COLD CLIMATE HOUSING RESEARCH CENTER

CCHRC

Promoting and advancing the development of healthy, durable and sustainable shelter for Alaskans and other circumpolar people.

Safe and Effective Exterior Insulation Retrofits: Phase I

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Introduction

CCHRC staff often receive questions from property owners interested in retrofitting their home using additional insulation so as to save money on heating bills. A common method for retrofitting walls is adding rigid foam insulation to the exterior. However, determining how much exterior foam to add can be tricky.

The conservative approach is to add enough exterior insulation so that the wall framing never cools to the dew point. In Fairbanks, this approach would require 2x6 walls to receive between six and 10 inches of exterior foam board (depending on the type) to compensate for the insulative effect of the existing insulation. Unfortunately, this approach is often prohibitively expensive. Based on practical experience, it seems that less exterior insulation can work, but exactly how much less is unknown. CCHRC researchers' concern is that the installation of a thin layer of exterior insulation may be problematic because it has the potential to allow condensation within the wall while also reducing the drying potential of the wall.

A further complication is the fact that most residential construction in Alaska contains a plastic vapor retarder between the interior finish, e.g., gypsum board or paneling, and the wall framing. This plastic sheeting is used to restrict air and vapor flow through the wall and keep water vapor from condensing within the walls during winter. In older homes, unsealed seams or penetrations have often compromised the vapor retarder. This is partially mitigated because the wall can dry to the exterior during the summer, allowing an escape path for moisture that collects in the winter.

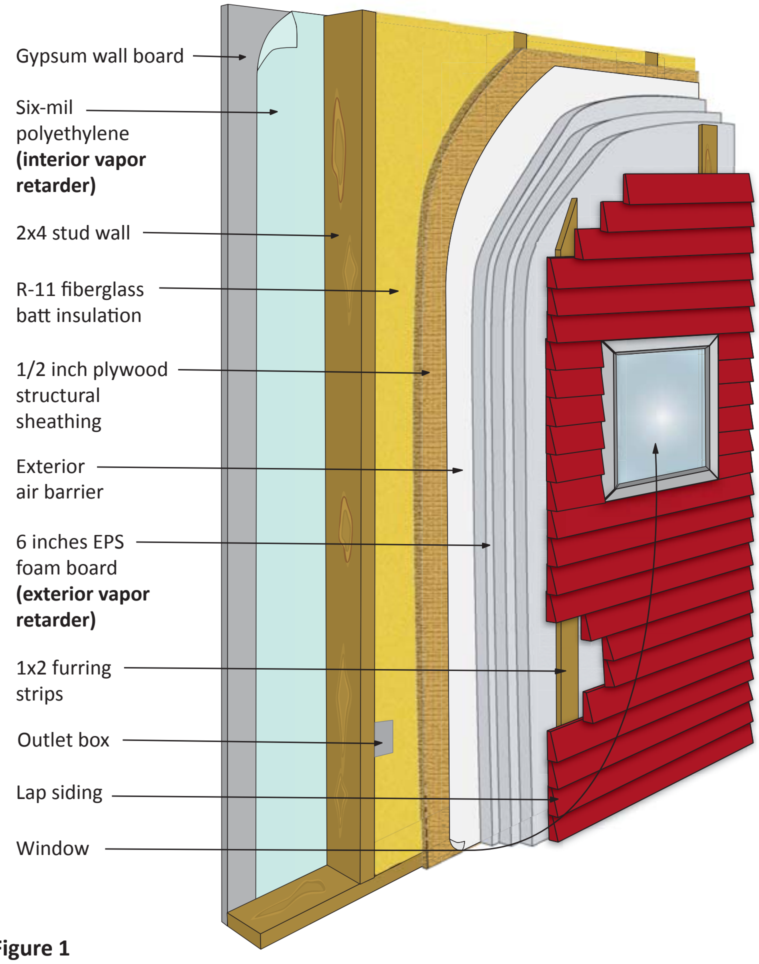

Figure 1
A general depiction of the wall system used in this study (not to scale). Variables across the nine wall sections include the presence or absence of an interior vapor barrier, 2x4 or 2x6 stud construction and the amounts of stud wall insulation and exterior foam insulation.

Exterior foam insulation can significantly inhibit drying. Because foam insulation is relatively impermeable to water vapor, the combination of an interior vapor retarder and exterior foam insulation is commonly called a "double vapor barrier." If the amount of exterior insulation does not prevent condensation in the wall, moisture may accumulate over time.

In this context, CCHRC staff designed a study to answer two questions:

- Based on field studies of best- and worst-case scenarios, what distributions of interior-to-exterior insulation prevent significant condensation within retrofitted walls?
- Does a double vapor barrier cause moisture problems in the dry and cold Interior Alaska climate?

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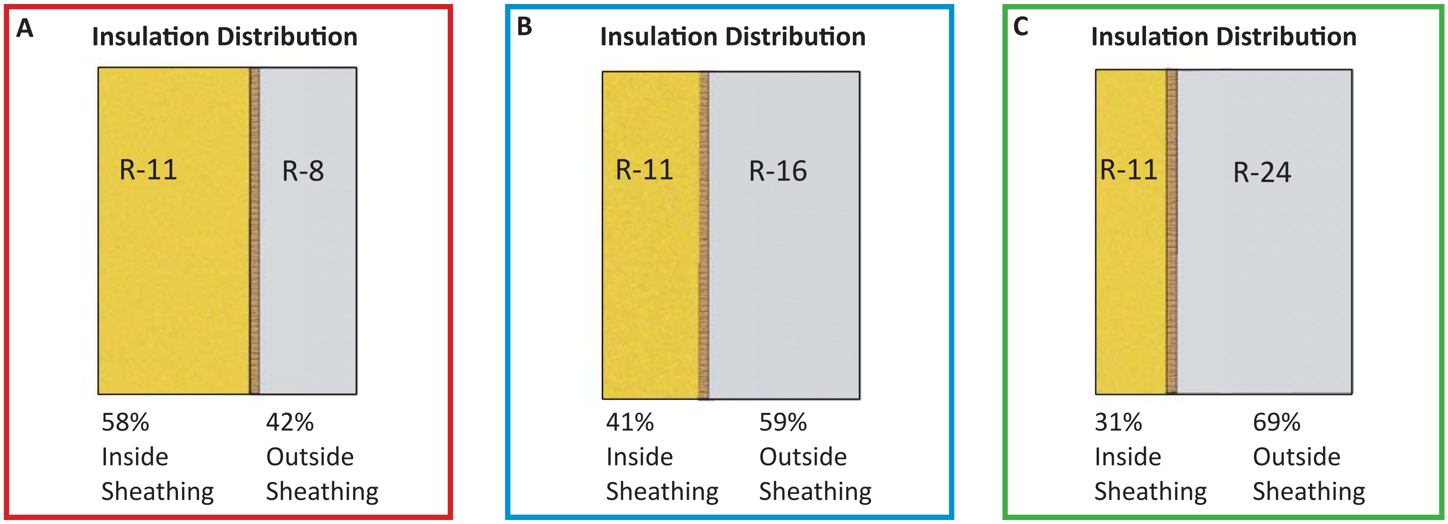

Figures 2

The stud cavity insulation (interior) and exterior insulation distributions in several of the Mobile Test Lab test wall sections. The illustrations do not represent cross-sectional thicknesses, rather the distribution of interior and exterior R-values relative to the total R-value for each wall section. For example, Figure A has a total insulation R-value of 19, of which 58% is within the stud cavity (R-11) and 42% is exterior to the wall sheathing (R-8). **NOTE: Figure 2 and Figure 3 refer to three wall sections which have corresponding letters.**

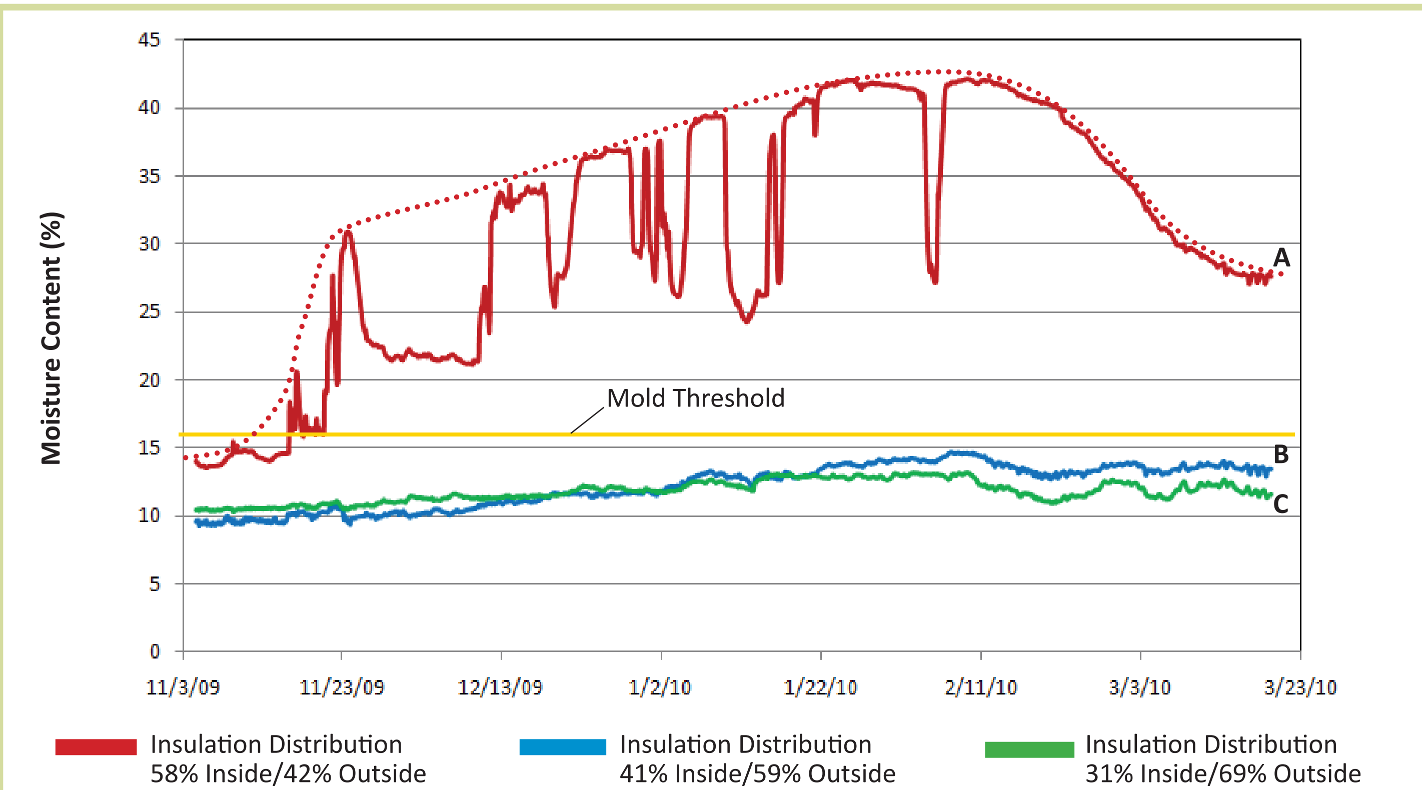

Figure 3

The wood moisture content of studs in select Mobile Test Lab wall sections over the winter of 2009-2010. The moisture content of concern for initiation of mold growth (16%) is illustrated for comparison to the test wall data. Dotted lines connecting peaks in the red data series represent inferences of wood moisture content during a period when the sensor area was below the freezing point of water. When frozen, the sensors falsely show a decrease in moisture content. The insulation distribution for each data series, identified as A, B and C, are shown above.

What does a 41%/59% R-value distribution mean in terms of construction materials?

- 2x4 w/R-11 requires 4.0 inches EPS
- 2x6 w/R-19 requires 6.8 inches EPS

Hint

The Mobile Test Lab

To answer these questions, we began an experiment in our Mobile Test Laboratory (MTL) in the fall of 2009. The MTL is a road-worthy trailer with nine 4x8 test wall bays. For this experiment, all nine test walls were built using typical building practices with 2x4 or 2x6 frame construction. Eight of the nine walls were covered with either polystyrene or polyurethane exterior insulation, with the ninth test wall kept as a control, with no exterior insulation. Photograph 1 shows the MTL during construction and installation of the test walls. The test walls have different distributions of insulation in the interior (yellow fiberglass batts filling the wall cavity in Figure 1) relative to the insulation on the exterior of the wall (rigid board foam in Figure 1). Most test walls have an interior vapor retarder. Some were left without to provide a means for comparison.

The interior conditions of this phase of the MTL experiment were designed to mimic a worst-case situation for homes. The trailer interior was maintained at 40% relative humidity, 70°F and with a slight positive air pressure (1 - 7 Pa) over the winter of 2009-2010. The test walls were monitored for moisture content of the wall framing, heat flux, temperature and stud cavity humidity over the course of the winter. This snapshot presents select wood moisture content findings from November 2009 to March 2010.

A Balance of R-Values

Determining the amount of exterior insulation required to remove the condensation potential within a wall is a function of the local winter temperatures and the amount of insulation in the stud bays. Because insulation properties vary, we refer to the distribution in terms of the insulation R-value in the stud cavities (interior) to that placed on the exterior (see Figures 2a -2c). For this study, we varied the distribution of interior to exterior R-values from 31%/69% to 70%/30%, and report select data within this spectrum of R-value distributions.

Figure 3 shows the wood moisture content for three of the test walls from November 2009 to March 2010. The reading is from the stud beneath the electrical outlet. All three test walls had interior vapor retarders with unsealed penetrations around the electrical outlets to simulate older construction practices. Compared to a conservative threshold for concern of 16% wood moisture content (when mold growth can initiate), it is readily apparent that a 58% interior and 42% exterior R-value distribution is problematic given the laboratory conditions maintained for this experiment. Note that most drops in moisture content during the winter do not represent periods of drying in this wall during relatively warm winter days, but instead indicate that the moisture content sensors were freezing during relatively cold periods. When the area surrounding the moisture content sensor freezes, the resulting signal falsely shows a decrease in moisture content.

Photograph 1
The Mobile Test Lab during installation of new test wall sections, August 2009.

In sharp contrast, both the 41%/59% and 31%/69% R-value distributions show robust resistance to condensation and water vapor absorption that kept the wood moisture content below the threshold of concern throughout the entire test period. No freezing at the wood moisture content sensor was recorded for these test walls throughout the monitoring period.

The Double Vapor Barrier Effect

To address the question of whether exterior insulation retrofits can pose a problem due to the double vapor barrier effect, we constructed the same three test walls with and without

Hint

Sources and Control of Moisture

Activities of everyday life are the common sources of water vapor in homes. Breathing, showering, and cooking are significant sources, while pets and plants are less obvious ones. Generally, the more occupants in a home, the more water vapor is generated.

The amount of water vapor in air is commonly expressed as relative humidity, which is a ratio of water vapor mass in the air to the mass in water saturated air at the same temperature. In winter, it is recommended that homes in very cold climates be kept around 25% relative humidity*. Higher relative humidity promotes condensation within the building envelope, and lower relative humidity can cause occupant discomfort.

The primary means for moisture control in cold climates is ventilation, which is most effectively achieved by a heat recovery ventilation system. In winter, the incoming fresh air contains significantly less water vapor than indoor air.

*Lstiburek and Carmody (1994) *Moisture Control Handbook: Principles and Practices for Residential and Small Commercial Buildings*. John Wiley & Sons, Inc.

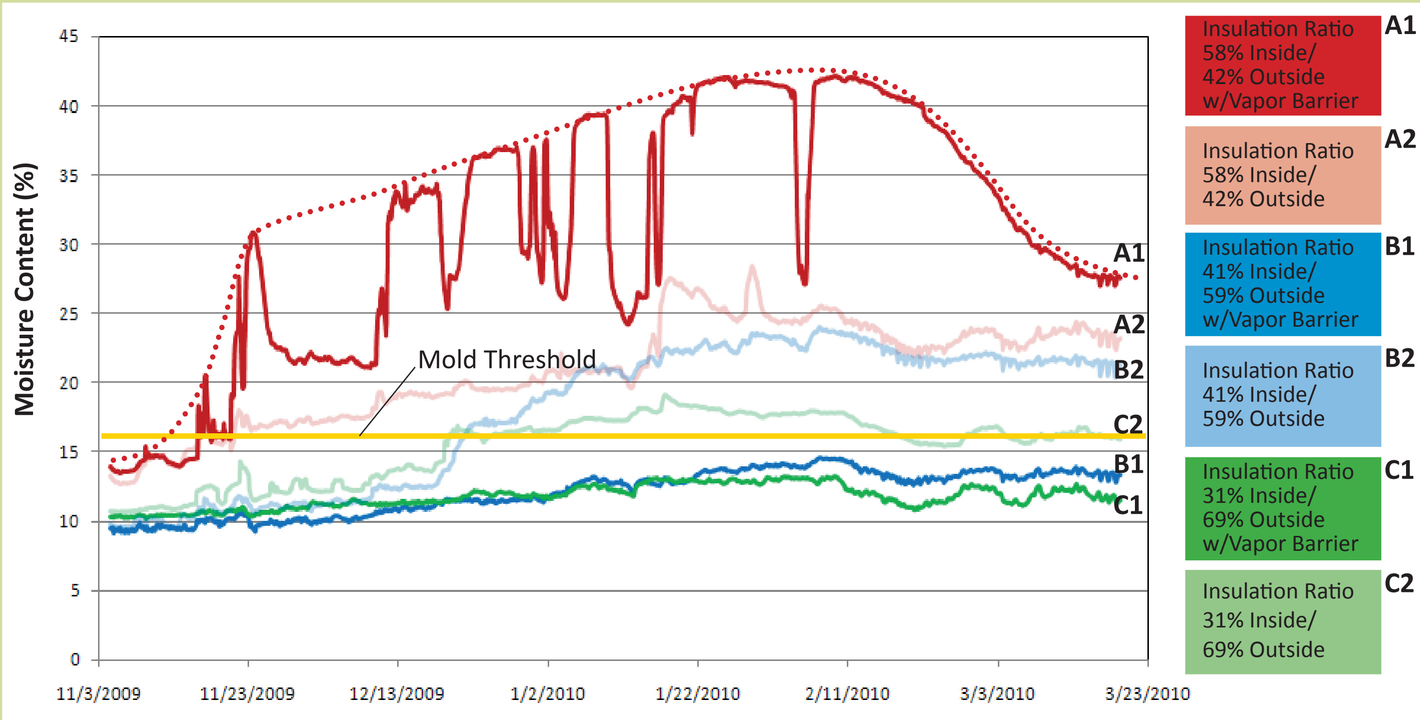

Figure 4

A similar illustration to Figure 3 with additional test wall sections displayed. The graph shows three pairs of test wall sections of different interior to exterior R-value distributions distinguished by color, each with an interior vapor barrier (bold color) and without an interior vapor barrier (pale color).

interior vapor retarders. The resulting wood moisture content data from November 2009 to March 2010 is illustrated in Figure 4. This graph shows the same data as Figure 3 for the test walls with interior vapor retarders (bold colors), and also includes the corresponding test wall insulation distributions without interior vapor retarders (light colors).

When considering the test walls based on the presence or absence of vapor barriers, the wood moisture content is consistently lower for walls with a greater percentage of R-value on the exterior. This result was expected, as more exterior insulation provides greater resistance to condensation within the wall. However, when comparing walls of the same insulation distribution, the results are more complex. For test walls with the majority of the R-value on the exterior (Figure 3, blue and green), the walls with vapor retarders have lower moisture contents. For the test wall with the majority of the R-value within the stud bays (red), the opposite was observed. Further discussion on these observations will follow in a subsequent technical report.

The practical implication is that wall constructions with greater exterior R-value distributions are more effective at controlling moisture, not that homeowners should remove an existing interior vapor barrier. While an interior vapor barrier drastically increased moisture accumulation in the test wall with the least exterior insulation, both test walls with this R-value distribution (58% interior, 42% exterior) remained above the threshold of concern for nearly the entire test period. The presence of an interior vapor barrier was beneficial to walls with greater exterior R-value, e.g., 59% exterior or greater, than within the stud bays for the data shown in Figure 4. However, wood moisture content at other locations within the test walls show conflicting results. Evaluation of the test wall moisture content during the summer season, when drying is anticipated, will help to determine the significance of the double vapor barrier effect. As for moisture accumulation during winter: the greater the exterior R-value of a test wall, the less an interior vapor retarder influences moisture accumulation.

More Results Pending

The moisture content of the test walls will be monitored over the summer, and results on the amount of drying with the test walls will be reported in the fall of 2010. In winter of 2010–2011, the experiments will continue at 25% relative humidity and neutral-to-slight negative pressure. These conditions are representative of a best case scenario that balances the needs of occupant comfort and durability of the building envelope.

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