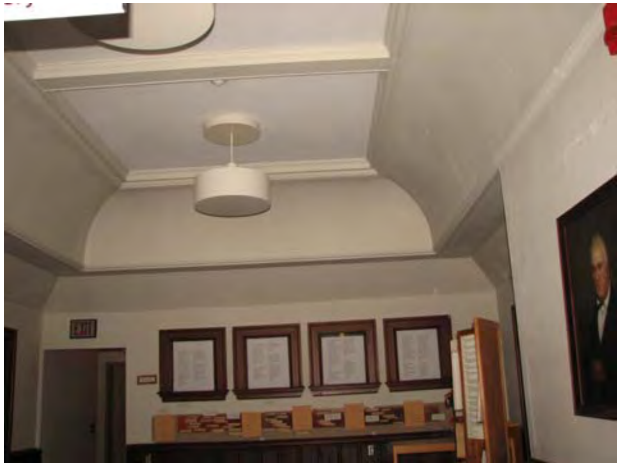

Amos Fortune Gallery
EXIT


Amos Fortune Gallery


71F
BATTERY

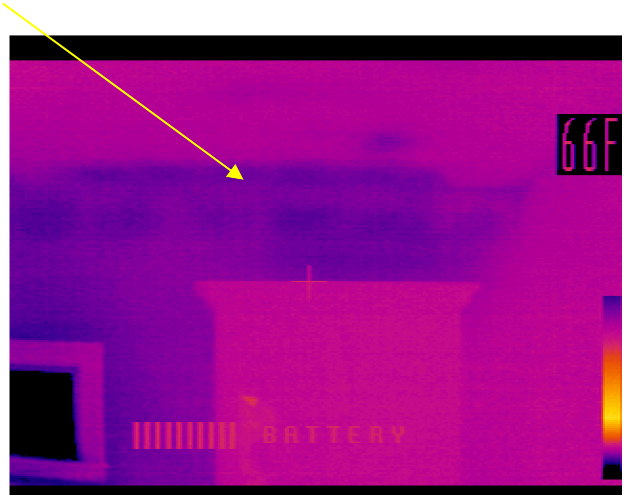

68F
BATTERY

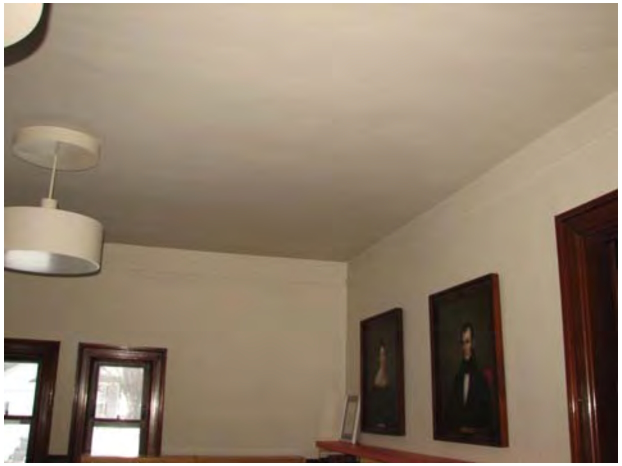

Amos Fortune Gallery

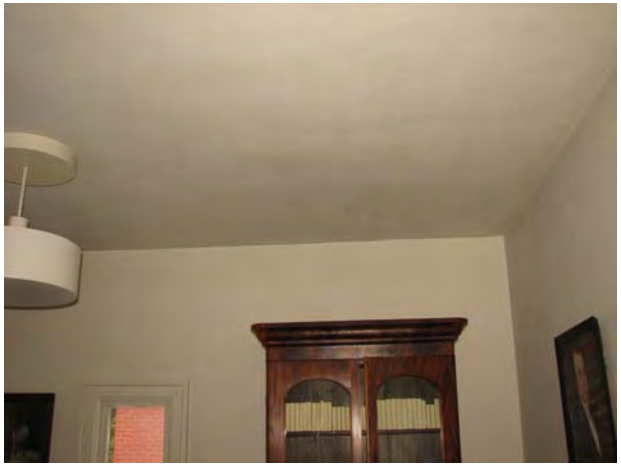


This appears to be a framed section of wall above the stone or brick- and an opportunity to insulate from above. Cellulose or even foam is recommended. Not fiberglass.

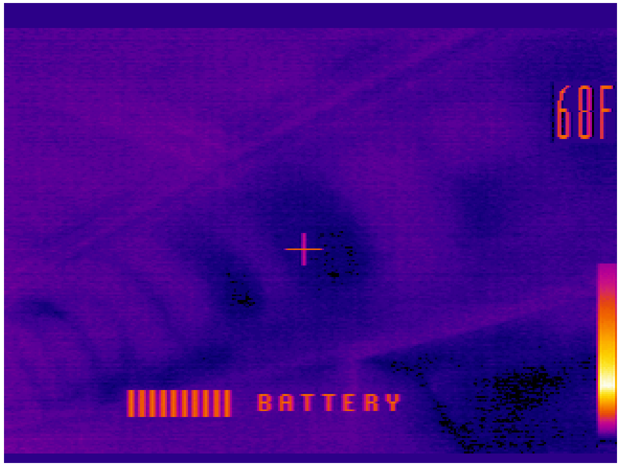
More opportunities which could be accessed from above

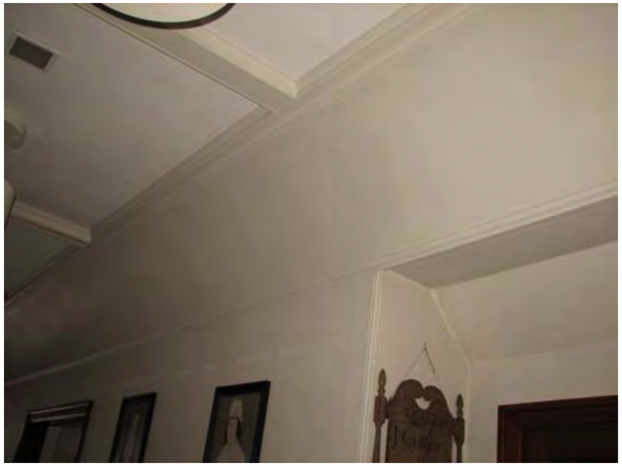


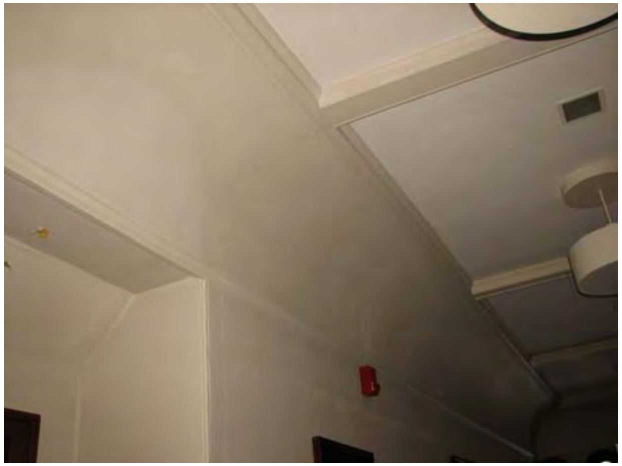


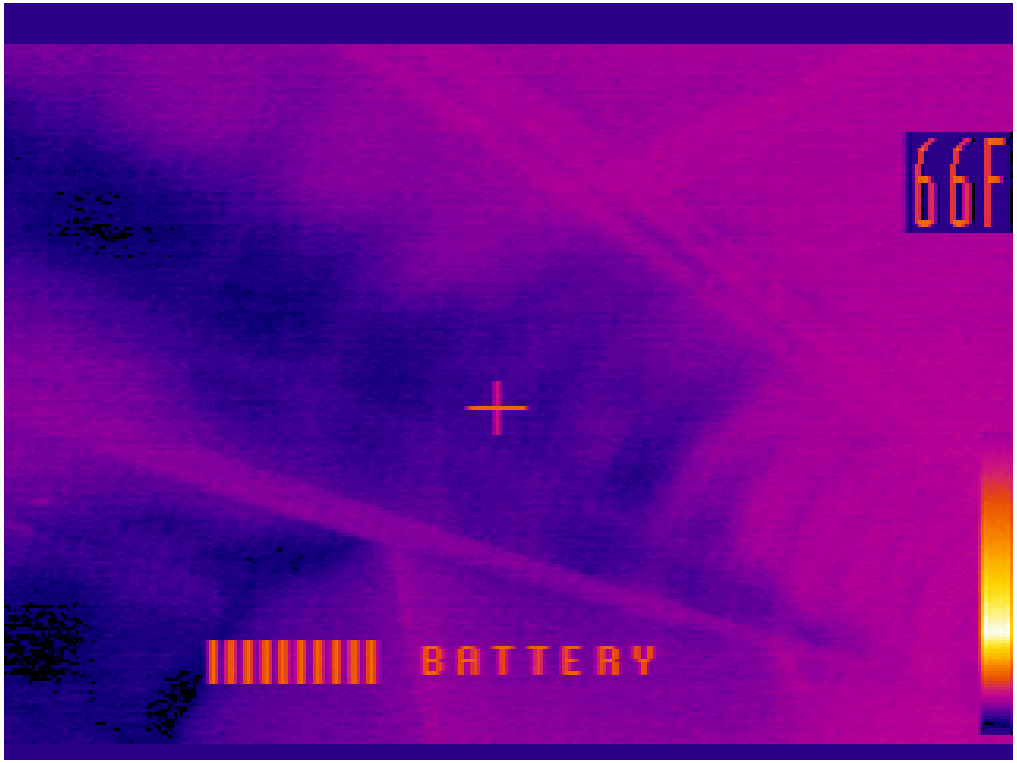


Single pane fixed windows are the coldest spots on this wall – then air leaking through double hung operable windows, then the window glazing itself – and finally, wall and ceiling cavities void of insulation. Energy conservation in buildings and historic preservation are often in conflict as thermodynamics is only influenced by material conductivity, thickness of that material, surface area, and temperature difference between inside and out.





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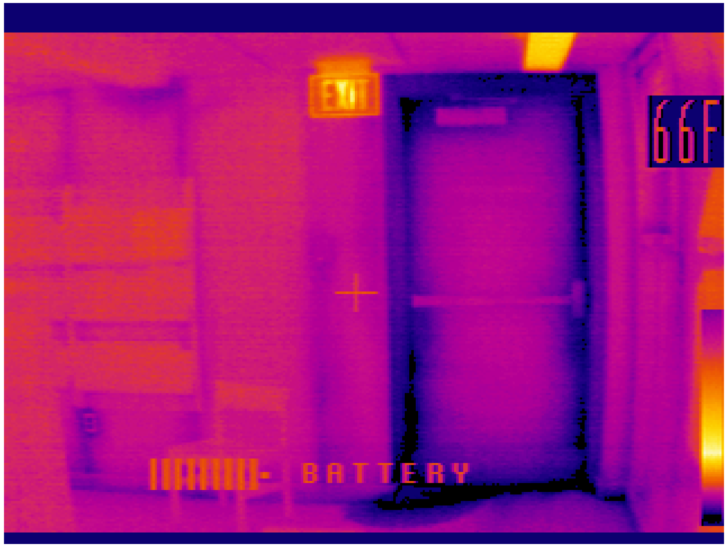
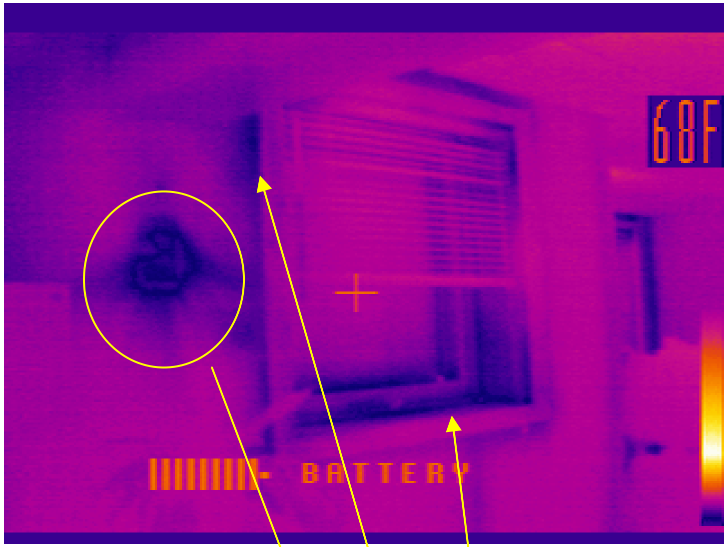
BATTERY

General Air Sealing Opportunities

Windows, doors, and even wall outlets are all 'holes in the envelope'. If they are not air sealed, they are a source of heat loss in the winter – and heat gain in the summer.

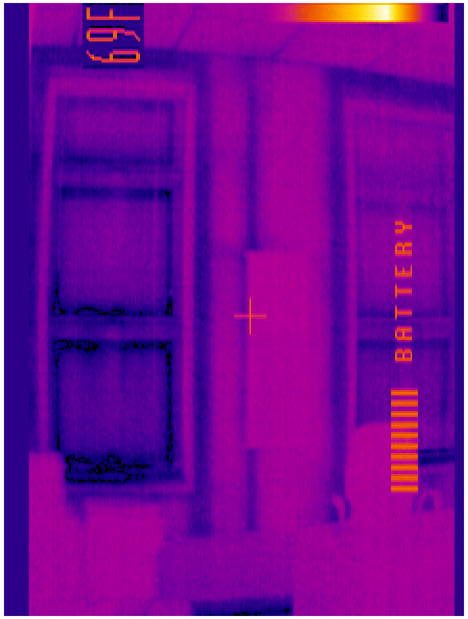


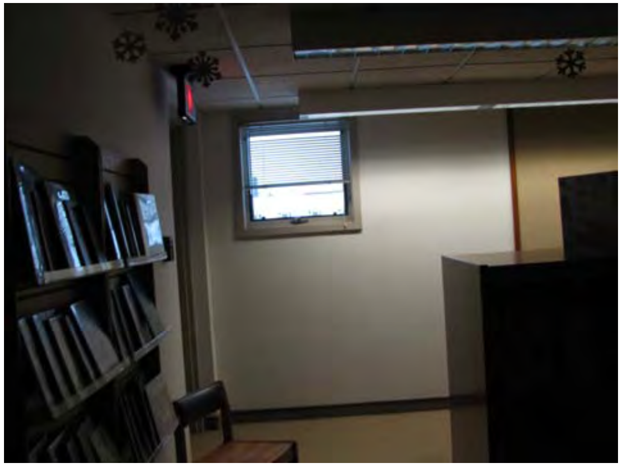


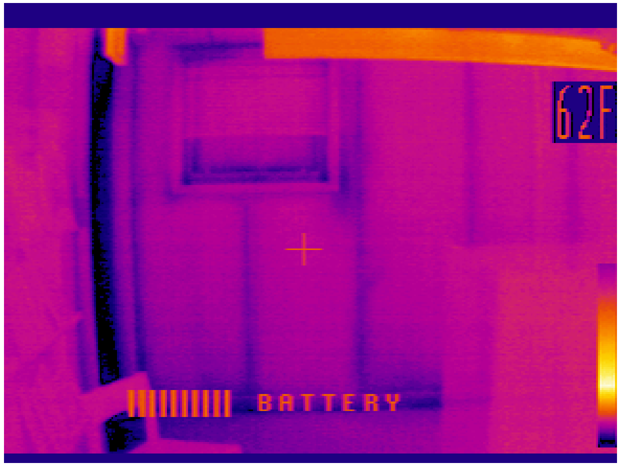
Dark colors indicate colder surface temperatures.

And the reality is, newer buildings are often leakier than many older buildings.

Windows

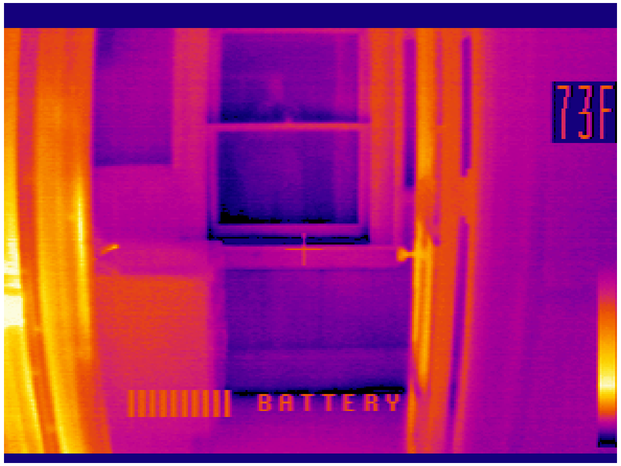




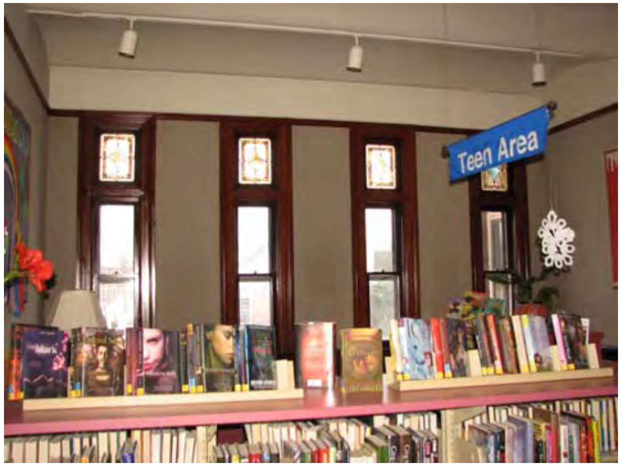


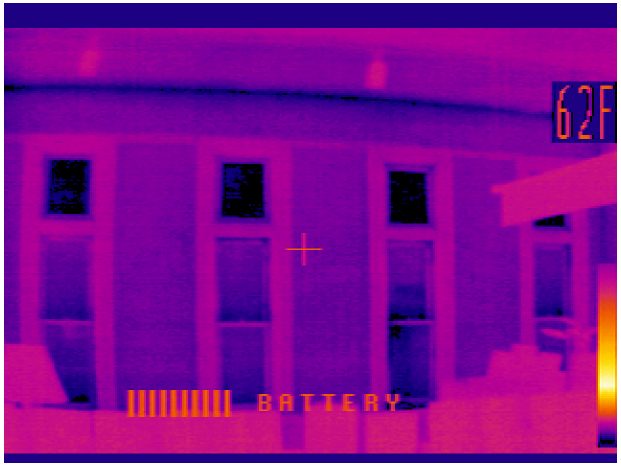

64F
BATTERY


62F
BATTERY


73F
BATTERY

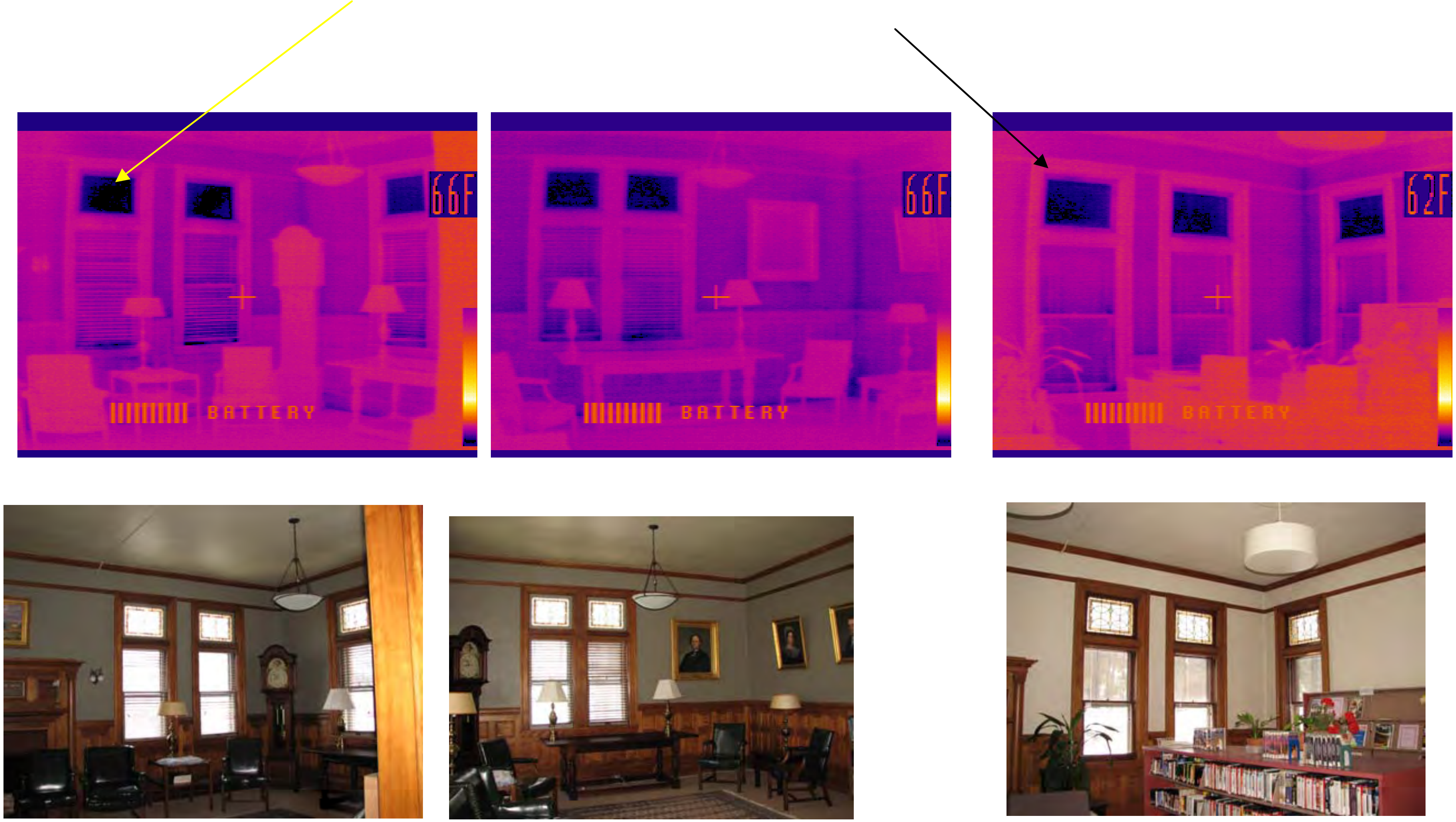

66F
BATTERY



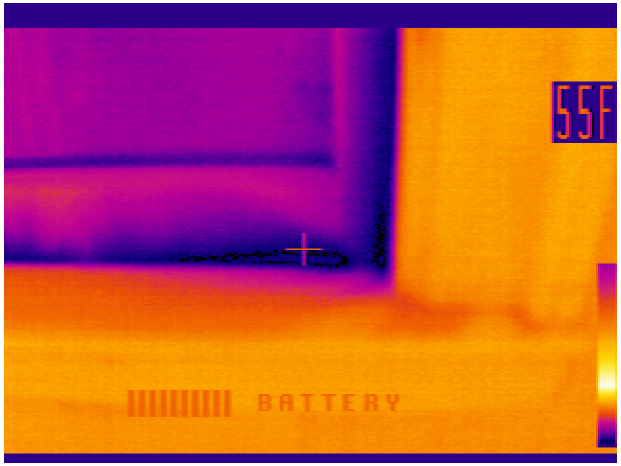


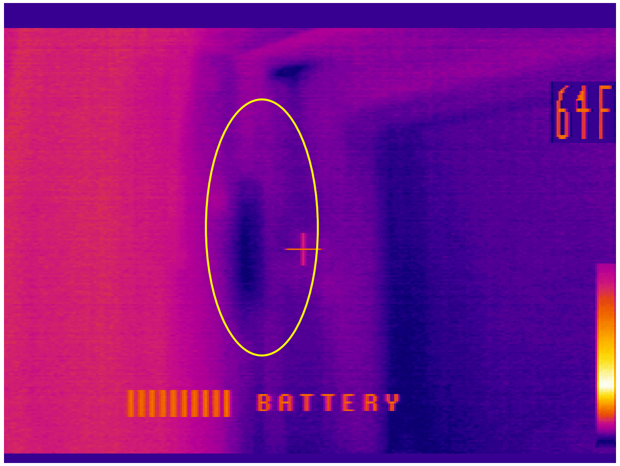
Recommend interior, therma pane, air sealed, storms on all fixed panes, and to consider removable interior storms for the operable sashes.

Note the dramatic difference between the fixed panes and the windows, and walls, below. And they add up in surface area as well!

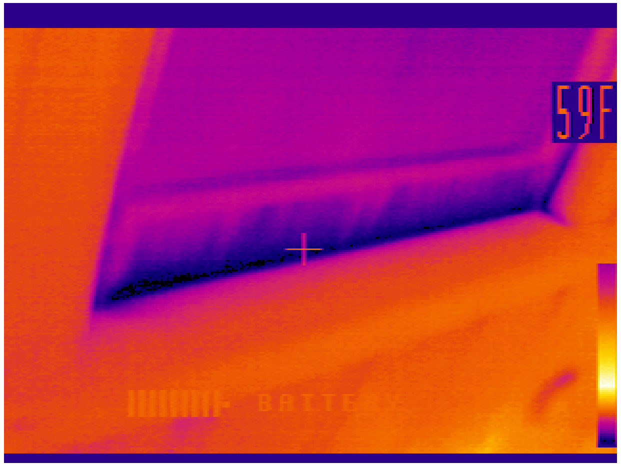


Metal tension spring tapes have become an acceptable replacement for rope and pulley systems which then allow for the weight cavity to be filled and air leakage reduced.





Window Masters of Dublin has tremendous experience and success with retrofitting historic windows; mixing craftsmanship and preservation goals with energy conservation.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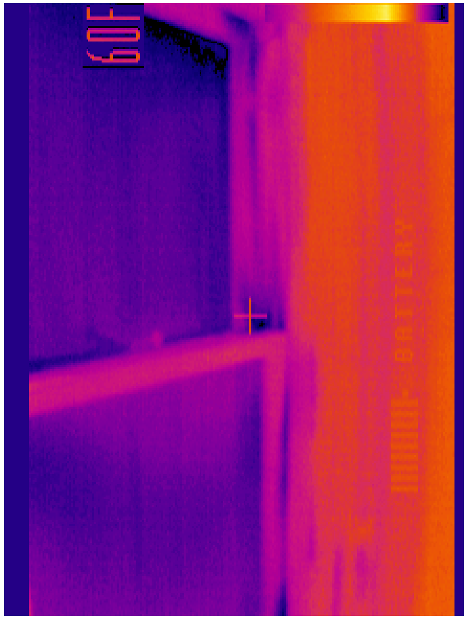
BATTERY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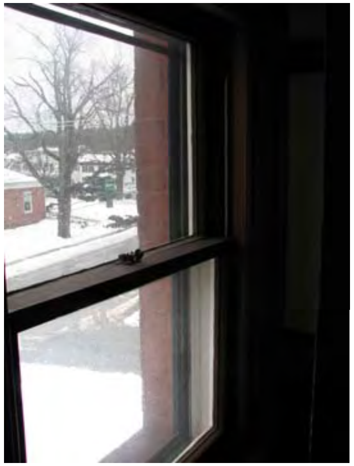

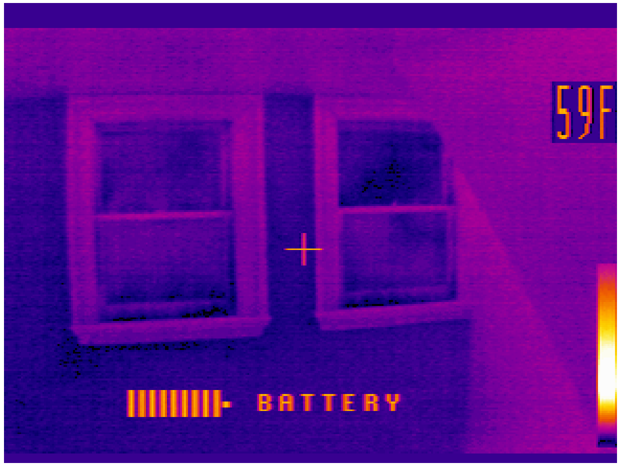
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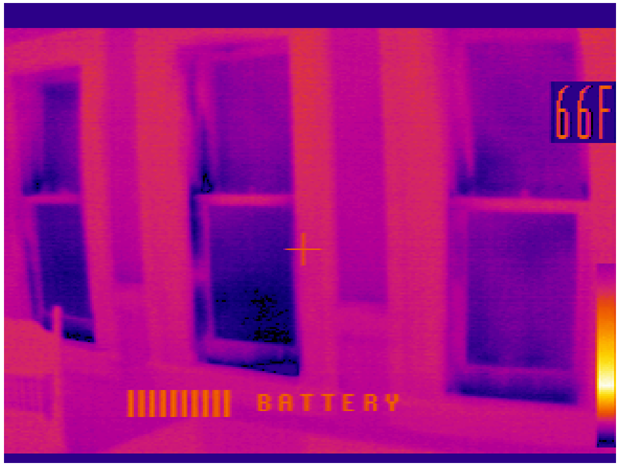
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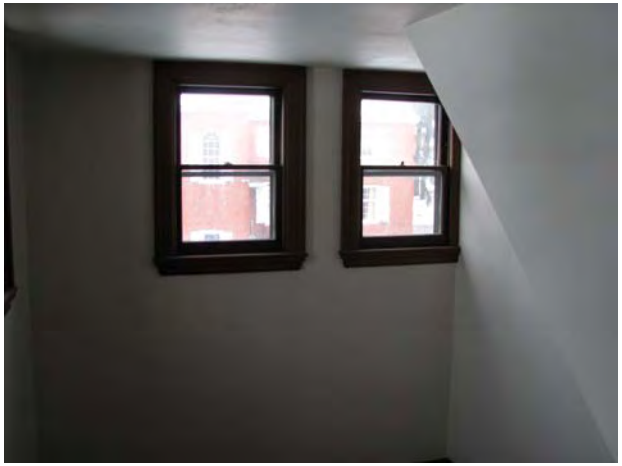


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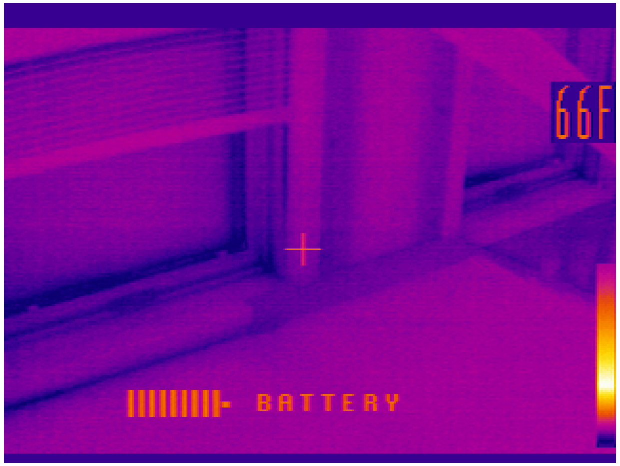
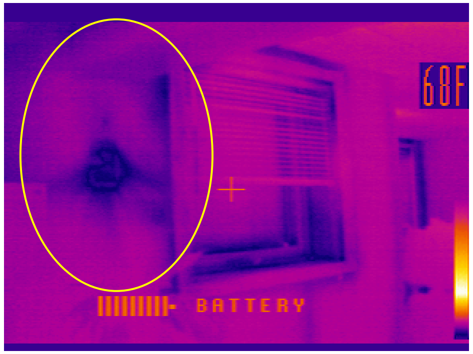
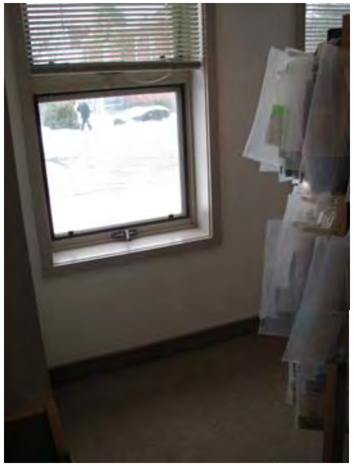
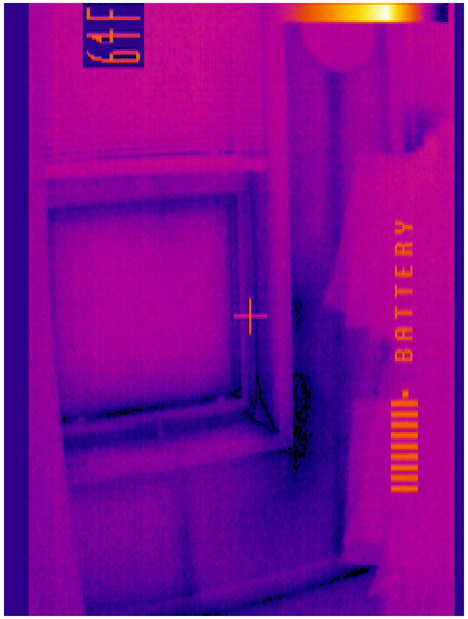

66F
BATTERY


COZY
UP
WITH
A
BOOK

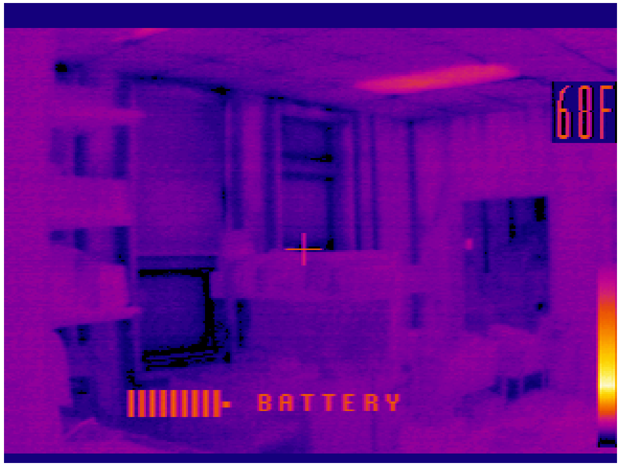
And newer construction practices sometimes waste more energy.







It can surprise people, but newer windows are often just as ‘leaky’!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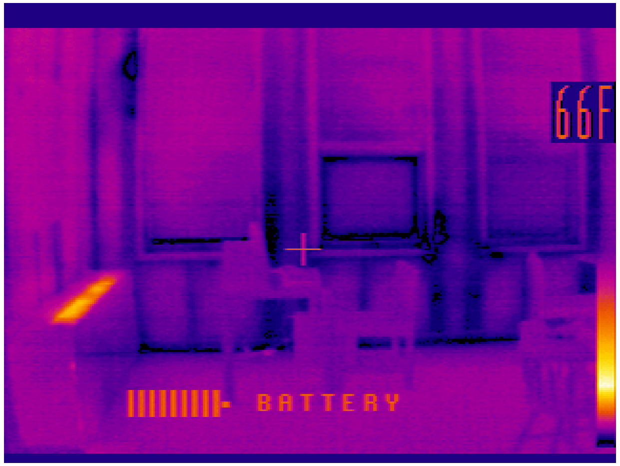
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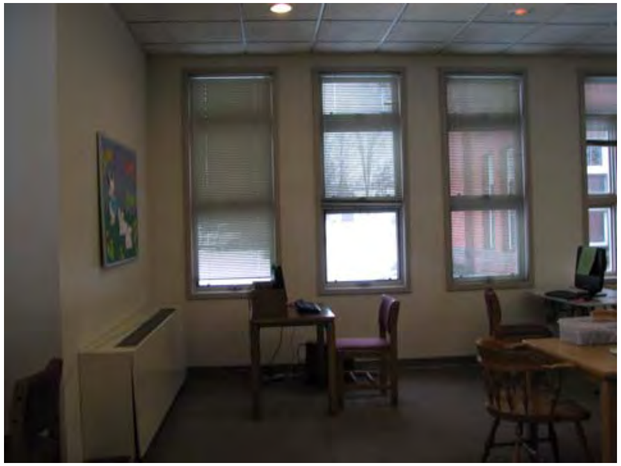
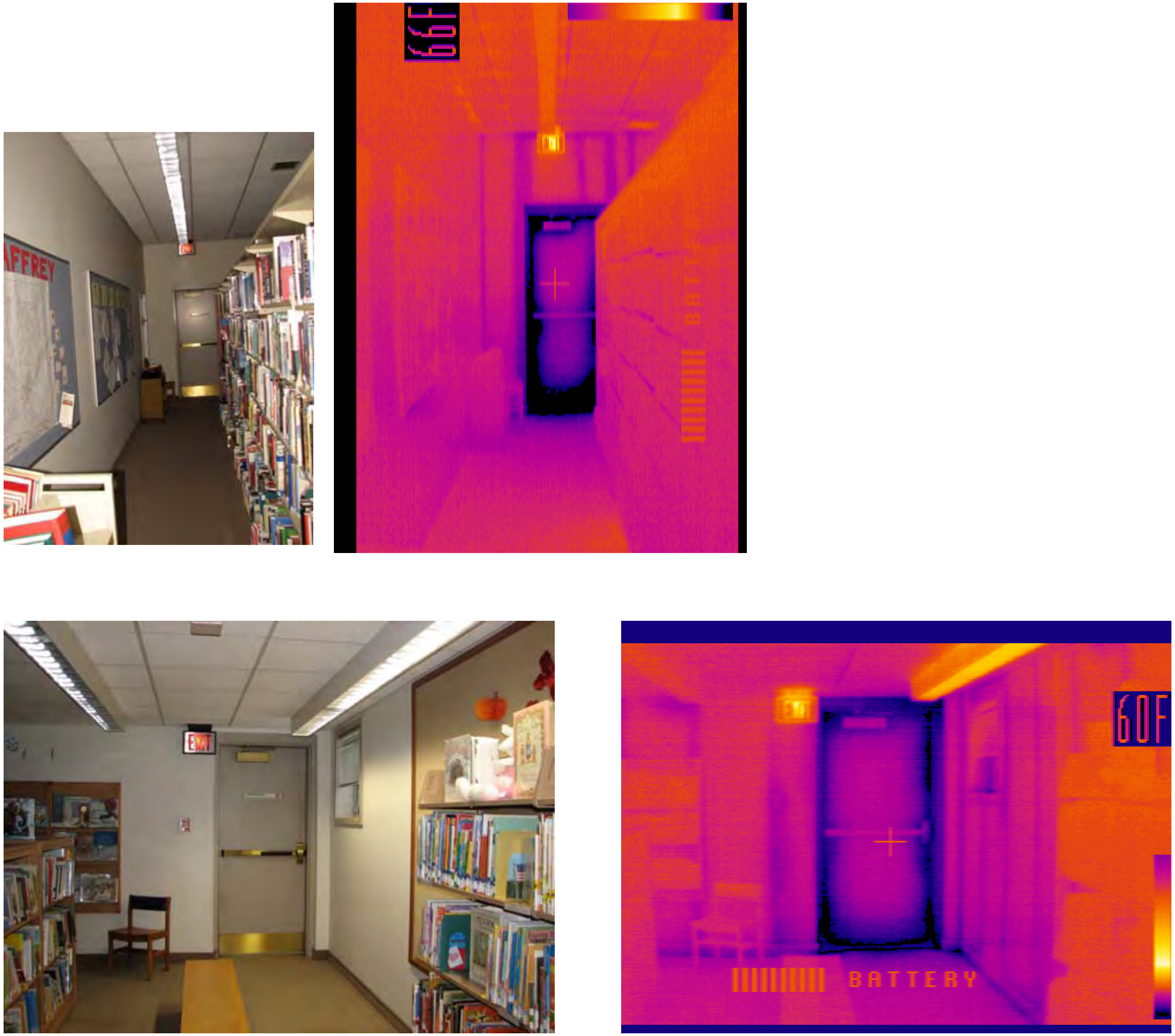
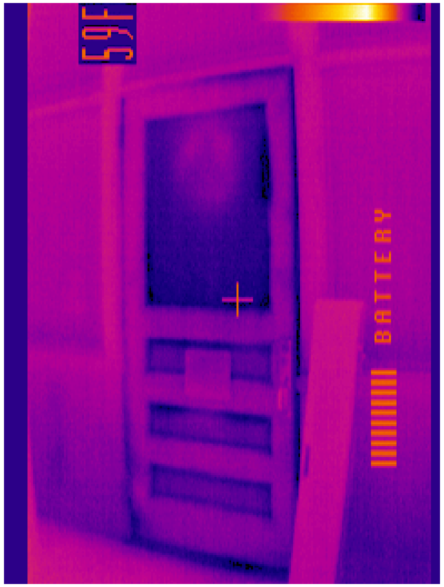


Doors

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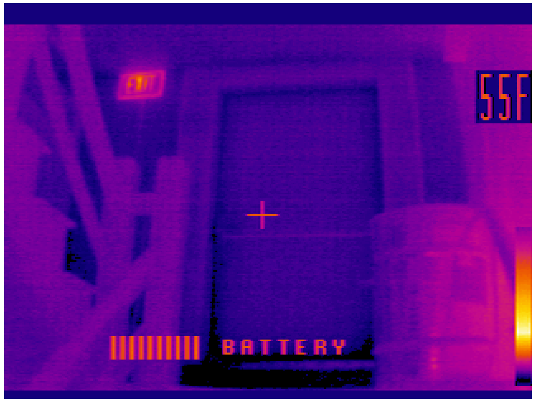
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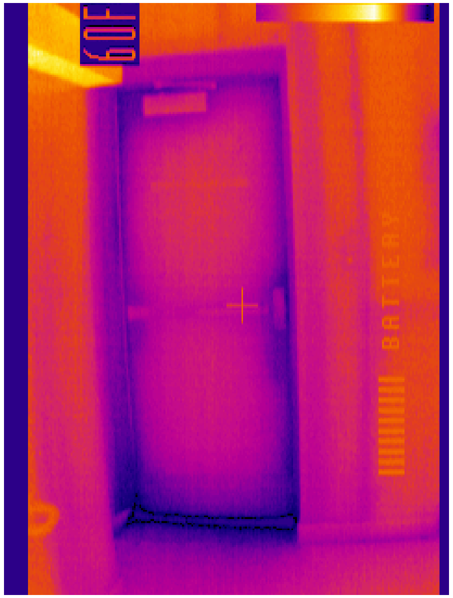
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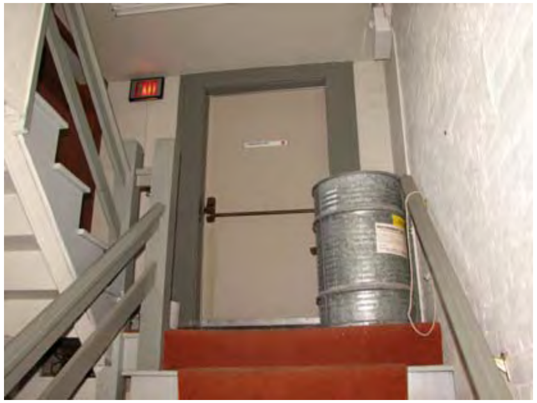
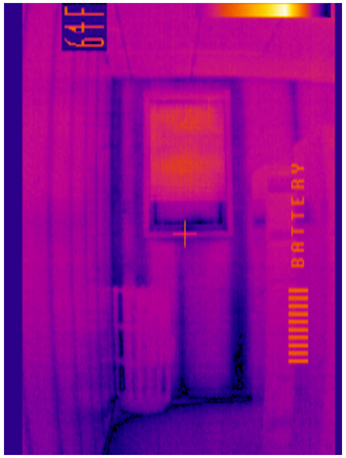


Walls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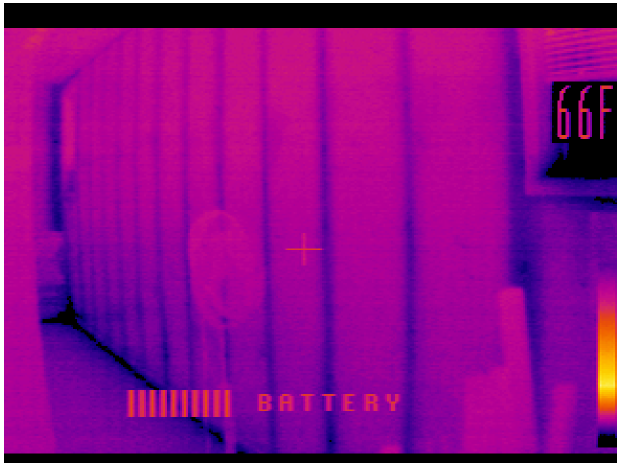
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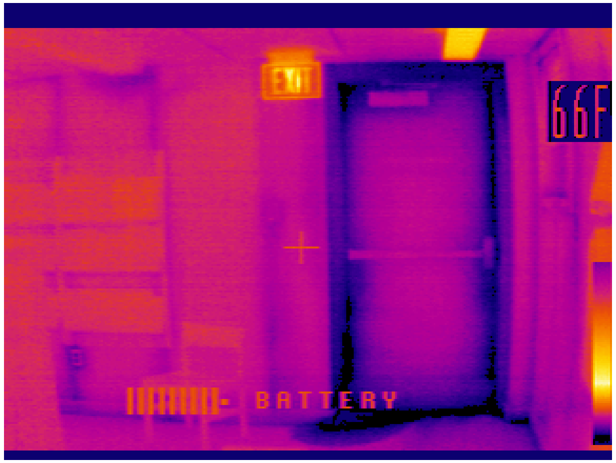
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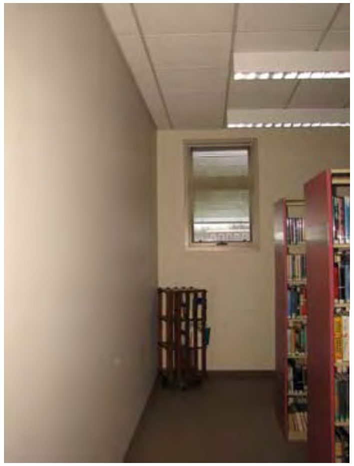

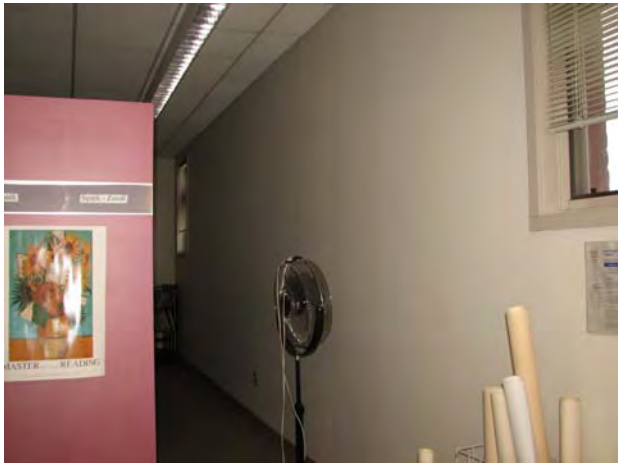
MASTER
READING


EXIT


68F
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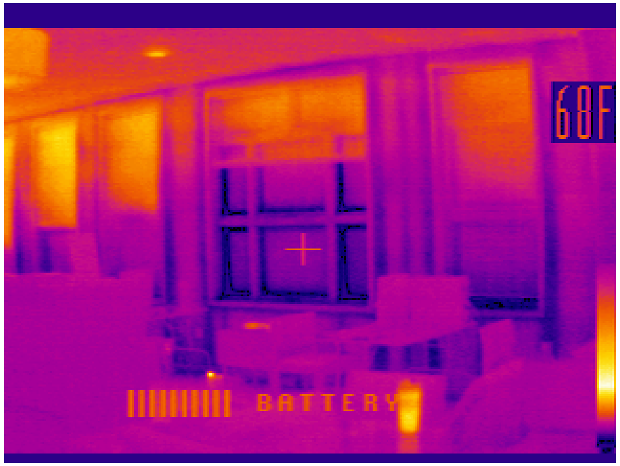
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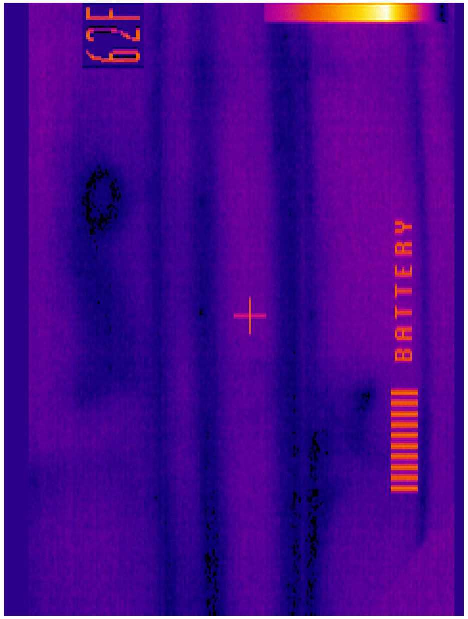

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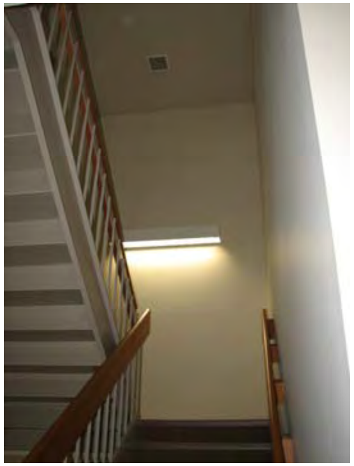

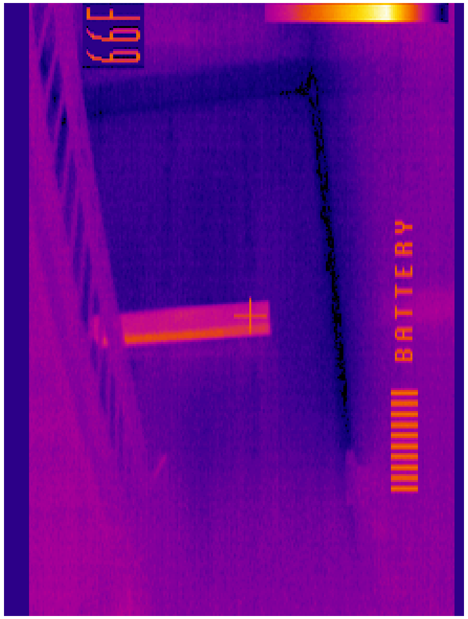

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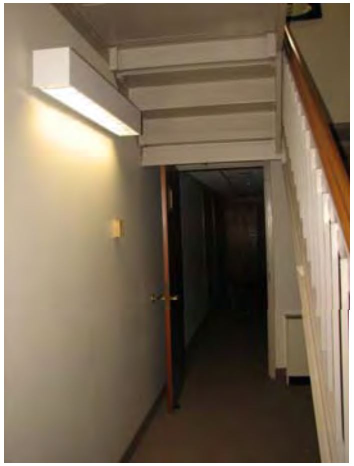

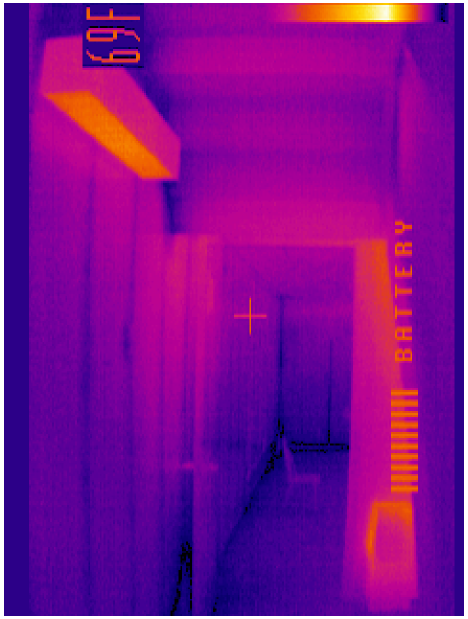
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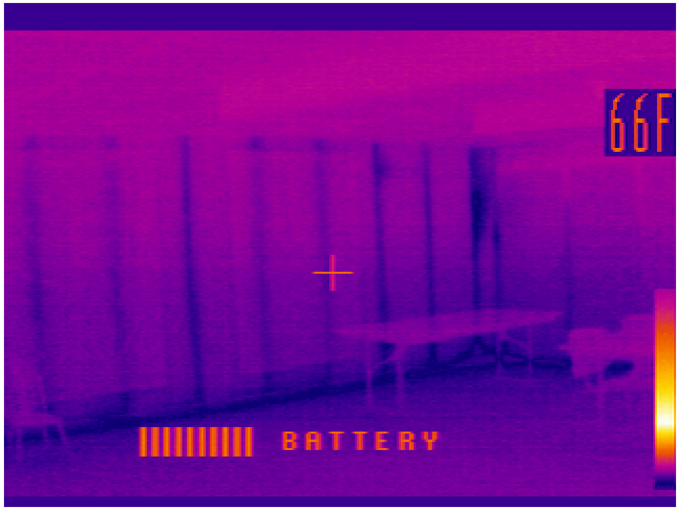
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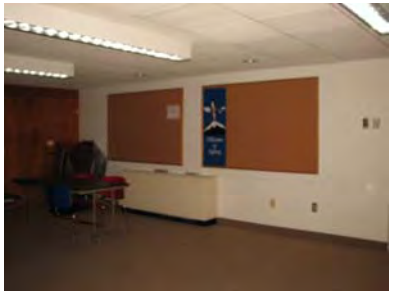

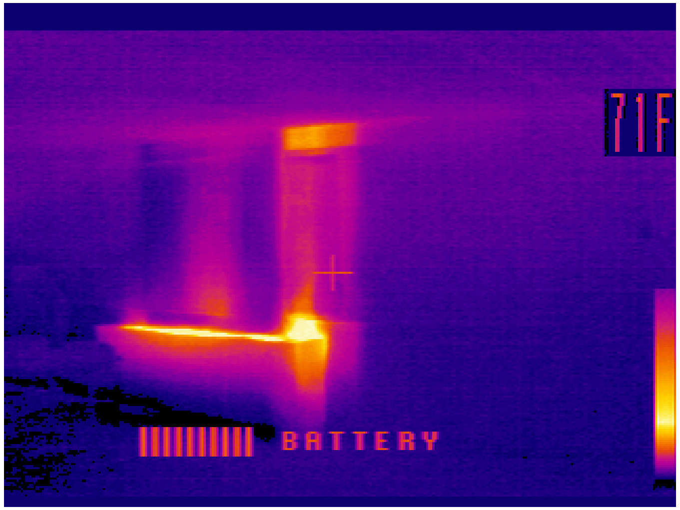
71F
BATTERY


60F
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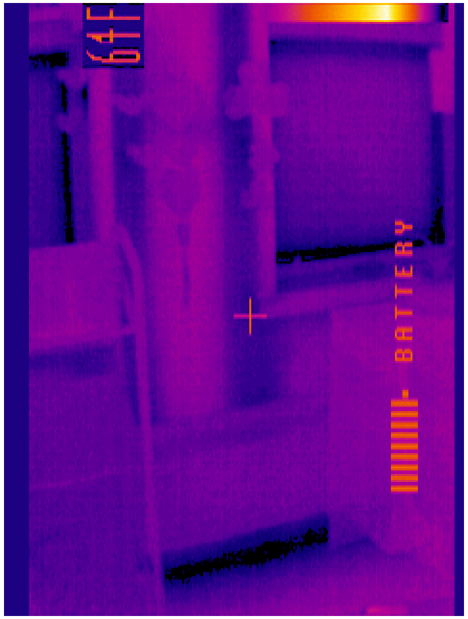
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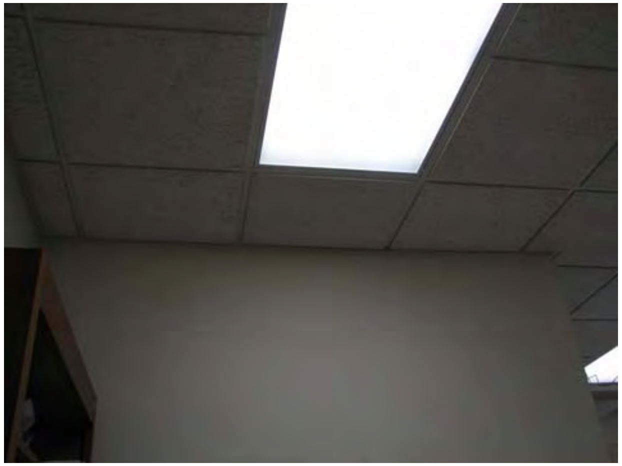

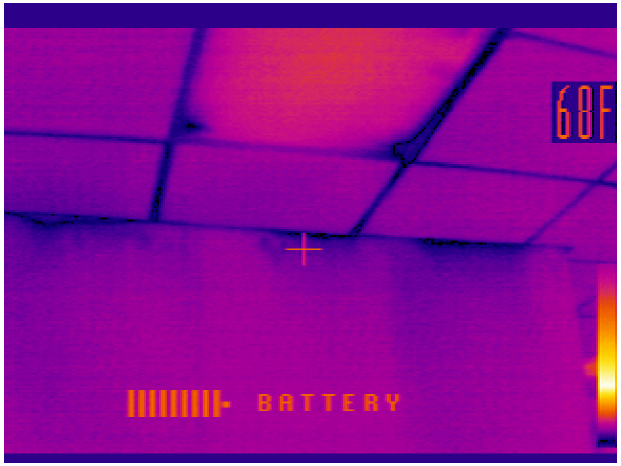
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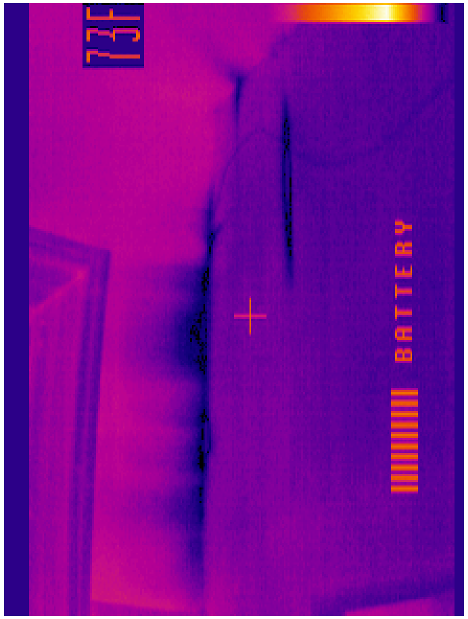
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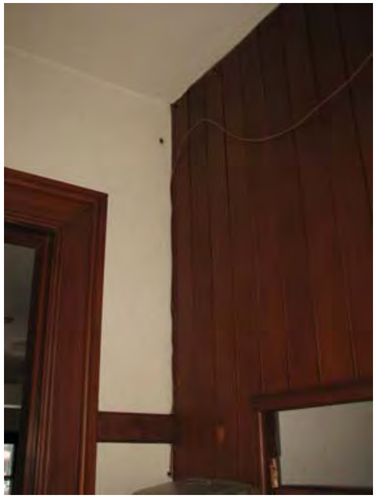
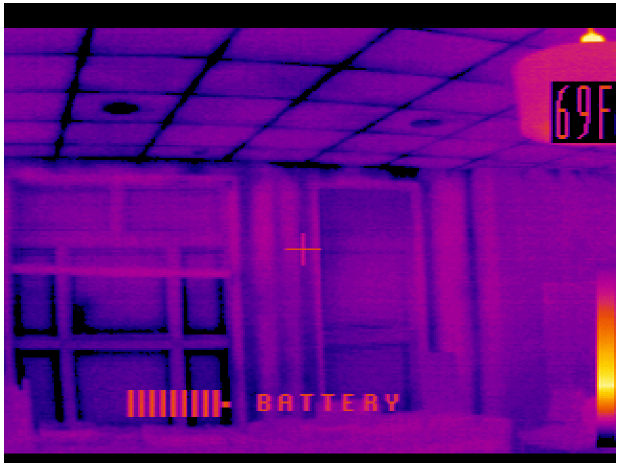
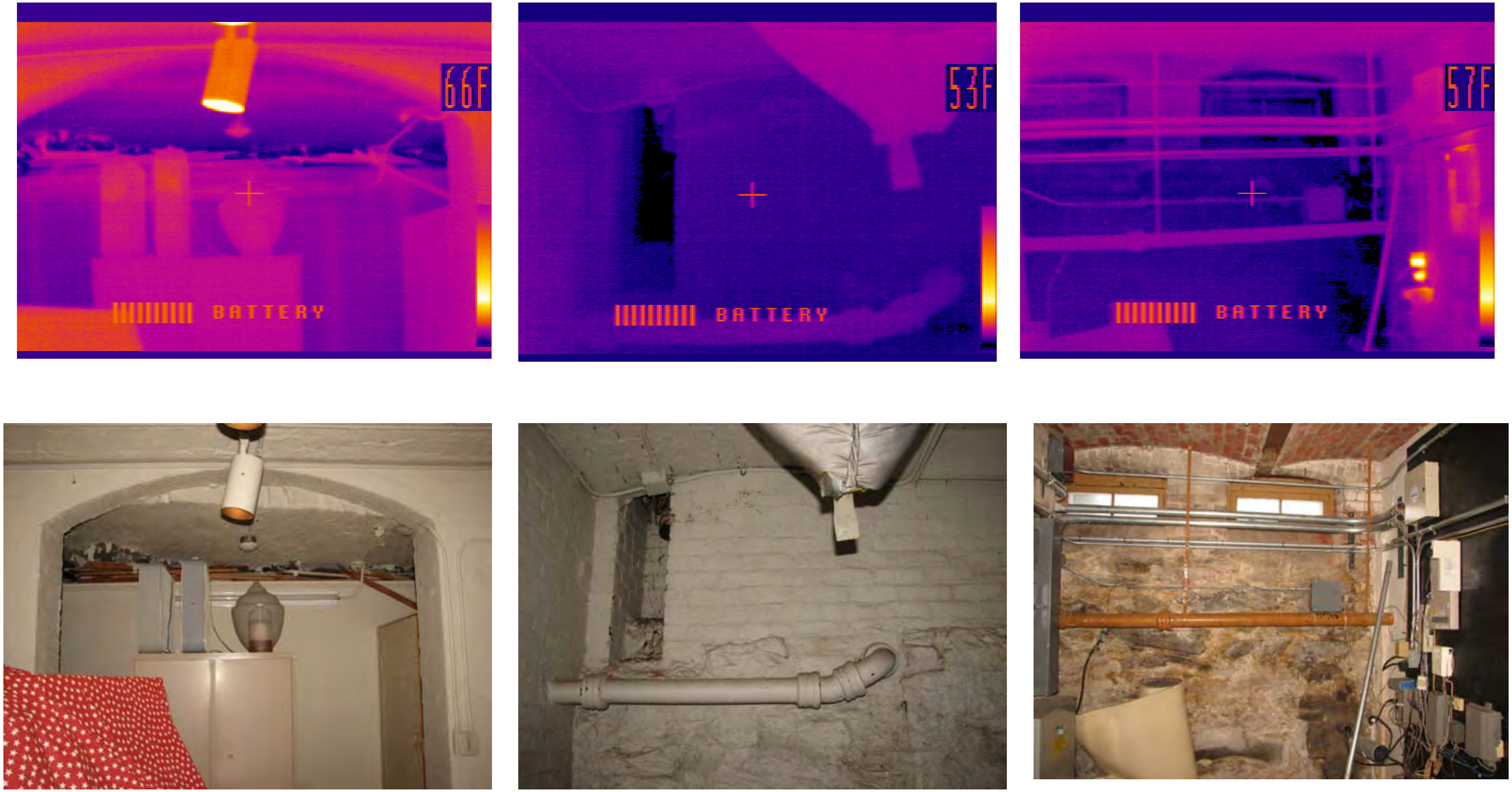



69F
BATTERY

Attic access over newer wing.

Foundation Wall



Foundation walls lose a lot of heat, estimated at 6% of envelope heat loss in this library. That's equal to the conductive losses from the 1990 addition!

Maintenance, building durability, human health and safety, and other code concerns

Water leaks

Oil tanks lack containment system.

Drainage discussed in the Turner Report

Police Station

Main Street

The Police Station is approximately 30'x58', two story, masonry structure built in 1954. Grade slopes on either side, making the lower level at grade on the north facing side, where a single story masonry "sally port" was added side in the mid 90's. The front faces Main Street and slightly southwest. It has impressive solar collecting roof potential.

Total energy costs from June '09 to July '10: $9,830 and 79.4KBtu/sf.

ANNUAL ENERGY USE SUMMARY

Heating Fuel

1,373 Gallons (4 yr avg)

#2 and Kerosene mix

Meter #W58654490

Electricity

46,056 Kwh

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)

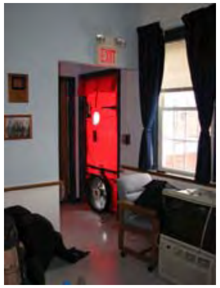
Oil: 1373 gallons x 140,000 Btu's/gallon =192,220,000 Btu's or **192.2 MMBtus**

Electricity : 46056kWh x 3412 Btu/kwh = **157,143,072 Btus or 157.1 MM Btu's for site energy**
46056kWh x 11,396 Btu/kWh = **524.9MMBtu's** includes generation source energy

Total Site Energy in Btu's = 349.3 MMBtu's /5160 FT2 = 79.4KBtu/ft2

Total Site Energy in Btu's = 717.9 MMBtu's / 5160 FT2 =163.2 KBtu/ft2

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



Building, excluding garage bay: 3887 CFM50

Means that **3887 cubic feet of air per minute** was pulled thorough leaks and gaps through the building's shell, including the garage bay, when the building was under pressure at -50 pascals with respect to outside.

Air Change per Hour Rate at -50pa: 5.57 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 6 times every hour**. The math: CFM50 x 60 / building volume

Commercial standards vary considerably, though brick and masonry buildings are generally tighter than frame.
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, there is no standard for non residential buildings.

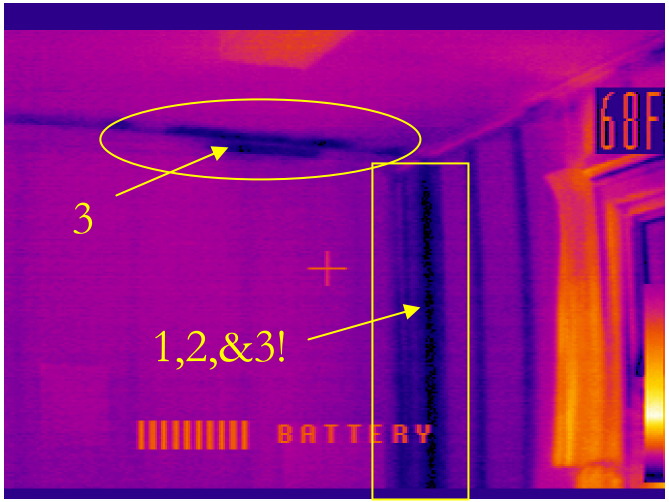
Estimated Annual Air Change Rate: . 31ACH Winter: .52ACH Summer: .27ACH
Conditions vary ACH day to day, but throughout the year the outdoor climate impacts indoors considerably. On average in winter, heated air is being replaced by outdoor air approximately every 30 minutes or so. However, on average throughout the year, there is likely to be inadequate air exchange for recommended ventilation rates for healthy indoor air quality, especially when fully occupied. The relative tightness is due to the combination of a masonry structure with only 6% glazing to wall ratio.

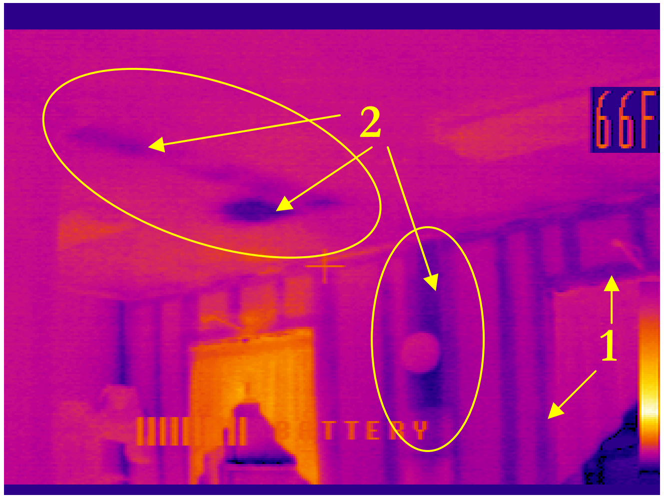
Estimated cost of envelope air leakage: **$816 at $3.00 gallon or approx 29% of heating bill**

Leakage Area (Canadian EqLA @10pa) 398 in2 or 2.76 sq feet
Total size of hole if add all cracks and gaps together

Minneapolis Leakage Ratio: **.66 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.



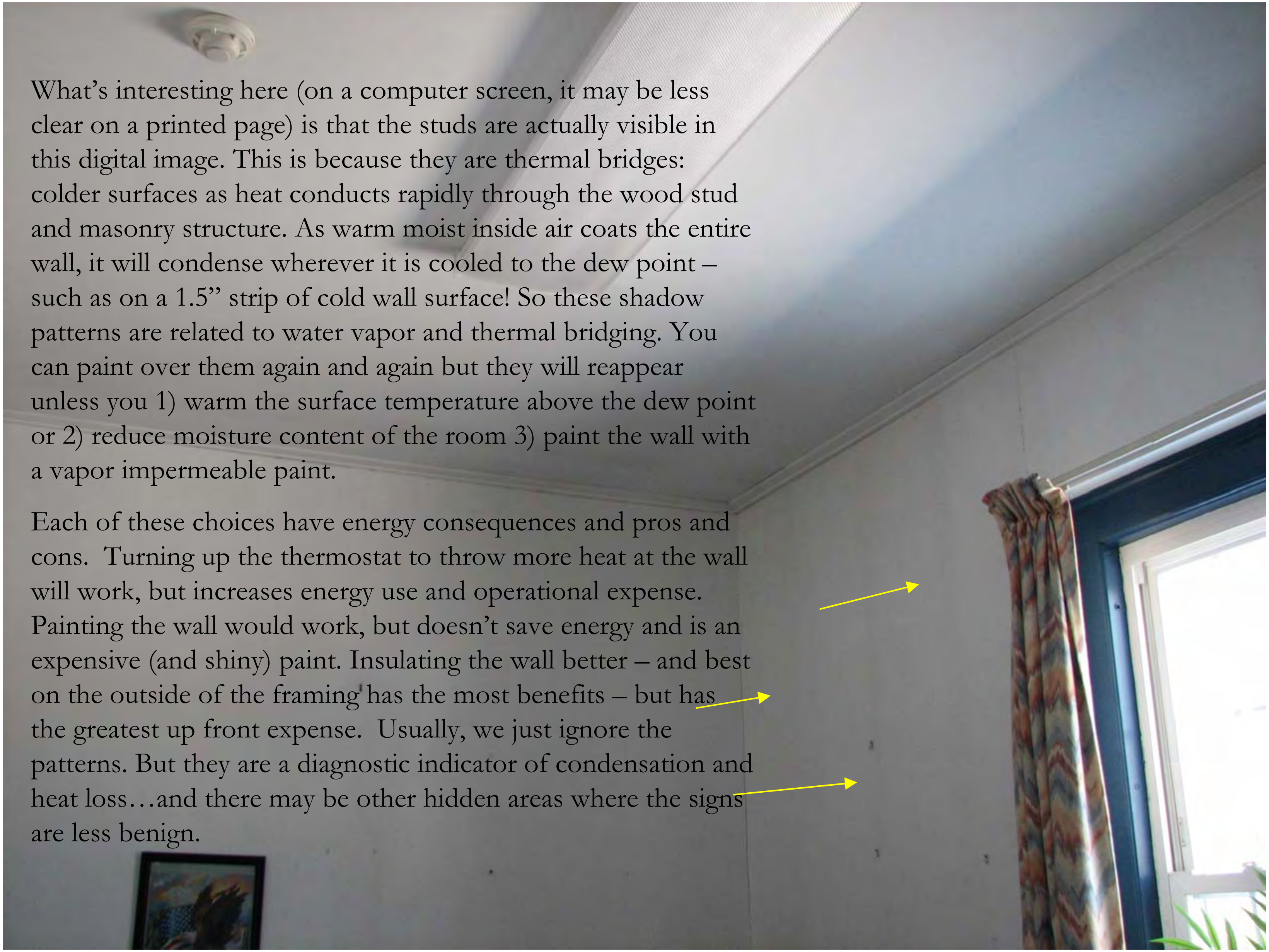


The outdoor temperature was in the upper 20’s on the day of the Infra Scan and blower door test.

Dark areas indicate cooler surface temperatures relative to surrounding surfaces due to differences in conductivity of the material or assembly. Examples include:

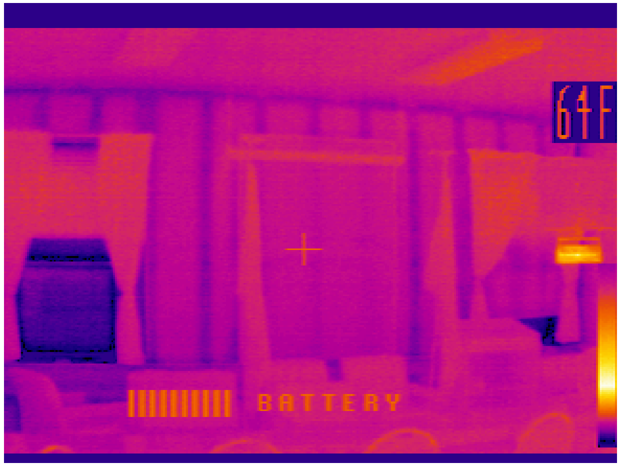
1. Thermal bridging, where conductive framing may be in contact with both the inside surface and outside surface – or in this case with the outside masonry structure;
2. Missing insulation, such as cavity voids; or
3. Air leakage causing “wind washing”.

Bright colors indicate relatively warmer surface temperatures. I suspect there is a radiator below the window above and washing the curtains and wall above with heat, warming those surfaces as warm air rises. Note the ceiling is slightly warmer as well.



What's interesting here (on a computer screen, it may be less clear on a printed page) is that the studs are actually visible in this digital image. This is because they are thermal bridges: colder surfaces as heat conducts rapidly through the wood stud and masonry structure. As warm moist inside air coats the entire wall, it will condense wherever it is cooled to the dew point – such as on a 1.5" strip of cold wall surface! So these shadow patterns are related to water vapor and thermal bridging. You can paint over them again and again but they will reappear unless you 1) warm the surface temperature above the dew point or 2) reduce moisture content of the room 3) paint the wall with a vapor impermeable paint.

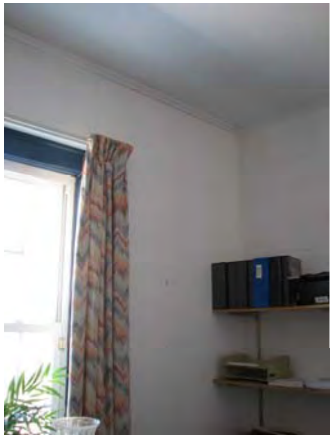
Each of these choices have energy consequences and pros and cons. Turning up the thermostat to throw more heat at the wall will work, but increases energy use and operational expense. Painting the wall would work, but doesn't save energy and is an expensive (and shiny) paint. Insulating the wall better – and best on the outside of the framing has the most benefits – but has the greatest up front expense. Usually, we just ignore the patterns. But they are a diagnostic indicator of condensation and heat loss…and there may be other hidden areas where the signs are less benign.



Conventional stud framing at 16”OC with insulated cavities and thermal bridging (greater rate of heat loss) at each stud.

Corners are typically colder because a) often multiple studs ie more thermal bridging and less room for insulation, and b) heat distribution system often does not move the heat into corners. Air doesn’t naturally fill in a boxed in corner, but moves between open areas.

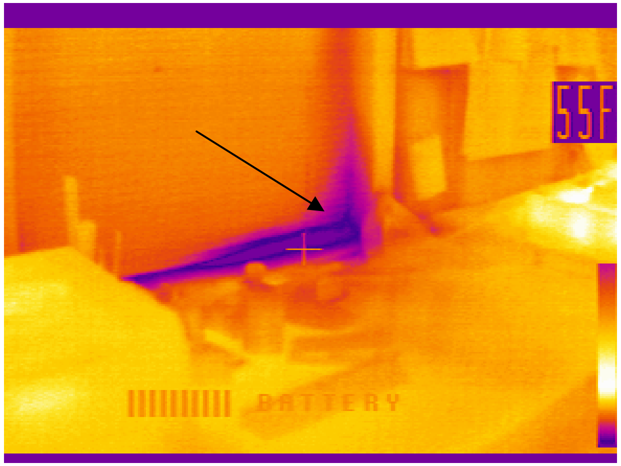
These images and narrative are presented here to help demonstrate how thermodynamics works in buildings and the impact of our construction practices. Upgrading the performance of the anomalies in the areas shown on this slide – ie improving the envelope assembly’s energy efficiency in here would be costly with a long payback period at *today’s* energy prices.

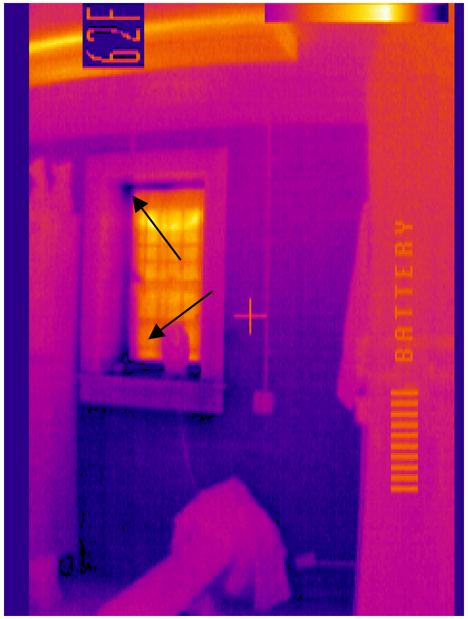


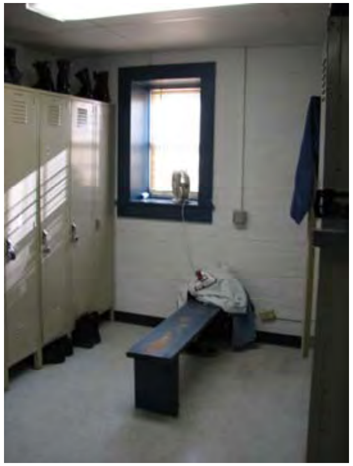
But what about when oil goes up to $140 barrel again? Or what if the building undergoes a major renovation? It is foreseeable that at some point in the future, someone is going to be willing to invest dollars into making changes. The goal of a SEEDS Assessment and Report is to visually describe how heat transfers in a specific building so that opportunities to optimize energy conservation can be realized whenever changes are made to that building.

Windows

At some point, all the original windows were removed are vinyl replacements installed. They have an estimated overall insulating value between R2 and R2.3. While there are some far higher performing window glazing and frames on the market today, total window glazing represents about 6% of total wall surface area. You could reduce heat loss by upgrading to an R3, R4 or R5, even an R10! But the incremental energy conservation from moving from R2 to R3 is very small in relation to the expense. And while moving from R2 to R10 is a far more impressive increase in energy savings, it is even a more impressive increase in costs! The point is that window Rvalues are important, but often the last on the list of priorities.

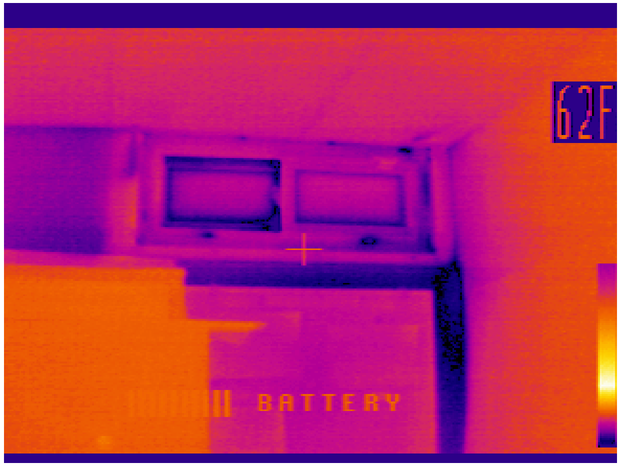


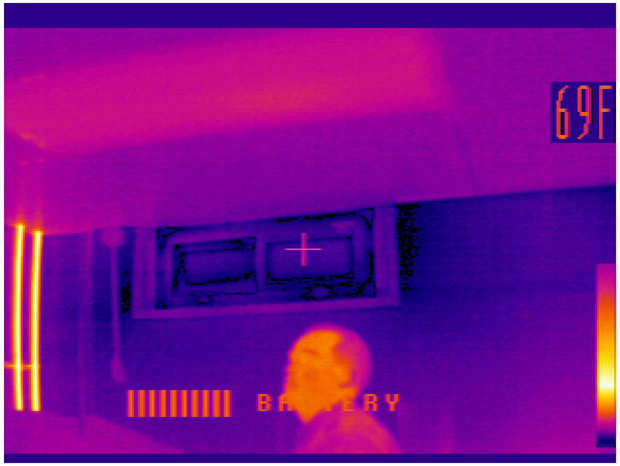


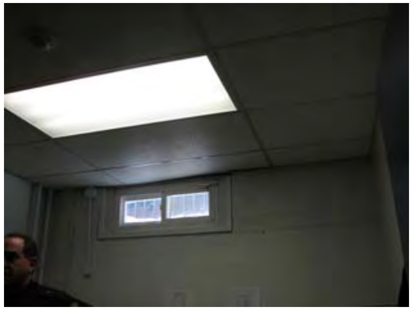


What is sometimes (often) at the top of the list of priorities is air sealing. Note the corners and edges in the IR images of these windows. That darkness indicates cold air infiltration which means convective heat losses in winter and heat gains in summer. Caulking and other air sealing or even installing tight interior storms are more cost effective ways of making significant improvements.

Windows

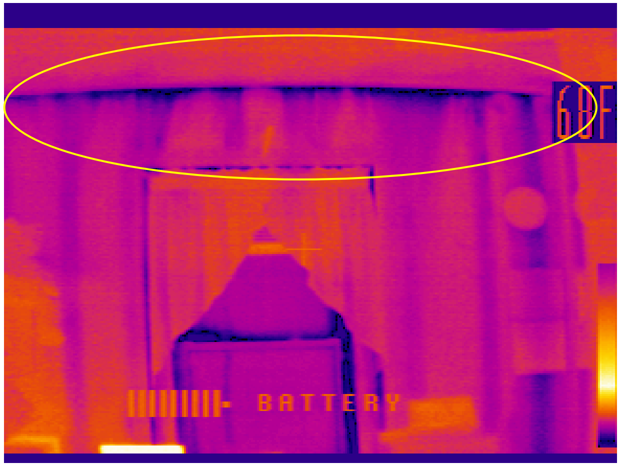


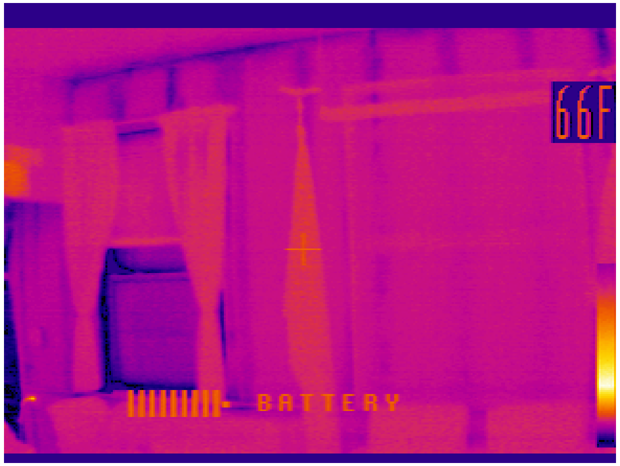


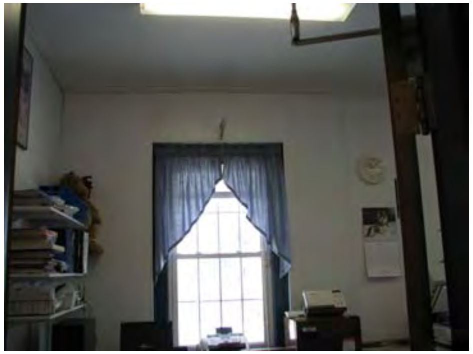


Air sealing is even more important in below grade areas because they are typically cooler in the summer when the outside air can be warm and humid. Air can move a tremendous amount of water vapor and what happens when warm moist air cools below the dew point? Condensation. We in New England are used to damp basements. They are as common as icy roads, ice dams, and black flies. We'd all be happier without any of them, but the difference is that damp basements and ice dams are preventable and the building will be less costly to operate and more comfortable without them. Air sealing is an important key to being rid of both of them.

Windows

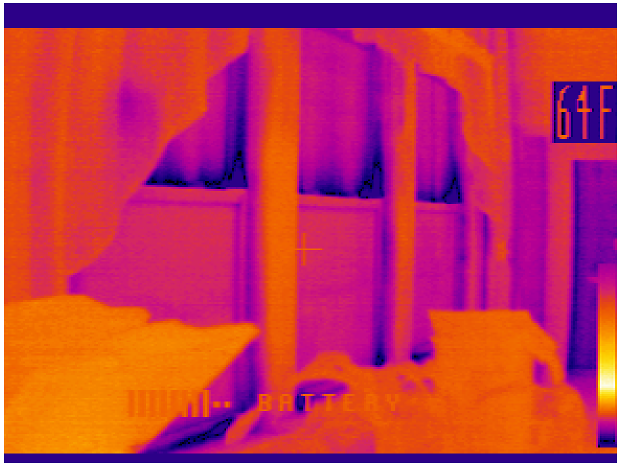


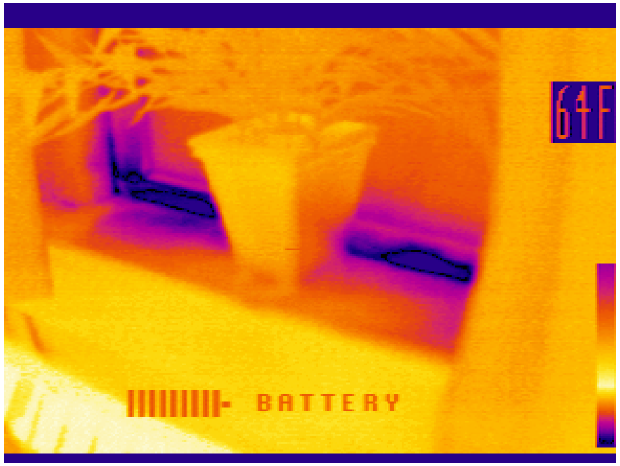


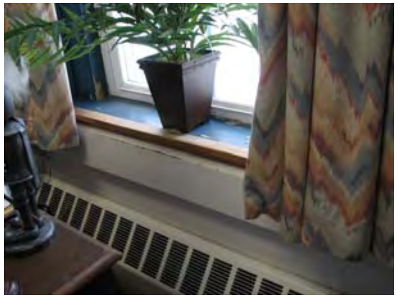


The wind washing evident at the top of this wall **may** be able to be stopped by foam sealing all along the top plate in the attic though access will be difficult in some places. It is likely that this is not air entering the room, but cold attic air 'washing' down behind the sheetrock and ultimately cooling the surface and increase rate of heat loss. Insulation without an air barrier can become nearly useless. But also note window air leakage which can be much easier to stop.

Windows

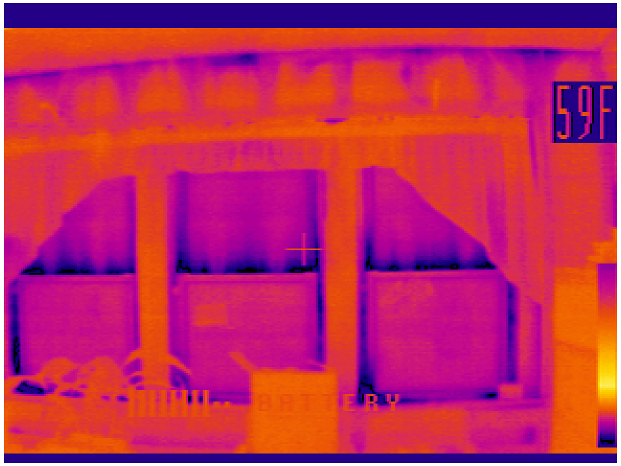




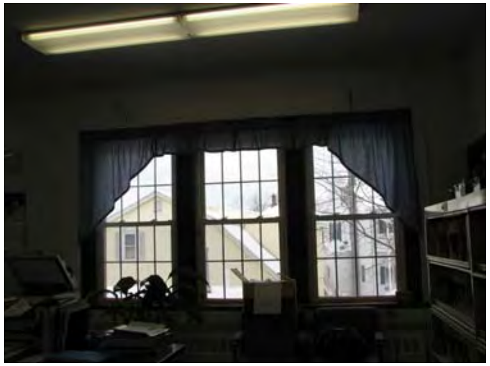


In spite of what was written on an earlier slide, a case can be made to install new windows if the existing ones don't close anymore. Vinyl replacements are notorious for becoming less and less tight over time. Still, the most important thing is to stop air – and that can be done without buying new ones. In addition, new windows don't guarantee tight fits! The rough opening can leak air and careful, quality, installation is very, very important. On the one hand, many contractors Have improved their practices and can make excellent installations. On the other, the increased interest in energy Efficiency and increase in public funds for EE has also increased the number of less experienced contractors. Buyer Beware remains sage advice.

Windows



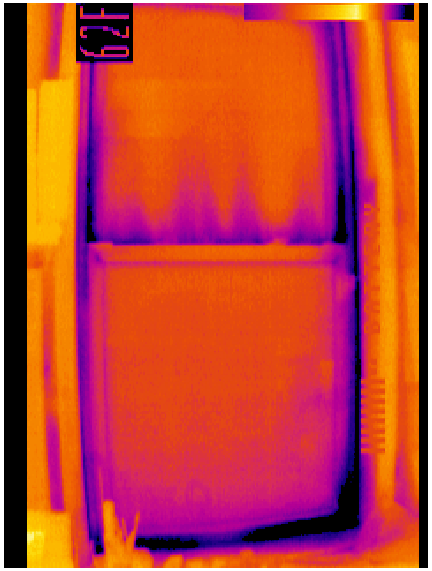
These images were taken with the blower door fan running and the building depressurized to -25 pascals. So while this is not a normal condition, it does approximate the kind of infiltration one could expect on a cold or windy day.

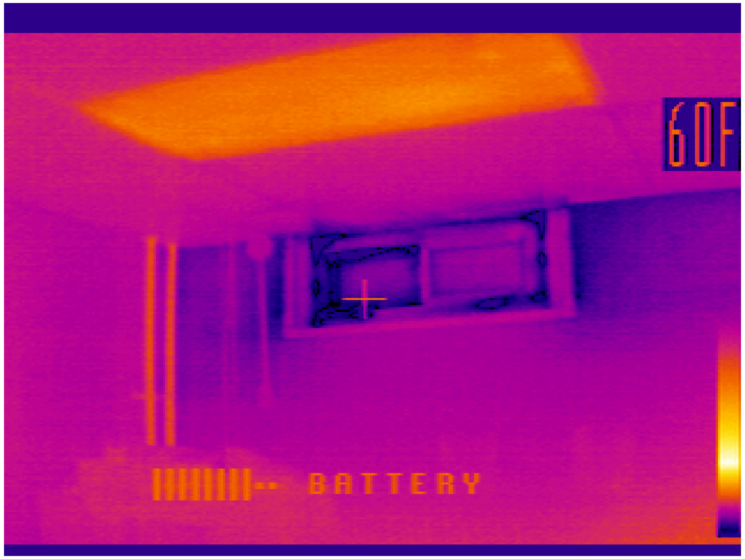


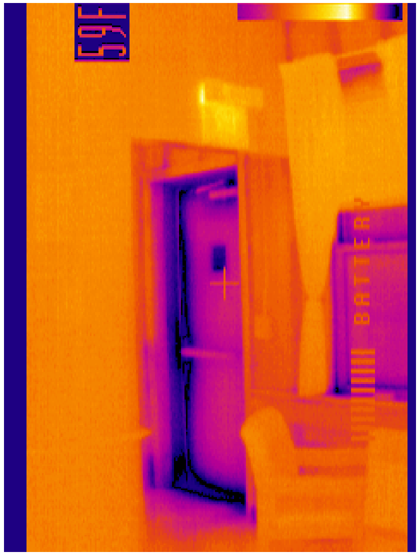
Note that replacement sashes would not necessarily even address this area above which is within the rough opening, but above the window unit. Installation, and details, matter.

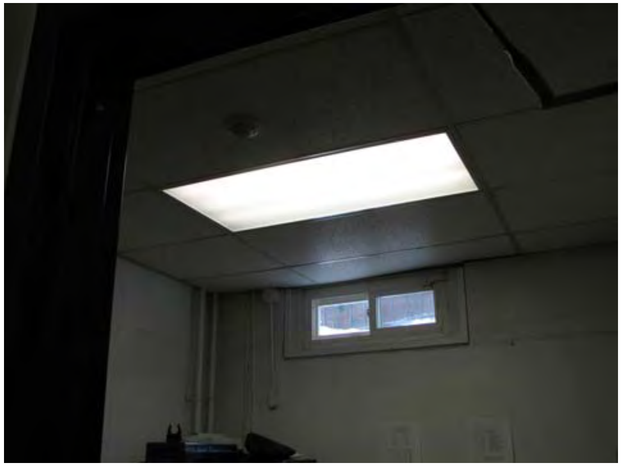
Windows and Doors:

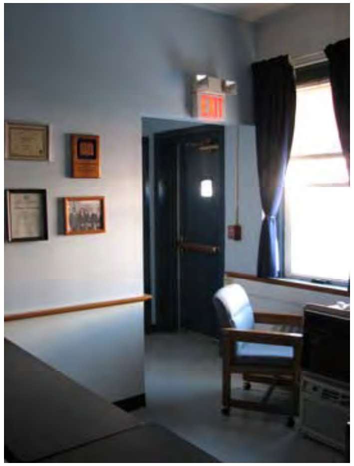
Both are big holes in the envelope



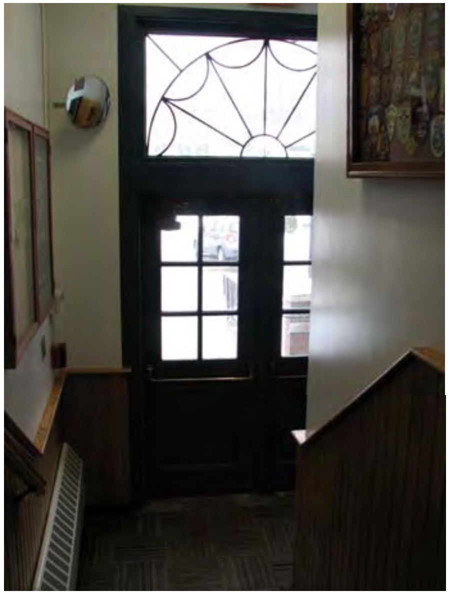


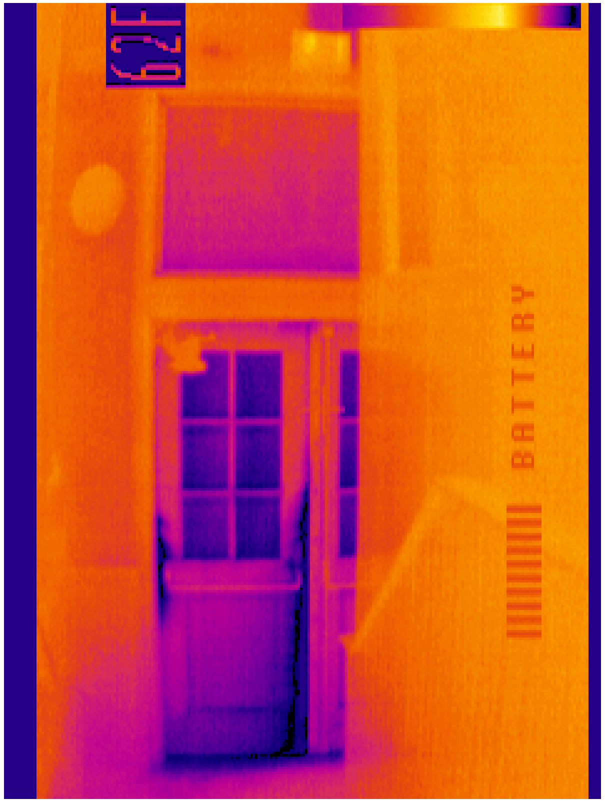




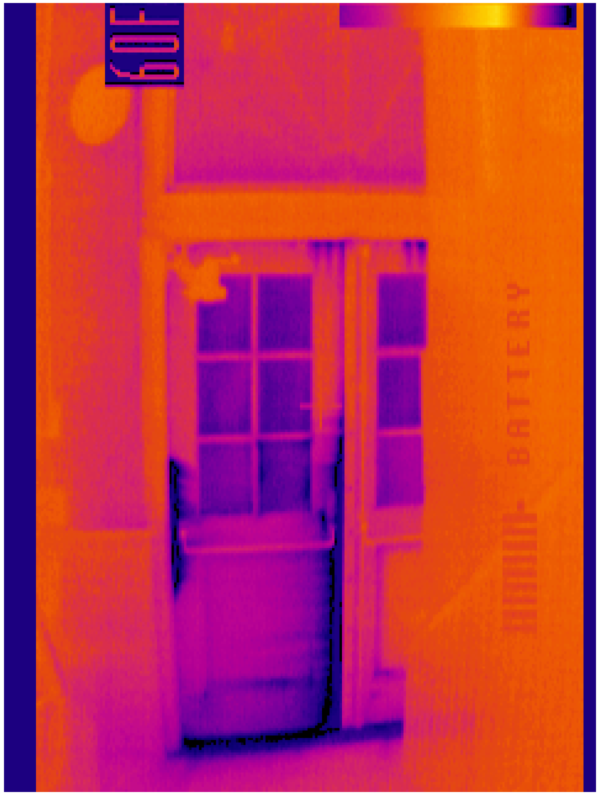


Doors



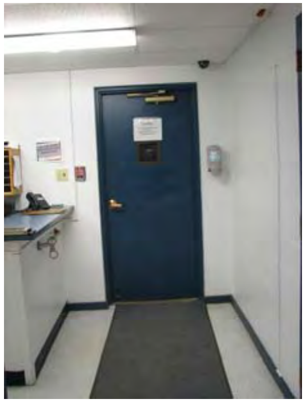


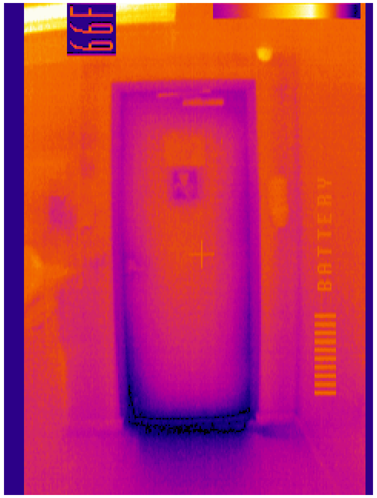
“normal”



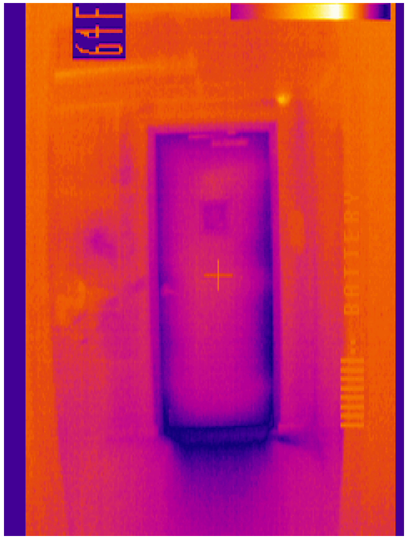
“at -30pa”

Doors



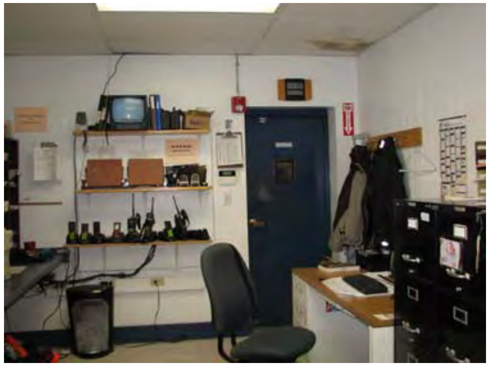


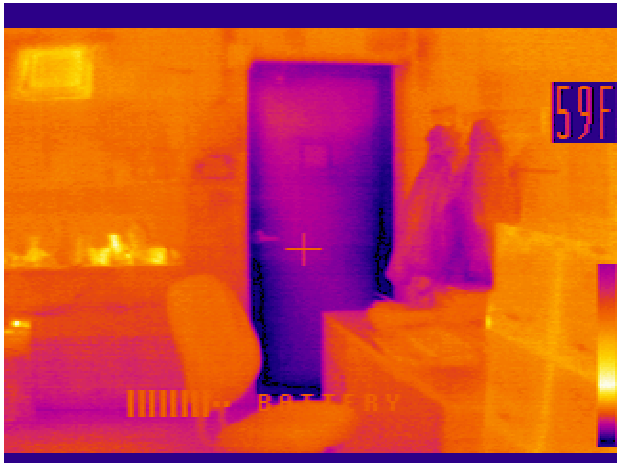
"normal"



"at -30pa"

This door is warped beyond repair and is a top candidate for replacement especially as this is a first line of defense against garage fumes entering conditioned occupied space.

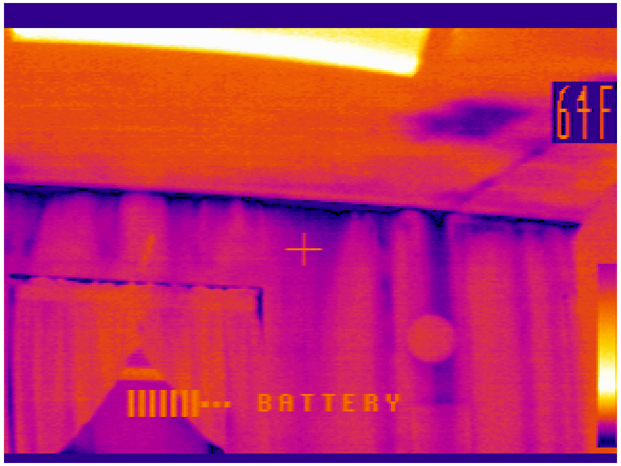


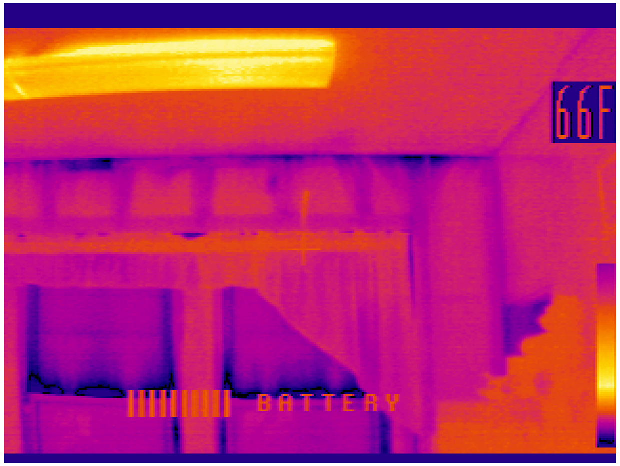


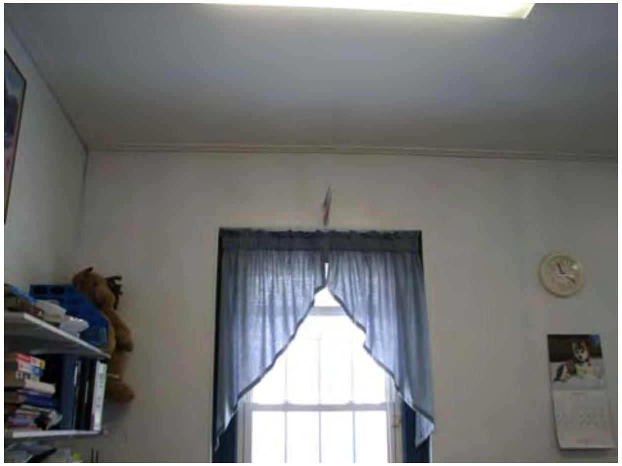
Doors and Other Holes

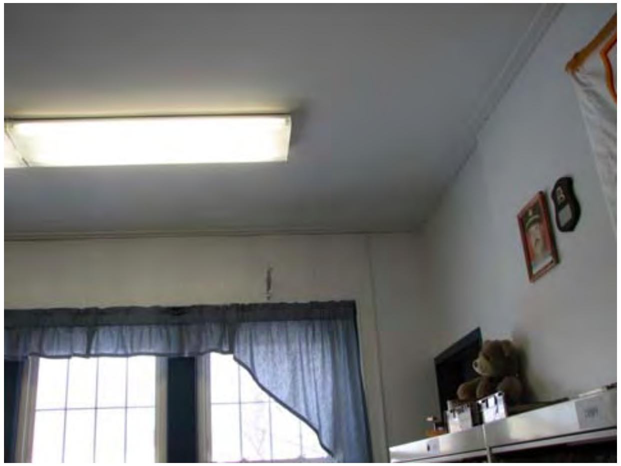
Ceilings

At -30pa

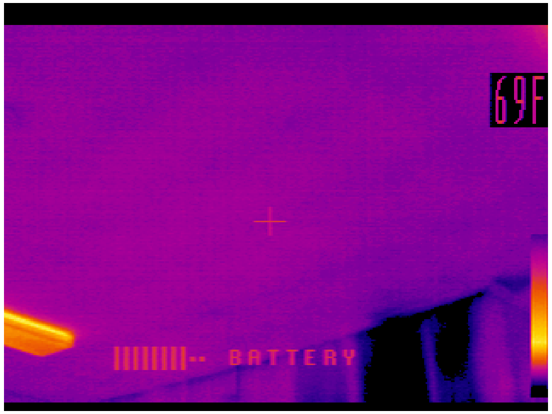


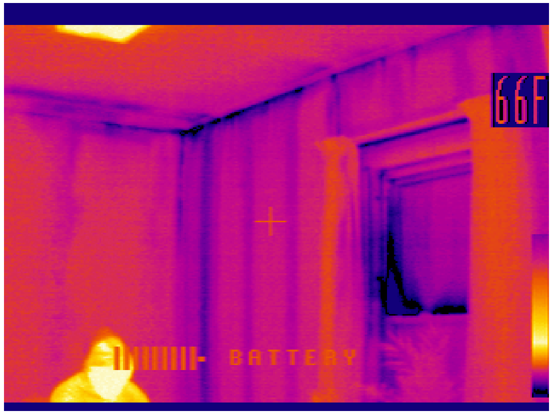


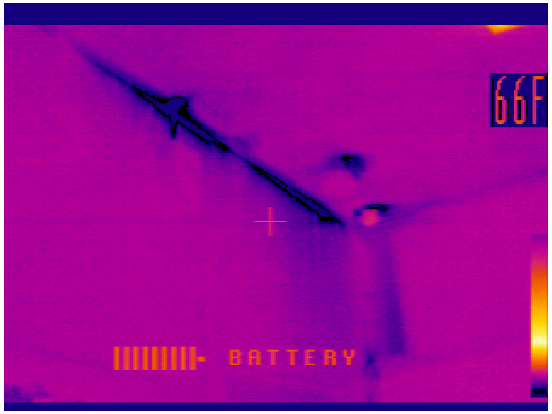


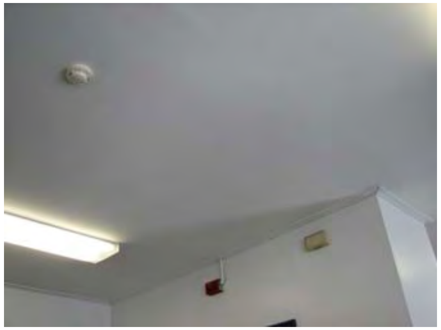


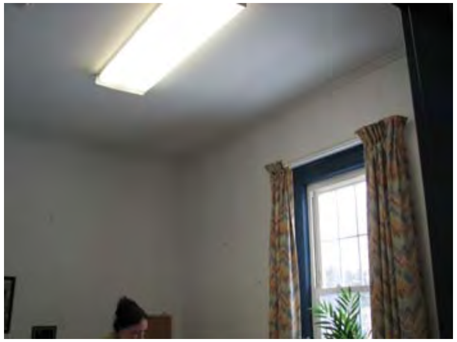
Ceiling











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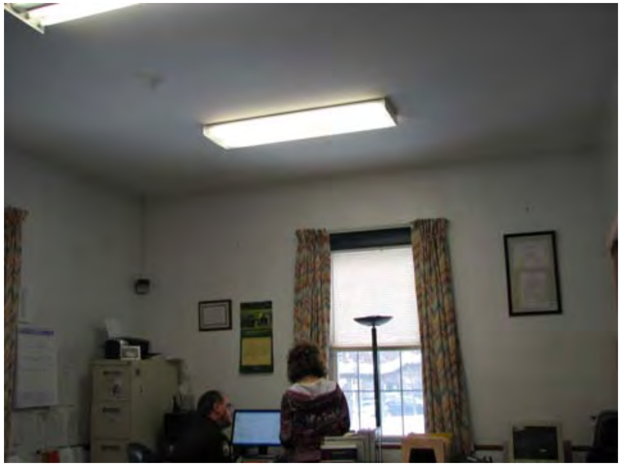
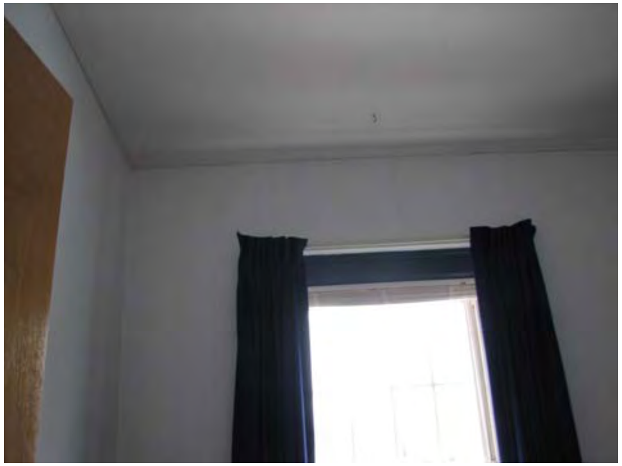
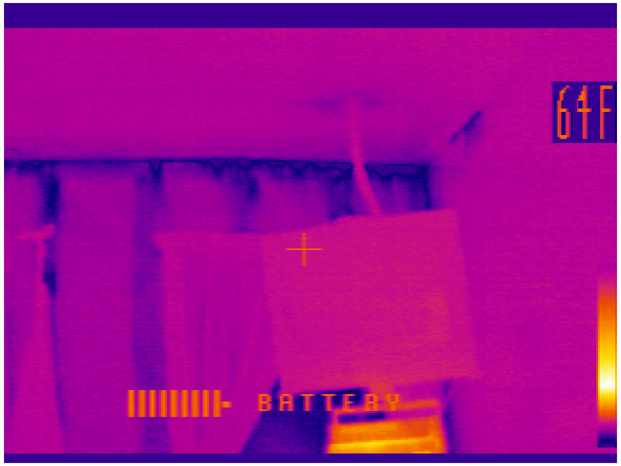
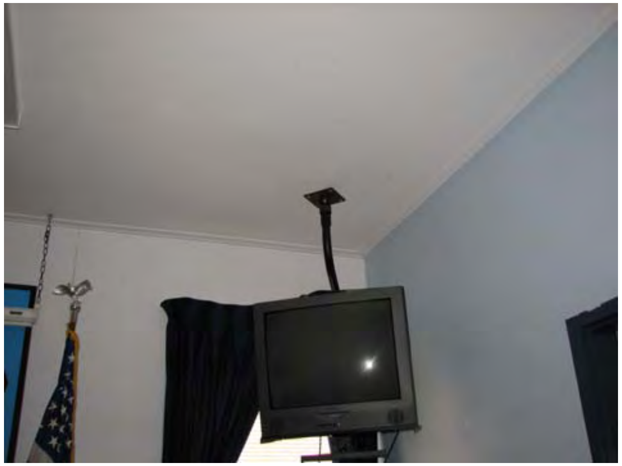
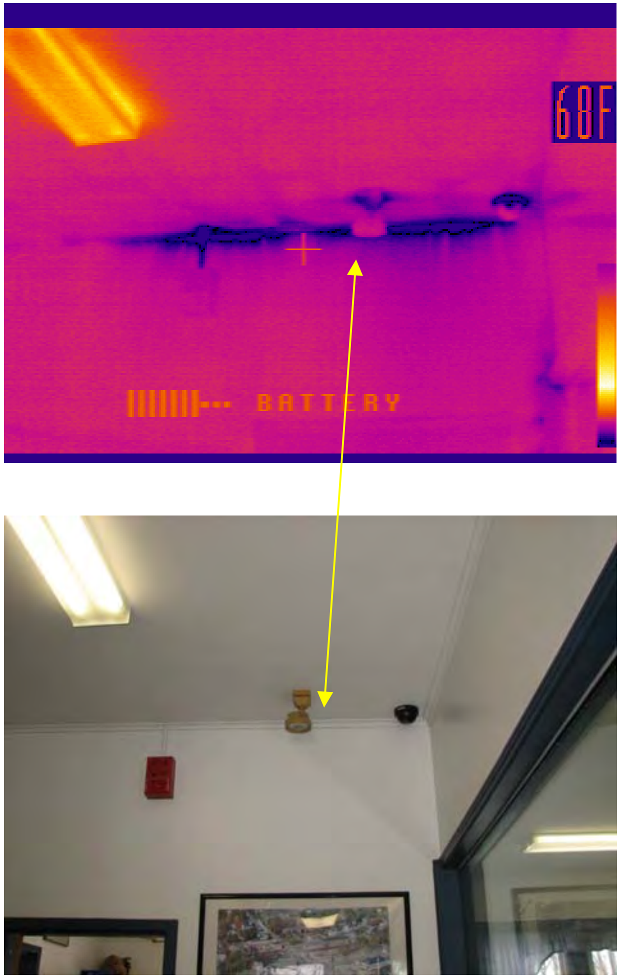




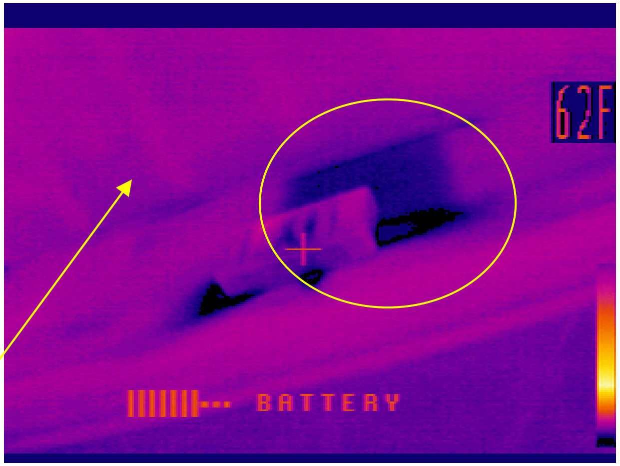
Ceiling



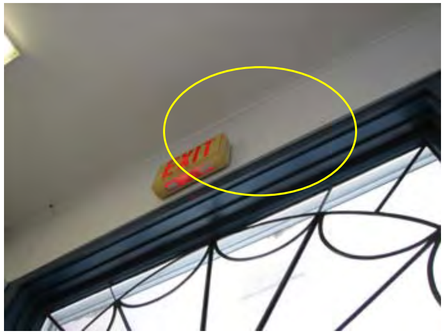




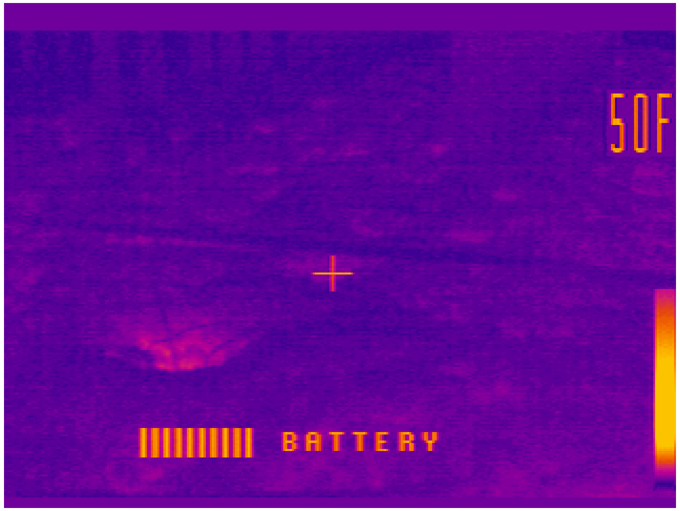
Ceilings and the Attics Above Them

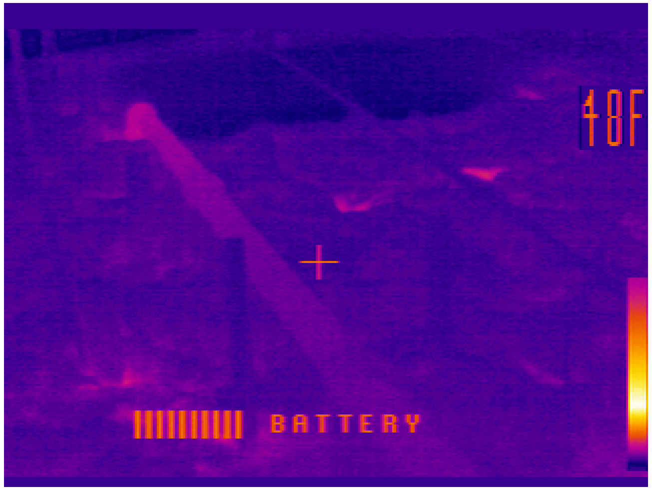


When framing serves as better insulation than cavities, you have a significant opportunity to reduce heat loss…by adding insulation to the cavities! And black holes like this are even bigger opportunities!



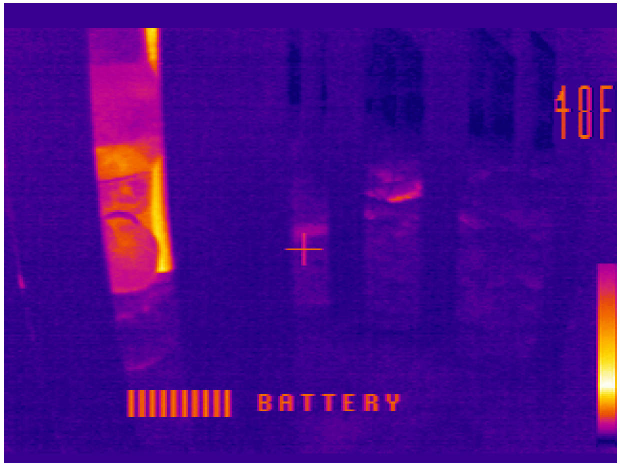
Attic

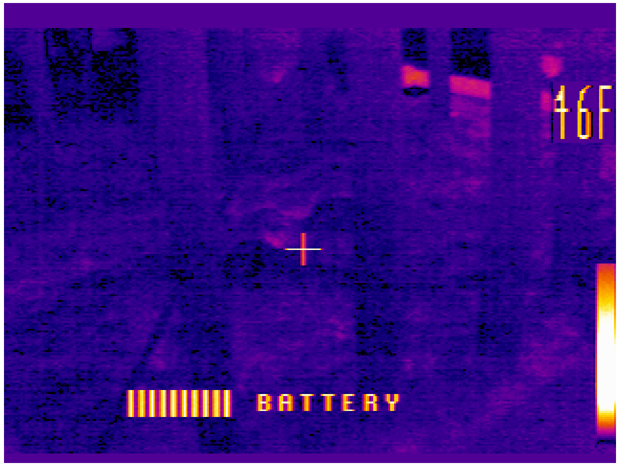




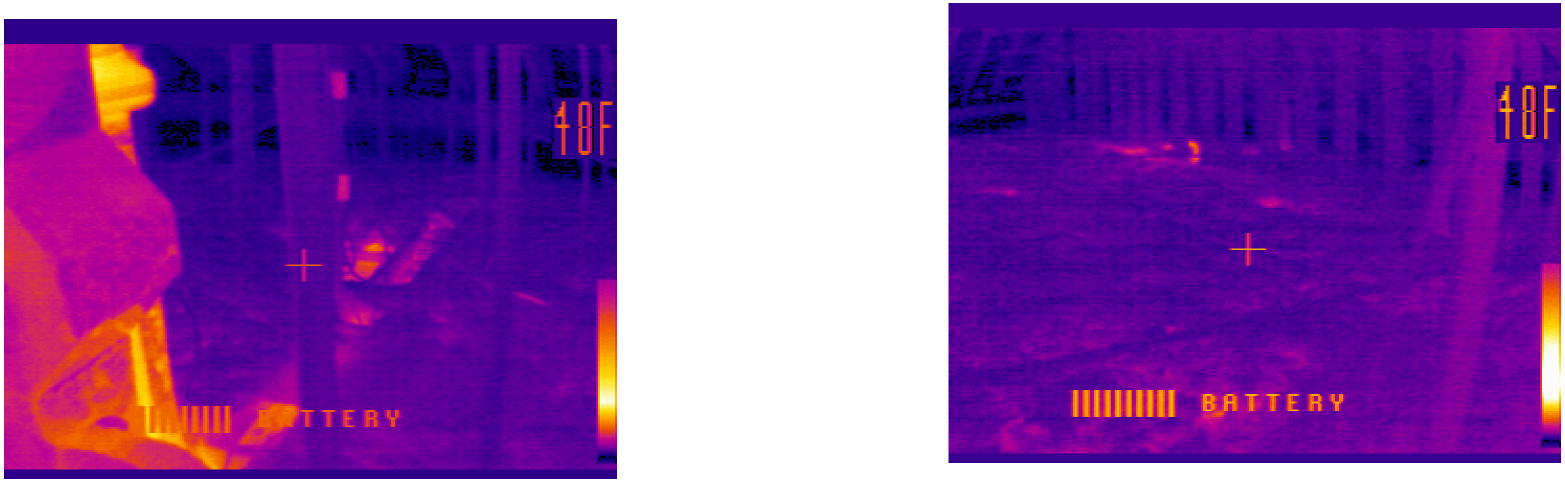
Windows and doors are big, obvious, holes in the envelope. Dozens of wire holes are less obvious but can add up to make one big hole! And when in the ceiling plane, where warm air rises naturally, every hole matters a lot.

Attic



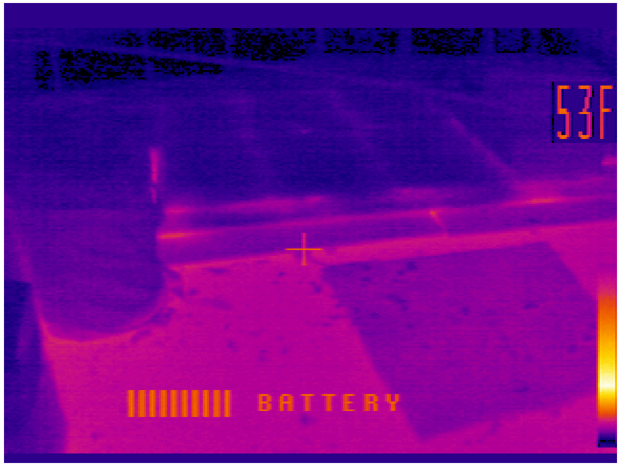


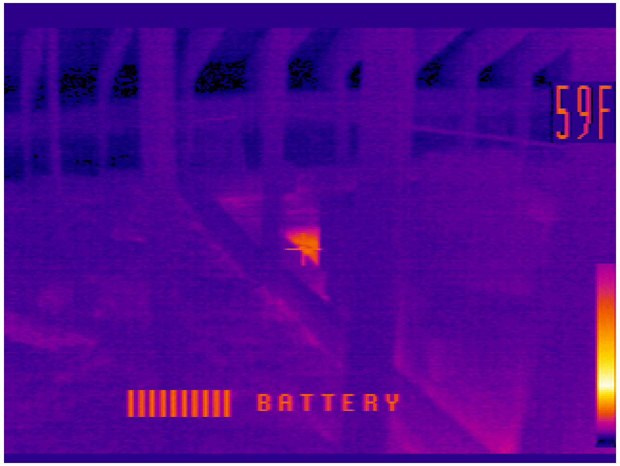
Attic



Equipment which distributes warm air or hot water into the building, or takes warm air out of conditioned space (as below), when located in an unconditioned attic, wastes a lot of energy.

Attic

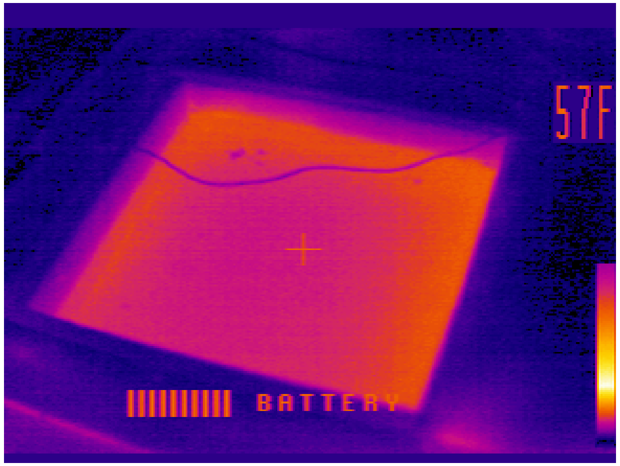




The final strategy to upgrade this attic to conserve energy will have to factor in the decision as to whether this will continue as storage space; expand as storage space; or essentially stop being storage space. It can continue to do both, but to serve as an effective envelope assembly for the next 5-50-100 years, it would incur the extra cost of building up the framing for a raised platform – so that insulation will not be compressed nor disturbed over time.

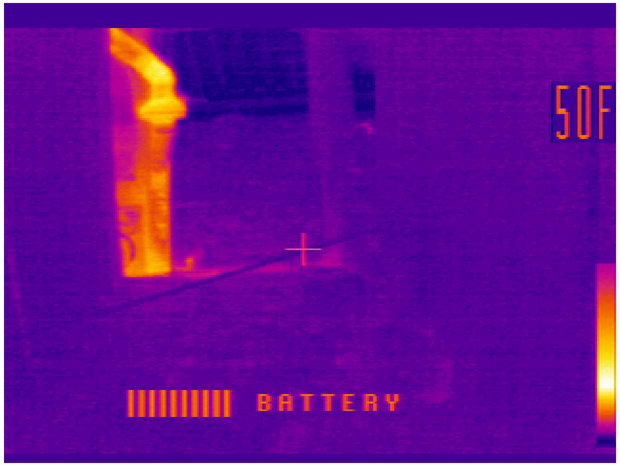
Attic

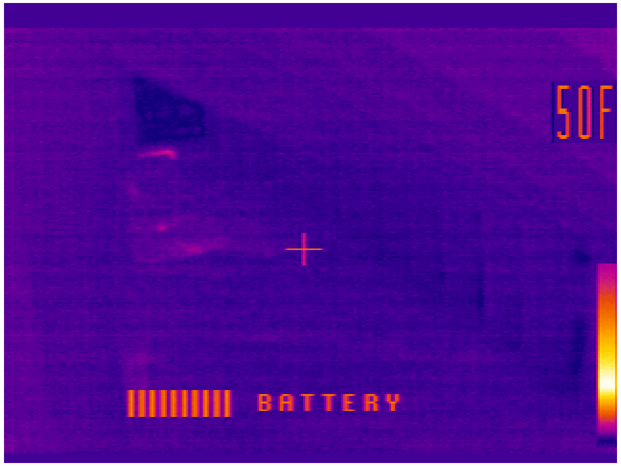
Bath fan



This is a small area but great opportunity.

Attic





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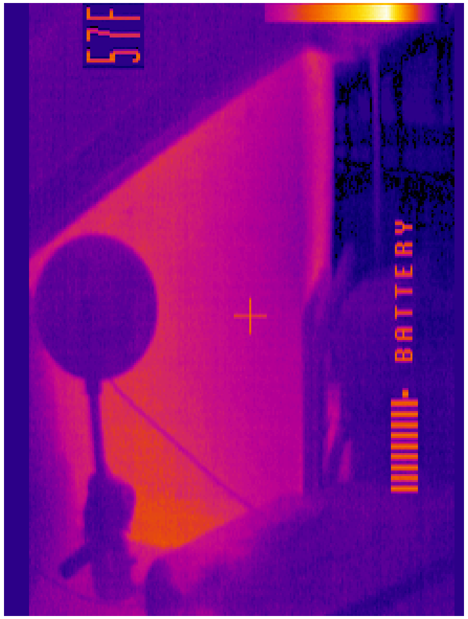


Attic Access

Attic drop down ladder has large air gaps, is uninsulated, and is also rickety.

Attic Insulation

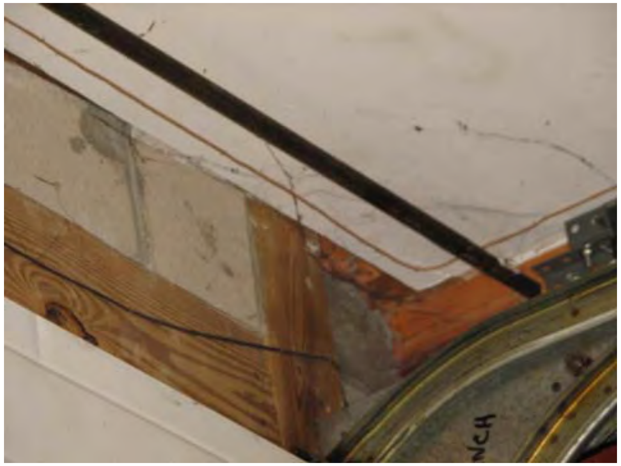
There is an old 3” batt covering most of the attic floor, which is covered by 1 to 6” of cellulose. Effective R-values range between R0-R14.

Attic Insulation

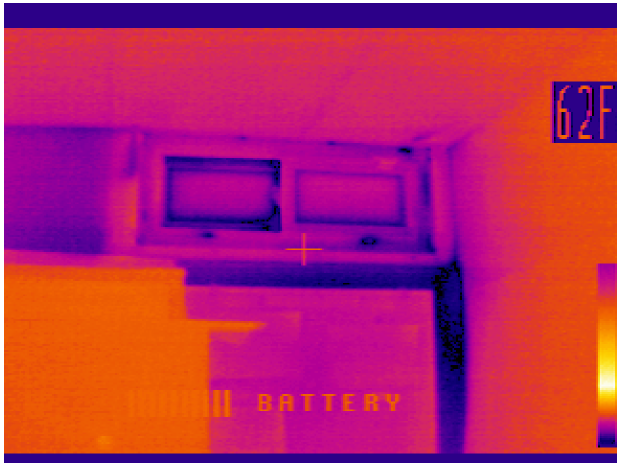
Of even greater impact are the many holes and air gaps.

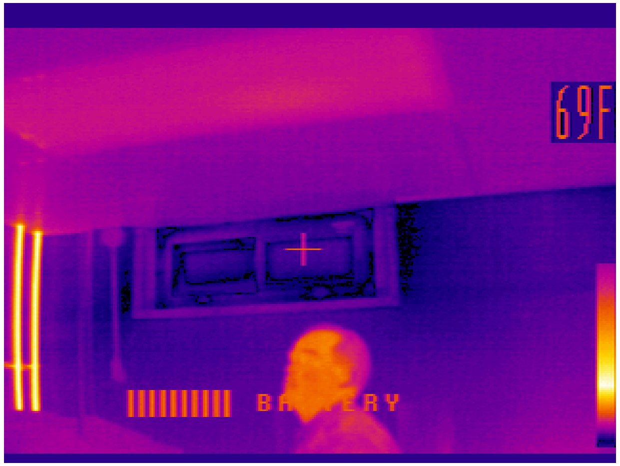
Garage Bay

Insulation levels above ceiling unknown.

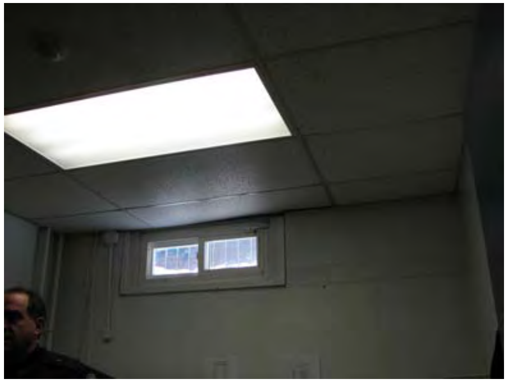


Foundation

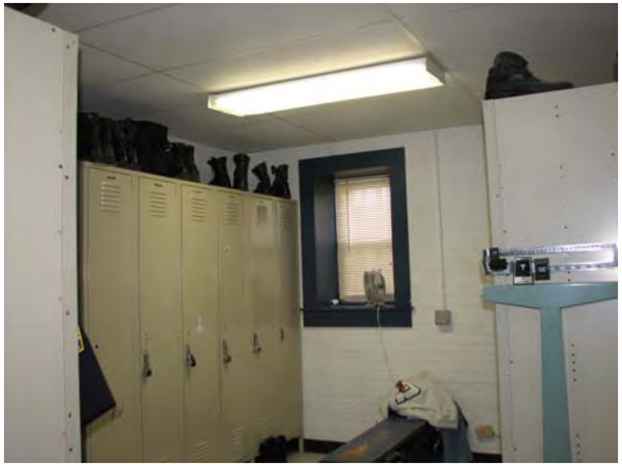


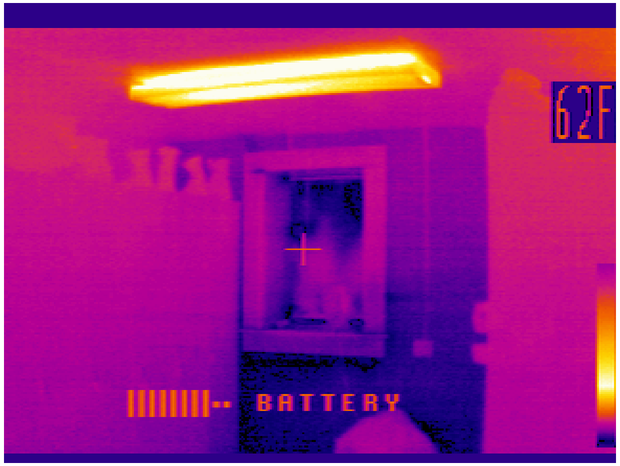


Insulating foundation walls reduces heat loss while also reducing moisture from the always damp earth.



Foundation





The Turner Report recommended replacing much of the worn floors, most especially the squad room slab. Any opportunity to also add insulation to the slab to stop moisture and heat loss would reduce energy and humid conditions throughout the building. As the ceiling is air sealed, moisture levels tend to increase. The building is already fairly tight so balanced mechanical ventilation with energy recovery would be of multiple benefits.

Heating Equipment

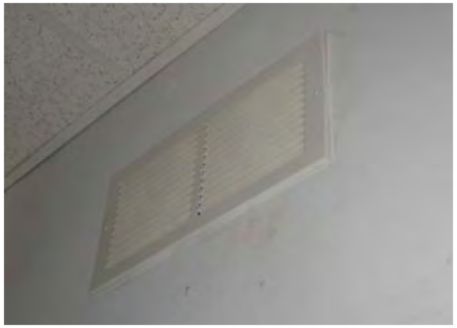
Weil McLean
68 Boiler
Model 768 rear flue
Installed 1991 (Turner)
DOE 240,000 216MBH

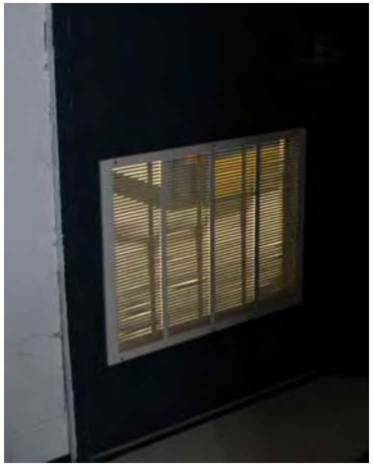
Carlin Burner 99RFD
150x60B

One 275 gallon tank - #2 oil and kerosene mix

Super Stor 30 30
Gallon Indirect hot
water heater

Equipment



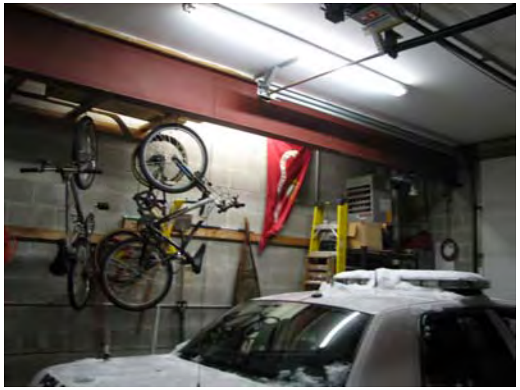


Combustion make up air.

I assume these vent openings were installed following the Turner Report to provide ‘high/low" combustion air according to code. Typically, these openings are to outside in part to maintain a closed boiler room and separate combustion air needs from human air needs.

When replacing the boiler, a sealed combustion, direct vent unit is strongly recommended.

Equipment



Manually operated exhaust fan; turned on with perceived need.
Exterior louvers remain partially open and losing heat.

Equipment

Propane space heater directed towards wall and, on this day, into boxes and a ladder.

Equipment

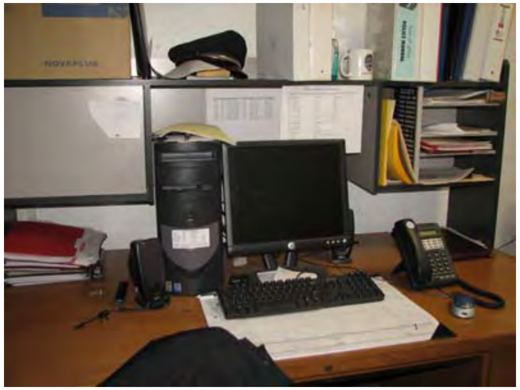
1. Fantech
Model FR 150
90 watt
2000RPM
moving 220
CFM @ .20

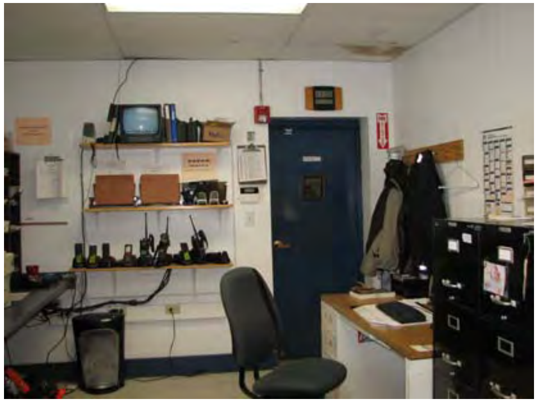
2. Model 225 150
watt 1.32watt 2700
RPM 400 CFM

Two inline fans provide exhaust from the basement. As the building is further tightened to reduce heat loss, this continuously running exhaust fan could depressurize the basement enough to cause back drafting in the boiler room.

Equipment

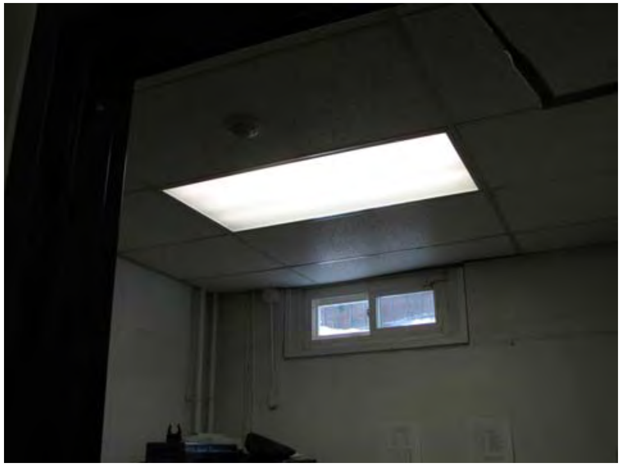
Electric Plug Loads

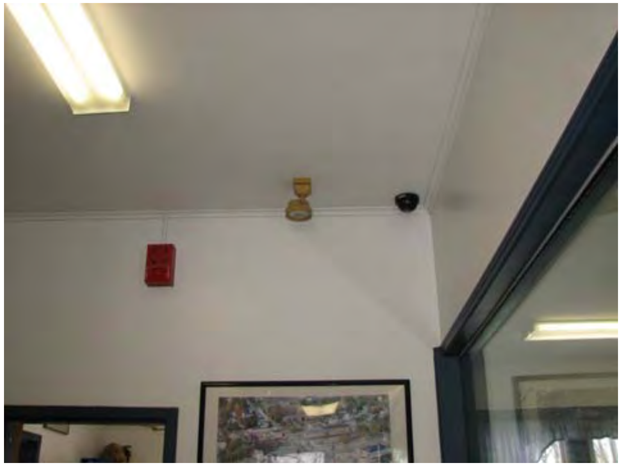




This fan runs continuously to cool this TV which overheats.

Lighting






Recreation Buildings

Administration and Garage

Rink and After School

The entire department's energy costs, at Hummiston Field Complex and Contoocook Beach, from June '00 to July'10: $6,923

Concession Stand

Bath House

Contoocook Beach, Squantum Road

ANNUAL ENERGY USE SUMMARY

Propane Heating

1490 Gals (4 yr avg; 970 gals ’09-’10)

Office and Garage

The Hummiston Field Complex

Electricity (entire complex)

22,160 Kwh Meter #01468463

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 1490 gallons x 91,333 Btu’s/gallon = 136,086,170 Btu’s or **136 MMBtus**

Electricity :**22,160**kWh x 3412 Btu/kwh =**75,609,920 Btu’s or 75.6 MM Btu’s for site energy**

22,160 kWh x 11,396 Btu/kWh = **252,535,360Btu**’s includes generation source energy

Total Site Energy in Btu’s = 211.6 MMBtu’s /1632 FT2 = 130 KBtu/ft2

Total Site Energy in Btu’s = 388.5 MMBtu’s / 1632 FT2 = 238 KBtu/ft2

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

Office and garage

Whole Building: 5475CFM50
Means that **5475 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: 15.48ACH50
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 15 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: 1.08ACH Winter: 1.22 ACH Summer: .67ACH
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 55 minutes or so.

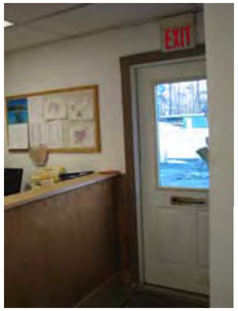
Estimated cost of envelope air leakage: $ 1332 at $3.00 gallon or approx 33% of heating bill

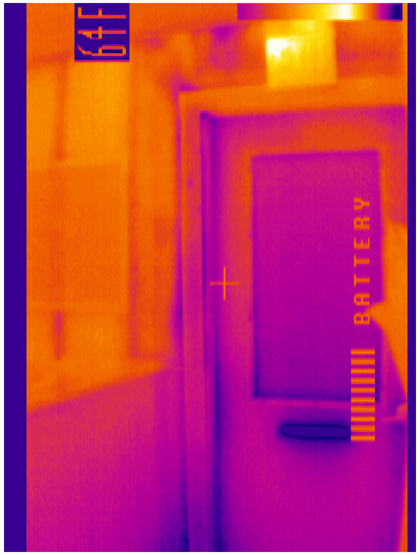
Leakage Area (Canadian EqLA @10pa) 604 in2 or 4.2 sq feet
Total size of hole if add all cracks and gaps together

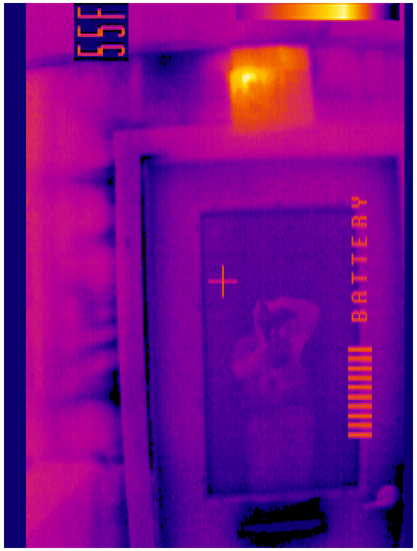
Minneapolis Leakage Ratio: 1.41 CFM50 per ft2 of envelope surface area
This is using the CFM50 relative to the surface area of the shell or envelope, since heat loss is based on surface area not volume.

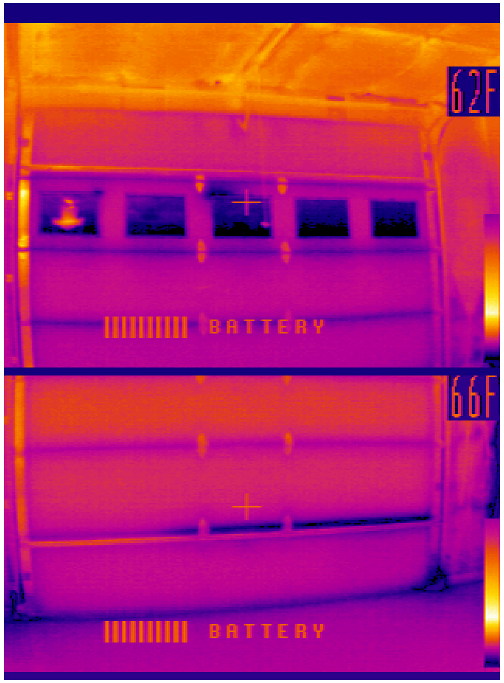
Brighter colors indicate heat greater rates of heat loss. Note most significant areas are garage doors, above the ceiling, slab edges, walls of the middle bay and windows.

Doors

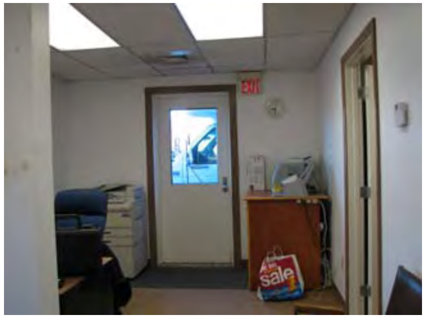


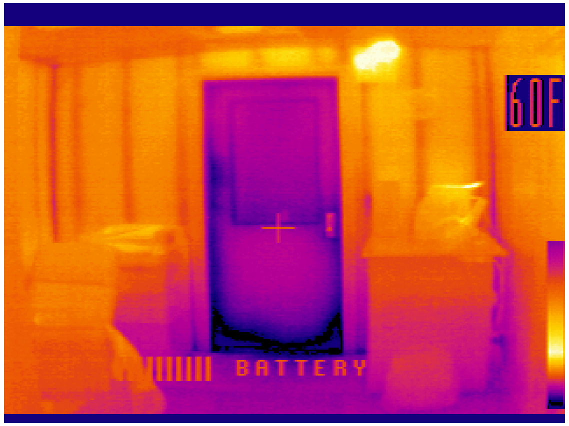






With or without the blower door fan running, air leakage around all doors edges, and trim, is significant.



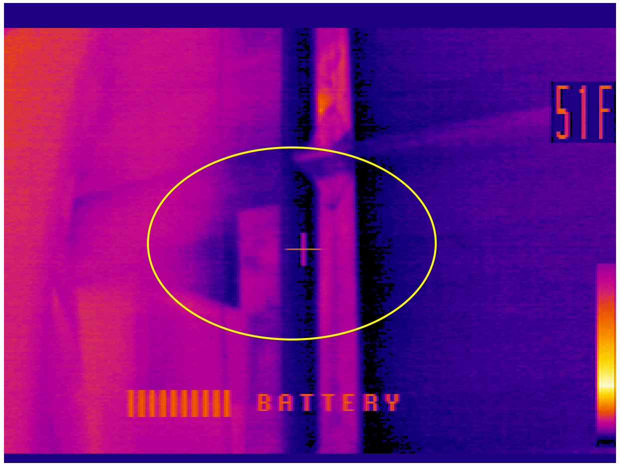


Doors

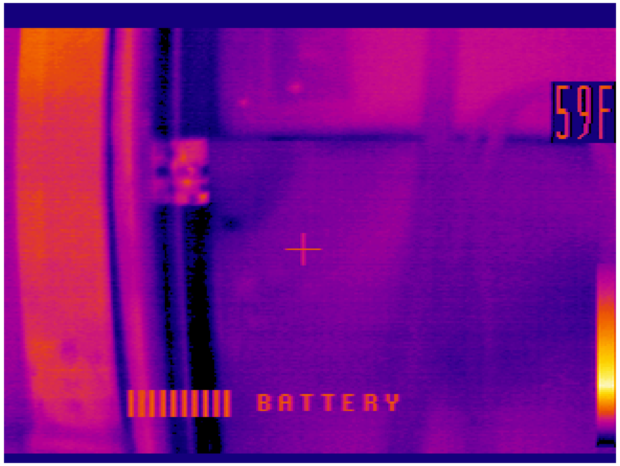
Greatest heat loss at gaps and cracks in holes or material transitions.

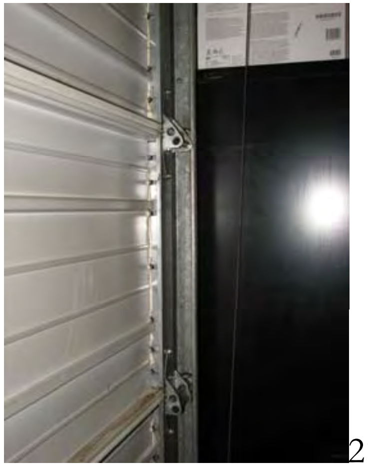
Note the reduced insulation value as the fiberglass is compressed. Darker color shades indicate greater heat loss.

Doors

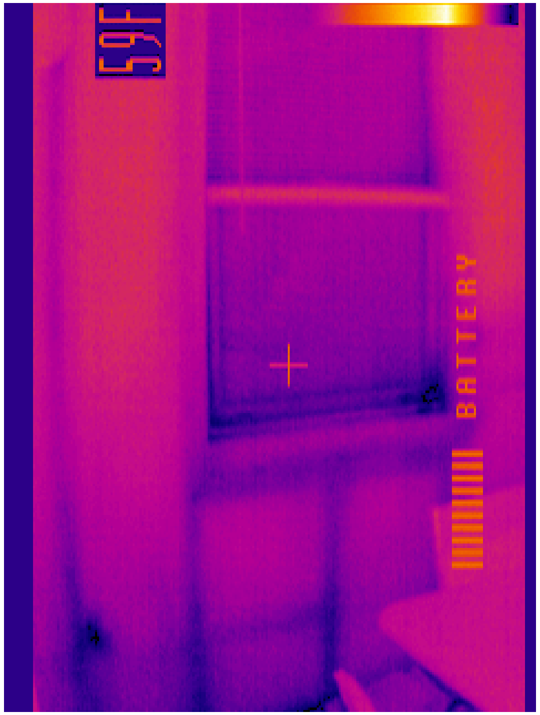


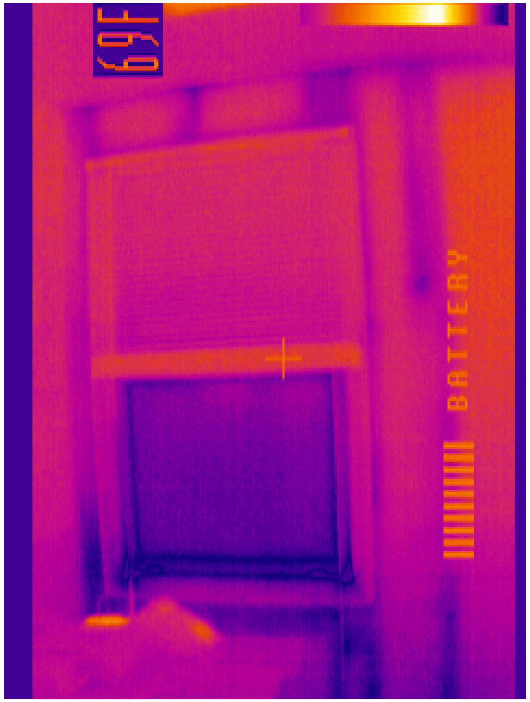
Doors

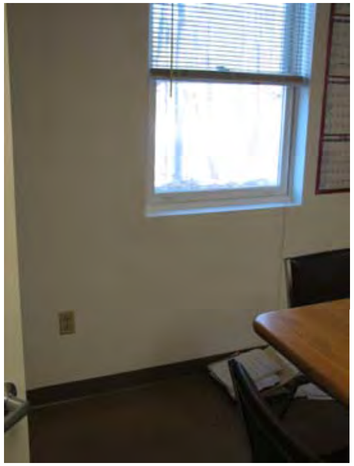




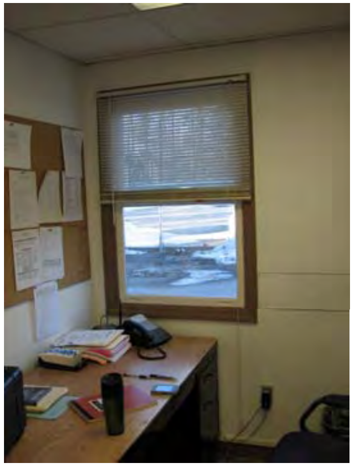
Windows



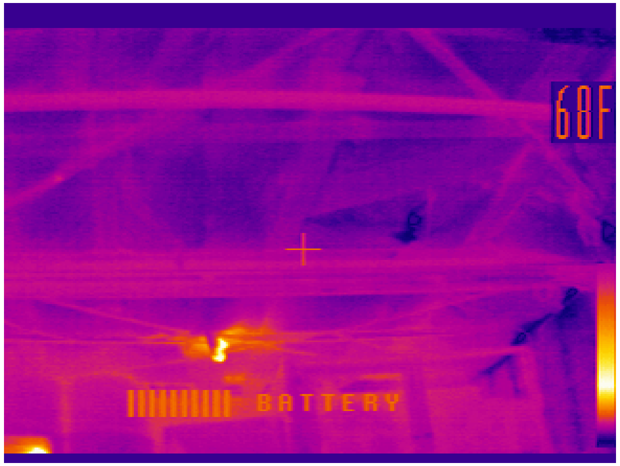


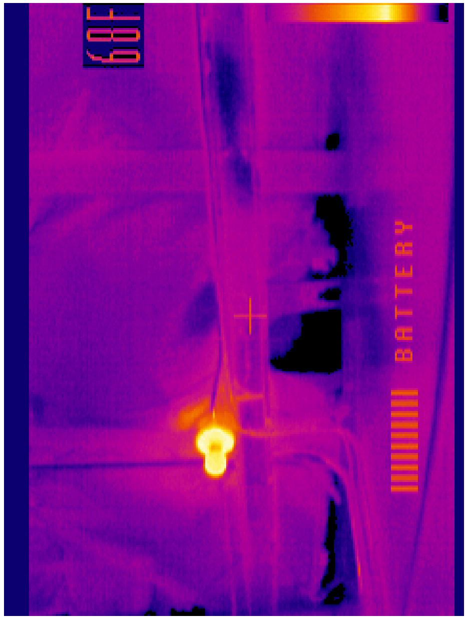


The only two windows are wood double pane with an estimated R value of 2.1. With the lites in the doors, glazing represents approximately 30 sf and just over 1% of wall surface area. Air leaks in at the corners and behind the trim through the rough opening. An effective caulk and weather-stripping would be a cost effective approach to improving these two windows.

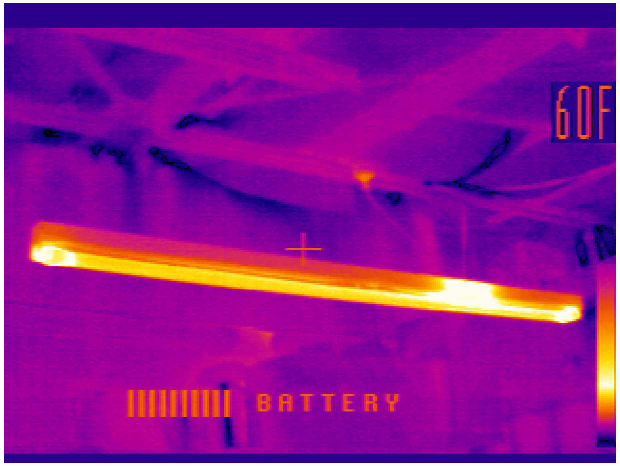


Ceilings



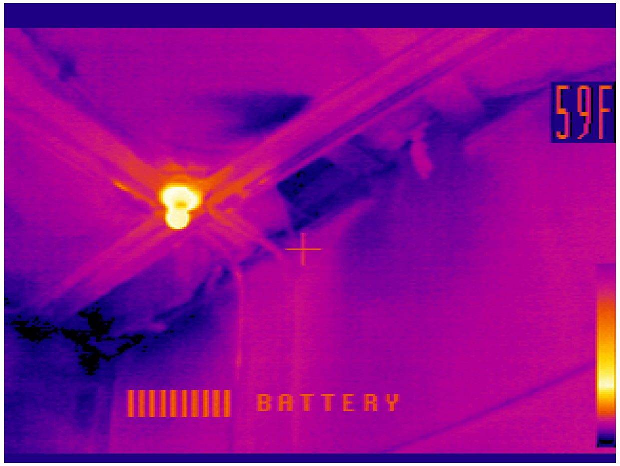


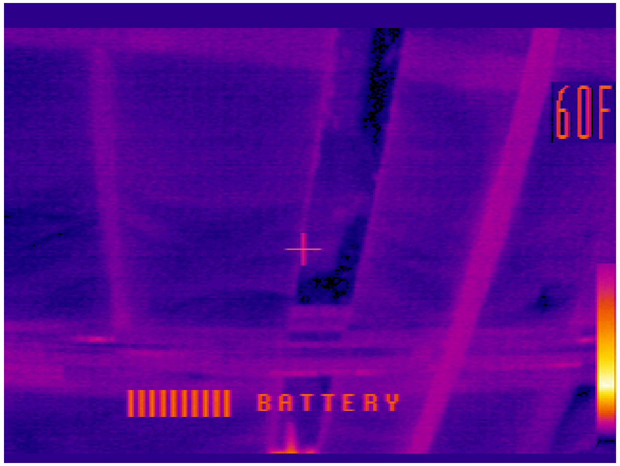
Ceilings



Fiberglass performs very well as a filter.

Ceilings





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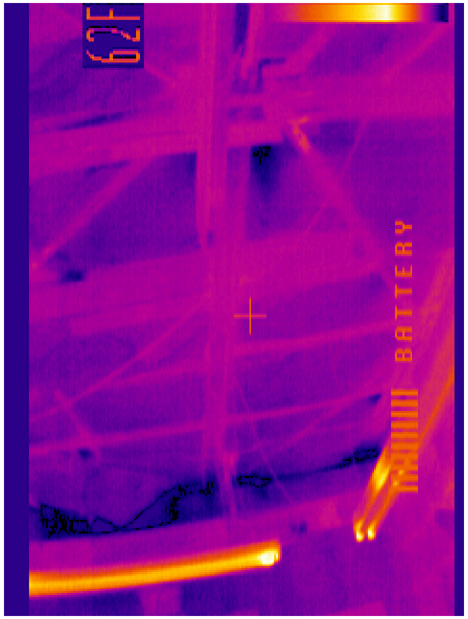

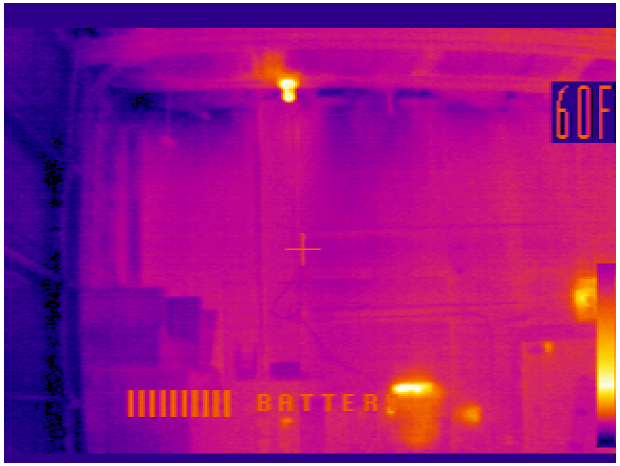

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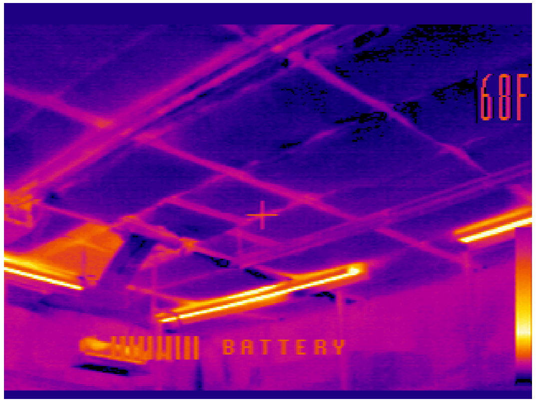
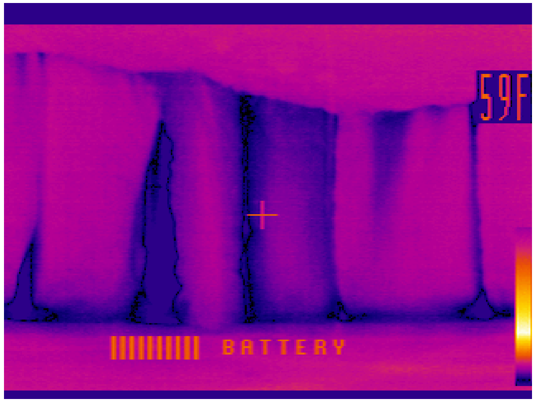
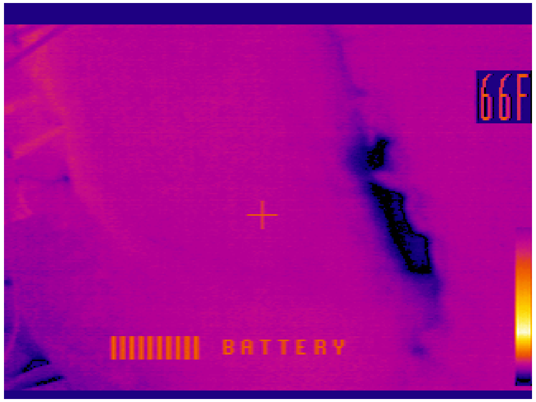


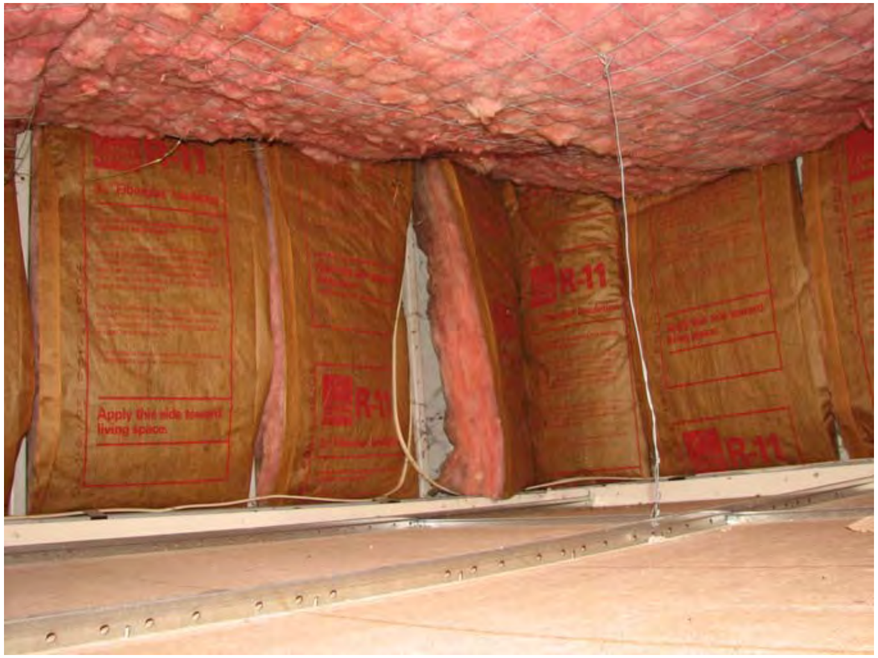
Ceilings

Ceilings



Over the suspended ceilings of the office.





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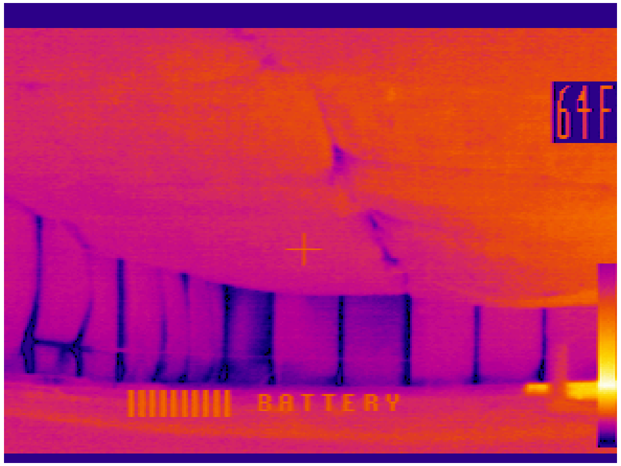

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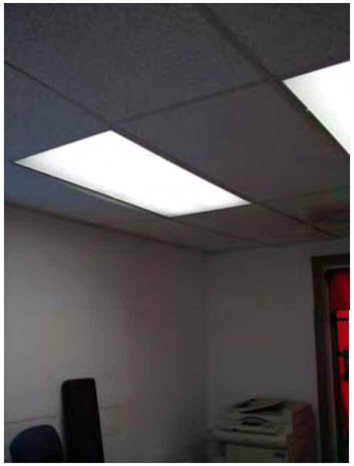
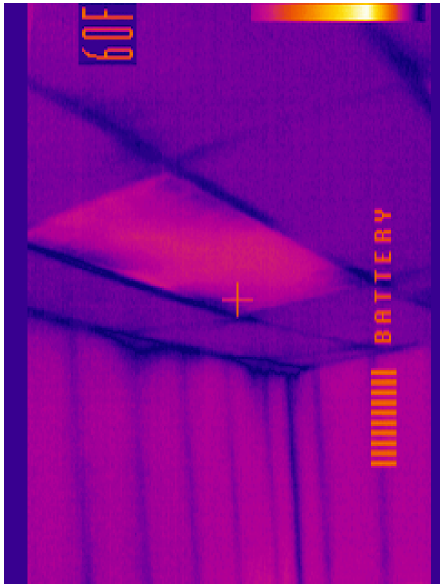
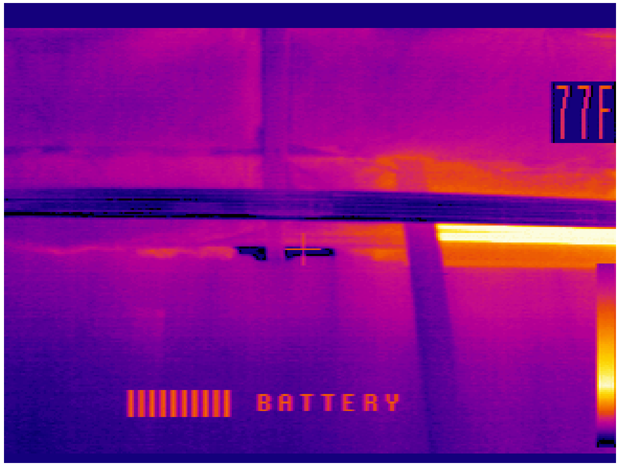
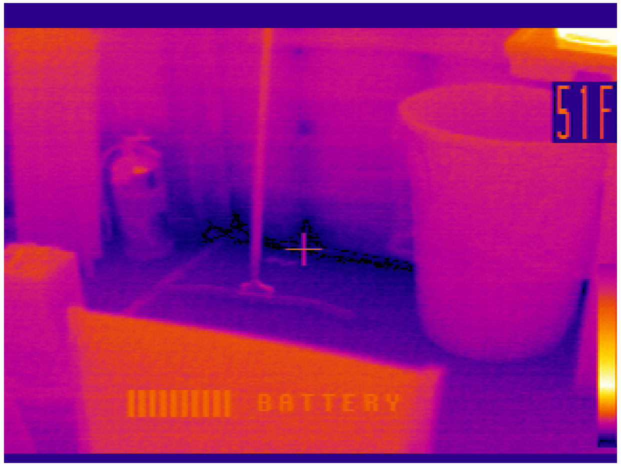




Walls

Walls





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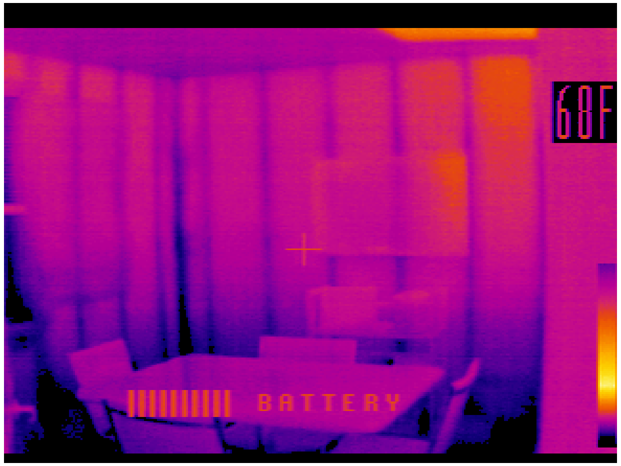

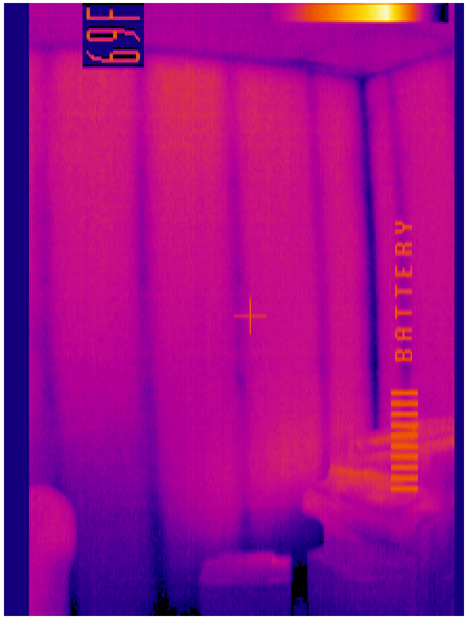

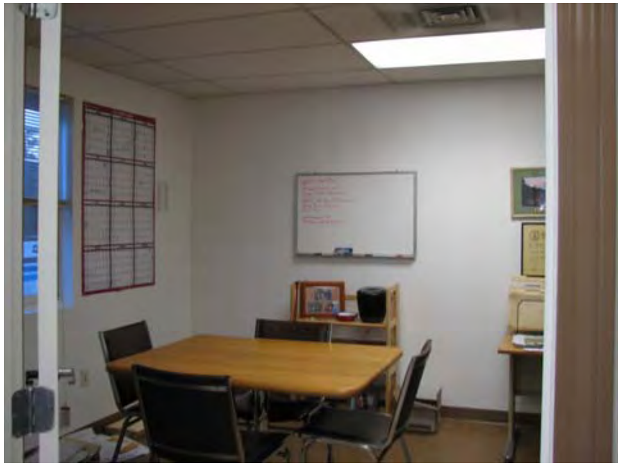

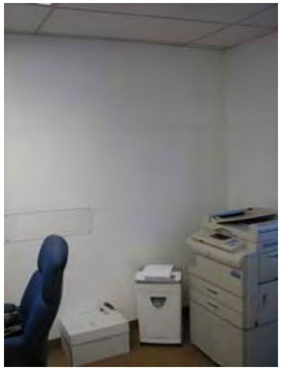

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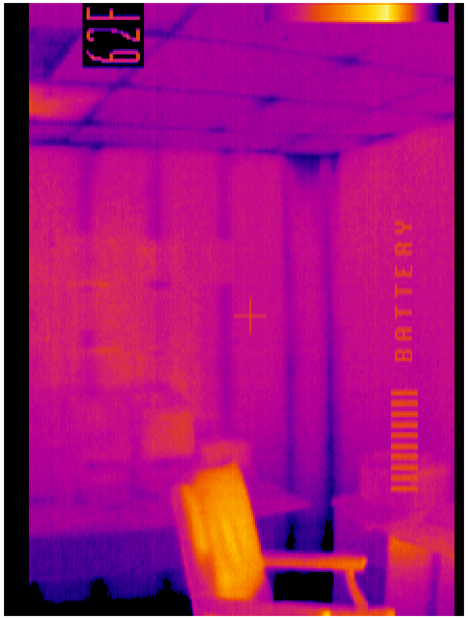

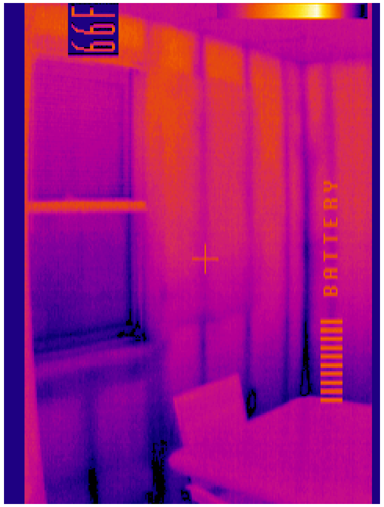

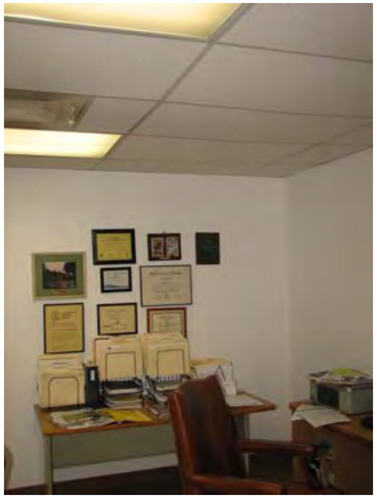

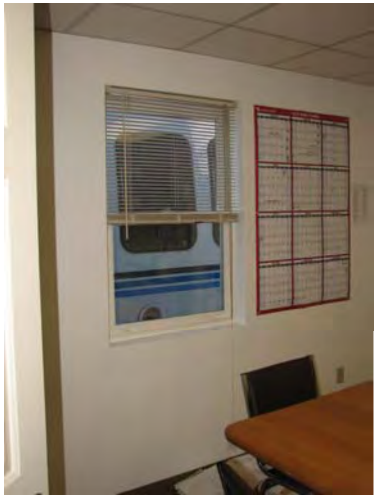

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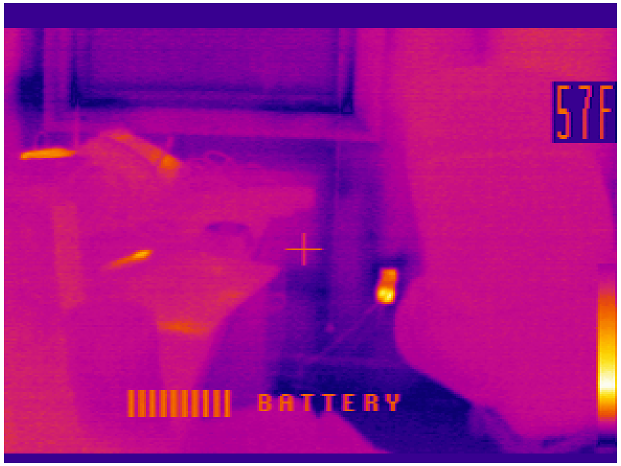
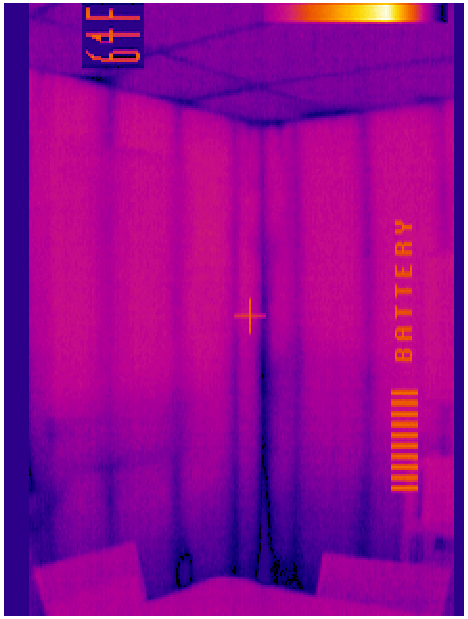
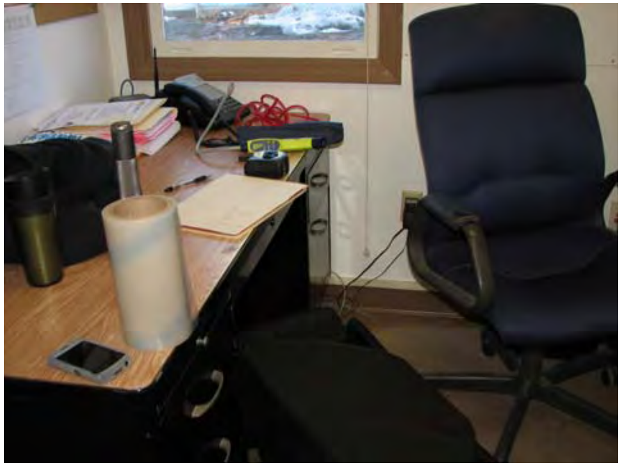
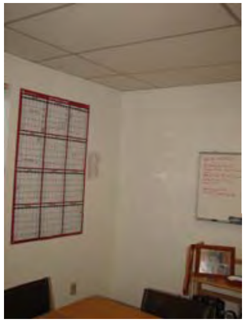




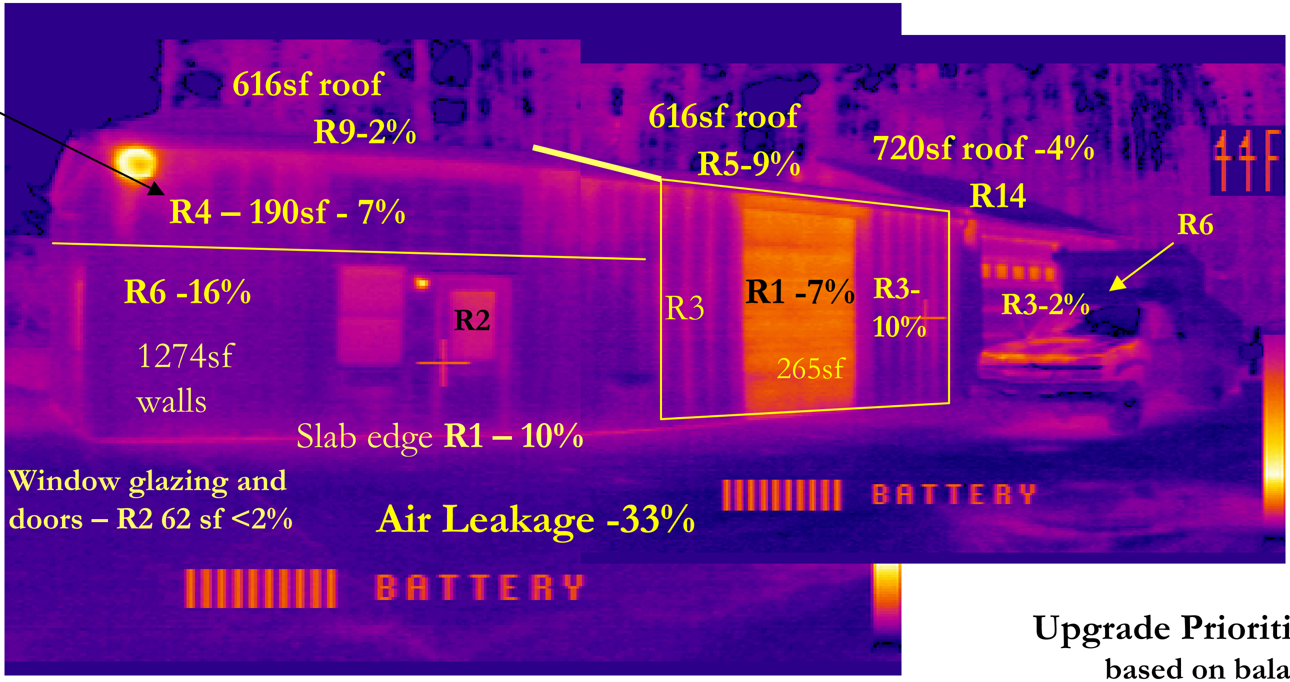




Envelope Heat Loss Assessment

3.5” wall batts and about 4” laid on suspended mesh wire from ceiling – all exposed

Walls:3.5” batts between metal siding and drywall and wood frame of addition



Brighter colors indicate heat greater rates of heat loss. Note most significant areas are middle door and walls, above the ceiling, slab edges, end garage door, and windows.

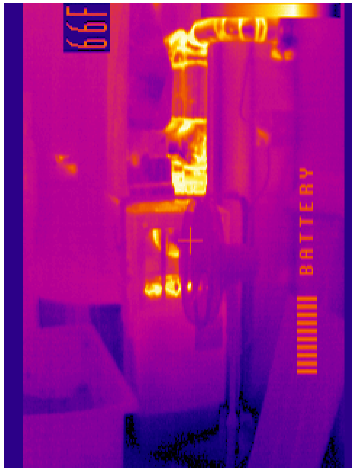
Upgrade Priorities:

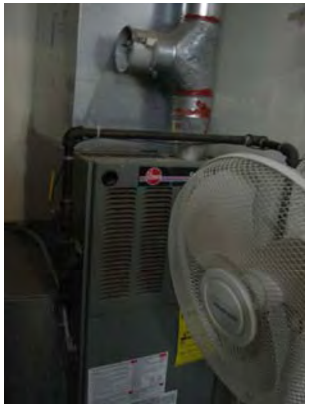
based on balancing impact, accessibility & cost

1. Air seal
2. Middle door and walls
3. Middle ceiling
4. Above office ceiling walls
5. Addition ceiling
6. Addition ceiling
7. Remaining walls
8. Slab


5
3
6
4
2
7
1
8

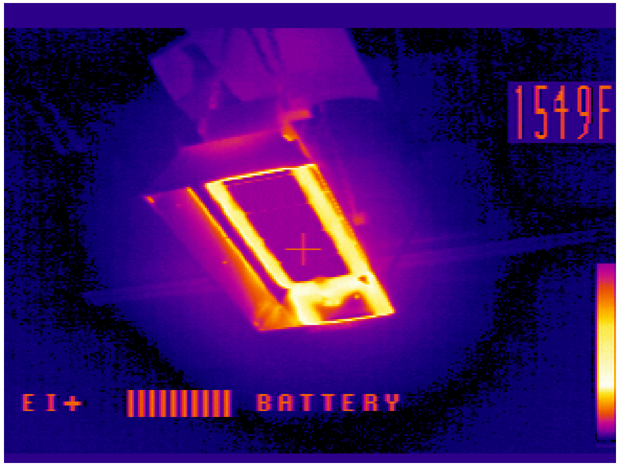
Space Heating Equipment





Rheem Criterion II forced hot air furnace – 80% AFUE

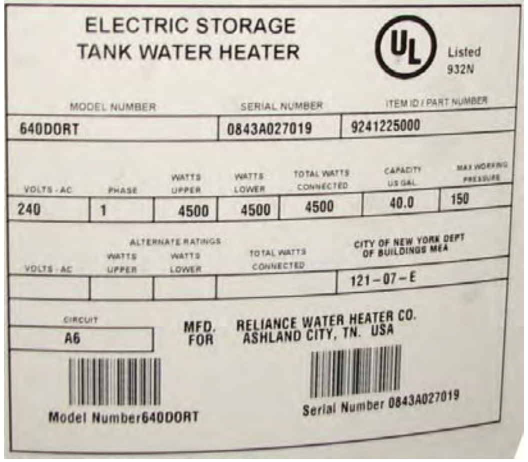
Space Heating Equipment



Propane fired; pilot light is difficult and somewhat dangerous to light

Marvin S460 Radiant heater – on 5 hours/day

Water Heating Equipment



ELECTRIC STORAGE
TANK WATER HEATER

Listed
932N

MODEL NUMBER	SERIAL NUMBER	ITEM ID / PART NUMBER
640DORT	0843A027019	9241225000

VOLTS - AC	PHASE	WATTS UPPER	WATTS LOWER	TOTAL WATTS CONNECTED	CAPACITY US GAL	MAX WORKING PRESSURE
240	1	4500	4500	4500	40.0	150

ALTERNATE RATINGS

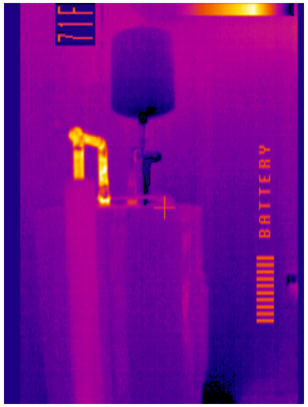
VOLTS - AC	WATTS UPPER	WATTS LOWER	TOTAL WATTS CONNECTED	CITY OF NEW YORK DEPT OF BUILDINGS MEA
				121 – 07 – E

CIRCUIT
A6

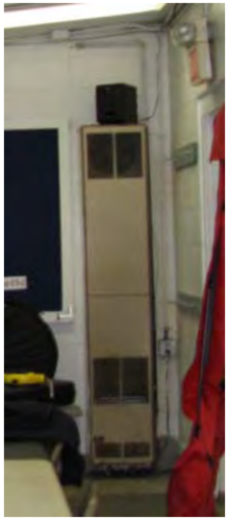
MFD. FOR RELIANCE WATER HEATER CO.
ASHLAND CITY, TN. USA

Model Number640DORT

Serial Number 0843A027019



ANNUAL ENERGY USE SUMMARY



Heating and Cooking Fuel

876 Gallons Propane (3 year average)

RINK

The buildings run close to north/ south

Electricity
Unknown Kwh

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: 876 gallons x 91,333 Btu's/gallon = 80,007,708 Btu's or **80MMBtus**

Electricity: 22,160kWh x 3412 Btu/kwh =**75,609,920 Btus or 75.6MM Btu's for site electrical**
22,160 kWh x 11,396 Btu/kWh = **252,535,360 Btu's** includes generation source energy

Total Site Energy in Btu's = 155.6 MMBtu's /1315FT2 = 118.3KBtu/ft2
Total Site Energy in Btu's = 332.5MMBtu's / 1315FT2 = 192KBtu/ft2

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

Whole Building: 1938CFM50
Means that **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: 11.06 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 **just over 11 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: .5 ACH Winter: .91 ACH Summer: .5 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 65 minutes or so.

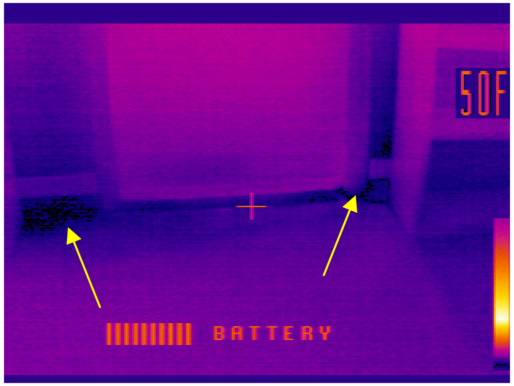
Estimated cost of envelope air leakage: **$475 at $3.00 gallon or approx 18% of heating bill**

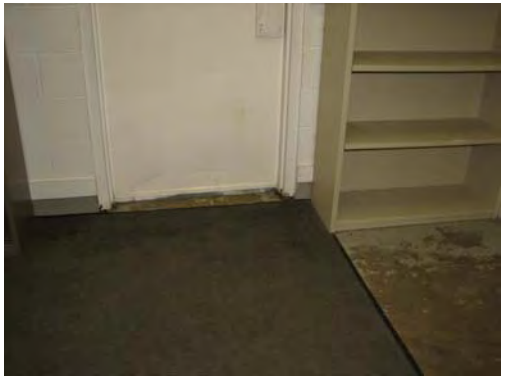
Leakage Area (Canadian EqLA @10pa) 220in2 or 1.5 sq feet
Total size of hole if add all cracks and gaps together

Minneapolis Leakage Ratio: **.71 CFM50 per ft2 of envelope surface area**

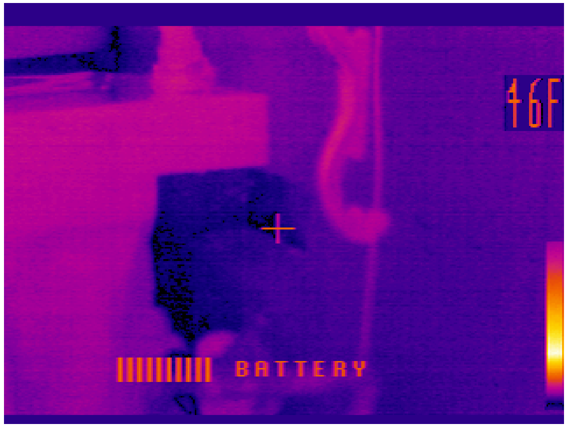
This is using the CFM50 relative to the surface area of the shell or envelope, since heat loss is based on surface area not volume.

Doors and other Holes



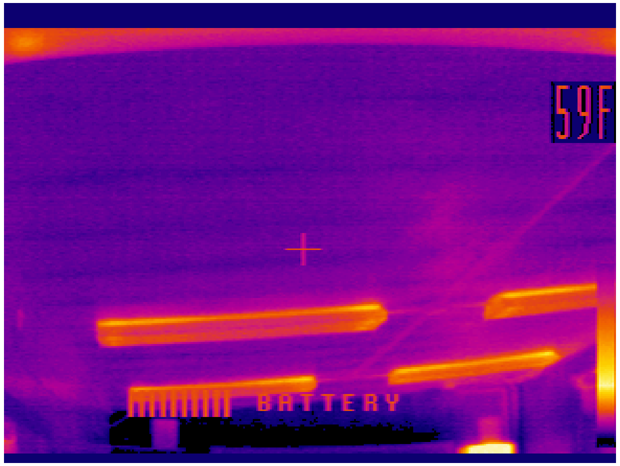


Doors and other Holes



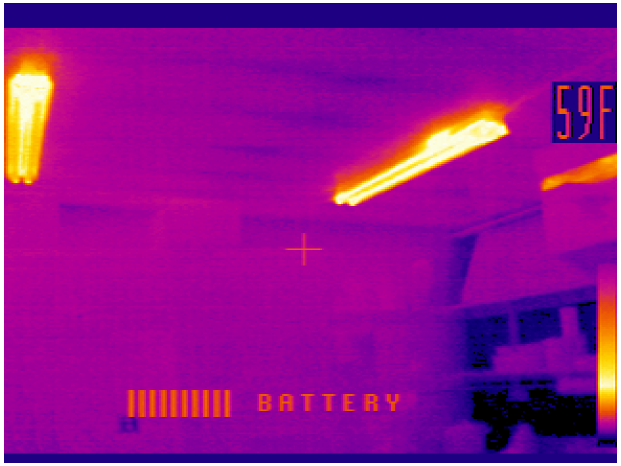
Lots of outside air enters through this hole in the hollow concrete wall– and lots of heat leaves the same way.

Ceiling

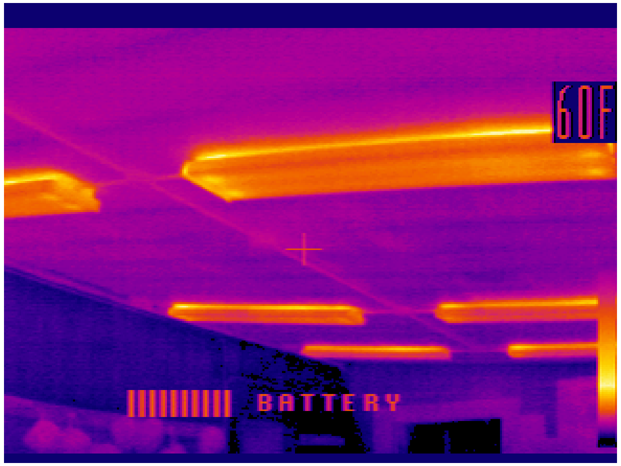


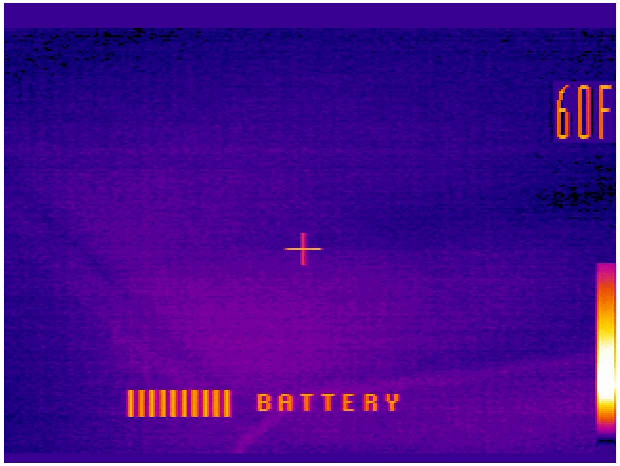
Insulation values above the ceiling are not known, but it appears that there may be some level of insulation over the framing, as if blown or a second layer of batts had been added. A guesstimate for the ceiling assembly is between R14-16.

Ceiling



Ceiling





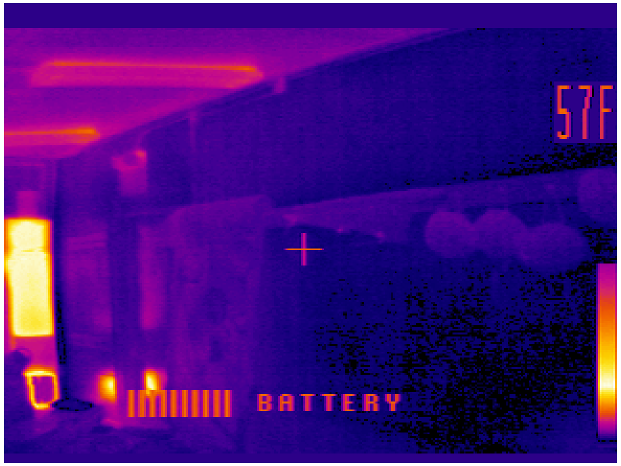
Ceiling

The framed section of the building appears to have more thermal bridging, suggesting bats only – in between 6” rafters would indicate approximate R15-16. Snow on this section of confirms it may be slightly better insulated that the first room – but also that this room is generally kept at a lower temperature.

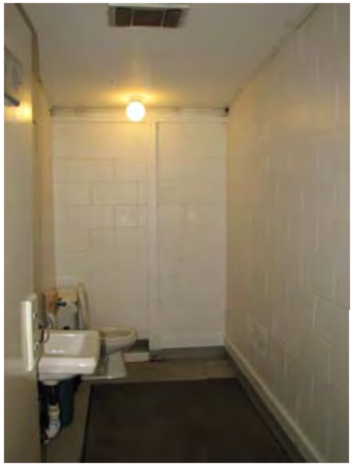
Walls

Far greater variation in the walls: A highly conductive concrete block (R1) as opposed to 3.5 inch batts framed inside 2x4's 16OC and a 4x4 support structure. (R7)

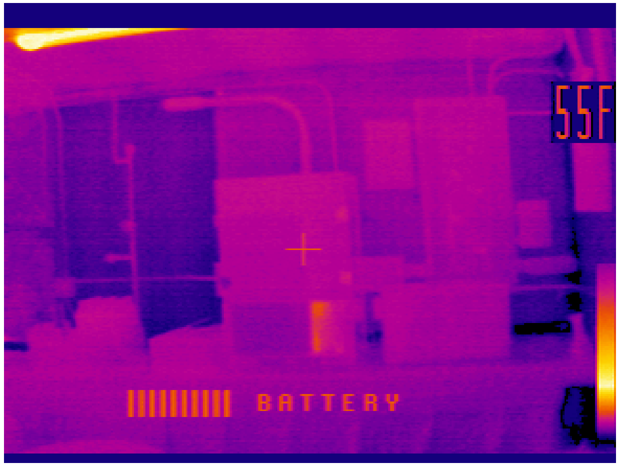
Walls



The concrete block walls represent 62% of envelope heat loss and are the largest opportunity to reduce propane use.

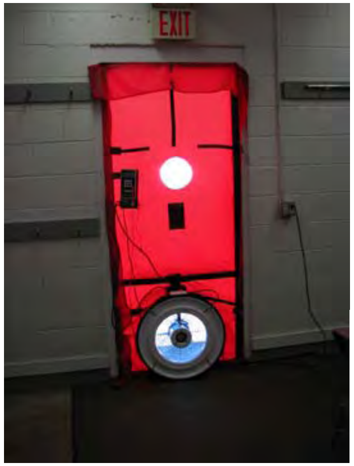


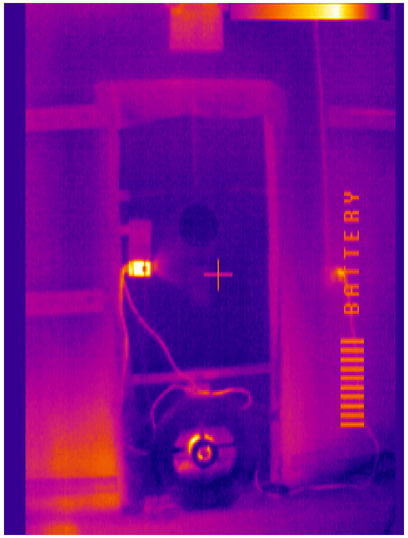
Walls



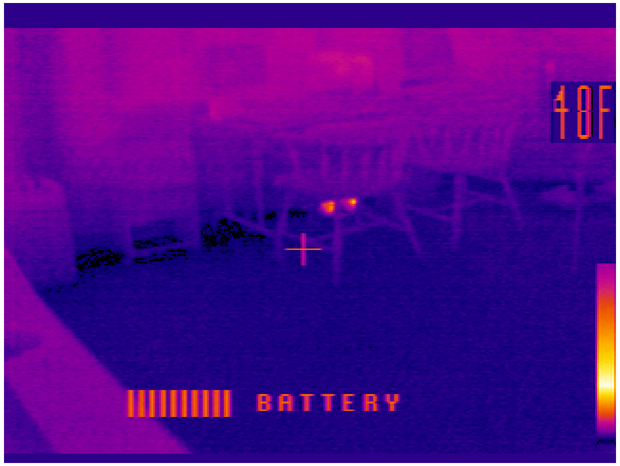
Insulating on the outside minimizes disturbance to equipment, wiring, and plumbing, as well as creating the best insulation value.

Walls





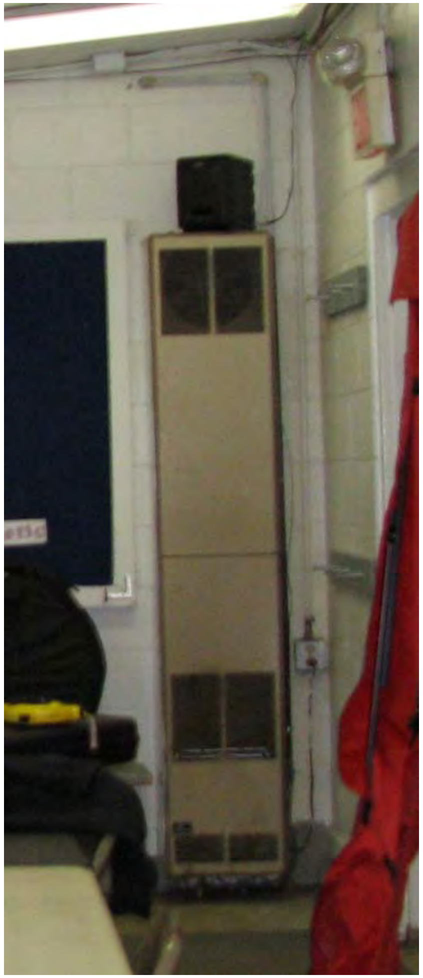
Walls



Edges where the walls meet the ceiling, and the slab, are sources of heat loss and personal discomfort.

Heating Equipment

Electric heater mounted near ceiling in the rec or ‘computer room’. This room is used after school but less frequently than the rink’s warming and concession areas.



Empire wall mounted propane fired space heater.

Electrical Equipment

Exhaust fan over grill

Indoor Lighting

Computers and TV

Gibson
Freezer
15.7cf

Refrigeration

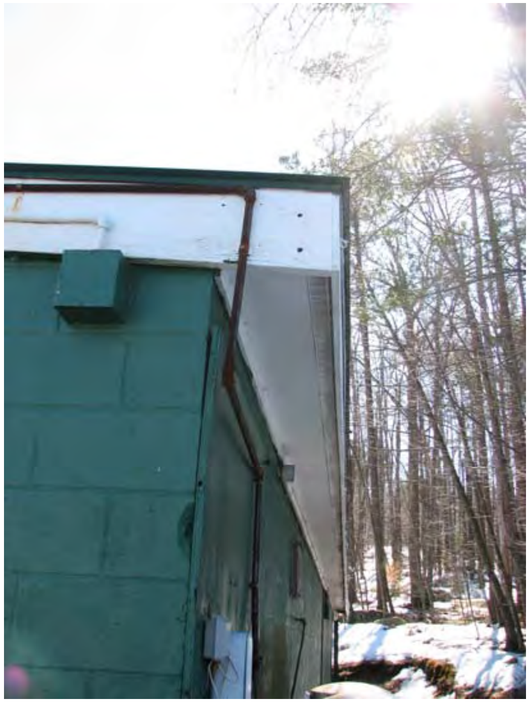
Outdoor lighting

Bath exhaust fan

Other holes

Grease from grill prevents fan damper from closing. Source of heat loss.

Evidently a sub panel off the admin building






Fairly new standing seam roof may be able to be raised to add continuous rigid. Underneath though any increase in ceiling or roof insulation would likely hold snow longer. Roof is now vented, so soffits would have to be sealed. There appears to be very little room to insulate from inside.

Drainage can also be installed along the back if not already present.

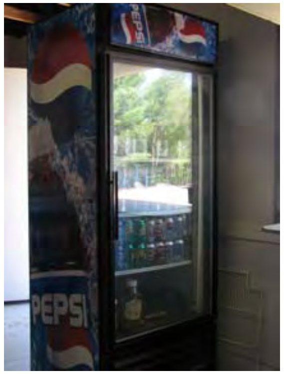
Two sides of the wall have draining capacity, while pavement comes right up to the slab edge on two sides. Best practice would involve breaking up the pavement about 2 feet from the building and installing a perimeter drain near the footing and washed stone. Importantly, it would also allow installing a moisture barrier and insulation at the edge of the slab down to footing if possible. The Tuff N Dri and Warm N Dri system is recommended. A slight paved ramp can be reinstalled at the doors.

Installing drainage, a moisture barrier and insulation is recommended prior to insulating the exterior of the building. While a good thing to do anyway, the expense would not be justified except to protect the insulation board and further insulate the slab.

ANNUAL ENERGY USE SUMMARY
Contoocook Beach Concession Stand

Cooking Fuel
100 Gallons Propane
Infra red garage space heater rarely used

Electricity
5,726Kwh



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: 100 gallons x 91,333 Btu's/gallon = 9,133,000 Btu's or **9 MMBtus**

Electricity : 5,726 kWh x 3412 Btu/kwh = **19,537,112 Btu's or 19.5MM Btu's for site energy**
5,726 kWh x 11,396 Btu/kWh = **65,253,496** includes generation source energy

Total Site Energy in Btu's = 28.5 MMBtu's /400FT2 = 71.2 KBtu/ft2
Total Site Energy in Btu's = 74 MMBtu's / 400FT2 = 185KBtu/ft2

Star Cook Top Model 6367 200,000 Btu/hr
On from 10:30 – 3:00 7days a week all
summer over 350 hours

Staff reports only using ½ the surface area, but grease builds and problems occur if both sides aren't turned on.

15 in Star-Max Char Broiler, 40,000 BTU, Countertop, Steel Radiants

Newer model 15x24" and only 40,000 Btu's. $689

Reliance
501 DHW

Five 4’ (2) T12

Popcorn maker –
not using while out
of popcorn

Fans used
when
necessary

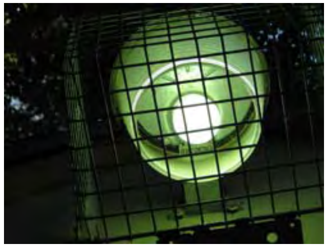
Elec stove
not working

Candy freezer
Kenmore 33207

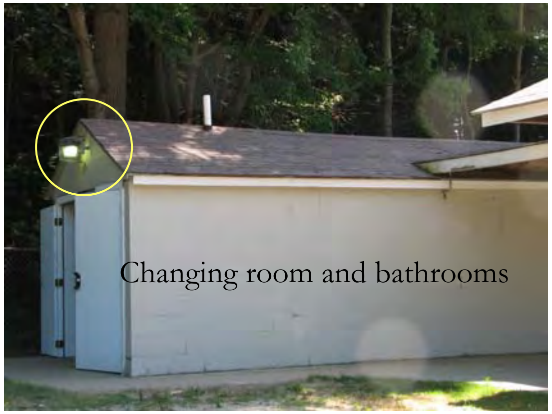
True Pepsicool
Runs constantly

Beverage Air cooler
borrowed from Team Center since Kenmore is broken

Total of four security lights.
One on at 11:30 am
Only one appears to be on
photo sensor



Concession Stand



Changing room and bathrooms

8’ (2) T12

Sewer pump

Transfer Station

Old Sharon Road

The building is a 1980's, 40' x 100', uninsulated metal building, framed as a 4"x6" pressure treated pole barn, running north/south. The 4" slab was poured with a frost wall. Heat is provided by overhead propane tube heaters.

There are two small shed like structures within the larger building with some insulation which serve as an office and bathroom. They are maintained at 70 degrees vis electric resistance heaters throughout the winter. An outside dumpster hut also has an electric space heater turned on when someone is inside.

Total energy costs from June '09 through July '10: $6,511 or 45.2KBtu/sf.

*ANNUAL ENERGY USE SUMMARY

Propane Heating Fuel
851 Propane Gallons

Oil for off
road skid steer
230 gallons

Meter #G28070033

Electricity
20,720 Kwh

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: 851 gallons x 91,333 Btu's/gallon =77,724,383Btu's or **77.7 MMBtus**
Oil: 230 gallons x 140,000 Btu's/gallon = 32,200,000 Btu's or **32.2 MMBtus**

Electricity : **20,720 kWh** x 3412 Btu/kwh = **70,696,640 Btus or 70.6 MM Btu's for site energy**
20,720 kWh x 11,396 Btu/kWh = **236.1MMBtus** includes generation source energy

Total Site Energy in Btu's = 180.6 MMBtu's / 4000FT2 = 45.2KBtu/ft2
Total Site Energy in Btu's = 346 MMBtu's / 4000FT2 = 86.5KBtu/ft2

*Narrative Section offers an entirely different analysis perspective.

Per Week

Hours open to the public: 28
Additional Staffed Hours: 12

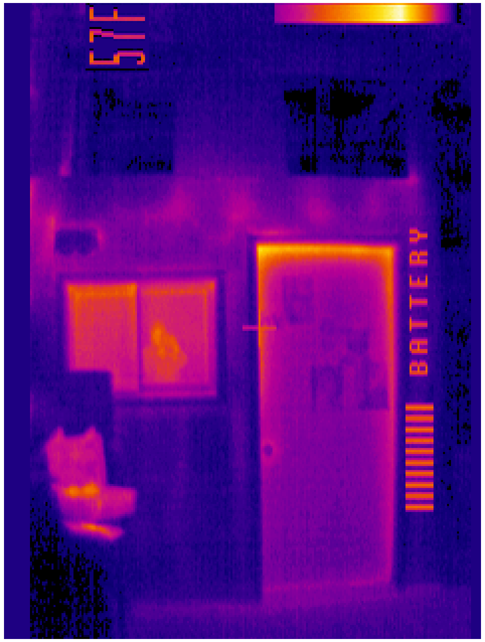
Un Occupied Hours: 128

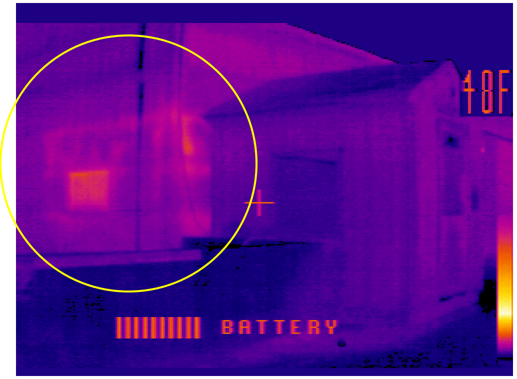
Per Heating Season

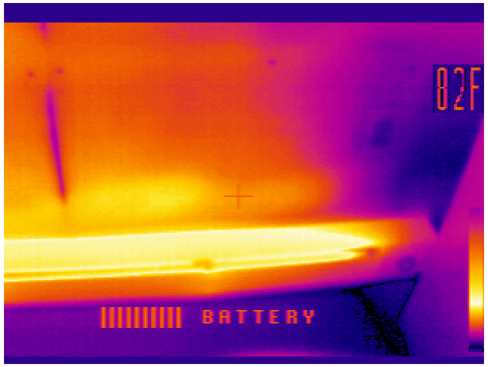
Hours open to the public: 728
Hours Additional Staffed Hours: 312
Un Occupied Hours: 3328

Somewhat insulated structures within the warehouse structure.

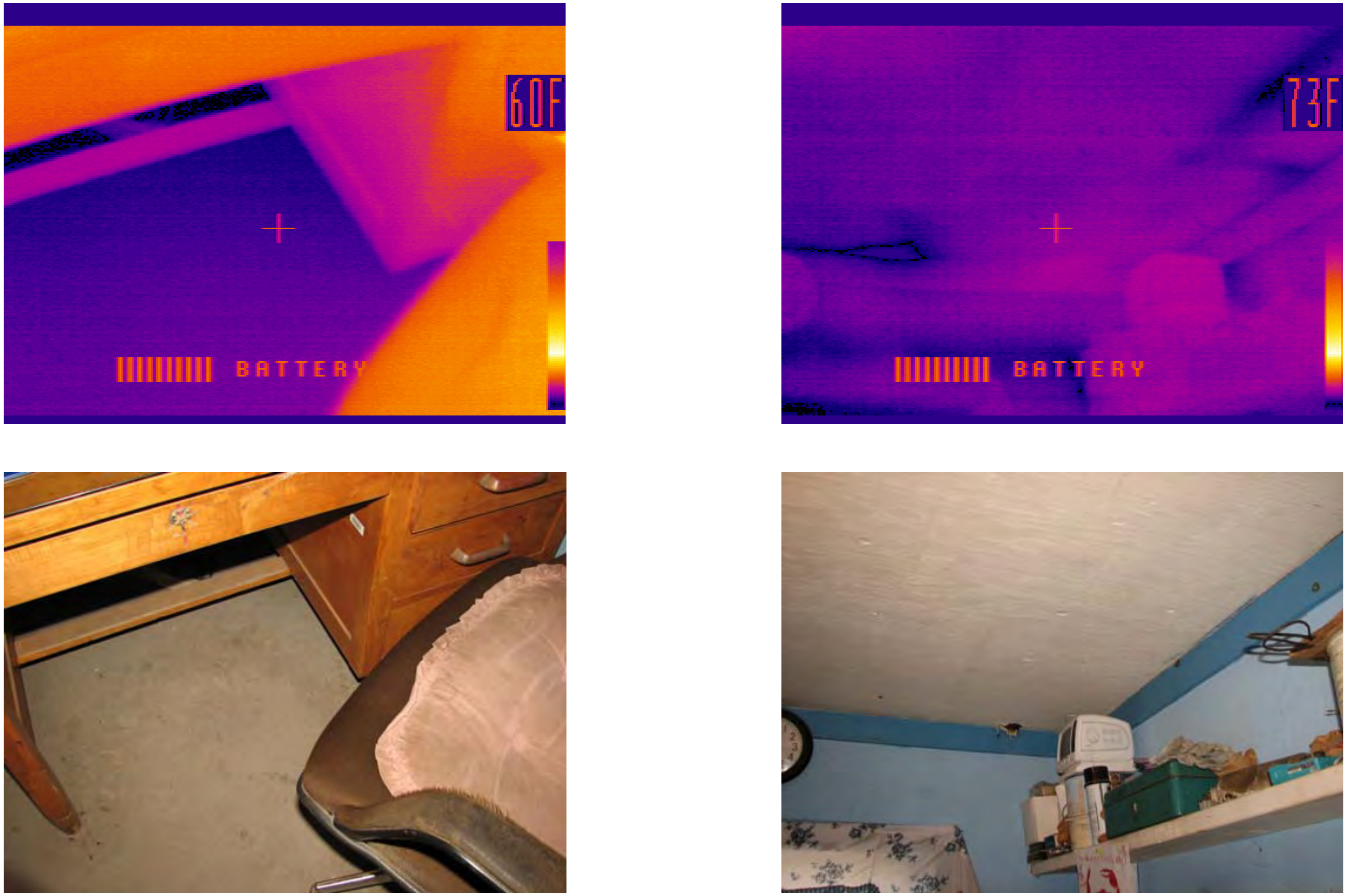
Electric Heating



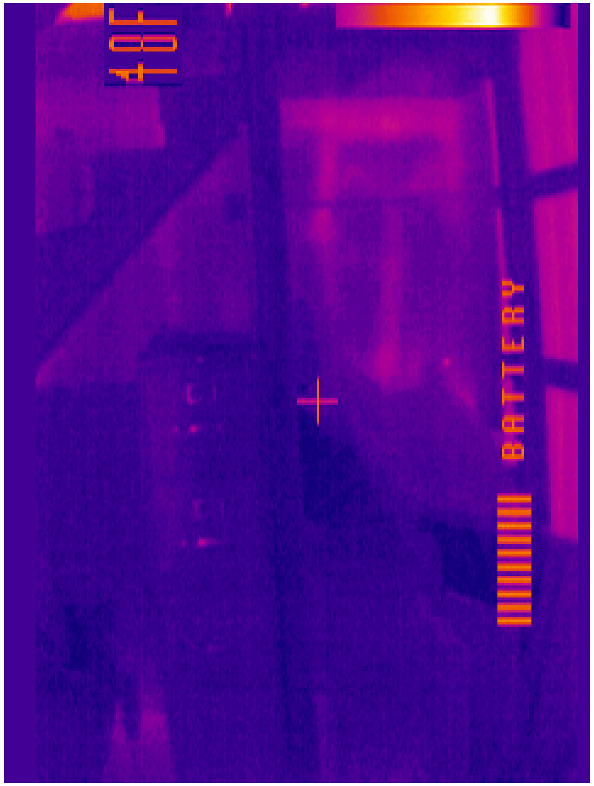


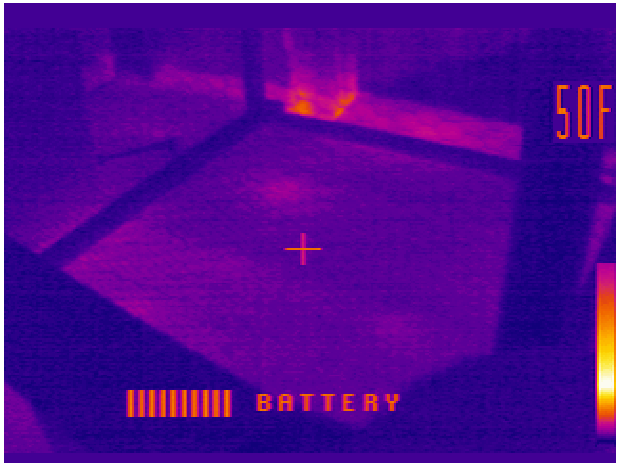


Heat was not on in the shack the day of the site visit as the facility was closed to the public.



Office Shed. Note 13° degree temperature difference between uninsulated slab floor and ceiling. Ambient temperature about 75° and felt very warm.


48F
BATTERY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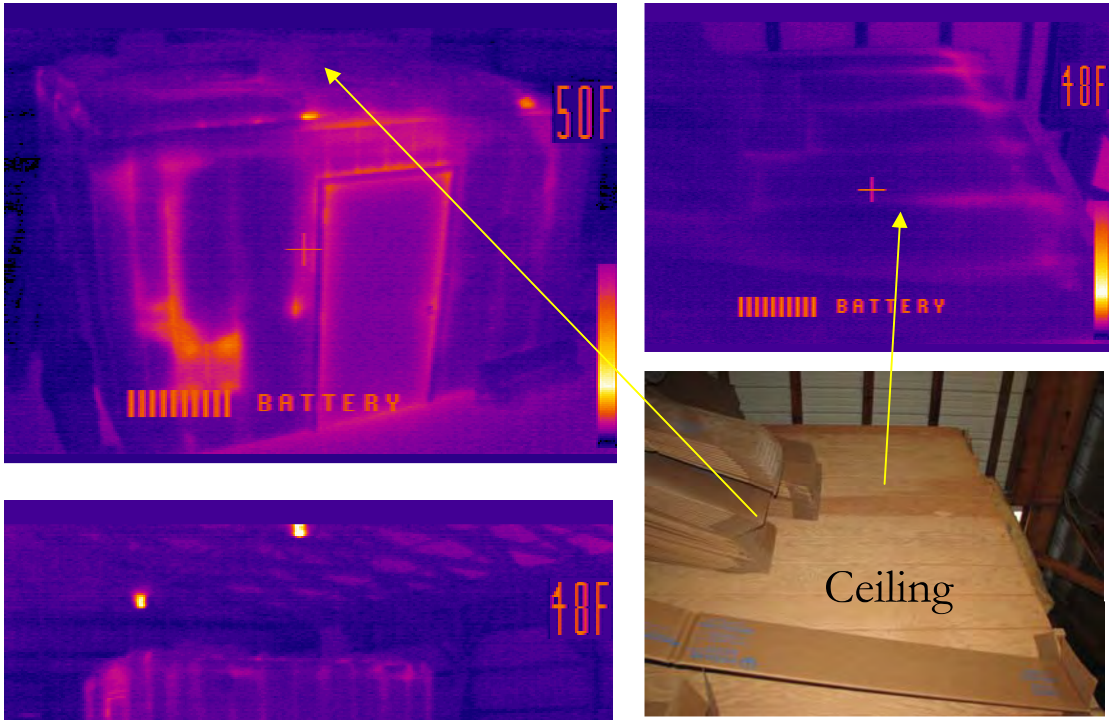
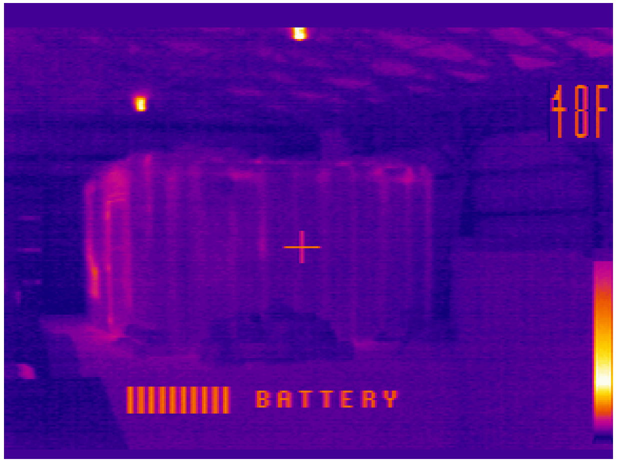
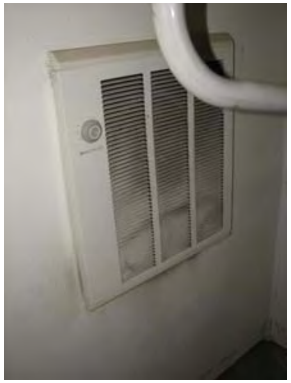
BATTERY

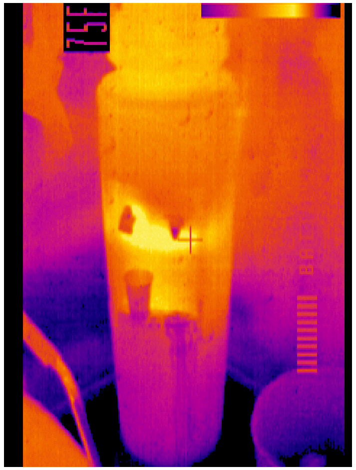
Electric Heating

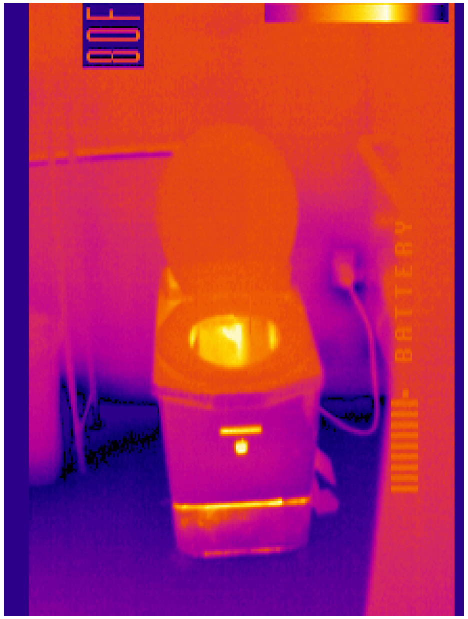


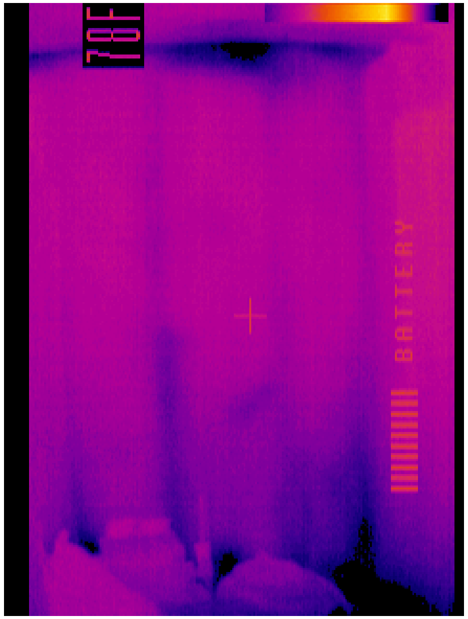


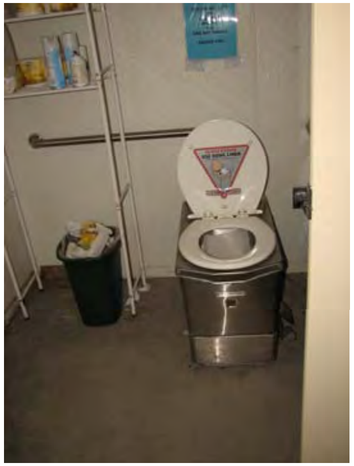
Berko electric wall heater





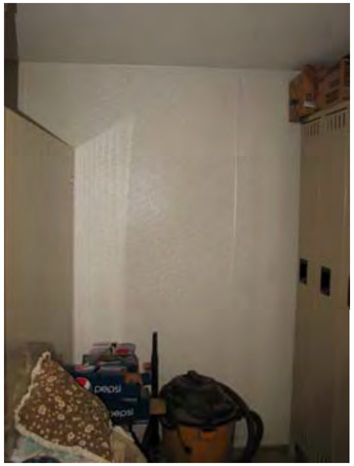


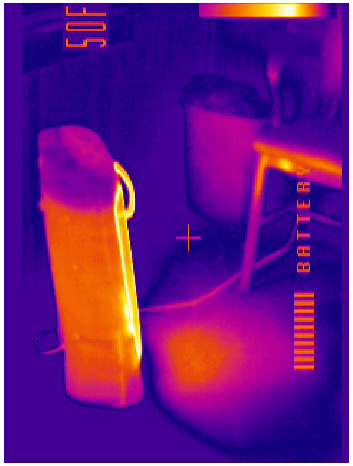




There are likely far more efficient ways to heat or chill water when wanted, or compost wastes. First you have know how much it takes now.

Measuring electrical consumption on these individual plug load devices is an important component of pursuing energy efficiency. These appliances DO contribute to the space heating of these sheds.

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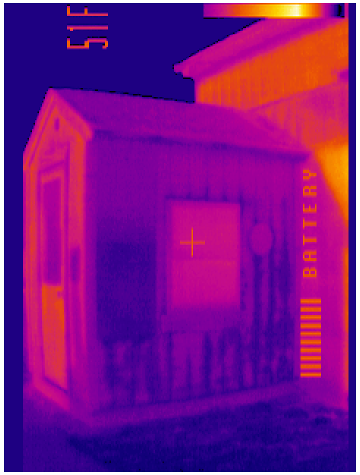
BATTERY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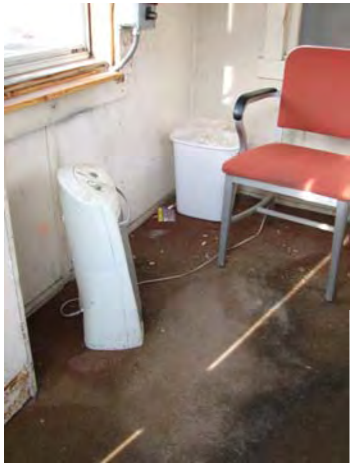
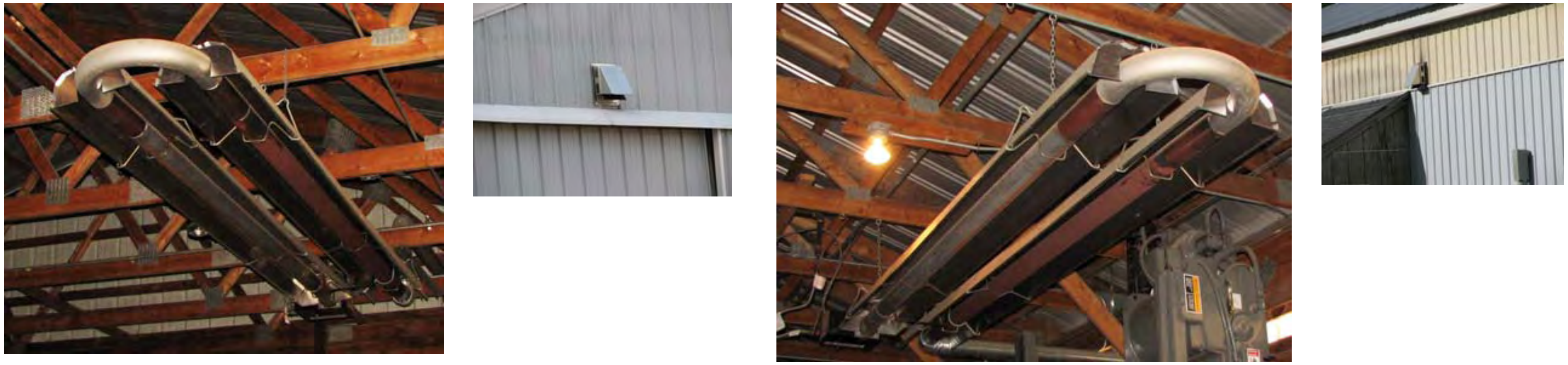
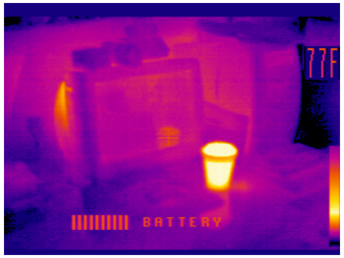
BATTERY



Propane Radiant Heaters



Recently installed and in good condition.



Plug Loads

Haier fridge with freezer box

GE Turntable
Microwave

And Lighting

Thirteen (13) Par 38 Halogen
75 watt, 130 Volt lamps

Glass Crusher
Model GB-1
Recycling Equipment,
Spokane, WA 509-487-6960

Load King Vertical Bailer Model 100 3910 Serial #12579 10 HP Motor, 3 phase, 14 AMPS, 208 volts

Jacksonville, Fla 904-354-8882

Selco Bailer Waste Compactor 82E8 Model #V5-HD Serial 120469029
3 Phase 208 volts

Harris Baxley, GA
800-447-3526

E-monitor

$689 from Energy Circle

HOBO Dataloggers is a company with a very wide range of monitoring equipment. Another interesting product is the E-monitor which was designed for home use but should work for many of the Town's electrical panels. It measures electrical consumption by circuit and reports in kWh's on a number of different spreadsheets. Takes about an hour to install and could be moved from one panel to another over time. For more information, go to the link below.

http://www.energycircle.com/shop/emonitor-energy-monitor-powerhouse-dynamics.html

Insulation strategies would involve detailing a continuous air barrier in direct contact with a continuous insulation barrier on the walls and connecting with the ceiling – while still providing for a vented roof.

Rigid wall panels made by Foard Panel in Chesterfield are believed to be the most cost effective approach to insulating these walls with good performance metrics. Drooping fiberglass batts, even in more framing, which is what is typically done, will put the fiberglass in contact with cold metal surfaces and invite condensation and mold. Nor will it effect insulation values near stamped R number, not stop air infiltration. It is not recommended.

Waste Water Administration and Pump Stations

2 Old Sharon - Office

4 Old Sharon – New Facility

There appears to be one account, labeled "sewer" for the entire waste water department, under one meter # G10482851. A one year total consumption of 482,400kWh. Total energy costs for the entire department is $74,812.

Rt 124 Monadnock St

Cross Street Pumping Station

Erin Lane

Hadley Rd
Photo N/A

ANNUAL ENERGY USE SUMMARY

Heating Fuel

979 Gallons of Oil

2 Old Sharon Road

Electricity N/A

One "sewer" meter #G10482851
for entire complex

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: 979 gallons x 140,000 Btu's/gallon = 137,060,000 Btu's or **137MMBtus**

Electricity : ? kWh x 3412 Btu/kwh = **Btus or MM Btu's for site electrical energy**
? kWh x 11,396 Btu/kWh includes generation source energy

Total Heating Fuel Energy = 137MMBtus / 2271sf = 60.3K/Btu/sf

Total Site Energy in Btu's = MMBtu's / 2271FT2 = KBtu/sf
Total Site Energy in Btu's = MMBtu's / 2271FT2 = KBtu/sf

Blower Door Test & Results

2 Old Sharon Road

Measuring Air Infiltration and the Air or Pressure Barrier

Convective and Conductive Heat Losses and Moisture Transfer

Whole Building with outside air registers open: 6467CFM50

Means that **6467 cubic feet of air per minute** was pulled thorough leaks and gaps in the air barrier and fresh air registers when the building was under pressure at -50 pascals with respect to outside.

Air Change per Hour Rate at -50pa: 17.98ACH50

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 18 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: 1.12 ACH Winter: 1.73 ACH Summer: .95ACH

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 40 minutes or so.

Estimated cost of envelope air leakage: $1158 at $3.00 gallon or approx 28% of heating bill

Leakage Area (Canadian EqLA @10pa) 811 in2 or 5.63sq feet

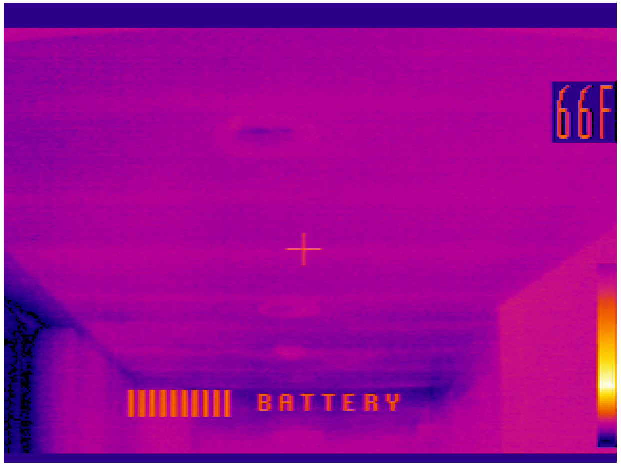
Total size of hole if add all cracks and gaps together

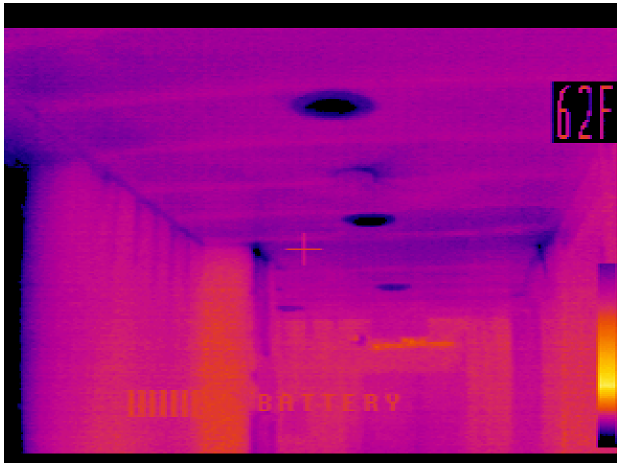
Minneapolis Leakage Ratio: 1.41 CFM50 per ft2 of envelope surface area

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.

The building was retested after tape sealing all registers connected to duct work in the attic as well as the air intake for the wall heating unit in the Lab. The Envelope Only test results were 5397cfm50 or 1070 cfm less air. This is the estimated amount of air being drawn through the wall vent in the Lab and all the registers connected to the attic and ultimately, the outdoors.

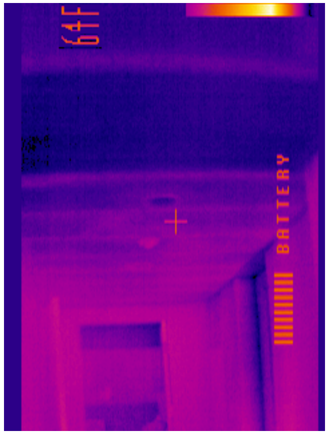
Hall Ceiling



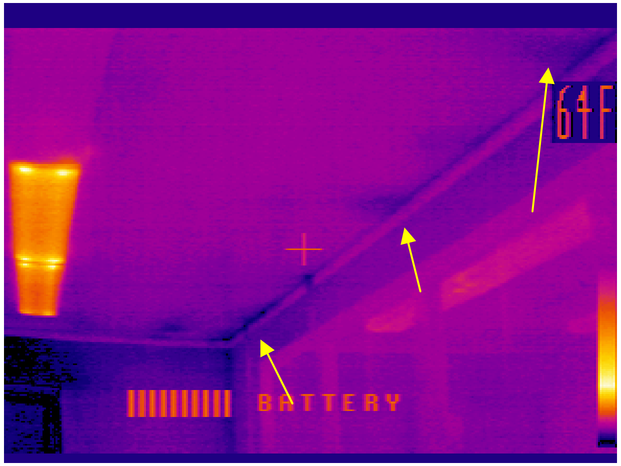


@-30pa

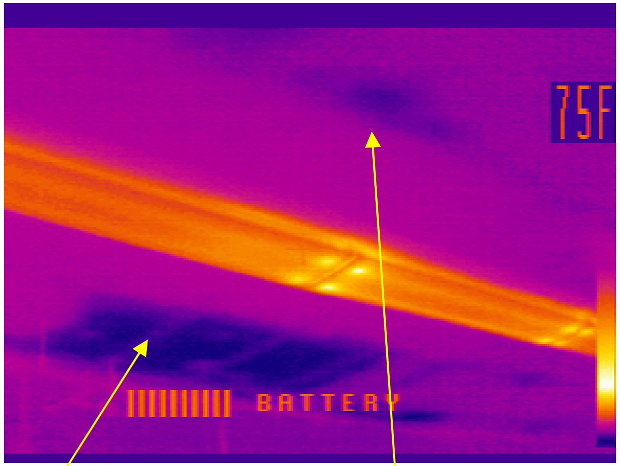
Slightly more pronounced heat loss under pressure. Note in both cases the rafters are warmer than the cavities, indicating low levels of effective insulation.



Lab Ceiling



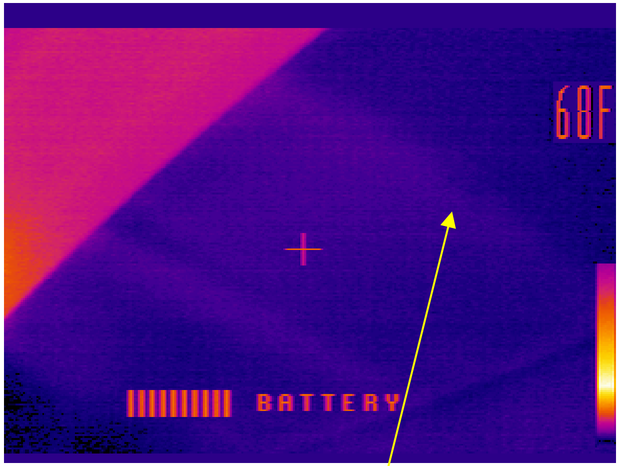
Cooling above the top plates is common, and often from air leakage ('wind washing') from soffits.

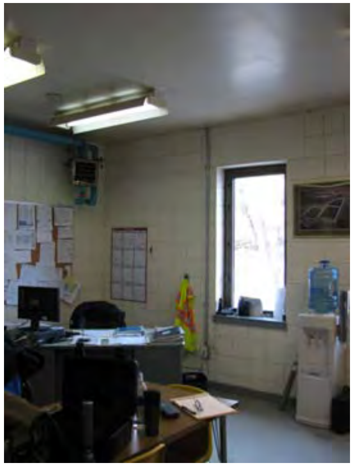


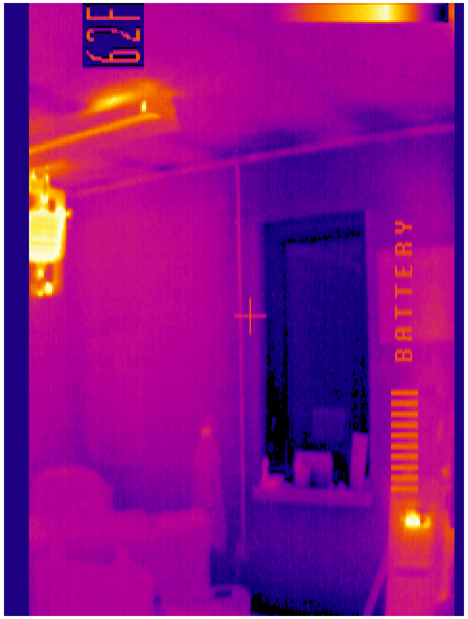
These cavity areas are completely void of insulation.

Its not a coincidence that the stain on the ceiling aligns with coolth pattern. Thermal bridging – conductive material in contact with both inside and outside surface – can cause condensation on interior spaces as warm moist air contacts with a surface below the dew point.

Office Ceiling

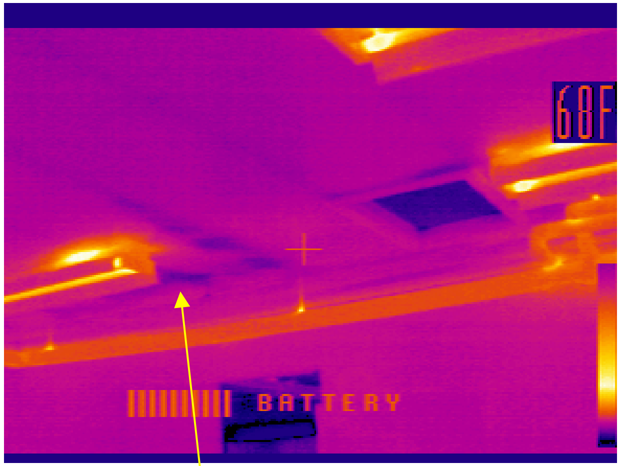


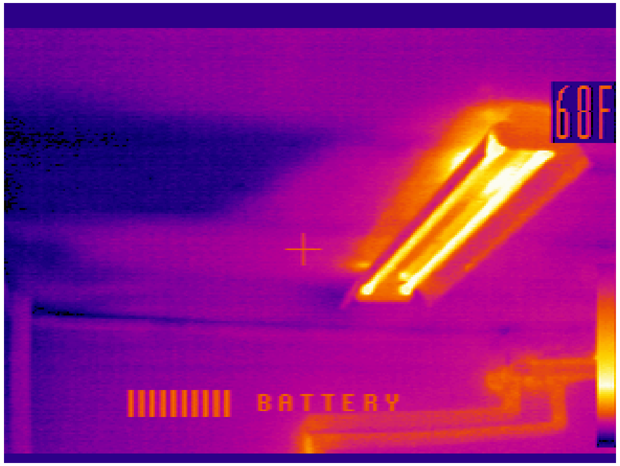




Faint, but here you can see the same situation in reverse! Where the ceiling is warmest where the 1.5” wood joist is touching the ceiling. Cavities here are sparsely, or not at all, insulated.

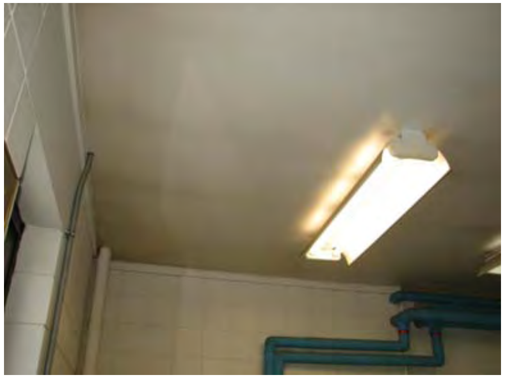
Office Ceiling



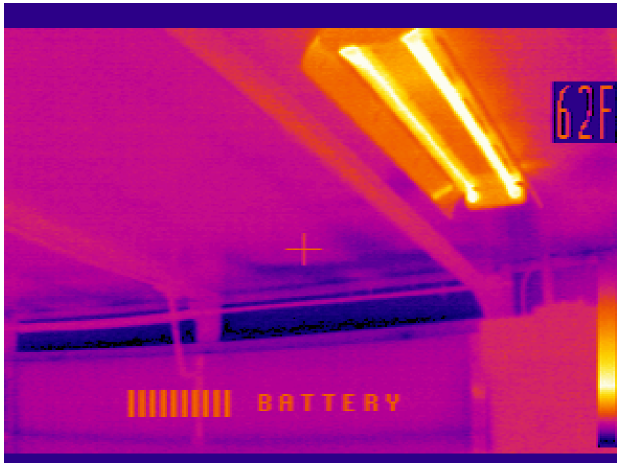


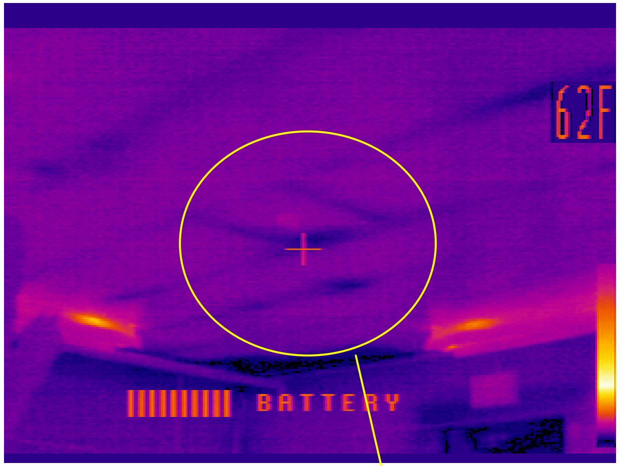
Similar patterns throughout.

Turner’s report indicated 8-9” insulation in the ceiling of this building. While there is a lot of fiberglass material above the ceiling, it is the opinion of this assessment that the insulation is not continuous nor very effective with considerable thermal bridging, gaps in an air barrier and voids.



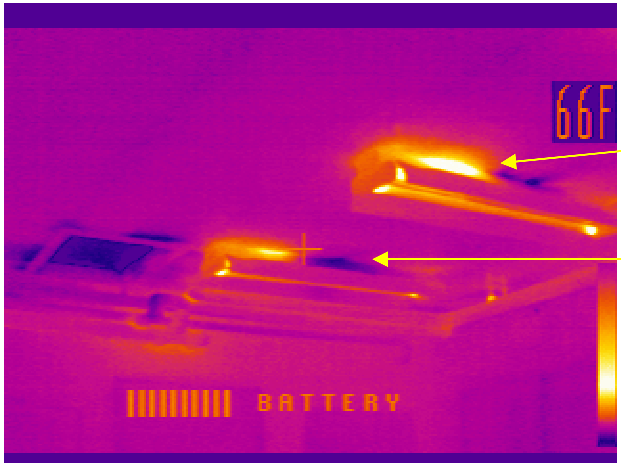
Garage Ceiling





This appears to be a structural header and highly conductive.

Generator Room Ceiling

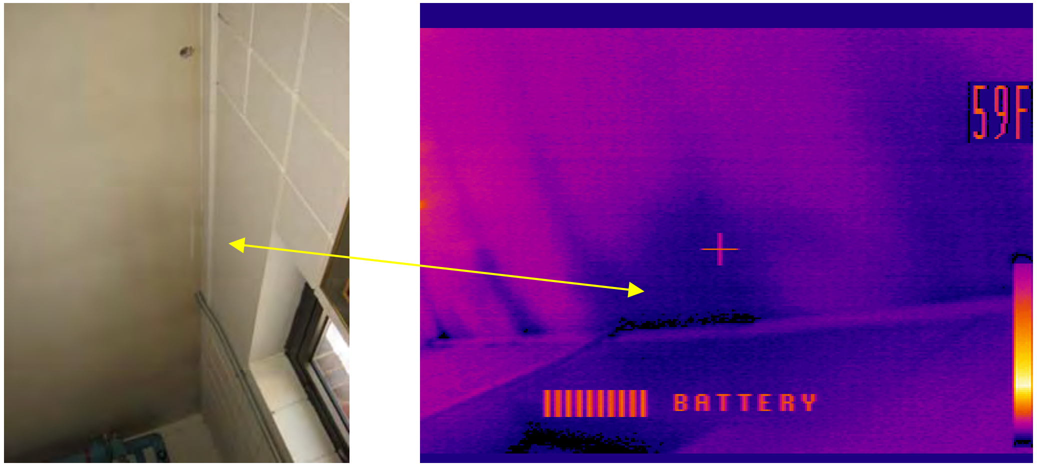


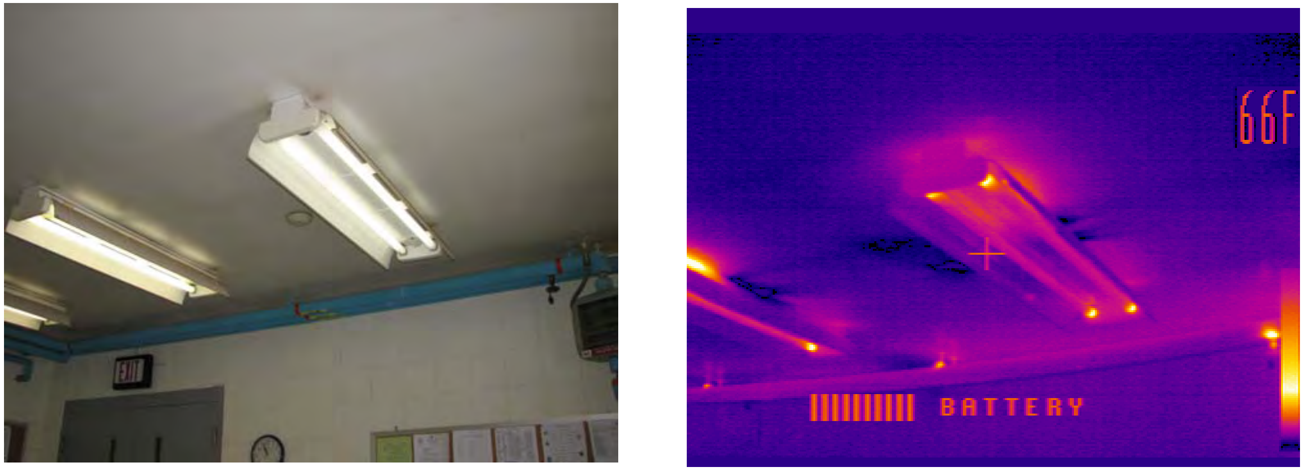
Wires running to fixtures create opportunities for more air sealing.

Attic hatch needs air sealing and an insulated cover.

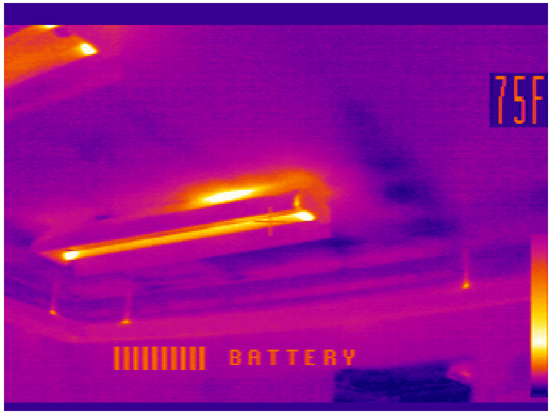
Doors appear un insulated.

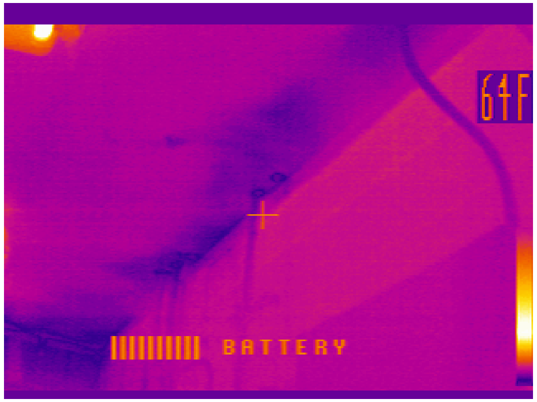
Office and Hall Ceiling

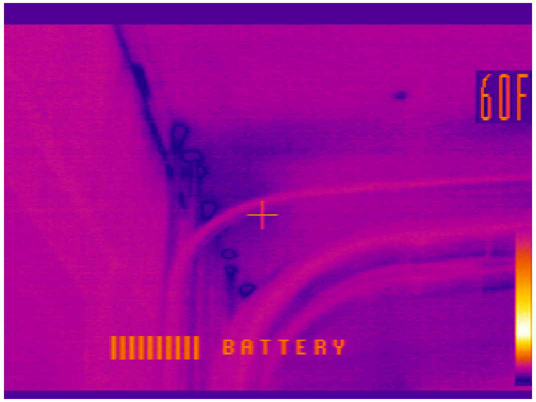


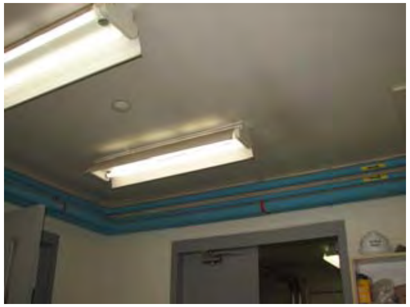


Ceiling

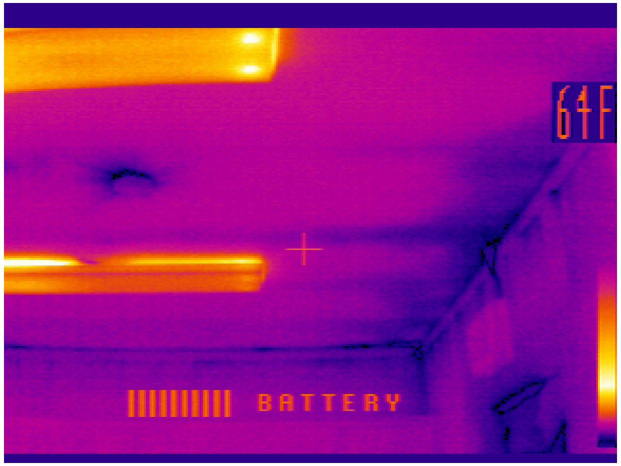


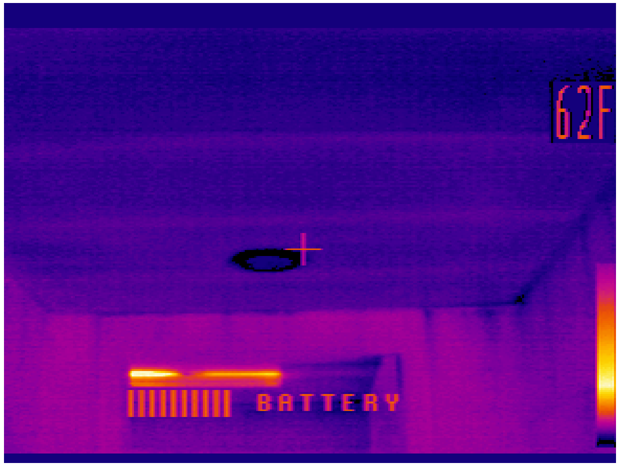


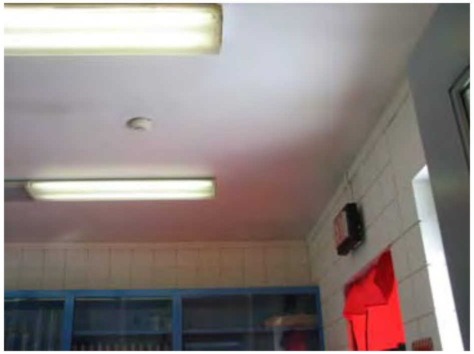




Lab Ceiling





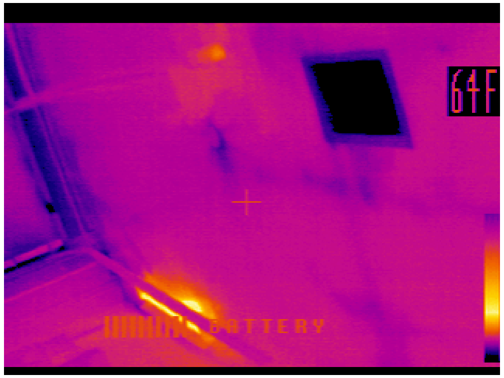


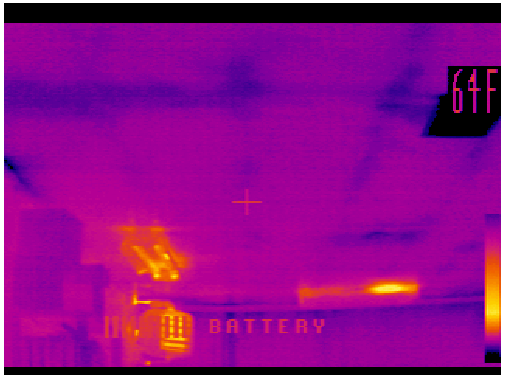
Patterns are heightened when the blower door fan is running and the building is put under pressure. In this case, IR images were taken at -30pa within 30 minutes from the fan being turned on. The longer the building is under pressure, the more surfaces are cooled.

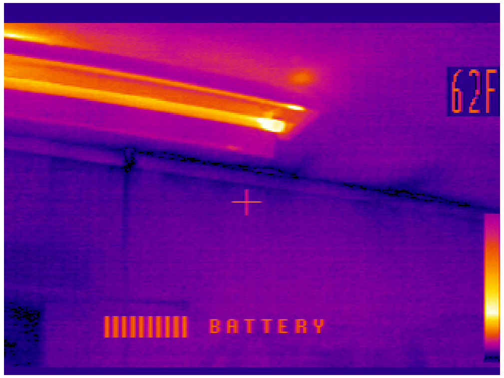
Lab Ceiling

Ceiling

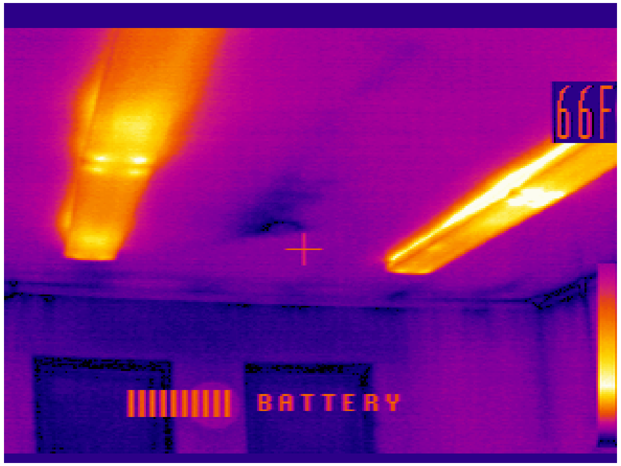
Garage Ceiling



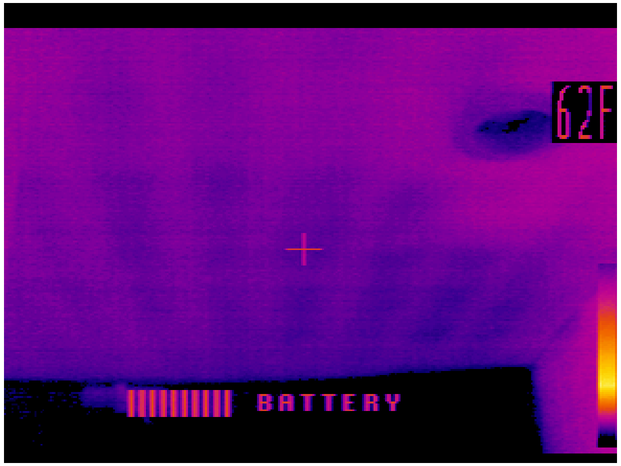


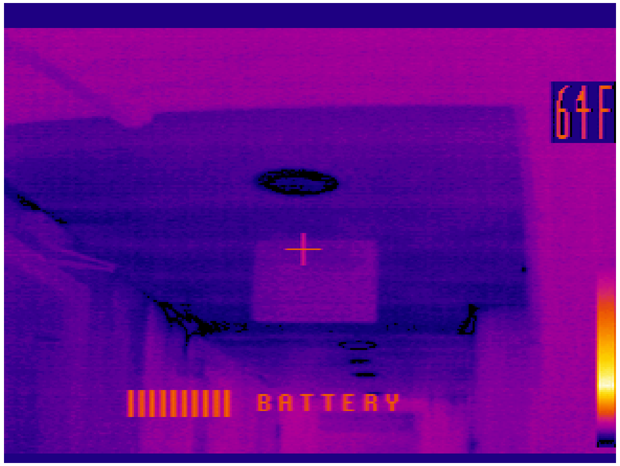


Lab Ceiling

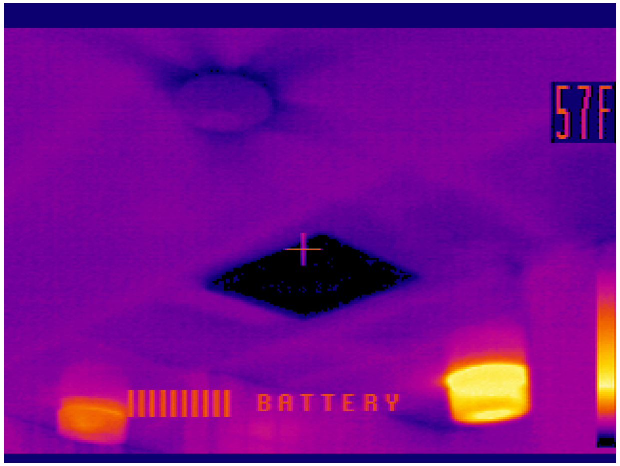


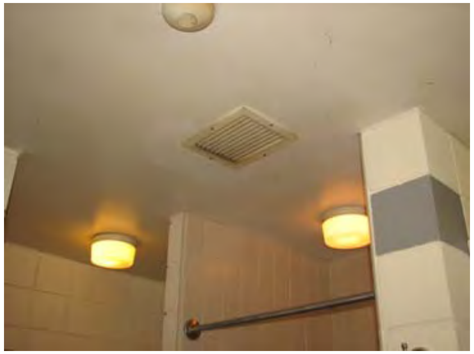
Hall Ceiling



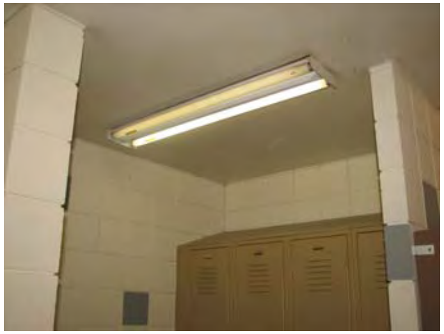


Bath Ceiling

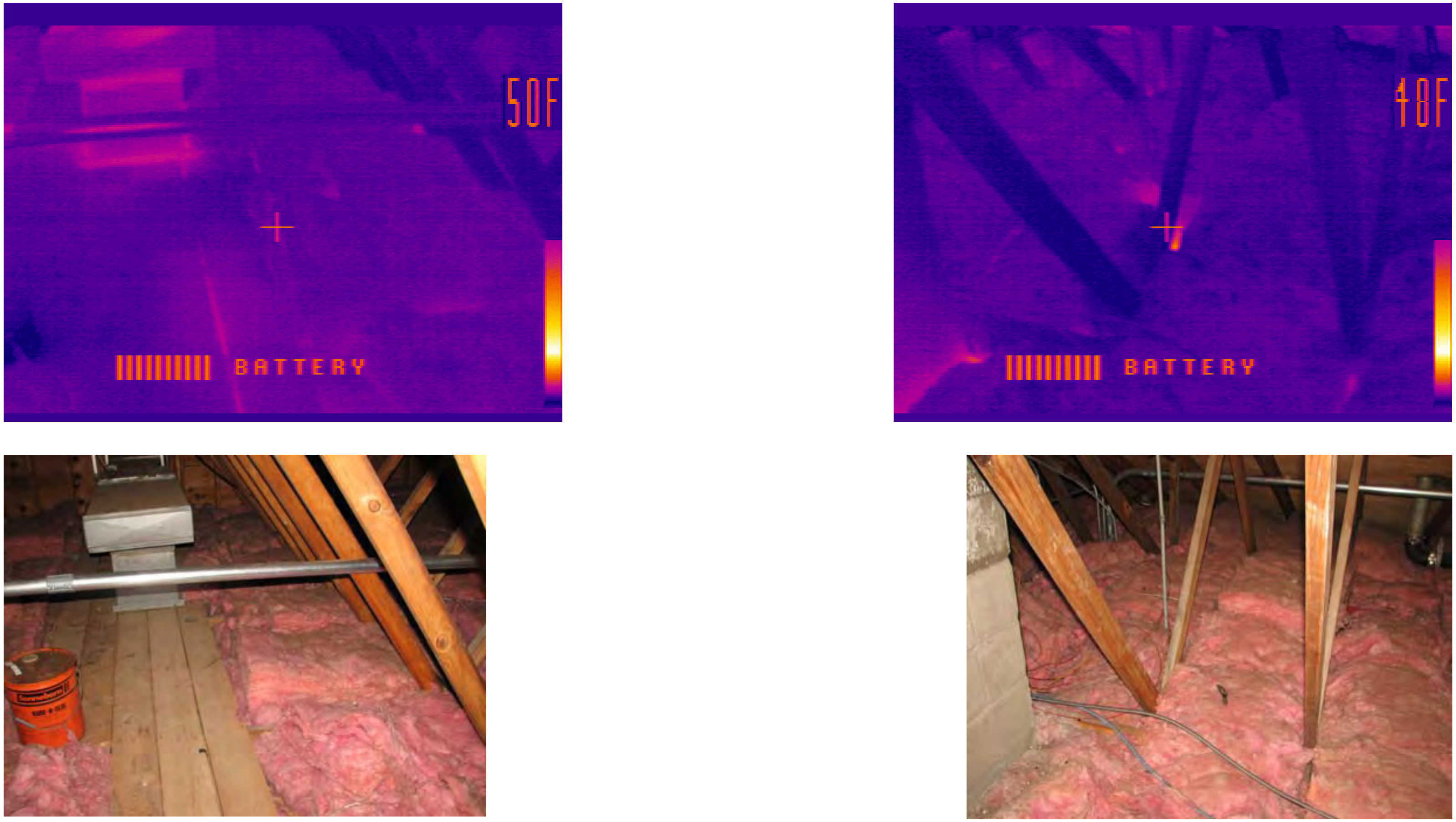




Ceiling rafters appear warmer than surrounding cavities which suggest wood framing R value exceeds cavity insulation.

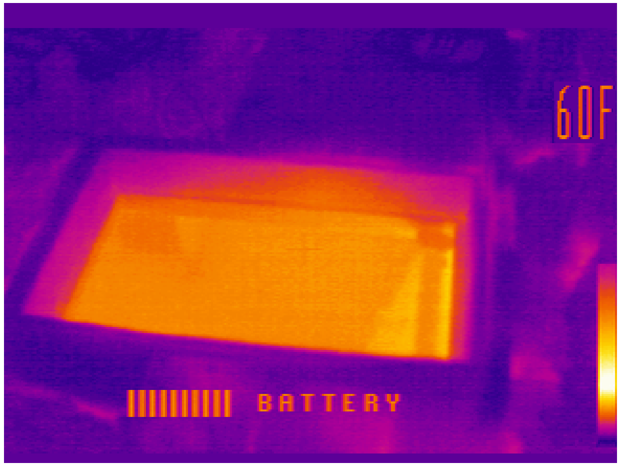


Attic

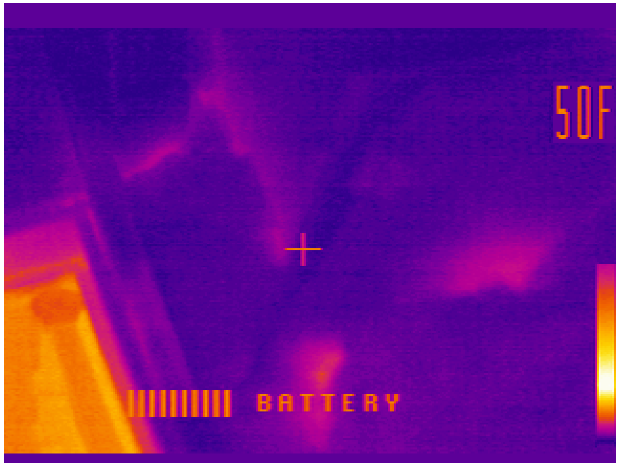


Conventional ‘energy efficiency’ improvements focused on the inexpensive approach of adding more insulation on top. Without comprehensive air sealing, and careful installation of effective insulation, these well intended efforts can make a relatively minimal difference. Unfortunately, meaningful improvements are more labor intensive – particularly when there are past efforts to work around. Fiberglass is rarely the optimal insulation for NH’s climate.

Attic

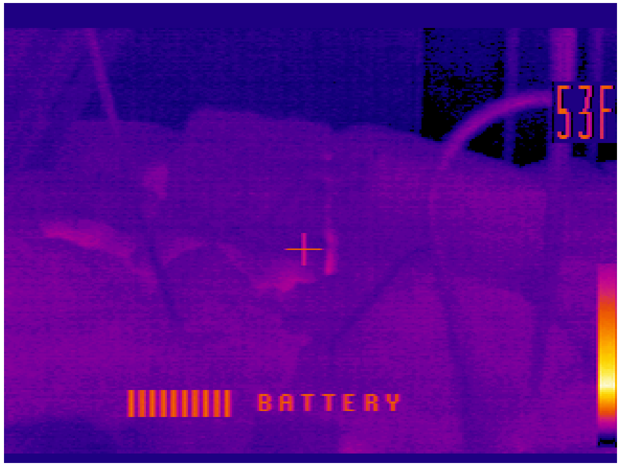


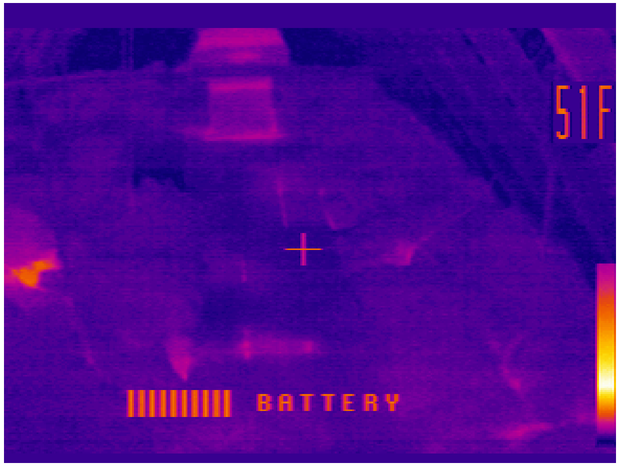
Attic



Chimneys can be effectively flashed with metal and caulked with a fire stop; eliminating warm air rising and allowing insulation to be safely installed.

Attic

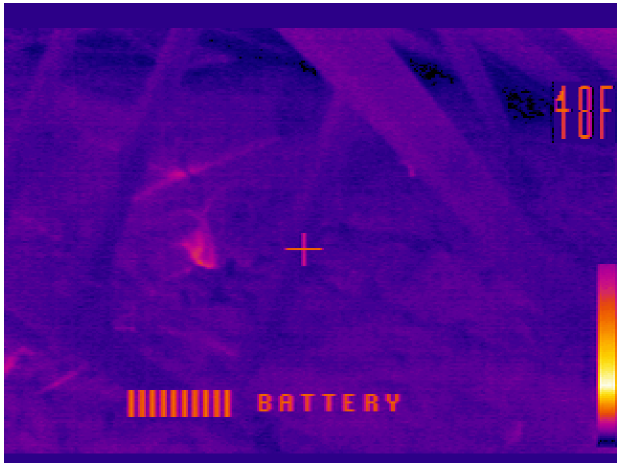


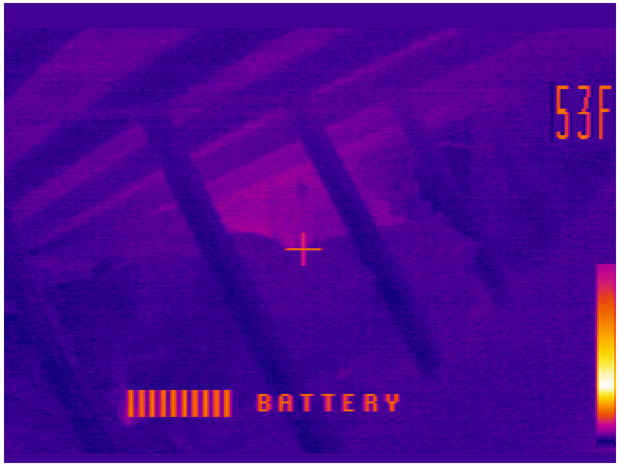


A thorough air sealing of this ceiling is necessary to realize meaningful heat loss reductions. In this case, with so many ceiling penetrations and evidence of moisture, removing all fiberglass and spraying a 1-2” skim layer of closed cell foam over the entire assembly (dry wall, strapping, and joists), will create a continuous barrier against moisture, air, and heat transfer. Best practice would be to then blow an even 15” of cellulose, but a case could be made to reuse all this material - carefully re-installing these fiberglass batts to a depth of 15” for as many sf as it will cover – then use cellulose for the remainder of the attics.

One could also argue for spraying 5-6” of foam and be done with it. This is not recommended because there is room to build up deeper levels of the less expensive fiber insulations and, by code, the foam should be covered with a material which gives it a 15 minute flame barrier, with 15” of cellulose should accomplish.

Attic





It is always best if soffit vents can be maintained, but equally best if at least 2-3" of foam can cover top plates – and help form an air seal between propa vents and insulation layers. Adequately venting a roof, while effectively air sealing and insulating the ceiling, or attic, is a best practice.

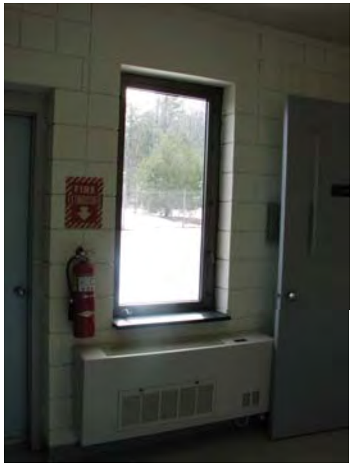
In this building, a case could be made for re-defining the envelope to the plane of the roof and insulating the sheathing and rafters, as well as all end walls. If insulation levels can create an effective R40 with no thermal bridging, it would effectively perform as a cold, unvented, roof assembly. The reason to do this would be to bring the attic into conditioned space. This attic area is likely not to be worth the extra expense, however the other attic area, over the lab is a far better candidate.

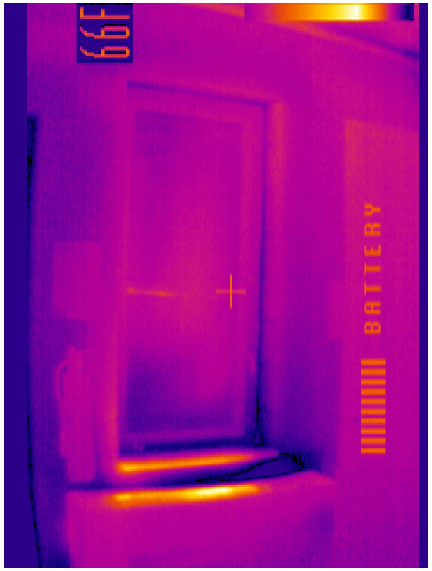
Attic

No matter what strategy is used, it is recommended that a new center walk way be built up above the prescribed insulation levels to allow access and limited storage.

General Air Sealing

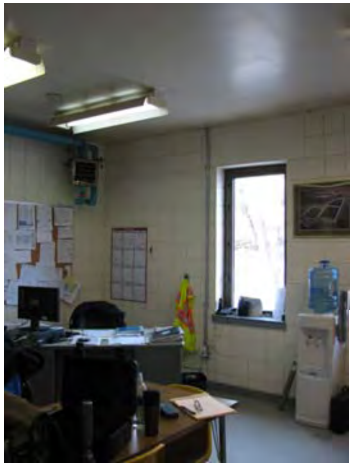
Windows

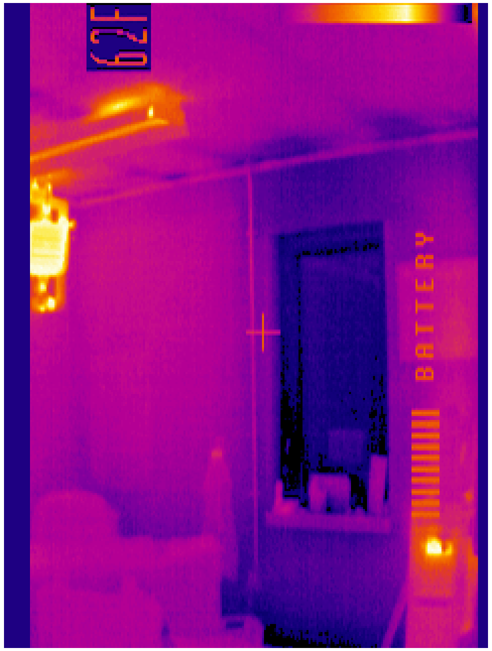


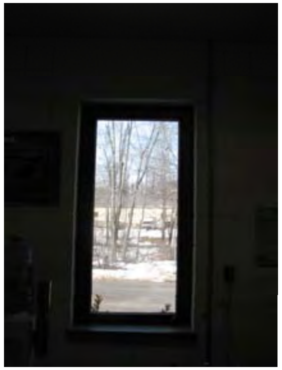


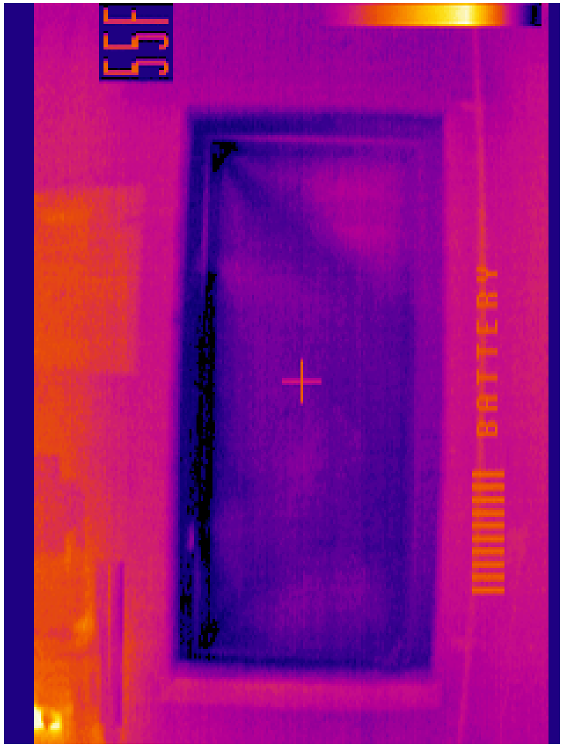
Window glazing accounts for less than 6% of the entire wall surface area from 6 casement windows and glass entry. The expense of replacement would take a long time to recover. However comprehensive air sealing would be a cost effective improvement.

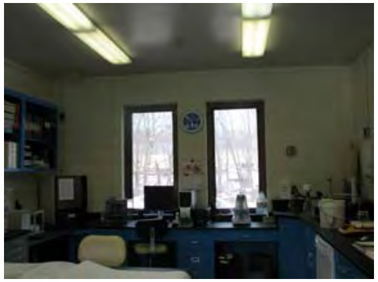
Windows





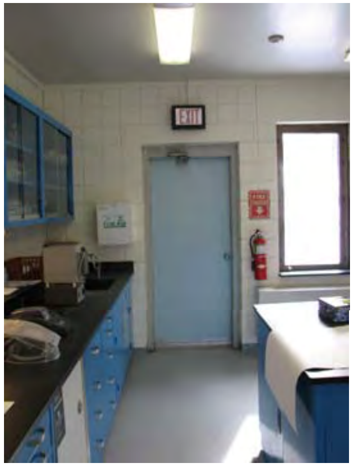


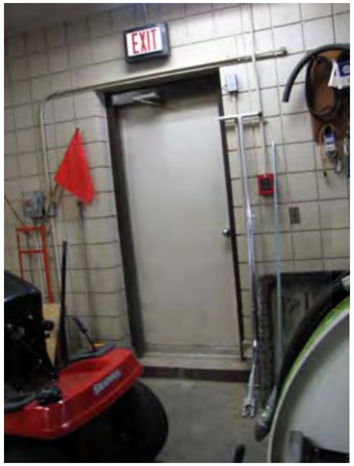


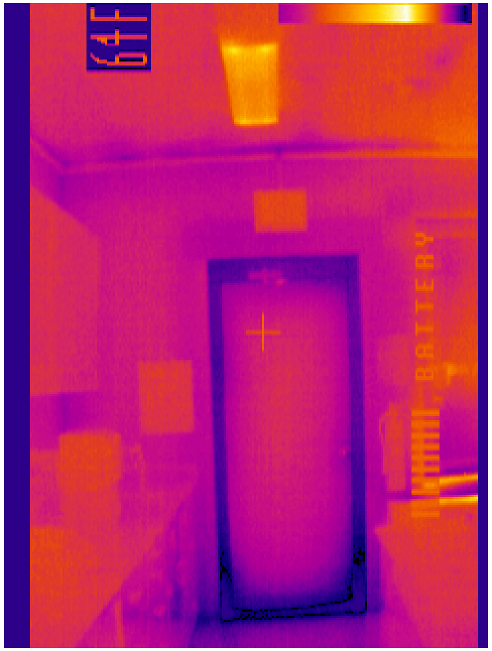


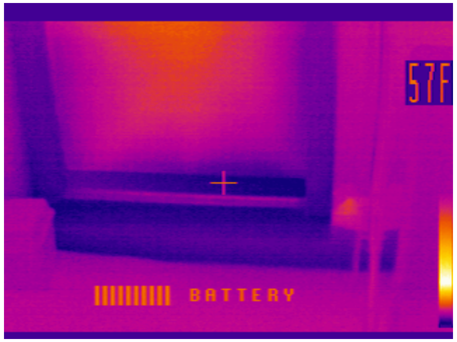
An even better upgrade for this building and its use would be to install air tight interior therma pane storm windows with insulated frames to minimize the thermal bridging of these frames without compromising security.

Doors

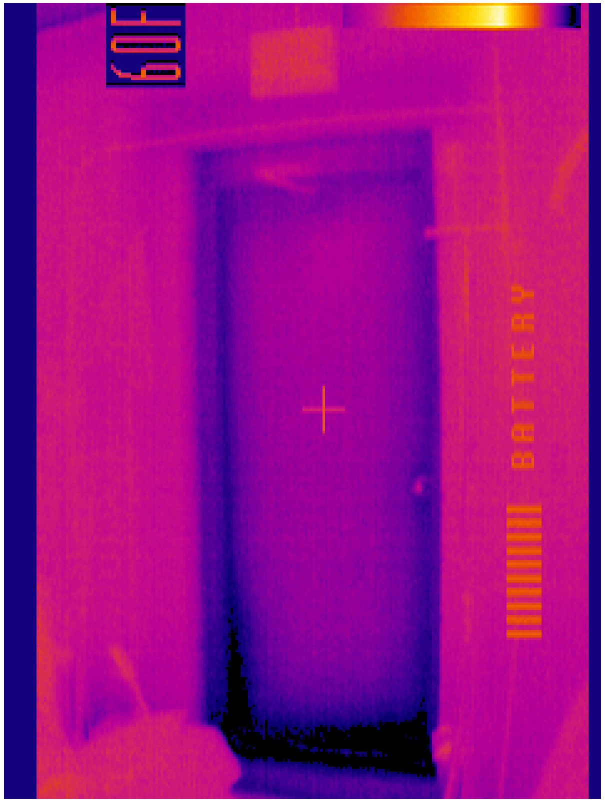




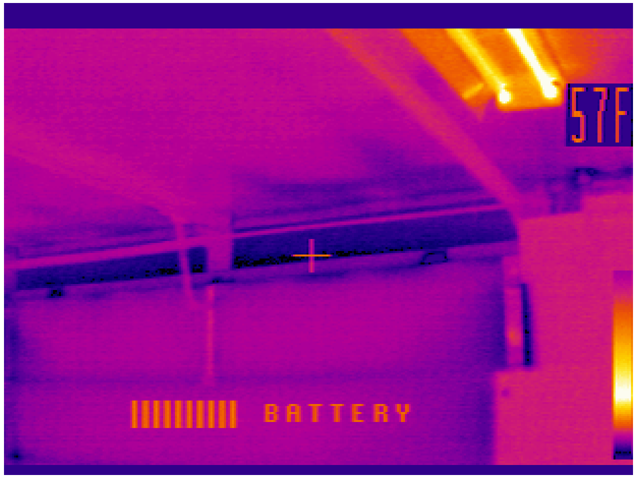




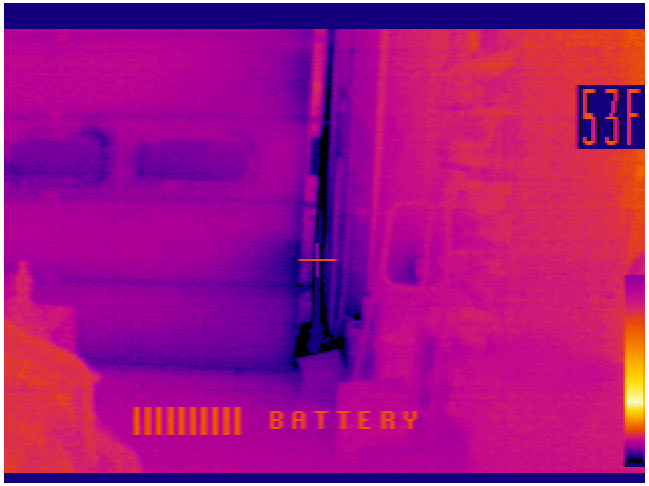
Similarly, weather-stripping these doors is more cost effective that replacing them, even though better insulated doors would lose less heat in winter and less gain in summer.



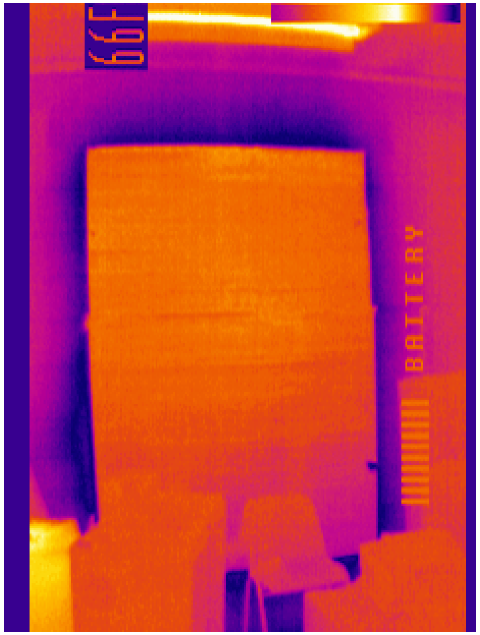
Garage Door

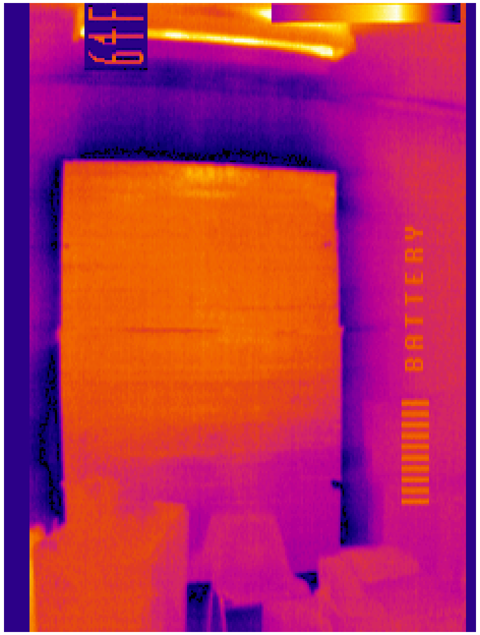


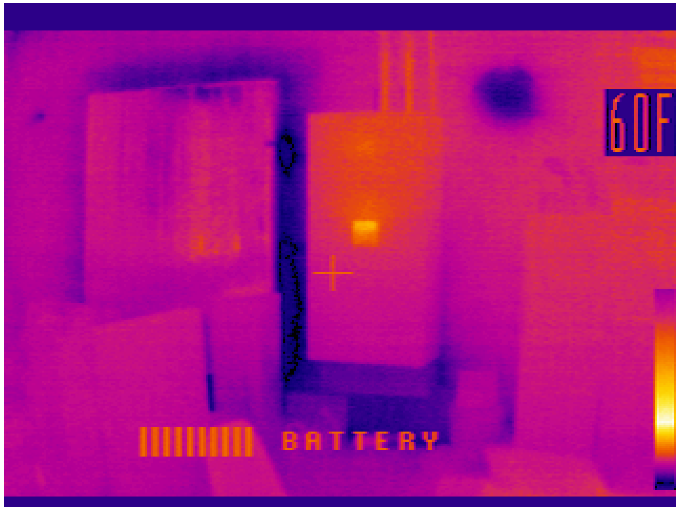
Installing a gasket on the garage door and sealing the window lights is advised, as is insulating the header.



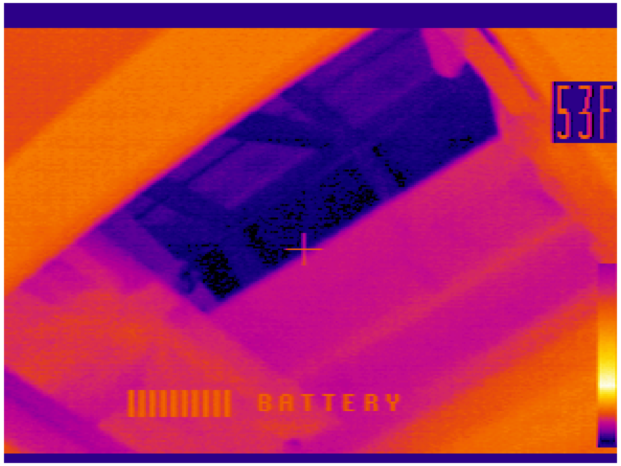
Garage Door

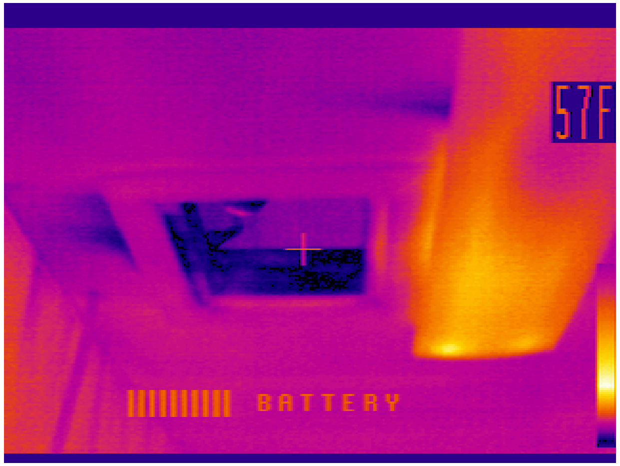


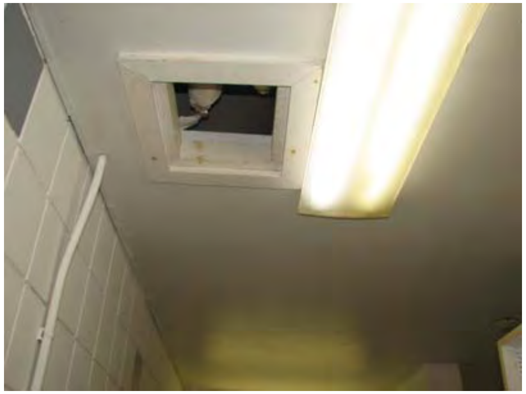




These foam panels were a good choice for covering the large vents previously needed for a generator in this room. However, without being sealed in place, a huge amount of heat is lost (gained).

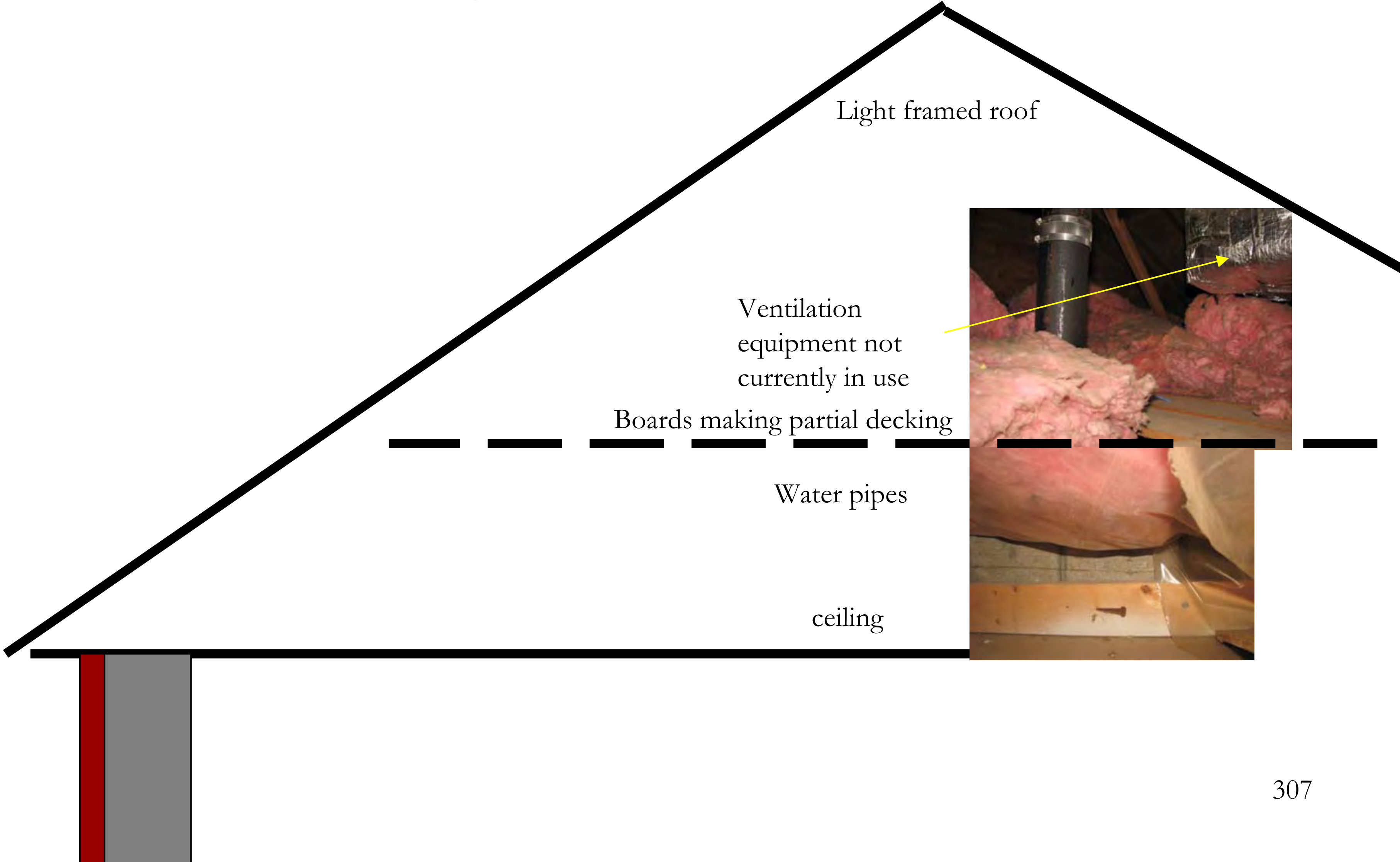






This attic hatch is left open so that conditioned air can keep pipes located in this attic from freezing. This is perhaps the greatest single source of heat loss in the building. Since IR indicates that there are anomalies throughout the ceiling and that comprehensive air sealing and insulation will have a significant impact on reducing energy use, sealing and insulating this hatch is an important goal. However, the more effective the ceiling insulation/air barrier – the colder the attic will become and the greater likelihood for freezing pipes! There are four options: 1) Do nothing and waste a lot of energy 2) Re locate the pipes in the attic to directly above the ceiling and encapsulate them at the bottom of the insulation layer 3) Bring all water pipes within conditioned space – ie run along the top of walls to bathroom and lab 4) Redefine the envelope at the roof plane and bring this entire attic into conditioned space.

Existing - conceptual



Light framed roof

Ventilation
equipment not
currently in use

Boards making partial decking

Water pipes

ceiling

Option One

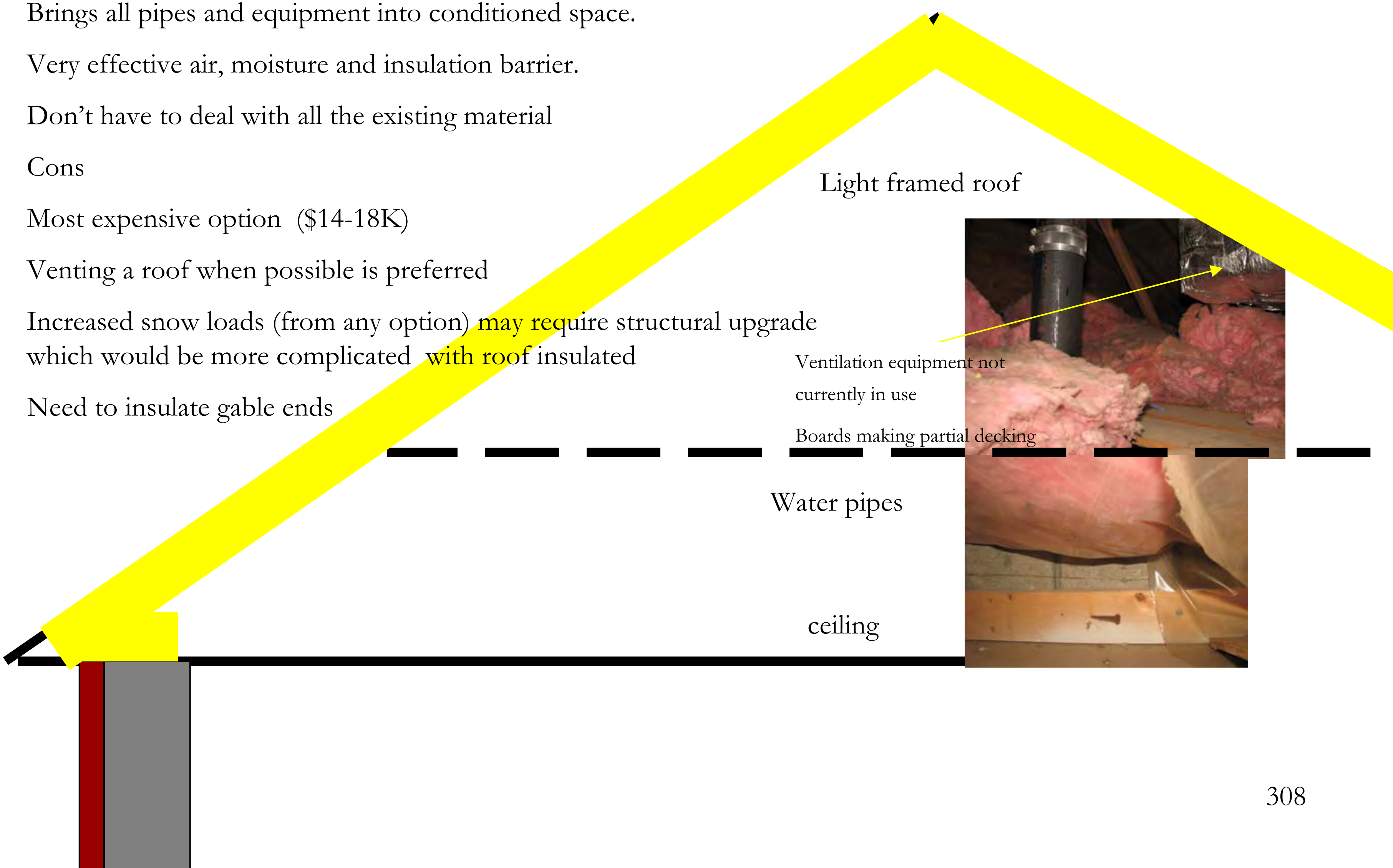
Spray 7” closed cell foam on sheathing and over rafters to create a cold, unvented roof through “super insulation” (R42 continuous)

- Pros:

1. Brings all pipes and equipment into conditioned space.
2. Very effective air, moisture and insulation barrier.
3. Don’t have to deal with all the existing material

Cons

1. Most expensive option ($14-18K)
2. Venting a roof when possible is preferred
3. Increased snow loads (from any option) may require structural upgrade which would be more complicated with roof insulated
4. Need to insulate gable ends



Option 2 - conceptual

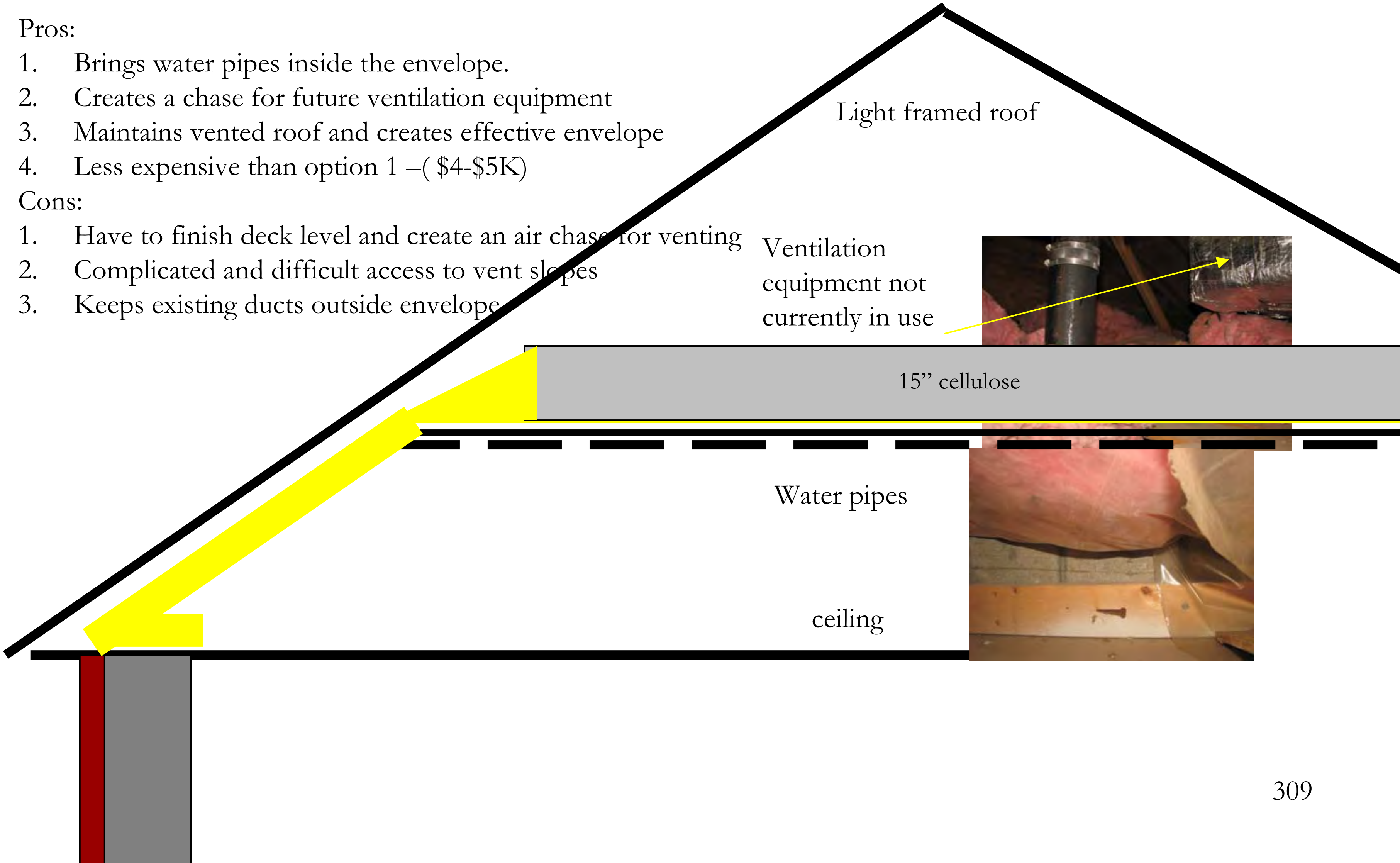
Establish thermal envelope at upper deck level Foam slopes and top plate and to create air barrier on improved deck. Blow 15" cellulose on top.

Pros:

1. Brings water pipes inside the envelope.
2. Creates a chase for future ventilation equipment
3. Maintains vented roof and creates effective envelope
4. Less expensive than option 1 –($4-$5K)

Cons:

1. Have to finish deck level and create an air chase for venting
2. Complicated and difficult access to vent slopes
3. Keeps existing ducts outside envelope



Option 3 -
Preferred

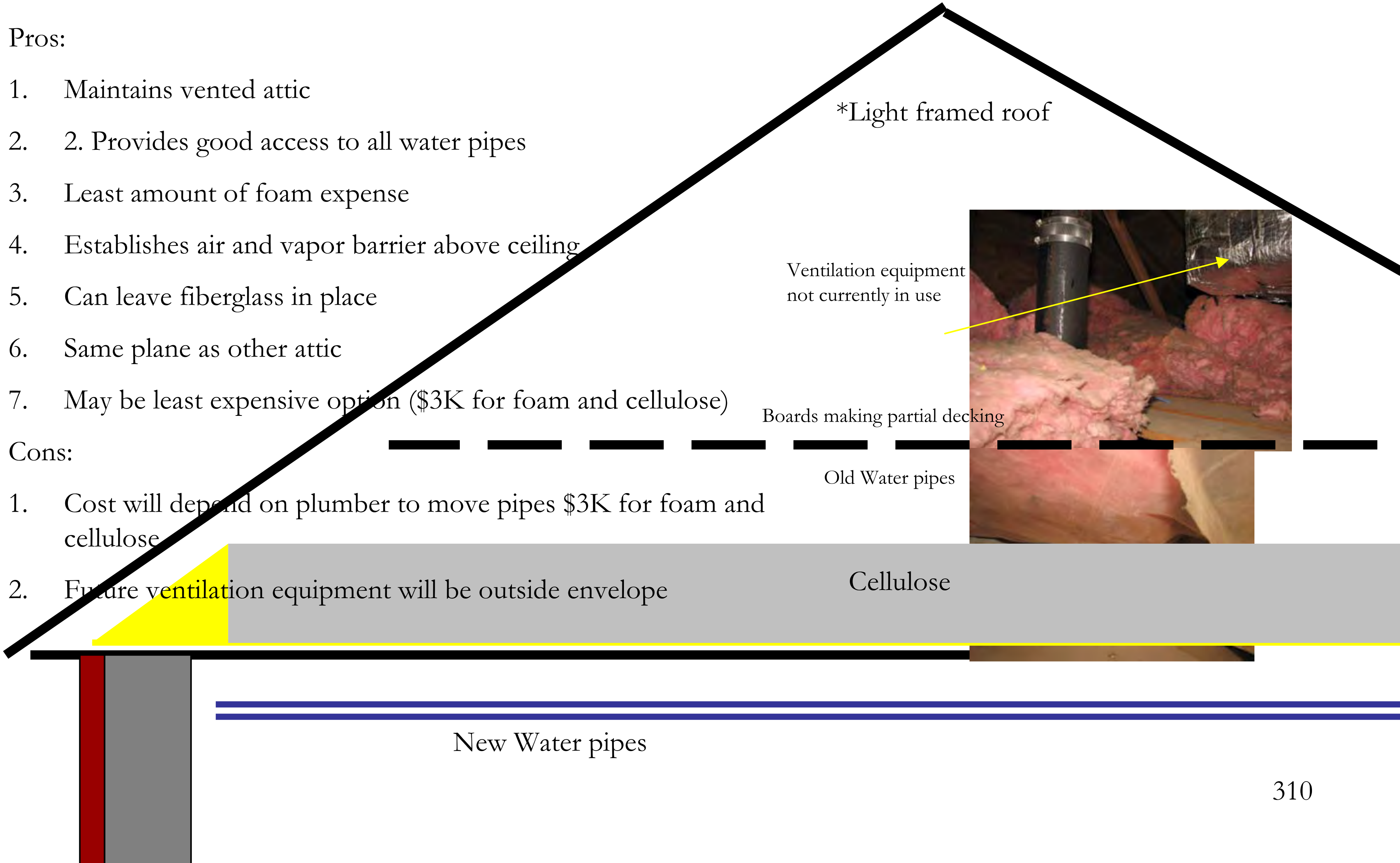
Re run all water pipes below ceiling, in conditioned space.
Air seal ceiling plane with 2” closed cell foam and blow in 15” cellulose

Pros:

1. Maintains vented attic
2. 2. Provides good access to all water pipes
3. Least amount of foam expense
4. Establishes air and vapor barrier above ceiling
5. Can leave fiberglass in place
6. Same plane as other attic
7. May be least expensive option ($3K for foam and cellulose)

Cons:

1. Cost will depend on plumber to move pipes $3K for foam and cellulose
2. Future ventilation equipment will be outside envelope



*Roof structure for increased snow loads will need to be assessed.

*Light framed roof

Ventilation equipment
not currently in use

Boards making partial decking

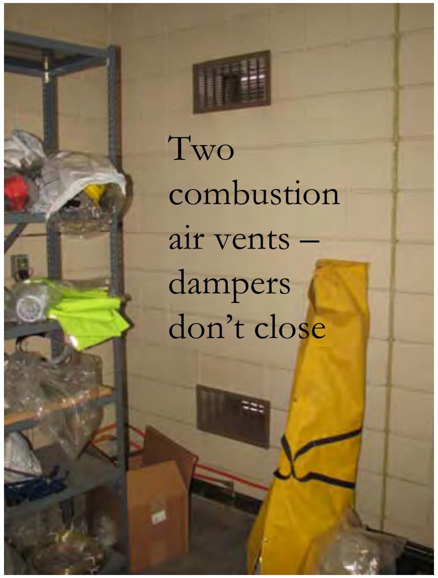
Old Water pipes

Cellulose

New Water pipes

Equipment

Buderus 6215/5 installed in 2009
Combustion tested at 87.5% efficiency



Two combustion air vents – dampers don't close

40 Gallon State, 4500 Watt Electric hot water heater recently installed

Equipment

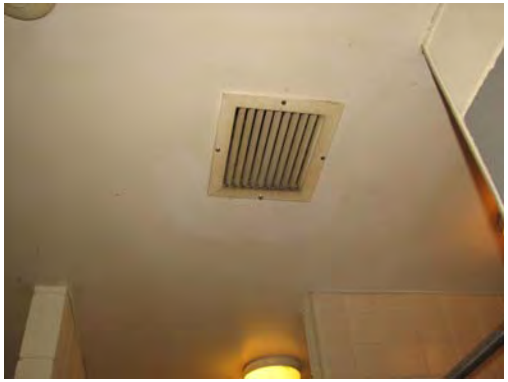
Bathroom and entry heated by wall mounted radiators

Electromode electric heater.

May not be necessary after both large vent openings have been closed and well air sealed/insulated.

Two thermostatically controlled hot water Modines – office and garage.

Equipment



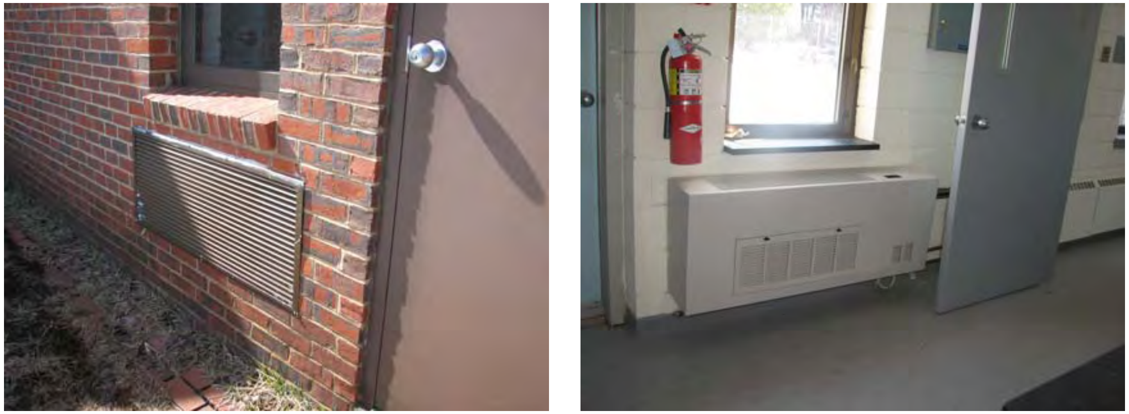
Bathroom exhaust appears to be vented into the attic. Needs to be ducted to outside.

Garage exhaust manually timer operated and without heat recovery

Code compliant non
metallic tank
Dehoust PE-Kombi

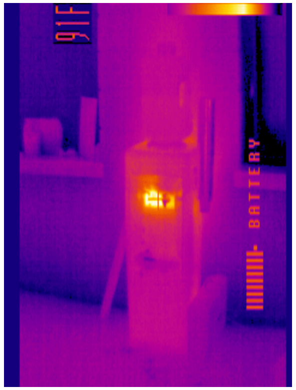
Equipment

Manually operated timed
wall exhaust in lab.



Hot water fan assisted wall heater with fresh air supply.

Electric Loads



Measured to draw
200-250kwh/month

Total of 30 (4') T12's

Total of three desk top computers,
HP Compaq 7600, Optiquest Q19WB2
and Dell Deskjet
Also: Coffee maker, Kenmore
washer and dryer in the garage

Kenmore refrigerators and freezer

Equipment

Laboratory
Equipment

Waste Pump Stations

Rt 124 / Jaffrey Center

Concrete block on slab

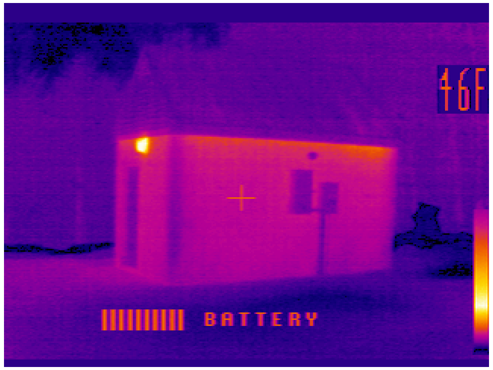
240ft2 (10x14) est 1920ft3
8'4" to ceiling; vented attic 150 gallon oil tank (under)

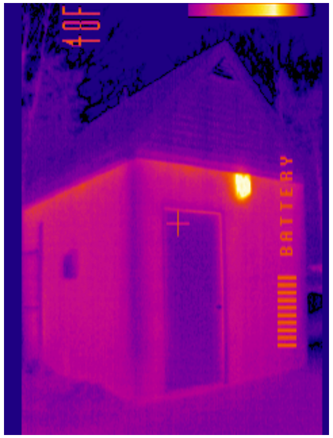
Meter # 01425421
Olympian Generator D60FI

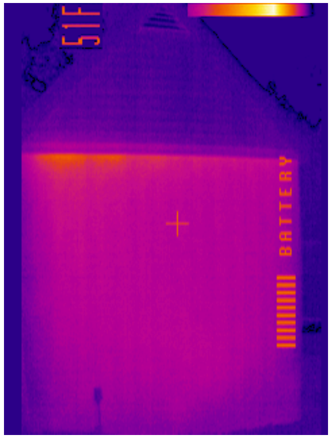
There were no delivery records for the '09-'10 heating season, though there is evidently a 150 gallon underground oil tank and anticipated 100 gallons/yr usage.

Waste Pump Stations

Rt 124







Waste Pump Stations

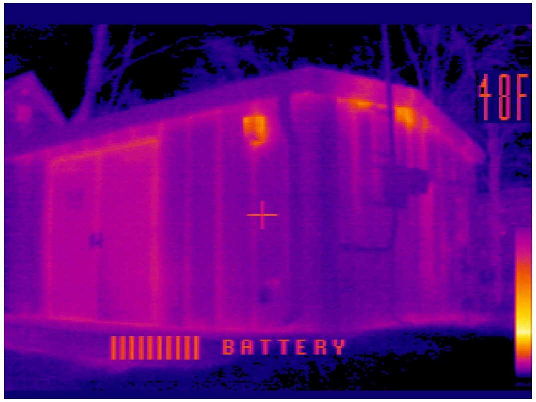
Cross Street

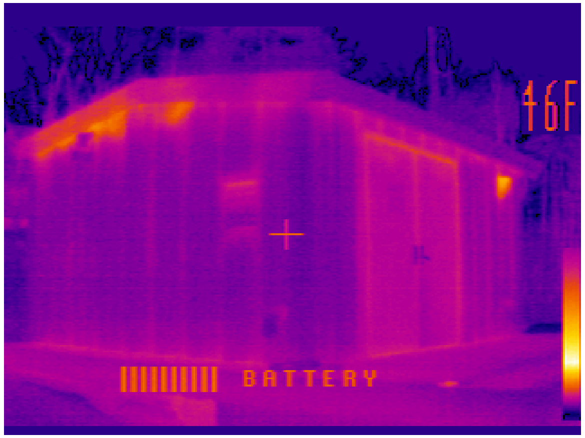
12'x16'Metal building on slab
"Steelox" metal roof 192 ft2 est 1500ft3
500 gallon propane tank #37423
PSNH meter #2512875

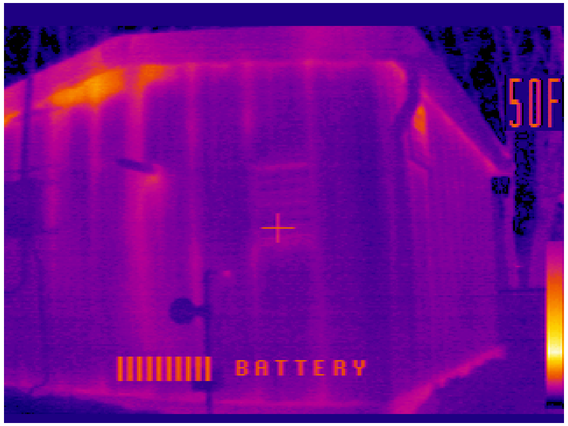
There are no fuel or electricity delivery records for the '09-'10 heating season, though there is a 500 gallon above ground propane tank and anticipated 250 gallons/yr usage.

Waste Pump Stations

Cross Street







Waste Pump Stations

Waste Pump Stations

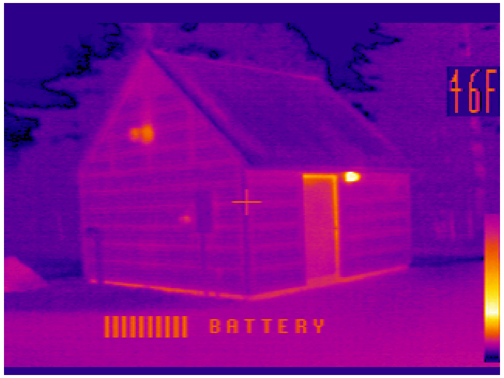
Erin Lane

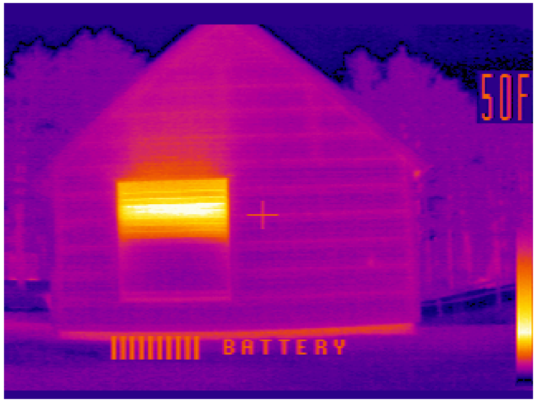
18'x16'7" wood frame/clapboard on slab
300ft2   est 2400ft3
vented shingle roof
275 gallon oil tank buried
PSNH meter #2512885

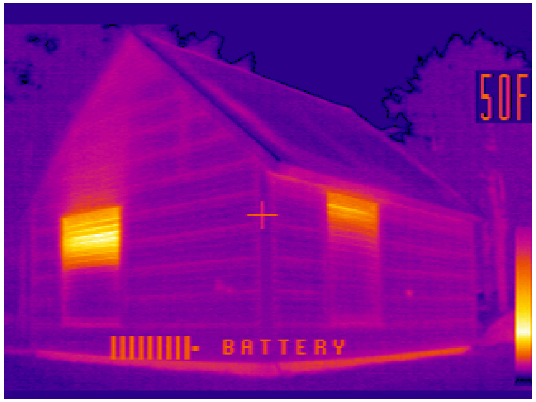
There are no fuel or electricity delivery records for the '09-'10 heating season, though there is evidently a 275 gallon underground oil tank and anticipated 150 gallons/yr usage.

Waste Pump Stations

Erin Lane







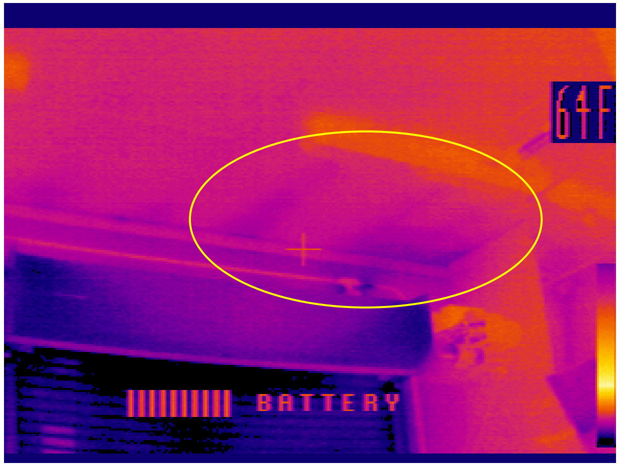
The New Waste Water Facility

PSNH sends one bill for Old Sharon Road for "Sewer" under Meter #G10482851. Total KWH consumed from June '09 through May '10 was 482,400 (1,645MMBtu's) or 41% of the town's total demand. At this time, it appears that this includes this facility, the old administration building and all pumping stations. Oil use for the winter of '09-'10 was 2961 gallons or 414,540,000Btu's. Assuming similar equipment efficiencies, it would take over 25 tons of wood pellets to generate this amount of heat.

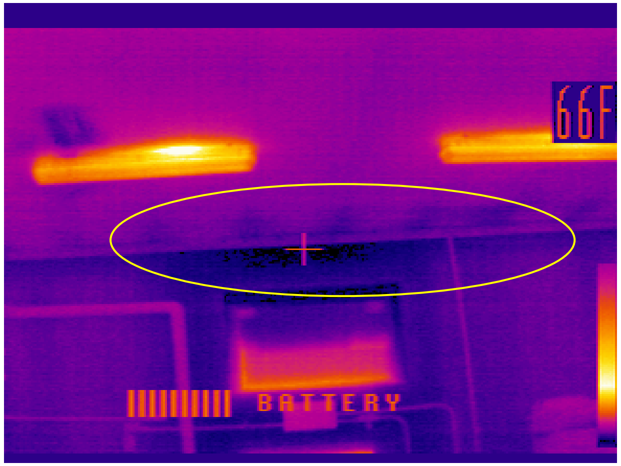
When heating for the pump stations and the admin building at 2 Old Sharon Road are included, total Wastewater energy load exceeds two billion Btu's.

Despite the relative proportion of this energy use to the total municipal load, this facility was not part of the S.E.E.D.S proposal for an audit of Jaffrey's Municipal buildings. A walk through was conducted, with the manager and an IR camera. Following are a few images taken on a fairly warm day which depict common heat loss patterns from standard construction practices.


EXIT


64F
BATTERY


EXIT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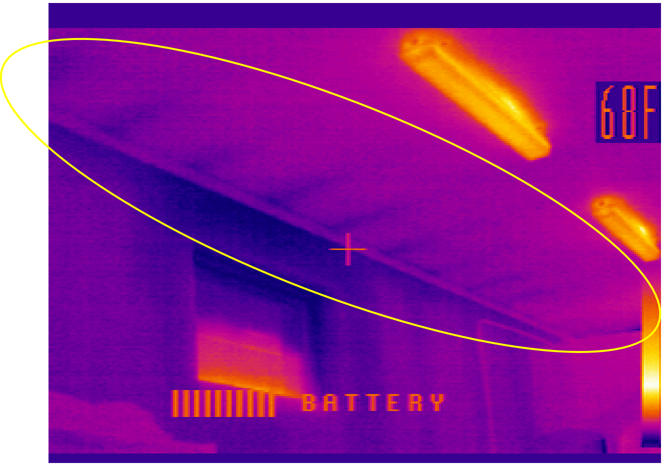
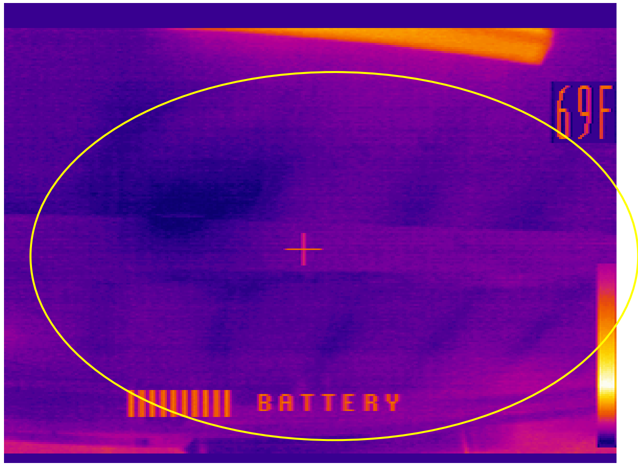

68F
BATTERY


2 TON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BATTERY


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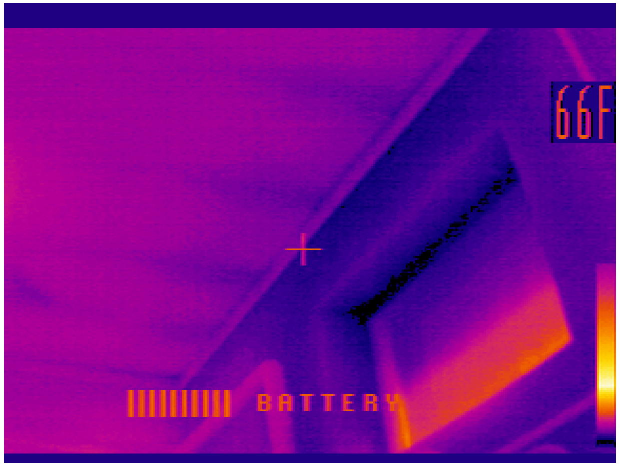
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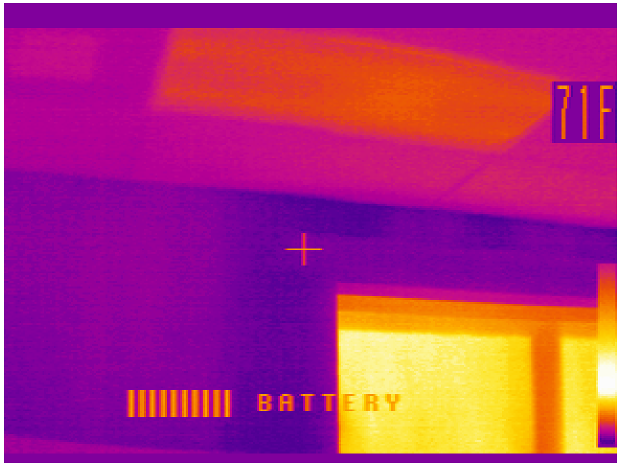
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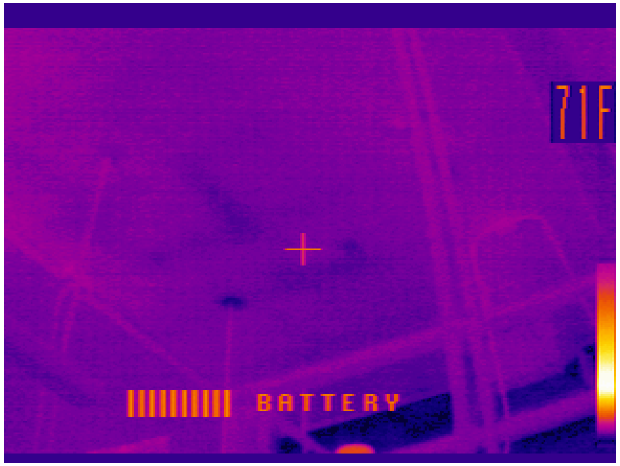
BATTERY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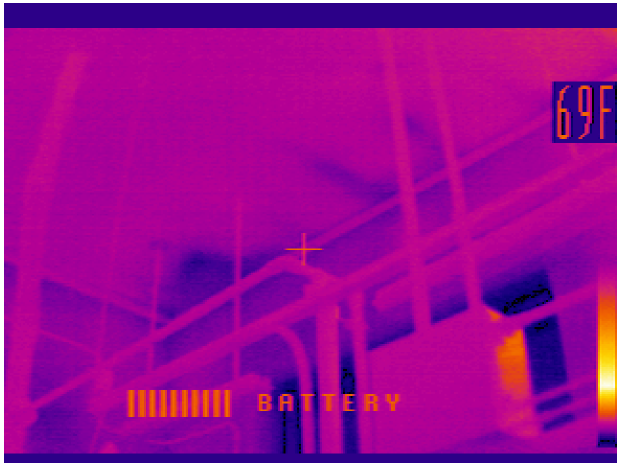
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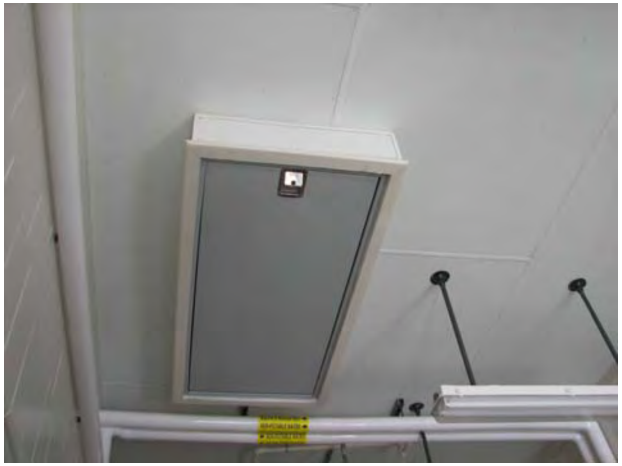
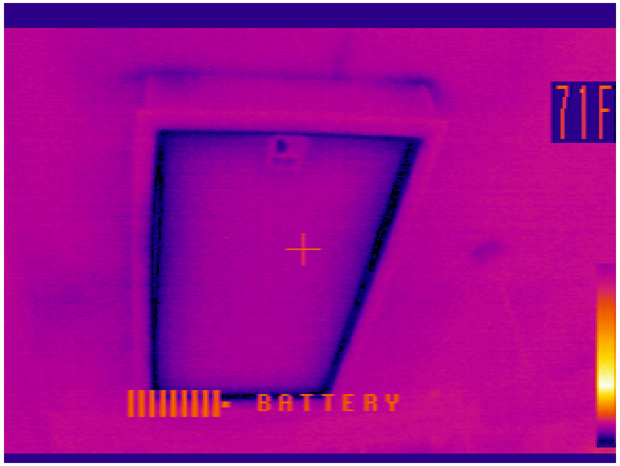
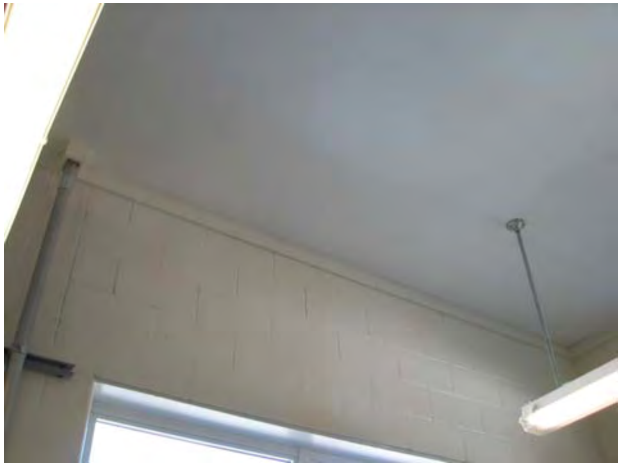
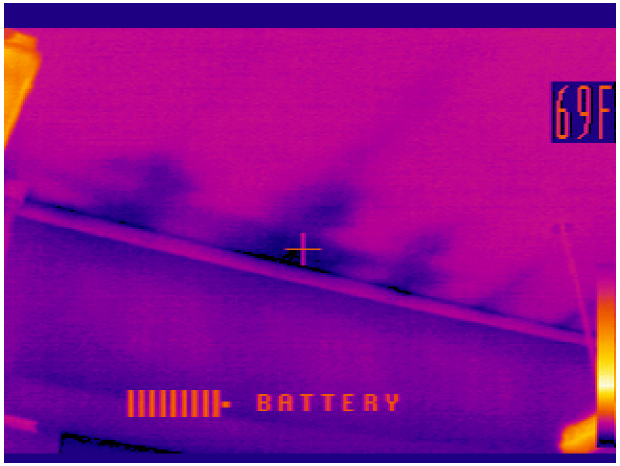




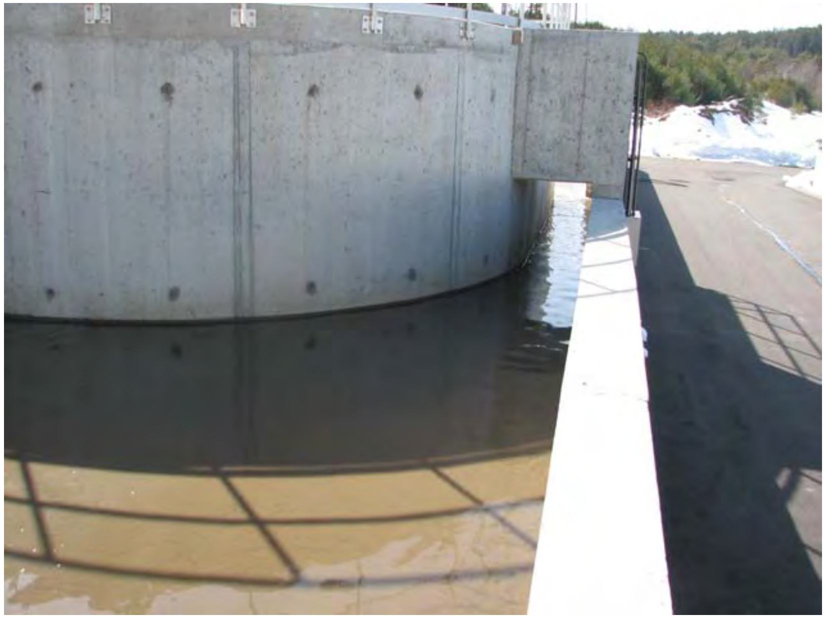
71F
BATTERY

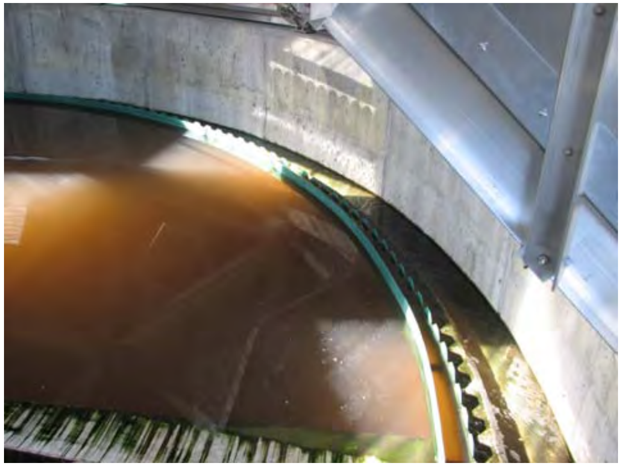
80F
BATTERY




69F
BATTERY

Plant is considered State of the Art and I lack the expertise to confirm or refute. State of the Art may, or may not, be the same thing as State of the Efficiency Art, so I recommend consulting with an electrical efficiency expert who can advise the town on a monitoring system that would alert pump or system inefficiencies. I suspect that is not the same thing as system malfunctioning which is monitored below – but I may also be wrong. We have been told by the construction trades that they are building to energy efficient standards for years and now know that has been very misleading. Therefore, I recommend developing a tracking system as well as monitoring all smaller loads. With a $66K electric bill every year, there many small inefficiencies accumulating but staying under the radar because of the total use. Things can add up appreciably!





Water Supply

Administration and Garage

16,020kWh 2500 gallons

shed

Bullet Tank
4,128kWh

Contoocook Well
172,919kWh 900 gals

Turnpike Well
60,840kWh 775 gallons

Poole Tank
4,482kWh

Prospect Booster
29,300kWh 455 gallons

Well and Pump Station Totals: 271,669 KWH's and 2130 gallons of propane

Total Water energy costs from June '09 through July '10: $51,732

Administration Office and Garage

Building Description
Approx 30’x 74’ concrete block building with Brick façade. Office portion has 2x4 steel framed interior wall, with 3.5” fiberglass batts and layer of polyethylene. Garage walls are not insulated. Truss roof rafters over ceiling frame with dropped ceiling tiles over the office area provide no air barrier. The garage bays face slightly west of south.

Building dimensions used in this report:
2220 ft2; 24198ft3 and 5454 ft2 surface area of shell

Staffed by two people 7:30-3:30 x 5 days 3-4 hours on weekends – total of 44 hours/wk or 26%

Office thermostat set to 68

Three Garage Modines: Off or 68

ANNUAL ENERGY USE SUMMARY

Heating Fuel
2549 Gallons Propane
(avg over 3 years – 2168 gals 7'09-6'10)

Meter #G80221220
Electricity
16,020 Kwh

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: 2549 gallons x 91,333 Btu's/gallon = **232,807,817 Btu's or 233MMBtus**

Electricity:16,020 kWh x 3412 Btu/kwh = **54,660,240 Btus or 54.7MM Btu's for site energy**
16,020 kWh x 11,396 Btu/kWh=**182,563,920Btu's** includes generation source energy

Total Site Energy in Btu's = 288 MMBtu's /2220FT2 = 124.4KBtu/ft2
Total Source Energy in Btu's = 415.5MMBtu's / 2220FT2 = 187KBtu/ft2

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

Whole Building: 7523CFM50

Means that **7523 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: 18.65ACH50

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 19 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: 1.66 ACH Winter: 2.23ACH Summer: 1.23 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 minutes or so.

Estimated cost of envelope air leakage: $ 2384 at $4.00 gallon or approx 39% of heating bill

Leakage Area (Canadian EqLA @10pa) 1086 in2 or 7.54 sq feet

Total size of hole if add all cracks and gaps together

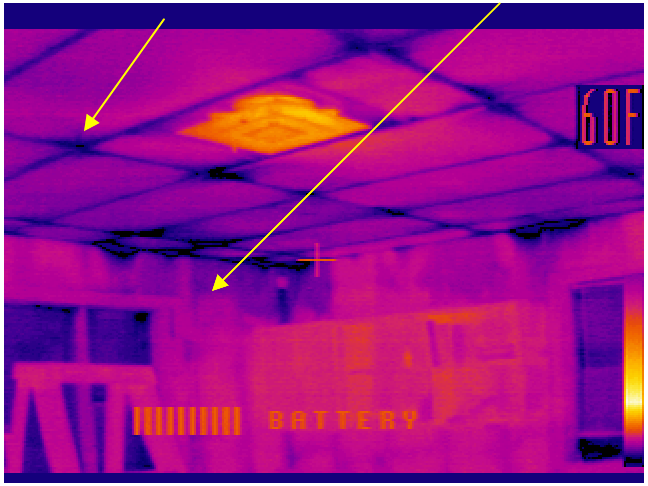
Minneapolis Leakage Ratio: 1.38 CFM50 per ft2 of envelope surface area

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.

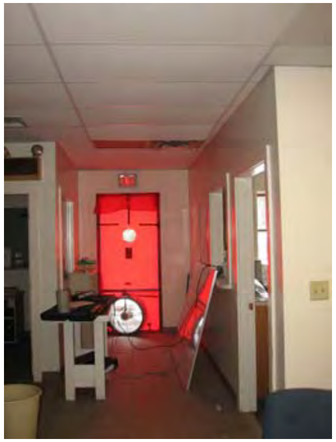
A second test was conducted for the office only by closing the door to the garage. The results are somewhat misleading because the attic is continuous over both spaces and lacks an air barrier. The Office only test indicated 5369CFM50 and over 25ACH50. This is due to the same air connection with the attic for about half the building volume. The pressure was measured in the garage while the office was at -25 WRT outside and indicated a positive 21pa. This suggests that while there is a connection between the office and the garage, in the testing scenario the garage was 'far more outside, than in". Establishing an effective air barrier between the two space is important terms of indoor air quality in the office.

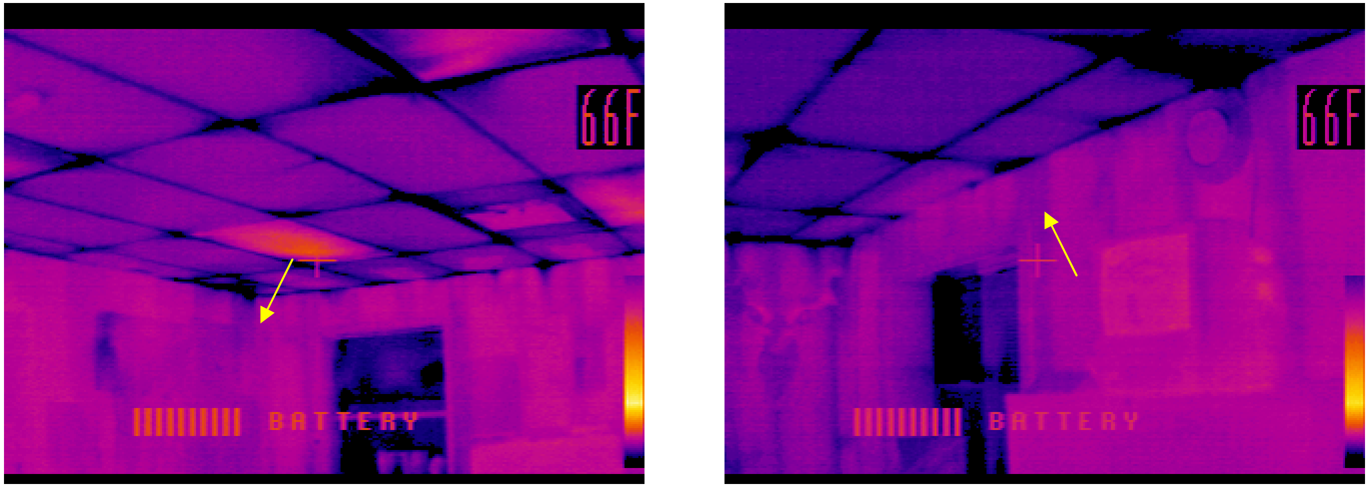
Insulation gaps in envelope create greater conductive heat losses.

Gaps in air barrier create convective heat losses, as well as diminish R-value performance of existing insulation.

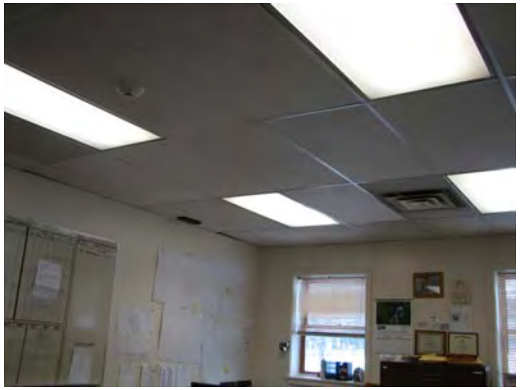


Inside temperature was 68°F and outside 39°F. IR image above on left was taken under normal conditions and the one on the left with the blower door fan running and the building depressurized to -30pascals with respect to outside.





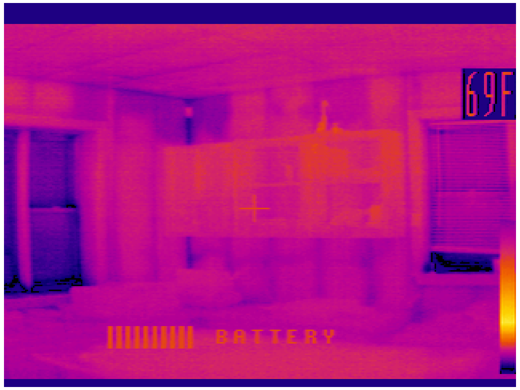
Note diminished insulating performance throughout walls where air (and moisture) are allowed to flow.

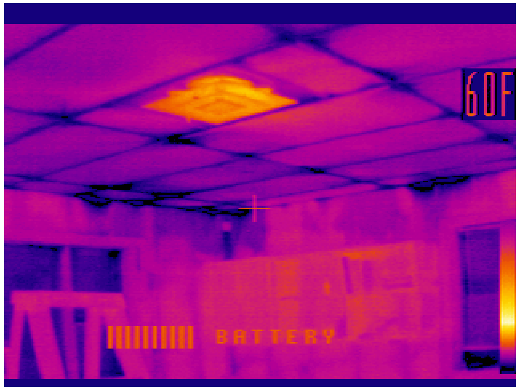


Effectively reducing heat loss means heating equipment can be smaller, use less energy, and provide greater comfort.

Snow melt patterns on roofs can indicate heat loss. Often, as is the case here, there is some insulation in the attic or ceiling to reduce heat moving to cold, but no air barrier to stop warm air from rising. The area on the left is above a drop ceiling without a continuous air barrier. The roof area to the right is above the garage bays with a drywall ceiling with a few unsealed penetrations. Adding insulation to the attic will often reduce energy use, but often air sealing all the gaps and cracks in the ceiling can save even more and make your insulation more effective!

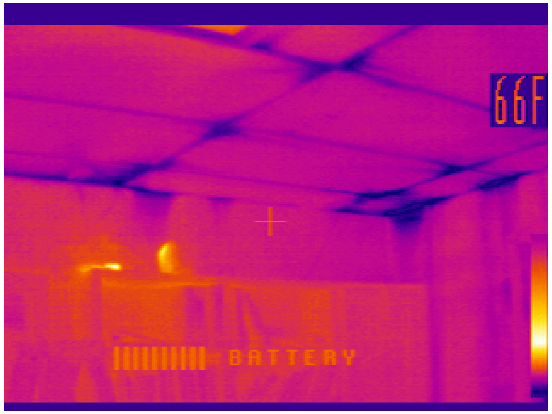
Ceiling

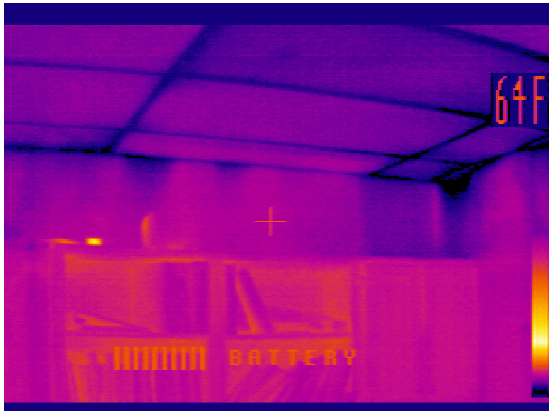




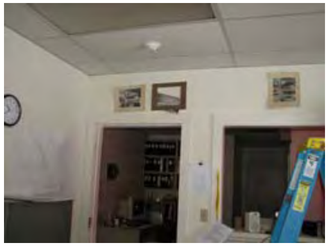
At -30 pa for 2 minutes and 15 minutes. Note the progressive cooling. After the 30 minutes, the room temperature had dropped from 67.8° to 63°.

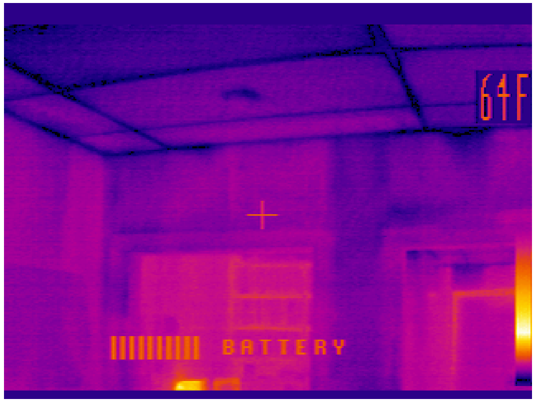
Ceiling



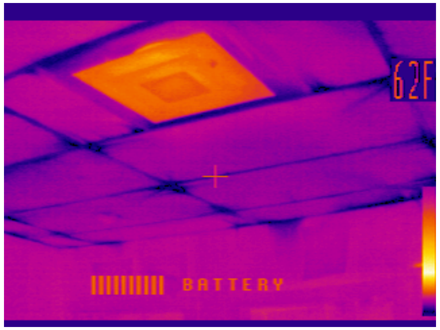


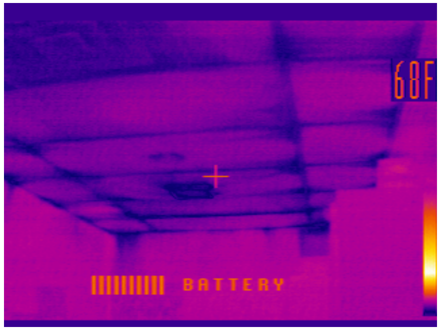
Again at 2 and 15 minutes. These are interior walls being cooled from the “outside” attic above.

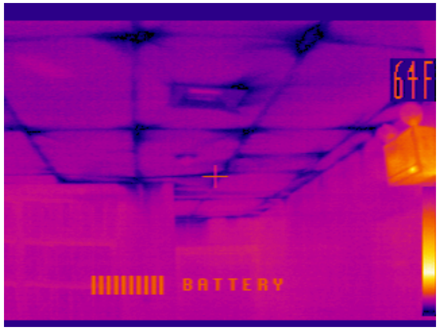


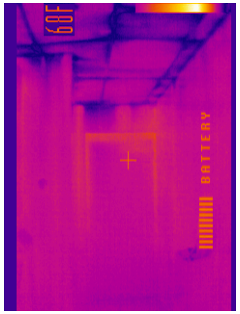


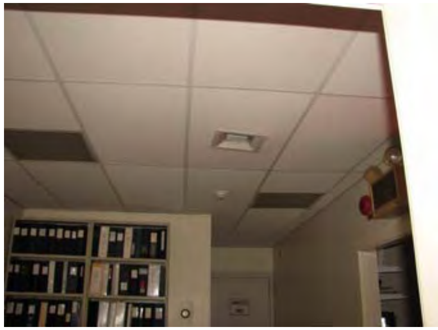
Ceiling

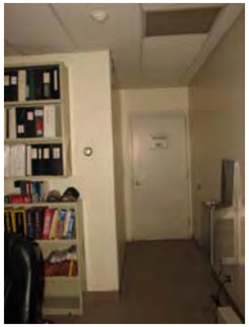


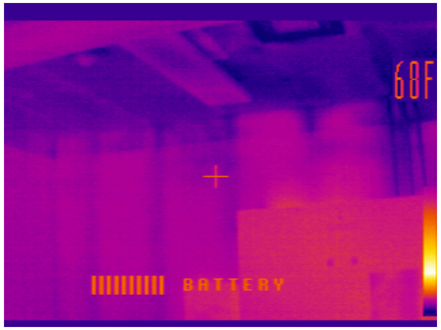






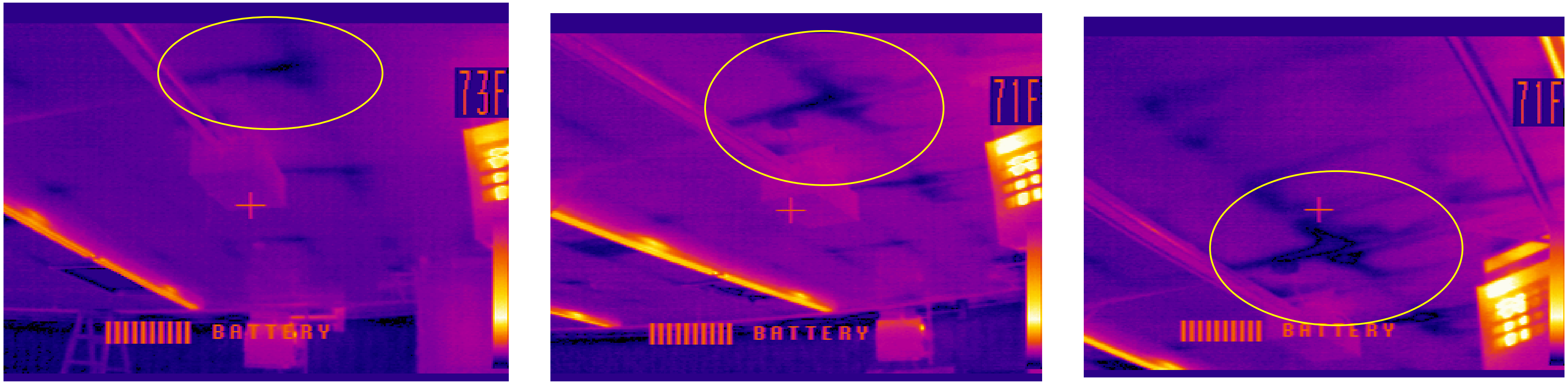




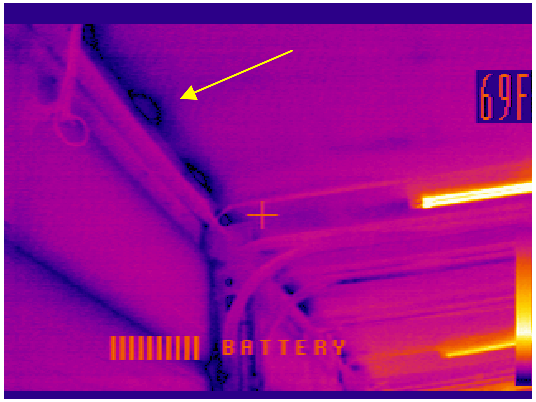


Establishing an air barrier above this dropped ceiling in direct contact with effective insulation levels will make a dramatic improvement in comfort and reduction of oil use.

Garage Ceiling

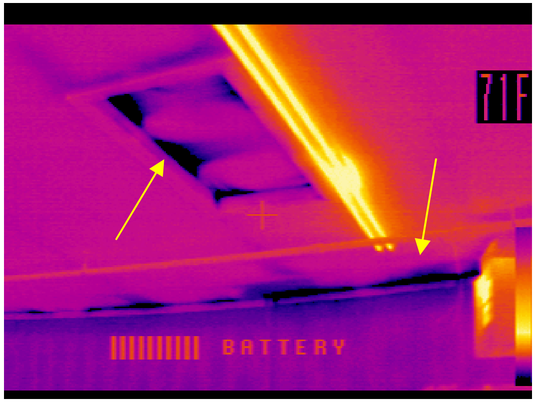


At -30pa about 15 minutes apart.

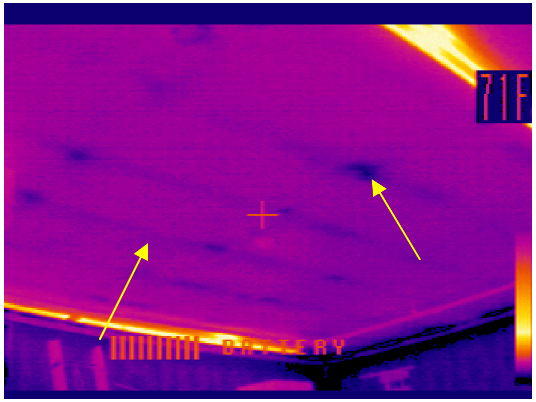


The garage ceiling has less air infiltration into the space, though there is still air movement evident between the joists and the drywall ceiling. Note the discoloring under joists as warmer, moist air condenses on the cooler surface below the wood joists. Unsealed / un-insulated top plates are typically colder and a source of air movement.

Garage Ceiling

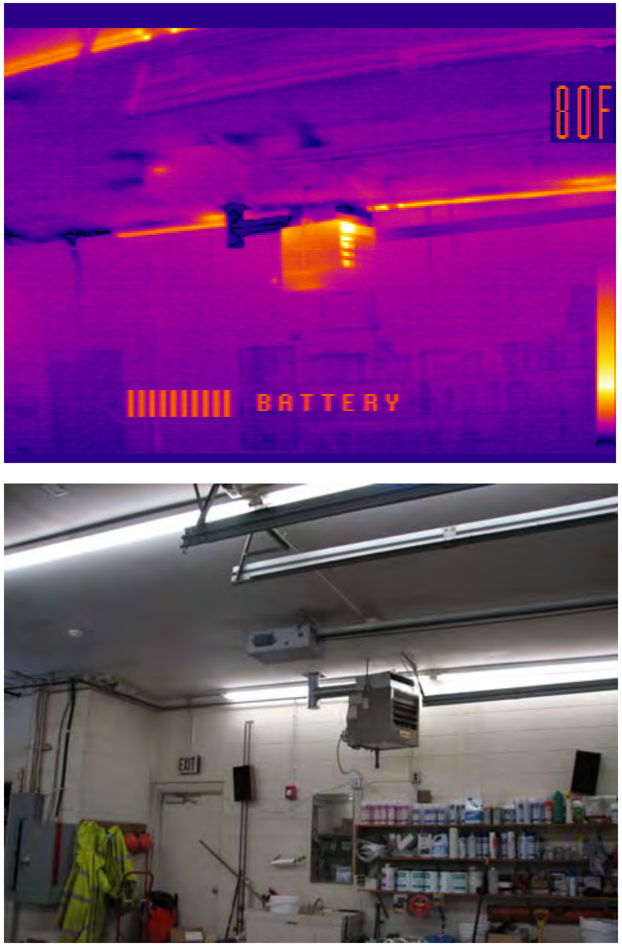


Coolth above is mostly due to convection or heat loss via air movement. Sealing the attic with a gasket seal will eliminate convective heat losses, as will foam sealing above the top plate.



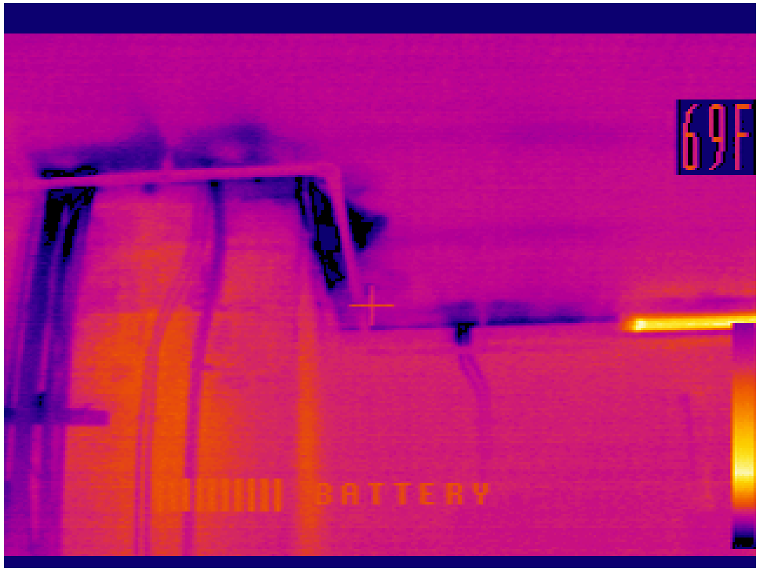
Here, the heat loss is primarily through thermal bridges – heat conducting to cold faster through framing members than insulated cavities. Note that IR images depict relative surface temperatures. Heat is moving to cold everywhere – just more quickly through R6 joists than R20+ insulated cavities.

Garage Ceiling



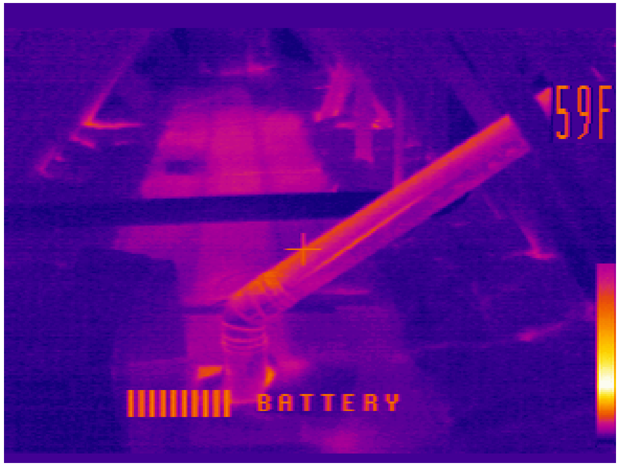
Compare the walls and ceilings of these two images. On the left, the interior, conditioned wall is warmer than the ceiling, where as on the right, that same ceiling is warmer than the essentially un insulated concrete block wall. If the exterior wall and ceiling were both effectively air sealed and insulated, ie, reducing rate of heat loss, it is likely that one Modine heating unit would be able to effectively and evenly warm this area.

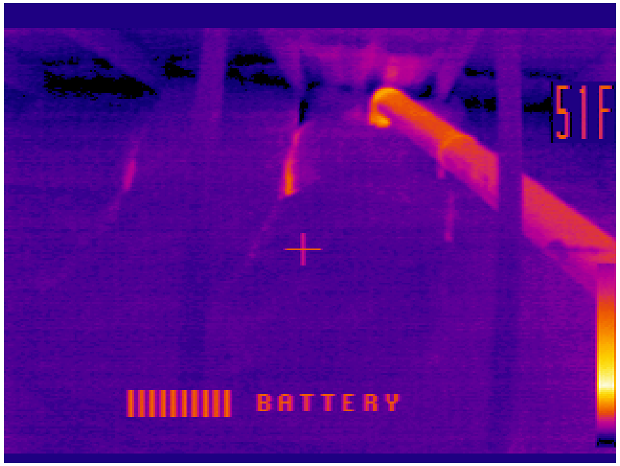
Garage Ceiling



Damage from past water leakage are a constant source of air leakage and heat loss.

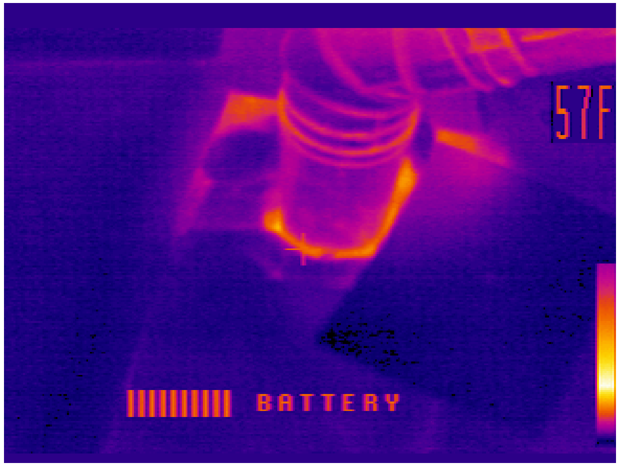
Attic

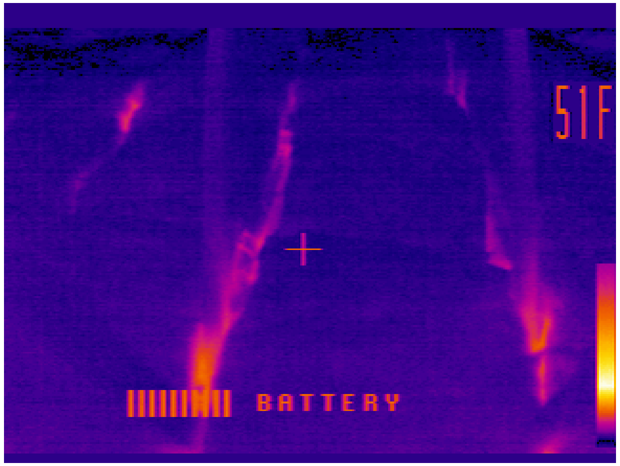




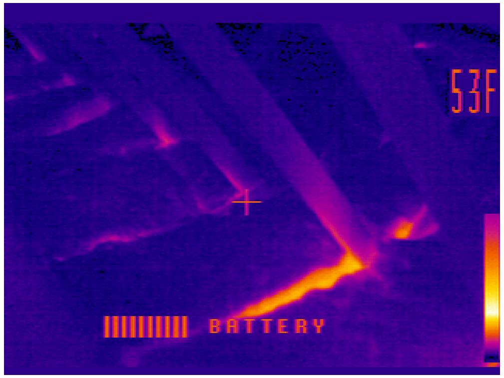
From "outside" conditioned space looking down, heat loss is now seen in brighter colors. Above, heat loss is most evident compressed, or missing, insulation under the walk way and between batts. Continuity matters!

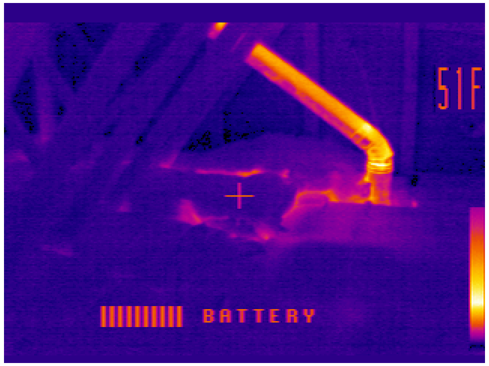
Attic

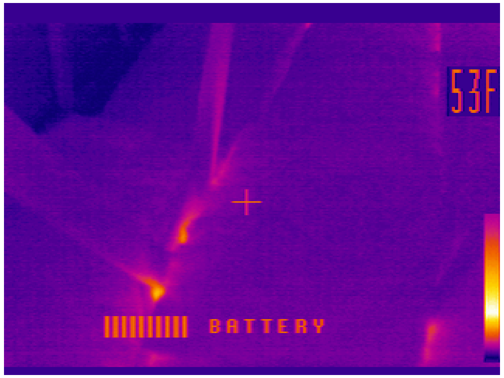




Attic

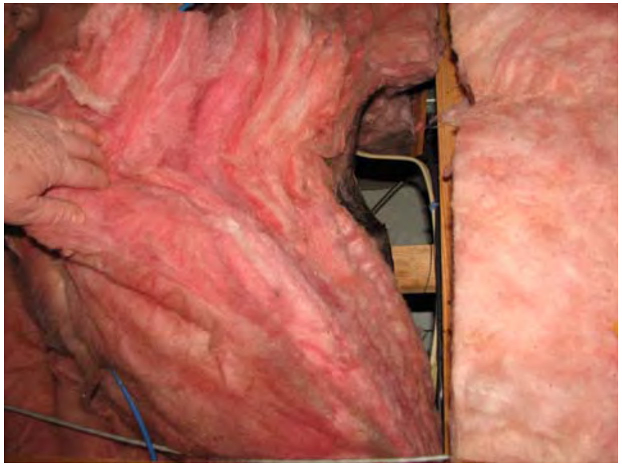






It is likely that the recent addition of another layer of fiberglass batts did help reduce the rate of heat loss. However an even greater opportunity now lies in creating a continuous air barrier. In direct contact with at least one side of this insulation. These batts will still not effect the “R-Value” stamped on the package, which was determined in a laboratory where the batts were installed with ideal loft and an air barrier on all six sides. For effective R30 to R50 levels, another type of insulation would be necessary.

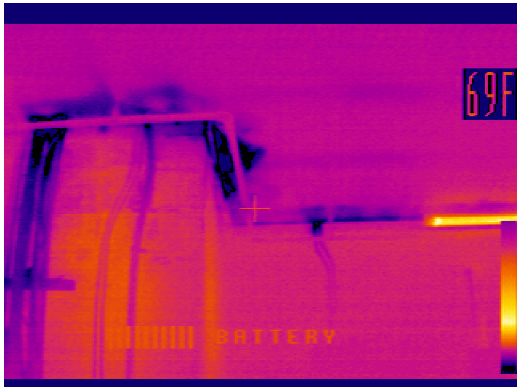
Attic

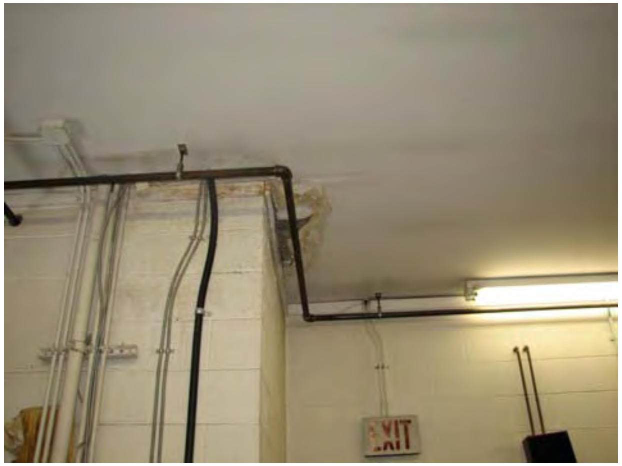


The challenge here is that there is no solid floor or ceiling below. While it would have been relatively inexpensive to create during initial construction, it is considerably more expensive to install after the fact which can make the cost/benefit analysis fall outside conventional energy efficiency formulas. Even so, establishing a continuous air barrier at this ceiling plane is the number one recommendation..

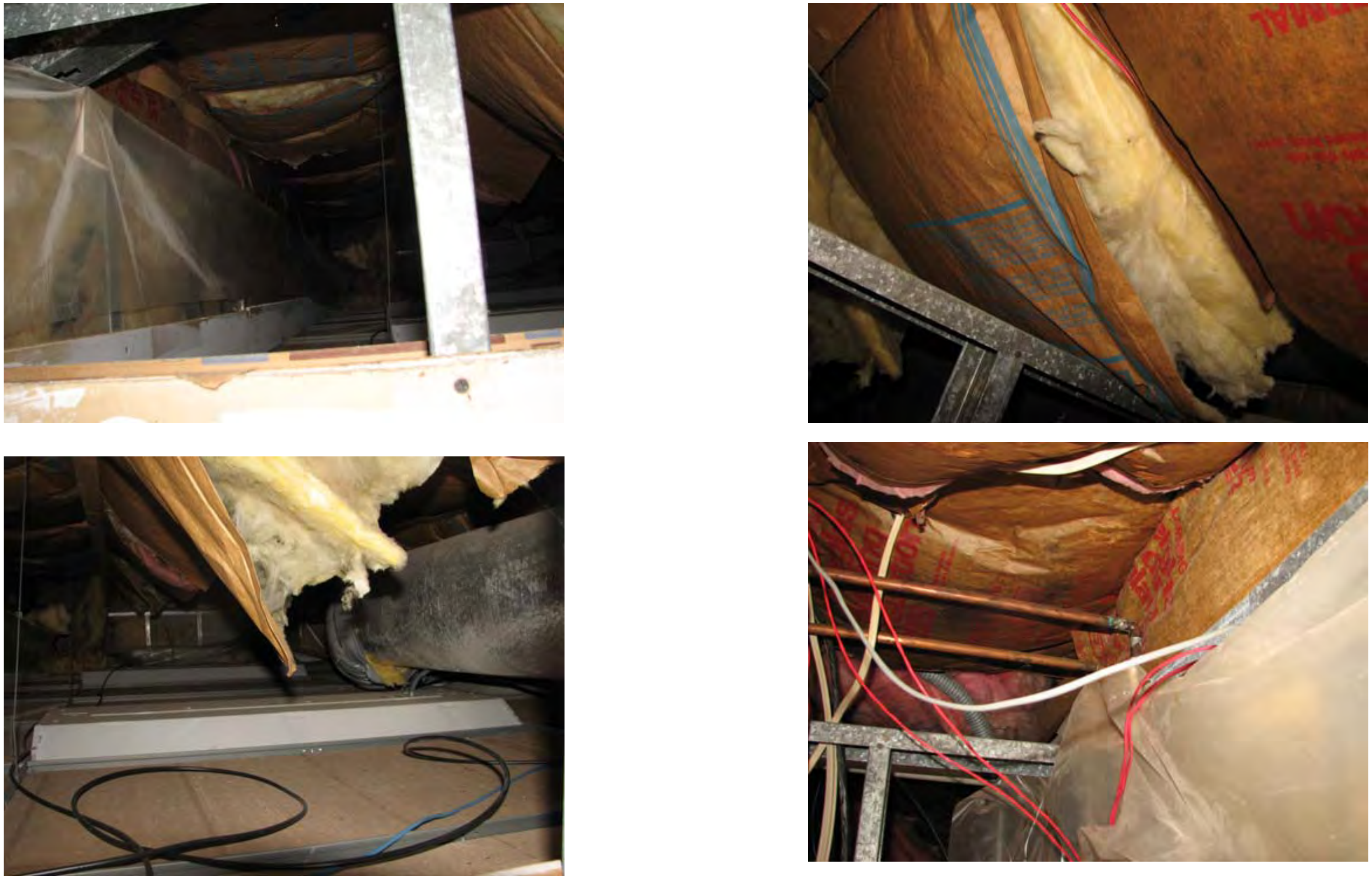
Moisture

Water leaks around the chimney appear to have been resolved. Smaller leaks may be attributed to either bulk water or repeated condensation pooling near holes in the plastic above the ceiling.





Ceiling Chase

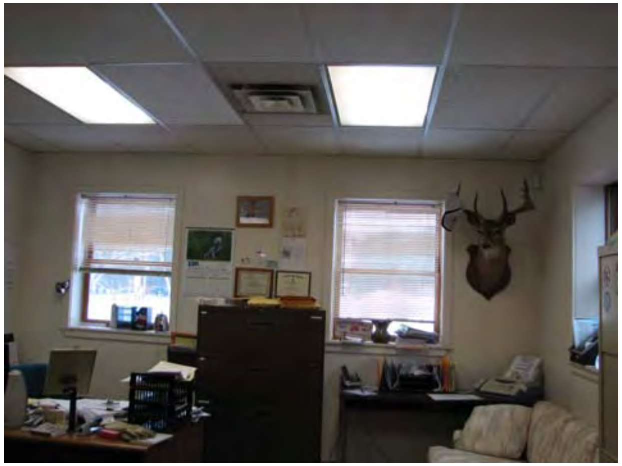


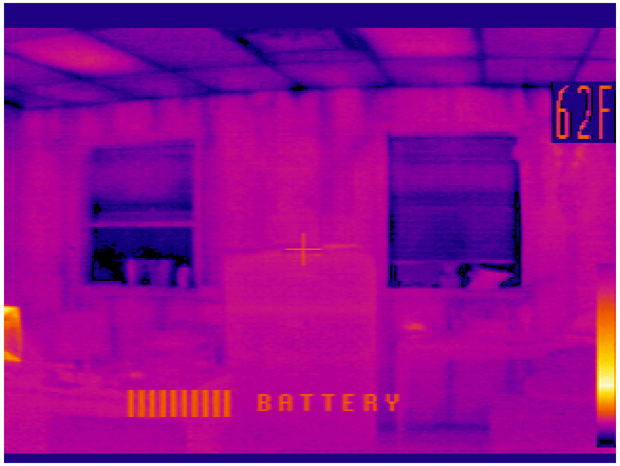
Establishing an air barrier above this ceiling chase will not only reduce heat loss but air transported vapor which, when comes into contact with cold metal or other surfaces, can condense and eventually cause a range of moisture related issues.

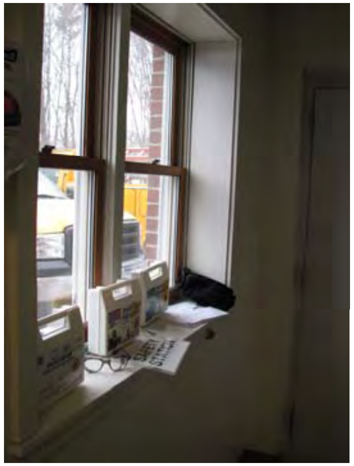
Ducts in Ceiling Chase

Pressure diagnostics indicate a fair amount of air leakage from the ducts in the chase, most likely at the seams and where the ducts connect to the registers. Again, an air barrier an effective insulation above will more effectively bring these ducts into conditioned space, thereby reducing energy loss. However, sealing all seams and junctions would reduce heat loss further by directing heat below the drop ceiling more efficiently.

Windows



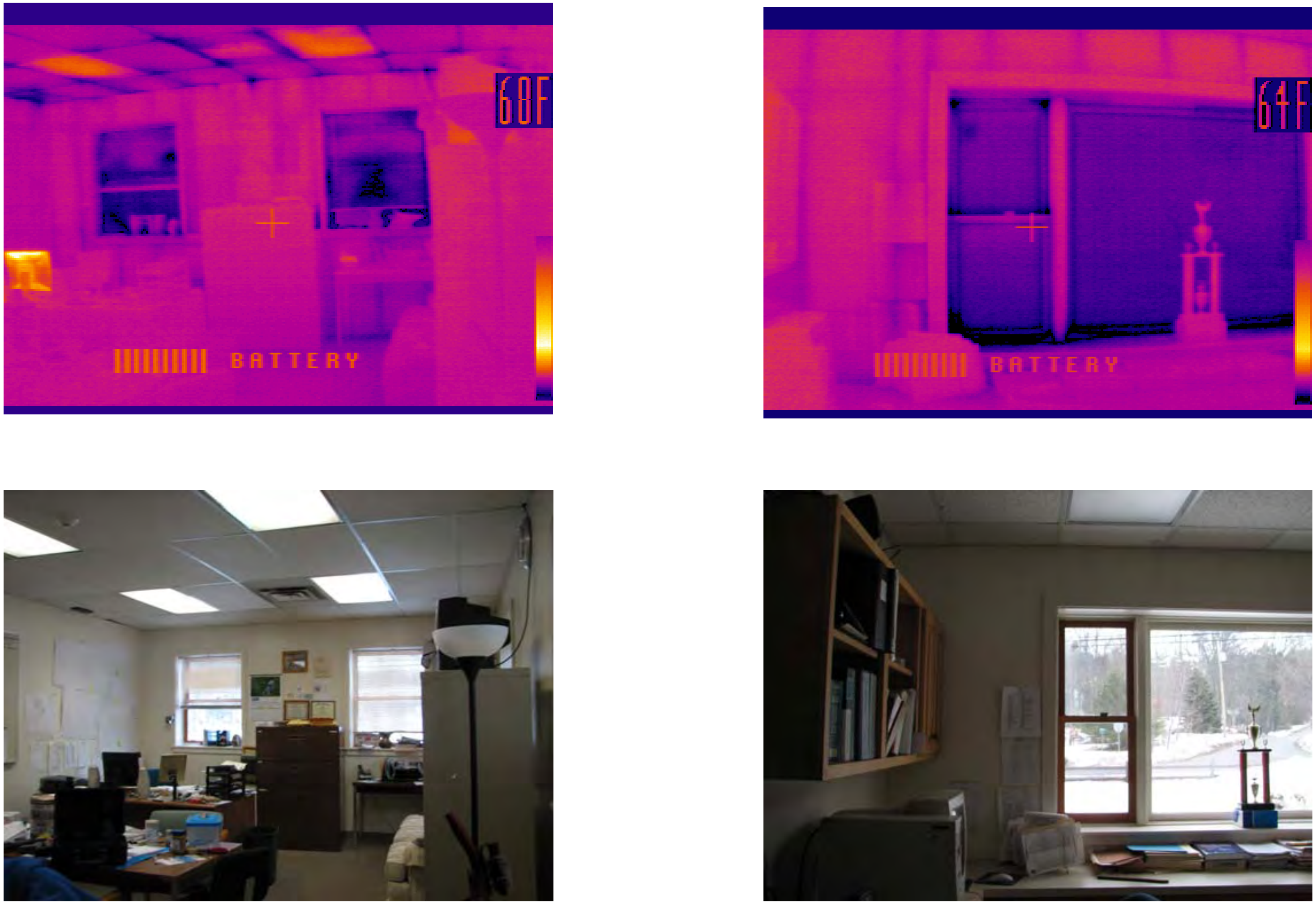




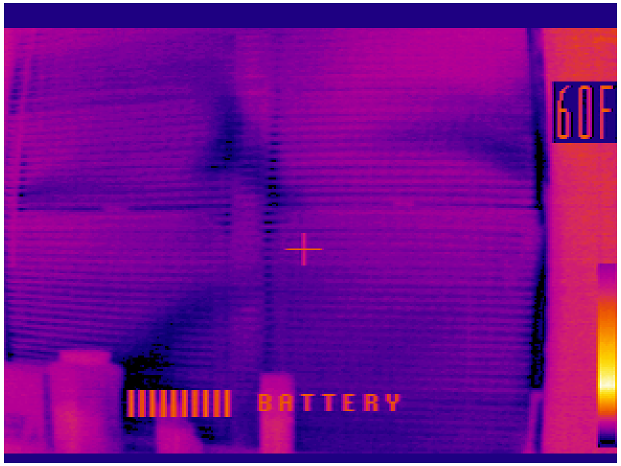
All the windows were found to leak considerable air. Caulking and sealing these windows by a professional will reduce air infiltration and a very cost effective improvement. Replacing them with higher performing windows would be recommended during a wall upgrade.

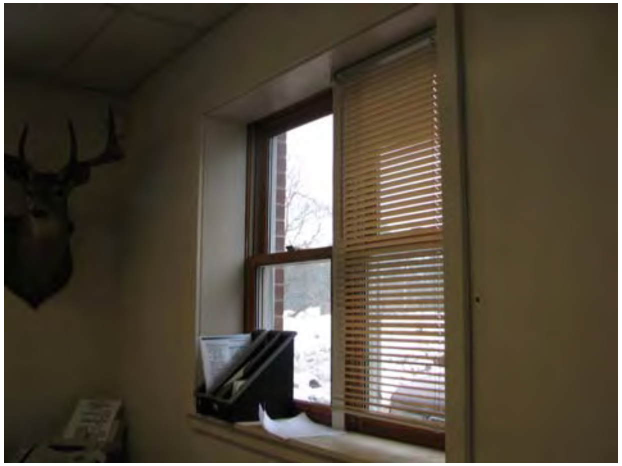
Installing insulated window curtains on tracks can also be very effective for about $9/ft or about $1,000. But simple air sealing remains the most cost effective solution for this relatively small wall area component.

Windows

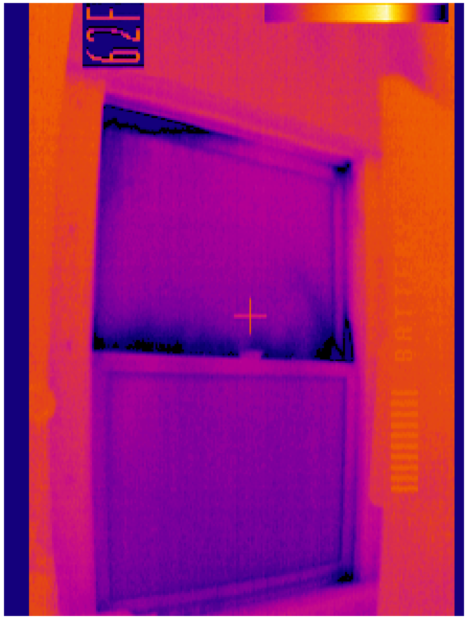


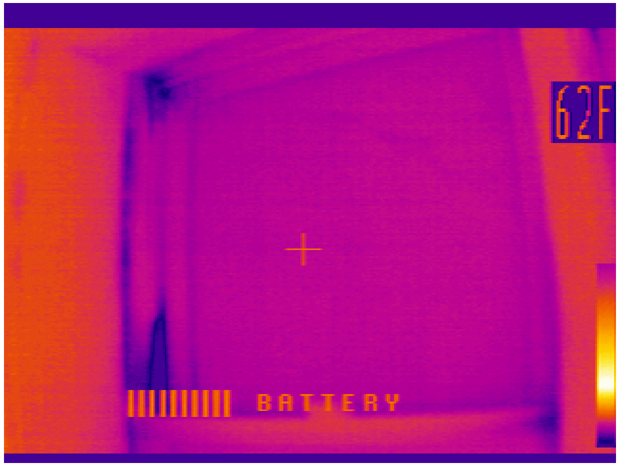
Windows

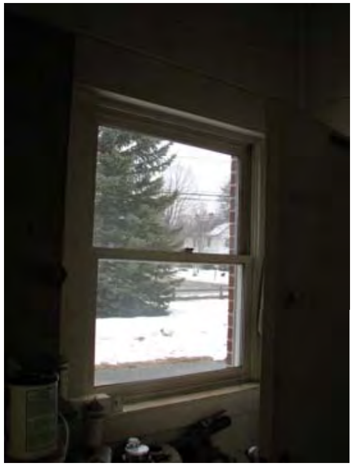




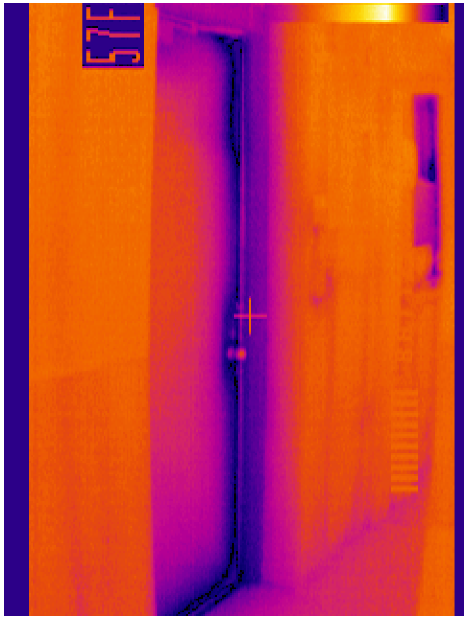
Windows

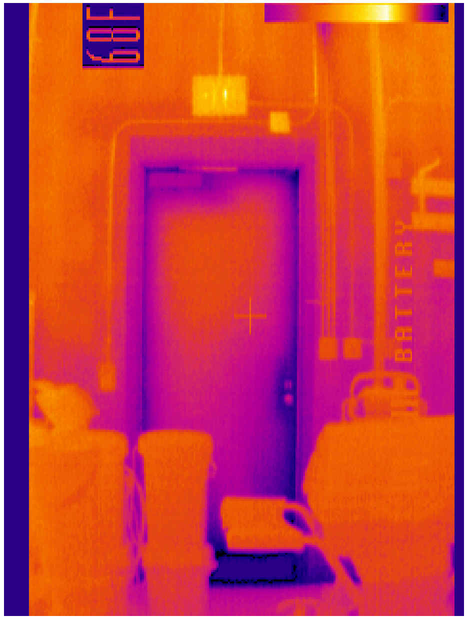




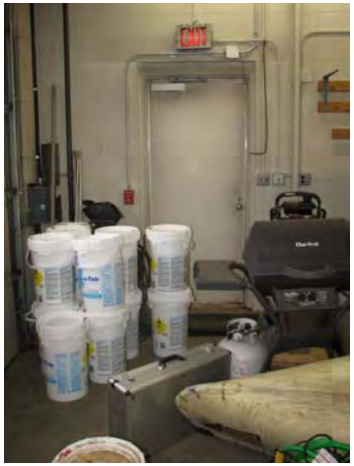


Doors

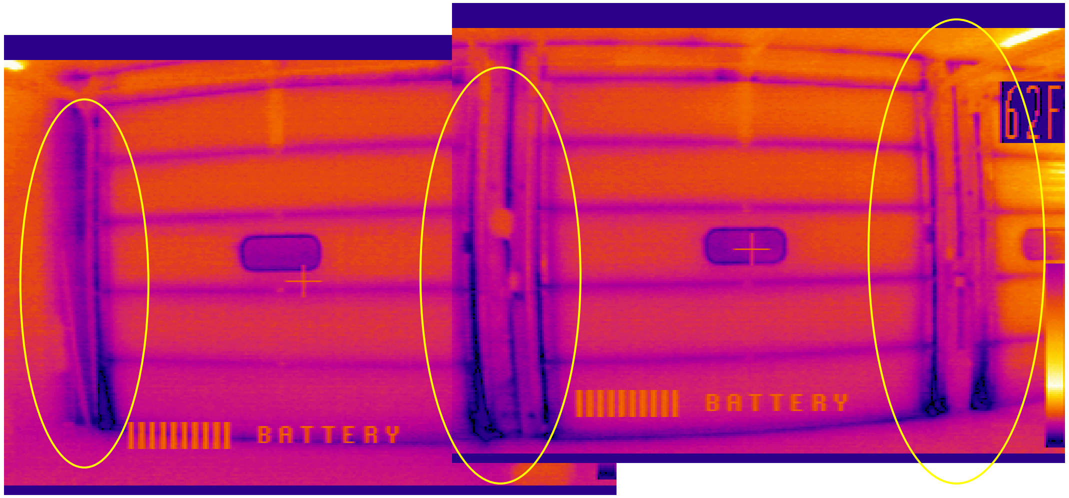




The door below was recently installed.



Garage Doors

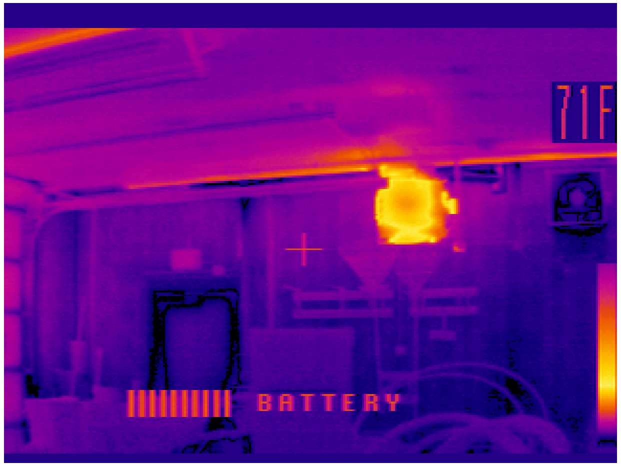


One recommendation which was not included in the summary report is to remove the garage bay door to the far right and replace with a well sealed and well insulated wall. The bay is not used for vehicles but storage of things which could as easily be rolled or moved in through the adjacent door. If the estimated value of the doors is R7, then the upgrade of 1/3 of the wall to R24 would be small, but not insignificant.

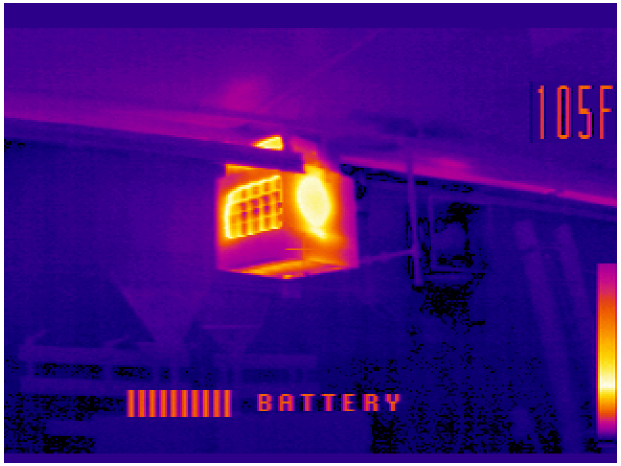
Garage Walls

Replacing this window is part of regular maintenance.

Garage Walls



Equipment



Equipment

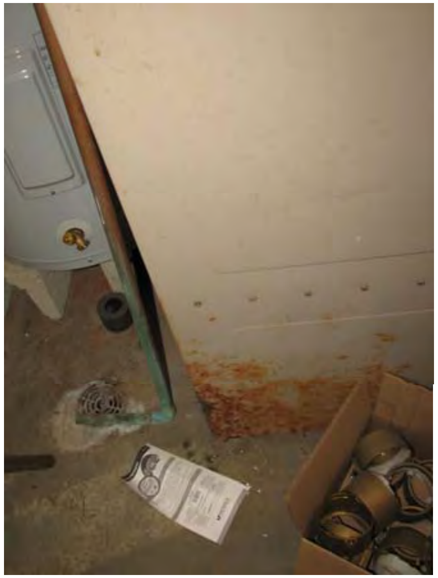
Pre 1984 propane furnace

Model PV36D16W09001A

90KBtu/hr

With envelope upgrades, a smaller, sealed combustion heating unit can be installed.

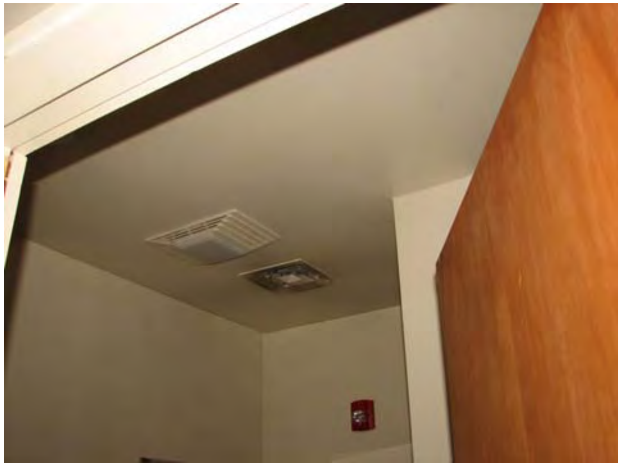
Equipment

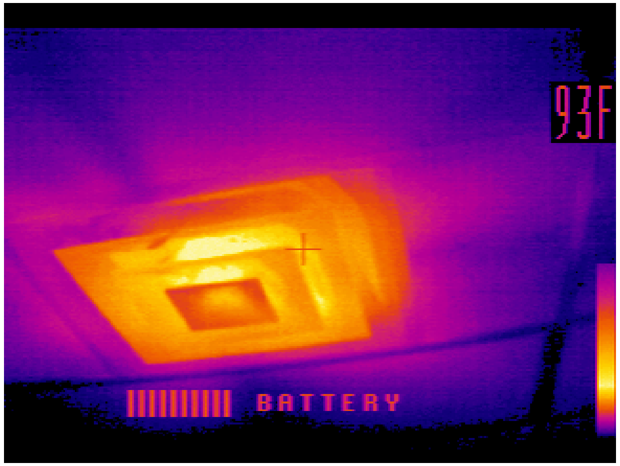


Past water intrusions have left furnace with rust.

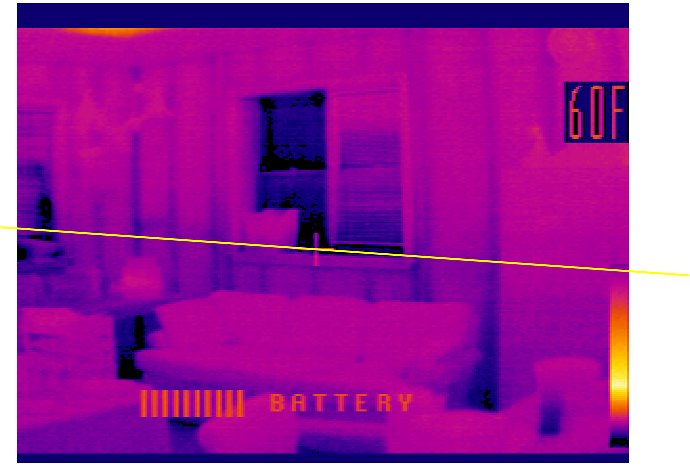
Electric water heater installed September 2008.

FHA Distribution





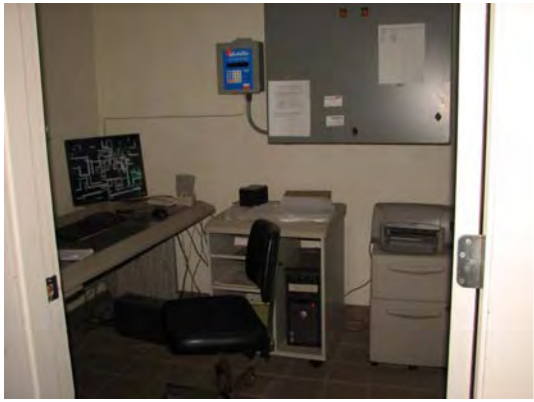
Warm air rises which means ceiling mounted heat registers have a challenge getting warmth to where people are. Air sealing and insulation can help maintain more even distribution, but people are generally more comfortable if their feet are warm and head cool – not the other way around.



Note how it is slightly warmer above the yellow line, and pressure plane, of the wall and room.

Equipment

Equipment

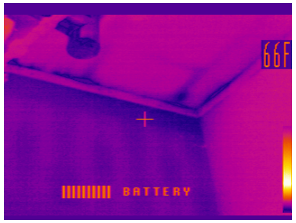


Equipment

Air Quality Concerns

Materials and vehicles stored in a garage can create a toxic environment. Effective exhaust, with a well sealed damper, is an important piece of equipment in any garage. Limiting the amount of time combustion engines are allowed to run inside a building is also important.

Equally important is an effectively maintained air barrier between the garage space and office or other areas. The air barrier at the ceiling will help considerably. But air sealing the shared wall and keeping the boiler room door closed is very important. Installing a high efficiency and sealed combustion boiler (hydro air unit) will allow this door to be kept closed at all times.



Water Tank Stations

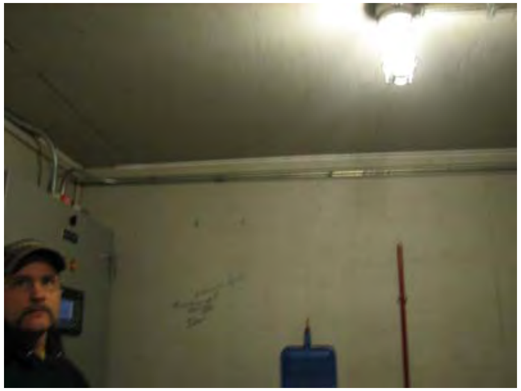
Bullet Tank

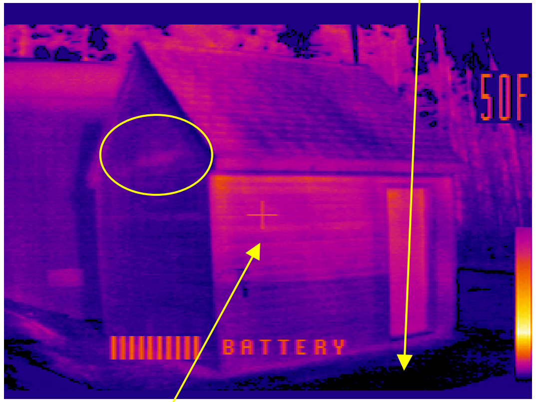
Approx 10 x 12 shed; 8' ceiling under vented roof. 2x4 framed walls with 3.5" fiberglass batts. Ceiling insulation present but unknown values.
120 ft2; 960 ft3; 432 ft2 surface area of shell

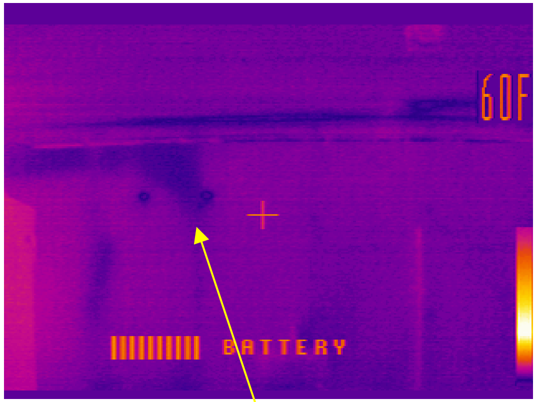
Annual Electric use: 4,128kWh

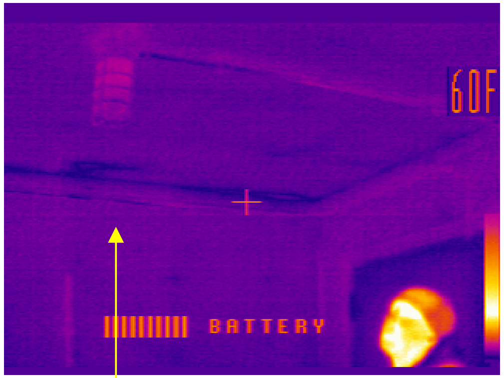
Water Tank Stations

Bullet Tank









Solar radiation. Lower half of wall is cooler because there had been a sheet of plywood leaning on the wall – which was laid flat just before the picture.

Batts settled and perimeter voids and air infiltration. Metal door needed to limit vandal damage. Building could be retrofitted to high performing, super insulated shed for between $3-$4K.

Water Tank Stations

Bullet Tank

Two CFL's in ceiling fixtures.
Electrical consumption in non heating months averages 45.6kWh and ranges from 36-48. Total annual consumption is 4128kWh of which 3,581kWh is used to run a Patton 1500 watt, 120 Volt electric heater (PVH 680) to keep chill off for the daily 10 minute visits. Electronic board was mounted on plywood outside for five years. Staff reported that it worked fine when left outside.

Water Tank Stations

Pool Tank

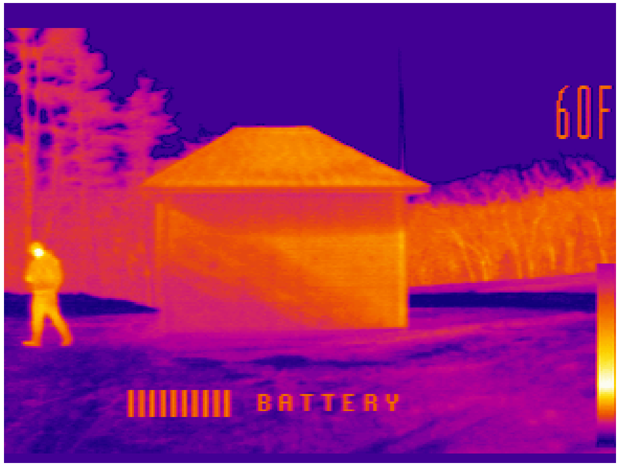
Approx 8 x 12 shed; 8’ ceiling under vented hip roof 96 ft2; 768 ft3 416 ft2 surface area of shell

Annual electrical consumption is 4,482kWh. Summer averages at 36.2 kWh/month which suggests 4,048kWh (91%) is used to keep the Patton electric heater on to keep off chill during the daily 5-10 minute visit (.005%) of a week and .02% of a person’s work week. Patton 1500 watt, 120 Volt electric heater (PVH 680) to keep chill off. Just like at Contoocook Well, electronic board was mounted on plywood outside for five years. Staff reported that it worked fine when left outside.

Water Tank Stations

Pool Tank

Inside temp day morning of site visit: 75°F. Outdoor temp – upper 30's.



Plugged in a kilowatt meter into the Patton Electric heater briefly. Measured draw: 10.64 amps; 120 watt hours/minute.

Electronic monitoring equipment was previously under shed roof cover only, just as at the Bullet Tank. Therefore the only reason to heat the building is for the comfort of staff for the 5 minutes each morning they come to take readings. On the rare occasion repairs require a longer stay in either Pool Tank Shed, an electric heater could be kept in the truck as used as needed.

Water Pump Stations

Woodbound

Approx 15’ x 33’ 12” concrete block on slab with two separate rooms; 10’ 2” ceilings under a 10” concrete slab roof. Double metal doors showing signs of vandal attempts.

Approximately 1650 ft2 surface area

Uninsulated and well vented building uses between 650-900 gallons propane a year for heating and emergency generator. Impossible to know how much of the fuel is used for the generator.

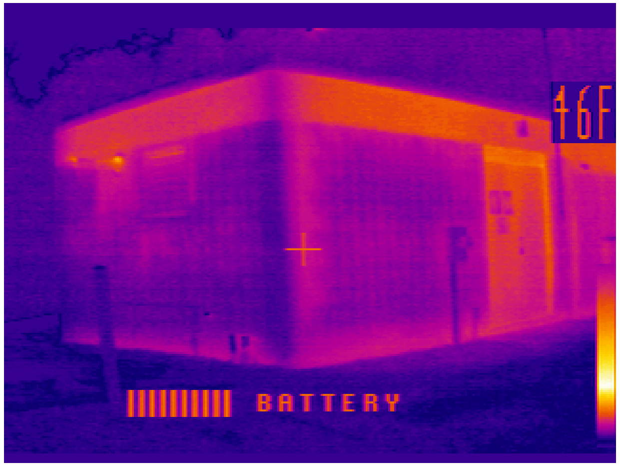
Retrofitting the exterior with continuous R20 Foard Foam Panels and a wood siding would cost approximately $15,000 and may save approximately 400-600 gallons propane. At $3.00 gallon, that would suggest a simple 9 year pay back. At $5.00 gallon. 5.5 years.

Water Pump Stations

Woodbound

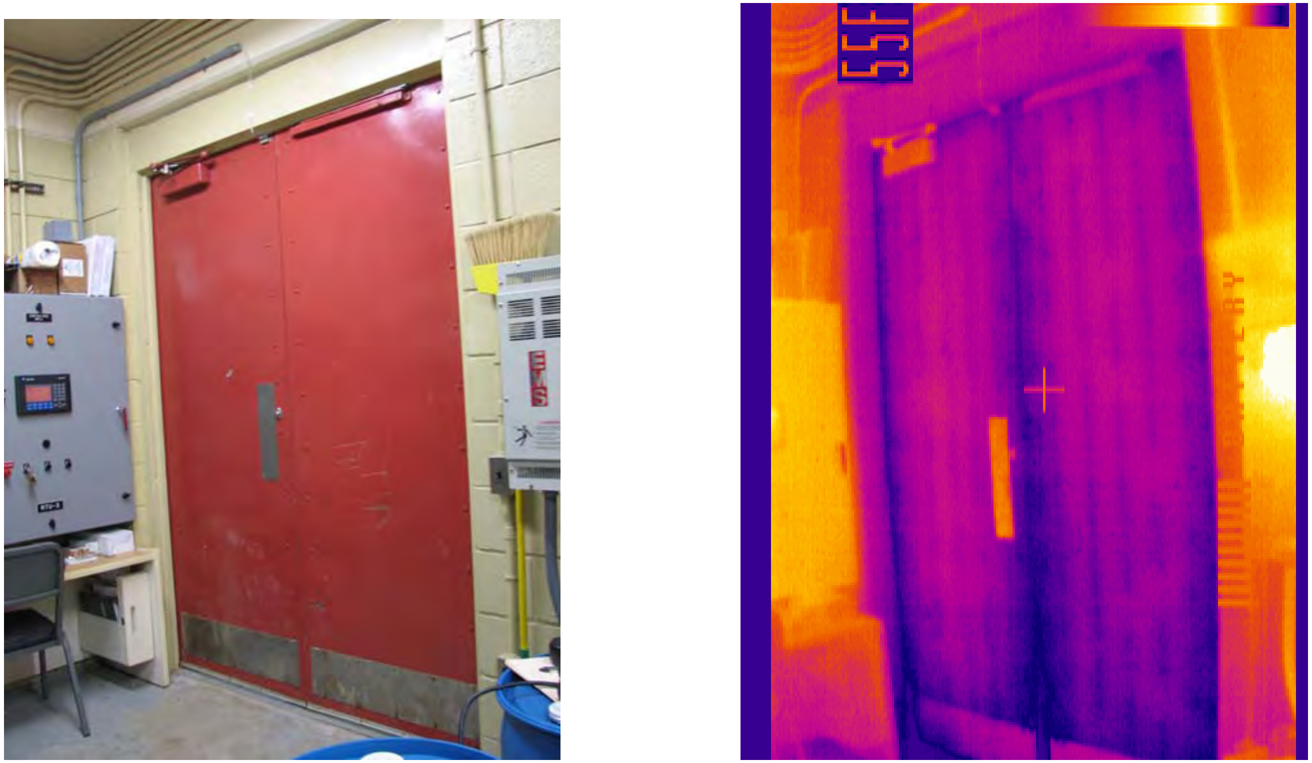
Averages 893 gallons annually of propane for space heating and emergency generator.

July '09 to Jun '10 electrical use:
172,919kWh



Water Pump Stations

Woodbound

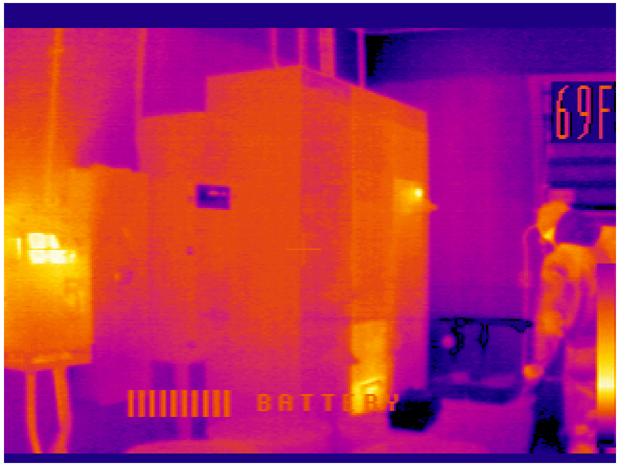


Significant heat loss through un insulated doors, slab, and walls and suspected minimal roof insulation.

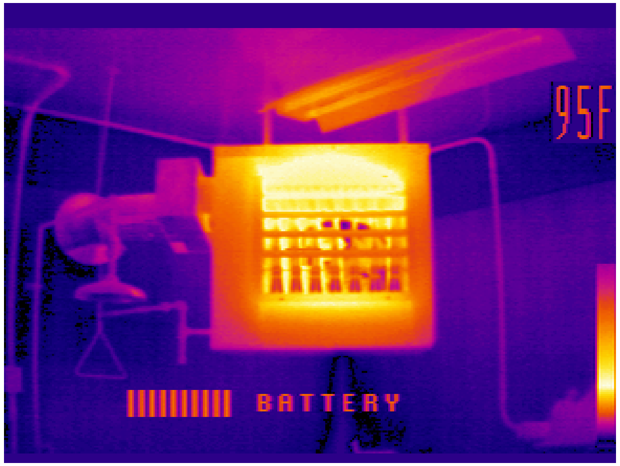
Water Pump Stations

Woodbound

Four (4) four foot T12 with two tubes each.



Reznor Propane heater with electric fan. Set to 70°F year round with low temp alarm.



Water Pump Stations

Woodbound

Chromalox electric heater
Cat WCRT-100 set to 62ºF

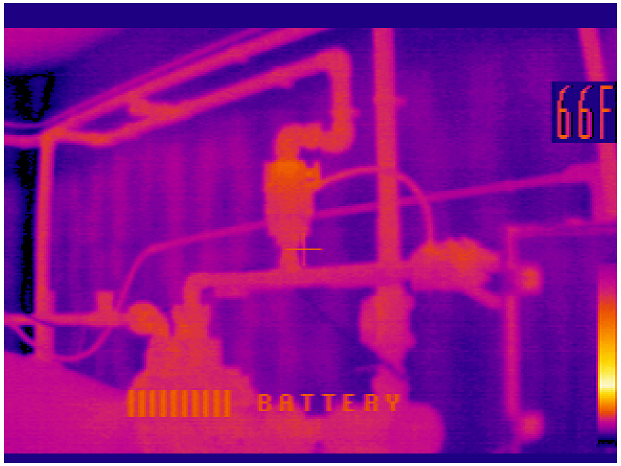
Ventilation needs are also high and with significant energy penalty.

Monitoring electrical use does seem immediately reasonable. With such high electrical load, there is no way to assess losses without monitoring the equipment performance.

Paragondel exhaust fan

Water Pump Stations

Woodbound

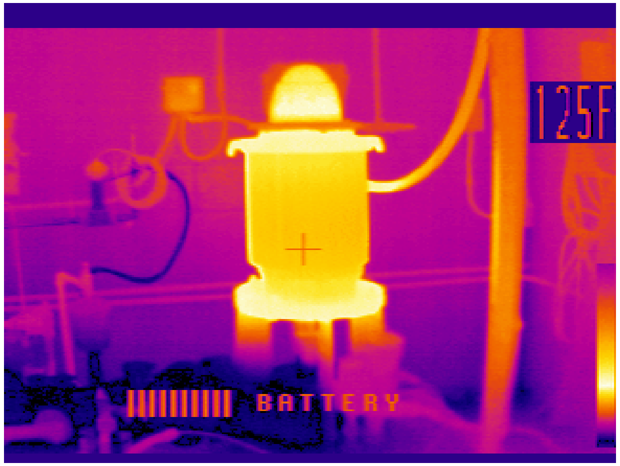


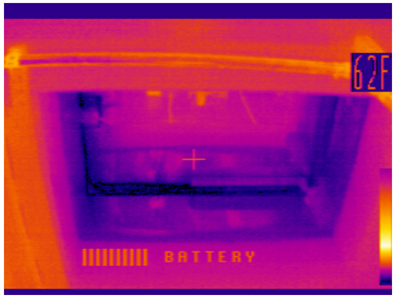
2nd room contains potassium hydroxide chlorine and is separately heated and ventilated.

Concrete blocks appear to be “insulated” in the cores. Thermal bridging of hollow blocks makes insulation nearly useless and wall R-values estimated at an overall R1.5.

Water Pump Stations

Woodbound





Water Pump Stations

Turnpike Road

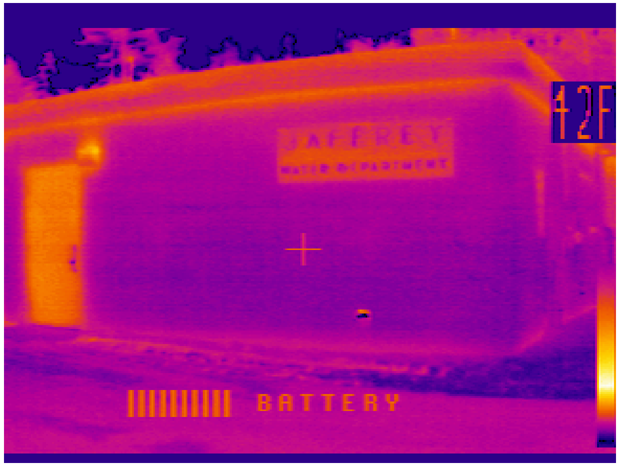
Approx 22’ x 34’ (12”) concrete block with brick façade over 9’ ceilings under 10” concrete slab roof 748 ft2 and 6800 ft3; 1812 ft2 surface area of shell. Three distinct rooms with separate heating and ventilation and a covered port out back.

Annual propane use between 500- 775 gallons. Electrical use from July ’09 to June ’10 was 29,300kWh.

It is still not clear how much propane is used for heating as opposed to emergency generator nor is it within the scope of this audit to analyze electrical equipment. While this building would also benefit from exterior insulation, the recommendation is to invest in data logging equipment to move throughout all pump houses and to track fuel use more carefully – or hours of generator time - for this building in particular. The substantial ventilation requirement because of chemicals adds an additional layer of complication – as with the Pump Station on Woodbound Road.

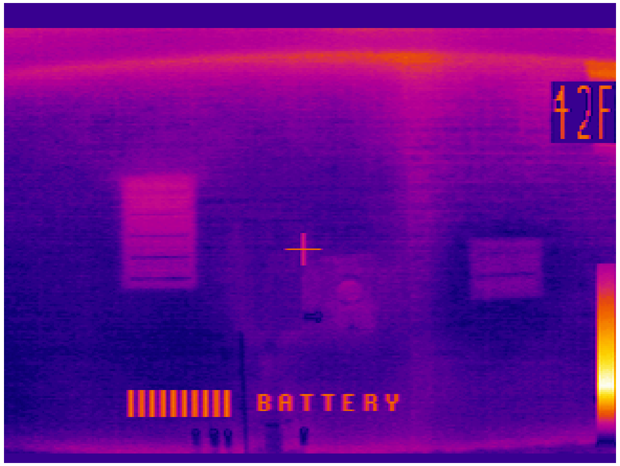
Water Pump Stations

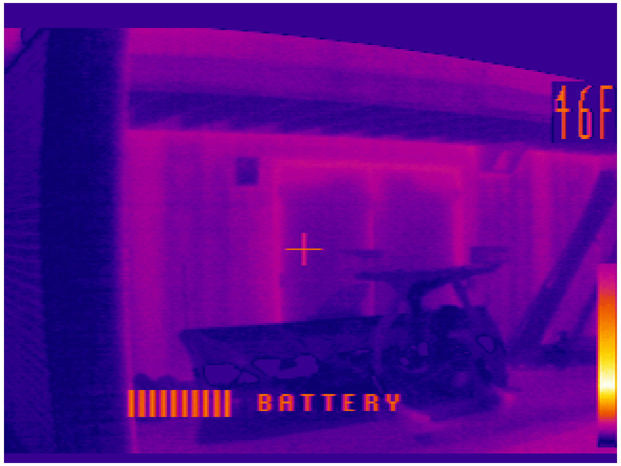
Turnpike Road



Water Pump Stations

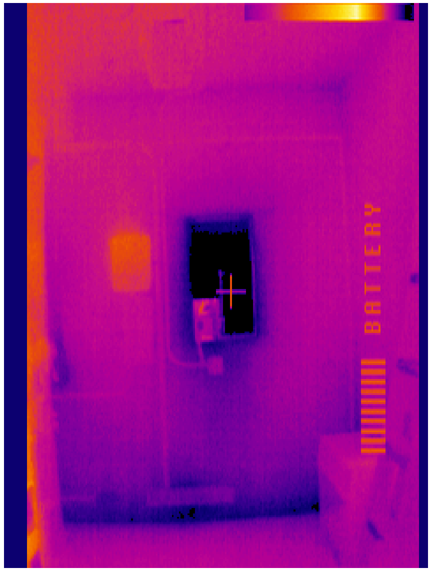
Turnpike Road

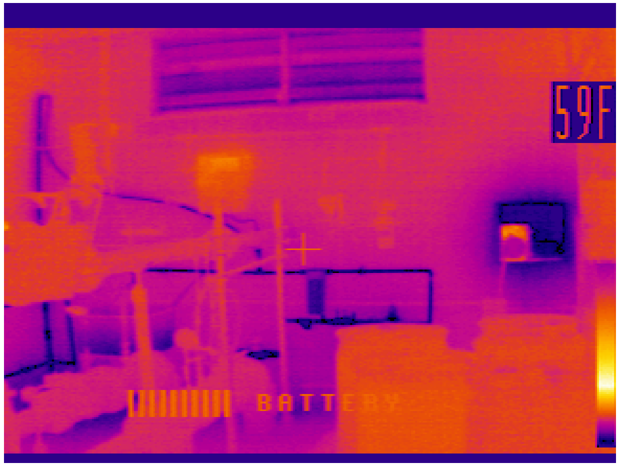




Water Pump Stations

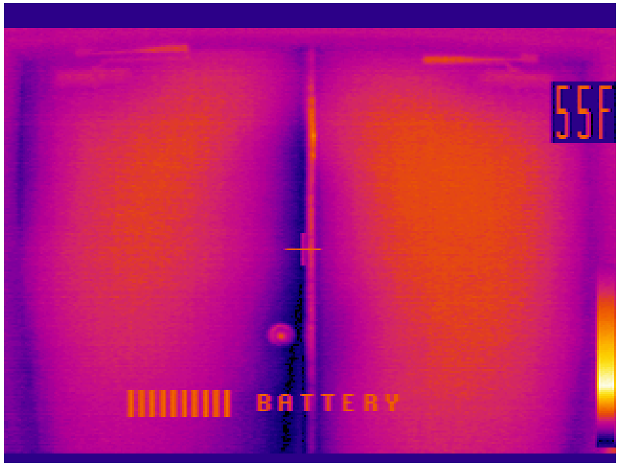
Turnpike Road

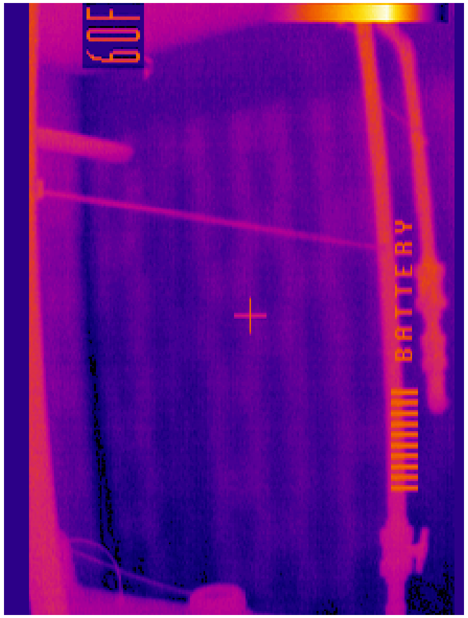




Water Pump Stations

Turnpike Road



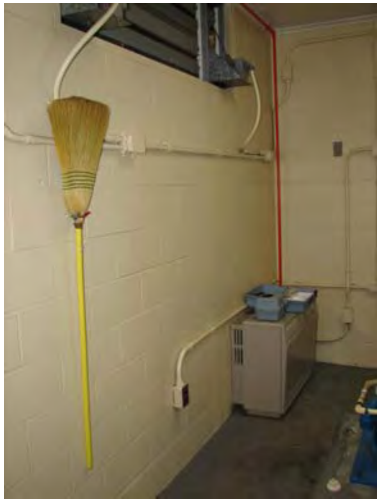


Water Pump Stations

Turnpike Road

1st room for electrical panels. Heated with Propane, wall vented Empire wall unit and Home Basix 1500W electric heater.

2nd, Pump Room, also heated with Propane Empire wall unit. Two mechanical louvered vents open for cross ventilation.



3rd room, for chemical treatments, heated by Electric Chromolux. Fresh air vented to floor.

Total of six 4' (2) T12's

Water Pump Stations

Prospect Street - also referred
to as “Main” and “124W”

Approx 20 x 24 shed with 2x4 framed walls; 3.5” fg batts. 10’2 ceilings and roof vented with continuous soffit and gable end vents.

490 ft2; 4895 ft3; and 1,390 ft2 surface area of shell

Reznor Propane

Greencheck SDE 12-12-DGE

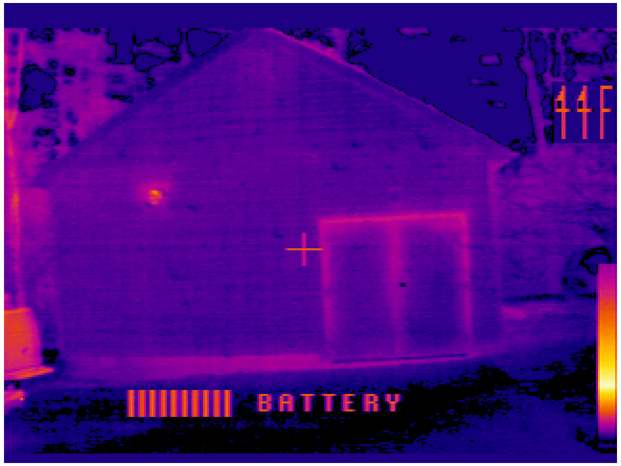
Olympian Generator

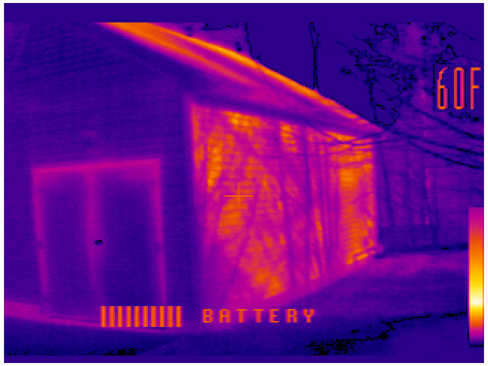
Eight 4’ (2) T12’s

Fuel use between 455-600 gallons and electricity use between July ’09 and June ’10 was 29,300kWh.

Water Pump Stations

Prospect Street



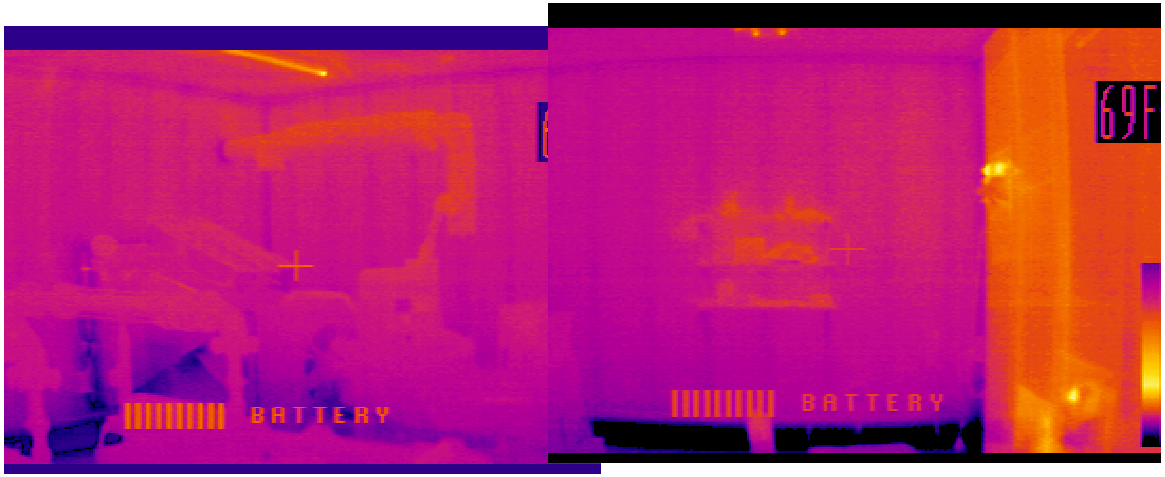


Water Pump Stations

Prospect Street

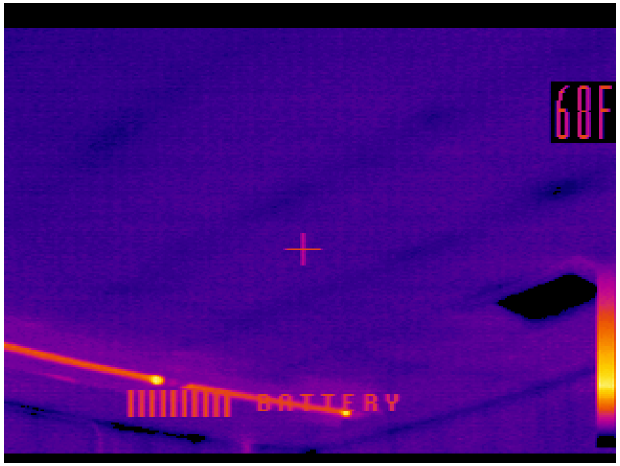
Water Pump Stations

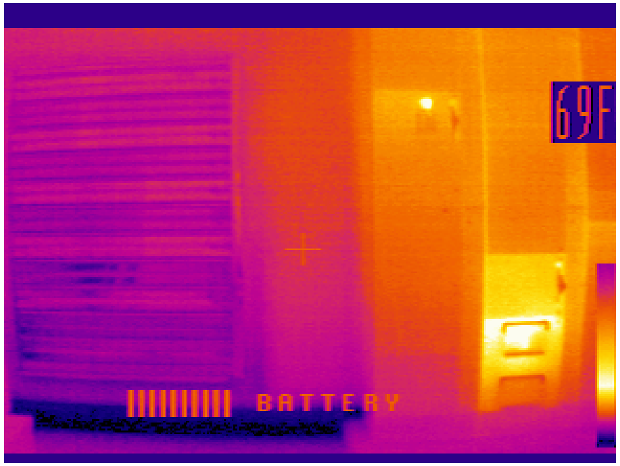
Prospect Street



Water Pump Stations

Prospect Street





One advantage to this framed building is the relative ease in air sealing the ceiling and adding insulation. Weather-stripping the door might also help; but as with the other, massive ventilation plays a large role.

Water Pump Stations

Prospect Street

Changing T-12's to T8's, T5's or even LED's will reduce energy somewhat. Again, these lights are on so infrequently, the 'pay back' would be fairly long.

Water Pump Stations

Prospect Street

Automated controls could be updated, though appear to be functioning well.

Though a blower door test was not conducted, it would be reasonable to assume that the insulation in the ceiling is fiberglass and that there is not an air barrier between soffit attic venting and the insulation.